K^0_L

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

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

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

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

VALUE (10^{10} $\hbar$ s^{-1})	*DOCUMENT ID*		*TECN*	*COMMENT*
0.5293 ±0.0009 OUR FIT	Error includes scale factor of 1.3. Assuming *CPT*			
0.5289 ±0.0010 OUR FIT	Not assuming *CPT*			
0.52797±0.00195	[1,2] ABOUZAID	11	KTEV	Not assuming *CPT*
0.52699±0.00123	[1,3] ABOUZAID	11	KTEV	Assuming *CPT*
0.5240 ±0.0044 ±0.0033	APOSTOLA...	99C	CPLR	K^0-$\overline{K}^0$ to $\pi^+\pi^-$
0.5297 ±0.0030 ±0.0022	[4] SCHWINGEN...	95	E773	20–160 GeV *K* beams
0.5286 ±0.0028	[5] GIBBONS	93	E731	Assuming *CPT*
0.5257 ±0.0049 ±0.0021	[4] GIBBONS	93C	E731	Not assuming *CPT*
0.5340 ±0.00255±0.0015	[6] GEWENIGER	74C	SPEC	Gap method
0.5334 ±0.0040 ±0.0015	[6,7] GJESDAL	74	SPEC	Assuming *CPT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.5261 ±0.0015	[8] ALAVI-HARATI	03	KTEV	Assuming *CPT*
0.5288 ±0.0043	[9] ALAVI-HARATI	03	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 ANGELOPOULOS 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 Δm, τ_S, ϕ_ϵ, Re(ϵ'/ϵ), and Im(ϵ'/ϵ) as free parameters. See Im(ϵ'/ϵ) in the "K^0_L *CP* violation" section for correlation information.

[3] ABOUZAID 11 fit has Δm and τ_S free but constrains ϕ_ϵ to the Superweak value, i.e. assumes *CPT*. See "K^0_S Mean Life" section for correlation information.

[4] Fits Δm and ϕ_{+-} 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.

[7] GJESDAL 74 uses charge asymmetry in $K^0_{\ell 3}$ decays.

[8] ALAVI-HARATI 03 fit Δm and $\tau_{K^0_S}$ simultaneously. ϕ_{+-} 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.

[9] ALAVI-HARATI 03 fit Δm, ϕ_{+-}, and τ_{K_S} simultaneously. See ϕ_{+-} in the "K_L *CP* violation" section for correlation information. Superseded by ABOUZAID 11.

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

[11] Uses $\overline{K}^0_{e3}$ and K^0_{e3} strangeness tagging at production and decay. Assumes *CPT* conservation on $\Delta S = -\Delta Q$ transitions.

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

[13] ARONSON 82 find that Δm may depend on the kaon energy.

[14] 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 η_{+-}.

K^0_L MEAN LIFE

VALUE (10^{-8} s)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
5.116±0.021 OUR FIT	Error includes scale factor of 1.1.				
5.099±0.021 OUR AVERAGE					
5.072±0.011±0.035	13M	[1] AMBROSINO	06	KLOE	$\sum_i \text{B}_i = 1$
5.092±0.017±0.025	15M	AMBROSINO	05C	KLOE	
5.154±0.044	0.4M	VOSBURGH	72	CNTR	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
5.15 ±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 ($\pi^+\pi^-$,$\pi^0\pi^0$,$\gamma\gamma$) is taken from PDG 04. This KLOE K_L lifetime is obtained by imposing $\sum_i \text{B}_i = 1$. The correlation matrix among the four measured K_L BR's and this K_L lifetime is

$$\begin{array}{cccccc}
 & K_{e3} & K_{\mu 3} & 3\pi^0 & \pi^+\pi^-\pi^0 & \tau_{K_L} \\
K_{e3} & 1 & -0.25 & -0.56 & -0.07 & 0.25 \\
K_{\mu 3} & & 1 & -0.43 & -0.20 & 0.33 \\
3\pi^0 & & & 1 & -0.39 & -0.21 \\
\pi^+\pi^-\pi^0 & & & & 1 & -0.39 \\
\tau_{K_L} & & & & & 1
\end{array}$$

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^0_L DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level

Semileptonic modes

Γ_1	$\pi^\pm e^\mp \nu_e$		[a]	(40.55 ± 0.11) %	S=1.7
	Called K^0_{e3}.				
Γ_2	$\pi^\pm \mu^\mp \nu_\mu$		[a]	(27.04 ± 0.07) %	S=1.1
	Called $K^0_{\mu 3}$.				
Γ_3	$(\pi \mu \text{atom}) \nu$			$(1.05 \pm 0.11) \times 10^{-7}$	
Γ_4	$\pi^0 \pi^\pm e^\mp \nu$		[a]	$(5.20 \pm 0.11) \times 10^{-5}$	
Γ_5	$\pi^\pm e^\mp \nu e^+ e^-$		[a]	$(1.26 \pm 0.04) \times 10^{-5}$	

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

Γ_6	$3\pi^0$			(19.52 ± 0.12) %	S=1.6
Γ_7	$\pi^+ \pi^- \pi^0$			(12.54 ± 0.05) %	
Γ_8	$\pi^+ \pi^-$	*CPV*	[b]	$(1.967 \pm 0.010) \times 10^{-3}$	S=1.5
Γ_9	$\pi^0 \pi^0$	*CPV*		$(8.64 \pm 0.06) \times 10^{-4}$	S=1.8

Semileptonic modes with photons

Γ_{10}	$\pi^\pm e^\mp \nu_e \gamma$		[a,c,d]	$(3.79 \pm 0.06) \times 10^{-3}$	
Γ_{11}	$\pi^\pm \mu^\mp \nu_\mu \gamma$			$(5.65 \pm 0.23) \times 10^{-4}$	

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

Γ_{12}	$\pi^0 \pi^0 \gamma$			$< 2.43 \times 10^{-7}$	CL=90%
Γ_{13}	$\pi^+ \pi^- \gamma$		[c,d]	$(4.15 \pm 0.15) \times 10^{-5}$	S=2.8
Γ_{14}	$\pi^+ \pi^- \gamma(\text{DE})$			$(2.84 \pm 0.11) \times 10^{-5}$	S=2.0
Γ_{15}	$\pi^0 2\gamma$		[c]	$(1.273 \pm 0.033) \times 10^{-6}$	
Γ_{16}	$\pi^0 \gamma e^+ e^-$			$(1.62 \pm 0.17) \times 10^{-8}$	

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

Γ_{17}	2γ			$(5.47 \pm 0.04) \times 10^{-4}$	S=1.1
Γ_{18}	3γ			$< 7.4 \times 10^{-8}$	CL=90%
Γ_{19}	$e^+ e^- \gamma$			$(9.4 \pm 0.4) \times 10^{-6}$	S=2.0
Γ_{20}	$\mu^+ \mu^- \gamma$			$(3.59 \pm 0.11) \times 10^{-7}$	S=1.3
Γ_{21}	$\mu^+ \mu^- \mu^+ \mu^-$			$< 2.3 \times 10^{-9}$	CL=90%
Γ_{22}	$e^+ e^- \gamma \gamma$		[c]	$(5.95 \pm 0.33) \times 10^{-7}$	
Γ_{23}	$\mu^+ \mu^- \gamma \gamma$		[c]	$(1.0 \, ^{+0.8}_{-0.6}) \times 10^{-8}$	

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

Γ_{24}	$\mu^+ \mu^-$	*S1*		$(6.84 \pm 0.11) \times 10^{-9}$	
Γ_{25}	$e^+ e^-$	*S1*		$(9 \, ^{+6}_{-4}) \times 10^{-12}$	
Γ_{26}	$\pi^+ \pi^- e^+ e^-$	*S1*	[c]	$(3.11 \pm 0.19) \times 10^{-7}$	
Γ_{27}	$\pi^0 \pi^0 e^+ e^-$	*S1*		$< 6.6 \times 10^{-9}$	CL=90%
Γ_{28}	$\pi^0 \pi^0 \mu^+ \mu^-$	*S1*		$< 9.2 \times 10^{-11}$	CL=90%
Γ_{29}	$\mu^+ \mu^- e^+ e^-$	*S1*		$(2.69 \pm 0.27) \times 10^{-9}$	
Γ_{30}	$e^+ e^- e^+ e^-$	*S1*		$(3.56 \pm 0.21) \times 10^{-8}$	

Γ_{31}	$\pi^0 \mu^+ \mu^-$	*CP,S1*	[e]	$<$	3.8	$\times 10^{-10}$	CL=90%
Γ_{32}	$\pi^0 e^+ e^-$	*CP,S1*	[e]	$<$	2.8	$\times 10^{-10}$	CL=90%
Γ_{33}	$\pi^0 \nu \overline{\nu}$	*CP,S1*	[f]	$<$	3.0	$\times 10^{-9}$	CL=90%
Γ_{34}	$\pi^0 \pi^0 \nu \overline{\nu}$	*S1*		$<$	8.1	$\times 10^{-7}$	CL=90%
Γ_{35}	$e^\pm \mu^\mp$	*LF*	[a]	$<$	4.7	$\times 10^{-12}$	CL=90%
Γ_{36}	$e^\pm e^\pm \mu^\mp \mu^\mp$	*LF*	[a]	$<$	4.12	$\times 10^{-11}$	CL=90%
Γ_{37}	$\pi^0 \mu^\pm e^\mp$	*LF*	[a]	$<$	7.6	$\times 10^{-11}$	CL=90%
Γ_{38}	$\pi^0 \pi^0 \mu^\pm e^\mp$	*LF*		$<$	1.7	$\times 10^{-10}$	CL=90%

Lorentz invariance violating modes

Γ_{39}	$\pi^0 \gamma$			$<$	1.7	$\times 10^{-7}$	CL=90%

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

[b] This mode includes gammas from inner bremsstrahlung but not the direct emission mode $K_L^0 \to \pi^+ \pi^- \gamma$(DE).

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

[d] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ's.

[e] Allowed by higher-order electroweak interactions.

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

CONSTRAINED FIT INFORMATION

> An overall fit to the mean life 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 $\left\langle\delta p_i \delta p_j\right\rangle/(\delta p_i\cdot\delta p_j)$, in percent, from the fit to parameters p_i, including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

x_2	−21									
x_6	−77	−29								
x_7	−15	−20	−18							
x_8	53	−11	−47	4						
x_9	30	−23	−11	−12	64					
x_{13}	6	−1	−6	0	12	8				
x_{14}	6	−1	−6	0	11	7	93			
x_{17}	−46	−22	64	−14	−21	8	−3	−3		
x_{19}	−5	−2	7	−1	−3	−1	0	0	4	
Γ	−27	−9	24	15	−13	−6	−2	−2	15	2
	x_1	x_2	x_6	x_7	x_8	x_9	x_{13}	x_{14}	x_{17}	x_{19}

	Mode		Rate (10^8 s^{-1})	Scale factor
Γ_1	$\pi^\pm e^\mp \nu_e$ Called K^0_{e3}.	[a]	0.07927 ± 0.00034	1.1
Γ_2	$\pi^\pm \mu^\mp \nu_\mu$ Called $K^0_{\mu3}$.	[a]	0.05286 ± 0.00025	1.1
Γ_6	$3\pi^0$		0.03815 ± 0.00030	1.5
Γ_7	$\pi^+\pi^-\pi^0$		0.02451 ± 0.00015	
Γ_8	$\pi^+\pi^-$	[b]	$(3.844 \pm 0.023) \times 10^{-4}$	1.2
Γ_9	$\pi^0\pi^0$		$(1.690 \pm 0.013) \times 10^{-4}$	1.4
Γ_{13}	$\pi^+\pi^-\gamma$	[c,d]	$(8.11 \pm 0.29) \times 10^{-6}$	2.7
Γ_{14}	$\pi^+\pi^-\gamma$(DE)		$(5.55 \pm 0.21) \times 10^{-6}$	2.0
Γ_{17}	2γ		$(1.069 \pm 0.010) \times 10^{-4}$	1.2
Γ_{19}	$e^+e^-\gamma$		$(1.84 \pm 0.08) \times 10^{-6}$	1.9

K^0_L DECAY RATES

$\Gamma(\pi^+\pi^-\pi^0)$ Γ_7

VALUE (10^6 s^{-1})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.451±0.015 OUR FIT				

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

$2.32^{+0.13}_{-0.15}$	192	BALDO-... 75	HLBC	Assumes *CP*
2.35 ± 0.20	180	[1] JAMES 72	HBC	Assumes *CP*
2.71 ± 0.28	99	CHO 71	DBC	Assumes *CP*
2.5 ± 0.3	98	[1] JAMES 71	HBC	Assumes *CP*
2.12 ± 0.33	50	MEISNER 71	HBC	Assumes *CP*
2.20 ± 0.35	53	WEBBER 70	HBC	Assumes *CP*
$2.62^{+0.28}_{-0.27}$	136	BEHR 66	HLBC	Assumes *CP*
3.26 ± 0.77	18	ANDERSON 65	HBC	
1.4 ± 0.4	14	FRANZINI 65	HBC	

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

$\Gamma(\pi^\pm e^\mp \nu_e)$ Γ_1

VALUE (10^6 s^{-1})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
7.927±0.034 OUR FIT	Error includes scale factor of 1.1.			
• • • We do not use the following data for averages, fits, limits, etc. • • •				
7.81 ± 0.56	620	CHAN 71	HBC	
$7.52^{+0.85}_{-0.72}$		AUBERT 65	HLBC	$\Delta S=\Delta Q$, *CP* assumed

$\Gamma(\pi^\pm e^\mp \nu_e) + \Gamma(\pi^\pm \mu^\mp \nu_\mu)$ $(\Gamma_1+\Gamma_2)$

VALUE (10^6 s^{-1})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
13.21±0.05 OUR FIT				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
12.4 ± 0.7	410	[1] BURGUN 72	HBC	$K^+ p \rightarrow K^0 p \pi^+$
8.47 ± 1.69	126	[1] MANN 72	HBC	$K^- p \rightarrow n \overline{K}^0$
13.1 ± 1.3	252	[1] WEBBER 71	HBC	$K^- p \rightarrow n \overline{K}^0$
11.6 ± 0.9	393	[1,2] CHO 70	DBC	$K^+ n \rightarrow K^0 p$
10.3 ± 0.8	335	[2] HILL 67	DBC	$K^+ n \rightarrow K^0 p$
$9.85^{+1.15}_{-1.05}$	109	[1] FRANZINI 65	HBC	

[1] Assumes $\Delta S = \Delta Q$ rule.

[2] CHO 70 includes events of HILL 67.

K^0_L BRANCHING RATIOS

Semileptonic modes

$\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*
0.4055±0.0011 OUR FIT	Error includes scale factor of 1.7.		
0.4047±0.0028 OUR AVERAGE	Error includes scale factor of 3.1.		
$0.4007 \pm 0.0005 \pm 0.0015$	13M	[1] AMBROSINO 06	KLOE
0.4067 ± 0.0011		[2] ALEXOPOU... 04	KTEV

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

[2] ALEXOPOULOS 04 constrains $\sum_i \mathrm{B}_i = 0.9993$ 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

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

$\Gamma(\pi^\pm \mu^\mp \nu_\mu)/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE	EVTS	DOCUMENT ID	TECN
0.2704±0.0007 OUR FIT	Error includes scale factor of 1.1.		
0.2700±0.0008 OUR AVERAGE			
0.2698±0.0005±0.0015	13M	[1] AMBROSINO 06	KLOE
0.2701±0.0009		[2] ALEXOPOU... 04	KTEV

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

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

$\left[\Gamma(\pi^\pm e^\mp \nu_e) + \Gamma(\pi^\pm \mu^\mp \nu_\mu)\right]/\Gamma_{\text{total}}$ $(\Gamma_1+\Gamma_2)/\Gamma$

VALUE	DOCUMENT ID
0.6760±0.0012 OUR FIT	Error includes scale factor of 1.6.

$\Gamma(\pi^\pm \mu^\mp \nu_\mu)/\Gamma(\pi^\pm e^\mp \nu_e)$ Γ_2/Γ_1

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.6669±0.0027 OUR FIT	Error includes scale factor of 1.2.			
0.666 ±0.004 OUR AVERAGE	Error includes scale factor of 1.6.			
• • • We use the following data for averages but not for fits. • • •				
0.6740±0.0059	13M	[1] AMBROSINO 06	KLOE	Not in fit
0.6640±0.0014±0.0022	394k	[2] ALEXOPOU... 04	KTEV	Not in fit
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.702 ±0.011	33k	CHO 80	HBC	
0.662 ±0.037	10k	WILLIAMS 74	ASPK	
0.741 ±0.044	6700	BRANDENB... 73	HBC	
0.662 ±0.030	1309	EVANS 73	HLBC	
0.68 ±0.08	3548	BASILE 70	OSPK	
0.71 ±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.

$\Gamma((\pi\mu\text{atom})\nu)/\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})$ Γ_3/Γ_2

VALUE (units 10^{-7})	*EVTS*	*DOCUMENT ID*		*TECN*
3.90±0.39	155	[1] ARONSON	86	SPEC
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	18	COOMBES	76	WIRE

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

$\Gamma(\pi^0\pi^{\pm}e^{\mp}\nu)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (units 10^{-5})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*
5.20±0.11 OUR AVERAGE					
5.21±0.07±0.09		5402	BATLEY	04	NA48
5.16±0.20±0.22		729	MAKOFF	93	E731
• • • We do not use the following data for averages, fits, limits, etc. • • •					
6.2 ±2.0		16	CARROLL	80C	SPEC
$<$ 220	90		[1] DONALDSON	74	SPEC

[1] DONALDSON 74 uses $K^0_L \to \pi^+\pi^-\pi^0/(\text{all } K^0_L)$ decays = 0.126.

$\Gamma(\pi^{\pm}e^{\mp}\nu e^+e^-)/\Gamma(\pi^+\pi^-\pi^0)$ Γ_5/Γ_7

VALUE (units 10^{-5})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
10.02±0.17±0.29	19k	[1] ABOUZAID	07C	KTEV	$M_{ee} > 5$ MeV, $E^*_{ee} > 30$ MeV

[1] E^*_{ee} is the energy of the e^+e^- pair in the kaon rest frame. ABOUZAID 07C reports $[\Gamma(K^0_L \to \pi^{\pm}e^{\mp}\nu e^+e^-)/\Gamma(K^0_L \to \pi^+\pi^-\pi^0)]$ / $[B(\pi^0 \to e^+e^-\gamma)] = (8.54 \pm 0.07 \pm 0.13) \times 10^{-3}$ which we multiply by our best value $B(\pi^0 \to e^+e^-\gamma) = (1.174 \pm 0.035) \times 10^{-2}$. 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

$\Gamma(3\pi^0)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.1952±0.0012 OUR FIT Error includes scale factor of 1.6.					
0.1969±0.0026 OUR AVERAGE Error includes scale factor of 2.0.					
• • • We use the following data for averages but not for fits. • • •					
0.1997±0.0003±0.0019	13M	[1] AMBROSINO	06	KLOE	Not fitted
0.1945±0.0018		[1] ALEXOPOU...	04	KTEV	Not fitted

[1] 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.

$\Gamma(3\pi^0)/\Gamma(\pi^{\pm}e^{\mp}\nu_e)$ Γ_6/Γ_1

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.481 ±0.004 OUR FIT Error includes scale factor of 1.8.					
• • • We use the following data for averages but not for fits. • • •					
0.4782±0.0014±0.0053	209k	[1] ALEXOPOU...	04	KTEV	Not in fit
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.545 ±0.004 ±0.009	38k	KREUTZ	95	NA31	

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

$\Gamma(3\pi^0)/[\Gamma(\pi^\pm e^\mp \nu_e)+\Gamma(\pi^\pm \mu^\mp \nu_\mu)+\Gamma(\pi^+\pi^-\pi^0)]$ $\Gamma_6/(\Gamma_1+\Gamma_2+\Gamma_7)$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.2436±0.0018 OUR FIT Error includes scale factor of 1.6.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.251 ±0.014	549	BUDAGOV	68	HLBC	ORSAY measur.
0.277 ±0.021	444	BUDAGOV	68	HLBC	Ecole polytec.meas
0.31 $^{+0.07}_{-0.06}$	29	KULYUKINA	68	CC	
0.24 ±0.08	24	ANIKINA	64	CC	

$\Gamma(3\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$ Γ_6/Γ_7

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1.557±0.012 OUR FIT Error includes scale factor of 1.3.					
• • • We use the following data for averages but not for fits. • • •					
1.582±0.027	13M	[1] AMBROSINO	06	KLOE	Not in fit
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.611±0.014±0.034	28k	KREUTZ	95	NA31	
1.65 ±0.07	883	BARMIN	72B	HLBC	Error statistical only
1.80 ±0.13	1010	BUDAGOV	68	HLBC	
2.0 ±0.6	188	ALEKSANYAN	64B	FBC	

[1] AMBROSINO 06 enters the fit via their separate measurements of these two modes.

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
0.1254±0.0005 OUR FIT				
0.1255±0.0006 OUR AVERAGE				
0.1263±0.0004±0.0011	13M	[1] AMBROSINO	06	KLOE
0.1252±0.0007		[2] ALEXOPOU...	04	KTEV

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

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

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma(\pi^\pm e^\mp \nu_e)$ Γ_7/Γ_1

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.3092±0.0016 OUR FIT Error includes scale factor of 1.1.					
• • • We use the following data for averages but not for fits. • • •					
0.3078±0.0005±0.0017	799k	[1] ALEXOPOU...	04	KTEV	Not in fit
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.336 ±0.003 ±0.007	28k	KREUTZ	95	NA31	

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

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

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.1565±0.0006 OUR FIT Error includes scale factor of 1.1.				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.163 ±0.003	6499	CHO 77	HBC	
0.1605±0.0038	1590	ALEXANDER 73B	HBC	
0.146 ±0.004	3200	BRANDENB... 73	HBC	
0.159 ±0.010	558	EVANS 73	HLBC	
0.167 ±0.016	1402	KULYUKINA 68	CC	
0.161 ±0.005		HOPKINS 67	HBC	
0.162 ±0.015	126	HAWKINS 66	HBC	
0.159 ±0.015	326	ASTBURY 65B	CC	
0.178 ±0.017	566	GUIDONI 65	HBC	
0.144 ±0.004	1729	HOPKINS 65	HBC	See HOPKINS 67

$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_8/Γ

Violates *CP* conservation.

VALUE (units 10^{-3})	*DOCUMENT ID*	*TECN*
1.967±0.010 OUR FIT Error includes scale factor of 1.5.		
1.975±0.012	[1] ALEXOPOU... 04	KTEV

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

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^\pm e^\mp \nu_e)$ Γ_8/Γ_1

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
4.849±0.020 OUR FIT Error includes scale factor of 1.1.				
4.840±0.020 OUR AVERAGE				
4.826±0.022±0.016	47k	[1] LAI 07	NA48	
• • • We use the following data for averages but not for fits. • • •				
4.856±0.017±0.023	84k	[2] ALEXOPOU... 04	KTEV	Not in fit

[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 $K_L^0 \to \pi^+\pi^-\gamma$(DE).

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

$[\Gamma(\pi^+\pi^-)+\Gamma(\pi^+\pi^-\gamma(\text{DE}))]/\Gamma(\pi^\pm \mu^\mp \nu_\mu)$ $(\Gamma_8+\Gamma_{14})/\Gamma_2$

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*
7.38 ±0.04 OUR FIT Error includes scale factor of 1.4.			
7.275±0.042±0.054	45k	[1] AMBROSINO 06F	KLOE

[1] Fully inclusive. Taking B($K_L^0 \to \pi \mu \nu$) from KLOE, AMBROSINO 06, B($K_L^0 \to \pi^+\pi^- + \pi^+\pi^-\gamma$(DE)) = $(1.963 \pm 0.012 \pm 0.017) \times 10^{-3}$ is obtained.

$\Gamma(\pi^+\pi^-)/[\Gamma(\pi^\pm e^\mp \nu_e)+\Gamma(\pi^\pm \mu^\mp \nu_\mu)]$ $\Gamma_8/(\Gamma_1+\Gamma_2)$

Violates *CP* conservation.

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.909±0.013 OUR FIT Error includes scale factor of 1.3.				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3.13 ±0.14	1687	COUPAL 85	SPEC	η_{+-}=2.28 ± 0.06
3.04 ±0.14	2703	DEVOE 77	SPEC	η_{+-}=2.25 ± 0.05
2.51 ±0.23	309	[1] DEBOUARD 67	OSPK	η_{+-}=2.00 ± 0.09
2.35 ±0.19	525	[1] FITCH 67	OSPK	η_{+-}=1.94 ± 0.08

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

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

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

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*
0.5006±0.0009 OUR FIT Error includes scale factor of 1.3.			
0.4978±0.0035	6.8M	LAI 04B	NA48

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

Violates *CP* conservation.

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.454±0.011 OUR FIT Error includes scale factor of 1.3.				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.60 ±0.07	4200	[1] MESSNER 73	ASPK	$\eta_{+-} = 2.23 \pm 0.05$

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

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$ Γ_8/Γ_7

Violates *CP* conservation.

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1.568±0.010 OUR FIT Error includes scale factor of 1.3.				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.64 ±0.04	4200	MESSNER 73	ASPK	$\eta_{+-} = 2.23$

$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_9/Γ

Violates *CP* conservation.

VALUE (units 10^{-3})	*DOCUMENT ID*	*TECN*
0.864±0.006 OUR FIT Error includes scale factor of 1.8.		
0.865±0.012	[1] ALEXOPOU... 04	KTEV

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

$\Gamma(\pi^0\pi^0)/\Gamma(\pi^+\pi^-)$ Γ_9/Γ_8

Violates *CP* conservation.

VALUE	*DOCUMENT ID*
0.4395±0.0023 OUR FIT Error includes scale factor of 2.0.	
0.4390±0.0012	ETAFIT 16

$\Gamma(\pi^0\pi^0)/\Gamma(3\pi^0)$ Γ_9/Γ_6

Violates *CP* conservation.

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.443 ±0.004 OUR FIT Error includes scale factor of 2.1.				
• • • We use the following data for averages but not for fits. • • •				
0.4446±0.0016±0.0019	100k	[1] ALEXOPOU... 04	KTEV	Not in fit

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

0.37	±0.08	29	BARMIN	70	HLBC	η_{00}=2.02 ± 0.23
0.32	±0.15	30	BUDAGOV	70	HLBC	η_{00}=1.9 ± 0.5
0.46	±0.11	57	BANNER	69	OSPK	η_{00}=2.2 ± 0.3

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

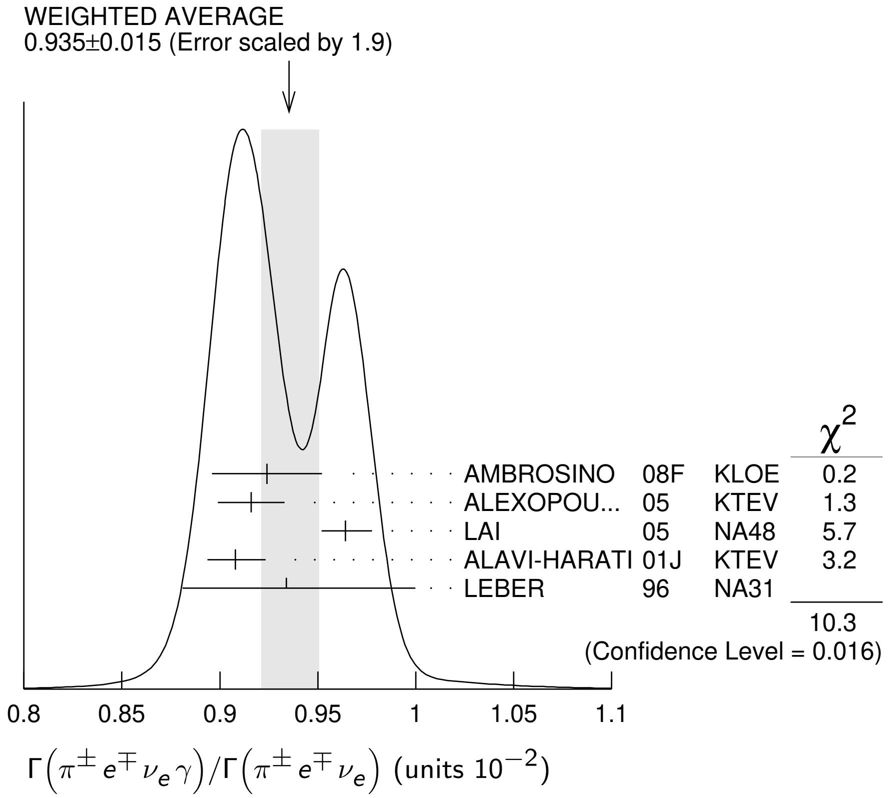
Semileptonic modes with photons

$\Gamma(\pi^\pm e^\mp \nu_e \gamma)/\Gamma(\pi^\pm e^\mp \nu_e)$ $\qquad$ Γ_{10}/Γ_1

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.935±0.015 OUR AVERAGE		Error includes scale factor of 1.9. See the ideogram below.			
$0.924 \pm 0.023 \pm 0.016$	9k	[1] AMBROSINO	08F	KLOE	E^*_γ >30 MeV, $\theta^*_{e\gamma}$ >20°
0.916 ± 0.017	4309	[2] ALEXOPOU...	05	KTEV	E^*_γ >30 MeV, $\theta^*_{e\gamma}$ >20°
$0.964 \pm 0.008 {}^{+0.011}_{-0.009}$	19k	LAI	05	NA48	E^*_γ >30 MeV, $\theta^*_{e\gamma}$ >20°
$0.908 \pm 0.008 {}^{+0.013}_{-0.012}$	15k	ALAVI-HARATI	01J	KTEV	$E^*_\gamma \geq 30$ MeV, $\theta^*_{e\gamma} \geq 20°$
$0.934 \pm 0.036 {}^{+0.055}_{-0.039}$	1384	LEBER	96	NA31	$E^*_\gamma \geq 30$ MeV, $\theta^*_{e\gamma} \geq 20°$

[1] Direct emission contribution measured $\langle X \rangle = -2.3 \pm 1.3 \pm 1.4$.

[2] Also measured cut E^*_γ >10 MeV, $\theta^*_{e\gamma}$ >0° 14221 evts: $\Gamma(\pi^\pm e^\mp \nu_e \gamma)$ / $\Gamma(\pi^\pm e^\mp \nu_e)$ = (4.942 ± 0.062)%.



$\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu}\gamma)/\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})$ Γ_{11}/Γ_{2}

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.09±0.08 OUR AVERAGE					
2.09±0.09		[1] ALEXOPOU...	05	KTEV	$E^{*}_{\gamma} > 30$ MeV
$2.08\pm0.17^{+0.16}_{-0.21}$	252	BENDER	98	NA48	$E^{*}_{\gamma} \geq 30$ MeV

[1] Also measured cut E^{*}_{γ} >10 MeV, 1385 evts: $\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu}\gamma)$ / $\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})$ = (0.530 ± 0.014 ± 0.012)%.

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

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

VALUE (units 10^{-6})	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 0.243	90	ABOUZAID	08B	KTEV	$K^{0}_{L} \rightarrow \pi^{0}\pi^{0}_{D}\gamma$, $\pi^{0}_{D} \rightarrow ee\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 5.6	90	BARR	94	NA31	
<230	90	ROBERTS	94	E799	

$\Gamma(\pi^{+}\pi^{-}\gamma)/\Gamma(\pi^{+}\pi^{-}\pi^{0})$ Γ_{13}/Γ_{7}

For earlier limits see our 1992 edition Physical Review **D45** S1 (1992).

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.23±0.13	516	[1,2] CARROLL	80B	SPEC	$E^{*}_{\gamma} > 20$ MeV
2.33±0.23	546	[1,3] CARROLL	80B	SPEC	
3.56±0.26	1062	[1,4] CARROLL	80B	SPEC	$E^{*}_{\gamma} > 20$ MeV

[1] CARROLL 80B quotes B($\pi^{+}\pi^{-}\gamma$) using normalization B($\pi^{+}\pi^{-}\pi^{0}$) = 0.1239. We divide by this value to obtain their measured $\Gamma(\pi^{+}\pi^{-}\gamma)$ / $\Gamma(\pi^{+}\pi^{-}\pi^{0})$.

[2] Internal Bremsstrahlung component only.

[3] Direct γ emission component only.

[4] Both IB and DE components.

$\Gamma(\pi^{+}\pi^{-}\gamma)/\Gamma(\pi^{+}\pi^{-})$ Γ_{13}/Γ_{8}

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.11±0.08 OUR FIT Error includes scale factor of 2.9.					
2.11±0.08 OUR AVERAGE Error includes scale factor of 2.9.					
2.08±0.02±0.02	8669	[1] ALAVI-HARATI	01B	KTEV	$E^{*}_{\gamma} > 20$ MeV
2.30±0.07	3136	RAMBERG	93	E731	$E^{*}_{\gamma} > 20$ MeV

[1] ALAVI-HARATI 01B includes both Direct Emission (DE) and Inner Bremsstrahlung (IB) processes.

$\Gamma(\pi^+\pi^-\gamma(\text{DE}))/\Gamma(\pi^+\pi^-\gamma)$ Γ_{14}/Γ_{13}

These values assume that $\Gamma(K^0_L \rightarrow \pi^+\pi^-\gamma) = \Gamma(K^0_L \rightarrow \pi^+\pi^-\gamma(\text{DE})) + \Gamma(K^0_L \rightarrow \pi^+\pi^-\gamma(\text{IB}))$, the sum of widths for the direct emission (DE) and inner bremsstrahlung (IE) processes, with no IB-DE interference. DE assumes a form factor as described in RAMBERG 93.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.684 ± 0.009 OUR FIT				
0.684 ± 0.009 OUR AVERAGE				
0.689 ± 0.021	111k	ABOUZAID 06A	KTEV	$E^*_\gamma > 20$ MeV
0.683 ± 0.011	8669	ALAVI-HARATI 01B	KTEV	$E^*_\gamma > 20$ MeV
0.685 ± 0.041	3136	RAMBERG 93	E731	$E^*_\gamma > 20$ MeV

$\Gamma(\pi^0 2\gamma)/\Gamma_{\text{total}}$ Γ_{15}/Γ

VALUE (units 10^{-6})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1.273 ± 0.033 OUR AVERAGE					
$1.28 \pm 0.06 \pm 0.01$		1.4k	[1] ABOUZAID 08	KTEV	
$1.27 \pm 0.04 \pm 0.01$		2.5k	[2] LAI 02B	NA48	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1.68 \pm 0.07 \pm 0.08$		884	[3] ALAVI-HARATI 99B	KTEV	
$1.7 \pm 0.2 \pm 0.2$		63	[4] BARR 92	NA31	
$1.86 \pm 0.60 \pm 0.60$		60	PAPADIMITR...91	E731	$m_{\gamma\gamma} > 280$ MeV
<5.1	90		PAPADIMITR...91	E731	$m_{\gamma\gamma} < 264$ MeV
2.1 ± 0.6		14	[5] BARR 90C	NA31	$m_{\gamma\gamma} > 280$ MeV

[1] ABOUZAID 08 reports $(1.29 \pm 0.03 \pm 0.05) \times 10^{-6}$ from a measurement of $[\Gamma(K^0_L \rightarrow \pi^0 2\gamma)/\Gamma_{\text{total}}]$ / $[B(K^0_L \rightarrow \pi^0\pi^0)]$ assuming $B(K^0_L \rightarrow \pi^0\pi^0) = (8.69 \pm 0.04) \times 10^{-4}$, which we rescale to our best value $B(K^0_L \rightarrow \pi^0\pi^0) = (8.64 \pm 0.06) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[2] LAI 02B reports $[\Gamma(K^0_L \rightarrow \pi^0 2\gamma)/\Gamma_{\text{total}}]$ / $[B(K^0_L \rightarrow \pi^0\pi^0)] = (1.467 \pm 0.032 \pm 0.032) \times 10^{-3}$ which we multiply by our best value $B(K^0_L \rightarrow \pi^0\pi^0) = (8.64 \pm 0.06) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. They also find that $B(\pi^0 2\gamma, m_{\gamma\gamma} < 110 \text{ MeV}) < 0.6 \times 10^{-8}$(90% CL).

[3] ALAVI-HARATI 99B finds that $\Gamma(\pi^0 2\gamma, m_{\gamma\gamma} < 240 \text{ MeV}))$ / $\Gamma(\pi^0 2\gamma) = (17.3 \pm 1.3 \pm 1.5)\%$. Superseded by ABOUZAID 08.

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

[5] BARR 90C superseded by BARR 92.

$\Gamma(\pi^0\gamma e^+ e^-)/\Gamma_{\text{total}}$ Γ_{16}/Γ

VALUE (units 10^{-8})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*
$1.62 \pm 0.14 \pm 0.09$		125	[1] ABOUZAID 07D	KTEV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$2.34 \pm 0.35 \pm 0.13$		44	ALAVI-HARATI 01E	KTEV
<71	90	0	MURAKAMI 99	SPEC

[1] ABOUZAID 07D includes 1997 (ALAVI-HARATI 01E) and 1999 data. It measures the ratio of B($K^0_L \rightarrow \pi^0 \gamma e^+ e^-$) / B($K^0_L \rightarrow \pi^0 \pi^0_D$), where π^0_D is the Dalitz decaying π^0, and uses PDG 06 values B($K^0_L \rightarrow \pi^0 \pi^0$) = $(8.69 \pm 0.04) \times 10^{-4}$, and B($\pi^0_D \rightarrow e^+ e^- \gamma$) = $(1.198 \pm 0.032) \times 10^{-2}$. Supersedes ALAVI-HARATI 01E result.

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

$\Gamma(2\gamma)/\Gamma_{\rm total}$ Γ_{17}/Γ

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
5.47±0.04 OUR FIT	Error includes scale factor of 1.1.				
• • • We do not use the following data for averages, fits, limits, etc. • • •					
4.54±0.84		[1] BANNER	72B	OSPK	
4.5 ±1.0	23	ENSTROM	71	OSPK	K^0_L 1.5–9 GeV/c
5.0 ±1.0		[2] REPELLIN	71	OSPK	
5.5 ±1.1	90	KUNZ	68	OSPK	Norm.to 3 π(C+N)

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

[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.

$\Gamma(2\gamma)/\Gamma(3\pi^0)$ Γ_{17}/Γ_6

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.802±0.017 OUR FIT					
2.802±0.018 OUR AVERAGE					
2.79 ±0.02 ±0.02	27k	ADINOLFI	03	KLOE	
2.81 ±0.01 ±0.02		LAI	03	NA48	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.13 ±0.43	28	BARMIN	71	HLBC	
2.24 ±0.28	115	BANNER	69	OSPK	
2.5 ±0.7	16	ARNOLD	68B	HLBC	Vacuum decay

$\Gamma(2\gamma)/\Gamma(\pi^0\pi^0)$ Γ_{17}/Γ_9

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
0.633±0.006 OUR FIT	Error includes scale factor of 1.4.			
0.632±0.004±0.008	110k	BURKHARDT	87	NA31

$\Gamma(3\gamma)/\Gamma_{\rm total}$ Γ_{18}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
$<7.4 \times 10^{-8}$	90	[1] TUNG	11	K391
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.4 \times 10^{-7}$	90	[2] BARR	95C	NA31

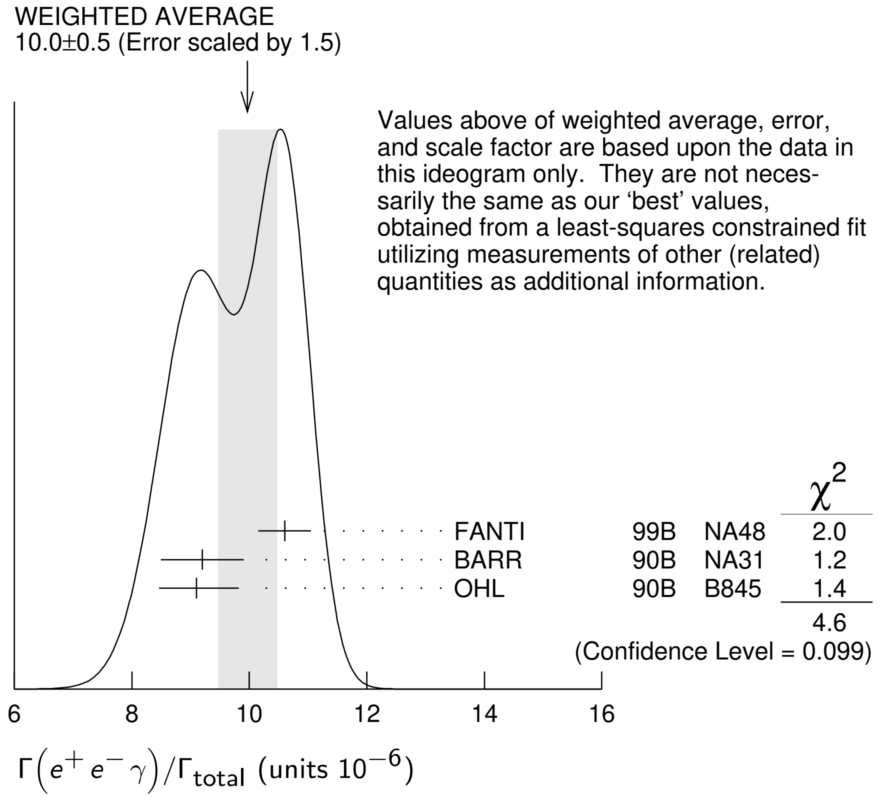
[1] TUNG 11 reports the result assuming parity violating interaction and using 2005 data (Run-II and III). Assuming parity conserving or phase space interaction, the 90% upper limits obtained are 7.5×10^{-8} and 8.6×10^{-8}, respectively.

[2] Assumes a phase-space decay distribution.

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

VALUE (units 10^{-6})	*EVTS*	*DOCUMENT ID*		*TECN*
9.4±0.4 OUR FIT Error includes scale factor of 2.0.				
10.0±0.5 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.				
$10.6\pm0.2\pm0.4$	6864	[1] FANTI	99B	NA48
$9.2\pm0.5\pm0.5$	1053	BARR	90B	NA31
$9.1\pm0.4^{+0.6}_{-0.5}$	919	OHL	90B	B845

[1] For FANTI 99B, the ±0.4 systematic error includes for uncertainties in the calculation, primarily uncertainties in the $\pi^0 \to e^+e^-\gamma$ and $K^0_L \to \pi^0\pi^0$ branching ratios, evaluated using our 1999 Web edition values.



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.

$\Gamma(e^+e^-\gamma)/\Gamma(3\pi^0)$ Γ_{19}/Γ_6

VALUE (units 10^{-5})	*EVTS*	*DOCUMENT ID*		*TECN*
4.82±0.21 OUR FIT Error includes scale factor of 2.0.				
4.63±0.04±0.13	83k	[1] ABOUZAID	07B	KTEV

[1] ABOUZAID 07B reports $[\Gamma(K^0_L \to e^+e^-\gamma)/\Gamma(K^0_L \to 3\pi^0)]$ / $[3\Gamma(\pi^0 \to 2\gamma)/\Gamma_{\text{total}} \times \Gamma(\pi^0 \to e^+e^-\gamma)/\Gamma_{\text{total}}] = (1.3302 \pm 0.0046 \pm 0.0103) \times 10^{-3}$ which we multiply by our best value $3\Gamma(\pi^0 \to 2\gamma)/\Gamma_{\text{total}} \times \Gamma(\pi^0 \to e^+e^-\gamma)/\Gamma_{\text{total}} = 0.0348 \pm 0.0010$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$ Γ_{20}/Γ

VALUE (units 10^{-7})	*EVTS*	*DOCUMENT ID*	*TECN*
3.59±0.11 OUR AVERAGE Error includes scale factor of 1.3.			
3.62±0.04±0.08	9100	ALAVI-HARATI 01G	KTEV
3.4 ±0.6 ±0.4	45	FANTI 97	NA48
3.23±0.23±0.19	197	SPENCER 95	E799

$\Gamma(\mu^+\mu^-\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{21}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<2.3\times10^{-9}$	90	[1] AAIJ 23AE	LHCB

[1] AAIJ 23AE uses 5.1 fb^{-1} of LHCb data recorded from 2016 to 2018.

$\Gamma(e^+e^-\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{22}/Γ

VALUE (units 10^{-7})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
5.95±0.33 OUR AVERAGE				
5.84±0.15±0.32	1543	ALAVI-HARATI 01F	KTEV	$E^*_\gamma > 5$ MeV
$8.0 \pm1.5\ ^{+1.4}_{-1.2}$	40	SETZU 98	NA31	$E^*_\gamma > 5$ MeV
6.5 ±1.2 ±0.6	58	NAKAYA 94	E799	$E^*_\gamma > 5$ MeV
6.6 ±3.2		MORSE 92	B845	$E^*_\gamma > 5$ MeV

$\Gamma(\mu^+\mu^-\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{23}/Γ

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

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

$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ Γ_{24}/Γ_8

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

VALUE (units 10^{-6})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
3.48 ±0.05 OUR AVERAGE				
3.474±0.057	6210	AMBROSE 00	B871	
3.87 ±0.30	179	[1] AKAGI 95	SPEC	
3.38 ±0.17	707	HEINSON 95	B791	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3.9 ±0.3 ±0.1	178	[2] AKAGI 91B	SPEC	In AKAGI 95
3.45 ±0.18 ±0.13	368	[3] HEINSON 91	SPEC	In HEINSON 95
4.1 ±0.5	54	INAGAKI 89	SPEC	In AKAGI 91B
2.8 ±0.3 ±0.2	87	MATHIAZHA...89B	SPEC	In HEINSON 91

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

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

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

$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ Γ_{25}/Γ

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

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

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

$\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}$ Γ_{26}/Γ

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

VALUE (units 10^{-7})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
3.11±0.19 OUR AVERAGE						
3.08±0.09±0.18		1125	[1] LAI	03C	NA48	
3.2 ±0.6 ±0.4		37	ADAMS	98	KTEV	
4.4 ±1.3 ±0.5		13	TAKEUCHI	98	SPEC	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<4.6	90		NOMURA	97	SPEC	$m_{ee} > 4$ MeV

[1] LAI 03C second error is 0.15(syst)±0.10(norm) combined in quadrature. The normalization uses BR($K_L \to \pi^+\pi^-\pi^0$) * BR($\pi^0 \to e^+e^-$) = $(1.505 \pm 0.047) \times 10^{-3}$ from our 2000 Edition.

$\Gamma(\pi^0\pi^0e^+e^-)/\Gamma_{\text{total}}$ Γ_{27}/Γ

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

VALUE (units 10^{-9})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*
<6.6	90	1	ALAVI-HARATI	02C	E799

$\Gamma(\pi^0\pi^0\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{28}/Γ

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

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
$\mathbf{<9.2 \times 10^{-11}}$	90	[1] ABOUZAID	11A	E799

[1] ABOUZAID 11A also reports B($K^0_L \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-$) $< 1.0 \times 10^{-10}$ 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 ± 0.5 MeV/c^2.

$\Gamma(\mu^+\mu^-e^+e^-)/\Gamma_{\text{total}}$ Γ_{29}/Γ

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

VALUE (units 10^{-9})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.69±0.27 OUR AVERAGE						
2.69±0.24±0.12		131	[1] ALAVI-HARATI	03B	KTEV	
$2.9^{+6.7}_{-2.4}$		1	GU	96	E799	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
2.62±0.40±0.17		43	ALAVI-HARATI	01H	KTEV	Sup. by ALAVI-HARATI 03B
<4900	90		BALATS	83	SPEC	

[1] ALAVI-HARATI 03B also measures the linear slope $\alpha = -1.59 \pm 0.37$.

$\Gamma(e^+e^-e^+e^-)/\Gamma_{\text{total}}$ Γ_{30}/Γ

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

VALUE (units 10^{-8})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
3.56±0.21 OUR AVERAGE				
3.30±0.24±0.25	200	[1] LAI 05B	NA48	
3.72±0.18±0.23	441	ALAVI-HARATI 01D	KTEV	
3.96±0.78±0.32	27	GU 94	E799	
3.07±1.25±0.26	6	VAGINS 93	B845	

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

VALUE (units 10^{-8})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
6 ±2 ±1	18	[2] AKAGI 95	SPEC	m_{ee} >470 MeV
7 ±3 ±2	6	[2] AKAGI 95	SPEC	m_{ee} >470 MeV
10.4 ±3.7 ±1.1	8	[3] BARR 95	NA31	
6 ±2 ±1	18	AKAGI 93	CNTR	Sup. by AKAGI 95
4 ±3	2	BARR 91	NA31	Sup. by BARR 95

[1] LAI 05B uses 1998 and 1999 data. Data are normalized to the observed events of $K^0_L \to \pi^+\pi^-\pi^0$ (π^0 into Dalitz pair) and PDG 04 values are used for B($K^0_L \to \pi^+\pi^-\pi^0$) and B($\pi^0 \to e^+e^-\gamma$). 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^0_L.

$\Gamma(\pi^0\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{31}/Γ

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

VALUE (units 10^{-9})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*
<0.38	90		ALAVI-HARATI 00D	KTEV

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

VALUE (units 10^{-9})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*
<5.1	90	0	HARRIS 93	E799

$\Gamma(\pi^0e^+e^-)/\Gamma_{\text{total}}$ Γ_{32}/Γ

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.

VALUE (units 10^{-10})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
< 2.8	90		[1] ALAVI-HARATI 04A	KTEV	combined result

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

VALUE (units 10^{-10})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
< 3.5	90		ALAVI-HARATI 04A	KTEV	
$0.0047^{+0.0022}_{-0.0018}$			[2] LAI 02B	NA48	*CP*-conserving part
< 5.1	90	2	ALAVI-HARATI 01	KTEV	
0.01 to 0.02			ALAVI-HARATI 99B	KTEV	*CP*-conserving part
< 43	90	0	HARRIS 93B	E799	
< 75	90	0	BARKER 90	E731	
< 55	90	0	OHL 90	B845	
< 400	90		BARR 88	NA31	
<3200	90		JASTRZEM... 88	SPEC	

[1] Combined result of ALAVI-HARATI 04A 1999-2000 data set and ALAVI-HARATI 01 1997 data set.

[2] LAI 02B uses the absence of a signal in $K^0_L \to \pi^0\gamma\gamma$ with $m(\gamma\gamma)<m(\pi^0)$ and their a_V value to predict this value.

$\Gamma(\pi^0 \nu\overline{\nu})/\Gamma_{\text{total}}$ Γ_{33}/Γ

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

VALUE (units 10^{-8})	*CL%*	*DOCUMENT ID*		*TECN*
$<$ 0.49	90	[1] AHN	21	KOTO
< 0.30	90	[2] AHN	19	KOTO
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<$ 5.1	90	[3] AHN	17	KOTO
$<$ 2.6	90	[4] AHN	10	K391
$<$ 6.7	90	[5] AHN	08	K391
$<$21	90	[6] AHN	06	K391
$<$59	90	ALAVI-HARATI	00	KTEV

[1] AHN 21 result is based on data collected in 2016, 2017 and 2018, which corresponds to 3.05×10^{19} protons on target. A single event sensitivity of $(7.20 \pm 0.05 \pm 0.66) \times 10^{-10}$ was achieved with 3 candidate events observed and total 1.22 ± 0.26 background events.

[2] AHN 19 result is based on data collected in 2015, which corresponds to 2.2×10^{19} protons on target. A single event sensitivity of $(1.30 \pm 0.01 \pm 0.14) \times 10^{-9}$ was achieved with no candidate events observed. An upper limit of $< 2.4 \times 10^{-9}$ at the 90% C.L. for the $K_L \rightarrow \pi^0 X^0$ decay was also set, where X^0 is an invisible particle with a mass of 135 MeV/c^2.

[3] AHN 17 result is based on the first 100 hours of physics running in 2013. One candidate event was observed with an expected background of 0.34 ± 0.16 events. An upper limit of $< 3.7 \times 10^{-8}$ at the 90% C.L. for the $K_L \rightarrow \pi^0 X^0$ decay was also set, where X^0 is an invisible particle with a mass of 135 MeV/c^2.

[4] Obtained combining Run-2 (AHN 08) and Run-3 data.

[5] Value obtained using data from February to April 2005.

[6] Value obtained analyzing 10% of data of RUN 1 (performed in 2004).

$\Gamma(\pi^0 \pi^0 \nu\overline{\nu})/\Gamma_{\text{total}}$ Γ_{34}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
$\boldsymbol{<8.1 \times 10^{-7}}$	90	[1] OGATA	11	K391
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4.7 \times 10^{-5}$	90	[2] NIX	07	K391

[1] Using 2005 Run-I data. OGATA 11 also sets a limit on the $K^0_L \rightarrow \pi^0 \pi^0 X \rightarrow$ invisible particles process: the limit on the branching fraction varied from 7.0×10^{-7} to 4.0×10^{-5} for the mass of X ranging from 50 to 200 MeV/c^2.

[2] Observed 1 event with expected background of 0.43 ± 0.35 events. NIX 07 also measured B($K^0_L \rightarrow \pi^0 \pi^0 P$) $< 1.2 \times 10^{-6}$ at 90% CL, where P is the pseudoscalar particle and $m_P < 100$ MeV.

$\Gamma(e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$ Γ_{35}/Γ

Test of lepton family number conservation.

VALUE (units 10^{-11})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*
<0.47	90		AMBROSE	98B	B871
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<$9.4	90	0	AKAGI	95	SPEC
$<$3.9	90	0	ARISAKA	93	B791
$<$3.3	90	0	[1] ARISAKA	93	B791

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

$\Gamma(e^{\pm}e^{\pm}\mu^{\mp}\mu^{\mp})/\Gamma_{\text{total}}$ Γ_{36}/Γ

Test of lepton family number conservation.

VALUE (units 10^{-11})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
< 4.12	90	0	ALAVI-HARATI	03B	KTEV	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 12.3	90	0	[1] ALAVI-HARATI	01H	KTEV	Sup. by ALAVI-HARATI 03B
<610	90	0	[1] GU	96	E799	

[1] Assuming uniform phase space distribution.

$\Gamma(\pi^0\mu^{\pm}e^{\mp})/\Gamma_{\text{total}}$ Γ_{37}/Γ

Test of lepton family number conservation.

VALUE (units 10^{-10})	*CL%*	*DOCUMENT ID*		*TECN*
< 0.76	90	ABOUZAID	08C	KTEV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<62	90	ARISAKA	98	E799

$\Gamma(\pi^0\pi^0\mu^{\pm}e^{\mp})/\Gamma_{\text{total}}$ Γ_{38}/Γ

Test of lepton family number conservation.

VALUE (units 10^{-10})	*CL%*	*DOCUMENT ID*		*TECN*
<1.7	90	ABOUZAID	08C	KTEV

Lorentz invariance violating modes

$\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$ Γ_{39}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*
$<1.7 \times 10^{-7}$	90	[1] SHIMIZU	20	KOTO

[1] SHIMIZU 20 uses data collected from 2016 to 2018 at the J-PARC KOTO experiment. The single event sensitivity is $(7.1 \pm 0.3 \pm 1.6) \times 10^{-8}$. No candidate event was observed.

See the related review(s):

V_{ud}, V_{us} the Cabibbo Angle, and CKM Unitarity

ENERGY DEPENDENCE OF K^0_L DALITZ PLOT

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

$$|\text{matrix element}|^2 = 1 + gu + hu^2 + jv + kv^2 + fuv$$

where $u = (s_3 - s_0)\ /\ m^2_{\pi}$ and $v = (s_2 - s_1)\ /\ m^2_{\pi}$

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.678 ±0.008 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.					
0.6823±0.0044±0.0044	500k	ANGELOPO...	98C	CPLR	
0.681 ±0.024	6499	CHO	77	HBC	
0.620 ±0.023	4709	PEACH	77	HBC	
0.677 ±0.010	509k	MESSNER	74	ASPK	$a_y = -0.917 \pm 0.013$

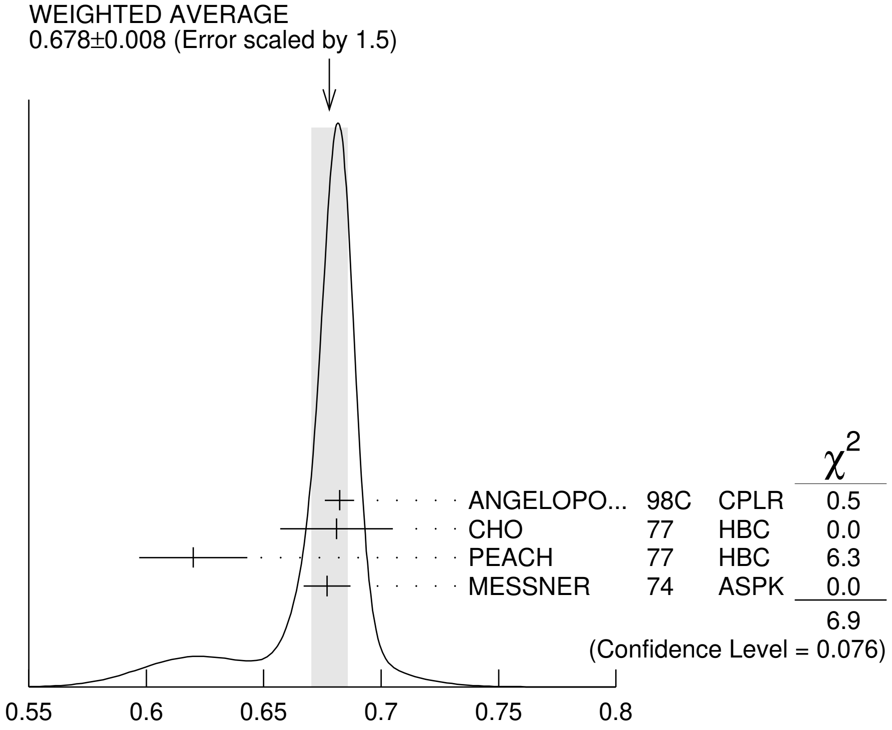
• • • We do not use the following data for averages, fits, limits, etc. • • •

0.69	±0.07	192	[1] BALDO-...	75	HLBC	
0.590	±0.022	56k	[1] BUCHANAN	75	SPEC	$a_u = -0.277 \pm 0.010$
0.619	±0.027	20k	[1,2] BISI	74	ASPK	$a_t = -0.282 \pm 0.011$
0.612	±0.032		[1] ALEXANDER	73B	HBC	
0.73	±0.04	3200	[1] BRANDENB...	73	HBC	
0.608	±0.043	1486	[1] KRENZ	72	HLBC	$a_t = -0.277 \pm 0.018$
0.650	±0.012	29k	[1] ALBROW	70	ASPK	$a_y = -0.858 \pm 0.015$
0.593	±0.022	36k	[1,3] BUCHANAN	70	SPEC	$a_u = -0.278 \pm 0.010$
0.664	±0.056	4400	[1] SMITH	70	OSPK	$a_t = -0.306 \pm 0.024$
0.400	±0.045	2446	[1] BASILE	68B	OSPK	$a_t = -0.188 \pm 0.020$
0.649	±0.044	1350	[1] HOPKINS	67	HBC	$a_t = -0.294 \pm 0.018$
0.428	±0.055	1198	[1] NEFKENS	67	OSPK	$a_u = -0.204 \pm 0.025$

[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^0_L momentum spectrum of second experiment (had same beam).



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

QUADRATIC COEFFICIENT *h* FOR $K_L^0 \to \pi^+\pi^-\pi^0$

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

VALUE	EVTS	DOCUMENT ID		TECN
0.076±0.006 OUR AVERAGE				
0.061±0.004±0.015	500k	ANGELOPO...	98C	CPLR
0.095±0.032	6499	CHO	77	HBC
0.048±0.036	4709	PEACH	77	HBC
0.079±0.007	509k	MESSNER	74	ASPK
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.011±0.018	29k	[1] ALBROW	70	ASPK
0.043±0.052	4400	[1] SMITH	70	OSPK

[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 $K_L^0 \to \pi^+\pi^-\pi^0$

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

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

Listed in *CP*-violation section below.

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

Listed in *CP*-violation section below.

QUADRATIC COEFFICIENT *h* FOR $K_L^0 \to \pi^0\pi^0\pi^0$

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

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN
+0.59±0.20±1.16	68M	[1] ABOUZAID	08A	KTEV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−6.1 ±0.9 ±0.5	14.7M	[2] LAI	01B	NA48
−3.3 ±1.1 ±0.7	5M	[2,3] SOMALWAR	92	E731

[1] Result obtained using CI3pl model of CABIBBO 05 to include $\pi\pi$ rescattering effects. The systematic error includes an external error of 1.06×10^{-3} from the parametrization input of $(a_0 - a_2)\, m_{\pi^+} = 0.268 \pm 0.017$ from BATLEY 06B.

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

[3] SOMALWAR 92 chose m_{π^+} as normalization to make it compatible with the Particle Data Group $K_L^0 \to \pi^+\pi^-\pi^0$ 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 π.

λ_+ and λ_0 are the linear expansion coefficients of f_+ and f_0:

$f_+(t) = f_+(0)\ (1 + \lambda_+ t\ /m^2_{\pi^+})$

For quadratic expansion

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

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

NA48 (K_{e3}) and ISTRA quadratic expansion coefficients are converted with

$\lambda'_+{}^{PDG} = \lambda_+{}^{NA48}$ and $\lambda''_+{}^{PDG} = 2\ \lambda'_+{}^{NA48}$

$\lambda'_+{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda_+{}^{ISTRA}$ and

$\lambda''_+{}^{PDG} = 2\ (\frac{m_{\pi^+}}{m_{\pi^0}})^4\ \lambda'_+{}^{ISTRA}$

ISTRA linear expansion coefficients are converted with

$\lambda_+{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda_+{}^{ISTRA}$ and $\lambda_0{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda_0{}^{ISTRA}$

The pole parametrization is

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

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

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

The dispersive parametrization is

$$f_+(t) = f_+(0)\ \exp[\ \frac{t}{m^2_\pi}\ (\Lambda_+ + H(t))\ ];$$

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

where Λ_+ is the slope parameter and $\ln[C\,] = \ln[\ f_0\ (m^2_K - m^2_\pi\ )\ ]$ 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 = π spectrum analysis.

MU = μ spectrum analysis.

POL= μ polarization analysis.

BR = $K^0_{\mu 3}/K^0_{e3}$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN K^0_{e3} DECAY)

For radiative correction of K^0_{e3} DP, see GINSBERG 67, BECHERRAWY 70, CIRIGLIANO 02, CIRIGLIANO 04, and ANDRE 07. Results labeled OUR FIT are discussed in the review "$K^{\pm}_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" in the $K^{\pm}$ Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.82 ±0.04 OUR FIT	Error includes scale factor of 1.1. Assuming μ-e universality			
2.85 ±0.04 OUR AVERAGE				
2.86 ±0.05 ±0.04	2M	AMBROSINO 06D	KLOE	
2.832±0.037±0.043	1.9M	ALEXOPOU... 04A	KTEV	PI, no $\mu = e$
2.88 ±0.04 ±0.11	5.6M	[1] LAI 04C	NA48	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.84 ±0.07 ±0.13	5.6M	[2] LAI 04C	NA48	DP
2.45 ±0.12 ±0.22	366k	APOSTOLA... 00	CPLR	DP
3.06 ±0.34	74k	BIRULEV 81	SPEC	DP
3.12 ±0.25	500k	GJESDAL 76	SPEC	DP
2.70 ±0.28	25k	BLUMENTHAL75	SPEC	DP

[1] Results from linear fit and assuming only vector and axial couplings.

[2] Results from linear fit with $|f_S/f_+|$ and $|f_T/f_+|$ free.

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

Results labeled OUR FIT are discussed in the review "$K^{\pm}_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" in the $K^{\pm}$ Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.82 ±0.04 OUR FIT	Error includes scale factor of 1.1. Assuming μ-e universality			
2.71 ±0.10 OUR FIT	Error includes scale factor of 1.4. Not assuming μ-e universality			
2.67 ±0.06 ±0.08	2.3M	[1] LAI 07A	NA48	DP
2.745±0.088±0.063	1.5M	ALEXOPOU... 04A	KTEV	DP, no $\mu = e$
2.813±0.051	3.4M	ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$
3.0 ±0.3	1.6M	DONALDSON 74B	SPEC	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •				
4.27 ±0.44	150k	BIRULEV 81	SPEC	DP

[1] LAI 07A gives a correlation −0.40 between their λ_0 and λ_+ measurements.

λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K^0_{\mu 3}$ DECAY)

Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ^{μ}_{+} and $d\xi(0)/d\lambda_+$. Results labeled OUR FIT are discussed in the review "$K^{\pm}_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" in the $K^{\pm}$ Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

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

1.635±0.121	−0.85	3.4M	[3] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$
+1.9 ±0.4	−0.47	1.6M	[4] DONALDSON 74B	SPEC	DP

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

3.41 ±0.67	unknown	150k	[5] BIRULEV 81	SPEC	DP

[1] LAI 07A gives a correlation −0.40 between their λ_0 and λ_+ measurements.

[2] ALEXOPOULOS 04A gives a correlation −0.38 between their λ_0 and λ_+ measurements.

[3] ALEXOPOULOS 04A gives a correlation −0.36 between their λ_0 and λ_+ measurements.

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

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

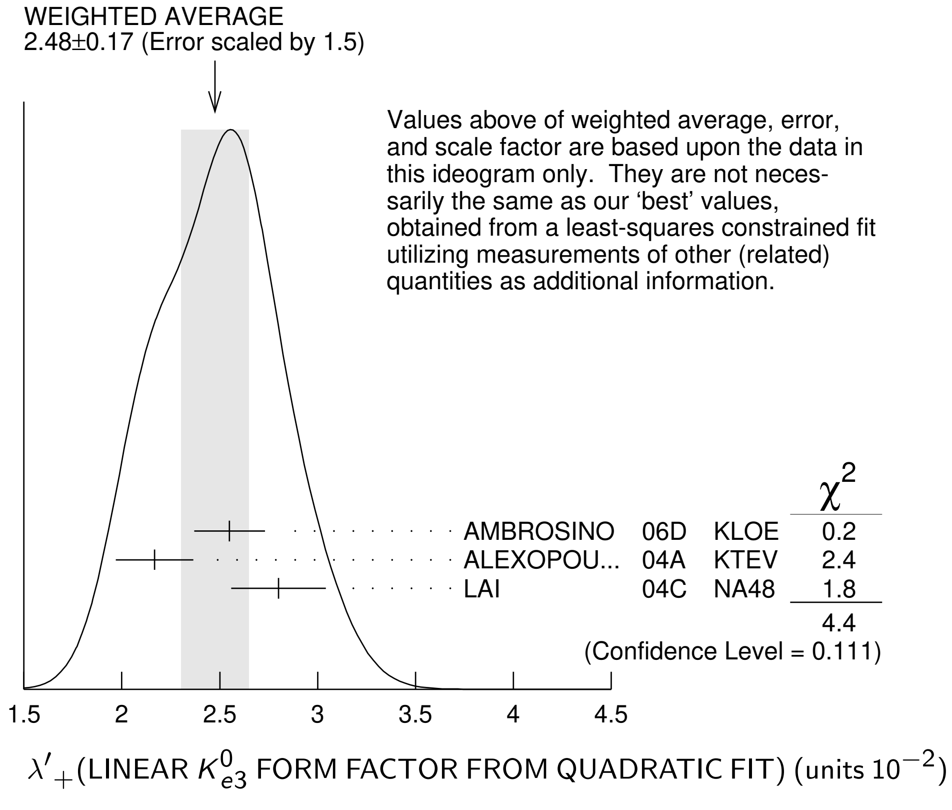
λ'_+(LINEAR K^0_{e3} FORM FACTOR FROM QUADRATIC FIT)

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.40 ±0.12 OUR FIT	Error includes scale factor of 1.2. Assuming μ-e universality			
2.49 ±0.13 OUR FIT	Error includes scale factor of 1.1. Not assuming μ-e universality			
2.48 ±0.17 OUR AVERAGE	Error includes scale factor of 1.5. See the ideogram below.			
2.55 ±0.15 ±0.10	2M	[1] AMBROSINO 06D	KLOE	
2.167±0.137±0.143	1.9M	[2] ALEXOPOU... 04A	KTEV	PI, no $\mu = e$
2.80 ±0.19 ±0.15	5.6M	[3] LAI 04C	NA48	DP

[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 λ'_+ in $K_{\mu 3}$ decays. AMBROSINO 06D gives a correlation −0.95 between their λ'_+ and λ''_+.

[2] ALEXOPOULOS 04A gives a correlation −0.97 between their λ'_+ and λ''_+.

[3] For LAI 04C we calculate a correlation −0.88 between their λ'_+ and λ''_+.



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.

λ''_+(QUADRATIC K^0_{e3} FORM FACTOR)

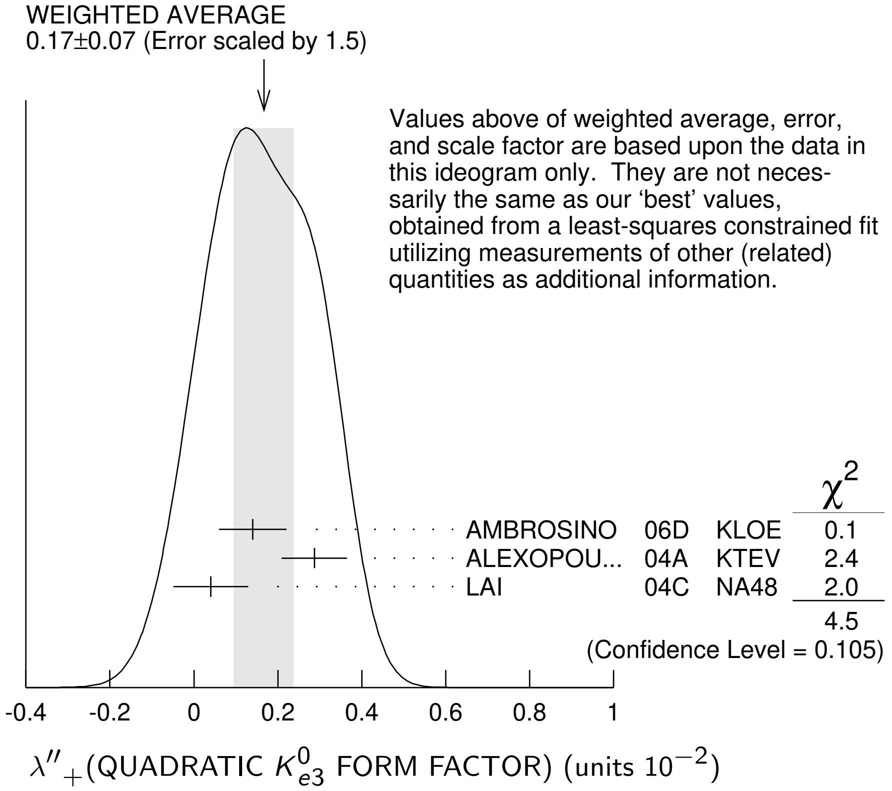
VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.20 ±0.05 OUR FIT	Error includes scale factor of 1.2. Assuming μ-e universality			
0.16 ±0.05 OUR FIT	Error includes scale factor of 1.1. Not assuming μ-e universality			
0.17 ±0.07 OUR AVERAGE	Error includes scale factor of 1.5. See the ideogram below.			
0.14 ±0.07 ±0.04	2M	[1] AMBROSINO 06D	KLOE	
0.287±0.057±0.053	1.9M	[2] ALEXOPOU... 04A	KTEV	PI, no $\mu = e$
0.04 ±0.08 ±0.04	5.6M	[3,4] LAI 04C	NA48	DP

[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 λ''_+ in $K_{\mu 3}$ decays. AMBROSINO 06D gives a correlation −0.95 between their λ'_+ and λ''_+.

[2] ALEXOPOULOS 04A gives a correlation −0.97 between their λ'_+ and λ''_+.

[3] Values doubled to agree with PDG conventions described above.

[4] LAI 04C gives a correlation −0.88 between their λ'_+ and λ''_+.



λ'_+(LINEAR $K^0_{\mu 3}$ FORM FACTOR FROM QUADRATIC FIT)

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.40 ±0.12 OUR FIT	Error includes scale factor of 1.2. Assuming μ-e universality			
1.89 ±0.24 OUR FIT	Not assuming μ-e universality			
2.23 ±0.98 ±0.37	1.8M	[1] AMBROSINO 07C	KLOE	no $\mu = e$
2.56 ±0.15 ±0.09	3.8M	[1] AMBROSINO 07C	KLOE	$\mu = e$
2.05 ±0.22 ±0.24	2.3M	[1] LAI 07A	NA48	DP
1.703±0.319±0.177	1.5M	[1] ALEXOPOU... 04A	KTEV	DP, no $\mu = e$
2.064±0.175	3.4M	[1] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$

[1] See section λ_0 below for correlations.

λ''_+(QUADRATIC $K^0_{\mu3}$ FORM FACTOR)

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.20 ±0.05 OUR FIT	Error includes scale factor of 1.2. Assuming μ-e universality			
0.37 ±0.12 OUR FIT	Error includes scale factor of 1.3. Not assuming μ-e universality			
0.48 ±0.49 ±0.16	1.8M	[1] AMBROSINO 07C	KLOE	no $\mu = e$
0.15 ±0.07 ±0.04	3.8M	[1] AMBROSINO 07C	KLOE	$\mu = e$
0.26 ±0.09 ±0.10	2.3M	[1] LAI 07A	NA48	DP
0.443±0.131±0.072	1.5M	[1] ALEXOPOU... 04A	KTEV	DP, no $\mu = e$
0.320±0.069	3.4M	[1] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$

[1] See section λ_0 below for correlations.

λ_0(LINEAR f_0 $K^0_{\mu3}$ FORM FACTOR FROM QUADRATIC FIT)

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1.16 ±0.09 OUR FIT	Error includes scale factor of 1.2. Assuming μ-e universality			
1.07 ±0.14 OUR FIT	Error includes scale factor of 1.3. Not assuming μ-e universality			
0.91 ±0.59 ±0.26	1.8M	[1] AMBROSINO 07C	KLOE	no $\mu = e$
1.54 ±0.18 ±0.13	3.8M	[2] AMBROSINO 07C	KLOE	$\mu = e$
0.95 ±0.11 ±0.08	2.3M	[3] LAI 07A	NA48	DP
1.281±0.136±0.122	1.5M	[4] ALEXOPOU... 04A	KTEV	DP, no $\mu = e$
1.372±0.131	3.4M	[5] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$

[1] AMBROSINO 07C, not assuming μ-e universality, gives a correlation matrix

$$\begin{array}{ccc} & \lambda'_+ & \lambda''_+ \\ \lambda''_+ & -0.97 & 1 \\ \lambda_0 & 0.81 & -0.91 \end{array}$$

[2] AMBROSINO 07C, assuming μ-e universality, gives a correlation matrix

$$\begin{array}{ccc} & \lambda'_+ & \lambda''_+ \\ \lambda''_+ & -0.95 & 1 \\ \lambda_0 & 0.29 & -0.38 \end{array}$$

[3] LAI 07A gives a correlation matrix

$$\begin{array}{ccc} & \lambda'_+ & \lambda''_+ \\ \lambda''_+ & -0.96 & 1 \\ \lambda_0 & 0.63 & -0.73 \end{array}$$

[4] ALEXOPOULOS 04A, not assuming μ-e universality, gives a correlation matrix

$$\begin{array}{cccc} & \lambda'_+ & \lambda''_+ & \lambda_0 \\ \lambda'_+ & 1 & & \\ \lambda''_+ & -0.96 & 1 & \\ \lambda_0 & 0.65 & -0.75 & 1 \end{array}$$

[5] ALEXOPOULOS 04A, assuming μ-e universality, gives a correlation matrix

$$\begin{array}{cccc} & \lambda'_+ & \lambda''_+ & \lambda_0 \\ \lambda'_+ & 1 & & \\ \lambda''_+ & -0.97 & 1 & \\ \lambda_0 & 0.34 & -0.44 & 1 \end{array}$$

M_V^e (POLE MASS FOR K^0_{e3} DECAY)

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
878 ± 6 OUR FIT				Error includes scale factor of 1.1. Assuming μ-e universality
875 ± 5 OUR AVERAGE				
870 ± 6 ±7	2M	AMBROSINO 06D	KLOE	
881.03± 5.12±4.94	1.9M	ALEXOPOU... 04A	KTEV	PI, no $\mu = e$
859 ±18	5.6M	LAI 04C	NA48	

M_V^μ (POLE MASS FOR $K^0_{\mu 3}$ DECAY)

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
878 ± 6 OUR FIT				Error includes scale factor of 1.1. Assuming μ-e universality
900 ±21 OUR FIT				Error includes scale factor of 1.7. Not assuming μ-e universality
905 ± 9 ±17	2.3M	[1] LAI 07A	NA48	DP
889.19±12.81± 9.92	1.5M	[1] ALEXOPOU... 04A	KTEV	DP, no $\mu = e$
882.32± 6.54	3.4M	[1] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$

[1] See section M_S^μ below for correlations.

M_S^μ (POLE MASS FOR $K^0_{\mu 3}$ DECAY)

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
1250 ±90 OUR FIT				Error includes scale factor of 2.6. Assuming μ-e universality
1220 ±80 OUR FIT				Error includes scale factor of 2.3. Not assuming μ-e universality
1400 ±46 ±53	2.3M	[1] LAI 07A	NA48	DP
1167.14±28.30±31.04	1.5M	[2] ALEXOPOU... 04A	KTEV	PI, no $\mu = e$
1173.80±39.47	3.4M	[3] ALEXOPOU... 04A	KTEV	PI, DP, $\mu = e$

[1] LAI 07A gives a correlation −0.47 between their M_S^μ and M_V^μ measurements, not assuming μ-e universality.

[2] ALEXOPOULOS 04A gives a correlation −0.46 between their M_S^μ and M_V^μ and measurements, not assuming μ-e universality.

[3] ALEXOPOULOS 04A gives a correlation −0.40 between their M_S^μ and M_V^μ and measurements, assuming μ-e universality.

Λ_+ (DISPERSIVE VECTOR FORM FACTOR FOR $K^0_{\mu 3}$ DECAY)

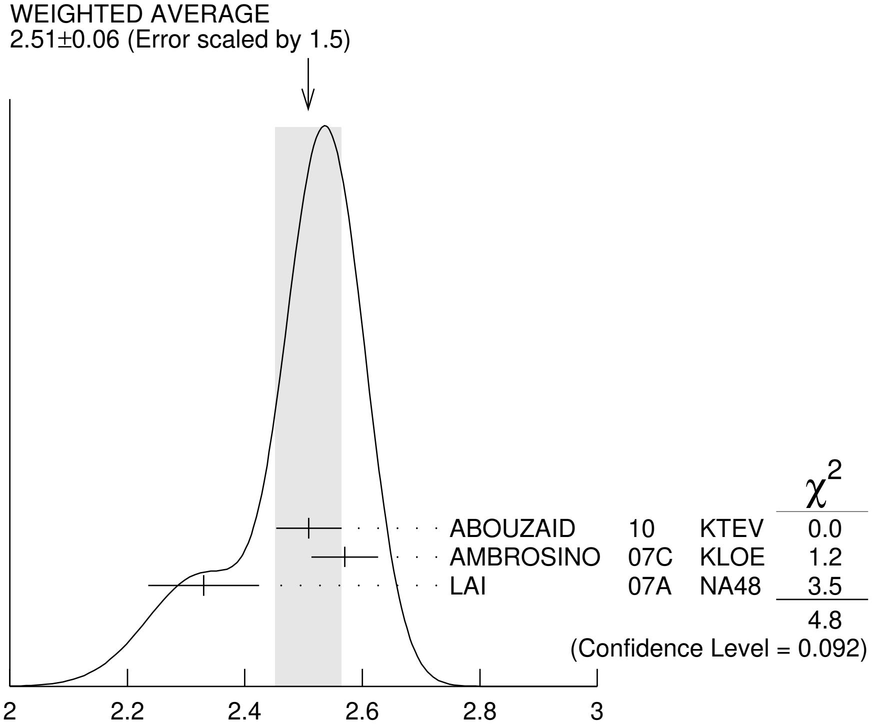
See the review on "$K^\pm_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" for details of the dispersive parametrization.

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.51 ±0.06 OUR AVERAGE				Error includes scale factor of 1.5. See the ideogram below.
2.509±0.035±0.043	3.4M	[1] ABOUZAID 10	KTEV	$\mu = e$
2.57 ±0.04 ±0.04	3.8M	[2] AMBROSINO 07C	KLOE	$\mu = e$
2.33 ±0.05 ±0.08	2.3M	[3] LAI 07A	NA48	DP

[1] Obtained from a sample of 1.9 M K_{e3} and 1.5 M $K_{\mu 3}$. The correlation between Λ_+ and ln(C) is −0.269.

[2] AMBROSINO 07C results include 2M K_{e3} events from AMBROSINO 06D. The correlation between Λ_+ and ln(C) is −0.26.

[3] LAI 07A gives a correlation −0.44 between their Λ_+ and ln(C) measurements.



Λ_+ (DISPERSIVE VECTOR FORM FACTOR FOR $K^0_{\mu3}$ DECAY) (units 10^{-2})

ln*(C)* (DISPERSIVE SCALAR FORM FACTOR FOR $K^0_{\mu3}$ DECAY)

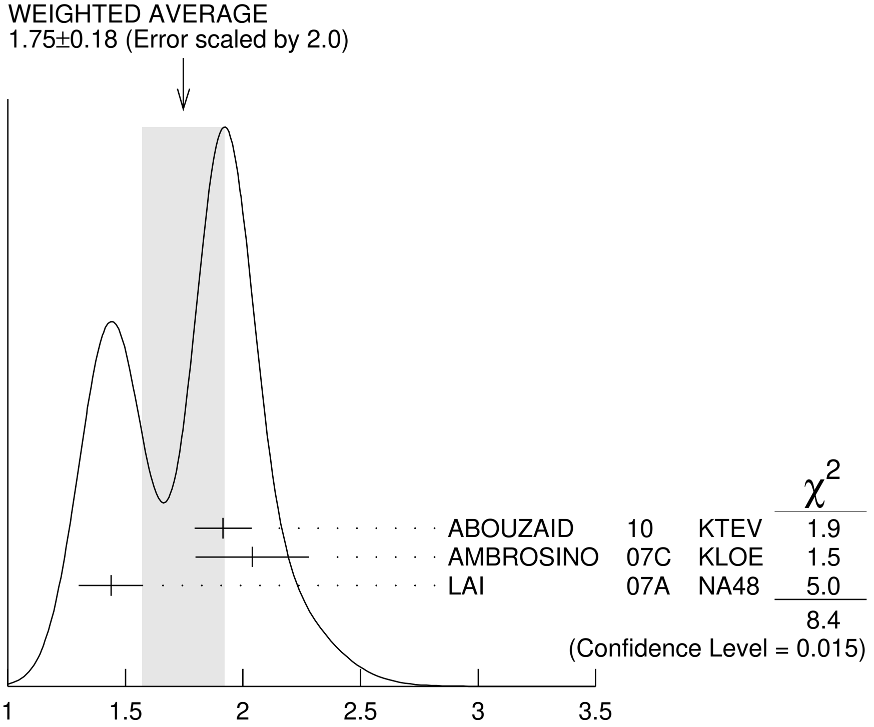
See the review on "$K^\pm_{\ell3}$ and $K^0_{\ell3}$ Form Factors" for details of the dispersive parametrization.

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

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

[2] AMBROSINO 07C results include 2M K_{e3} events from AMBROSINO 06D. We convert (Λ_+, Λ_0) to (Λ_+, ln*(C)*) parametrization using $\ln(C) = (\Lambda_0 \cdot 11.713 + 0.0398) \pm 0.0041$, where the error is due to theory parametrization of the form factor. The correlation between Λ_+ and ln*(C)* is −0.26.

[3] LAI 07A gives a correlation −0.44 between their Λ_+ and ln*(C)* measurements.



ln*(C)* (DISPERSIVE SCALAR FORM FACTOR FOR $K^0_{\mu 3}$ DECAY) (units 10^{-1})

$a_1(t_0, Q^2)$ FORM FACTOR PARAMETER

See HILL 06 for a definition of this parameter.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*
1.023±0.028±0.029	2M	[1] ABOUZAID 06C	KTEV

[1] $Q^2 = 2$ 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.

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*
0.75±1.58±1.47	2M	[1] ABOUZAID 06C	KTEV

[1] $Q^2 = 2$ 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_{e3} DECAY

Ratio of scalar to f_+ couplings.

VALUE (units 10^{-2})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{1.5^{+0.7}_{-1.0}\pm1.2}$		5.6M	[1] LAI 04C	NA48	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<9.5	95	18k	HILL 78	STRC	
<7.	68	48k	BIRULEV 76	SPEC	See also BIRULEV 81
<4.	68	25k	BLUMENTHAL75	SPEC	

[1] Results from linear fit with $|f_S/f_+|$ and $|f_T/f_+|$ free.

$|f_T/f_+|$ FOR K^0_{e3} DECAY

Ratio of tensor to f_+ couplings.

VALUE (units 10^{-2})	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{5^{+3}_{-4}\pm3}$		5.6M	[1] LAI	04C	NA48	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<40.	95	18k	HILL	78	STRC	
<34.	68	48k	BIRULEV	76	SPEC	See also BIRULEV 81
<23.	68	25k	BLUMENTHAL	75	SPEC	

[1] Results from linear fit with $|f_S/f_+|$ and $|f_T/f_+|$ free.

$|f_T/f_+|$ FOR $K^0_{\mu3}$ DECAY

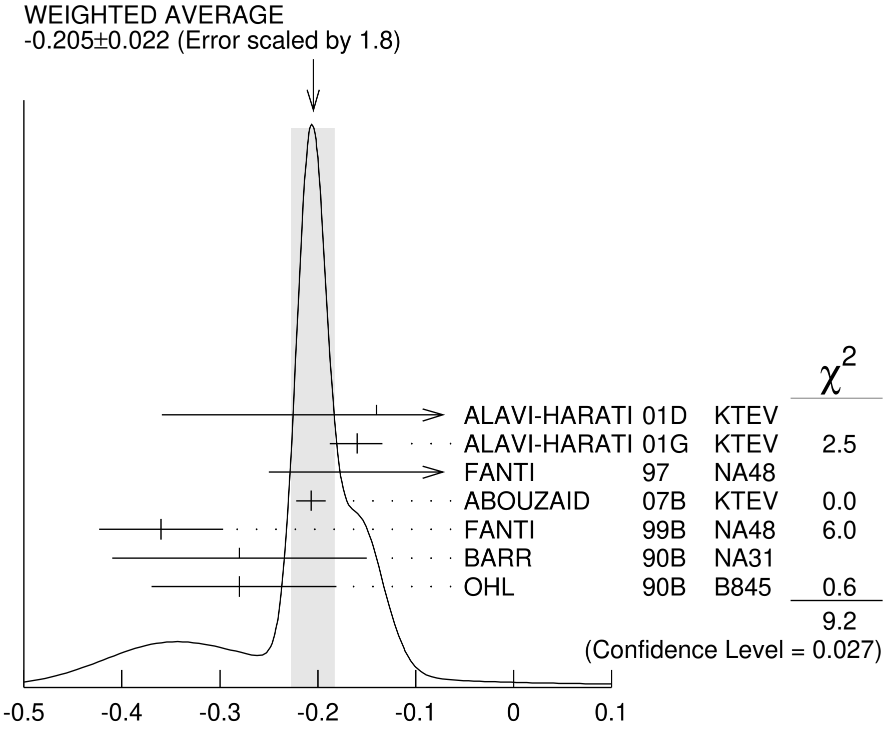
Ratio of tensor to f_+ couplings.

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*
12.±12.	BIRULEV	81	SPEC

α_{K^*} DECAY FORM FACTOR FOR $K_L \rightarrow \ell^+\ell^-\gamma$, $K^0_L \rightarrow \ell^+\ell^-\ell'^+\ell'^-$

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

VALUE	*DOCUMENT ID*
−0.205±0.022 OUR AVERAGE Includes data from the 3 datablocks that follow this one. Error includes scale factor of 1.8. See the ideogram below.	



α_{K^*} DECAY FORM FACTOR FOR $K_L \rightarrow \ell^+\ell^-\gamma$, $K^0_L \rightarrow \ell^+\ell^-\ell'^+\ell'^-$

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

α_{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 $K_L \to \pi, \eta, \eta' \to \gamma\gamma^*$.

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
-0.217 ± 0.034 OUR AVERAGE	Error includes scale factor of 2.4.			
$-0.207 \pm 0.012 \pm 0.009$	83k	[1] ABOUZAID	07B	KTEV
$-0.36 \pm 0.06 \pm 0.02$	6864	FANTI	99B	NA48
-0.28 ± 0.13		BARR	90B	NA31
$-0.280^{+0.099}_{-0.090}$		OHL	90B	B845

[1] ABOUZAID 07B measures $C \cdot \alpha_{K^*} = -0.517 \pm 0.030 \pm 0.022$. We assume $C = 2.5$, as in all other measurements.

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

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

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
-0.158 ± 0.027 OUR AVERAGE				
$-0.160^{+0.026}_{-0.028}$	9100	ALAVI-HARATI	01G	KTEV
$-0.04^{+0.24}_{-0.21}$		FANTI	97	NA48

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

$\alpha^{\text{eff}}_{K^*}$ 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.

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
$-0.14 \pm 0.16 \pm 0.15$	441	ALAVI-HARATI	01D	KTEV

α_{DIP} DECAY FORM FACTOR FOR $K^0_L \to \ell^+ \ell^- \gamma$, $K^0_L \to \ell^+ \ell^- \ell'^+ \ell'^-$

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

VALUE	*DOCUMENT ID*
-1.69 ± 0.08 OUR AVERAGE	Includes data from the 3 datablocks that follow this one.

Error includes scale factor of 1.7.

α_{DIP} DECAY FORM FACTOR FOR $K^0_L \to e^+ e^- \gamma$

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

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
$-1.729 \pm 0.043 \pm 0.028$	83k	ABOUZAID	07B	KTEV

α_{DIP} DECAY FORM FACTOR FOR $K^0_L \to \mu^+\mu^-\gamma$

α_{DIP} is a constant in the model of DAMBROSIO 98 described in the previous section.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
The data in this block is included in the average printed for a previous datablock.				
−1.54±0.10	9100	ALAVI-HARATI	01G	KTEV

α_{DIP} DECAY FORM FACTOR FOR $K^0_L \to e^+e^-\mu^+\mu^-$

α_{DIP} is a constant in the model of DAMBROSIO 98 described in the previous section.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
The data in this block is included in the average printed for a previous datablock.				
−1.59±0.37	131	ALAVI-HARATI	03B	KTEV

a_1/a_2 FORM FACTOR FOR M1 DIRECT EMISSION AMPLITUDE

Form factor $= \tilde{g}_{M1}\left[1+\frac{a_1/a_2}{(M^2_\rho - M^2_K)+2M_K E^*_\gamma}\right]$ as described in ALAVI-HARATI 00B.

VALUE (GeV^2)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.737±0.014 OUR AVERAGE					
−0.744±0.027±0.032	5241	[1] ABOUZAID	06	KTEV	$\pi^+\pi^-e^+e^-$
−0.738±0.007±0.018	111k	[2] ABOUZAID	06A	KTEV	$\pi^+\pi^+\gamma$
$-0.81\ ^{+0.07}_{-0.13}\ \pm0.02$		[3] LAI	03C	NA48	$\pi^+\pi^-e^+e^-$
−0.737±0.026±0.022		[4] ALAVI-HARATI	01B		$\pi^+\pi^-\gamma$
−0.720±0.028±0.009	1766	[5] ALAVI-HARATI	00B	KTEV	$\pi^+\pi^-e^+e^-$

[1] ABOUZAID 06 also measured $|\tilde{g}_{M1}| = 1.11 \pm 0.14$.

[2] ABOUZAID 06A 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 χ^2/DOF = 38.8/27. Linear and quadratic fits give χ^2/DOF = 43.2/27 and 37.6/26 respectively.

[5] ALAVI-HARATI 00B also measured $|\tilde{g}_{M1}| = 1.35^{+0.20}_{-0.17} \pm 0.04$.

$\overline{f}_S$ DECAY FORM FACTOR FOR $K^0_L \to \pi^\pm\pi^0 e^\mp\nu_e$

VALUE	*DOCUMENT ID*		*TECN*
0.049±0.011 OUR AVERAGE Error includes scale factor of 1.7.			
0.052±0.006±0.002	BATLEY	04	NA48
0.010±0.016±0.017	MAKOFF	93	E731

$\overline{f}_P$ DECAY FORM FACTOR FOR $K^0_L \to \pi^\pm\pi^0 e^\mp\nu_e$

VALUE	*DOCUMENT ID*		*TECN*
−0.052±0.012 OUR AVERAGE			
−0.051±0.011±0.005	BATLEY	04	NA48
−0.079±0.049±0.022	MAKOFF	93	E731

λ_g DECAY FORM FACTOR FOR $K^0_L \to \pi^\pm\pi^0 e^\mp\nu_e$

VALUE	*DOCUMENT ID*		*TECN*
0.085±0.020 OUR AVERAGE			
0.087±0.019±0.006	BATLEY	04	NA48
0.014±0.087±0.070	MAKOFF	93	E731

$\overline{h}$ DECAY FORM FACTOR FOR $K_L^0 \to \pi^\pm \pi^0 e^\mp \nu_e$

VALUE	*DOCUMENT ID*		*TECN*
−0.30±0.13 OUR AVERAGE			
−0.32±0.12±0.07	BATLEY	04	NA48
−0.07±0.31±0.31	MAKOFF	93	E731

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

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*
−3.96±0.28 OUR AVERAGE	Error includes scale factor of 1.6.		
−4.1 ±0.2	BATLEY	04	NA48
−3.4 ±0.4	[1] MAKOFF	93	E731

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

a_V, VECTOR MESON EXCHANGE CONTRIBUTION

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.43±0.06 OUR AVERAGE		Error includes scale factor of 1.5.			
−0.31±0.05±0.07	1.4k	[1] ABOUZAID	08	KTEV	
−0.46±0.03±0.04		LAI	02B	NA48	$K_L^0 \to \pi^0 2\gamma$
−0.67±0.21±0.12		ALAVI-HARATI	01E	KTEV	$K_L^0 \to \pi^0 e^+ e^- \gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.72±0.05±0.06		[2] ALAVI-HARATI	99B	KTEV	$K_L^0 \to \pi^0 2\gamma$

[1] Using KTeV dataset collected in 1996, 1997, and 1999.

[2] Superseded by ABOUZAID 08.

See the related review(s):

CP Violation in K_L^0 Decays

CP-VIOLATION PARAMETERS IN K_L^0 DECAYS

CHARGE ASYMMETRY IN $K_{\ell 3}^0$ DECAYS

Such asymmetry violates *CP*. It is related to Re(ϵ).

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

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

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.332±0.006 OUR AVERAGE		Includes data from the 2 datablocks that follow this one.			
0.333±0.050	33M	WILLIAMS	73	ASPK	$K_{\mu 3} + K_{e3}$

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

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

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*
The data in this block is included in the average printed for a previous datablock.				
0.304±0.025 OUR AVERAGE				
0.313±0.029	15M	GEWENIGER	74	ASPK
0.278±0.051	7.7M	PICCIONI	72	ASPK

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

0.60 ±0.14	4.1M	MCCARTHY	73	CNTR
0.57 ±0.17	1M	[1] PACIOTTI	69	OSPK
0.403±0.134	1M	[1] DORFAN	67	OSPK

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

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

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

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

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*
0.334 ±0.007 OUR AVERAGE				
0.3322±0.0058±0.0047	298M	ALAVI-HARATI	02	
0.341 ±0.018	34M	GEWENIGER	74	ASPK
0.318 ±0.038	40M	FITCH	73	ASPK
0.346 ±0.033	10M	MARX	70	CNTR
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.36 ±0.18	600k	ASHFORD	72	ASPK
0.246 ±0.059	10M	[1] SAAL	69	CNTR
0.224 ±0.036	10M	[1] BENNETT	67	CNTR

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

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

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

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

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

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
2.220±0.011 OUR FIT	Error includes scale factor of 1.8.			
2.243±0.014	BRFIT	16		
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.47 ±0.31 ±0.24	ANGELOPO...	98	CPLR	
2.49 ±0.40	[1] ADLER	96B	CPLR	Sup. by ANGELOPOULOS 98
2.33 ±0.18	CHRISTENS...	79	ASPK	
2.71 ±0.37	[2] WOLFF	71	OSPK	Cu reg., 4γ's
2.95 ±0.63	[2] CHOLLET	70	OSPK	Cu reg., 4γ's

[1] Error is statistical only.

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

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

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
2.232±0.011 OUR FIT	Error includes scale factor of 1.8.			
2.226±0.007		BRFIT	16	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.223±0.012		[1] LAI	07 NA48	
2.219±0.013		[2] AMBROSINO	06F KLOE	
2.228±0.010		[3] ALEXOPOU...	04 KTEV	
2.286±0.023±0.026	70M	[4] APOSTOLA...	99C CPLR	K^0-$\overline{K}^0$ asymmetry
2.310±0.043±0.031		[5] ADLER	95B CPLR	K^0-$\overline{K}^0$ asymmetry
2.32 ±0.14 ±0.03	10^5	ADLER	92B CPLR	K^0-$\overline{K}^0$ asymmetry
2.30 ±0.035		GEWENIGER	74B ASPK	

[1] Value obtained from the NA48 measurements of $\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma(K^0_L \to \pi e \nu_e)$ and $\tau_{K^0_S}$ and KLOE measurements of $B(K^0_S \to \pi^+\pi^-)$ and $\tau_{K^0_L}$. $\Gamma(K^0_L \to \pi^+\pi^-)$ is defined to include the inner bremsstrahlung component $\Gamma(K^0_L \to \pi^+\pi^-\gamma(\mathrm{IB}))$ but exclude the direct emission component $B(K^0_S \to \pi^+\pi^-(\mathrm{DE}))$. Their $\left|\eta_{+-}\right|$ 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 τ_L together with τ_S from PDG 04. Their $\left|\eta_{+-}\right|$ value is not directly used in our fit, but enters the fit via their branching ratio and lifetime measurements.

[3] ALEXOPOULOS 04 $\left|\eta_{+-}\right|$ uses their $K^0_L \to \pi\pi$ branching fractions, $\tau_S = (0.8963 \pm 0.0005) \times 10^{-10}$ s from the average of KTeV and NA48 τ_S measurements, and assumes that $\Gamma(K^0_S \to \pi\ell\nu_\ell) = \Gamma(K^0_L \to \pi\ell\nu_\ell)$ giving $B(K^0_S \to \pi\ell\nu_\ell) = 0.118\%$. Their η_{+-} is not directly used in our fit, but enters our fit via their branching ratio measurements.

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

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

$\left|\epsilon\right| = (2\left|\eta_{+-}\right| + \left|\eta_{00}\right|)/3$

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.

VALUE (units 10^{-3})	*DOCUMENT ID*
2.228±0.011 OUR FIT	Error includes scale factor of 1.8.

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

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*
0.9950±0.0007 OUR FIT Error includes scale factor of 1.6.				
0.9930±0.0020 OUR AVERAGE				
0.9931±0.0020		[1,2] BARR	93D	NA31
0.9904±0.0084±0.0036		[3] WOODS	88	E731
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.9939±0.0013±0.0015	1M	[1] BARR	93D	NA31
0.9899±0.0020±0.0025		[1] BURKHARDT	88	NA31

[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 (ϵ'/ϵ) value.

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

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

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
1.66 ±0.23 OUR FIT Error includes scale factor of 1.6.				
1.68 ±0.20 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.				
1.92 ±0.21	[1] ABOUZAID	11	KTEV	Assuming *CPT*
1.47 ±0.22	BATLEY	02	NA48	
0.74 ±0.52 ±0.29	GIBBONS	93B	E731	
• • • We use the following data for averages but not for fits. • • •				
2.3 ±0.65	[2,3] BARR	93D	NA31	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.110±0.343	[1,4] ABOUZAID	11	KTEV	Not assuming *CPT*
2.07 ±0.28	ALAVI-HARATI	03	KTEV	In ABOUZAID 11
1.53 ±0.26	LAI	01C	NA48	Incl. in BATLEY 02
2.80 ±0.30 ±0.28	ALAVI-HARATI	99D	KTEV	In ALAVI-HARATI 03
1.85 ±0.45 ±0.58	FANTI	99C	NA48	In LAI 01C
2.0 ±0.7	[5] BARR	93D	NA31	
−0.4 ±1.4 ±0.6	PATTERSON	90	E731	in GIBBONS 93B
3.3 ±1.1	[5] BURKHARDT	88	NA31	
3.2 ±2.8 ±1.2	[2] WOODS	88	E731	

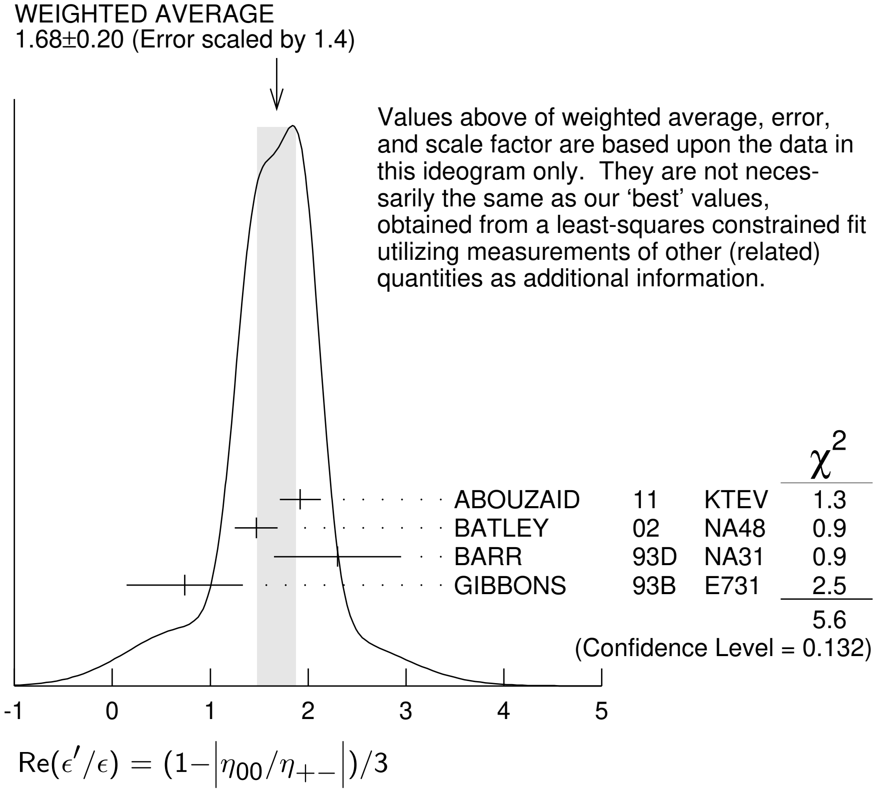
[1] The two ABOUZAID 11 values use the same data. The fits are performed with and without *CPT* invariance requirement.

[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 $\text{Re}(\epsilon'/\epsilon)$ value with *CPT* assumption in our fits for $|\eta_{+-}|$, $|\eta_{00}|$, and $\text{Re}(\epsilon'/\epsilon)$.

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



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.

ϕ_{+-}, PHASE of η_{+-}

The dependence of the phase on Δm and τ_S is given for each experiment in the comments below, where Δm is the $K^0_L - K^0_S$ mass difference in units 10^{10} $\hbar s^{-1}$ and τ_s is the K_S mean life in units 10^{-10} s. We also give the regeneration phase ϕ_f in the comments below.

OUR FIT is described in the note on "*CP* violation in K_L decays" in the K^0_L 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 ϕ_{+-} because their errors are large compared to that assuming *CPT*, but they influence Δm and τ_s through their dependencies on these parameters, which are given in the footnotes.

VALUE (°)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
43.51±0.05 OUR FIT	Error includes scale factor of 1.2. Assuming *CPT*				
43.4 ±0.5 OUR FIT	Error includes scale factor of 1.2. Not assuming *CPT*				
42.9 ±0.6 ±0.3	70M	[1] APOSTOLA...	99C	CPLR	K^0-$\overline{K}^0$ asymmetry
42.9 ±0.8 ±0.2		[2,3] SCHWINGEN...	95	E773	$CH_{1.1}$ regenerator
41.4 ±0.9 ±0.2		[3,4] GIBBONS	93	E731	B_4C regenerator
44.5 ±1.6 ±0.5		[5] CAROSI	90	NA31	Vacuum regen.
43.3 ±1.0 ±0.5		[6] GEWENIGER	74B	ASPK	Vacuum regen.
• • • We do not use the following data for averages, fits, limits, etc. • • •					
43.76±0.64		[7] ABOUZAID	11	KTEV	Not assuming *CPT*
44.12±0.72±1.20		[8] ALAVI-HARATI	03	KTEV	Not assuming *CPT*
42.5 ±0.4 ±0.3		[9,10] ADLER	96C	RVUE	
43.4 ±1.1 ±0.3		[11] ADLER	95B	CPLR	K^0-$\overline{K}^0$ asymmetry
42.3 ±4.4 ±1.4	100k	[12] ADLER	92B	CPLR	K^0-$\overline{K}^0$ asymmetry
47.7 ±2.0 ±0.9		[3,13] KARLSSON	90	E731	
44.3 ±2.8 ±0.2		[14] CARITHERS	75	SPEC	C regenerator

[1] APOSTOLAKIS 99C measures $\phi_{+-} = (43.19 \pm 0.53 \pm 0.28)\ + 300\ [\Delta m - 0.5301]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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 $\phi_{+-} = (43.53 \pm 0.76)\ + 173\ [\Delta m - 0.5282] - 275\ [\tau_S - 0.8926]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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.

[3] These experiments measure ϕ_{+-}–ϕ_f and calculate the regeneration phase from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. SCHWINGENHEUER 95 [GIBBONS 93] includes a systematic error of 0.35° [0.5°] for uncertainties in their modeling of the regeneration amplitude.

[4] GIBBONS 93 measures $\phi_{+-} = (42.21 \pm 0.9)\ + 189\ [\Delta m - 0.5257] - 460\ [\tau_S - 0.8922]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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. This is actually reported in SCHWINGENHEUER 95, footnote 8. GIBBONS 93 reports ϕ_{+-} $(42.2 \pm 1.4)^\circ$. They measure ϕ_{+}–ϕ_f and calculate the regeneration phase ϕ_f from the power law momentum dependence of the regeneration amplitude using analyticity. An error of 0.6° is included for possible uncertainties in the regeneration phase.

[5] CAROSI 90 measures $\phi_{+-} = (46.9 \pm 1.4 \pm 0.7)\ + 579\ [\Delta m - 0.5351] + 303\ [\tau_S - 0.8922]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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 74B measures $\phi_{+-} = (49.4 \pm 1.0)\ + 565\ [\Delta m - 0.540]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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 ABOUZAID 11.

[8] ALAVI-HARATI 03 ϕ_{+-} is correlated with their $\Delta m = m_{K^0_L} - m_{K^0_S}$ and τ_{K_S} measurements in the K^0_L and K^0_S sections respectively. The correlation coefficients are $\rho(\phi_{+-}, \Delta m) = +0.955$, $\rho(\phi_{+-}, \tau_S) = -0.871$, and $\rho(\tau_S, \Delta m) = -0.840$. *CPT* is not assumed. Uses scintillator Pb regenerator. Superseded by ABOUZAID 11.

[9] ADLER 96C measures $\phi_{+-} = (43.82 \pm 0.41)\ + 339\ [\Delta m - 0.5307] - 252\ [\tau_S - 0.8922]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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 $\phi_{+-} = (42.7 \pm 0.9 \pm 0.6)\ + 316\ [\Delta m - 0.5274] + 30\ [\tau_S - 0.8926]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}$ $\hbar$ 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 Δm.

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

[14] CARITHERS 75 measures $\phi_{+-} = (45.5 \pm 2.8) + 224\,[\Delta m - 0.5348]$ (°). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}\ \hbar\ \mathrm{s}^{-1}$). Our first error is their experiment's error and our second error is the systematic error from using our best values. $\phi_f = -40.9 \pm 2.6^\circ$.

ϕ_{00}, PHASE OF η_{00}

See comment in ϕ_{+-} header above for treatment of Δm and τ_S dependence, as well as for the inclusion of data in both the "Assuming *CPT*" and "Not Assuming *CPT*" fits.

OUR FIT is described in the note on "*CP* violation in K_L decays" in the K_L^0 Particle Listings.

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
43.52±0.05 OUR FIT	Error includes scale factor of 1.2. Assuming *CPT*			
43.7 ±0.6 OUR FIT	Error includes scale factor of 1.2. Not assuming *CPT*			
44.5 ±2.3 ±0.5	[1] CAROSI	90	NA31	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
44.06±0.68	[2] ABOUZAID	11	KTEV	Not assuming *CPT*
41.7 ±5.9 ±0.2	[3] ANGELOPO...	98	CPLR	
50.8 ±7.1 ±1.7	[4] ADLER	96B	CPLR	Sup. by ANGELOPOULOS 98
47.4 ±1.4 ±0.9	[5] KARLSSON	90	E731	

[1] CAROSI 90 measures $\phi_{00} = (47.1 \pm 2.1 \pm 1.0) + 579\,[\Delta m - 0.5351] + 252\,[\tau_S - 0.8922]$ (°). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}\ \hbar\ \mathrm{s}^{-1}$), ($\tau_S = 0.8954 \pm 0.0004$) ($10^{-10}$ s). Our first error is their experiment's error and our second error is the systematic error from using our best values.

[2] Not independent of other phase parameters reported in ABOUZAID 11.

[3] ANGELOPOULOS 98 measures $\phi_{00} = (42.0 \pm 5.6 \pm 1.9) + 240\,[\Delta m - 0.5307]$ (°). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}\ \hbar\ \mathrm{s}^{-1}$). Our first error is their experiment's error and our second error is the systematic error from using our best values. The τ_S dependence is negligible.

[4] ADLER 96B identified initial neutral kaon individually as being a K^0 or a $\overline{K}^0$. The systematic uncertainty is ±1.5° combined in quadrature with ±0.8° due to Δm.

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

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

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 ϵ'/ϵ, and small theoretical ambiguities.

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
43.52 ±0.04 OUR FIT	Error includes scale factor of 1.2. Assuming *CPT*			
43.5 ±0.5 OUR FIT	Error includes scale factor of 1.3. Not assuming *CPT*			
43.5164±0.0002±0.0509	[1] SUPERWEAK	16		Assuming *CPT*
43.86 ±0.63	[2] ABOUZAID	11	KTEV	Not assuming *CPT*

[1] SUPERWEAK 16 is a fake measurement used to impose the *CPT* or Superweak constraint $\phi_{+-} = \phi_{SW} = \tan^{-1}[2\,\frac{\Delta m}{\hbar}\,(\frac{\tau_S \tau_L}{\tau_L - \tau_S})]$. This "measurement" is linearized using values near the PDG 04 edition values of Δm, τ_S and τ_L, and then adjusted to our current values as described in the following "measurement". SUPERWEAK 16 measures $\phi_\epsilon = (43.50258 \pm 0.00021) + 54.1\,[\Delta m - 0.5289] + 32.0\,[\tau_S - 0.89564]$ (°). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10}\ \hbar\ \mathrm{s}^{-1}$), ($\tau_S = 0.8954 \pm 0.0004$) ($10^{-10}$ s). Our first error is their experiment's error and our second error is the systematic error from using our best values.

[2] ABOUZAID 11 uses the full KTeV dataset collected in 1996, 1997, and 1999. See Im(ϵ'/ϵ) section for correlation information.

$\mathrm{Im}(\epsilon'/\epsilon) = -(\phi_{00} - \phi_{+-})/3$

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

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.002 ±0.005 OUR FIT	Error includes scale factor of 1.7. Assuming *CPT*			
−0.11 ±0.11 OUR FIT	Not assuming *CPT*			
−0.0985±0.1157	[1] ABOUZAID	11	KTEV	Not assuming *CPT*

[1] ABOUZAID 11 uses the full KTeV dataset collected in 1996, 1997, and 1999. The fit has Δm, τ_S, ϕ_ϵ, $\mathrm{Re}(\epsilon'/\epsilon)$, and $\mathrm{Im}(\epsilon'/\epsilon)$ as free parameters. The reported value of $\mathrm{Im}(\epsilon'/\epsilon)$ $= (-17.20 \pm 20.20) \times 10^{-4}$ rad. The correlation coefficients are $\rho(\phi_\epsilon, \Delta m) = 0.828$, $\rho(\phi_\epsilon, \tau_S) = -0.765$, $\rho(\Delta m, \tau_S) = -0.858$, $\rho(\mathrm{Im}(\epsilon'/\epsilon), \phi_\epsilon) = -0.041$, $\rho(\mathrm{Im}(\epsilon'/\epsilon), \Delta m) = 0.026$, $\rho(\mathrm{Im}(\epsilon'/\epsilon), \tau_S) = -0.010$.

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

This is the *CP*-violating asymmetry

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

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

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

VALUE (%)	*DOCUMENT ID*		*TECN*
13.7±1.5 OUR AVERAGE			
13.6±1.4±1.5	ABOUZAID	06	KTEV
14.2±3.0±1.9	LAI	03C	NA48
13.6±2.5±1.2	ALAVI-HARATI	00B	KTEV

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

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

$$d\Gamma/d\phi \propto 1 + \beta_{CP}\cos(2\phi) + \gamma_{CP}\sin(2\phi)$$

where $\beta_{CP} = -0.20$ and $\gamma_{CP} = 0$ values correspond to no *CP* violation.

β_{CP} from $K_L^0 \rightarrow e^+e^-e^+e^-$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.19±0.07 OUR AVERAGE					
−0.13±0.10±0.03	200	[1] LAI	05B	NA48	
−0.23±0.09±0.02	441	ALAVI-HARATI	01D	KTEV	$M_{ee} > 8$ MeV/c^2

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

γ_{CP} from $K_L^0 \rightarrow e^+e^-e^+e^-$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.01±0.11 OUR AVERAGE	Error includes scale factor of 1.6.				
+0.13±0.10±0.03	200	LAI	05B	NA48	
−0.09±0.09±0.02	441	ALAVI-HARATI	01D	KTEV	$M_{ee} > 8$ MeV/c^2

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

These are *CP*-violating charge-asymmetry parameters, defined at beginning of section "LINEAR COEFFICIENT *g* FOR $K^0_L \rightarrow \pi^+\pi^-\pi^0$ 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 $K^0_L \rightarrow \pi^+\pi^-\pi^0$

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*
0.0012±0.0008 OUR AVERAGE			
0.0010±0.0024±0.0030	500k	ANGELOPO... 98C	CPLR
−0.001 ±0.011	6499	CHO 77	
0.001 ±0.003	4709	PEACH 77	
0.0013±0.0009	3M	SCRIBANO 70	
0.0 ±0.017	4400	SMITH 70	OSPK
0.001 ±0.004	238k	BLANPIED 68	

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

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

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

$|\eta_{+-\gamma}| = |\mathrm{A}(K^0_L \rightarrow \pi^+\pi^-\gamma$, *CP* violating)$/\mathrm{A}(K^0_S \rightarrow \pi^+\pi^-\gamma)|$

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

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

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

$|\epsilon'_{+-\gamma}|/\epsilon$ for $K^0_L \rightarrow \pi^+\pi^-\gamma$

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*
<0.3	90	3671	[1] RAMBERG 93B	E731

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

$|g_{E1}|$ for $K^0_L \rightarrow \pi^+\pi^-\gamma$

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

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.21	90	111k	ABOUZAID 06A	KTEV	$E^*_\gamma > 20$ MeV

T VIOLATION TESTS IN K_L^0 DECAYS

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

Test of *T* reversal invariance.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.007±0.026 OUR AVERAGE					
0.009±0.030	12M	MORSE	80	CNTR	Polarization
0.35 ±0.30	207k	[1] CLARK	77	SPEC	POL, t=0
−0.085±0.064	2.2M	[2] SANDWEISS	73	CNTR	POL, t=0
−0.02 ±0.08		LONGO	69	CNTR	POL, t=3.3
−0.2 ±0.6		ABRAMS	68B	OSPK	Polarization
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.012±0.026		SCHMIDT	79	CNTR	Repl. by MORSE 80

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

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

CPT-INVARIANCE TESTS IN K_L^0 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^0 Particle Listings.

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.006±0.014 OUR FIT	Error includes scale factor of 1.7. Assuming *CPT*			
0.34 ±0.32 OUR FIT	Not assuming *CPT*			
0.006±0.008	[1] SUPERWEAK	16		Assuming *CPT*
−0.30 ±0.88	[2] SCHWINGEN...	95		Combined E731, E773
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.30 ±0.35	[3] ABOUZAID	11	KTEV	Not assuming *CPT*
0.39 ±0.22 ±0.45	[4] ALAVI-HARATI	03	KTEV	
0.62 ±0.71 ±0.75	SCHWINGEN...	95	E773	
−1.6 ±1.2	[5] GIBBONS	93	E731	
0.2 ±2.6 ±1.2	[6] CAROSI	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(ϵ'/ϵ), Im(ϵ'/ϵ), Δm, τ_S, and ϕ_{+-} simultaneously, not assuming *CPT*. Phase difference is obtained from $\phi_{00} - \phi_{+-} \approx -3\mathrm{Im}(\epsilon'/\epsilon)$ for small $\left|\epsilon'/\epsilon\right|$. Superseded by ABOUZAID 11.

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

[6] CAROSI 90 is excluded from the fit because it it is not independent of ϕ_{+-} and ϕ_{00} values.

PHASE DIFFERENCE $\phi_{+-} - \phi_{SW}$

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

VALUE (°)	*DOCUMENT ID*	*TECN*
0.61±0.62±1.01	[1] ALAVI-HARATI 03	KTEV

[1] ALAVI-HARATI 03 fit is the same as their ϕ_{+-}, τ_{K_S}, Δm fit, except that the parameter $\phi_{+-} - \phi_{SW}$ is used in place of ϕ.

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

Test of *CPT*

VALUE (units 10^{-6})	*DOCUMENT ID*	*TECN*	*COMMENT*
−3±35	[1] ALAVI-HARATI 02	E799	Uses A_L from K_{e3} decays

[1] ALAVI-HARATI 02 uses PDG 00 values of η_{+-} and η_{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

$$x = A(\overline{K}^0 \to \pi^-\ell^+\nu)/A(K^0 \to \pi^-\ell^+\nu)\ .$$

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

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

REAL PART OF x

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.0018±0.0041±0.0045		ANGELOPO...	98D	CPLR	K_{e3} from K^0
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.10\ ^{+0.18}_{-0.19}$	79	SMITH	75B	WIRE	$\pi^- p \to K^0\Lambda$
0.04 ±0.03	4724	NIEBERGALL	74	ASPK	$K^+ p \to K^0 p\pi^+$
−0.008 ±0.044	1757	FACKLER	73	OSPK	K_{e3} from K^0
−0.03 ±0.07	1367	HART	73	OSPK	K_{e3} from $K^0\Lambda$
−0.070 ±0.036	1079	MALLARY	73	OSPK	K_{e3} from $K^0\Lambda X$
0.03 ±0.06	410	[1] BURGUN	72	HBC	$K^+ p \to K^0 p\pi^+$
$0.04\ ^{+0.10}_{-0.13}$	100	[2] GRAHAM	72	OSPK	$K_{\mu3}$ from $K^0\Lambda$
−0.05 ±0.09	442	[2] GRAHAM	72	OSPK	$\pi^- p \to K^0\Lambda$
$0.26\ ^{+0.10}_{-0.14}$	126	MANN	72	HBC	$K^- p \to n\overline{K}^0$
−0.13 ±0.11	342	[2] MANTSCH	72	OSPK	K_{e3} from $K^0\Lambda$
$0.04\ ^{+0.07}_{-0.08}$	222	[1] BURGUN	71	HBC	$K^+ p \to K^0 p\pi^+$

0.25 $^{+0.07}_{-0.09}$	252	WEBBER 71	HBC	$K^- p \to n \overline{K}^0$
0.12 ±0.09	215	[3] CHO 70	DBC	$K^+ d \to K^0 p p$
−0.020 ±0.025		[4] BENNETT 69	CNTR	Charge asym+ Cu regen.
0.09 $^{+0.14}_{-0.16}$	686	LITTENBERG 69	OSPK	$K^+ n \to K^0 p$
0.03 ±0.03		[4] BENNETT 68	CNTR	
0.09 $^{+0.07}_{-0.09}$	121	JAMES 68	HBC	$\overline{p} p$
0.17 $^{+0.16}_{-0.35}$	116	FELDMAN 67B	OSPK	$\pi^- p \to K^0 \Lambda$
0.17 ±0.10	335	[3] HILL 67	DBC	$K^+ d \to K^0 p p$
0.035 $^{+0.11}_{-0.13}$	196	AUBERT 65	HLBC	K^+ charge exch.
0.06 $^{+0.18}_{-0.44}$	152	[5] BALDO-... 65	HLBC	K^+ charge exch.
−0.08 $^{+0.16}_{-0.28}$	109	[6] FRANZINI 65	HBC	$\overline{p} p$

[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 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.

IMAGINARY PART OF *x*

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0012±0.0019±0.0009	640k	ANGELOPO... 01B	CPLR	K_{e3} from K^0
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.0012±0.0019	640k	[1] ANGELOPO... 98E	CPLR	K_{e3} from K^0
−0.10 $^{+0.16}_{-0.19}$	79	SMITH 75B	WIRE	$\pi^- p \to K^0 \Lambda$
−0.06 ±0.05	4724	NIEBERGALL 74	ASPK	$K^+ p \to K^0 p \pi^+$
−0.017 ±0.060	1757	FACKLER 73	OSPK	K_{e3} from K^0
0.09 ±0.07	1367	HART 73	OSPK	K_{e3} from $K^0 \Lambda$
0.107 $^{+0.092}_{-0.074}$	1079	MALLARY 73	OSPK	K_{e3} from $K^0 \Lambda X$
0.07 $^{+0.06}_{-0.07}$	410	[2] BURGUN 72	HBC	$K^+ p \to K^0 p \pi^+$
0.12 $^{+0.17}_{-0.16}$	100	[3] GRAHAM 72	OSPK	$K_{\mu 3}$ from $K^0 \Lambda$
0.05 ±0.13	442	[3] GRAHAM 72	OSPK	$\pi^- p \to K^0 \Lambda$
0.21 $^{+0.15}_{-0.12}$	126	MANN 72	HBC	$K^- p \to n \overline{K}^0$
−0.04 ±0.16	342	[3] MANTSCH 72	OSPK	K_{e3} from $K^0 \Lambda$
0.12 $^{+0.08}_{-0.09}$	222	[2] BURGUN 71	HBC	$K^+ p \to K^0 p \pi^+$
0.0 ±0.08	252	WEBBER 71	HBC	$K^- p \to n \overline{K}^0$
−0.08 ±0.07	215	[4] CHO 70	DBC	$K^+ d \to K^0 p p$
−0.11 $^{+0.10}_{-0.11}$	686	LITTENBERG 69	OSPK	$K^+ n \to K^0 p$

$+0.22$	$^{+0.37}_{-0.29}$	121	JAMES	68	HBC	$\overline{p}p$
0.0	± 0.25	116	FELDMAN	67B	OSPK	$\pi^- p \to K^0 \Lambda$
-0.20	± 0.10	335	[4] HILL	67	DBC	$K^+ d \to K^0 pp$
-0.21	$^{+0.11}_{-0.15}$	196	AUBERT	65	HLBC	K^+ charge exch.
-0.44	$^{+0.32}_{-0.19}$	152	[5] BALDO-...	65	HLBC	K^+ charge exch.
$+0.24$	$^{+0.40}_{-0.30}$	109	[6] FRANZINI	65	HBC	$\overline{p}p$

[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.

K^0_L REFERENCES

AAIJ	23AE	PR D108 L031102	R. Aaij *et al.*	(LHCb Collab.)
AHN	21	PRL 126 121801	J.K. Ahn *et al.*	(KOTO Collab.)
SHIMIZU	20	PR D102 051103	N. Shimizu *et al.*	(KOTO Collab.)
AHN	19	PRL 122 021802	J.K. Ahn *et al.*	(KOTO Collab.)
AHN	17	PTEP 2017 021C01	J.K. Ahn *et al.*	(KOTO Collab.)
BRFIT	16	RPP 2016 edition	C.-J. Lin	(PDG Collab.)
ETAFIT	16	RPP 2016 edition	C.-J. Lin	(PDG Collab.)
SUPERWEAK	16	RPP 2016 edition	C.-J. Lin	(PDG Collab.)
ABOUZAID	11	PR D83 092001	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	11A	PRL 107 201803	E. Abouzaid *et al.*	(KTeV Collab.)
OGATA	11	PR D84 052009	R. Ogata *et al.*	(KEK E391a Collab.)
TUNG	11	PR D83 031101	Y.C. Tung *et al.*	(KEK E391a Collab.)
ABOUZAID	10	PR D81 052001	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
AHN	10	PR D81 072004	J.K. Ahn *et al.*	(KEK E391a Collab.)
ABOUZAID	08	PR D77 112004	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	08A	PR D78 032009	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	08B	PR D78 032014	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	08C	PRL 100 131803	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
AHN	08	PRL 100 201802	J.K. Ahn *et al.*	(KEK E391a Collab.)
AMBROSINO	08F	EPJ C55 539	F. Ambrosino *et al.*	(KLOE Collab.)
ABOUZAID	07B	PRL 99 051804	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	07C	PRL 99 081803	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
ABOUZAID	07D	PR D76 052001	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
AMBROSINO	07C	JHEP 0712 105	F. Ambrosino *et al.*	(KLOE Collab.)
ANDRE	07	ANP 322 2518	T. Andre	(EFI)
LAI	07	PL B645 26	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	07A	PL B647 341	A. Lai *et al.*	(CERN NA48 Collab.)
NIX	07	PR D76 011101	J. Nix *et al.*	(KEK E391a Collab.)
ABOUZAID	06	PRL 96 101801	E. Abouzaid *et al.*	(KTeV Collab.)
ABOUZAID	06A	PR D74 032004	E. Abouzaid *et al.*	(KTeV Collab.)
Also		PR D74 039905 (errat.)	E. Abouzaid *et al.*	(KTeV Collab.)
ABOUZAID	06C	PR D74 097101	E. Abouzaid *et al.*	(KTeV Collab.)
AHN	06	PR D74 051105	J.K. Ahn *et al.*	(KEK E391a Collab.)
Also		PR D74 079901 (errat.)	J.K. Ahn *et al.*	(KEK E391a Collab.)
AMBROSINO	06	PL B632 43	F. Ambrosino *et al.*	(KLOE Collab.)
AMBROSINO	06D	PL B636 166	F. Ambrosino *et al.*	(KLOE Collab.)
AMBROSINO	06F	PL B638 140	F. Ambrosino *et al.*	(KLOE Collab.)
BATLEY	06B	PL B633 173	J.R. Batley *et al.*	(CERN NA48/2 Collab.)
HILL	06	PR D74 096006	R.J. Hill	(FNAL)
PDG	06	JP G33 1	W.-M. Yao *et al.*	(PDG Collab.)
ALEXOPOU...	05	PR D71 012001	T. Alexopoulos *et al.*	(FNAL KTeV Collab.)
AMBROSINO	05C	PL B626 15	F. Ambrosino *et al.*	(KLOE Collab.)
CABIBBO	05	JHEP 0503 021	N. Cabibbo, G. Isidori	(CERN, ROMAI, FRAS)
LAI	05	PL B605 247	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	05B	PL B615 31	A. Lai *et al.*	(CERN NA48 Collab.)

PARK	05	PRL 94 021801	H.K. Park *et al.*	(FNAL HyperCP Collab.)
ALAVI-HARATI	04A	PRL 93 021805	A. Alavi-Harati *et al.*	(FNAL KTeV/E799 Collab.)
ALEXOPOU...	04	PR D70 092006	T. Alexopoulos *et al.*	(FNAL KTeV Collab.)
ALEXOPOU...	04A	PR D70 092007	T. Alexopoulos *et al.*	(FNAL KTeV Collab.)
BATLEY	04	PL B595 75	J.R. Batley *et al.*	(CERN NA48 Collab.)
CIRIGLIANO	04	EPJ C35 53	V. Cirigliano, H. Neufeld, H. Pichl	(CIT, VALE+)
LAI	04B	PL B602 41	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	04C	PL B604 1	A. Lai *et al.*	(CERN NA48 Collab.)
PDG	04	PL B592 1	S. Eidelman *et al.*	(PDG Collab.)
SOZZI	04	EPJ C36 37	M. Sozzi	(PISA)
ADINOLFI	03	PL B566 61	M. Adinolfi *et al.*	(KLOE Collab.)
ALAVI-HARATI	03	PR D67 012005	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
Also		PR D70 079904 (errat.)	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	03B	PRL 90 141801	A. ALavi-Harati *et al.*	(FNAL KTeV Collab.)
LAI	03	PL B551 7	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	03C	EPJ C30 33	A. Lai *et al.*	(CERN NA48 Collab.)
ALAVI-HARATI	02	PRL 88 181601	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	02C	PRL 89 211801	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
BATLEY	02	PL B544 97	J.R. Batley *et al.*	(CERN NA48 Collab.)
CIRIGLIANO	02	EPJ C23 121	V. Cirigliano *et al.*	(VIEN, VALE, MARS)
LAI	02B	PL B536 229	A. Lai *et al.*	(CERN NA48 Collab.)
ALAVI-HARATI	01	PRL 86 397	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01B	PRL 86 761	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01D	PRL 86 5425	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01E	PRL 87 021801	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01F	PR D64 012003	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01G	PRL 87 071801	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01H	PRL 87 111802	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	01J	PR D64 112004	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ANGELOPO...	01	PL B503 49	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ANGELOPO...	01B	EPJ C22 55	A. Angelopoulos *et al.*	(CPLEAR Collab.)
LAI	01B	PL B515 261	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	01C	EPJ C22 231	A. Lai *et al.*	(CERN NA48 Collab.)
ALAVI-HARATI	00	PR D61 072006	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	00B	PRL 84 408	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	00D	PRL 84 5279	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	00E	PR D62 112001	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
AMBROSE	00	PRL 84 1389	D. Ambrose *et al.*	(BNL E871 Collab.)
APOSTOLA...	00	PL B473 186	A. Apostolakis *et al.*	(CPLEAR Collab.)
PDG	00	EPJ C15 1	D.E. Groom *et al.*	(PDG Collab.)
ALAVI-HARATI	99B	PRL 83 917	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
ALAVI-HARATI	99D	PRL 83 22	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
APOSTOLA...	99C	PL B458 545	A. Apostolakis *et al.*	(CPLEAR Collab.)
Also		EPJ C18 41	A. Apostolakis *et al.*	(CPLEAR Collab.)
FANTI	99B	PL B458 553	V. Fanti *et al.*	(CERN NA48 Collab.)
FANTI	99C	PL B465 335	V. Fanti *et al.*	(CERN NA48 Collab.)
MURAKAMI	99	PL B463 333	K. Murakami *et al.*	(KEK E162 Collab.)
ADAMS	98	PRL 80 4123	J. Adams *et al.*	(FNAL KTeV Collab.)
AMBROSE	98	PRL 81 4309	D. Ambrose *et al.*	(BNL E871 Collab.)
AMBROSE	98B	PRL 81 5734	D. Ambrose *et al.*	(BNL E871 Collab.)
ANGELOPO...	98	PL B420 191	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ANGELOPO...	98C	EPJ C5 389	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ANGELOPO...	98D	PL B444 38	A. Angelopoulos *et al.*	(CPLEAR Collab.)
Also		EPJ C22 55	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ANGELOPO...	98E	PL B444 43	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ARISAKA	98	PL B432 230	K. Arisaka *et al.*	(FNAL E799 Collab.)
BENDER	98	PL B418 411	M. Bender *et al.*	(CERN NA48 Collab.)
DAMBROSIO	98	PL B423 385	G. D'Ambrosio, G. Isidori, J. Portoles	
SETZU	98	PL B420 205	M.G. Setzu *et al.*	
TAKEUCHI	98	PL B443 409	Y. Takeuchi *et al.*	(KYOT, KEK, HIRO)
FANTI	97	ZPHY C76 653	V. Fanti *et al.*	(CERN NA48 Collab.)
NOMURA	97	PL B408 445	T. Nomura *et al.*	(KYOT, KEK, HIRO)
ADLER	96B	ZPHY C70 211	R. Adler *et al.*	(CPLEAR Collab.)
ADLER	96C	PL B369 367	R. Adler *et al.*	(CPLEAR Collab.)
GU	96	PRL 76 4312	P. Gu *et al.*	(RUTG, UCLA, EFI, COLO+)
LEBER	96	PL B369 69	F. Leber *et al.*	(MAINZ, CERN, EDIN, ORSAY+)
PDG	96	PR D54 1	R. M. Barnett *et al.*	(PDG Collab.)
ADLER	95	PL B363 237	R. Adler *et al.*	(CPLEAR Collab.)
ADLER	95B	PL B363 243	R. Adler *et al.*	(CPLEAR Collab.)
AKAGI	95	PR D51 2061	T. Akagi *et al.*	(TOHOK, TOKY, KYOT, KEK)
BARR	95	ZPHY C65 361	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)

BARR	95C	PL B358 399	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
HEINSON	95	PR D51 985	A.P. Heinson *et al.*	(BNL E791 Collab.)
KREUTZ	95	ZPHY C65 67	A. Kreutz *et al.*	(SIEG, EDIN, MAINZ, ORSAY+)
MATTHEWS	95	PRL 75 2803	J.N. Matthews *et al.*	(RUTG, EFI, ELMT+)
SCHWINGEN...	95	PRL 74 4376	B. Schwingenheuer *et al.*	(EFI, CHIC+)
SPENCER	95	PRL 74 3323	M.B. Spencer *et al.*	(UCLA, EFI, COLO+)
BARR	94	PL B328 528	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
GU	94	PRL 72 3000	P. Gu *et al.*	(RUTG, UCLA, EFI, COLO+)
NAKAYA	94	PRL 73 2169	T. Nakaya *et al.*	(OSAK, UCLA, EFI, COLU+)
ROBERTS	94	PR D50 1874	D. Roberts *et al.*	(UCLA, EFI, COLU+)
AKAGI	93	PR D47 2644	T. Akagi *et al.*	(TOHOK, TOKY, KYOT, KEK)
ARISAKA	93	PRL 70 1049	K. Arisaka *et al.*	(BNL E791 Collab.)
ARISAKA	93B	PRL 71 3910	K. Arisaka *et al.*	(BNL E791 Collab.)
BARR	93D	PL B317 233	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
GIBBONS	93	PRL 70 1199	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
Also		PR D55 6625	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
GIBBONS	93B	PRL 70 1203	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
GIBBONS	93C	Thesis RX-1487	L.K. Gibbons	(CHIC)
Also		PR D55 6625	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
HARRIS	93	PRL 71 3914	D.A. Harris *et al.*	(EFI, UCLA, COLO+)
HARRIS	93B	PRL 71 3918	D.A. Harris *et al.*	(EFI, UCLA, COLO+)
MAKOFF	93	PRL 70 1591	G. Makoff *et al.*	(FNAL E731 Collab.)
Also		PRL 75 2069 (errat.)	G. Makoff *et al.*	
RAMBERG	93	PRL 70 2525	E. Ramberg *et al.*	(FNAL E731 Collab.)
RAMBERG	93B	PRL 70 2529	E.J. Ramberg *et al.*	(FNAL E731 Collab.)
VAGINS	93	PRL 71 35	M.R. Vagins *et al.*	(BNL E845 Collab.)
ADLER	92B	PL B286 180	R. Adler *et al.*	(CPLEAR Collab.)
Also		SJNP 55 840	R. Adler *et al.*	(CPLEAR Collab.)
BARR	92	PL B284 440	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
MORSE	92	PR D45 36	W.M. Morse *et al.*	(BNL, YALE, VASS)
PDG	92	PR D45 S1	K. Hikasa *et al.*	(KEK, LBL, BOST+)
SOMALWAR	92	PRL 68 2580	S.V. Somalwar *et al.*	(FNAL E731 Collab.)
AKAGI	91B	PRL 67 2618	T. Akagi *et al.*	(TOHOK, TOKY, KYOT, KEK)
BARR	91	PL B259 389	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
HEINSON	91	PR D44 1	A.P. Heinson *et al.*	(UCI, UCLA, LANL+)
PAPADIMITR...	91	PR D44 573	V. Papadimitriou *et al.*	(FNAL E731 Collab.)
BARKER	90	PR D41 3546	A.R. Barker *et al.*	(FNAL E731 Collab.)
Also		PRL 61 2661	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
BARR	90B	PL B240 283	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
BARR	90C	PL B242 523	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
CAROSI	90	PL B237 303	R. Carosi *et al.*	(CERN, EDIN, MAINZ, LALO+)
KARLSSON	90	PRL 64 2976	M. Karlsson *et al.*	(FNAL E731 Collab.)
OHL	90	PRL 64 2755	K.E. Ohl *et al.*	(BNL E845 Collab.)
OHL	90B	PRL 65 1407	K.E. Ohl *et al.*	(BNL E845 Collab.)
PATTERSON	90	PRL 64 1491	J.R. Patterson *et al.*	(FNAL E731 Collab.)
INAGAKI	89	PR D40 1712	T. Inagaki *et al.*	(KEK, TOKY, KYOT)
MATHIAZHA...	89	PRL 63 2181	C. Mathiazhagan *et al.*	(UCI, UCLA, LANL+)
MATHIAZHA...	89B	PRL 63 2185	C. Mathiazhagan *et al.*	(UCI, UCLA, LANL+)
WAHL	89	CERN-EP/89-86	H. Wahl	(CERN)
BARR	88	PL B214 303	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
BURKHARDT	88	PL B206 169	H. Burkhardt *et al.*	(CERN, EDIN, MAINZ+)
JASTRZEM...	88	PRL 61 2300	E. Jastrzembski *et al.*	(BNL, YALE)
WOODS	88	PRL 60 1695	M. Woods *et al.*	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt *et al.*	(CERN, EDIN, MAINZ+)
ARONSON	86	PR D33 3180	S.H. Aronson *et al.*	(BNL, CHIC, STAN+)
Also		PRL 48 1078	S.H. Aronson *et al.*	(BNL, CHIC, STAN+)
PDG	86C	PL 170B 132	M. Aguilar-Benitez *et al.*	(CERN, CIT+)
COUPAL	85	PRL 55 566	D.P. Coupal *et al.*	(CHIC, SACL)
BALATS	83	SJNP 38 556	M.Y. Balats *et al.*	(ITEP)
		Translated from YAF 38 927.		
BERGSTROM	83	PL 131B 229	L. Bergstrom, E. Masso, P. Singer	(CERN)
ARONSON	82	PRL 48 1078	S.H. Aronson *et al.*	(BNL, CHIC, STAN+)
ARONSON	82B	PRL 48 1306	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
Also		PL 116B 73	E. Fischbach *et al.*	(PURD, BNL, CHIC)
Also		PR D28 476	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
Also		PR D28 495	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
PDG	82B	PL 111B 70	M. Roos *et al.*	(HELS, CIT, CERN)
BIRULEV	81	NP B182 1	V.K. Birulev *et al.*	(JINR)
Also		SJNP 31 622	V.K. Birulev *et al.*	(JINR)
		Translated from YAF 31 1204.		

CARROLL	80B	PRL 44 529	A.S. Carroll *et al.*	(BNL, ROCH)
CARROLL	80C	PL 96B 407	A.S. Carroll *et al.*	(BNL, ROCH)
CHO	80	PR D22 2688	Y. Cho *et al.*	(ANL, CMU)
MORSE	80	PR D21 1750	W.M. Morse *et al.*	(BNL, YALE)
CHRISTENS...	79	PRL 43 1209	J.H. Christenson *et al.*	(NYU)
SCHMIDT	79	PRL 43 556	M.P. Schmidt *et al.*	(YALE, BNL)
HILL	78	PL 73B 483	D.G. Hill *et al.*	(BNL, SLAC, SBER)
CHO	77	PR D15 587	Y. Cho *et al.*	(ANL, CMU)
CLARK	77	PR D15 553	A.R. Clark *et al.*	(LBL)
Also		Thesis LBL-4275	G. Shen	(LBL)
DEVOE	77	PR D16 565	R. Devoe *et al.*	(EFI, ANL)
PEACH	77	NP B127 399	K.J. Peach *et al.*	(BGNA, EDIN, GLAS+)
BIRULEV	76	SJNP 24 178	V.K. Birulev *et al.*	(JINR)
		Translated from YAF 24 340.		
COOMBES	76	PRL 37 249	R.W. Coombes *et al.*	(STAN, NYU)
GJESDAL	76	NP B109 118	G. Gjesdal *et al.*	(CERN, HEIDH)
BALDO-...	75	NC 25A 688	M. Baldo-Ceolin *et al.*	(PADO, WISC)
BLUMENTHAL	75	PRL 34 164	R.B. Blumenthal *et al.*	(PENN, CHIC, TEMP)
BUCHANAN	75	PR D11 457	C.D. Buchanan *et al.*	(UCLA, SLAC, JHU)
CARITHERS	75	PRL 34 1244	W.C.J. Carithers *et al.*	(COLU, NYU)
SMITH	75B	Thesis UCSD unpub.	J.G. Smith	(UCSD)
BISI	74	PL 50B 504	V. Bisi, M.I. Ferrero	(TORI)
DONALDSON	74	Thesis SLAC-0184	G. Donaldson	(SLAC)
Also		PR D14 2839	G. Donaldson *et al.*	(SLAC)
DONALDSON	74B	PR D9 2960	G. Donaldson *et al.*	(SLAC, UCSC)
Also		PRL 31 337	G. Donaldson *et al.*	(SLAC, UCSC)
GEWENIGER	74	PL 48B 483	C. Geweniger *et al.*	(CERN, HEIDH)
Also		Thesis CERN Int. 74-4	V. Luth	(CERN)
GEWENIGER	74B	PL 48B 487	C. Geweniger *et al.*	(CERN, HEIDH)
Also		PL 52B 119	S. Gjesdal *et al.*	(CERN, HEIDH)
GEWENIGER	74C	PL 52B 108	C. Geweniger *et al.*	(CERN, HEIDH)
GJESDAL	74	PL 52B 113	S. Gjesdal *et al.*	(CERN, HEIDH)
MESSNER	74	PRL 33 1458	R. Messner *et al.*	(COLO, SLAC, UCSC)
NIEBERGALL	74	PL 49B 103	F. Niebergall *et al.*	(CERN, ORSAY, VIEN)
WILLIAMS	74	PRL 33 240	H.H. Williams *et al.*	(BNL, YALE)
ALEXANDER	73B	NP B65 301	G. Alexander *et al.*	(TELA, HEID)
BRANDENB...	73	PR D8 1978	G.W. Brandenburg *et al.*	(SLAC)
EVANS	73	PR D7 36	G.R. Evans *et al.*	(EDIN, CERN)
Also		PRL 23 427	G.R. Evans *et al.*	(EDIN, CERN)
FACKLER	73	PRL 31 847	O. Fackler *et al.*	(MIT)
FITCH	73	PRL 31 1524	V.L. Fitch *et al.*	(PRIN)
Also		Thesis COO-3072-13	R.C. Webb	(PRIN)
HART	73	NP B66 317	J.C. Hart *et al.*	(CAVE, RHEL)
MALLARY	73	PR D7 1953	M.L. Mallary *et al.*	(CIT)
Also		PRL 25 1214	F.J. Sciulli *et al.*	(CIT)
MCCARTHY	73	PR D7 687	R.L. McCarthy *et al.*	(LBL)
Also		PL 42B 291	R.L. McCarthy *et al.*	(LBL)
Also		Thesis LBL-550	R.L. McCarthy	(LBL)
MESSNER	73	PRL 30 876	R. Messner *et al.*	(COLO, SLAC, UCSC)
SANDWEISS	73	PRL 30 1002	J. Sandweiss *et al.*	(YALE, ANL)
WILLIAMS	73	PRL 31 1521	H.H. Williams *et al.*	(BNL, YALE)
ASHFORD	72	PL 38B 47	V.A. Ashford *et al.*	(UCSD)
BANNER	72B	PRL 29 237	M. Banner *et al.*	(PRIN)
BARMIN	72B	SJNP 15 638	V.V. Barmin *et al.*	(ITEP)
		Translated from YAF 15 1152.		
BURGUN	72	NP B50 194	G. Burgun *et al.*	(SACL, CERN, OSLO)
GRAHAM	72	NC 9A 166	M.F. Graham *et al.*	(ILL, NEAS)
JAMES	72	NP B49 1	F. James *et al.*	(CERN, SACL, OSLO)
KRENZ	72	LNC 4 213	W. Krenz *et al.*	(AACH, CERN, EDIN)
MANN	72	PR D6 137	W.A. Mann *et al.*	(MASA, BNL, YALE)
MANTSCH	72	NC 9A 160	P.M. Mantsch *et al.*	(ILL, NEAS)
MCCARTHY	72	PL 42B 291	R.L. McCarthy *et al.*	(LBL)
PICCIONI	72	PRL 29 1412	R. Piccioni *et al.*	(SLAC)
Also		PR D9 2939	R. Piccioni *et al.*	(SLAC, UCSC, COLO)
VOSBURGH	72	PR D6 1834	K.G. Vosburgh *et al.*	(RUTG, MASA)
Also		PRL 26 866	K.G. Vosburgh *et al.*	(RUTG, MASA)
BALATS	71	SJNP 13 53	M.Y. Balats *et al.*	(ITEP)
		Translated from YAF 13 93.		

BARMIN	71	PL 35B 604	V.V. Barmin *et al.*	(ITEP)
BURGUN	71	LNC 2 1169	G. Burgun *et al.*	(SACL, CERN, OSLO)
CARNEGIE	71	PR D4 1	R.K. Carnegie *et al.*	(PRIN)
CHAN	71	Thesis LBL-350	J.H.S. Chan	(LBL)
CHO	71	PR D3 1557	Y. Cho *et al.*	(CMU, BNL, CASE)
ENSTROM	71	PR D4 2629	J. Enstrom *et al.*	(SLAC, STAN)
Also		Thesis SLAC-0125	J.E. Enstrom	(STAN)
JAMES	71	PL 35B 265	F. James *et al.*	(CERN, SACL, OSLO)
MEISNER	71	PR D3 59	G.W. Meisner *et al.*	(MASA, BNL, YALE)
REPELLIN	71	PL 36B 603	J.P. Repellin *et al.*	(ORSAY, CERN)
WEBBER	71	PR D3 64	B.R. Webber *et al.*	(LRL)
Also		PRL 21 498	B.R. Webber *et al.*	(LRL)
Also		Thesis UCRL 19226	B.R. Webber	(LRL)
WOLFF	71	PL 36B 517	B. Wolff *et al.*	(ORSAY, CERN)
ALBROW	70	PL 33B 516	M.G. Albrow *et al.*	(MCHS, DARE)
ARONSON	70	PRL 25 1057	S.H. Aronson *et al.*	(EFI, ILLC, SLAC)
BARMIN	70	PL 33B 377	V.V. Barmin *et al.*	(ITEP, JINR)
BASILE	70	PR D2 78	P. Basile *et al.*	(SACL)
BECHERRAWY	70	PR D1 1452	T. Becherrawy	(ROCH)
BUCHANAN	70	PL 33B 623	C.D. Buchanan *et al.*	(SLAC, JHU, UCLA)
Also		Private Comm.	A.J. Cox	
BUDAGOV	70	PR D2 815	I.A. Budagov *et al.*	(CERN, ORSAY, EPOL)
Also		PL 28B 215	I.A. Budagov *et al.*	(CERN, ORSAY, EPOL)
CHO	70	PR D1 3031	Y. Cho *et al.*	(CMU, BNL, CASE)
Also		PRL 19 668	D.G. Hill *et al.*	(BNL, CMU)
CHOLLET	70	PL 31B 658	J.C. Chollet *et al.*	(CERN)
CULLEN	70	PL 32B 523	M. Cullen *et al.*	(AACH, CERN, TORI)
MARX	70	PL 32B 219	J. Marx *et al.*	(COLU, HARV, CERN)
Also		Thesis Nevis 179	J. Marx	(COLU)
SCRIBANO	70	PL 32B 224	A. Scribano *et al.*	(PISA, COLU, HARV)
SMITH	70	PL 32B 133	R.C. Smith *et al.*	(UMD, BNL)
WEBBER	70	PR D1 1967	B.R. Webber *et al.*	(LRL)
Also		Thesis UCRL 19226	B.R. Webber	(LRL)
BANNER	69	PR 188 2033	M. Banner *et al.*	(PRIN)
Also		PRL 21 1103	M. Banner *et al.*	(PRIN)
Also		PRL 21 1107	J.W. Cronin, J.K. Liu, J.E. Pilcher	(PRIN)
BENNETT	69	PL 29B 317	S. Bennett *et al.*	(COLU, BNL)
FAISSNER	69	PL 30B 204	H. Faissner *et al.*	(AACH3, CERN, TORI)
LITTENBERG	69	PRL 22 654	L.S. Littenberg *et al.*	(UCSD)
LONGO	69	PR 181 1808	M.J. Longo, K.K. Young, J.A. Helland	(MICH, UCLA)
PACIOTTI	69	Thesis UCRL 19446	M.A. Paciotti	(LRL)
SAAL	69	Thesis	H.J. Saal	(COLU)
ABRAMS	68B	PR 176 1603	R.J. Abrams *et al.*	(ILL)
ARNOLD	68B	PL 28B 56	R.G. Arnold *et al.*	(CERN, ORSAY)
BASILE	68B	PL 28B 58	P. Basile *et al.*	(SACL)
BENNETT	68	PL 27B 244	S. Bennett *et al.*	(COLU, CERN)
BLANPIED	68	PRL 21 1650	W.A. Blanpied *et al.*	(CASE, HARV, MCGI)
BOHM	68B	PL 27B 594	A. Bohm *et al.*	
BUDAGOV	68	NC 57A 182	I.A. Budagov *et al.*	(CERN, ORSAY, IPNP)
Also		PL 28B 215	I.A. Budagov *et al.*	(CERN, ORSAY, EPOL)
JAMES	68	NP B8 365	F. James, H. Briand	(IPNP, CERN)
Also		PRL 21 257	J.A. Helland, M.J. Longo, K.K. Young	(UCLA, MICH)
KULYUKINA	68	JETP 26 20	L.A. Kulyukina *et al.*	(JINR)
		Translated from ZETF 53 29.		
KUNZ	68	Thesis PU-68-46	P.F. Kunz	(PRIN)
BENNETT	67	PRL 19 993	S. Bennett *et al.*	(COLU)
DEBOUARD	67	NC 52A 662	X. de Bouard *et al.*	(CERN)
Also		PL 15 58	X. de Bouard *et al.*	(CERN, ORSAY, MPIM)
DEVLIN	67	PRL 18 54	T.J. Devlin *et al.*	(PRIN, UMD)
Also		PR 169 1045	G.A. Sayer *et al.*	(UMD, PPA, PRIN)
DORFAN	67	PRL 19 987	D.E. Dorfan *et al.*	(SLAC, LRL)
FELDMAN	67B	PR 155 1611	L. Feldman *et al.*	(PENN)
FITCH	67	PR 164 1711	V.L. Fitch *et al.*	(PRIN)
GINSBERG	67	PR 162 1570	E.S. Ginsberg	(MASB)
HILL	67	PRL 19 668	D.G. Hill *et al.*	(BNL, CMU)
HOPKINS	67	PRL 19 185	H.W.K. Hopkins, T.C. Bacon, F.R. Eisler	(BNL)
NEFKENS	67	PR 157 1233	B.M.K. Nefkens *et al.*	(ILL)
SCHMIDT	67	Thesis Nevis 160	P. Schmidt	(COLU)
BEHR	66	PL 22 540	L. Behr *et al.*	(EPOL, MILA, PADO, ORSAY)
HAWKINS	66	PL 21 238	C.J.B. Hawkins	(YALE)
Also		PR 156 1444	C.J.B. Hawkins	(YALE)

ANDERSON	65	PRL 14 475	J.A. Anderson *et al.*	(LRL, WISC)
ASTBURY	65B	PL 18 175	P. Astbury *et al.*	(CERN, ZURI)
AUBERT	65	PL 17 59	B. Aubert *et al.*	(EPOL, ORSAY)
Also		PL 24B 75	J.P. Lowys *et al.*	(EPOL, ORSAY)
BALDO-...	65	NC 38 684	M. Baldo-Ceolin *et al.*	(PADO)
FRANZINI	65	PR 140 B127	P. Franzini *et al.*	(COLU, RUTG)
GUIDONI	65	Argonne Conf. 49	P. Guidoni *et al.*	(BNL, YALE)
HOPKINS	65	Argonne Conf. 67	H.W.K. Hopkins, T.C. Bacon, F. Eisler	(VAND+)
ALEKSANYAN	64B	Dubna Conf. 2 102	A.S. Aleksanyan *et al.*	(YERE)
Also		JETP 19 1019	A.S. Aleksanyan *et al.*	(LEBD, MPEI, YERE)
		Translated from ZETF 46 1504.		
ANIKINA	64	JETP 19 42	M.K. Anikina *et al.*	(GEOR, JINR)
		Translated from ZETF 46 59.		
FITCH	61	NC 22 1160	V.L. Fitch, P.A. Piroue, R.B. Perkins	(PRIN+)
GOOD	61	PR 124 1223	R.H. Good *et al.*	(LRL)

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"The Search for Direct *CP* Violation"				
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Status and Perspectives of *K* Decay Physics				
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Tests of *CPT* conservation in the neutral kaon system.				
KLEINKNECHT	92	CNPP 20 281	K. Kleinknecht	(MAINZ)
New Results on *CP* Violation in Decays of Neutral *K* Mesons.				
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"Rare Kaon Decays"				
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GINSBERG	70	PR D1 229	E.S. Ginsberg	(HAIF)
HEUSSE	70	LNC 3 449	P. Heusse *et al.*	(ORSAY)
CRONIN	68C	Vienna Conf. 281	J.W. Cronin	(PRIN)
RUBBIA	67	PL 24B 531	C. Rubbia, J. Steinberger	(CERN, COLU)
Also		PL 23 167	C. Rubbia, J. Steinberger	(CERN, COLU)
Also		PL 20 207	C. Alff-Steinberger *et al.*	(CERN)
Also		PL 21 595	C. Alff-Steinberger *et al.*	(CERN)
AUERBACH	66	PR 149 1052	L.B. Auerbach *et al.*	(PENN)
Also		PRL 14 192	L.B. Auerbach *et al.*	(PENN)
FIRESTONE	66B	PRL 17 116	A. Firestone *et al.*	(YALE, BNL)
BEHR	65	Argonne Conf. 59	L. Behr *et al.*	(EPOL, MILA, PADO)
MESTVIRISH...	65	JINR P 2449	A.N. Mestvirishvili *et al.*	(JINR)
TRILLING	65B	UCRL 16473	G.N. Trilling	(LRL)
Updated from 1965 Argonne Conference, page 115.				
JOVANOV...	63	BNL Conf. 42	J.V. Jovanovich *et al.*	(BNL, UMD)