K^0_S

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

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

VALUE (10^{-10} 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, Re(ϵ'/ϵ), and Im(ϵ'/ϵ) as free parameters. See Im(ϵ'/ϵ) in the "K^0_L *CP* violation" section for correlation information.

[3] ABOUZAID 11 fit has Δm and τ_S free but constrains ϕ_ϵ to the Superweak value, i.e. assumes *CPT*. This τ_S value is correlated with their $\Delta m = m_{K^0_L} - m_{K^0_S}$ measurement in the K^0_L 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 $\Delta m = m_{K^0_L} - m_{K^0_S}$ measurement in the K^0_L listings. The correlation coefficient $\rho(\tau_S,\Delta m) = -0.396$. Superseded by ABOUZAID 11.

[6] This 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.

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

[8] CARITHERS 75 measures the Δm dependence of the total decay rate (inverse mean life) to be $\Gamma(K_S^0) = \left[(1.122 \pm 0.004) + 0.16(\Delta m - 0.5348)/\Delta m\right] 10^{10}$/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 (Δm = 0.5293 ± 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.

[9] HILL 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.

[10] Pre-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	
Γ_1	$\pi^0\pi^0$			(30.69 ± 0.05) %	
Γ_2	$\pi^+\pi^-$			(69.20 ± 0.05) %	
Γ_3	$\pi^+\pi^-\pi^0$			$(3.5\ ^{+1.1}_{-0.9}) \times 10^{-7}$	
				Modes with photons or $\ell\overline{\ell}$ pairs	
Γ_4	$\pi^+\pi^-\gamma$		[a,b]	$(1.79\pm0.05) \times 10^{-3}$	
Γ_5	$\pi^+\pi^-e^+e^-$			$(4.79\pm0.15) \times 10^{-5}$	
Γ_6	$\pi^0\gamma\gamma$		[a]	$(4.9\ \pm1.8\ ) \times 10^{-8}$	
Γ_7	$\gamma\gamma$			$(2.63\pm0.17) \times 10^{-6}$	S=3.1
Γ_8	$\mu^+\mu^-\mu^+\mu^-$			$< 5.1 \times 10^{-12}$	CL=90%
				Semileptonic modes	
Γ_9	$\pi^\pm e^\mp \nu_e$		[c]	$(7.14\pm0.06) \times 10^{-4}$	
Γ_{10}	$\pi^\pm \mu^\mp \nu_\mu$		[c,d]	$(4.56\pm0.20) \times 10^{-4}$	
				***CP* violating (*CP*) and $\Delta S = 1$ weak neutral current (*S1*) modes**	
Γ_{11}	$3\pi^0$	*CP*		$< 2.6 \times 10^{-8}$	CL=90%
Γ_{12}	$\mu^+\mu^-$	*S1*		$< 2.1 \times 10^{-10}$	CL=90%
Γ_{13}	e^+e^-	*S1*		$< 9 \times 10^{-9}$	CL=90%
Γ_{14}	$\pi^0 e^+e^-$	*S1*	[a]	$(3.0\ ^{+1.5}_{-1.2}) \times 10^{-9}$	
Γ_{15}	$\pi^0\mu^+\mu^-$	*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·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 χ^2 = 0.6 for 2 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, 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_9	−9	8	
x_{10}	−1	−3	0
	x_1	x_2	x_9

K^0_S DECAY RATES

$\Gamma(\pi^{\pm} e^{\mp} \nu_e)$ — Γ_9

VALUE (10^6 s^{-1})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
8.1 ±1.6	75	[1] AKHMETSHIN	99	CMD2	Tagged K^0_S using $\phi \rightarrow K^0_L K^0_S$
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	ΔS=ΔQ, *CP* cons. not assumed

[1] AKHMETSHIN 99 is from a measured branching ratio B($K^0_S \rightarrow \pi e \nu_e$)= (7.2 ± 1.4) × 10^{-4} and $\tau_{K^0_S}$ = (0.8934 ± 0.0008) × 10^{-10} s. Not independent of measured branching ratio.

[2] PDG 98 from K^0_L measurements, assuming that ΔS=ΔQ in K^0 decay so that $\Gamma(K^0_S \rightarrow \pi^{\pm} e^{\mp} \nu_e) = \Gamma(K^0_L \rightarrow \pi^{\pm} e^{\mp} \nu_e)$.

$\Gamma(\pi^{\pm} \mu^{\mp} \nu_\mu)$ — Γ_{10}

VALUE (10^6 s^{-1})	DOCUMENT ID	
• • • We do not use the following data for averages, fits, limits, etc. • • •		
5.25±0.07	[1] PDG	98

[1] PDG 98 from K^0_L measurements, assuming that ΔS=ΔQ in K^0 decay so that $\Gamma(K^0_S \to \pi^\pm \mu^\mp \nu_\mu)$= $\Gamma(K^0_L \to \pi^\pm \mu^\mp \nu_\mu)$.

K^0_S BRANCHING RATIOS

Hadronic modes

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

$\Gamma(\pi^+\pi^-)/\Gamma_{total}$ — 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	$\pi^- p \to \Lambda K^0$

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^0\pi^0)$ — 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	$\pi^- p \to \Lambda K^0$
2.169 ±0.094	16k	COWELL	74	OSPK	$\pi^- p \to \Lambda K^0$
2.16 ±0.08	4799	HILL	73	DBC	$K^+ d \to K^0 p p$
2.22 ±0.10	3068	[3] ALITTI	72	HBC	$K^+ p \to \pi^+ p K^0$
2.22 ±0.08	6380	MORSE	72B	DBC	$K^+ n \to K^0 p$
2.10 ±0.11	701	[4] NAGY	72	HLBC	$K^+ n \to K^0 p$
2.22 ±0.095	6150	[5] BALTAY	71	HBC	$K p \to K^0$ neutrals
2.282 ±0.043	7944	[6] MOFFETT	70	OSPK	$K^+ n \to K^0 p$
2.12 ±0.17	267	[4] BOZOKI	69	HLBC	
2.285 ±0.055	3016	[6] GOBBI	69	OSPK	$K^+ n \to K^0 p$
2.10 ±0.06	3700	MORFIN	69	HLBC	$K^+ n \to K^0 p$

[1] This result combines AMBROSINO 06C KLOE 2001-02 data with ALOISIO 02B KLOE 2000 data. $K^0_S \to \pi^+\pi^-$ fully inclusive.

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

[3] The directly measured quantity is $K^0_S \to \pi^+\pi^-$/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 $K^0_S \to \pi^+\pi^-$/all $\overline{K}^0 = 0.345 \pm 0.005$.

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

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

VALUE (units 10^{-7})	EVTS	DOCUMENT ID		TECN	COMMENT
$3.5^{+1.1}_{-0.9}$ OUR AVERAGE					
$4.7^{+2.2+1.7}_{-1.7-1.5}$		[1] BATLEY	05	NA48	
$2.5^{+1.3+0.5}_{-1.0-0.6}$	500k	[2] ADLER	97B	CPLR	
$4.8^{+2.2}_{-1.6}\pm1.1$		[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, $K_L \to \pi^+\pi^-\pi^0$: Re(λ) = 0.038 ± 0.008 ± 0.006 and Im(λ) = −0.013 ± 0.005 ± 0.004; the correlation coeff. between Re(λ) and Im(λ) is 0.66 (statistical only).

[2] ADLER 97B find the *CP*-conserving parameters Re(λ) = $(28 \pm 7 \pm 3) \times 10^{-3}$, Im($\lambda$) = $(-10 \pm 8 \pm 2) \times 10^{-3}$. They estimate B($K^0_S \to \pi^+\pi^-\pi^0$) from Re($\lambda$) and the K^0_L 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 Re(λ) = $0.036 \pm 0.010^{+0.002}_{-0.003}$ and Im(λ) 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($K^0_S \to \pi^+\pi^-\pi^0$, $I = 2$)/A($K^0_L \to \pi^+\pi^-\pi^0$).

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

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

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

[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.

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

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	COMMENT
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 $[\Gamma(K^0_S \to \pi^+\pi^-e^+e^-)/\Gamma_{total}]$ / $[B(K^0_L \to \pi^+\pi^-\pi^0)]$ / $[B(\pi^0 \to e^+e^-\gamma)] = (3.28 \pm 0.06 \pm 0.04) \times 10^{-2}$ which we multiply by our best values $B(K^0_L \to \pi^+\pi^-\pi^0) = (12.54 \pm 0.05) \times 10^{-2}$, $B(\pi^0 \to e^+e^-\gamma) = (1.174 \pm 0.035) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best 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 $BR(K_L \to \pi^+\pi^-\pi^0)$*$BR(\pi^0 \to e^+e^-) = (1.505 \pm 0.047) \times 10^{-3}$ from our 2000 Edition.

[3] Second error is 0.16(syst)±0.15(norm) combined in quadrature.

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

VALUE (units 10^{-8})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
4.9±1.6±0.9		17	[1] LAI	04	NA48	$m^2_{\gamma\gamma}/m^2_K > 0.2$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<33	90		LAI	03B	NA48	$m^2_{\gamma\gamma}/m^2_K > 0.2$

[1] Spectrum also measured and found consistent with the one generated by a constant matrix element.

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

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
2.63 ±0.17 OUR AVERAGE			Error includes scale factor of 3.1.			
2.26 ±0.12 ±0.06		711	[1] AMBROSINO	08C	KLOE	$\phi \to K^0_S K^0_L$
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 $[\Gamma(K^0_S \to \gamma\gamma)/\Gamma_{total}] \times [B(K^0_S \to \pi^0\pi^0)]$ assuming $B(K^0_S \to \pi^0\pi^0) = (30.69 \pm 0.05) \times 10^{-2}$.

[2] LAI 03 reports $[\Gamma(K^0_S \to \gamma\gamma)/\Gamma_{total}]$ / $[B(K^0_S \to \pi^0\pi^0)] = (8.84 \pm 0.18 \pm 0.10) \times 10^{-6}$ which we multiply by our best value $B(K^0_S \to \pi^0\pi^0) = (30.69 \pm 0.05) \times 10^{-2}$. 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 $B(K_L \to \gamma\gamma) = (5.86 \pm 0.17) \times 10^{-4}$.

[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.

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

VALUE	CL%	DOCUMENT ID	TECN
<5.1 × 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

$\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma_{total}$ — 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±0.18±0.16		[1] BATLEY 07D	NA48	$K^0(\overline{K}^0)(t) \to \pi e \nu$
6.91 ±0.34±0.15	624	[2] ALOISIO 02	KLOE	Tagged K^0_S using $\phi \to K^0_L K^0_S$
• • • We use the following data for averages but not for fits. • • •				
7.05 ±0.09	13k	[3] 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^0_S using $\phi \to K^0_L K^0_S$

[1] Reconstructed from $K^0(\overline{K}^0)(t) \to \pi e \nu$ distributions using PDG values of B($K^0_L \to \pi e \nu$) $= 0.4053 \pm 0.0015$, $\tau_L = (5.114 \pm 0.021) \times 10^{-8}$ s and $\tau_S = (0.8958 \pm 0.0005) \times 10^{-10}$ s.

[2] Uses the PDG 00 value for B($K^0_S \to \pi^+\pi^-$).

[3] Obtained by imposing Σ_i B($K^0_S \to i$) $= 1$, 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($K^0_S \to \pi^+\pi^-$) / B($K^0_S \to \pi^0\pi^0$) from AMBROSINO 06C is used. To derive $\Gamma(K^0_S \to \pi^+ \mu \nu)$ / $\Gamma(K^0_S \to \pi^+ e \nu)$, 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.

$\Gamma(\pi^\pm \mu^\mp \nu_\mu)/\Gamma_{total}$ — Γ_{10}/Γ

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

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

$\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma(\pi^+\pi^-)$ — Γ_9/Γ_2

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN
1.032 ±0.008 OUR FIT			
1.0338±0.0054±0.0064		[1] BABUSCI 23	KLOE
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.019 ±0.011 ±0.007	13k	[2] AMBROSINO 06E	KLOE

[1] BABUSCI 23 measured $\Gamma(K^0_S \to \pi e \nu)/\Gamma(K^0_S \to \pi^+\pi^-) = (1.0421 \pm 0.0066 \pm 0.0075) \times 10^{-3}$ 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

$\Gamma(3\pi^0)/\Gamma_{total}$ — Γ_{11}/Γ

Violates CP conservation.

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.26	90	590M	[1] BABUSCI	13C	KLOE	$\phi \to K^0_L K^0_S$

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

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID		TECN
< 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 $\phi \to K^0_L K^0_S$ decays with K^0_L 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 $K^0_S \to 2\pi^0$ decays.

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

[3] ANGELOPOULOS 98B is from Im(η_{000}) = $-0.05 \pm 0.12 \pm 0.05$, assuming Re(η_{000}) = Re(ϵ) = 1.635×10^{-3} and using the value B($K^0_L \to \pi^0\pi^0\pi^0$) = 0.2112 ± 0.0027.

$\Gamma(\mu^+\mu^-)/\Gamma_{total}$ — Γ_{12}/Γ

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	[1] AAIJ	20AE	LHCB

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

VALUE	CL%	DOCUMENT ID		TECN
$<8 \times 10^{-10}$	90	[2] AAIJ	17BQ	LHCB
$<9 \times 10^{-9}$	90	[3] AAIJ	13G	LHCB
$<3.2 \times 10^{-7}$	90	GJESDAL	73	ASPK
$<7 \times 10^{-6}$	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($K^0_S \to \pi^+\pi^-$) = $(69.20 \pm 0.05) \times 10^{-2}$ 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($K^0_S \to \pi^+\pi^-$) = $(69.20 \pm 0.05) \times 10^{-2}$ 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($K^0_S \to \mu^+\mu^-$) $< 11 \times 10^{-9}$ at 95% C.L.

$\Gamma(e^+e^-)/\Gamma_{total}$ — Γ_{13}/Γ

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
< 0.09	90	[1] AMBROSINO	09A	KLOE	$e^+e^- \to \phi \to K^0_S K^0_L$

• • • 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 $[\Gamma(K^0_S \to e^+e^-)/\Gamma_{total}]$ / $[B(K^0_S \to \pi^+\pi^-)]$ assuming $B(K^0_S \to \pi^+\pi^-) = (69.20 \pm 0.05) \times 10^{-2}$.

$\Gamma(\pi^0 e^+ e^-)/\Gamma_{total}$ — 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
$3.0^{+1.5}_{-1.2}\pm0.2$		7	[1] 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	

[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 $(5.8^{+2.9}_{-2.4}) \times 10^{-9}$.

$\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{total}$ — 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
$2.9^{+1.5}_{-1.2}\pm0.2$	6	[1] BATLEY	04A	NA48	NA48/1 K^0_S beam

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

K^0_S 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^0_S than K^0_L by the ratio of the mean lives, the K^0_S semileptonic form factor has so far been measured only in the K_{e3} mode using the linear expansion $f_+(t) = f_+(0)\ (1 + \lambda_+ t\ /m^2_{\pi^+})$, which gives the vector form factor $f_+(t)$ relative to its value at $t = 0$.

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

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

CP VIOLATION IN $K_S \to 3\pi$

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

The possible final states for the decay $K^0 \to \pi^+\pi^-\pi^0$ 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 $K_S \to \pi^+\pi^-\pi^0$, it is necessary to observe the interference between K_S and K_L decay, which determines the amplitude ratio

$$\eta_{+-0} = \frac{A(K_S \to \pi^+\pi^-\pi^0)}{A(K_L \to \pi^+\pi^-\pi^0)} \; . \tag{1}$$

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 $K^0 \to \pi^0\pi^0\pi^0$ 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

$$\eta_{000} = \frac{A(K_S \to \pi^0\pi^0\pi^0)}{A(K_L \to \pi^0\pi^0\pi^0)} \; . \tag{2}$$

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

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

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

CP-VIOLATION PARAMETERS IN K_S^0 DECAY

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

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

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

[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 $K_S^0 \to 3\pi$ DECAY

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

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

VALUE	CL%	EVTS	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.23	90	601	[1] BARMIN	85	HLBC
<0.12	90	384	METCALF	72	ASPK

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

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

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 $\mathrm{Re}(\eta_{+-0}) = -0.002 \pm 0.007^{+0.004}_{-0.001}$. See also ANGELOPOULOS 98C.

[2] The ADLER 96D fit also yields $\mathrm{Re}(\eta_{+-0}) = 0.006 \pm 0.013 \pm 0.001$ 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 $\mathrm{Re}(\eta_{+-0}) = \mathrm{Re}(\epsilon) = 0.0016$. Without this constraint they find $\mathrm{Im}(\eta_{+-0}) = 0.019 \pm 0.061$ and $\mathrm{Re}(\eta_{+-0}) = 0.019 \pm 0.027$.

$\mathrm{Im}(\eta_{000})^2 = \Gamma(K^0_S \rightarrow 3\pi^0) \;/\; \Gamma(K^0_L \rightarrow 3\pi^0)$

CPT assumed valid (i.e. $\mathrm{Re}(\eta_{000}) \simeq 0$). This limit determines branching ratio $\Gamma(3\pi^0)/\Gamma_{\mathrm{total}}$ above.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • 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 $\mathrm{Re}(\eta_{000}) = (-0.08\pm0.18)$ and $\mathrm{Im}(\eta_{000}) = (-0.05\pm0.27)$. Assuming *CPT* invariance they obtain the limit quoted above.

[2] GJESDAL 74B uses $K2\pi$, $K_{\mu3}$, and K_{e3} decay results, unitarity, and *CPT*. Calculates $|(\eta_{000})| = 0.26 \pm 0.20$. We convert to upper limit.

$\mathrm{Im}(\eta_{000}) = \mathrm{Im}(A(K^0_S \rightarrow \pi^0\pi^0\pi^0)/A(K^0_L \rightarrow \pi^0\pi^0\pi^0))$

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

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
−0.001±0.016 OUR AVERAGE					
0.000±0.009±0.013	4.9M	[1] LAI	05A	NA48	Assumes *CPT*
−0.05 ±0.12 ±0.05	17300	[2] ANGELOPO...	98B	CPLR	Assumes *CPT*

[1] LAI 05A assumes $\mathrm{Re}(\eta_{000})=\mathrm{Re}(\epsilon)=1.66 \times 10^{-3}$. The equivalent limit is $|\eta_{000}|_{CPT} < 0.025$ at 90% CL Without assuming *CPT* invariance, they obtain $\mathrm{Re}(\eta_{000})=-0.002 \pm 0.011 \pm 0.015$ and $\mathrm{Im}(\eta_{000})=-0.003 \pm 0.013 \pm 0.017$ 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 $\mathrm{Re}(\eta_{000}) = \mathrm{Re}(\epsilon) = 1.635 \times 10^{-3}$. Without assuming *CPT* invariance, they obtain $\mathrm{Re}(\eta_{000}) = 0.18 \pm 0.14 \pm 0.06$ and $\mathrm{Im}(\eta_{000}) = 0.15 \pm 0.20 \pm 0.03$.

$|\eta_{000}| = |A(K^0_S \rightarrow 3\pi^0)/A(K^0_L \rightarrow 3\pi^0)|$

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

CP asymmetry *A* in $K^0_S \rightarrow \pi^+\pi^- e^+ e^-$

VALUE (%)	DOCUMENT ID		TECN	COMMENT
−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

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

K^0_S REFERENCES

AAIJ	23AE	PR D108 L031102	R. Aaij *et al.*	(LHCb Collab.)
BABUSCI	23	JHEP 2302 098	D. Babusci *et al.*	(KLOE-2 Collab.)
AAIJ	20AE	PRL 125 231801	R. Aaij *et al.*	(LHCb Collab.)
BABUSCI	20	PL B804 135378	D. Babusci *et al.*	(KLOE-2 Collab.)
ANASTASI	18A	JHEP 1809 021	A. Anastasi *et al.*	(KLOE-2 Collab.)
PDG	18	PR D98 030001	M. Tanabashi *et al.*	(PDG Collab.)
AAIJ	17BQ	EPJ C77 678	R. Aaij *et al.*	(LHCb Collab.)
PDG	16	CP C40 100001	C. Patrignani *et al.*	(PDG Collab.)
AAIJ	13G	JHEP 1301 090	R. Aaij *et al.*	(LHCb Collab.)
BABUSCI	13C	PL B723 54	D. Babusci *et al.*	(KLOE-2 Collab.)
ABOUZAID	11	PR D83 092001	E. Abouzaid *et al.*	(FNAL KTeV Collab.)
AMBROSINO	11	EPJ C71 1604	F. Ambrosino *et al.*	(KLOE Collab.)
BATLEY	11	PL B694 301	J.R. Batley *et al.*	(CERN NA48/1 Collab.)
AMBROSINO	09A	PL B672 203	F. Ambrosino *et al.*	(KLOE Collab.)
AMBROSINO	08C	JHEP 0805 051	F. Ambrosino *et al.*	(KLOE Collab.)
ANDRE	07	ANP 322 2518	T. Andre	(EFI)
BATLEY	07D	PL B653 145	J.R. Batley *et al.*	(CERN NA48 Collab.)
AMBROSINO	06C	EPJ C48 767	F. Ambrosino *et al.*	(KLOE Collab.)
AMBROSINO	06E	PL B636 173	F. Ambrosino *et al.*	(KLOE Collab.)
AMBROSINO	05B	PL B619 61	F. Ambrosino *et al.*	(KLOE Collab.)
BATLEY	05	PL B630 31	J.R. Batley *et al.*	(NA48 Collab.)
LAI	05A	PL B610 165	A. Lai *et al.*	(CERN NA48 Collab.)
ALEXOPOU...	04A	PR D70 092007	T. Alexopoulos *et al.*	(FNAL KTeV Collab.)
BATLEY	04A	PL B599 197	J.R. Batley *et al.*	(NA48 Collab.)
LAI	04	PL B578 276	A. Lai *et al.*	(CERN NA48 Collab.)
PDG	04	PL B592 1	S. Eidelman *et al.*	(PDG Collab.)
ALAVI-HARATI	03	PR D67 012005	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
Also		PR D70 079904 (errat.)	A. Alavi-Harati *et al.*	(FNAL KTeV Collab.)
BATLEY	03	PL B576 43	J.R. Batley *et al.*	(CERN NA48 Collab.)
LAI	03	PL B551 7	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	03B	PL B556 105	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	03C	EPJ C30 33	A. Lai *et al.*	(CERN NA48 Collab.)
ALOISIO	02	PL B535 37	A. Aloisio *et al.*	(KLOE Collab.)
ALOISIO	02B	PL B538 21	A. Aloisio *et al.*	(KLOE Collab.)
LAI	02C	PL B537 28	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	01	PL B514 253	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	00	PL B493 29	A. Lai *et al.*	(CERN NA48 Collab.)
LAI	00B	PL B496 137	A. Lai *et al.*	(CERN NA48 Collab.)
PDG	00	EPJ C15 1	D.E. Groom *et al.*	(PDG Collab.)
ACHASOV	99D	PL B459 674	M.N. Achasov *et al.*	
AKHMETSHIN	99	PL B456 90	R.R. Akhmetshin *et al.*	(Novosibirsk CMD-2 Collab.)
ANGELOPO...	98B	PL B425 391	A. Angelopoulos *et al.*	(CPLEAR Collab.)
ANGELOPO...	98C	EPJ C5 389	A. Angelopoulos *et al.*	(CPLEAR Collab.)
PDG	98	EPJ C3 1	C. Caso *et al.*	(PDG Collab.)
ADLER	97B	PL B407 193	R. Adler *et al.*	(CPLEAR Collab.)
ANGELOPO...	97	PL B413 232	A. Angelopoulos *et al.*	(CPLEAR Collab.)
BERTANZA	97	ZPHY C73 629	L. Bertanza	(PISA, CERN, EDIN, MAINZ, ORSAY+)
ADLER	96D	PL B370 167	R. Adler *et al.*	(CPLEAR Collab.)
ADLER	96E	PL B374 313	R. Adler *et al.*	(CPLEAR Collab.)
ZOU	96	PL B369 362	Y. Zou *et al.*	(RUTG, MINN, MICH)
BARR	95B	PL B351 579	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
SCHWINGEN...	95	PRL 74 4376	B. Schwingenheuer *et al.*	(EFI, CHIC+)
BLICK	94	PL B334 234	A.M. Blick *et al.*	(SERP, JINR)
THOMSON	94	PL B337 411	G.B. Thomson *et al.*	(RUTG, MINN, MICH)
ZOU	94	PL B329 519	Y. Zou *et al.*	(RUTG, MINN, MICH)
BARR	93B	PL B304 381	G.D. Barr *et al.*	(CERN, EDIN, MAINZ, LALO+)
GIBBONS	93	PRL 70 1199	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
Also		PR D55 6625	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
RAMBERG	93	PRL 70 2525	E. Ramberg *et al.*	(FNAL E731 Collab.)
BALATS	89	SJNP 49 828	M.Y. Balats *et al.*	(ITEP)
		Translated from YAF 49 1332.		
GIBBONS	88	PRL 61 2661	L.K. Gibbons *et al.*	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt *et al.*	(CERN, EDIN, MAINZ+)
GROSSMAN	87	PRL 59 18	N. Grossman *et al.*	(MINN, MICH, RUTG)
BARMIN	86	SJNP 44 622	V.V. Barmin *et al.*	(ITEP)
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BARMIN	86B	NC 96A 159	V.V. Barmin *et al.*	(ITEP, PADO)
PDG	86B	PL 170B 130	M. Aguilar-Benitez *et al.*	(CERN, CIT+)
BARMIN	85	NC 85A 67	V.V. Barmin *et al.*	(ITEP, PADO)
Also		SJNP 41 759	V.V. Barmin *et al.*	(ITEP)
		Translated from YAF 41 1187.		
BARMIN	83	PL 128B 129	V.V. Barmin *et al.*	(ITEP, PADO)
Also		SJNP 39 269	V.V. Barmin *et al.*	(ITEP, PADO)
		Translated from YAF 39 428.		
ARONSON	82	PRL 48 1078	S.H. Aronson *et al.*	(BNL, CHIC, STAN+)
ARONSON	82B	PRL 48 1306	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
Also		PL 116B 73	E. Fischbach *et al.*	(PURD, BNL, CHIC)
Also		PR D28 476	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
Also		PR D28 495	S.H. Aronson *et al.*	(BNL, CHIC, PURD)
ARONSON	76	NC 32A 236	S.H. Aronson *et al.*	(WISC, EFI, UCSD+)
EVERHART	76	PR D14 661	G.C. Everhart *et al.*	(PENN)
TAUREG	76	PL 65B 92	H. Taureg *et al.*	(HEIDH, CERN, DORT)
BALDO-...	75	NC 25A 688	M. Baldo-Ceolin *et al.*	(PADO, WISC)
CARITHERS	75	PRL 34 1244	W.C.J. Carithers *et al.*	(COLU, NYU)
BOBISUT	74	LNC 11 646	F. Bobisut *et al.*	(PADO)
COWELL	74	PR D10 2083	P.L. Cowell *et al.*	(STON, COLU)
GEWENIGER	74B	PL 48B 487	C. Geweniger *et al.*	(CERN, HEIDH)
GJESDAL	74B	PL 52B 119	S. Gjesdal *et al.*	(CERN, HEIDH)
BURGUN	73	PL 46B 481	G. Burgun *et al.*	(SACL, CERN)
GJESDAL	73	PL 44B 217	S. Gjesdal *et al.*	(CERN, HEIDH)
HILL	73	PR D8 1290	D.G. Hill *et al.*	(BNL, CMU)
ALITTI	72	PL 39B 568	J. Alitti, E. Lesquoy, A. Muller	(SACL)
BURGUN	72	NP B50 194	G. Burgun *et al.*	(SACL, CERN, OSLO)
METCALF	72	PL 40B 703	M. Metcalf *et al.*	(CERN, IPN, WIEN)
MORSE	72B	PRL 28 388	R. Morse *et al.*	(COLO, PRIN, UMD)
NAGY	72	NP B47 94	E. Nagy, F. Telbisz, G. Vesztergombi	(BUDA)
Also		PL 30B 498	G. Bozoki *et al.*	(BUDA)
SKJEGGEST...	72	NP B48 343	O. Skjeggestad *et al.*	(OSLO, CERN, SACL)
BALTAY	71	PRL 27 1678	C. Baltay *et al.*	(COLU)
Also		Thesis Nevis 187	W.A. Cooper	(COLU)
MOFFETT	70	BAPS 15 512	R. Moffett *et al.*	(ROCH)
BOZOKI	69	PL 30B 498	G. Bozoki *et al.*	(BUDA)
DOYLE	69	Thesis UCRL 18139	J.C. Doyle	(LRL)
GOBBI	69	PRL 22 682	B. Gobbi *et al.*	(ROCH)
HYAMS	69B	PL 29B 521	B.D. Hyams *et al.*	(CERN, MPIM)
MORFIN	69	PRL 23 660	J.G. Morfin, D. Sinclair	(MICH)
DONALD	68B	PL 27B 58	R.A. Donald *et al.*	(LIVP, CERN, IPNP+)
HILL	68	PR 171 1418	D.G. Hill *et al.*	(BNL, CMU)
AUBERT	65	PL 17 59	B. Aubert *et al.*	(EPOL, ORSAY)
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