



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

## $K_S^0$ 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>		
$\Gamma_1$ $\pi^0 \pi^0$	$(30.69 \pm 0.05) \%$	
$\Gamma_2$ $\pi^+ \pi^-$	$(69.20 \pm 0.05) \%$	
$\Gamma_3$ $\pi^+ \pi^- \pi^0$	$( 3.5 \begin{smallmatrix} +1.1 \\ -0.9 \end{smallmatrix} ) \times 10^{-7}$	
<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=3.0
<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] $( 4.69 \pm 0.05 ) \times 10^{-4}$	
<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 $< 9 \times 10^{-9}$	CL=90%
$\Gamma_{12}$ $e^+ e^-$	S1 $< 9 \times 10^{-9}$	CL=90%
$\Gamma_{13}$ $\pi^0 e^+ e^-$	S1 [a] $( 3.0 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix} ) \times 10^{-9}$	
$\Gamma_{14}$ $\pi^0 \mu^+ \mu^-$	S1 $( 2.9 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix} ) \times 10^{-9}$	

[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	3	
$x_9$	-6	3	100
	$x_1$	$x_2$	$x_8$

### $K_S^0$ 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>11</sup> AKHMETSHIN 99	CMD2	Tagged $K_S^0$ using $\phi \rightarrow K_L^0 K_S^0$
7.50 ± 0.08		<sup>12</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>11</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>12</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>13</sup> PDG 98
<sup>13</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

**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

**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

**2.255 ± 0.005 OUR FIT**

**2.2549 ± 0.0054**

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

		<sup>14</sup> AMBROSINO	06C	KLOE	
2.2555 ± 0.0012 ± 0.0054		<sup>15</sup> AMBROSINO	06C	KLOE	
2.236 ± 0.003 ± 0.015	766k	<sup>15</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>16</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>17</sup> NAGY	72	HLBC	$K^+ n \rightarrow K^0 p$
2.22 ± 0.095	6150	<sup>18</sup> BALTAY	71	HBC	$K p \rightarrow K^0 \text{ neutrals}$
2.282 ± 0.043	7944	<sup>19</sup> MOFFETT	70	OSPK	$K^+ n \rightarrow K^0 p$
2.12 ± 0.17	267	<sup>17</sup> BOZOKI	69	HLBC	
2.285 ± 0.055	3016	<sup>19</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>14</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>15</sup> Includes radiative decays  $\pi^+\pi^-\gamma$ .

<sup>16</sup> The directly measured quantity is  $K_S^0 \rightarrow \pi^+\pi^-/\text{all } K^0 = 0.345 \pm 0.005$ .

<sup>17</sup> NAGY 72 is a final result which includes BOZOKI 69.

<sup>18</sup> The directly measured quantity is  $K_S^0 \rightarrow \pi^+\pi^-/\text{all } \bar{K}^0 = 0.345 \pm 0.005$ .

<sup>19</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

**$3.5^{+1.1}_{-0.9}$  OUR AVERAGE**

$4.7^{+2.2+1.7}_{-1.7-1.5}$		20	BATLEY	05	NA48
$2.5^{+1.3+0.5}_{-1.0-0.6}$	500k	21	ADLER	97B	CPLR
$4.8^{+2.2+1.1}_{-1.6}$		22	ZOU	96	E621

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

$4.1^{+2.5+0.5}_{-1.9-0.6}$		23	ADLER	96E	CPLR Sup. by ADLER 97B
$3.9^{+5.4+0.9}_{-1.8-0.7}$		24	THOMSON	94	E621 Sup. by ZOU 96

<sup>20</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>21</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>22</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>23</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>24</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

**$2.59 \pm 0.08$  OUR AVERAGE**

$2.56 \pm 0.09$	1286		RAMBERG	93	E731 $p_\gamma > 50 \text{ MeV}/c$
$2.68 \pm 0.15$		25	TAUREG	76	SPEC $p_\gamma > 50 \text{ MeV}/c$
$7.10 \pm 0.22$	3723		RAMBERG	93	E731 $p_\gamma > 20 \text{ MeV}/c$
$3.0 \pm 0.6$	29	26	BOBISUT	74	HLBC $p_\gamma > 40 \text{ MeV}/c$
$2.8 \pm 0.6$		27	BURGUN	73	HBC $p_\gamma > 50 \text{ MeV}/c$

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

<sup>25</sup> TAUREG 76 find direct emission contribution  $< 0.06$ ,  $CL = 90\%$ .

<sup>26</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>27</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
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**4.79 ± 0.15 OUR AVERAGE**

4.83 ± 0.11 ± 0.14	23k	28 BATLEY	11 NA48	2002 data
4.69 ± 0.30	676	29 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	29,30 LAI	03C NA48	1999 data
4.5 ± 0.7 ± 0.4	56	LAI	00B NA48	1998 data

<sup>28</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>29</sup> Uses normalization  $BR(K_L \rightarrow \pi^+\pi^-\pi^0) \cdot BR(\pi^0 \rightarrow e^+e^-) = (1.505 \pm 0.047) \times 10^{-3}$  from our 2000 Edition.

<sup>30</sup> Second error is  $0.16(\text{syst}) \pm 0.15(\text{norm})$  combined in quadrature.

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

VALUE (units $10^{-8}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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**4.9 ± 1.6 ± 0.9**      17      <sup>31</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>31</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
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**2.63 ± 0.17 OUR AVERAGE**      Error includes scale factor of 3.0.

2.26 ± 0.12 ± 0.06      711      <sup>32</sup> AMBROSINO      08C      KLOE       $\phi \rightarrow K_S^0 K_L^0$

2.713 ± 0.063 ± 0.005      7.5k      <sup>33</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>34</sup> BARR      95B      NA31

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

< 13      90      BALATS      89      SPEC

2.4 ± 1.2      19      BURKHARDT      87      NA31

<133      90      BARMIN      86B      XEBC

<sup>32</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>33</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>34</sup> BARR 95B result is calculated using  $B(K_L \rightarrow \gamma\gamma) = (5.86 \pm 0.17) \times 10^{-4}$ .

<sup>35</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.

————— **Semileptonic modes** —————

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

VALUE (units  $10^{-4}$ )    EVTS    DOCUMENT ID    TECN    COMMENT

**7.04 ± 0.08 OUR FIT**

**7.04 ± 0.08 OUR AVERAGE**

7.046 ± 0.18 ± 0.16    <sup>36</sup> BATLEY    07D NA48     $K^0(\bar{K}^0)(t) \rightarrow \pi e \nu$   
 6.91 ± 0.34 ± 0.15    624 <sup>37</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>38</sup> AMBROSINO    06E KLOE    Not fitted

• • • 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  $\phi \rightarrow K_L^0 K_S^0$

<sup>36</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>37</sup> Uses the PDG 00 value for  $B(K_S^0 \rightarrow \pi^+ \pi^-)$ .

<sup>38</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.

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

The PDG 06 value below has not been measured but is computed to be 0.666 times the  $K_S \rightarrow \pi^\pm e^\mp \nu_e$  branching fraction. It is included in the fit that constrains the four branching ratios  $\pi^+ \pi^-$ ,  $\pi^0 \pi^0$ ,  $\pi e \nu$ , and  $\pi \mu \nu$  to sum to 1. This treatment, used by AMBROSINO 06E, is preferable to our previous practice of constraining the  $\pi^+ \pi^-$  and  $\pi^0 \pi^0$  modes to sum to 1. The 0.666 factor is obtained from AMBROSINO 06E and assumes lepton universality, radiative corrections from ANDRE 07, and phase space integrals from KTeV, ALEXOPOULOS 04A.

VALUE (units  $10^{-4}$ )    DOCUMENT ID    COMMENT

**4.69 ± 0.06 OUR FIT**

**4.691 ± 0.001 ± 0.056**    <sup>39</sup> PDG    06    calculated from  $\pi^\pm e^\mp \nu_e$

<sup>39</sup> The PDG 06 value is computed to be  $B_{\text{PDG06}}(\pi \mu \nu) = 0.666 B_{\text{FIT}}(\pi e \nu)$ . The first error specifies the arbitrarily small error,  $0.001 \times 10^{-4}$ , on  $B_{\text{PDG06}}(\pi \mu \nu)$  for fixed  $B_{\text{FIT}}(\pi e \nu)$ . The second error is that due to the uncertainty in  $B_{\text{FIT}}(\pi e \nu)$ .

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

VALUE (units  $10^{-4}$ )    EVTS    DOCUMENT ID    TECN

**10.18 ± 0.12 OUR FIT**

**10.19 ± 0.11 ± 0.07**    13k    AMBROSINO    06E    KLOE

**CP violating (CP) and  $\Delta S = 1$  weak neutral current (S1) modes**

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

Violates CP conservation.

VALUE (units $10^{-7}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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< 0.26	90	590M	<sup>40</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
< 7.4	90	4.9M	<sup>41</sup> LAI	05A	NA48
<140	90	7M	ACHASOV	99D	SND
<190	90	17300	<sup>42</sup> ANGELOPO...	98B	CPLR
<370	90		BARMIN	83	HLBC

<sup>40</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>41</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>42</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 (units $10^{-9}$ )	CL%	DOCUMENT ID	TECN
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< 9	90	<sup>43</sup> AAIJ	13G LHCB
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< $3.2 \times 10^2$	90	GJESDAL	73 ASPK
< $7 \times 10^3$	90	HYAMS	69B OSPK

<sup>43</sup> AAIJ 13G uses  $1.0 \text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 7 \text{ TeV}$ . 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
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< 0.09	90	<sup>44</sup> AMBROSINO	09A	KLOE $e^+ e^- \rightarrow \phi \rightarrow K_S^0 K_L^0$
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• • • 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>44</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>45</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>45</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>46</sup> BATLEY	04A NA48	NA48/1 $K_S^0$ beam

<sup>46</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

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## $CP$ -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
$1.5 \pm 9.6 \pm 2.9$	13k	AMBROSINO 06E	KLOE

————— 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>47</sup> BARMIN	85 HLBC
<0.12	90	384	METCALF	72 ASPK

<sup>47</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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$-0.002 \pm 0.009$ $^{+0.002}_{-0.001}$	500k	<sup>48</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>49</sup> ADLER	96D	CPLR Sup. by ADLER 97B
$-0.015 \pm 0.017 \pm 0.025$	272k	<sup>50</sup> ZOU	94	SPEC

<sup>48</sup> ADLER 97B also find  $\text{Re}(\eta_{+-0}) = -0.002 \pm 0.007$   
 $^{+0.004}_{-0.001}$ . See also ANGELOPOU-LOS 98C.

<sup>49</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>50</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>51</sup> BARMIN	83 HLBC
<0.28	90		<sup>52</sup> GJESDAL	74B SPEC Indirect meas.

<sup>51</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>52</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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**$-0.001 \pm 0.016$  OUR AVERAGE**

$0.000 \pm 0.009 \pm 0.013$	4.9M	<sup>53</sup> LAI	05A NA48	Assumes <i>CPT</i>
$-0.05 \pm 0.12 \pm 0.05$	17300	<sup>54</sup> ANGELOPO...	98B CPLR	Assumes <i>CPT</i>

- <sup>53</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>54</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
<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
<b>-0.4 ± 0.8 OUR AVERAGE</b>			
-0.4 ± 0.8	<sup>55</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>55</sup> The result is used to set the limit  $A < 1.5\%$  at 90% C.L.

## $K_S^0$ REFERENCES

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.)
PDG	06	JP G33 1	W.-M. Yao <i>et al.</i>	(PDG 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 (errata.)	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	98B	PL B425 391	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO... 98C	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	97	PL B413 232	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
BERTANZA	97	ZPHY C73 629	L. Bertanza <i>et al.</i>	(PISA, CERN, EDIN, 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, MANZ, LALO+)
SCHWINGEN... 95	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, MANZ, 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)
GIBBONS	88	Translated from YAF 49 1332.	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt <i>et al.</i>	(CERN, EDIN, MANZ+)
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)
BARMIN	86B	Translated from YAF 44 965.	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
PDG	86B	NC 96A 159	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
BARMIN	85	PL 170B 130	M. Aguilar-Benitez <i>et al.</i>	(CERN, CIT+)
Also		NC 85A 67	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
BARMIN	83	SJNP 41 759	V.V. Barmin <i>et al.</i>	(ITEP)
Also		Translated from YAF 41 1187.	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
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)
ARONSON	82	Translated from YAF 39 428.	S.H. Aronson <i>et al.</i>	(BNL, CHIC, STAN+)
ARONSON	82B	PRL 48 1078	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
Also		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)
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