



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

$$m_{K_L^0} - m_{K_S^0}$$

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^0 decays” in the K_L^0 Particle Listings. The result labeled “OUR FIT Assuming CPT” [“OUR FIT Not assuming CPT”] includes all measurements except those with the comment “Not assuming CPT” [“Assuming CPT”]. Measurements with neither comment do not assume CPT and enter both fits.

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} ABOUZAIID	11	KTEV Not assuming CPT
0.52699 ± 0.00123	^{1,3} ABOUZAIID	11	KTEV Assuming CPT
0.5240 ± 0.0044 ± 0.0033	APOSTOLA...	99C	CPLR $K^0-\bar{K}^0$ 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-HARATI03	KTEV	Assuming CPT
0.5288 ± 0.0043	⁹ ALAVI-HARATI03	KTEV	Not assuming CPT
0.5343 ± 0.0063 ± 0.0025	¹⁰ ANGELOPO...	01	CPLR
0.5295 ± 0.0020 ± 0.0003	¹¹ ANGELOPO...	98D	CPLR Assuming CPT
0.5307 ± 0.0013	¹² ADLER	96C	RVUE
0.5274 ± 0.0029 ± 0.0005	¹¹ ADLER	95	CPLR Sup. by ANGELOPOU-LOS 98D
0.482 ± 0.014	¹³ ARONSON	82B	SPEC $E=30-110$ GeV
0.534 ± 0.007	¹⁴ CARNEGIE	71	ASPK Gap method
0.542 ± 0.006	¹⁴ ARONSON	70	ASPK Gap method
0.542 ± 0.006	CULLEN	70	CNTR

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

² ABOUZAIID 11 fit has Δm , τ_S , ϕ_ϵ , $\text{Re}(\epsilon'/\epsilon)$, and $\text{Im}(\epsilon'/\epsilon)$ as free parameters. See $\text{Im}(\epsilon'/\epsilon)$ in the “ K_L^0 CP violation” section for correlation information.

³ ABOUZAIID 11 fit has Δm and τ_S free but constrains ϕ_ϵ to the Superweak value, i.e. assumes CPT. See “ K_S^0 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 $K_{\ell 3}^0$ decays.
- ⁸ ALAVI-HARATI 03 fit Δm and $\tau_{K_S^0}$ simultaneously. ϕ_{+-} is constrained to the Super-weak value, i.e. CPT is assumed. See “ K_S^0 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 \bar{K}_{e3}^0 and K_{e3}^0 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_S^0 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_S^0 mean life or in η_{+-} .

K_L^0 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	$\sum_i B_i = 1$		
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 $\sum_i B_i = 1$. The correlation matrix among the four measured K_L BR's and this K_L lifetime is						
	K_{e3}	$K_{\mu 3}$	$3\pi^0$	$\pi^+ \pi^- \pi^0$	τ_{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
	τ_{K_L}					1

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

K_L^0 DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Semileptonic modes		
Γ_1 $\pi^\pm e^\mp \nu_e$ Called K_{e3}^0 .	[a] $(40.55 \pm 0.11) \%$	S=1.7
Γ_2 $\pi^\pm \mu^\mp \nu_\mu$ Called $K_{\mu 3}^0$.	[a] $(27.04 \pm 0.07) \%$	S=1.1

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	$3\pi^0$		$(19.52 \pm 0.12) \%$	S=1.6
Γ_7	$\pi^+\pi^-\pi^0$		$(12.54 \pm 0.05) \%$	
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 $\ell\bar{\ell}$ 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 $\ell\bar{\ell}$ 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}	$e^+e^-\gamma\gamma$	[c]	$(5.95 \pm 0.33) \times 10^{-7}$	
Γ_{22}	$\mu^+\mu^-\gamma\gamma$	[c]	$(1.0 \pm_{-0.6}^{+0.8}) \times 10^{-8}$	

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

Γ_{23}	$\mu^+\mu^-$	S1	$(6.84 \pm 0.11) \times 10^{-9}$	
Γ_{24}	e^+e^-	S1	$(9 \pm_{-4}^{+6}) \times 10^{-12}$	
Γ_{25}	$\pi^+\pi^-e^+e^-$	S1 [c]	$(3.11 \pm 0.19) \times 10^{-7}$	
Γ_{26}	$\pi^0\pi^0e^+e^-$	S1	$< 6.6 \times 10^{-9}$	CL=90%
Γ_{27}	$\pi^0\pi^0\mu^+\mu^-$	S1	$< 9.2 \times 10^{-11}$	CL=90%
Γ_{28}	$\mu^+\mu^-e^+e^-$	S1	$(2.69 \pm 0.27) \times 10^{-9}$	
Γ_{29}	$e^+e^-e^+e^-$	S1	$(3.56 \pm 0.21) \times 10^{-8}$	
Γ_{30}	$\pi^0\mu^+\mu^-$	CP,S1 [e]	$< 3.8 \times 10^{-10}$	CL=90%
Γ_{31}	$\pi^0e^+e^-$	CP,S1 [e]	$< 2.8 \times 10^{-10}$	CL=90%
Γ_{32}	$\pi^0\nu\bar{\nu}$	CP,S1 [f]	$< 3.0 \times 10^{-9}$	CL=90%
Γ_{33}	$\pi^0\pi^0\nu\bar{\nu}$	S1	$< 8.1 \times 10^{-7}$	CL=90%
Γ_{34}	$e^\pm\mu^\mp$	LF [a]	$< 4.7 \times 10^{-12}$	CL=90%
Γ_{35}	$e^\pm e^\pm\mu^\mp\mu^\mp$	LF [a]	$< 4.12 \times 10^{-11}$	CL=90%
Γ_{36}	$\pi^0\mu^\pm e^\mp$	LF [a]	$< 7.6 \times 10^{-11}$	CL=90%
Γ_{37}	$\pi^0\pi^0\mu^\pm e^\mp$	LF	$< 1.7 \times 10^{-10}$	CL=90%

Lorentz invariance violating modes

$$\Gamma_{38} \pi^0 \gamma < 1.7 \times 10^{-7} \quad \text{CL}=90\%$$

- [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 $K_L^0 \rightarrow \pi^+ \pi^- \gamma$ (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 $\langle \delta p_i \delta p_j \rangle / (\delta p_i \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

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	$\pi^\pm e^\mp \nu_{e3}$ Called K_{e3}^0 .	[a] 0.07927 ± 0.00034	1.1
Γ_2	$\pi^\pm \mu^\mp \nu_{\mu3}$ Called $K_{\mu3}^0$.	[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_L^0 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	

¹JAMES 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	$K^- p \rightarrow n \bar{K}^0$
13.1 ± 1.3	252	¹ WEBBER	71	HBC	$K^- p \rightarrow n \bar{K}^0$
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	

¹Assumes $\Delta S = \Delta Q$ rule.

²CHO 70 includes events of HILL 67.

K_L^0 BRANCHING RATIOS

Semileptonic modes

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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 ± 0.0005 ± 0.0015	13M	¹ AMBROSINO 06	KLOE
0.4067 ± 0.0011		² ALEXOPOU... 04	KTEV

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

² ALEXOPOULOS 04 constrains $\sum_i B_i = 0.9993$ 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

	K_{e3}	$K_{\mu 3}$	$3\pi^0$	$\pi^+ \pi^- \pi^0$	$\pi^+ \pi^-$	$\pi^0 \pi^0$
K_{e3}	1					
$K_{\mu 3}$	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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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: $B(K_L \rightarrow \pi e \nu)$, $B(K_L \rightarrow \pi \mu \nu)$, $B(K_L \rightarrow 3\pi^0)$, $B(K_L \rightarrow \pi^+ \pi^- \pi^0)$, and 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 $B(K_L \rightarrow \pi e \nu)$ measurement.

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

<u>VALUE</u>	<u>DOCUMENT ID</u>
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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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 $K_L^0 \rightarrow \pi^+ \pi^- \pi^0 / (\text{all } K_L^0) \text{ decays} = 0.126$.

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

VALUE (units 10 ⁻⁵)	EVTS	DOCUMENT ID	TECN	COMMENT
10.02 ± 0.17 ± 0.29	19k	¹ ABOUZAID 07c	KTEV	$M_{ee} > 5 \text{ MeV}, E_{ee}^* > 30 \text{ MeV}$

¹ E_{ee}^* is the energy of the $e^+ e^-$ pair in the kaon rest frame. ABOUZAID 07c reports $[\Gamma(K_L^0 \rightarrow \pi^\pm e^\mp \nu e^+ e^-)/\Gamma(K_L^0 \rightarrow \pi^+ \pi^- \pi^0)] / [B(\pi^0 \rightarrow e^+ e^- \gamma)] = (8.54 \pm 0.07 \pm 0.13) \times 10^{-3}$ which we multiply by our best value $B(\pi^0 \rightarrow e^+ e^- \gamma) = (1.174 \pm 0.035) \times 10^{-2}$. 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 $B(K_L \rightarrow 3\pi^0)$ 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
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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 ¹ALEXOPOU... 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
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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
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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 ¹AMBROSINO 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
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0.1254 ± 0.0005 OUR FIT

0.1255 ± 0.0006 OUR AVERAGE

0.1263 ± 0.0004 ± 0.0011 13M ¹AMBROSINO 06 KLOE

0.1252 ± 0.0007 ²ALEXOPOU... 04 KTEV

¹ There are correlations between these five KLOE measurements: $B(K_L \rightarrow \pi e \nu)$, $B(K_L \rightarrow \pi \mu \nu)$, $B(K_L \rightarrow 3\pi^0)$, $B(K_L \rightarrow \pi^+ \pi^- \pi^0)$, and 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 $B(K_L \rightarrow \pi e \nu)$ measurement.

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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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 ¹ALEXOPOU... 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.

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

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

$$\frac{\Gamma(\pi^+\pi^-)}{\Gamma_{\text{total}}} \quad \Gamma_8/\Gamma$$

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 ¹ALEXOPOU... 04 KTEV

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

$$\frac{\Gamma(\pi^+\pi^-)}{\Gamma(\pi^\pm e^\mp \nu_e)} \quad \Gamma_8/\Gamma_1$$

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 ¹LAI 07 NA48

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

4.856±0.017±0.023 84k ²ALEXOPOU... 04 KTEV Not in fit

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

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

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

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 ¹AMBROSINO 06F KLOE

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

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

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 $\eta_{+-}=2.28 \pm 0.06$

3.04 ±0.14 2703 DEVOE 77 SPEC $\eta_{+-}=2.25 \pm 0.05$

2.51 ± 0.23	309	¹ DEBOUARD	67	OSPK	$\eta_{+-} = 2.00 \pm 0.09$
2.35 ± 0.19	525	¹ FITCH	67	OSPK	$\eta_{+-} = 1.94 \pm 0.08$

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

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

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

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

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

Violates *CP* conservation.

<u>VALUE (units 10⁻³)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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	$\eta_{+-} = 2.23 \pm 0.05$
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¹From same data as $\Gamma(\pi^+ \pi^-) / \Gamma(\pi^+ \pi^- \pi^0)$ MESSNER 73, but with different normalization.

$$\Gamma(\pi^+ \pi^-) / \Gamma(\pi^+ \pi^- \pi^0) \quad \Gamma_8 / \Gamma_7$$

Violates *CP* conservation.

<u>VALUE (units 10⁻²)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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	$\eta_{+-} = 2.23$
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$$\Gamma(\pi^0 \pi^0) / \Gamma_{\text{total}} \quad \Gamma_9 / \Gamma$$

Violates *CP* conservation.

<u>VALUE (units 10⁻³)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
0.864 ± 0.006 OUR FIT		Error includes scale factor of 1.8.
0.865 ± 0.012	¹ ALEXOPOU... 04	KTEV

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

$$\Gamma(\pi^0 \pi^0) / \Gamma(\pi^+ \pi^-) \quad \Gamma_9 / \Gamma_8$$

Violates *CP* conservation.

<u>VALUE</u>	<u>DOCUMENT ID</u>
0.4395 ± 0.0023 OUR FIT	Error includes scale factor of 2.0.
0.4390 ± 0.0012	ETAFIT 16

$$\Gamma(\pi^0 \pi^0) / \Gamma(3\pi^0) \quad \Gamma_9 / \Gamma_6$$

Violates *CP* conservation.

<u>VALUE (units 10⁻²)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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
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• • • We do not use the following data for averages, fits, limits, etc. • • •

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

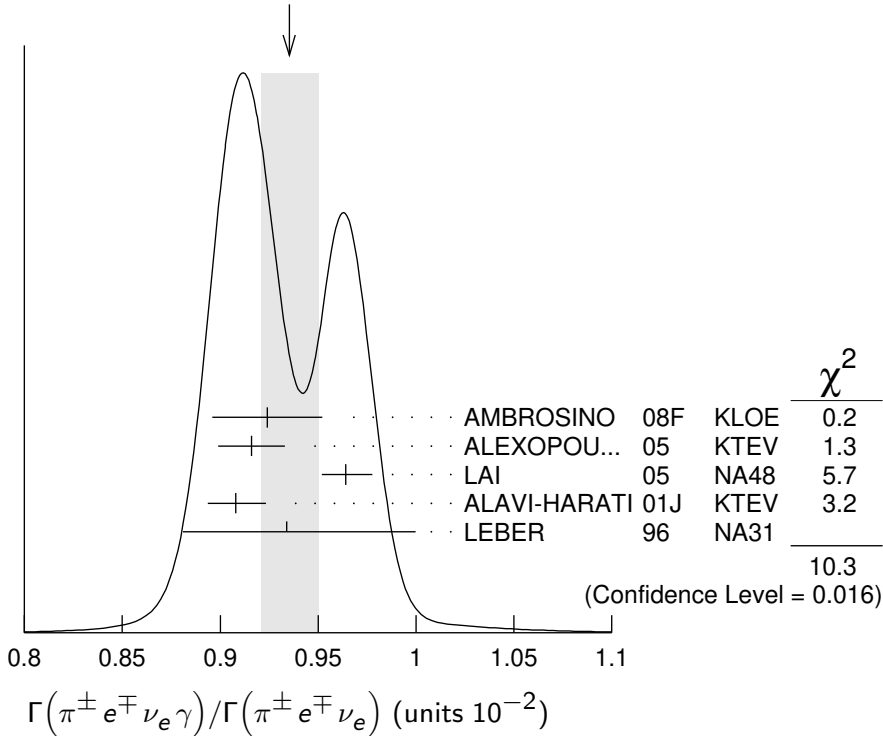
¹This measurement enters the fit via their separate measurements for the two modes.

———— Semileptonic modes with photons ————

$\Gamma(\pi^\pm e^\mp \nu_e \gamma) / \Gamma(\pi^\pm e^\mp \nu_e)$ 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 ± 0.023 ± 0.016	9k	¹ AMBROSINO 08F	KLOE	$E_\gamma^* > 30$ MeV, $\theta_{e\gamma}^* > 20^\circ$
0.916 ± 0.017	4309	² ALEXOPOU... 05	KTEV	$E_\gamma^* > 30$ MeV, $\theta_{e\gamma}^* > 20^\circ$
0.964 ± 0.008 ^{+0.011} _{-0.009}	19k	LAI 05	NA48	$E_\gamma^* > 30$ MeV, $\theta_{e\gamma}^* > 20^\circ$
0.908 ± 0.008 ^{+0.013} _{-0.012}	15k	ALAVI-HARATI01J	KTEV	$E_\gamma^* \geq 30$ MeV, $\theta_{e\gamma}^* \geq 20^\circ$
0.934 ± 0.036 ^{+0.055} _{-0.039}	1384	LEBER 96	NA31	$E_\gamma^* \geq 30$ MeV, $\theta_{e\gamma}^* \geq 20^\circ$

WEIGHTED AVERAGE
0.935 ± 0.015 (Error scaled by 1.9)



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

² Also measured cut $E_\gamma^* > 10$ MeV, $\theta_{e\gamma}^* > 0^\circ$ 14221 evts: $\Gamma(\pi^\pm e^\mp \nu_e \gamma) / \Gamma(\pi^\pm e^\mp \nu_e) = (4.942 \pm 0.062)\%$.

$\Gamma(\pi^\pm \mu^\mp \nu_\mu \gamma) / \Gamma(\pi^\pm \mu^\mp \nu_\mu)$ Γ_{11} / Γ_2

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN	COMMENT
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2.09 ± 0.08 OUR AVERAGE

2.09 ± 0.09		¹ ALEXOPOU...	05	KTEV $E_\gamma^* > 30$ MeV
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2.08 ± 0.17 ^{+0.16} _{-0.21}	252	BENDER	98	NA48 $E_\gamma^* \geq 30$ MeV
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¹ Also measured cut $E_\gamma^* > 10$ MeV, 1385 evts: $\Gamma(\pi^\pm \mu^\mp \nu_\mu \gamma) / \Gamma(\pi^\pm \mu^\mp \nu_\mu) = (0.530 \pm 0.014 \pm 0.012)\%$.

————— Hadronic modes with photons or $\ell\bar{\ell}$ pairs —————

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

VALUE (units 10^{-6})	CL%	DOCUMENT ID	TECN	COMMENT
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< 0.243	90	ABOUZAID	08B	KTEV $K_L^0 \rightarrow \pi^0 \pi_D^0 \gamma, \pi_D^0 \rightarrow e e \gamma$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< 5.6	90	BARR	94	NA31
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< 230	90	ROBERTS	94	E799
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$\Gamma(\pi^+ \pi^- \gamma) / \Gamma(\pi^+ \pi^- \pi^0)$ 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
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• • • 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
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2.33 ± 0.23	546	^{1,3} CARROLL	80B	SPEC
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3.56 ± 0.26	1062	^{1,4} CARROLL	80B	SPEC $E_\gamma^* > 20$ MeV
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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
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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-HARATI01B	KTEV	$E_\gamma^* > 20$ MeV
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2.30 ± 0.07	3136	RAMBERG	93	E731 $E_\gamma^* > 20$ MeV
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¹ ALAVI-HARATI 01B includes both Direct Emission (DE) and Inner Bremsstrahlung (IB) processes.

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

These values assume that $\Gamma(K_L^0 \rightarrow \pi^+ \pi^- \gamma) = \Gamma(K_L^0 \rightarrow \pi^+ \pi^- \gamma(\text{DE})) + \Gamma(K_L^0 \rightarrow \pi^+ \pi^- \gamma(\text{IB}))$, 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
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0.684 ± 0.009 OUR FIT

0.684 ± 0.009 OUR AVERAGE

0.689 ± 0.021	111k	ABOUZAID	06A	KTEV $E_\gamma^* > 20$ MeV
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0.683±0.011	8669	ALAVI-HARATI01B	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 ±0.06 ±0.01		1.4k	¹ ABOUZAID	08	KTEV
1.27 ±0.04 ±0.01		2.5k	² LAI	02B	NA48
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.68 ±0.07 ±0.08		884	³ ALAVI-HARATI99B		KTEV
1.7 ±0.2 ±0.2		63	⁴ BARR	92	NA31
1.86 ±0.60 ±0.60		60	PAPADIMITR...91	E731	$m_{\gamma\gamma} > 280$ MeV
<5.1	90		PAPADIMITR...91	E731	$m_{\gamma\gamma} < 264$ MeV
2.1 ±0.6		14	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 $[\Gamma(K_L^0 \rightarrow \pi^0 2\gamma)/\Gamma_{\text{total}}] / [B(K_L^0 \rightarrow \pi^0 \pi^0)]$ assuming $B(K_L^0 \rightarrow \pi^0 \pi^0) = (8.69 \pm 0.04) \times 10^{-4}$, which we rescale to our best value $B(K_L^0 \rightarrow \pi^0 \pi^0) = (8.64 \pm 0.06) \times 10^{-4}$. 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 $[\Gamma(K_L^0 \rightarrow \pi^0 2\gamma)/\Gamma_{\text{total}}] / [B(K_L^0 \rightarrow \pi^0 \pi^0)] = (1.467 \pm 0.032 \pm 0.032) \times 10^{-3}$ which we multiply by our best value $B(K_L^0 \rightarrow \pi^0 \pi^0) = (8.64 \pm 0.06) \times 10^{-4}$. 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±0.14±0.09				
		125	¹ ABOUZAID	07D

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

2.34±0.35±0.13		44	ALAVI-HARATI01E	KTEV
<71	90	0	MURAKAMI	99

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

———— Other modes with photons or $\ell\bar{\ell}$ pairs ————

$\Gamma(2\gamma)/\Gamma_{\text{total}}$ **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_L^0 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, $\Gamma(2\gamma)/\Gamma_{\text{total}} = [(4.32 \pm 0.55) \times 10^{-4}] [(\eta_{00}/\eta_{+-})^2]$.

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

$\Gamma(2\gamma)/\Gamma(3\pi^0)$

Γ_{17}/Γ_6

<u>VALUE (units 10⁻³)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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0.633 ± 0.006 OUR FIT Error includes scale factor of 1.4.

0.632 ± 0.004 ± 0.008 110k BURKHARDT 87 NA31

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

Γ_{18}/Γ

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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< 7.4 × 10⁻⁸ 90 ¹ TUNG 11 K391

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

< 2.4 × 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

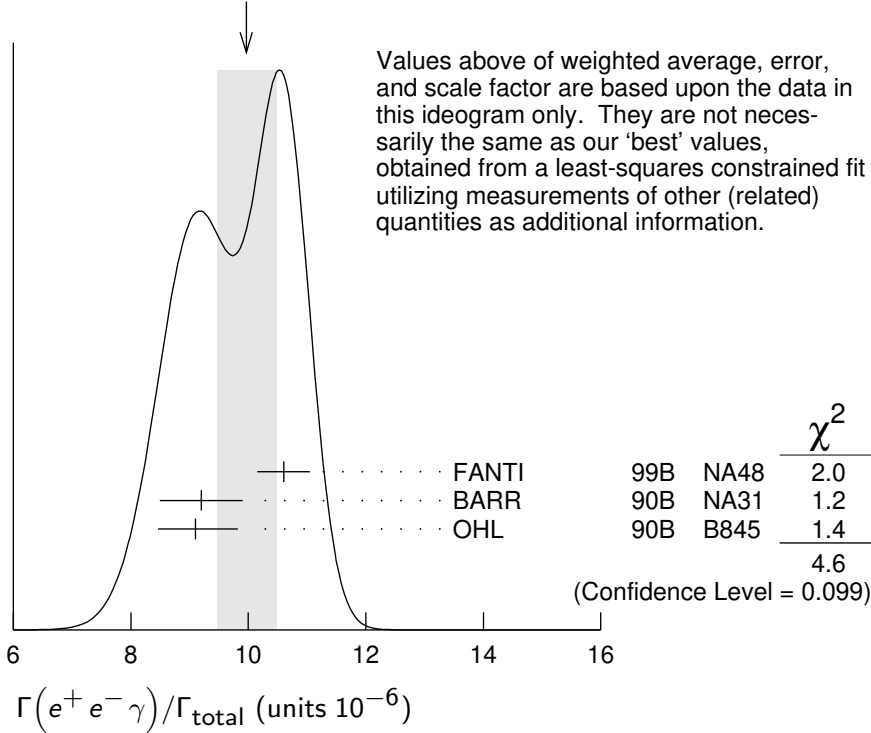
<u>VALUE (units 10⁻⁶)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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9.4 ± 0.4 OUR FIT Error includes scale factor of 2.0.

10.0 ± 0.5 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.

10.6 ± 0.2 ± 0.4	6864	¹ FANTI	99B	NA48
9.2 ± 0.5 ± 0.5	1053	BARR	90B	NA31
9.1 ± 0.4 ^{+0.6} / _{-0.5}	919	OHL	90B	B845

WEIGHTED AVERAGE
 10.0 ± 0.5 (Error scaled by 1.5)



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

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

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.	
$4.63 \pm 0.04 \pm 0.13$	83k	¹ ABOUZAID 07B	KTEV

¹ABOUZAID 07B reports $[\Gamma(K_L^0 \rightarrow e^+ e^- \gamma) / \Gamma(K_L^0 \rightarrow 3\pi^0)] / [3\Gamma(\pi^0 \rightarrow 2\gamma) / \Gamma_{\text{total}} \times \Gamma(\pi^0 \rightarrow e^+ e^- \gamma) / \Gamma_{\text{total}}] = (1.3302 \pm 0.0046 \pm 0.0103) \times 10^{-3}$ which we multiply by our best value $3\Gamma(\pi^0 \rightarrow 2\gamma) / \Gamma_{\text{total}} \times \Gamma(\pi^0 \rightarrow e^+ e^- \gamma) / \Gamma_{\text{total}} = 0.0348 \pm 0.0010$. 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.	
$3.62 \pm 0.04 \pm 0.08$	9100	ALAVI-HARATI01G	KTEV
$3.4 \pm 0.6 \pm 0.4$	45	FANTI 97	NA48
$3.23 \pm 0.23 \pm 0.19$	197	SPENCER 95	E799

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

Γ_{21} / Γ

VALUE (units 10^{-7})	EVTS	DOCUMENT ID	TECN	COMMENT
5.95 ± 0.33 OUR AVERAGE				
$5.84 \pm 0.15 \pm 0.32$	1543	ALAVI-HARATI01F	KTEV	$E_\gamma^* > 5 \text{ MeV}$
$8.0 \pm 1.5 \begin{smallmatrix} +1.4 \\ -1.2 \end{smallmatrix}$	40	SETZU 98	NA31	$E_\gamma^* > 5 \text{ MeV}$

6.5 ±1.2 ±0.6	58	NAKAYA	94	E799	$E_\gamma^* > 5 \text{ MeV}$
6.6 ±3.2		MORSE	92	B845	$E_\gamma^* > 5 \text{ MeV}$

$\Gamma(\mu^+ \mu^- \gamma\gamma)/\Gamma_{\text{total}}$					Γ_{22}/Γ
VALUE (units 10^{-9})	EVTS	DOCUMENT ID	TECN	COMMENT	
10.4^{+7.5}_{-5.9} ±0.7	4	ALAVI-HARATI00E	KTEV	$m_{\gamma\gamma} \geq 1 \text{ MeV}/c^2$	

————— **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_{23}/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

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

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

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

$\Gamma(e^+ e^-)/\Gamma_{\text{total}}$					Γ_{24}/Γ
Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.					
VALUE (units 10^{-10})	CL%	EVTS	DOCUMENT ID	TECN	
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 ¹ARISAKA 93B B791

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

$\Gamma(\pi^+ \pi^- e^+ e^-)/\Gamma_{\text{total}}$					Γ_{25}/Γ
Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.					
VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
3.11 ±0.19 OUR AVERAGE					

3.08 ±0.09 ±0.18 1125 ¹LAI 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 $0.15(\text{syst}) \pm 0.10(\text{norm})$ combined in quadrature. The normalization uses $\text{BR}(K_L^0 \rightarrow \pi^+ \pi^- \pi^0) * \text{BR}(\pi^0 \rightarrow e^+ e^-) = (1.505 \pm 0.047) \times 10^{-3}$ from our 2000 Edition.

$\Gamma(\pi^0 \pi^0 e^+ e^-) / \Gamma_{\text{total}}$ **Γ_{26} / Γ**

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

VALUE (units 10^{-9})	CL%	EVTS	DOCUMENT ID	TECN
<6.6	90	1	ALAVI-HARATI02C	E799

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

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

VALUE	CL%	DOCUMENT ID	TECN
<9.2 $\times 10^{-11}$	90	¹ ABOUZAIID 11A	E799

¹ ABOUZAIID 11A also reports $\text{B}(K_L^0 \rightarrow \pi^0 \pi^0 X^0 \rightarrow \pi^0 \pi^0 \mu^+ \mu^-) < 1.0 \times 10^{-10}$ 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_{28} / 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 $\pm 0.24 \pm 0.12$		131	¹ ALAVI-HARATI03B	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 $\pm 0.40 \pm 0.17$ 43 ALAVI-HARATI01H 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_{29} / 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 $\pm 0.24 \pm 0.25$	200	¹ LAI 05B	NA48	
3.72 $\pm 0.18 \pm 0.23$	441	ALAVI-HARATI01D	KTEV	
3.96 $\pm 0.78 \pm 0.32$	27	GU	94	E799
3.07 $\pm 1.25 \pm 0.26$	6	VAGINS	93	B845

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

6 $\pm 2 \pm 1$	18	² AKAGI	95	SPEC	$m_{ee} > 470$ MeV
7 $\pm 3 \pm 2$	6	² AKAGI	95	SPEC	$m_{ee} > 470$ MeV
10.4 $\pm 3.7 \pm 1.1$	8	³ BARR	95	NA31	
6 $\pm 2 \pm 1$	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 $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$ (π^0 into Dalitz pair) and PDG 04 values are used for $\text{B}(K_L^0 \rightarrow \pi^+ \pi^- \pi^0)$ and $\text{B}(\pi^0 \rightarrow e^+ e^- \gamma)$. The systematic error includes a normalization error of ± 0.10 .

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

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

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

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

<u>VALUE (units 10^{-9})</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<0.38	90		ALAVI-HARATI00D	KTEV

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

<5.1	90	0	HARRIS	93 E799
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$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{31}/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.

<u>VALUE (units 10^{-10})</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
< 2.8	90		¹ ALAVI-HARATI04A	KTEV	combined result

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

< 3.5	90		ALAVI-HARATI04A	KTEV	
0.0047 ^{+0.0022} _{-0.0018}			² LAI	02B NA48	CP -conserving part
< 5.1	90	2	ALAVI-HARATI01	KTEV	
0.01 to 0.02			ALAVI-HARATI99B	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 $K_L^0 \rightarrow \pi^0 \gamma \gamma$ with $m(\gamma \gamma) < m(\pi^0)$ and their a_V value to predict this value.

$\Gamma(\pi^0 \nu \bar{\nu})/\Gamma_{\text{total}}$ Γ_{32}/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.

<u>VALUE (units 10^{-8})</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
< 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-HARATI00	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/c².

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/c².

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).

$\Gamma(\pi^0 \pi^0 \nu \bar{\nu})/\Gamma_{\text{total}}$

Γ_{33}/Γ

VALUE	CL%	DOCUMENT ID	TECN
<8.1 × 10⁻⁷	90	¹ OGATA 11	K391

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

<4.7 × 10 ⁻⁵	90	² NIX 07	K391
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¹ Using 2005 Run-I data. OGATA 11 also sets a limit on the $K_L^0 \rightarrow \pi^0 \pi^0 X \rightarrow$ invisible particles process: the limit on the branching fraction varied from 7.0×10^{-7} to 4.0×10^{-5} for the mass of X ranging from 50 to 200 MeV/c².

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

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

Γ_{34}/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_{35}/Γ

Test of lepton family number conservation.

VALUE (units 10 ⁻¹¹)	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 4.12	90	0	ALAVI-HARATI03B	KTEV	

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

< 12.3	90	0	¹ ALAVI-HARATI01H	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_{36}/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
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$\Gamma(\pi^0 \pi^0 \mu^\pm e^\mp) / \Gamma_{\text{total}}$ Γ_{37} / Γ

Test of lepton family number conservation.

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

————— Lorentz invariance violating modes —————

$\Gamma(\pi^0 \gamma) / \Gamma_{\text{total}}$ Γ_{38} / Γ

VALUE	CL%	DOCUMENT ID	TECN
<1.7 × 10 ⁻⁷	90	¹ SHIMIZU 20	KOTO

¹SHIMIZU 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_L^0 DALITZ PLOT

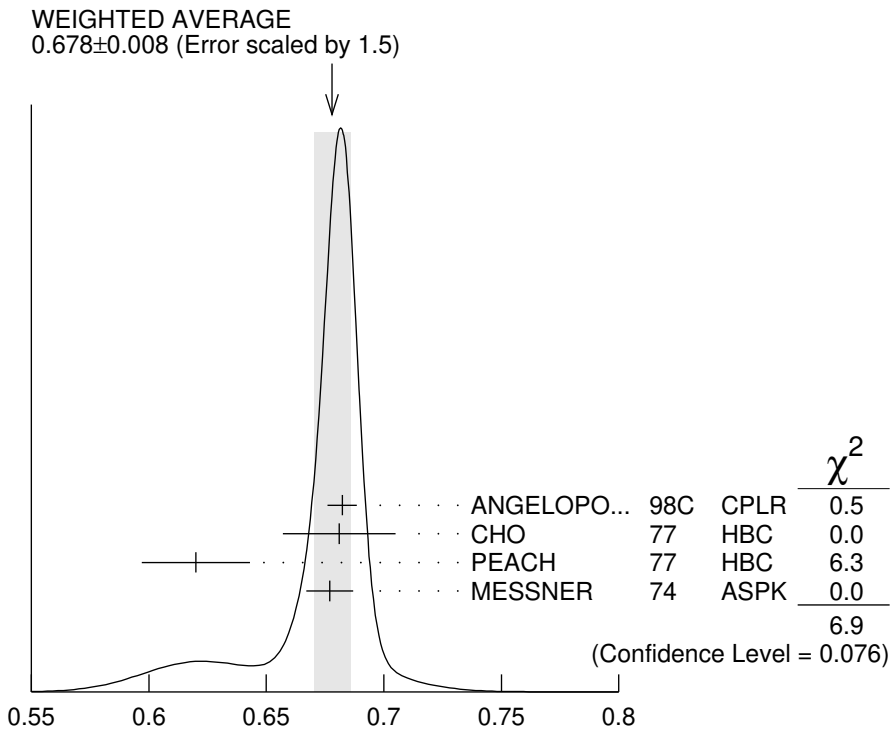
For discussion, see note on Dalitz plot parameters in the K^\pm section of the Particle Listings above. For definitions of a_v , a_t , a_u , and a_y , see the earlier version of the same note in the 1982 edition of this *Review* published in Physics Letters **111B** 70 (1982).

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

where $u = (s_3 - s_0) / m_\pi^2$ and $v = (s_2 - s_1) / m_\pi^2$

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.678 ± 0.008	OUR AVERAGE	Error includes scale factor of 1.5. See the ideogram below.		
0.6823 ± 0.0044 ± 0.0044	500k	ANGELOPO...	98C	CPLR
0.681 ± 0.024	6499	CHO	77	HBC
0.620 ± 0.023	4709	PEACH	77	HBC
0.677 ± 0.010	509k	MESSNER	74	ASPK $a_y = -0.917 \pm 0.013$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
0.69 ± 0.07	192	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 $a_u = -0.204 \pm 0.025$



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

- ¹ Quadratic dependence required by some experiments. (See sections on “QUADRATIC COEFFICIENT h ” and “QUADRATIC COEFFICIENT k ” below.) Correlations prevent us from averaging results of fits not including g , h , and k terms.
- ² BISI 74 value comes from quadratic fit with quad. term consistent with zero. g error is thus larger than if linear fit were used.
- ³ BUCHANAN 70 result revised by BUCHANAN 75 to include radiative correlations and to use more reliable K_L^0 momentum spectrum of second experiment (had same beam).

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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
0.076 ± 0.006 OUR AVERAGE			
$0.061 \pm 0.004 \pm 0.015$	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 $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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 $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$ (*CP*-VIOLATING TERM)

Listed in *CP*-violation section below.

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

Listed in *CP*-violation section below.

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

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

<u>VALUE (units 10^{-3})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
+0.59 ± 0.20 ± 1.16	68M	¹ ABOUZAIID 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 $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$ definitions.

K_L^0 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.

$$f_0(t) = f_+(t) + f_-(t) t / (m_{K^0}^2 - m_{\pi^+}^2).$$

t = momentum transfer to the π .

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

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

For quadratic expansion

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

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 $\lambda''_{+ PDG} = 2 \lambda'_{+ NA48}$
 $\lambda'_{+ PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_{+ ISTRA}$ and
 $\lambda''_{+ PDG} = 2 \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^4 \lambda'_{+ ISTRA}$

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

The pole parametrization is

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

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

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

The dispersive parametrization is

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

$$f_0(t) = f_0(0) \exp\left[\frac{t}{m_K^2 - m_{\pi}^2} (\ln[C] - G(t)) \right],$$

where Λ_{+} is the slope parameter and $\ln[C] = \ln[f_0(m_K^2 - m_{\pi}^2)]$

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 = $K_{\mu 3}^0 / K_{e 3}^0$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

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

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

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 $K_{\mu 3}^0$ DECAY)

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

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 $K_{\mu 3}^0$ DECAY)

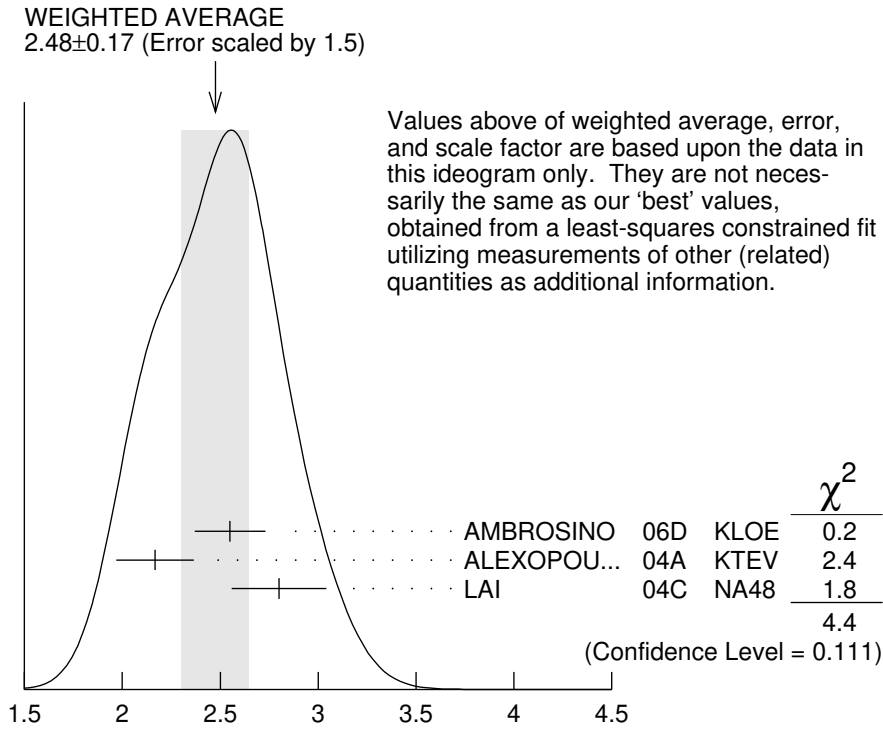
Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ_+^μ and $d\xi(0)/d\lambda_+$. Results labeled OUR FIT are discussed in the review “ $K_{\ell 3}^\pm$ and $K_{\ell 3}^0$ Form Factors” in the K^\pm Listings. For earlier, lower statistics results,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

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 $d\lambda_0/d\lambda_+ = 0$.

$\lambda'_+($ LINEAR K_{e3}^0 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



$\lambda'_+($ LINEAR K_{e3}^0 FORM FACTOR FROM QUADRATIC FIT) (units 10^{-2})

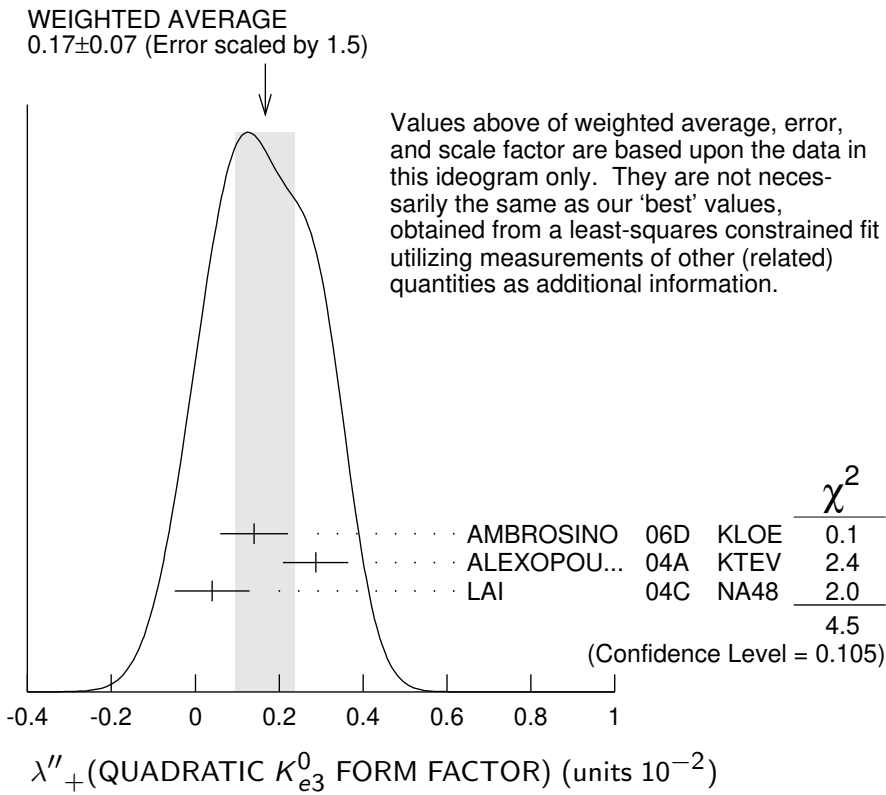
¹ We use AMBROSINO 06D result in the fit not assuming μ - e universality. This result enters the fit assuming μ - e universality via AMBROSINO 07C measurement of λ'_+ in $K_{\mu 3}$ decays. AMBROSINO 06D gives a correlation -0.95 between their λ'_+ and λ''_+ .

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''_+ .

$\lambda''_+($ QUADRATIC K_{e3}^0 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



¹We 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''_+ .

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

³Values doubled to agree with PDG conventions described above.

⁴LAI 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 $\mu-e$ universality
1.89 ±0.24 OUR FIT				Not assuming $\mu-e$ 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, $\mu = e$

¹See section λ_0 below for correlations.

λ''_+ (QUADRATIC $K^0_{\mu 3}$ 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 $\mu-e$ universality
0.37 ±0.12 OUR FIT				Error includes scale factor of 1.3. Not assuming $\mu-e$ 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 $f_0 K_{\mu 3}^0$ 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

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

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

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

³ LAI 07A gives a correlation matrix

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

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

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

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

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

M_{ν}^e (POLE MASS FOR K_{e3}^0 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 $K_{\mu 3}^0$ 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 $K_{\mu 3}^0$ DECAY)

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1252 ± 90	OUR FIT	Error includes scale factor of 2.6. Assuming μ -e universality		
1222 ± 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.

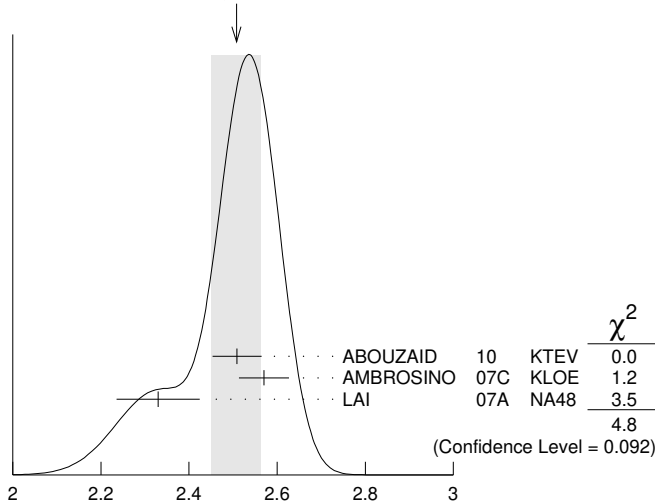
³ ALEXOPOULOS 04A gives a correlation -0.40 between their M_S^μ and M_V^μ and measurements, assuming μ -e universality.

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

See the review on " $K_{\ell 3}^\pm$ and $K_{\ell 3}^0$ 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 ABOUZAIID	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

WEIGHTED AVERAGE
2.51 ± 0.06 (Error scaled by 1.5)



Λ_+ (DISPERSIVE VECTOR FORM FACTOR FOR $K_{\mu 3}^0$ DECAY) (units 10^{-2})

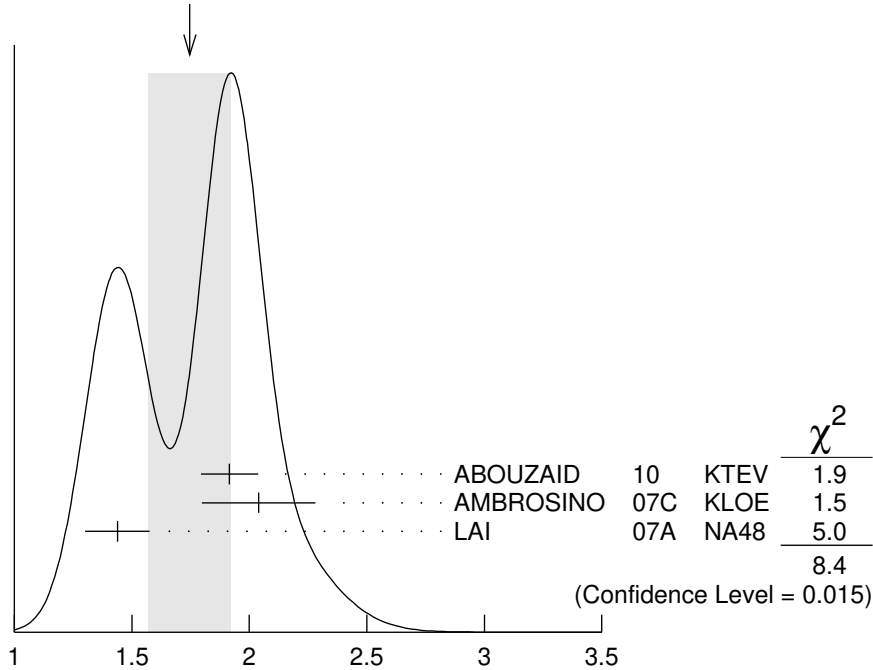
- ¹ Obtained from a sample of 1.9 M K_{e3} and 1.5 M $K_{\mu3}$. The correlation between Λ_+ and $\ln(C)$ is -0.269 .
- ² AMBROSINO 07C results include 2M K_{e3} events from AMBROSINO 06D. The correlation between Λ_+ and $\ln(C)$ is -0.26 .
- ³ LAI 07A gives a correlation -0.44 between their Λ_+ and $\ln(C)$ measurements.

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

See the review on " $K_{\ell 3}^{\pm}$ and $K_{\ell 3}^0$ 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

WEIGHTED AVERAGE
1.75 ± 0.18 (Error scaled by 2.0)



$\ln(C)$ (DISPERSIVE SCALAR FORM FACTOR FOR $K_{\mu3}^0$ DECAY) (units 10^{-1})

- 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 $(\Lambda_+, \ln(C))$ 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.

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

See HILL 06 for a definition of this parameter.

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
1.023±0.028±0.029	2M	¹ ABOUZAIID	06C KTEV

¹ $Q^2 = 2 \text{ GeV}^2$, $t_0 = 0.49 (m_K - m_\pi)^2$. Correlation between a_1 and a_2 : $\rho_{12} = -0.064$.

$a_2(t_0, Q^2)$ FORM FACTOR PARAMETER

See HILL 06 for a definition of this parameter.

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
0.75±1.58±1.47	2M	¹ ABOUZAIID	06C KTEV

¹ $Q^2 = 2 \text{ GeV}^2$, $t_0 = 0.49 (m_K - m_\pi)^2$. Correlation between a_1 and a_2 : $\rho_{12} = -0.064$.

$|f_S/f_+|$ FOR K_{e3}^0 DECAY

Ratio of scalar to f_+ couplings.

<u>VALUE (units 10^{-2})</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
1.5^{+0.7}_{-1.0}±1.2		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_{e3}^0 DECAY

Ratio of tensor to f_+ couplings.

<u>VALUE (units 10^{-2})</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
5⁺³₋₄±3		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	BLUMENTHAL75		SPEC	

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

$|f_T/f_+|$ FOR $K_{\mu 3}^0$ DECAY

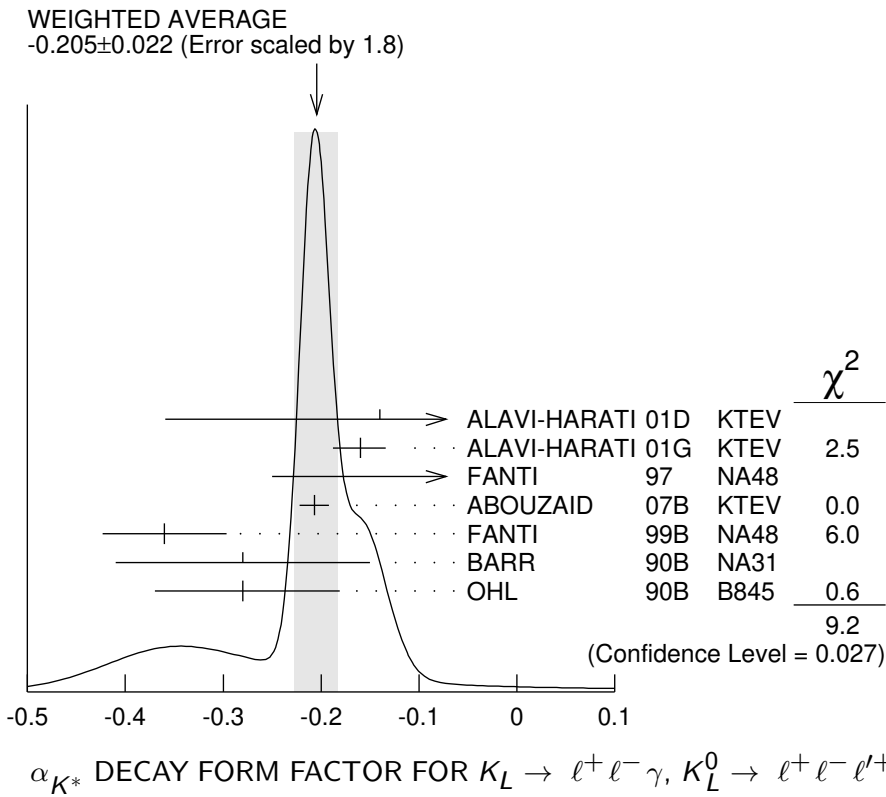
Ratio of tensor to f_+ couplings.

<u>VALUE (units 10^{-2})</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
12.±12.	BIRULEV 81	SPEC

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

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

<u>VALUE</u>	<u>DOCUMENT ID</u>
-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 $K_L \rightarrow e^+ e^- \gamma$

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

VALUE	EVTS	DOCUMENT ID	TECN
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The data in this block is included in the average printed for a previous datablock.

-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

¹ABOUZAID 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 $K_L \rightarrow \mu^+ \mu^- \gamma$

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

VALUE	EVTS	DOCUMENT ID	TECN
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The data in this block is included in the average printed for a previous datablock.

-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

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

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

VALUE EVTS DOCUMENT ID TECN

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

-0.14 ± 0.16 ± 0.15 441 ALAVI-HARATI01D KTEV

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

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 $K_L^0 \rightarrow e^+ e^- \gamma$

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

VALUE EVTS DOCUMENT ID TECN

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

-1.729 ± 0.043 ± 0.028 83k ABOUZAID 07B KTEV

α_{DIP} DECAY FORM FACTOR FOR $K_L^0 \rightarrow \mu^+ \mu^- \gamma$

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-HARATI01G KTEV

α_{DIP} DECAY FORM FACTOR FOR $K_L^0 \rightarrow e^+ e^- \mu^+ \mu^-$

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-HARATI03B KTEV

a_1/a_2 FORM FACTOR FOR M1 DIRECT EMISSION AMPLITUDE

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

VALUE (GeV²) 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 $\begin{smallmatrix} +0.07 \\ -0.13 \end{smallmatrix}$ ± 0.02 3 LAI 03C NA48 $\pi^+ \pi^- e^+ e^-$

-0.737 ± 0.026 ± 0.022 4 ALAVI-HARATI01B $\pi^+ \pi^- \gamma$

-0.720 ± 0.028 ± 0.009 1766 5 ALAVI-HARATI00B KTEV $\pi^+ \pi^- e^+ e^-$

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

² ABOUZAIID 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 $\chi^2/\text{DOF} = 38.8/27$. Linear and quadratic fits give $\chi^2/\text{DOF} = 43.2/27$ and $37.6/26$ respectively.

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

\bar{f}_S DECAY FORM FACTOR FOR $K_L^0 \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$

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

\bar{f}_P DECAY FORM FACTOR FOR $K_L^0 \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$

VALUE	DOCUMENT ID	TECN
-0.052 ± 0.012 OUR AVERAGE		
$-0.051 \pm 0.011 \pm 0.005$	BATLEY 04	NA48
$-0.079 \pm 0.049 \pm 0.022$	MAKOFF 93	E731

λ_g DECAY FORM FACTOR FOR $K_L^0 \rightarrow \pi^\pm \pi^0 e^\mp \nu_e$

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

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

VALUE	DOCUMENT ID	TECN
-0.30 ± 0.13 OUR AVERAGE		
$-0.32 \pm 0.12 \pm 0.07$	BATLEY 04	NA48
$-0.07 \pm 0.31 \pm 0.31$	MAKOFF 93	E731

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

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.		
$-0.31 \pm 0.05 \pm 0.07$	1.4k	¹ ABOUZAIID 08	KTEV	
$-0.46 \pm 0.03 \pm 0.04$		LAI 02B	NA48	$K_L^0 \rightarrow \pi^0 2\gamma$
$-0.67 \pm 0.21 \pm 0.12$		ALAVI-HARATI01E	KTEV	$K_L^0 \rightarrow \pi^0 e^+ e^- \gamma$
$-0.72 \pm 0.05 \pm 0.06$		² ALAVI-HARATI99B	KTEV	$K_L^0 \rightarrow \pi^0 2\gamma$

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

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

² Superseded by ABOUZAIID 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 $\text{Re}(\epsilon)$.

$A_L =$ 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 $K_{\mu 3} + K_{e3}$

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

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

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

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

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

VALUE (%)	EVTS	DOCUMENT ID	TECN
The data in this block is included in the average printed for a previous datablock.			

0.334 ±0.007 OUR AVERAGE

0.3322±0.0058±0.0047	298M	ALAVI-HARATI02		
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

¹SAAL 69 is a reanalysis of BENNETT 67.

————— **PARAMETERS FOR $K_L^0 \rightarrow 2\pi$ DECAY** —————

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

$$\eta_{00} = A(K_L^0 \rightarrow \pi^0\pi^0) / A(K_S^0 \rightarrow \pi^0\pi^0)$$

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

$$|\eta_{00}| = |A(K_L^0 \rightarrow 2\pi^0) / A(K_S^0 \rightarrow 2\pi^0)|$$

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

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

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 $K^0-\bar{K}^0$ asymmetry
2.310±0.043±0.031		⁵ ADLER	95B	CPLR $K^0-\bar{K}^0$ asymmetry
2.32 ±0.14 ±0.03	10^5	ADLER	92B	CPLR $K^0-\bar{K}^0$ asymmetry
2.30 ±0.035		GEWENIGER	74B	ASPK

¹ Value obtained from the NA48 measurements of $\Gamma(K_L^0 \rightarrow \pi^+\pi^-)/\Gamma(K_L^0 \rightarrow \pi^+\pi^- + \pi^0\pi^0)$ and $\tau_{K_S^0}$ and KLOE measurements of $B(K_S^0 \rightarrow \pi^+\pi^-)$ and $\tau_{K_L^0}$. $\Gamma(K_L^0 \rightarrow \pi^+\pi^-)$ is defined to include the inner bremsstrahlung component $\Gamma(K_L^0 \rightarrow \pi^+\pi^-\gamma(\text{IB}))$ but exclude the direct emission component $B(K_S^0 \rightarrow \pi^+\pi^-(\text{DE}))$. Their $|\eta_{+-}|$ value

is not directly used in our fit, but enters the fit via their branching ratio and lifetime measurements.

² AMBROSINO 06F uses KLOE branching ratios and τ_L together with τ_S from PDG 04.

Their $|\eta_{+-}|$ value is not directly used in our fit, but enters the fit via their branching ratio and lifetime measurements.

³ ALEXOPOULOS 04 $|\eta_{+-}|$ uses their $K_L^0 \rightarrow \pi\pi$ 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 $\Gamma(K_S^0 \rightarrow \pi\ell\nu_\ell) = \Gamma(K_L^0 \rightarrow \pi\ell\nu_\ell)$ giving $B(K_S^0 \rightarrow \pi\ell\nu_\ell) = 0.118\%$. 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 $\Delta m = (0.5304 \pm 0.0014) \times 10^{-10} \text{ } \hbar s^{-1}$ and $\tau_S = (0.8927 \pm 0.0009) \times 10^{-10}$ s. Superseded by APOSTOLAKIS 99C.

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

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

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.
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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	

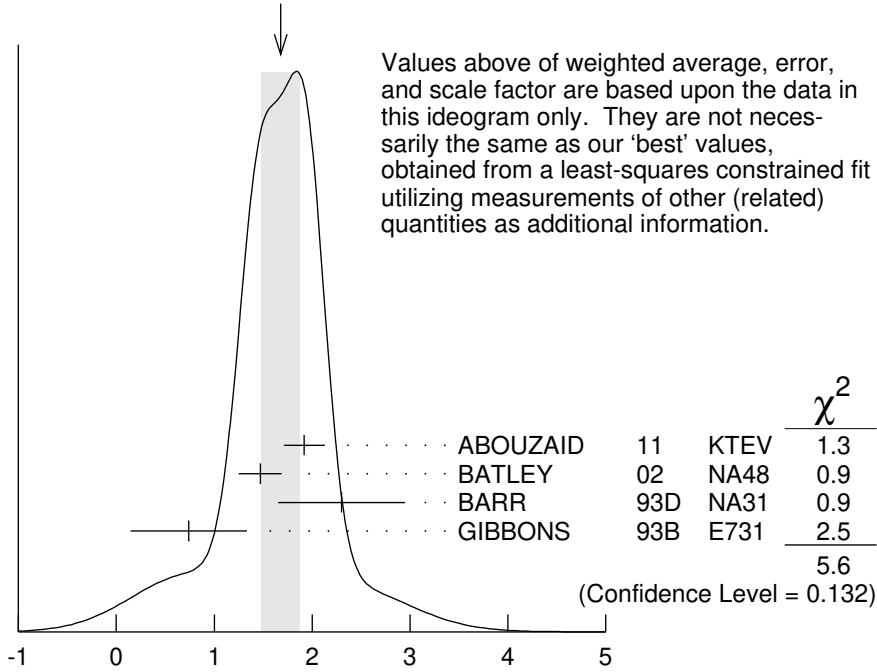
• • • We use the following data for averages but not for fits. • • •

2.3 ± 0.65	^{2,3}	BARR	93D	NA31
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• • • We do not use the following data for averages, fits, limits, etc. • • •

2.110 ± 0.343	^{1,4} ABOUZAID	11	KTEV	Not assuming <i>CPT</i>
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	

WEIGHTED AVERAGE
1.68 ± 0.20 (Error scaled by 1.4)



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

- 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.

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 $K_L^0 - K_S^0$ mass difference in units $10^{10} \text{ } \hbar s^{-1}$ 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_L^0 Particle Listings. Most experiments in this section are included in both the “Not Assuming *CPT*” and “Assuming *CPT*” fits. In the latter fit, they have little direct influence on 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 <i>CPT</i>			
43.4 ±0.5 OUR FIT	Error includes scale factor of 1.2. Not assuming <i>CPT</i>			
42.9 ±0.6 ±0.3	70M	¹ APOSTOLA...	99C CPLR	$K^0-\bar{K}^0$ 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 ₄ C regenerator
44.5 ±1.6 ±0.6		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 ABOUZAIID	11 KTEV	Not assuming <i>CPT</i>
44.12±0.72±1.20		⁸ ALAVI-HARATI	103 KTEV	Not assuming <i>CPT</i>
42.5 ±0.4 ±0.3		^{9,10} ADLER	96C RVUE	
43.4 ±1.1 ±0.3		¹¹ ADLER	95B CPLR	$K^0-\bar{K}^0$ asymmetry
42.3 ±4.4 ±1.4	100k	¹² ADLER	92B CPLR	$K^0-\bar{K}^0$ 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 $\phi_{+-} - \phi_f$ and calculate the regeneration phase from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. SCHWINGENHEUER 95 [GIBBONS 93] includes a systematic error of 0.35° [0.5°] for uncertainties in their modeling of the regeneration amplitude.

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 $\phi_{+-} (42.2 \pm 1.4)^\circ$. They measure $\phi_{+-} - \phi_f$ 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 $\Delta m = m_{K_L^0} - m_{K_S^0}$ and τ_{K_S} measurements in the K_L^0 and K_S^0 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 $\phi_{+-} = (45.5 \pm 2.8) + 224 [\Delta m - 0.5348]$ ($^\circ$). 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. $\phi_f = -40.9 \pm 2.6^\circ$.

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 ($^\circ$)	DOCUMENT ID	TECN	COMMENT
43.52 ± 0.05 OUR FIT	Error includes scale factor of 1.3. Assuming <i>CPT</i>		
43.7 ± 0.6 OUR FIT	Error includes scale factor of 1.2. Not assuming <i>CPT</i>		
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 <i>CPT</i>
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 $\phi_{00} = (47.1 \pm 2.1 \pm 1.0) + 579 [\Delta m - 0.5351] + 252 [\tau_S - 0.8922]$ ($^\circ$). 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.

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

³ ANGELOPOULOS 98 measures $\phi_{00} = (42.0 \pm 5.6 \pm 1.9) + 240 [\Delta m - 0.5307]$ ($^\circ$). We have adjusted the measurement to use our best values of ($\Delta m = 0.5293 \pm 0.0009$)

($10^{10} \hbar \text{ s}^{-1}$). Our first error is their experiment's error and our second error is the systematic error from using our best values. The τ_S dependence is negligible.

⁴ ADLER 96B identified initial neutral kaon individually as being a K^0 or a \bar{K}^0 . The systematic uncertainty is $\pm 1.5^\circ$ combined in quadrature with $\pm 0.8^\circ$ 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 $\text{Re } \epsilon'/\epsilon$, and small theoretical ambiguities.

VALUE (°)	DOCUMENT ID	TECN	COMMENT
43.52 ± 0.05 OUR FIT			Error includes scale factor of 1.2. Assuming <i>CPT</i>
43.5 ± 0.5 OUR FIT			Error includes scale factor of 1.3. Not assuming <i>CPT</i>
43.5164 ± 0.0002 ± 0.0518	¹ SUPERWEAK 16		Assuming <i>CPT</i>
43.86 ± 0.63	² ABOUZAID 11	KTEV	Not assuming <i>CPT</i>

¹ SUPERWEAK 16 is a fake measurement used to impose the *CPT* or Superweak constraint $\phi_{+-} = \phi_{\text{SW}} = \tan^{-1}[2 \frac{\Delta m}{\hbar} (\frac{\tau_S \tau_L}{\tau_L - \tau_S})]$. 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 ($\Delta m = 0.5293 \pm 0.0009$) ($10^{10} \hbar \text{ s}^{-1}$), ($\tau_S = 0.8954 \pm 0.0004$) (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 $\text{Im}(\epsilon'/\epsilon)$ section for correlation information.

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

For small $|\epsilon'/\epsilon|$, $\text{Im}(\epsilon'/\epsilon)$ 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 <i>CPT</i>
-0.11 ± 0.11 OUR FIT			Not assuming <i>CPT</i>
-0.0985 ± 0.1157	¹ ABOUZAID 11	KTEV	Not assuming <i>CPT</i>

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

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

This is the *CP*-violating asymmetry

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

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-HARATI00B	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				
$-0.13 \pm 0.10 \pm 0.03$	200	¹ LAI	05B NA48	
$-0.23 \pm 0.09 \pm 0.02$	441	ALAVI-HARATI01D	KTEV	$M_{ee} > 8 \text{ MeV}/c^2$

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.
$+0.13 \pm 0.10 \pm 0.03$	200	LAI	05B NA48	
$-0.09 \pm 0.09 \pm 0.02$	441	ALAVI-HARATI01D	KTEV	$M_{ee} > 8 \text{ MeV}/c^2$

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

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

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

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

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

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

VALUE	EVTS	DOCUMENT ID	TECN
$0.0045 \pm 0.0024 \pm 0.0059$	500k	ANGELOPO...	98C CPLR

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

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

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

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

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

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

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

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

$|g_{E1}| \text{ for } K_L^0 \rightarrow \pi^+\pi^-\gamma$

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

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

T VIOLATION TESTS IN K_L^0 DECAYS

Im(ξ) in $K_{\mu 3}^0$ 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 +0.21Re[$\xi(0)$].

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^0 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 <i>CPT</i>
0.39 ± 0.22 ± 0.45	⁴ ALAVI-HARATI	03	KTEV	
0.62 ± 0.71 ± 0.75	SCHWINGENHEUER	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 $\text{Re}(\epsilon'/\epsilon)$, $\text{Im}(\epsilon'/\epsilon)$, Δm , τ_S , and ϕ_{+-} simultaneously, not assuming *CPT*. Phase difference is obtained from $\phi_{00} - \phi_{+-} \approx -3\text{Im}(\epsilon'/\epsilon)$ for small $|\epsilon'/\epsilon|$. 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 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 $\Delta\Gamma = \hbar(\tau_L - \tau_S)/(\tau_L\tau_S)$.

<u>VALUE (°)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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 .

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

Test of *CPT*

<u>VALUE (units 10⁻⁶)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
-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

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

We list $\text{Re}\{x\}$ and $\text{Im}\{x\}$ for K_{e3} and $K_{\mu 3}$ combined.

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

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	$\pi^- p \rightarrow K^0 \Lambda$
0.04 ± 0.03	4724	NIEBERGALL	74 ASPK	$K^+ p \rightarrow K^0 p \pi^+$
-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	$K^+ p \rightarrow K^0 p \pi^+$
0.04 ^{+0.10} / _{-0.13}	100	² GRAHAM	72 OSPK	$K_{\mu 3}$ from $K^0 \Lambda$
-0.05 ± 0.09	442	² GRAHAM	72 OSPK	$\pi^- p \rightarrow K^0 \Lambda$
0.26 ^{+0.10} / _{-0.14}	126	MANN	72 HBC	$K^- p \rightarrow n \bar{K}^0$
-0.13 ± 0.11	342	² MANTSCH	72 OSPK	K_{e3} from $K^0 \Lambda$
0.04 ^{+0.07} / _{-0.08}	222	¹ BURGUN	71 HBC	$K^+ p \rightarrow K^0 p \pi^+$
0.25 ^{+0.07} / _{-0.09}	252	WEBBER	71 HBC	$K^- p \rightarrow n \bar{K}^0$
0.12 ± 0.09	215	³ CHO	70 DBC	$K^+ d \rightarrow K^0 p p$
-0.020 ± 0.025		⁴ BENNETT	69 CNTR	Charge asym + Cu regen.
0.09 ^{+0.14} / _{-0.16}	686	LITTENBERG	69 OSPK	$K^+ n \rightarrow K^0 p$
0.03 ± 0.03		⁴ BENNETT	68 CNTR	
0.09 ^{+0.07} / _{-0.09}	121	JAMES	68 HBC	$\bar{p} p$
0.17 ^{+0.16} / _{-0.35}	116	FELDMAN	67B OSPK	$\pi^- p \rightarrow K^0 \Lambda$
0.17 ± 0.10	335	³ HILL	67 DBC	$K^+ d \rightarrow K^0 p p$
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	$\bar{p} p$

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 $\text{Re}(x)$ and $\text{Im}(x)$.

⁶ FRANZINI 65 gives x and θ for $\text{Re}(x)$ and $\text{Im}(x)$. See SCHMIDT 67.

IMAGINARY PART OF x

Assumes $m_{K_L^0} - m_{K_S^0}$ 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	$\pi^- p \rightarrow K^0 \Lambda$
-0.06 ±0.05	4724	NIEBERGALL	74	ASPK	$K^+ p \rightarrow K^0 p \pi^+$
-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	$K^+ p \rightarrow K^0 p \pi^+$
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	$\pi^- p \rightarrow K^0 \Lambda$
0.21 +0.15 -0.12	126	MANN	72	HBC	$K^- p \rightarrow n \bar{K}^0$
-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	$K^+ p \rightarrow K^0 p \pi^+$
0.0 ±0.08	252	WEBBER	71	HBC	$K^- p \rightarrow n \bar{K}^0$
-0.08 ±0.07	215	⁴ CHO	70	DBC	$K^+ d \rightarrow K^0 p p$
-0.11 +0.10 -0.11	686	LITTENBERG	69	OSPK	$K^+ n \rightarrow K^0 p$
+0.22 +0.37 -0.29	121	JAMES	68	HBC	$\bar{p} p$
0.0 ±0.25	116	FELDMAN	67B	OSPK	$\pi^- p \rightarrow K^0 \Lambda$
-0.20 ±0.10	335	⁴ HILL	67	DBC	$K^+ d \rightarrow K^0 p p$
-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	$\bar{p} p$

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 $\text{Re}(x)$ and $\text{Im}(x)$.

⁶ FRANZINI 65 gives x and θ for $\text{Re}(x)$ and $\text{Im}(x)$. See SCHMIDT 67.

K_L^0 REFERENCES

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SHIMIZU	20	PR D102 051103	N. Shimizu <i>et al.</i>	(KOTO Collab.)
AHN	19	PRL 122 021802	J.K. Ahn <i>et al.</i>	(KOTO Collab.)
AHN	17	PTEP 2017 021C01	J.K. Ahn <i>et al.</i>	(KOTO Collab.)
BRFIT	16	RPP 2016 edition	C.-J. Lin	(PDG Collab.)
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ABOUZAID	10	PR D81 052001	E. Abouzaid <i>et al.</i>	(FNAL KTeV Collab.)
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ABOUZAID	08	PR D77 112004	E. Abouzaid <i>et al.</i>	(FNAL KTeV Collab.)

ABOUZAID	08A	PR D78 032009	E. Abouzaid <i>et al.</i>	(FNAL KTeV Collab.)
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AMBROSINO	08F	EPJ C55 539	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
ABOUZAID	07B	PRL 99 051804	E. Abouzaid <i>et al.</i>	(FNAL KTeV Collab.)
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ANDRE	07	ANP 322 2518	T. Andre	(EF)
LAI	07	PL B645 26	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
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ABOUZAID	06C	PR D74 097101	E. Abouzaid <i>et al.</i>	(KTeV Collab.)
AHN	06	PR D74 051105	J.K. Ahn <i>et al.</i>	(KEK E391a Collab.)
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AMBROSINO	06D	PL B636 166	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
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AMBROSINO	05C	PL B626 15	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
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ALAVI-HARATI	01B	PRL 86 761	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01D	PRL 86 5425	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01E	PRL 87 021801	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01F	PR D64 012003	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01G	PRL 87 071801	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01H	PRL 87 111802	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	01J	PR D64 112004	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ANGELOPO...	01	PL B503 49	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	01B	EPJ C22 55	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
LAI	01B	PL B515 261	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	01C	EPJ C22 231	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
ALAVI-HARATI	00	PR D61 072006	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	00B	PRL 84 408	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	00D	PRL 84 5279	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
ALAVI-HARATI	00E	PR D62 112001	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
AMBROSE	00	PRL 84 1389	D. Ambrose <i>et al.</i>	(BNL E871 Collab.)
APOSTOLA...	00	PL B473 186	A. Apostolakis <i>et al.</i>	(CPLEAR Collab.)
PDG	00	EPJ C15 1	D.E. Groom <i>et al.</i>	(PDG Collab.)
ALAVI-HARATI	99B	PRL 83 917	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)

ALAVI-HARATI	99D	PRL 83 22	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
APOSTOLA...	99C	PL B458 545	A. Apostolakis <i>et al.</i>	(CPLEAR Collab.)
Also		EPJ C18 41	A. Apostolakis <i>et al.</i>	(CPLEAR Collab.)
FANTI	99B	PL B458 553	V. Fanti <i>et al.</i>	(CERN NA48 Collab.)
FANTI	99C	PL B463 335	V. Fanti <i>et al.</i>	(CERN NA48 Collab.)
MURAKAMI	99	PL B463 333	K. Murakami <i>et al.</i>	(KEK E162 Collab.)
ADAMS	98	PRL 80 4123	J. Adams <i>et al.</i>	(FNAL KTeV Collab.)
AMBROSE	98	PRL 81 4309	D. Ambrose <i>et al.</i>	(BNL E871 Collab.)
AMBROSE	98B	PRL 81 5734	D. Ambrose <i>et al.</i>	(BNL E871 Collab.)
ANGELOPO...	98	PL B420 191	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	98C	EPJ C5 389	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	98D	PL B444 38	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
Also		EPJ C22 55	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	98E	PL B444 43	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ARISAKA	98	PL B432 230	K. Arisaka <i>et al.</i>	(FNAL E799 Collab.)
BENDER	98	PL B418 411	M. Bender <i>et al.</i>	(CERN NA48 Collab.)
DAMBROSIO	98	PL B423 385	G. D'Ambrosio, G. Isidori, J. Portoles	
SETZU	98	PL B420 205	M.G. Setzu <i>et al.</i>	
TAKEUCHI	98	PL B443 409	Y. Takeuchi <i>et al.</i>	(KYOT, KEK, HIRO)
FANTI	97	ZPHY C76 653	V. Fanti <i>et al.</i>	(CERN NA48 Collab.)
NOMURA	97	PL B408 445	T. Nomura <i>et al.</i>	(KYOT, KEK, HIRO)
ADLER	96B	ZPHY C70 211	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ADLER	96C	PL B369 367	R. Adler <i>et al.</i>	(CPLEAR Collab.)
GU	96	PRL 76 4312	P. Gu <i>et al.</i>	(RUTG, UCLA, EFI, COLO+)
LEBER	96	PL B369 69	F. Leber <i>et al.</i>	(MAINZ, CERN, EDIN, ORSAY+)
PDG	96	PR D54 1	R. M. Barnett <i>et al.</i>	(PDG Collab.)
ADLER	95	PL B363 237	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ADLER	95B	PL B363 243	R. Adler <i>et al.</i>	(CPLEAR Collab.)
AKAGI	95	PR D51 2061	T. Akagi <i>et al.</i>	(TOHOK, TOKY, KYOT, KEK)
BARR	95	ZPHY C65 361	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
BARR	95C	PL B358 399	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
HEINSON	95	PR D51 985	A.P. Heinson <i>et al.</i>	(BNL E791 Collab.)
KREUTZ	95	ZPHY C65 67	A. Kreutz <i>et al.</i>	(SIEG, EDIN, MAINZ, ORSAY+)
MATTHEWS	95	PRL 75 2803	J.N. Matthews <i>et al.</i>	(RUTG, EFI, ELMT+)
SCHWINGEN...	95	PRL 74 4376	B. Schwingenheuer <i>et al.</i>	(EFI, CHIC+)
SPENCER	95	PRL 74 3323	M.B. Spencer <i>et al.</i>	(UCLA, EFI, COLO+)
BARR	94	PL B328 528	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
GU	94	PRL 72 3000	P. Gu <i>et al.</i>	(RUTG, UCLA, EFI, COLO+)
NAKAYA	94	PRL 73 2169	T. Nakaya <i>et al.</i>	(OSAK, UCLA, EFI, COLU+)
ROBERTS	94	PR D50 1874	D. Roberts <i>et al.</i>	(UCLA, EFI, COLU+)
AKAGI	93	PR D47 2644	T. Akagi <i>et al.</i>	(TOHOK, TOKY, KYOT, KEK)
ARISAKA	93	PRL 70 1049	K. Arisaka <i>et al.</i>	(BNL E791 Collab.)
ARISAKA	93B	PRL 71 3910	K. Arisaka <i>et al.</i>	(BNL E791 Collab.)
BARR	93D	PL B317 233	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
GIBBONS	93	PRL 70 1199	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
Also		PR D55 6625	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
GIBBONS	93B	PRL 70 1203	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
GIBBONS	93C	Thesis RX-1487	L.K. Gibbons	(CHIC)
Also		PR D55 6625	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
HARRIS	93	PRL 71 3914	D.A. Harris <i>et al.</i>	(EFI, UCLA, COLO+)
HARRIS	93B	PRL 71 3918	D.A. Harris <i>et al.</i>	(EFI, UCLA, COLO+)
MAKOFF	93	PRL 70 1591	G. Makoff <i>et al.</i>	(FNAL E731 Collab.)
Also		PRL 75 2069 (erratum)	G. Makoff <i>et al.</i>	
RAMBERG	93	PRL 70 2525	E. Ramberg <i>et al.</i>	(FNAL E731 Collab.)
RAMBERG	93B	PRL 70 2529	E.J. Ramberg <i>et al.</i>	(FNAL E731 Collab.)
VAGINS	93	PRL 71 35	M.R. Vagins <i>et al.</i>	(BNL E845 Collab.)
ADLER	92B	PL B286 180	R. Adler <i>et al.</i>	(CPLEAR Collab.)
Also		SJNP 55 840	R. Adler <i>et al.</i>	(CPLEAR Collab.)
BARR	92	PL B284 440	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
MORSE	92	PR D45 36	W.M. Morse <i>et al.</i>	(BNL, YALE, VASS)
PDG	92	PR D45 S1	K. Hikasa <i>et al.</i>	(KEK, LBL, BOST+)
SOMALWAR	92	PRL 68 2580	S.V. Somalwar <i>et al.</i>	(FNAL E731 Collab.)
AKAGI	91B	PL 67 2618	T. Akagi <i>et al.</i>	(TOHOK, TOKY, KYOT, KEK)
BARR	91	PL B259 389	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
HEINSON	91	PR D44 1	A.P. Heinson <i>et al.</i>	(UCI, UCLA, LANL+)
PAPADIMITR...	91	PR D44 573	V. Papadimitriou <i>et al.</i>	(FNAL E731 Collab.)
BARKER	90	PR D41 3546	A.R. Barker <i>et al.</i>	(FNAL E731 Collab.)
Also		PRL 61 2661	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
BARR	90B	PL B240 283	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
BARR	90C	PL B242 523	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
CAROSI	90	PL B237 303	R. Carosi <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)

KARLSSON	90	PRL 64 2976	M. Karlsson <i>et al.</i>	(FNAL E731 Collab.)
OHL	90	PRL 64 2755	K.E. Ohl <i>et al.</i>	(BNL E845 Collab.)
OHL	90B	PRL 65 1407	K.E. Ohl <i>et al.</i>	(BNL E845 Collab.)
PATTERSON	90	PRL 64 1491	J.R. Patterson <i>et al.</i>	(FNAL E731 Collab.)
INAGAKI	89	PR D40 1712	T. Inagaki <i>et al.</i>	(KEK, TOKY, KYOT)
MATHIAZHAGAN...	89	PRL 63 2181	C. Mathiazhagan <i>et al.</i>	(UCI, UCLA, LANL+)
MATHIAZHAGAN...	89B	PRL 63 2185	C. Mathiazhagan <i>et al.</i>	(UCI, UCLA, LANL+)
WAHL	89	CERN-EP/89-86	H. Wahl	(CERN)
BARR	88	PL B214 303	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
BURKHARDT	88	PL B206 169	H. Burkhardt <i>et al.</i>	(CERN, EDIN, MAINZ+)
JASTRZEMSKI...	88	PRL 61 2300	E. Jastrzemski <i>et al.</i>	(BNL, YALE)
WOODS	88	PRL 60 1695	M. Woods <i>et al.</i>	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt <i>et al.</i>	(CERN, EDIN, MAINZ+)
ARONSON	86	PR D33 3180	S.H. Aronson <i>et al.</i>	(BNL, CHIC, STAN+)
Also		PRL 48 1078	S.H. Aronson <i>et al.</i>	(BNL, CHIC, STAN+)
PDG	86C	PL 170B 132	M. Aguilar-Benitez <i>et al.</i>	(CERN, CIT+)
COUPAL	85	PRL 55 566	D.P. Coupal <i>et al.</i>	(CHIC, SACL)
BALATS	83	SJNP 38 556	M.Y. Balats <i>et al.</i>	(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 <i>et al.</i>	(BNL, CHIC, STAN+)
ARONSON	82B	PRL 48 1306	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
Also		PL 116B 73	E. Fischbach <i>et al.</i>	(PURD, BNL, CHIC)
Also		PR D28 476	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
Also		PR D28 495	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
PDG	82B	PL 111B 70	M. Roos <i>et al.</i>	(HELS, CIT, CERN)
BIRULEV	81	NP B182 1	V.K. Birulev <i>et al.</i>	(JINR)
Also		SJNP 31 622	V.K. Birulev <i>et al.</i>	(JINR)
		Translated from YAF 31 1204.		
CARROLL	80B	PRL 44 529	A.S. Carroll <i>et al.</i>	(BNL, ROCH)
CARROLL	80C	PL 96B 407	A.S. Carroll <i>et al.</i>	(BNL, ROCH)
CHO	80	PR D22 2688	Y. Cho <i>et al.</i>	(ANL, CMU)
MORSE	80	PR D21 1750	W.M. Morse <i>et al.</i>	(BNL, YALE)
CHRISTENS...	79	PRL 43 1209	J.H. Christenson <i>et al.</i>	(NYU)
SCHMIDT	79	PRL 43 556	M.P. Schmidt <i>et al.</i>	(YALE, BNL)
HILL	78	PL 73B 483	D.G. Hill <i>et al.</i>	(BNL, SLAC, SBER)
CHO	77	PR D15 587	Y. Cho <i>et al.</i>	(ANL, CMU)
CLARK	77	PR D15 553	A.R. Clark <i>et al.</i>	(LBL)
Also		Thesis LBL-4275	G. Shen	(LBL)
DEVOE	77	PR D16 565	R. Devoe <i>et al.</i>	(EFI, ANL)
PEACH	77	NP B127 399	K.J. Peach <i>et al.</i>	(BGNA, EDIN, GLAS+)
BIRULEV	76	SJNP 24 178	V.K. Birulev <i>et al.</i>	(JINR)
		Translated from YAF 24 340.		
COOMBES	76	PRL 37 249	R.W. Coombes <i>et al.</i>	(STAN, NYU)
GJESDAL	76	NP B109 118	G. Gjesdal <i>et al.</i>	(CERN, HEIDH)
BALDO...	75	NC 25A 688	M. Baldo-Ceolin <i>et al.</i>	(PADO, WISC)
BLUMENTHAL	75	PRL 34 164	R.B. Blumenthal <i>et al.</i>	(PENN, CHIC, TEMP)
BUCHANAN	75	PR D11 457	C.D. Buchanan <i>et al.</i>	(UCLA, SLAC, JHU)
CARITHERS	75	PRL 34 1244	W.C.J. Carithers <i>et al.</i>	(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 <i>et al.</i>	(SLAC)
DONALDSON	74B	PR D9 2960	G. Donaldson <i>et al.</i>	(SLAC, UCSC)
Also		PRL 31 337	G. Donaldson <i>et al.</i>	(SLAC, UCSC)
GEWENIGER	74	PL 48B 483	C. Geweniger <i>et al.</i>	(CERN, HEIDH)
Also		Thesis CERN Int. 74-4	V. Luth	(CERN)
GEWENIGER	74B	PL 48B 487	C. Geweniger <i>et al.</i>	(CERN, HEIDH)
Also		PL 52B 119	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
GEWENIGER	74C	PL 52B 108	C. Geweniger <i>et al.</i>	(CERN, HEIDH)
GJESDAL	74	PL 52B 113	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
MESSNER	74	PRL 33 1458	R. Messner <i>et al.</i>	(COLO, SLAC, UCSC)
NIEBERGALL	74	PL 49B 103	F. Niebergall <i>et al.</i>	(CERN, ORSAY, VIEN)
WILLIAMS	74	PRL 33 240	H.H. Williams <i>et al.</i>	(BNL, YALE)
ALEXANDER	73B	NP B65 301	G. Alexander <i>et al.</i>	(TELA, HEID)
BRANDENB...	73	PR D8 1978	G.W. Brandenburg <i>et al.</i>	(SLAC)
EVANS	73	PR D7 36	G.R. Evans <i>et al.</i>	(EDIN, CERN)
Also		PRL 23 427	G.R. Evans <i>et al.</i>	(EDIN, CERN)
FACKLER	73	PRL 31 847	O. Fackler <i>et al.</i>	(MIT)
FITCH	73	PRL 31 1524	V.L. Fitch <i>et al.</i>	(PRIN)
Also		Thesis COO-3072-13	R.C. Webb	(PRIN)
HART	73	NP B66 317	J.C. Hart <i>et al.</i>	(CAVE, RHEL)

MALLARY	73	PR D7 1953	M.L. Mallery <i>et al.</i>	(CIT)
Also		PRL 25 1214	F.J. Sciulli <i>et al.</i>	(CIT)
MCCARTHY	73	PR D7 687	R.L. McCarthy <i>et al.</i>	(LBL)
Also		PL 42B 291	R.L. McCarthy <i>et al.</i>	(LBL)
Also		Thesis LBL-550	R.L. McCarthy	(LBL)
MESSNER	73	PRL 30 876	R. Messner <i>et al.</i>	(COLO, SLAC, UCSC)
SANDWEISS	73	PRL 30 1002	J. Sandweiss <i>et al.</i>	(YALE, ANL)
WILLIAMS	73	PRL 31 1521	H.H. Williams <i>et al.</i>	(BNL, YALE)
ASHFORD	72	PL 38B 47	V.A. Ashford <i>et al.</i>	(UCSD)
BANNER	72B	PRL 29 237	M. Banner <i>et al.</i>	(PRIN)
BARMIN	72B	SJNP 15 638	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 15 1152.		
BURGUN	72	NP B50 194	G. Burgun <i>et al.</i>	(SACL, CERN, OSLO)
GRAHAM	72	NC 9A 166	M.F. Graham <i>et al.</i>	(ILL, NEAS)
JAMES	72	NP B49 1	F. James <i>et al.</i>	(CERN, SACL, OSLO)
KRENZ	72	LNC 4 213	W. Krenz <i>et al.</i>	(AACH, CERN, EDIN)
MANN	72	PR D6 137	W.A. Mann <i>et al.</i>	(MASA, BNL, YALE)
MANTSCH	72	NC 9A 160	P.M. Mantsch <i>et al.</i>	(ILL, NEAS)
MCCARTHY	72	PL 42B 291	R.L. McCarthy <i>et al.</i>	(LBL)
PICCIONI	72	PRL 29 1412	R. Piccioni <i>et al.</i>	(SLAC)
Also		PR D9 2939	R. Piccioni <i>et al.</i>	(SLAC, UCSC, COLO)
VOSBURGH	72	PR D6 1834	K.G. Vosburgh <i>et al.</i>	(RUTG, MASA)
Also		PRL 26 866	K.G. Vosburgh <i>et al.</i>	(RUTG, MASA)
BALATS	71	SJNP 13 53	M.Y. Balats <i>et al.</i>	(ITEP)
		Translated from YAF 13 93.		
BARMIN	71	PL 35B 604	V.V. Barmin <i>et al.</i>	(ITEP)
BURGUN	71	LNC 2 1169	G. Burgun <i>et al.</i>	(SACL, CERN, OSLO)
CARNEGIE	71	PR D4 1	R.K. Carnegie <i>et al.</i>	(PRIN)
CHAN	71	Thesis LBL-350	J.H.S. Chan	(LBL)
CHO	71	PR D3 1557	Y. Cho <i>et al.</i>	(CMU, BNL, CASE)
ENSTROM	71	PR D4 2629	J. Enstrom <i>et al.</i>	(SLAC, STAN)
Also		Thesis SLAC-0125	J.E. Enstrom	(STAN)
JAMES	71	PL 35B 265	F. James <i>et al.</i>	(CERN, SACL, OSLO)
MEISNER	71	PR D3 59	G.W. Meisner <i>et al.</i>	(MASA, BNL, YALE)
REPELLIN	71	PL 36B 603	J.P. Repellin <i>et al.</i>	(ORSAY, CERN)
WEBBER	71	PR D3 64	B.R. Webber <i>et al.</i>	(LRL)
Also		PRL 21 498	B.R. Webber <i>et al.</i>	(LRL)
Also		Thesis UCRL 19226	B.R. Webber	(LRL)
WOLFF	71	PL 36B 517	B. Wolff <i>et al.</i>	(ORSAY, CERN)
ALBROW	70	PL 33B 516	M.G. Albrow <i>et al.</i>	(MCHS, DARE)
ARONSON	70	PRL 25 1057	S.H. Aronson <i>et al.</i>	(EFI, ILLC, SLAC)
BARMIN	70	PL 33B 377	V.V. Barmin <i>et al.</i>	(ITEP, JINR)
BASILE	70	PR D2 78	P. Basile <i>et al.</i>	(SACL)
BECHERRAWY	70	PR D1 1452	T. Becherrawy	(ROCH)
BUCHANAN	70	PL 33B 623	C.D. Buchanan <i>et al.</i>	(SLAC, JHU, UCLA)
Also		Private Comm.	A.J. Cox	
BUDAGOV	70	PR D2 815	I.A. Budagov <i>et al.</i>	(CERN, ORSAY, EPOL)
Also		PL 28B 215	I.A. Budagov <i>et al.</i>	(CERN, ORSAY, EPOL)
CHO	70	PR D1 3031	Y. Cho <i>et al.</i>	(CMU, BNL, CASE)
Also		PRL 19 668	D.G. Hill <i>et al.</i>	(BNL, CMU)
CHOLLET	70	PL 31B 658	J.C. Chollet <i>et al.</i>	(CERN)
CULLEN	70	PL 32B 523	M. Cullen <i>et al.</i>	(AACH, CERN, TORI)
MARX	70	PL 32B 219	J. Marx <i>et al.</i>	(COLU, HARV, CERN)
Also		Thesis Nevis 179	J. Marx	(COLU)
SCRIBANO	70	PL 32B 224	A. Scribano <i>et al.</i>	(PISA, COLU, HARV)
SMITH	70	PL 32B 133	R.C. Smith <i>et al.</i>	(UMD, BNL)
WEBBER	70	PR D1 1967	B.R. Webber <i>et al.</i>	(LRL)
Also		Thesis UCRL 19226	B.R. Webber	(LRL)
BANNER	69	PR 188 2033	M. Banner <i>et al.</i>	(PRIN)
Also		PRL 21 1103	M. Banner <i>et al.</i>	(PRIN)
Also		PRL 21 1107	J.W. Cronin, J.K. Liu, J.E. Pilcher	(PRIN)
BENNETT	69	PL 29B 317	S. Bennett <i>et al.</i>	(COLU, BNL)
FAISSNER	69	PL 30B 204	H. Faissner <i>et al.</i>	(AACH3, CERN, TORI)
LITTENBERG	69	PRL 22 654	L.S. Littenberg <i>et al.</i>	(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 <i>et al.</i>	(ILL)
ARNOLD	68B	PL 28B 56	R.G. Arnold <i>et al.</i>	(CERN, ORSAY)
BASILE	68B	PL 28B 58	P. Basile <i>et al.</i>	(SACL)
BENNETT	68	PL 27B 244	S. Bennett <i>et al.</i>	(COLU, CERN)

BLANPIED	68	PRL 21 1650	W.A. Blanpied <i>et al.</i>	(CASE, HARV, MCGI)
BOHM	68B	PL 27B 594	A. Bohm <i>et al.</i>	
BUDAGOV	68	NC 57A 182	I.A. Budagov <i>et al.</i>	(CERN, ORSAY, IPNP)
Also		PL 28B 215	I.A. Budagov <i>et al.</i>	(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 <i>et al.</i>	(JINR)
		Translated from ZETF 53 29.		
KUNZ	68	Thesis PU-68-46	P.F. Kunz	(PRIN)
BENNETT	67	PRL 19 993	S. Bennett <i>et al.</i>	(COLU)
DEBOUARD	67	NC 52A 662	X. de Bouard <i>et al.</i>	(CERN)
Also		PL 15 58	X. de Bouard <i>et al.</i>	(CERN, ORSAY, MPIM)
DEVLIN	67	PRL 18 54	T.J. Devlin <i>et al.</i>	(PRIN, UMD)
Also		PR 169 1045	G.A. Sayer <i>et al.</i>	(UMD, PPA, PRIN)
DORFAN	67	PRL 19 987	D.E. Dorfan <i>et al.</i>	(SLAC, LRL)
FELDMAN	67B	PR 155 1611	L. Feldman <i>et al.</i>	(PENN)
FITCH	67	PR 164 1711	V.L. Fitch <i>et al.</i>	(PRIN)
GINSBERG	67	PR 162 1570	E.S. Ginsberg	(MASB)
HILL	67	PRL 19 668	D.G. Hill <i>et al.</i>	(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 <i>et al.</i>	(ILL)
SCHMIDT	67	Thesis Nevis 160	P. Schmidt	(COLU)
BEHR	66	PL 22 540	L. Behr <i>et al.</i>	(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 <i>et al.</i>	(LRL, WISC)
ASTBURY	65B	PL 18 175	P. Astbury <i>et al.</i>	(CERN, ZURI)
AUBERT	65	PL 17 59	B. Aubert <i>et al.</i>	(EPOL, ORSAY)
Also		PL 24B 75	J.P. Lowys <i>et al.</i>	(EPOL, ORSAY)
BALDO-...	65	NC 38 684	M. Baldo-Ceolin <i>et al.</i>	(PADO)
FRANZINI	65	PR 140 B127	P. Franzini <i>et al.</i>	(COLU, RUTG)
GUIDONI	65	Argonne Conf. 49	P. Guidoni <i>et al.</i>	(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 <i>et al.</i>	(YERE)
Also		JETP 19 1019	A.S. Aleksanyan <i>et al.</i>	(LEBD, MPEI, YERE)
		Translated from ZETF 46 1504.		
ANIKINA	64	JETP 19 42	M.K. Anikina <i>et al.</i>	(GEOR, JINR)
		Translated from ZETF 46 59.		
FITCH	61	NC 22 1160	V.L. Fitch, P.A. Piroue, R.B. Perkins	(PRIN+)
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AUERBACH	66	PR 149 1052	L.B. Auerbach <i>et al.</i>	(PENN)
Also		PRL 14 192	L.B. Auerbach <i>et al.</i>	(PENN)
FIRESTONE	66B	PRL 17 116	A. Firestone <i>et al.</i>	(YALE, BNL)
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