



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

## $K_S^0$ 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
<b>0.8954 ± 0.0004 OUR FIT</b>				Error includes scale factor of 1.1. Assuming <i>CPT</i>
<b>0.89564 ± 0.00033 OUR FIT</b>				Not assuming <i>CPT</i>
0.89589 ± 0.00070		<sup>1,2</sup> ABOUZAID	11	KTEV Not assuming <i>CPT</i>
0.89623 ± 0.00047		<sup>1,3</sup> ABOUZAID	11	KTEV Assuming <i>CPT</i>
0.89562 ± 0.00029 ± 0.00043	20M	<sup>4</sup> AMBROSINO	11	KLOE Not assuming <i>CPT</i>
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 <i>CPT</i>
0.8929 ± 0.0016		GIBBONS	93	E731 Assuming <i>CPT</i>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
0.8965 ± 0.0007		<sup>5</sup> ALAVI-HARATI03	KTEV	Assuming <i>CPT</i>
0.8958 ± 0.0013		<sup>6</sup> ALAVI-HARATI03	KTEV	Not assuming <i>CPT</i>
0.8920 ± 0.0044	214k	GROSSMAN	87	SPEC
0.905 ± 0.007		<sup>7</sup> ARONSON	82B	SPEC
0.881 ± 0.009	26k	ARONSON	76	SPEC
0.8926 ± 0.0032 ± 0.0002		<sup>8</sup> CARITHERS	75	SPEC
0.8937 ± 0.0048	6M	GEWENIGER	74B	ASPK
0.8958 ± 0.0045	50k	<sup>9</sup> SKJEGGEST...	72	HBC
0.856 ± 0.008	19994	<sup>10</sup> DONALD	68B	HBC
0.872 ± 0.009	20000	<sup>9,10</sup> HILL	68	DBC

<sup>1</sup> 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.

<sup>2</sup> ABOUZAID 11 fit has  $\Delta m$ ,  $\tau_S$ ,  $\phi_\epsilon$ ,  $\text{Re}(\epsilon'/\epsilon)$ , and  $\text{Im}(\epsilon'/\epsilon)$  as free parameters. See  $\text{Im}(\epsilon'/\epsilon)$  in the “ $K_L^0$  *CP* violation” section for correlation information.

<sup>3</sup> ABOUZAID 11 fit has  $\Delta m$  and  $\tau_S$  free but constrains  $\phi_\epsilon$  to the Superweak value, i.e. assumes *CPT*. This  $\tau_S$  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  $\rho(\tau_S, \Delta m) = -0.670$ .

<sup>4</sup> Fit to the proper time distribution.

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 Superseded by ABOUZAID 11.

<sup>6</sup>This ALAVI-HARATI 03 fit has  $\Delta m$ ,  $\phi_{+-}$ , and  $\tau_{K_S}$  free. See  $\phi_{+-}$  in the “ $K_L$  CP violation” section for correlation information. Superseded by ABOUZAIID 11.

<sup>7</sup>ARONSON 82 find that  $K_S^0$  mean life may depend on the kaon energy.

<sup>8</sup>CARITHERS 75 measures the  $\Delta m$  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.

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

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

## $K_S^0$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level
<b>Hadronic modes</b>		
$\Gamma_1$ $\pi^0 \pi^0$	$(30.69 \pm 0.05) \%$	
$\Gamma_2$ $\pi^+ \pi^-$	$(69.20 \pm 0.05) \%$	
$\Gamma_3$ $\pi^+ \pi^- \pi^0$	$(3.5^{+1.1}_{-0.9}) \times 10^{-7}$	
<b>Modes with photons or <math>\ell\bar{\ell}</math> pairs</b>		
$\Gamma_4$ $\pi^+ \pi^- \gamma$	[a,b] $(1.79 \pm 0.05) \times 10^{-3}$	
$\Gamma_5$ $\pi^+ \pi^- e^+ e^-$	$(4.79 \pm 0.15) \times 10^{-5}$	
$\Gamma_6$ $\pi^0 \gamma \gamma$	[a] $(4.9 \pm 1.8) \times 10^{-8}$	
$\Gamma_7$ $\gamma \gamma$	$(2.63 \pm 0.17) \times 10^{-6}$	S=3.1
<b>Semileptonic modes</b>		
$\Gamma_8$ $\pi^\pm e^\mp \nu_e$	[c] $(7.04 \pm 0.08) \times 10^{-4}$	
$\Gamma_9$ $\pi^\pm \mu^\mp \nu_\mu$	[c,d] $(4.56 \pm 0.20) \times 10^{-4}$	
<b>CP violating (CP) and <math>\Delta S = 1</math> weak neutral current (S1) modes</b>		
$\Gamma_{10}$ $3\pi^0$	CP $< 2.6 \times 10^{-8}$	CL=90%
$\Gamma_{11}$ $\mu^+ \mu^-$	S1 $< 2.1 \times 10^{-10}$	CL=90%
$\Gamma_{12}$ $e^+ e^-$	S1 $< 9 \times 10^{-9}$	CL=90%
$\Gamma_{13}$ $\pi^0 e^+ e^-$	S1 [a] $(3.0^{+1.5}_{-1.2}) \times 10^{-9}$	
$\Gamma_{14}$ $\pi^0 \mu^+ \mu^-$	S1 $(2.9^{+1.5}_{-1.2}) \times 10^{-9}$	

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

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

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

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

### CONSTRAINED FIT INFORMATION

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

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

$x_2$	-100			
$x_8$	-6	4		
$x_9$	-1	-3	0	
		$x_1$	$x_2$	$x_8$

### $K_S^0$ DECAY RATES

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

$\Gamma_8$

<u>VALUE</u> ( $10^6 \text{ s}^{-1}$ )	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
8.1 ± 1.6	75	<sup>1</sup> AKHMETSHIN 99	CMD2	Tagged $K_S^0$ using $\phi \rightarrow K_L^0 K_S^0$
7.50 ± 0.08		<sup>2</sup> 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

<sup>1</sup> 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  $\tau_{K_S^0} = (0.8934 \pm 0.0008) \times 10^{-10}$  s. Not independent of measured branching ratio.

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

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

$\Gamma_9$

<u>VALUE</u> ( $10^6 \text{ s}^{-1}$ )	<u>DOCUMENT ID</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●	
5.25 ± 0.07	<sup>1</sup> PDG 98
<sup>1</sup> PDG 98 from $K_L^0$ measurements, assuming that $\Delta S = \Delta Q$ in $K^0$ decay so that $\Gamma(K_S^0 \rightarrow \pi^\pm \mu^\mp \nu_\mu) = \Gamma(K_L^0 \rightarrow \pi^\pm \mu^\mp \nu_\mu)$ .	

$K_S^0$  BRANCHING RATIOS

## Hadronic modes

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

VALUE	EVTS	DOCUMENT ID	TECN
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**0.3069 ± 0.0005 OUR FIT**

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

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

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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**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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 $\Gamma(\pi^+\pi^-)/\Gamma(\pi^0\pi^0)$  $\Gamma_2/\Gamma_1$ 

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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**2.255 ± 0.005 OUR FIT****2.2549 ± 0.0054**

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

		<sup>1</sup> AMBROSINO	06C	KLOE	
2.2555 ± 0.0012 ± 0.0054		<sup>2</sup> AMBROSINO	06C	KLOE	
2.236 ± 0.003 ± 0.015	766k	<sup>2</sup> 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	<sup>3</sup> 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	<sup>4</sup> NAGY	72	HLBC	$K^+ n \rightarrow K^0 p$
2.22 ± 0.095	6150	<sup>5</sup> BALTAY	71	HBC	$K p \rightarrow K^0 \text{neutrals}$
2.282 ± 0.043	7944	<sup>6</sup> MOFFETT	70	OSPK	$K^+ n \rightarrow K^0 p$
2.12 ± 0.17	267	<sup>4</sup> BOZOKI	69	HLBC	
2.285 ± 0.055	3016	<sup>6</sup> GOBBI	69	OSPK	$K^+ n \rightarrow K^0 p$
2.10 ± 0.06	3700	MORFIN	69	HLBC	$K^+ n \rightarrow K^0 p$

<sup>1</sup> This result combines AMBROSINO 06C KLOE 2001-02 data with ALOISIO 02B KLOE 2000 data.  $K_S^0 \rightarrow \pi^+\pi^-$  fully inclusive.<sup>2</sup> Includes radiative decays  $\pi^+\pi^-\gamma$ .<sup>3</sup> The directly measured quantity is  $K_S^0 \rightarrow \pi^+\pi^-/\text{all } K^0 = 0.345 \pm 0.005$ .<sup>4</sup> NAGY 72 is a final result which includes BOZOKI 69.<sup>5</sup> The directly measured quantity is  $K_S^0 \rightarrow \pi^+\pi^-/\text{all } \bar{K}^0 = 0.345 \pm 0.005$ .<sup>6</sup> MOFFETT 70 is a final result which includes GOBBI 69. $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$  $\Gamma_3/\Gamma$ 

VALUE (units $10^{-7}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**3.5<sup>+1.1</sup><sub>-0.9</sub> OUR AVERAGE**

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

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

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

<sup>1</sup> 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).

<sup>2</sup> 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.

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

<sup>4</sup> 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  $\lambda$  is the same as  $\rho_{+-0}$  used in other footnotes.

<sup>5</sup> 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 ————

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

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.59 ± 0.08 OUR AVERAGE</b>				
2.56 ± 0.09	1286	RAMBERG	93 E731	$p_\gamma > 50 \text{ MeV}/c$
2.68 ± 0.15		<sup>1</sup> TAUREG	76 SPEC	$p_\gamma > 50 \text{ MeV}/c$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
7.10 ± 0.22	3723	RAMBERG	93 E731	$p_\gamma > 20 \text{ MeV}/c$
3.0 ± 0.6	29	<sup>2</sup> BOBISUT	74 HLBC	$p_\gamma > 40 \text{ MeV}/c$
2.8 ± 0.6		<sup>3</sup> BURGUN	73 HBC	$p_\gamma > 50 \text{ MeV}/c$

<sup>1</sup> TAUREG 76 find direct emission contribution  $< 0.06$ , CL = 90%.

<sup>2</sup> BOBISUT 74 not included in average because  $p_\gamma$  cut differs. Estimates direct emission contribution to be 0.5 or less, CL = 95%.

<sup>3</sup> BURGUN 73 estimates that direct emission contribution is  $0.3 \pm 0.6$ .

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

VALUE (units $10^{-5}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>4.79 ± 0.15 OUR AVERAGE</b>				
4.83 ± 0.11 ± 0.14	23k	<sup>1</sup> BATLEY	11 NA48	2002 data
4.69 ± 0.30	676	<sup>2</sup> 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

<sup>1</sup> 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.

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

<sup>3</sup> Second error is 0.16(syst) ± 0.15(norm) combined in quadrature.

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

VALUE (units $10^{-8}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>4.9 ± 1.6 ± 0.9</b>		17	<sup>1</sup> LAI	04 NA48	$m_{\gamma\gamma}^2 / m_K^2 > 0.2$

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

<33      90      LAI      03B NA48     $m_{\gamma\gamma}^2 / m_K^2 > 0.2$

<sup>1</sup> Spectrum also measured and found consistent with the one generated by a constant matrix element.

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

VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>2.63 ± 0.17 OUR AVERAGE</b>			Error includes scale factor of 3.1.		
2.26 ± 0.12 ± 0.06		711	<sup>1</sup> AMBROSINO	08C KLOE	$\phi \rightarrow K_S^0 K_L^0$
2.713 ± 0.063 ± 0.005		7.5k	<sup>2</sup> 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      <sup>3</sup> BARR    95B NA31

2.4 ± 0.9              35      <sup>4</sup> BARR    95B NA31

< 13                  90      BALATS    89 SPEC

2.4 ± 1.2              19      BURKHARDT 87 NA31

<133                  90      BARMIN    86B XEBC

<sup>1</sup> 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  $B(K_S^0 \rightarrow \pi^0 \pi^0) = (30.69 \pm 0.05) \times 10^{-2}$ .

<sup>2</sup> 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.

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

<sup>4</sup> 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.

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**Semileptonic modes**


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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**7.04 ± 0.08 OUR FIT****7.04 ± 0.08 OUR AVERAGE**

7.046 ± 0.18 ± 0.16		<sup>1</sup> BATLEY	07D NA48	$K^0(\bar{K}^0)(t) \rightarrow \pi e \nu$
6.91 ± 0.34 ± 0.15	624	<sup>2</sup> 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	<sup>3</sup> 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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<sup>1</sup> Reconstructed from  $K^0(\bar{K}^0)(t) \rightarrow \pi e \nu$  distributions using PDG values of  $B(K_L^0 \rightarrow \pi e \nu) = 0.4053 \pm 0.0015$ ,  $\tau_L = (5.114 \pm 0.021) \times 10^{-8}$  s and  $\tau_S = (0.8958 \pm 0.0005) \times 10^{-10}$  s.

<sup>2</sup> Uses the PDG 00 value for  $B(K_S^0 \rightarrow \pi^+ \pi^-)$ .

<sup>3</sup> 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.

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**4.56 ± 0.20 OUR FIT**

4.56 ± 0.11 ± 0.17	7223	<sup>1</sup> BABUSCI	20 KLOE	direct measurement
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<sup>1</sup> 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  $|V_{us} f_+(0)|_{K_S^0 \rightarrow \pi \mu \nu}^2 / |V_{us} f_+(0)|_{K_S^0 \rightarrow \pi e \nu}^2 = 0.975 \pm 0.044$ .

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**10.18 ± 0.12 OUR FIT**

10.19 ± 0.11 ± 0.07	13k	AMBROSINO	06E KLOE
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**CP violating (CP) and  $\Delta S = 1$  weak neutral current (S1) modes**


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

Violates CP conservation.

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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<b>&lt; 0.26</b>	90	590M	<sup>1</sup> BABUSCI	13C KLOE	$\phi \rightarrow K_L^0 K_S^0$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< 1.2	90	37.8M	AMBROSINO	05B KLOE
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< 7.4	90	4.9M	<sup>2</sup> LAI	05A NA48
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< 140	90	7M	ACHASOV	99D SND
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<190	90	17300	<sup>3</sup> ANGELOPO...	98B	CPLR
<370	90		BARMIN	83	HLBC

<sup>1</sup> BABUSCI 13C uses  $1.7 \text{ fb}^{-1}$  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.

<sup>2</sup> 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

<sup>3</sup> 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  $B(K_L^0 \rightarrow \pi^0 \pi^0 \pi^0) = 0.2112 \pm 0.0027$ .

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

### $\Gamma_{11} / \Gamma$

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

VALUE	CL%	DOCUMENT ID	TECN
< $2.1 \times 10^{-10}$	90	<sup>1</sup> AAIJ	20AE LHCB

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

< $8 \times 10^{-10}$	90	<sup>2</sup> AAIJ	17BQ LHCB
< $9 \times 10^{-9}$	90	<sup>3</sup> AAIJ	13G LHCB
< $3.2 \times 10^{-7}$	90	GJESDAL	73 ASPK
< $7 \times 10^{-6}$	90	HYAMS	69B OSPK

<sup>1</sup> AAIJ 20AE uses  $8.6 \text{ fb}^{-1}$  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.

<sup>2</sup> AAIJ 17BQ uses  $3.0 \text{ fb}^{-1}$  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.

<sup>3</sup> AAIJ 13G uses  $1.0 \text{ fb}^{-1}$  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.

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

### $\Gamma_{12} / \Gamma$

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

VALUE (units $10^{-7}$ )	CL%	DOCUMENT ID	TECN	COMMENT
< <b>0.09</b>	90	<sup>1</sup> 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

<sup>1</sup> 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  $B(K_S^0 \rightarrow \pi^+ \pi^-) = (69.20 \pm 0.05) \times 10^{-2}$ .



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

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

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

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

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

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

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

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

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

<sup>1</sup> 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  $t = 0$ .

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

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN
$3.39 \pm 0.41$	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  $\eta_{+-0}$  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  $\eta_{+-0}$  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  $\eta_{+-0}$ ,  $\eta_{000}$  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;  $\epsilon$  is determined from  $CP$  violation in  $K_L \rightarrow 2\pi$  decays. The real parts of  $\eta_{+-0}$  and  $\eta_{000}$  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	<sup>1</sup> 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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<sup>1</sup> 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  $1.63 \text{ fb}^{-1}$  is  $A_S = (-4.9 \pm 5.7 \pm 2.6) \times 10^{-3}$ .

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

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

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

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

<0.23	90	601	<sup>1</sup> BARMIN 85	HLBC
<0.12	90	384	METCALF 72	ASPK

<sup>1</sup> 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.

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
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$-0.002 \pm 0.009 \pm 0.002$ $-0.001$	500k	<sup>1</sup> ADLER 97B	CPLR	
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• • • We do not use the following data for averages, fits, limits, etc. • • •

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

<sup>1</sup> ADLER 97B also find  $\text{Re}(\eta_{+-0}) = -0.002 \pm 0.007 \pm 0.004$ . See also ANGELOPOULOS 98c.

<sup>2</sup> 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.

<sup>3</sup> 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	<sup>1</sup> BARMIN 83	HLBC	
<0.28	90		<sup>2</sup> GJESDAL 74B	SPEC	Indirect meas.

<sup>1</sup> 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.

<sup>2</sup> GJESDAL 74B uses  $K_{2\pi}$ ,  $K_{\mu 3}$ , 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	EVTS	DOCUMENT ID	TECN	COMMENT
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**-0.001 ± 0.016 OUR AVERAGE**

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

<sup>1</sup> LAI 05A assumes  $\text{Re}(\eta_{000}) = \text{Re}(\epsilon) = 1.66 \times 10^{-3}$ . The equivalent limit is  $|\eta_{000}|_{CPT} < 0.025$  at 90% CL Without assuming  $CPT$  invariance, they obtain  $\text{Re}(\eta_{000}) = -0.002 \pm 0.011 \pm 0.015$  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

<sup>2</sup> 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
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**<0.0088** 90 590M BABUSCI 13C KLOE

• • • 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  $\phi$  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 <sup>1</sup> 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

<sup>1</sup> The result is used to set the limit  $A < 1.5\%$  at 90% C.L.

## $K_S^0$ REFERENCES

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)
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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)
MOFFETT	70	BAPS 15 512	R. Moffett <i>et al.</i>	(ROCH)
BOZOKI	69	PL 30B 498	G. Bozoki <i>et al.</i>	(BUDA)
DOYLE	69	Thesis UCRL 18139	J.C. Doyle	(LRL)
GOBBI	69	PRL 22 682	B. Gobbi <i>et al.</i>	(ROCH)
HYAMS	69B	PL 29B 521	B.D. Hyams <i>et al.</i>	(CERN, MPIM)
MORFIN	69	PRL 23 660	J.G. Morfin, D. Sinclair	(MICH)
DONALD	68B	PL 27B 58	R.A. Donald <i>et al.</i>	(LIVP, CERN, IPNP+)
HILL	68	PR 171 1418	D.G. Hill <i>et al.</i>	(BNL, CMU)
AUBERT	65	PL 17 59	B. Aubert <i>et al.</i>	(EPOL, ORSAY)
BROWN	63	PR 130 769	J.L. Brown <i>et al.</i>	(LRL, MICH)
CHRETIEN	63	PR 131 2208	M. Chretien <i>et al.</i>	(BRAN, BROW, HARV+)
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### OTHER RELATED PAPERS

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