



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

K^0 MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
497.611±0.013 OUR FIT		Error includes scale factor of 1.2.		
497.611±0.013 OUR AVERAGE		Error includes scale factor of 1.2.		
497.607±0.007±0.015	261k	¹ TOMARADZE 14		$\psi(2S) \rightarrow K_S^0 X$
497.583±0.005±0.020	35k	AMBROSINO 07B	KLOE	$e^+e^- \rightarrow K_L^0 K_S^0$
497.625±0.001±0.031	655k	LAI 02	NA48	K_L^0 beam
497.661±0.033	3713	BARKOV 87B	CMD	$e^+e^- \rightarrow K_L^0 K_S^0$
497.742±0.085	780	BARKOV 85B	CMD	$e^+e^- \rightarrow K_L^0 K_S^0$
● ● ● 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 $\bar{p}p$
497.44 ±0.33	2223	KIM 65B	HBC	K^0 from $\bar{p}p$
498.1 ±0.4		CHRISTENS... 64	OSPK	
¹ Obtained by analyzing CLEO-c data but not authored by the CLEO Collaboration.				

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

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
3.934±0.020 OUR FIT		Error includes scale factor of 1.6.			
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.95 ±0.21	417	HILL 68B	DBC	+	$K^+d \rightarrow K^0 pp$
3.90 ±0.25	9	BURNSTEIN 65	HBC	-	
3.71 ±0.35	7	KIM 65B	HBC	-	$K^-p \rightarrow n\bar{K}^0$
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	$K_L^0 \rightarrow \pi^+\pi^-e^+e^-$
-0.090±0.021		LAI 03C	NA48	$K_L^0 \rightarrow \pi^+\pi^-e^+e^-$
-0.054±0.026		MOLZON 78		K_S^0 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^0 regen. by electrons

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

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

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

<u>VALUE (units 10^{-3})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
$6.6 \pm 1.3 \pm 1.0$	640k	² ANGELOPO... 98E	CPLR

² ANGELOPOULOS 98E measures the asymmetry $A_T = [\Gamma(\bar{K}_{t=0}^0 \rightarrow e^+ \pi^- \nu_{t=\tau}) - \Gamma(K_{t=0}^0 \rightarrow e^- \pi^+ \bar{\nu}_{t=\tau})] / [\Gamma(\bar{K}_{t=0}^0 \rightarrow e^+ \pi^- \nu_{t=\tau}) + \Gamma(K_{t=0}^0 \rightarrow e^- \pi^+ \bar{\nu}_{t=\tau})]$ 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 $p\bar{p} \rightarrow K^- \pi^+ K^0$ and $p\bar{p} \rightarrow K^+ \pi^- \bar{K}^0$. 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 $\Delta S = \Delta S$ conserving parameter (for its definition, see Review below) $4\text{Re}(\epsilon) = (6.2 \pm 1.4 \pm 1.0) \times 10^{-3}$.

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CP-VIOLATION PARAMETERS

Re(ϵ)

<u>VALUE (units 10^{-3})</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
1.596 ± 0.013	³ AMBROSINO 06H	KLOE

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

1.664 ± 0.010	⁴ LAI	05A NA48
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³ AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ in AMBROSINO 06F, $B(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0)$ in AMBROSINO 05B, the K_S^0 -semileptonic charge asymmetry in AMBROSINO 06E, and K^0 -semileptonic results in ANGELOPOULOS 98F.

⁴ 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 $K^0-\bar{K}^0$ 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

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

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

and

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

The parameter δ specifies the CPT -violating part.

Estimates of δ are given below assuming the validity of the $\Delta S = \Delta Q$ 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.

<u>VALUE (units 10^{-4})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
2.51 ± 2.25		⁵ ABOUZAIID	11	KTEV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
2.3 ± 2.7		⁶ AMBROSINO	06H	KLOE
2.4 ± 2.8		⁷ APOSTOLA...	99B	RVUE
2.9 ± 2.6 ± 0.6	1.3M	⁸ ANGELOPO...	98F	CPLR
180 ± 200	6481	⁹ DEMIDOV	95	$K_{\ell 3}$ reanalysis

⁵ ABOUZAIID 11 uses Bell-Steinberger relations.

⁶ AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ in AMBROSINO 06F, $B(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0)$ in AMBROSINO 05B, the K_S^0 -semileptonic charge asymmetry in AMBROSINO 06E, and K^0 -semileptonic results in ANGELOPOULOS 98F.

⁷ APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

⁸ ANGELOPOULOS 98F use $\Delta S = \Delta Q$. If $\Delta S = \Delta Q$ is not assumed, they find $\text{Re}\delta = (3.0 \pm 3.3 \pm 0.6) \times 10^{-4}$.

⁹ DEMIDOV 95 reanalyzes data from HART 73 and NIEBERGALL 74.

IMAGINARY PART OF δ

A nonzero value violates *CPT* invariance.

<u>VALUE (units 10^{-5})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
– 1.5 ± 1.6		¹⁰ ABOUZAIID	11	KTEV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
0.4 ± 2.1		¹¹ AMBROSINO	06H	KLOE
– 0.2 ± 2.0		¹² LAI	05A	NA48
2.4 ± 5.0		¹³ APOSTOLA...	99B	RVUE
– 90 ± 290 ± 100	1.3M	¹⁴ ANGELOPO...	98F	CPLR
2100 ± 3700	6481	¹⁵ DEMIDOV	95	$K_{\ell 3}$ reanalysis

¹⁰ ABOUZAIID 11 uses Bell-Steinberger relations.

¹¹ AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ in AMBROSINO 06F, $B(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0)$ in AMBROSINO 05B, the K_S^0 -semileptonic charge asymmetry in AMBROSINO 06E, and K^0 -semileptonic results in ANGELOPOULOS 98F.

¹² 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.

¹³ APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

¹⁴ If $\Delta S = \Delta Q$ is not assumed, ANGELOPOULOS 98F finds $\text{Im}\delta = (-15 \pm 23 \pm 3) \times 10^{-3}$.

¹⁵ 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:

$$\text{Re}(y) = \text{Re} \left(\frac{A(\bar{K}^0 \rightarrow e^- \pi^+ \bar{\nu}_e)^* - A(K^0 \rightarrow e^+ \pi^- \nu_e)}{A(\bar{K}^0 \rightarrow e^- \pi^+ \bar{\nu}_e)^* + A(K^0 \rightarrow e^+ \pi^- \nu_e)} \right)$$

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN
0.4±2.5	13k	¹⁶ AMBROSINO 06E	KLOE

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

0.3±3.1		¹⁷ APOSTOLA... 99B	CPLR
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¹⁶ They use the PDG 04 for the K_L^0 semileptonic charge asymmetry and PDG 04 (*CP* review, *CPT* NOT ASSUMED) for Re(ϵ).

¹⁷ 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:

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

VALUE (units 10^{-3})	EVTS	DOCUMENT ID	TECN	COMMENT
-2.9± 2.0		¹⁸ AMBROSINO 06H	KLOE	

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

-0.8± 2.5	13k	¹⁹ AMBROSINO 06E	KLOE	
-0.5± 3.0		²⁰ APOSTOLA... 99B	CPLR	Strangeness tagged
2 ±13 ±3	650k	ANGELOPO... 98F	CPLR	Strangeness tagged

¹⁸ AMBROSINO 06H uses Bell-Steinberger relations with the following measurements: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ in AMBROSINO 06F, $B(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0)$ in AMBROSINO 05B, the K_S^0 -semileptonic charge asymmetry in AMBROSINO 06E, and K^0 -semileptonic results in ANGELOPOULOS 98F.

¹⁹ Uses PDG 04 for the K_L^0 semileptonic charge asymmetry and Re(δ) from CPLEAR, ANGELOPOULOS 98F.

²⁰ Constrained by Bell-Steinberger (or unitarity) relation.

$$\left| m_{K^0} - m_{\bar{K}^0} \right| / m_{\text{average}}$$

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
<6 × 10⁻¹⁹	90	PDG	12

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

(-3 ± 4) × 10 ⁻¹⁸		²¹ ANGELOPO... 99B	RVUE
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²¹ ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR and other results.

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

A test of *CPT* invariance.

VALUE	DOCUMENT ID	TECN
(7.8±8.4) × 10⁻¹⁸	²² ANGELOPO... 99B	RVUE

²² ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR with other results. Correlated with $(m_{K^0} - m_{\bar{K}^0}) / m_{\text{average}}$ 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
-0.9 ± 3.0 OUR AVERAGE			
-2 ± 10		²³ BATLEY 07D	NA48
-0.5 ± 3.6	13k	²⁴ AMBROSINO 06E	KLOE
-1.8 ± 6.1		²⁵ ANGELOPO... 98D	CPLR

²³ Result obtained from the measurement $\Gamma(K_S^0 \rightarrow \pi e \nu) / \Gamma(K_L^0 \rightarrow \pi e \nu) = 0.993 \pm 0.34$, neglecting possible *CPT* non-invariance and using PDG 06 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.

²⁴ Re(x₊) can be shown to be equal to the following combination of rates:

$$\text{Re}(x_+) = \frac{1}{2} \frac{\Gamma(K_S^0 \rightarrow \pi e \nu) - \Gamma(K_L^0 \rightarrow \pi e \nu)}{\Gamma(K_S^0 \rightarrow \pi e \nu) + \Gamma(K_L^0 \rightarrow \pi e \nu)}$$

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

²⁵ Obtained neglecting *CPT* violating amplitudes.

K⁰ REFERENCES

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