K^0

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

K^0 MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
497.648±0.022 OUR FIT					
497.648±0.022 OUR AVERAGE					
497.625±0.001±0.031	655k	LAI	02	NA48	K^0_L beam
497.661±0.033	3713	BARKOV	87B	CMD	$e^+e^- \to K^0_L K^0_S$
497.742±0.085	780	BARKOV	85B	CMD	$e^+e^- \to K^0_L K^0_S$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
497.44 ±0.50		FITCH	67	OSPK	
498.9 ±0.5	4500	BALTAY	66	HBC	K^0 from $\overline{p}p$
497.44 ±0.33	2223	KIM	65B	HBC	K^0 from $\overline{p}p$
498.1 ±0.4		CHRISTENS...	64	OSPK	

$m_{K^0} - m_{K^\pm}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.972±0.027 OUR FIT Error includes scale factor of 1.2.						
• • • We do not use the following data for averages, fits, limits, etc. • • •						
3.95 ±0.21	417	HILL	68B	DBC	+	$K^+ d \to K^0 pp$
3.90 ±0.25	9	BURNSTEIN	65	HBC	−	
3.71 ±0.35	7	KIM	65B	HBC	−	$K^- p \to n\overline{K}^0$
5.4 ±1.1		CRAWFORD	59	HBC	+	
3.9 ±0.6		ROSENFELD	59	HBC	−	

K^0 MEAN SQUARE CHARGE RADIUS

VALUE (fm^2)	EVTS	DOCUMENT ID		TECN	COMMENT
−0.077±0.010 OUR AVERAGE					
−0.077±0.007±0.011	5037	ABOUZAID	06	KTEV	$K^0_L \to \pi^+\pi^- e^+ e^-$
−0.090±0.021		LAI	03C	NA48	$K^0_L \to \pi^+\pi^- e^+ e^-$
−0.054±0.026		MOLZON	78		K_S regen. by electrons
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.087±0.046		BLATNIK	79		VMD + dispersion relations
−0.050±0.130		FOETH	69B		K_S regen. by electrons

T-VIOLATION PARAMETER IN K^0-$\overline{K}^0$ MIXING

The asymmetry $A_T = \frac{\Gamma(\overline{K}^0 \to K^0) - \Gamma(K^0 \to \overline{K}^0)}{\Gamma(\overline{K}^0 \to K^0) + \Gamma(K^0 \to \overline{K}^0)}$ must vanish if T invariance holds.

ASYMMETRY A_T IN K^0-$\overline{K}^0$ MIXING

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN
6.6±1.3±1.0	640k	[1] ANGELOPO...	98E	CPLR

[1] ANGELOPOULOS 98E measures the asymmetry $A_T = [\Gamma(\overline{K}^0_{t=0} \rightarrow e^+\pi^-\nu_{t=\tau}) - \Gamma(K^0_{t=0} \rightarrow e^-\pi^+\overline{\nu}_{t=\tau})]/[\Gamma(\overline{K}^0_{t=0} \rightarrow e^+\pi^-\nu_{t=\tau}) + \Gamma(K^0_{t=0} \rightarrow e^-\pi^+\overline{\nu}_{t=\tau})]$ as a function of the neutral-kaon eigentime τ. The initial strangeness of the neutral kaon is tagged by the charge of the accompanying charged kaon in the reactions $p\overline{p} \rightarrow K^-\pi^+K^0$ and $p\overline{p} \rightarrow K^+\pi^-\overline{K}^0$. The strangeness at the time of the decay is tagged by the lepton charge. The reported result is the average value of A_T over the interval $1\tau_S < \tau < 20\tau_S$. From this value of A_T ANGELOPOULOS 01B, assuming CPT invariance in the $e\pi\nu$ decay amplitude, determine the T-violating as ΔS=ΔS conserving parameter (for its definition, see Review below) $4\text{Re}(\epsilon) = (6.2 \pm 1.4 \pm 1.0) \times 10^{-3}$.

A REVIEW GOES HERE – Check our WWW List of Reviews

CP-VIOLATION PARAMETERS

Re(ϵ)

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*
1.596±0.013	[2] AMBROSINO	06H	KLOE
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.664±0.010	[3] LAI	05A	NA48

[2] AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: B($K^0_L \rightarrow \pi^+\pi^-$) in AMBROSINO 06F, B($K^0_S \rightarrow \pi^0\pi^0\pi^0$) in AMBROSINO 05B, the K^0_S-semileptonic charge asymmetry in AMBROSINO 06E, and K^0-semileptonic results in ANGELOPOULOS 98F.

[3] LAI 05A values are obtained through unitarity (Bell-Steinberger relations), improving determination of η_{000} and combining other data from PDG 04 and APOSTOLAKIS 99B.

CPT-VIOLATION PARAMETERS

In K^0-$\overline{K}^0$ mixing, if CP-violating interactions include a T conserving part then

$$|K_S\rangle = [|K_1\rangle + (\epsilon+\delta)|K_2\rangle]/\sqrt{1+|\epsilon+\delta|^2}$$
$$|K_L\rangle = [|K_2\rangle + (\epsilon-\delta)|K_1\rangle]/\sqrt{1+|\epsilon-\delta|^2}$$

where

$$|K_1\rangle = [|K^0\rangle + |\overline{K}^0\rangle]/\sqrt{2}$$
$$|K_2\rangle = [|K^0\rangle - |\overline{K}^0\rangle]/\sqrt{2}$$

and

$$|\overline{K}^0\rangle = CP|K^0\rangle.$$

The parameter δ specifies the CPT-violating part.

Estimates of δ are given below assuming the validity of the ΔS=ΔQ rule. See also THOMSON 95 for a test of CPT-symmetry conservation in K^0 decays using the Bell-Steinberger relation.

REAL PART OF δ

A nonzero value violates CPT invariance.

VALUE (units 10^{-4})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
2.3± 2.7		[4] AMBROSINO	06H	KLOE	

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

2.4± 2.8		[5] APOSTOLA...	99B	RVUE	
2.9± 2.6±0.6	1.3M	[6] ANGELOPO...	98F	CPLR	
180 ±200	6481	[7] DEMIDOV	95		$K_{\ell 3}$ reanalysis

[4] AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: B($K^0_L \rightarrow \pi^+\pi^-$) in AMBROSINO 06F, B($K^0_S \rightarrow \pi^0\pi^0\pi^0$) in AMBROSINO 05B, the K^0_S-semileptonic charge asymmetry in AMBROSINO 06E, and K^0-semileptonic results in ANGELOPOULOS 98F.

[5] APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

[6] ANGELOPOULOS 98F use ΔS=ΔQ. If ΔS=ΔQ is not assumed, they find Reδ=(3.0 ± 3.3 ± 0.6) × 10^{-4}.

[7] DEMIDOV 95 reanalyzes data from HART 73 and NIEBERGALL 74.

IMAGINARY PART OF δ

A nonzero value violates *CPT* invariance.

VALUE (units 10^{-5})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.4± 2.1		[8] AMBROSINO	06H	KLOE	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
− 0.2± 2.0		[9] LAI	05A	NA48	
2.4± 5.0		[10] APOSTOLA...	99B	RVUE	
− 90 ± 290 ±100	1.3M	[11] ANGELOPO...	98F	CPLR	
2100 ±3700	6481	[12] DEMIDOV	95		$K_{\ell 3}$ reanalysis

[8] AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: B($K^0_L \rightarrow \pi^+\pi^-$) in AMBROSINO 06F, B($K^0_S \rightarrow \pi^0\pi^0\pi^0$) in AMBROSINO 05B, the K^0_S-semileptonic charge asymmetry in AMBROSINO 06E, and K^0-semileptonic results in ANGELOPOULOS 98F.

[9] LAI 05A values are obtained through unitarity (Bell-Steinberger relations), improving determination of η_{000} and combining other data from PDG 04 and APOSTOLAKIS 99B.

[10] APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

[11] If ΔS=ΔQ is not assumed, ANGELOPOULOS 98F finds Imδ=($-15 \pm 23 \pm 3$) × 10^{-3}.

[12] DEMIDOV 95 reanalyzes data from HART 73 and NIEBERGALL 74.

Re(y)

A non-zero value would violate *CPT* invariance in $\Delta S = \Delta Q$ amplitude. Re(y) is the following combination of K_{e3} decay amplitudes:

$$\mathrm{Re(y)} = \mathrm{Re}\Big(\frac{A(\overline{K}^0 \rightarrow e^- \pi^+ \overline{\nu}_e)^* - A(K^0 \rightarrow e^+ \pi^- \nu_e)}{A(\overline{K}^0 \rightarrow e^- \pi^+ \overline{\nu}_e)^* + A(K^0 \rightarrow e^+ \pi^- \nu_e)} \Big)$$

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*		*TECN*
0.4±2.5	13k	[13] AMBROSINO	06E	KLOE
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.3±3.1		[14] APOSTOLA...	99B	CPLR

[13] They use the PDG 04 for the K^0_L semileptonic charge asymmetry and PDG 04 (*CP* review, *CPT* NOT ASSUMED) for Re(ϵ).

[14] Constrained by Bell-Steinberger (or unitarity) relation.

Re(x_)

A non-zero value would violate *CPT* invariance in decay amplitudes with $\Delta S \neq \Delta Q$. x_-, used here to define Re(x_-), and x_+, used below in the $\Delta S = \Delta Q$ section are the following combinations of K_{e3} decay amplitudes:

$$x_\pm = \frac{1}{2}\left(\frac{A(\overline{K}^0 \to \pi^- e^+ \nu_e)}{A(K^0 \to \pi^- e^+ \nu_e)} \pm \frac{A(K^0 \to \pi^+ e^- \overline{\nu}_e)^*}{A(\overline{K}^0 \to \pi^+ e^- \overline{\nu}_e)^*} \right).$$

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	COMMENT
−2.9± 2.0		[15] AMBROSINO	06H	KLOE	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.8± 2.5	13k	[16] AMBROSINO	06E	KLOE	
−0.5± 3.0		[17] APOSTOLA...	99B	CPLR	Strangeness tagged
2 ±13 ±3	650k	ANGELOPO...	98F	CPLR	Strangeness tagged

[15] AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: B($K_L^0 \to \pi^+\pi^-$) in AMBROSINO 06F, B($K_S^0 \to \pi^0\pi^0\pi^0$) in AMBROSINO 05B, the K_S^0-semileptonic charge asymmetry in AMBROSINO 06E, and K^0-semileptonic results in ANGELOPOULOS 98F.

[16] Uses PDG 04 for the K_L^0 semileptonic charge asymmetry and Re(δ) from CPLEAR, ANGELOPOULOS 98F.

[17] Constrained by Bell-Steinberger (or unitarity) relation.

$|m_{K^0} - m_{\overline{K}^0}| \,/\, m_{\text{average}}$

A test of *CPT* invariance. "Our Evaluation" is described in the "Tests of Conservation Laws" section. It assumes *CPT* invariance in the decay and neglects some contributions from decay channels other than $\pi\pi$.

VALUE	CL%	DOCUMENT ID		TECN
< 10^{-18} (CL = 90%) OUR EVALUATION				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$(-\ 3\pm4) \times 10^{-18}$		[18] ANGELOPO...	99B	RVUE

[18] ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR and other results.

$(\Gamma_{K^0} - \Gamma_{\overline{K}^0})/m_{\text{average}}$

A test of *CPT* invariance.

VALUE	DOCUMENT ID		TECN
$(7.8\pm8.4) \times 10^{-18}$	[19] ANGELOPO...	99B	RVUE

[19] ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR with other results. Correlated with $(m_{K^0} - m_{\overline{K}^0})\,/\,m_{\text{average}}$ with a correlation coefficient of −0.95.

TESTS OF $\Delta S = \Delta Q$ RULE

Re(x_+)

A non-zero value would violate the $\Delta S = \Delta Q$ rule in *CPT* conserving transitions. x_+ is defined above in the Re(x_-) section.

VALUE (units 10^{-3})	*EVTS*	*DOCUMENT ID*		*TECN*
-0.8 ± 3.1 OUR AVERAGE				
-0.5 ± 3.6	13k	[20] AMBROSINO	06E	KLOE
-1.8 ± 6.1		[21] ANGELOPO...	98D	CPLR

[20] Re(x_+) can be shown to be equal to the following combination of rates:

$$\mathrm{Re}(x_+) = \frac{1}{2}\,\frac{\Gamma(K^0_S \to \pi e \nu) - \Gamma(K^0_L \to \pi e \nu)}{\Gamma(K^0_S \to \pi e \nu) + \Gamma(K^0_L \to \pi e \nu)}$$

which is valid up to first order in terms violating *CPT* and/or the $\Delta S = \Delta Q$ rule.

[21] Obtained neglecting *CPT* violating amplitudes.

K^0 REFERENCES

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