



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

K_S^0 MEAN LIFE

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

OUR FIT is described in the note on “ CP violation in K_L^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} s)	EVTS	DOCUMENT ID	TECN	COMMENT
0.8954 ± 0.0004 OUR FIT	Error includes scale factor of 1.1. Assuming CPT			
0.89564 ± 0.00033 OUR FIT	Not assuming CPT			
0.89589 ± 0.00070		^{1,2} ABOUZAID	11	KTEV Not assuming CPT
0.89623 ± 0.00047		^{1,3} ABOUZAID	11	KTEV Assuming CPT
0.89562 ± 0.00029 ± 0.00043	20M	⁴ AMBROSINO	11	KLOE Not assuming CPT
0.89598 ± 0.00048 ± 0.00051	16M	LAI	02C	NA48
0.8971 ± 0.0021		BERTANZA	97	NA31
0.8941 ± 0.0014 ± 0.0009		SCHWINGEN...	95	E773 Assuming CPT
0.8929 ± 0.0016		GIBBONS	93	E731 Assuming CPT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.8965 ± 0.0007		⁵ ALAVI-HARATI	03	KTEV Assuming CPT
0.8958 ± 0.0013		⁶ ALAVI-HARATI	03	KTEV Not assuming CPT
0.8920 ± 0.0044	214k	GROSSMAN	87	SPEC
0.905 ± 0.007		⁷ ARONSON	82B	SPEC
0.881 ± 0.009	26k	ARONSON	76	SPEC
0.8926 ± 0.0032 ± 0.0002		⁸ CARITHERS	75	SPEC
0.8937 ± 0.0048	6M	GEWENIGER	74B	ASPK
0.8958 ± 0.0045	50k	⁹ SKJEGGEST...	72	HBC
0.856 ± 0.008	19994	¹⁰ DONALD	68B	HBC
0.872 ± 0.009	20000	^{9,10} HILL	68	DBC

¹ The two ABOUZAID 11 values use the same full KTeV dataset from 1996, 1997, and 1999. The first enters the “assuming CPT ” fit and the second enters the “not assuming CPT ” fit.

² ABOUZAID 11 fit has Δm , τ_S , ϕ_ϵ , $\text{Re}(\epsilon'/\epsilon)$, 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 ABOUZAID 11 fit has Δm and τ_S free but constrains ϕ_ϵ to the Superweak value, i.e. assumes CPT . This τ_S value is correlated with their $\Delta m = m_{K_L^0} - m_{K_S^0}$ measurement in the K_L^0 listings. The correlation coefficient $\rho(\tau_S, \Delta m) = -0.670$.

⁴ Fit to the proper time distribution.

⁵ This ALAVI-HARATI 03 fit has Δm and τ_S free but constrains ϕ_{+-} to the Superweak value, i.e. assumes CPT . This τ_S value is correlated with their $\Delta m = m_{K_L^0} - m_{K_S^0}$ measurement in the K_L^0 listings. The correlation coefficient $\rho(\tau_S, \Delta m) = -0.396$. Superseded by ABOUZAID 11.

⁶This ALAVI-HARATI 03 fit has Δm , ϕ_{+-} , and τ_{K_S} free. See ϕ_{+-} in the “ K_L CP violation” section for correlation information. Superseded by ABOUZAID 11.

⁷ARONSON 82 find that K_S^0 mean life may depend on the kaon energy.

⁸CARITHERS 75 measures the Δm dependence of the total decay rate (inverse mean life) to be $\Gamma(K_S^0) = [(1.122 \pm 0.004) + 0.16(\Delta m - 0.5348)/\Delta m] 10^{10}/s$, or, in terms of mean life, CARITHERS 75 measures $\tau_S = (0.8913 \pm 0.0032) - 0.238 [\Delta m - 0.5348] (10^{-10} s)$. We have adjusted the measurement to use our best values of $(\Delta m = 0.5293 \pm 0.0009) (10^{10} \hbar s^{-1})$. Our first error is their experiment's error and our second error is the systematic error from using our best values.

⁹HILL 68 has been changed by the authors from the published value (0.865 ± 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

¹⁰Pre-1971 experiments are excluded from the average because of disagreement with later more precise experiments.

K_S^0 DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Hadronic modes		
$\Gamma_1 \quad \pi^0 \pi^0$	$(30.69 \pm 0.05) \%$	
$\Gamma_2 \quad \pi^+ \pi^-$	$(69.20 \pm 0.05) \%$	
$\Gamma_3 \quad \pi^+ \pi^- \pi^0$	$(3.5^{+1.1}_{-0.9}) \times 10^{-7}$	
Modes with photons or $\ell\bar{\ell}$ pairs		
$\Gamma_4 \quad \pi^+ \pi^- \gamma$	$[a,b] \quad (1.79 \pm 0.05) \times 10^{-3}$	
$\Gamma_5 \quad \pi^+ \pi^- e^+ e^-$	$(4.79 \pm 0.15) \times 10^{-5}$	
$\Gamma_6 \quad \pi^0 \gamma \gamma$	$[a] \quad (4.9 \pm 1.8) \times 10^{-8}$	
$\Gamma_7 \quad \gamma \gamma$	$(2.63 \pm 0.17) \times 10^{-6}$	S=3.1
$\Gamma_8 \quad \mu^+ \mu^- \mu^+ \mu^-$	$< 5.1 \times 10^{-12}$	CL=90%
Semileptonic modes		
$\Gamma_9 \quad \pi^\pm e^\mp \nu_e$	$[c] \quad (7.14 \pm 0.06) \times 10^{-4}$	
$\Gamma_{10} \quad \pi^\pm \mu^\mp \nu_\mu$	$[c,d] \quad (4.56 \pm 0.20) \times 10^{-4}$	
CP violating (CP) and $\Delta S = 1$ weak neutral current (S1) modes		
$\Gamma_{11} \quad 3\pi^0$	CP $< 2.6 \times 10^{-8}$	CL=90%
$\Gamma_{12} \quad \mu^+ \mu^-$	S1 $< 2.1 \times 10^{-10}$	CL=90%
$\Gamma_{13} \quad e^+ e^-$	S1 $< 9 \times 10^{-9}$	CL=90%
$\Gamma_{14} \quad \pi^0 e^+ e^-$	S1 $[a] \quad (3.0^{+1.5}_{-1.2}) \times 10^{-9}$	
$\Gamma_{15} \quad \pi^0 \mu^+ \mu^-$	S1 $(2.9^{+1.5}_{-1.2}) \times 10^{-9}$	

- [a] See the Particle Listings below for the energy limits used in this measurement.
- [b] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [c] The value is for the sum of the charge states or particle/antiparticle states indicated.
- [d] Not a measurement. Calculated as $0.666 \cdot B(\pi^\pm e^\mp \nu_e)$.

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 5 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 = 0.6$ for 2 degrees of freedom.

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

x_2	−100		
x_9	−9	8	
x_{10}	−1	−3	0
	x_1	x_2	x_9

K_S^0 DECAY RATES

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

Γ_9

VALUE (10^6 s^{-1})	EVTs	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

8.1 ± 1.6	75	¹ AKHMETSHIN 99	CMD2	Tagged K_S^0 using $\phi \rightarrow K_L^0 K_S^0$
7.50 ± 0.08		² PDG	98	
seen		BURGUN	72	HBC $K^+ p \rightarrow K^0 p \pi^+$
9.3 ± 2.5		AUBERT	65	HLBC $\Delta S = \Delta Q$, CP cons. not assumed

¹ AKHMETSHIN 99 is from a measured branching ratio $B(K_S^0 \rightarrow \pi e \nu_e) = (7.2 \pm 1.4) \times 10^{-4}$ and $\tau_{K_S^0} = (0.8934 \pm 0.0008) \times 10^{-10} \text{ s}$. Not independent of measured branching

ratio.
² PDG 98 from K_L^0 measurements, assuming that $\Delta S = \Delta Q$ in K^0 decay so that $\Gamma(K_S^0 \rightarrow \pi^\pm e^\mp \nu_e) = \Gamma(K_L^0 \rightarrow \pi^\pm e^\mp \nu_e)$.

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

Γ_{10}

VALUE (10^6 s^{-1})	DOCUMENT ID
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• • • We do not use the following data for averages, fits, limits, etc. • • •

5.25 ± 0.07	¹ PDG	98
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¹PDG 98 from K_L^0 measurements, assuming that $\Delta S = \Delta Q$ in K^0 decay so that $\Gamma(K_S^0 \rightarrow \pi^\pm \mu^\mp \nu_\mu) = \Gamma(K_L^0 \rightarrow \pi^\pm \mu^\mp \nu_\mu)$.

K_S^0 BRANCHING RATIOS

Hadronic modes

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

Γ_1/Γ

VALUE EVTS DOCUMENT ID TECN

0.3069 ± 0.0005 OUR FIT

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

0.335 ± 0.014	1066	BROWN	63	HLBC
0.288 ± 0.021	198	CHRETIEN	63	HLBC
0.30 ± 0.035		BROWN	61	HLBC

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

Γ_2/Γ

VALUE EVTS DOCUMENT ID TECN COMMENT

0.6920 ± 0.0005 OUR FIT

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

0.670 ± 0.010	3447	DOYLE	69	HBC	$\pi^- p \rightarrow \Lambda K^0$
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$\Gamma(\pi^+ \pi^-)/\Gamma(\pi^0 \pi^0)$

Γ_2/Γ_1

VALUE EVTS DOCUMENT ID TECN COMMENT

2.255 ± 0.005 OUR FIT

2.2549 ± 0.0054

¹ AMBROSINO 06C KLOE

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

2.2555 ± 0.0012 ± 0.0054		² AMBROSINO	06C	KLOE	
2.236 ± 0.003 ± 0.015	766k	² ALOISIO	02B	KLOE	
2.11 ± 0.09	1315	EVERHART	76	WIRE	$\pi^- p \rightarrow \Lambda K^0$
2.169 ± 0.094	16k	COWELL	74	OSPK	$\pi^- p \rightarrow \Lambda K^0$
2.16 ± 0.08	4799	HILL	73	DBC	$K^+ d \rightarrow K^0 p p$
2.22 ± 0.10	3068	³ ALITTI	72	HBC	$K^+ p \rightarrow \pi^+ p K^0$
2.22 ± 0.08	6380	MORSE	72B	DBC	$K^+ n \rightarrow K^0 p$
2.10 ± 0.11	701	⁴ NAGY	72	HLBC	$K^+ n \rightarrow K^0 p$
2.22 ± 0.095	6150	⁵ BALTAY	71	HBC	$K p \rightarrow K^0 \text{ neutrals}$
2.282 ± 0.043	7944	⁶ MOFFETT	70	OSPK	$K^+ n \rightarrow K^0 p$
2.12 ± 0.17	267	⁴ BOZOKI	69	HLBC	
2.285 ± 0.055	3016	⁶ GOBBI	69	OSPK	$K^+ n \rightarrow K^0 p$
2.10 ± 0.06	3700	MORFIN	69	HLBC	$K^+ n \rightarrow K^0 p$

¹ This result combines AMBROSINO 06C KLOE 2001-02 data with ALOISIO 02B KLOE 2000 data. $K_S^0 \rightarrow \pi^+ \pi^-$ fully inclusive.

² Includes radiative decays $\pi^+ \pi^- \gamma$.

³ The directly measured quantity is $K_S^0 \rightarrow \pi^+ \pi^- / \text{all } K^0 = 0.345 \pm 0.005$.

⁴ NAGY 72 is a final result which includes BOZOKI 69.

⁵ The directly measured quantity is $K_S^0 \rightarrow \pi^+ \pi^- / \text{all } \bar{K}^0 = 0.345 \pm 0.005$.

⁶ MOFFETT 70 is a final result which includes GOBBI 69.

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_3/Γ

$VALUE$ (units 10^{-7})	$EVTs$	$DOCUMENT ID$	$TECN$	$COMMENT$
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$3.5^{+1.1}_{-0.9}$ OUR AVERAGE

$4.7^{+2.2+1.7}_{-1.7-1.5}$		¹ BATLEY	05	NA48
$2.5^{+1.3+0.5}_{-1.0-0.6}$	500k	² ADLER	97B	CPLR
$4.8^{+2.2+1.1}_{-1.6-1.1}$		³ ZOU	96	E621

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

$4.1^{+2.5+0.5}_{-1.9-0.6}$		⁴ ADLER	96E	CPLR Sup. by ADLER 97B
$3.9^{+5.4+0.9}_{-1.8-0.7}$		⁵ THOMSON	94	E621 Sup. by ZOU 96

¹ BATLEY 05 is obtained by measuring the interference parameters in $K_S, K_L \rightarrow \pi^+\pi^-\pi^0$: $\text{Re}(\lambda) = 0.038 \pm 0.008 \pm 0.006$ and $\text{Im}(\lambda) = -0.013 \pm 0.005 \pm 0.004$; the correlation coeff. between $\text{Re}(\lambda)$ and $\text{Im}(\lambda)$ is 0.66 (statistical only).

² ADLER 97B find the CP -conserving parameters $\text{Re}(\lambda) = (28 \pm 7 \pm 3) \times 10^{-3}$, $\text{Im}(\lambda) = (-10 \pm 8 \pm 2) \times 10^{-3}$. They estimate $B(K_S^0 \rightarrow \pi^+\pi^-\pi^0)$ from $\text{Re}(\lambda)$ and the K_L^0 decay parameters. See also ANGELOPOULOS 98c.

³ ZOU 96 is from the the measured quantities $|\rho_{+-0}| = 0.039^{+0.009}_{-0.006} \pm 0.005$ and $\phi_\rho = (-9 \pm 18)^\circ$.

⁴ ADLER 96E is from the measured quantities $\text{Re}(\lambda) = 0.036 \pm 0.010^{+0.002}_{-0.003}$ and $\text{Im}(\lambda)$ consistent with zero. Note that the quantity λ is the same as ρ_{+-0} used in other footnotes.

⁵ THOMSON 94 calculates this branching ratio from their measurements $|\rho_{+-0}| = 0.035^{+0.019}_{-0.011} \pm 0.004$ and $\phi_\rho = (-59 \pm 48)^\circ$ where $|\rho_{+-0}|e^{i\phi_\rho} = A(K_S^0 \rightarrow \pi^+\pi^-\pi^0, I=2)/A(K_L^0 \rightarrow \pi^+\pi^-\pi^0)$.

Modes with photons or $\ell\bar{\ell}$ pairs

$\Gamma(\pi^+\pi^-\gamma)/\Gamma(\pi^+\pi^-)$ Γ_4/Γ_2

$VALUE$ (units 10^{-3})	$EVTs$	$DOCUMENT ID$	$TECN$	$COMMENT$
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2.59 ± 0.08 OUR AVERAGE

2.56 ± 0.09	1286	RAMBERG	93	E731 $p_\gamma > 50 \text{ MeV}/c$
2.68 ± 0.15		¹ TAUREG	76	SPEC $p_\gamma > 50 \text{ MeV}/c$
7.10 ± 0.22	3723	RAMBERG	93	E731 $p_\gamma > 20 \text{ MeV}/c$
3.0 ± 0.6	29	² BOBISUT	74	HLBC $p_\gamma > 40 \text{ MeV}/c$
2.8 ± 0.6		³ BURGUN	73	HBC $p_\gamma > 50 \text{ MeV}/c$

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

¹ TAUREG 76 find direct emission contribution < 0.06 , CL = 90%.

² BOBISUT 74 not included in average because p_γ cut differs. Estimates direct emission contribution to be 0.5 or less, CL = 95%.

³ BURGUN 73 estimates that direct emission contribution is 0.3 ± 0.6 .

$\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID	TECN	COMMENT
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4.79±0.15 OUR AVERAGE

4.83±0.11±0.14	23k	¹ BATLEY	11 NA48	2002 data
4.69±0.30	676	² LAI	03C NA48	1998+1999 data

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

4.71±0.23±0.22	620	^{2,3} LAI	03C NA48	1999 data
4.5 ±0.7 ±0.4	56	LAI	00B NA48	1998 data

¹ BATLEY 11 reports $[\Gamma(K_S^0 \rightarrow \pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}] / [B(K_L^0 \rightarrow \pi^+\pi^-\pi^0)] / [B(\pi^0 \rightarrow e^+e^-\gamma)] = (3.28 \pm 0.06 \pm 0.04) \times 10^{-2}$ which we multiply by our best values $B(K_L^0 \rightarrow \pi^+\pi^-\pi^0) = (12.54 \pm 0.05) \times 10^{-2}$, $B(\pi^0 \rightarrow e^+e^-\gamma) = (1.174 \pm 0.035) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best values. Also a limit on the absolute value of the interference between bremsstrahlung and E1 transition is given : $< 4 \times 10^{-7}$ at 90% C.L.

² Uses normalization $BR(K_L \rightarrow \pi^+\pi^-\pi^0) \cdot BR(\pi^0 \rightarrow e^+e^-\gamma) = (1.505 \pm 0.047) \times 10^{-3}$ from our 2000 Edition.

³ Second error is $0.16(\text{syst}) \pm 0.15(\text{norm})$ combined in quadrature.

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

VALUE (units 10^{-8})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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4.9±1.6±0.9

17	¹ LAI	04 NA48	$m_{\gamma\gamma}^2/m_K^2 > 0.2$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<33	90	LAI	03B NA48	$m_{\gamma\gamma}^2/m_K^2 > 0.2$
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¹ Spectrum also measured and found consistent with the one generated by a constant matrix element.

 $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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2.63 ±0.17 OUR AVERAGE

Error includes scale factor of 3.1.

2.26 ±0.12 ±0.06	711	¹ AMBROSINO	08C KLOE	$\phi \rightarrow K_S^0 K_L^0$
2.713±0.063±0.005	7.5k	² LAI	03 NA48	

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

2.58 ±0.36 ±0.22	149	LAI	00 NA48	
2.2 ±1.1	16	³ BARR	95B NA31	
2.4 ±0.9	35	⁴ BARR	95B NA31	
< 13	90	BALATS	89 SPEC	
2.4 ±1.2	19	BURKHARDT	87 NA31	
<133	90	BARMIN	86B XEBC	

¹ AMBROSINO 08C reports $(2.26 \pm 0.12 \pm 0.06) \times 10^{-6}$ from a measurement of $[\Gamma(K_S^0 \rightarrow \gamma\gamma)/\Gamma_{\text{total}}] \times [B(K_S^0 \rightarrow \pi^0\pi^0)]$ assuming $B(K_S^0 \rightarrow \pi^0\pi^0) = (30.69 \pm 0.05) \times 10^{-2}$.

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

³ BARR 95B result is calculated using $B(K_L \rightarrow \gamma\gamma) = (5.86 \pm 0.17) \times 10^{-4}$.

⁴ BARR 95B quotes this as the combined BARR 95B + BURKHARDT 87 result after rescaling BURKHARDT 87 to use same branching ratios and lifetimes as BARR 95B.

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

VALUE	CL%	DOCUMENT ID	TECN
$<5.1 \times 10^{-12}$	90	¹ AAIJ	23AE LHCB

¹ AAIJ 23AE uses 5.1 fb^{-1} of LHCb data recorded from 2016 to 2018.**Semileptonic modes** $\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
7.14 ± 0.06 OUR FIT				
7.04 ± 0.08 OUR AVERAGE				

7.046 $\pm 0.18 \pm 0.16$		¹ BATLEY	07D NA48	$K^0(\bar{K}^0)(t) \rightarrow \pi e \nu$
6.91 $\pm 0.34 \pm 0.15$	624	² ALOISIO	02 KLOE	Tagged K_S^0 using $\phi \rightarrow K_L^0 K_S^0$

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

7.05 ± 0.09	13k	³ AMBROSINO	06E KLOE	Not fitted
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• • • We do not use the following data for averages, fits, limits, etc. • • •

7.2 ± 1.4	75	AKHMETSHIN	99 CMD2	Tagged K_S^0 using $\phi \rightarrow K_L^0 K_S^0$
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¹ Reconstructed from $K^0(\bar{K}^0)(t) \rightarrow \pi e \nu$ distributions using PDG values of $B(K_L^0 \rightarrow \pi e \nu) = 0.4053 \pm 0.0015$, $\tau_L = (5.114 \pm 0.021) \times 10^{-8} \text{ s}$ and $\tau_S = (0.8958 \pm 0.0005) \times 10^{-10} \text{ s}$.² Uses the PDG 00 value for $B(K_S^0 \rightarrow \pi^+ \pi^-)$.³ Obtained by imposing $\sum_i B(K_S^0 \rightarrow i) = 1$, where i runs over all the four branching ratios $\pi^+ \pi^-$, $\pi^0 \pi^0$, $\pi e \nu$, and $\pi \mu \nu$. Input value of $B(K_S^0 \rightarrow \pi^+ \pi^-) / B(K_S^0 \rightarrow \pi^0 \pi^0)$ from AMBROSINO 06C is used. To derive $\Gamma(K_S^0 \rightarrow \pi^+ \mu \nu) / \Gamma(K_S^0 \rightarrow \pi^+ e \nu)$, lepton universality is assumed, radiative corrections from ANDRE 07 are used, and phase space integrals are taken from KTeV, ALEXOPOULOS 04A. This branching fraction enters our fit via their $\Gamma(\pi^\pm e^\mp \nu_e) / \Gamma(\pi^+ \pi^-)$ branching ratio measurement. $\Gamma(\pi^\pm \mu^\mp \nu_\mu)/\Gamma_{\text{total}}$ Γ_{10}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
4.56 ± 0.20 OUR FIT				
4.56 $\pm 0.11 \pm 0.17$	7223	¹ BABUSCI	20 KLOE	direct measurement

¹ Value obtained by normalizing to the KLOE measurement $B(K_S^0 \rightarrow \pi^+ \pi^-) = (69.196 \pm 0.051)\%$. Also comparison with the PDG 18 based derived value leads to a lepton flavor universality test $|V_{us} f_+(0)|_{K_S^0 \rightarrow \pi \mu \nu}^2 / |V_{us} f_+(0)|_{K_S^0 \rightarrow \pi e \nu}^2 = 0.975 \pm 0.044$. $\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma(\pi^+ \pi^-)$ Γ_9/Γ_2

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN
1.032 ± 0.008 OUR FIT			
1.0338 $\pm 0.0054 \pm 0.0064$		¹ BABUSCI	23 KLOE

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

1.019 $\pm 0.011 \pm 0.007$	13k	² AMBROSINO	06E KLOE
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¹ BABUSCI 23 measured $\Gamma(K_S^0 \rightarrow \pi e \nu)/\Gamma(K_S^0 \rightarrow \pi^+ \pi^-) = (1.0421 \pm 0.0066 \pm 0.0075) \times 10^{-3}$ based on data collected from 2004 to 2005. About 50k signal events were reconstructed from the dataset corresponding to an integrated luminosity of 1.63 fb^{-1} . The quoted value is their combination of this result with the previous measurement of AMBROSINO 06E. The correlation coefficient between the two measurements is 12%.² AMBROSINO 06E result is included in BABUSCI 23.

CP violating (CP) and $\Delta S = 1$ weak neutral current ($S1$) modes **$\Gamma(3\pi^0)/\Gamma_{\text{total}}$** Violates CP conservation. **Γ_{11}/Γ**

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 0.26	90	590M	¹ BABUSCI	13C	KLOE $\phi \rightarrow K_L^0 K_S^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 1.2	90	37.8M	AMBROSINO	05B	KLOE
< 7.4	90	4.9M	² LAI	05A	NA48
<140	90	7M	ACHASOV	99D	SND
<190	90	17300	³ ANGELOPO...	98B	CPLR
<370	90		BARMIN	83	HLBC

¹ BABUSCI 13C uses 1.7 fb^{-1} of data of $\phi \rightarrow K_L^0 K_S^0$ decays with K_L^0 interaction in the calorimeter, collected from 2004 to 2005. No candidate events were found in the data with an expected background of $0.04^{+0.15}_{-0.03}$ events. Upper limit is obtained by normalizing to $K_S^0 \rightarrow 2\pi^0$ decays.

² LAI 05A value is obtained from their bound on $|\eta_{000}|$ (not assuming CPT) and $B(K_L^0 \rightarrow 3\pi^0) = 0.211 \pm 0.003$, and PDG 04 values for K_L^0 and K_S^0 lifetimes. If CPT is assumed then $B(K_S^0 \rightarrow 3\pi^0)_{CPT} < 2.3 \times 10^{-7}$ at 90% CL

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

 $\Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}}$ Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction. **Γ_{12}/Γ**

VALUE	CL%	DOCUMENT ID	TECN
< 2.1×10^{-10}	90	¹ AAIJ	20AE LHCB
• • • We do not use the following data for averages, fits, limits, etc. • • •			
< 8×10^{-10}	90	² AAIJ	17BQ LHCB
< 9×10^{-9}	90	³ AAIJ	13G LHCB
< 3.2×10^{-7}	90	GJESDAL	73 ASPK
< 7×10^{-6}	90	HYAMS	69B OSPK

¹ AAIJ 20AE uses 8.6 fb^{-1} of LHCb data from 2011 to 2012 and 2016 to 2018. The result utilizes the normalization mode branching fraction $B(K_S^0 \rightarrow \pi^+ \pi^-) = (69.20 \pm 0.05) \times 10^{-2}$ from PDG 18. Supersedes AAIJ 17BQ.

² AAIJ 17BQ uses 3.0 fb^{-1} of pp collisions at $\sqrt{s} = 7$ and 8 TeV. The result utilizes the normalization mode branching fraction $B(K_S^0 \rightarrow \pi^+ \pi^-) = (69.20 \pm 0.05) \times 10^{-2}$ from PDG 16. Supersedes AAIJ 13G.

³ AAIJ 13G uses 1.0 fb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV. They obtained $B(K_S^0 \rightarrow \mu^+ \mu^-) < 11 \times 10^{-9}$ at 95% C.L.

 $\Gamma(e^+ e^-)/\Gamma_{\text{total}}$ Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction. **Γ_{13}/Γ**

VALUE (units 10^{-7})	CL%	DOCUMENT ID	TECN	COMMENT
< 0.09	90	¹ AMBROSINO	09A	KLOE $e^+ e^- \rightarrow \phi \rightarrow K_S^0 K_L^0$

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

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

¹ AMBROSINO 09A reports $< 0.09 \times 10^{-7}$ from a measurement of $[\Gamma(K_S^0 \rightarrow e^+ e^-) / \Gamma_{\text{total}}] / [B(K_S^0 \rightarrow \pi^+ \pi^-)]$ assuming $B(K_S^0 \rightarrow \pi^+ \pi^-) = (69.20 \pm 0.05) \times 10^{-2}$.

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

Γ_{14} / Γ

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

VALUE (units 10^{-9})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$3.0^{+1.5}_{-1.2} \pm 0.2$		7	¹ BATLEY	03 NA48	$m_{ee} > 0.165 \text{ GeV}$

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

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

¹ BATLEY 03 extrapolate also to the full kinematical region using a constant form factor and a vector matrix element. The resulting branching ratio is $(5.8^{+2.9}_{-2.4}) \times 10^{-9}$.

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

Γ_{15} / Γ

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

VALUE (units 10^{-9})	EVTS	DOCUMENT ID	TECN	COMMENT
$2.9^{+1.5}_{-1.2} \pm 0.2$	6	¹ BATLEY	04A NA48	NA48/1 K_S^0 beam

¹ Background estimate is $0.22^{+0.18}_{-0.11}$ events. Branching ratio assumes a vector matrix element and unit form factor.

K_S^0 FORM FACTORS

For discussion, see note on $K_{\ell 3}$ form factors in the $K^\pm$ section of the Particle Listings above. Because the semileptonic branching fraction is smaller in K_S^0 than K_L^0 by the ratio of the mean lives, the K_S^0 semileptonic form factor has so far been measured only in the K_{e3} mode using the linear expansion $f_+(t) = f_+(0) (1 + \lambda_+ t / m_{\pi^+}^2)$, which gives the vector form factor $f_+(t)$ relative to its value at $t = 0$.

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

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

CP VIOLATION IN $K_S \rightarrow 3\pi$

Written 1996 by T. Nakada (Paul Scherrer Institute) and L. Wolfenstein (Carnegie-Mellon University).

The possible final states for the decay $K^0 \rightarrow \pi^+\pi^-\pi^0$ have isospin $I = 0, 1, 2$, and 3 . The $I = 0$ and $I = 2$ states have $CP = +1$ and K_S can decay into them without violating CP symmetry, but they are expected to be strongly suppressed by centrifugal barrier effects. The $I = 1$ and $I = 3$ states, which have no centrifugal barrier, have $CP = -1$ so that the K_S decay to these requires CP violation.

In order to see CP violation in $K_S \rightarrow \pi^+\pi^-\pi^0$, it is necessary to observe the interference between K_S and K_L decay, which determines the amplitude ratio

$$\eta_{+-0} = \frac{A(K_S \rightarrow \pi^+\pi^-\pi^0)}{A(K_L \rightarrow \pi^+\pi^-\pi^0)} . \quad (1)$$

If η_{+-0} is obtained from an integration over the whole Dalitz plot, there is no contribution from the $I = 0$ and $I = 2$ final states and a nonzero value of η_{+-0} is entirely due to CP violation.

Only $I = 1$ and $I = 3$ states, which are $CP = -1$, are allowed for $K^0 \rightarrow \pi^0\pi^0\pi^0$ decays and the decay of K_S into $3\pi^0$ is an unambiguous sign of CP violation. Similarly to η_{+-0} , η_{000} is defined as

$$\eta_{000} = \frac{A(K_S \rightarrow \pi^0\pi^0\pi^0)}{A(K_L \rightarrow \pi^0\pi^0\pi^0)} . \quad (2)$$

If one assumes that CPT invariance holds and that there are no transitions to $I = 3$ (or to nonsymmetric $I = 1$ states), it can be shown that

$$\begin{aligned} \eta_{+-0} &= \eta_{000} \\ &= \epsilon + i \frac{\text{Im } a_1}{\text{Re } a_1} . \end{aligned} \quad (3)$$

With the Wu-Yang phase convention, a_1 is the weak decay amplitude for K^0 into $I = 1$ final states; ϵ is determined from

CP violation in $K_L \rightarrow 2\pi$ decays. The real parts of η_{+-0} and η_{000} are equal to $\text{Re}(\epsilon)$. Since currently-known upper limits on $|\eta_{+-0}|$ and $|\eta_{000}|$ are much larger than $|\epsilon|$, they can be interpreted as upper limits on $\text{Im}(\eta_{+-0})$ and $\text{Im}(\eta_{000})$ and so as limits on the CP -violating phase of the decay amplitude a_1 .

CP -VIOLATION PARAMETERS IN K_S^0 DECAY

$$A_S = [\Gamma(K_S^0 \rightarrow \pi^- e^+ \nu_e) - \Gamma(K_S^0 \rightarrow \pi^+ e^- \bar{\nu}_e)] / \text{SUM}$$

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

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN
$-3.8 \pm 5.0 \pm 2.6$	83k	¹ ANASTASI	18A KLOE

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

$1.5 \pm 9.6 \pm 2.9$	13k	AMBROSINO	06E KLOE
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¹ ANASTASI 18A result is a combination of the new measurement and AMBROSINO 06E. The new ANASTASI 18A measurement using data collected from 2004–2005, which corresponds to an integrated luminosity of 1.63 fb^{-1} is $A_S = (-4.9 \pm 5.7 \pm 2.6) \times 10^{-3}$.

PARAMETERS FOR $K_S^0 \rightarrow 3\pi$ DECAY

$$\text{Im}(\eta_{+-0})^2 = \Gamma(K_S^0 \rightarrow \pi^+ \pi^- \pi^0, CP\text{-violating}) / \Gamma(K_L^0 \rightarrow \pi^+ \pi^- \pi^0)$$

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

VALUE	CL%	EVTS	DOCUMENT ID	TECN
<0.23	90	601	¹ BARMIN	85 HLBC
<0.12	90	384	METCALF	72 ASPK

¹ BARMIN 85 find $\text{Re}(\eta_{+-0}) = (0.05 \pm 0.17)$ and $\text{Im}(\eta_{+-0}) = (0.15 \pm 0.33)$. Includes events of BALDO-CEOLIN 75.

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$-0.002 \pm 0.009^{+0.002}_{-0.001}$	500k	¹ ADLER	97B	CPLR

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

$-0.002 \pm 0.018 \pm 0.003$	137k	² ADLER	96D	CPLR Sup. by ADLER 97B
$-0.015 \pm 0.017 \pm 0.025$	272k	³ ZOU	94	SPEC

¹ ADLER 97B also find $\text{Re}(\eta_{+-0}) = -0.002 \pm 0.007^{+0.004}_{-0.001}$. See also ANGELOPOULOS 98C.

² The ADLER 96D fit also yields $\text{Re}(\eta_{+-0}) = 0.006 \pm 0.013 \pm 0.001$ with a correlation $+0.66$ between real and imaginary parts. Their results correspond to $|\eta_{+-0}| < 0.037$ with 90% CL.

³ ZOU 94 use theoretical constraint $\text{Re}(\eta_{+-0}) = \text{Re}(\epsilon) = 0.0016$. Without this constraint they find $\text{Im}(\eta_{+-0}) = 0.019 \pm 0.061$ and $\text{Re}(\eta_{+-0}) = 0.019 \pm 0.027$.

$$\text{Im}(\eta_{000})^2 = \Gamma(K_S^0 \rightarrow 3\pi^0) / \Gamma(K_L^0 \rightarrow 3\pi^0)$$

CPT assumed valid (i.e. $\text{Re}(\eta_{000}) \simeq 0$). This limit determines branching ratio

$\Gamma(3\pi^0)/\Gamma_{\text{total}}$ above.

VALUE	CL%	EVTs	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.1	90	632	¹ BARMIN	83	HLBC
<0.28	90		² GJESDAL	74B	SPEC Indirect meas.

¹ BARMIN 83 find $\text{Re}(\eta_{000}) = (-0.08 \pm 0.18)$ and $\text{Im}(\eta_{000}) = (-0.05 \pm 0.27)$. Assuming *CPT* invariance they obtain the limit quoted above.

² GJESDAL 74B uses $K2\pi$, $K_{\mu 3}$, and K_{e3} decay results, unitarity, and *CPT*. Calculates $|\eta_{000}| = 0.26 \pm 0.20$. We convert to upper limit.

$$\text{Im}(\eta_{000}) = \text{Im}(A(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0)/A(K_L^0 \rightarrow \pi^0 \pi^0 \pi^0))$$

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

VALUE	CL%	EVTs	DOCUMENT ID	TECN	COMMENT
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=0.001±0.016 OUR AVERAGE

0.000±0.009±0.013	4.9M	¹ LAI	05A	NA48	Assumes <i>CPT</i>
-0.05 ±0.12 ±0.05	17300	² ANGELOPO...	98B	CPLR	Assumes <i>CPT</i>

¹ LAI 05A assumes $\text{Re}(\eta_{000}) = \text{Re}(\epsilon) = 1.66 \times 10^{-3}$. The equivalent limit is $|\eta_{000}|_{\text{CPT}} < 0.025$ at 90% CL Without assuming *CPT* invariance, they obtain $\text{Re}(\eta_{000}) = -0.002 \pm 0.011 \pm 0.015$ and $\text{Im}(\eta_{000}) = -0.003 \pm 0.013 \pm 0.017$ with a statistical correlation coefficient of 0.77 and an overall correlation coefficient of 0.57 between imaginary and real part. The equivalent limit is $|\eta_{000}| < 0.045$ at 90% CL

² ANGELOPOULOS 98B assumes $\text{Re}(\eta_{000}) = \text{Re}(\epsilon) = 1.635 \times 10^{-3}$. Without assuming *CPT* invariance, they obtain $\text{Re}(\eta_{000}) = 0.18 \pm 0.14 \pm 0.06$ and $\text{Im}(\eta_{000}) = 0.15 \pm 0.20 \pm 0.03$.

$$|\eta_{000}| = |A(K_S^0 \rightarrow 3\pi^0)/A(K_L^0 \rightarrow 3\pi^0)|$$

A non-zero value violates *CP* invariance.

VALUE	CL%	EVTs	DOCUMENT ID	TECN	COMMENT
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<0.0088

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

<0.018	90	37.8M	AMBROSINO	05B	KLOE
<0.045	90	4.9M	LAI	05A	NA48

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

This is the *CP*-violating asymmetry

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

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

CP asymmetry A in $K_S^0 \rightarrow \pi^+ \pi^- e^+ e^-$

VALUE (%)	DOCUMENT ID	TECN	COMMENT
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-0.4±0.8 OUR AVERAGE

-0.4±0.8	¹ BATLEY	11	NA48 2002 data
-1.1±4.1	LAI	03C	NA48 1998+1999 data

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

0.5±4.0±1.6	LAI	03C	NA48 1999 data
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¹ The result is used to set the limit $A < 1.5\%$ at 90% C.L. **K_S^0 REFERENCES**

AAIJ	23AE	PR D108 L031102	R. Aaij <i>et al.</i>	(LHCb Collab.)
BABUSCI	23	JHEP 2302 098	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
AAIJ	20AE	PRL 125 231801	R. Aaij <i>et al.</i>	(LHCb Collab.)
BABUSCI	20	PL B804 135378	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
ANASTASI	18A	JHEP 1809 021	A. Anastasi <i>et al.</i>	(KLOE-2 Collab.)
PDG	18	PR D98 030001	M. Tanabashi <i>et al.</i>	(PDG Collab.)
AAIJ	17BQ	EPJ C77 678	R. Aaij <i>et al.</i>	(LHCb Collab.)
PDG	16	CP C40 100001	C. Patrignani <i>et al.</i>	(PDG Collab.)
AAIJ	13G	JHEP 1301 090	R. Aaij <i>et al.</i>	(LHCb Collab.)
BABUSCI	13C	PL B723 54	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
ABOUZAID	11	PR D83 092001	E. Abouzaid <i>et al.</i>	(FNAL KTeV Collab.)
AMBROSINO	11	EPJ C71 1604	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BATLEY	11	PL B694 301	J.R. Batley <i>et al.</i>	(CERN NA48/1 Collab.)
AMBROSINO	09A	PL B672 203	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
AMBROSINO	08C	JHEP 0805 051	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
ANDRE	07	ANP 322 2518	T. Andre	(EFI)
BATLEY	07D	PL B653 145	J.R. Batley <i>et al.</i>	(CERN NA48 Collab.)
AMBROSINO	06C	EPJ C48 767	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
AMBROSINO	06E	PL B636 173	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
AMBROSINO	05B	PL B619 61	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BATLEY	05	PL B630 31	J.R. Batley <i>et al.</i>	(NA48 Collab.)
LAI	05A	PL B610 165	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
ALEXOPOU...	04A	PR D70 092007	T. Alexopoulos <i>et al.</i>	(FNAL KTeV Collab.)
BATLEY	04A	PL B599 197	J.R. Batley <i>et al.</i>	(NA48 Collab.)
LAI	04	PL B578 276	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
PDG	04	PL B592 1	S. Eidelman <i>et al.</i>	(PDG Collab.)
ALAVI-HARATI	03	PR D67 012005	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
Also		PR D70 079904 (errat.)	A. Alavi-Harati <i>et al.</i>	(FNAL KTeV Collab.)
BATLEY	03	PL B576 43	J.R. Batley <i>et al.</i>	(CERN NA48 Collab.)
LAI	03	PL B551 7	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	03B	PL B556 105	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	03C	EPJ C30 33	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
ALOISIO	02	PL B535 37	A. Aloisio <i>et al.</i>	(KLOE Collab.)
ALOISIO	02B	PL B538 21	A. Aloisio <i>et al.</i>	(KLOE Collab.)
LAI	02C	PL B537 28	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	01	PL B514 253	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	00	PL B493 29	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
LAI	00B	PL B496 137	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
PDG	00	EPJ C15 1	D.E. Groom <i>et al.</i>	(PDG Collab.)
ACHASOV	99D	PL B459 674	M.N. Achasov <i>et al.</i>	
AKHMETSHIN	99	PL B456 90	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
ANGELOPO...	98B	PL B425 391	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	98C	EPJ C5 389	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
PDG	98	EPJ C3 1	C. Caso <i>et al.</i>	(PDG Collab.)
ADLER	97B	PL B407 193	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	97	PL B413 232	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
BERTANZA	97	ZPHY C73 629	L. Bertanza	(PISA, CERN, EDIN, MAINZ, ORSAY+)
ADLER	96D	PL B370 167	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ADLER	96E	PL B374 313	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ZOU	96	PL B369 362	Y. Zou <i>et al.</i>	(RUTG, MINN, MICH)
BARR	95B	PL B351 579	G.D. Barr <i>et al.</i>	(CERN, EDIN, MAINZ, LALO+)
SCHWINGEN...	95	PRL 74 4376	B. Schwingenheuer <i>et al.</i>	(EFI, CHIC+)
BLICK	94	PL B334 234	A.M. Blick <i>et al.</i>	(SERP, JINR)
THOMSON	94	PL B337 411	G.B. Thomson <i>et al.</i>	(RUTG, MINN, MICH)
ZOU	94	PL B329 519	Y. Zou <i>et al.</i>	(RUTG, MINN, MICH)
BARR	93B	PL B304 381	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.)
RAMBERG	93	PRL 70 2525	E. Ramberg <i>et al.</i>	(FNAL E731 Collab.)
BALATS	89	SJNP 49 828	M.Y. Balats <i>et al.</i>	(ITEP)
		Translated from YAF 49 1332.		
GIBBONS	88	PRL 61 2661	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt <i>et al.</i>	(CERN, EDIN, MAINZ+)
GROSSMAN	87	PRL 59 18	N. Grossman <i>et al.</i>	(MINN, MICH, RUTG)
BARMIN	86	SJNP 44 622	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 44 965.		

BARMIN	86B	NC 96A 159	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
PDG	86B	PL 170B 130	M. Aguilar-Benitez <i>et al.</i>	(CERN, CIT+)
BARMIN	85	NC 85A 67	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
Also		SJNP 41 759	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 41 1187.		
BARMIN	83	PL 128B 129	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
Also		SJNP 39 269	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
		Translated from YAF 39 428.		
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)
ARONSON	76	NC 32A 236	S.H. Aronson <i>et al.</i>	(WISC, EFI, UCSD+)
EVERHART	76	PR D14 661	G.C. Everhart <i>et al.</i>	(PENN)
TAUREG	76	PL 65B 92	H. Taureg <i>et al.</i>	(HEIDH, CERN, DORT)
BALDO-...	75	NC 25A 688	M. Baldo-Ceolin <i>et al.</i>	(PADO, WISC)
CARITHERS	75	PRL 34 1244	W.C.J. Carithers <i>et al.</i>	(COLU, NYU)
BOBISUT	74	LNC 11 646	F. Bobisut <i>et al.</i>	(PADO)
COWELL	74	PR D10 2083	P.L. Cowell <i>et al.</i>	(STON, COLU)
GEWENIGER	74B	PL 48B 487	C. Geweniger <i>et al.</i>	(CERN, HEIDH)
GJESDAL	74B	PL 52B 119	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
BURGUN	73	PL 46B 481	G. Burgun <i>et al.</i>	(SACL, CERN)
GJESDAL	73	PL 44B 217	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
HILL	73	PR D8 1290	D.G. Hill <i>et al.</i>	(BNL, CMU)
ALITTI	72	PL 39B 568	J. Alitti, E. Lesquoy, A. Muller	(SACL)
BURGUN	72	NP B50 194	G. Burgun <i>et al.</i>	(SACL, CERN, OSLO)
METCALF	72	PL 40B 703	M. Metcalf <i>et al.</i>	(CERN, IPN, WIEN)
MORSE	72B	PRL 28 388	R. Morse <i>et al.</i>	(COLO, PRIN, UMD)
NAGY	72	NP B47 94	E. Nagy, F. Telbisz, G. Vesztergombi	(BUDA)
Also		PL 30B 498	G. Bozoki <i>et al.</i>	(BUDA)
SKJEGGEST...	72	NP B48 343	O. Skjeggstad <i>et al.</i>	(OSLO, CERN, SACL)
BALTAY	71	PRL 27 1678	C. Baltay <i>et al.</i>	(COLU)
Also		Thesis Nevis 187	W.A. Cooper	(COLU)
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