



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

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	

¹Obtained 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

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

¹ 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) $4\text{Re}(\epsilon) = (6.2 \pm 1.4 \pm 1.0) \times 10^{-3}$.

See the related review(s):

[CPT Invariance Tests in Neutral Kaon Decay](#)

CP-VIOLATION PARAMETERS

Re(ϵ)

VALUE (units 10^{-3})	DOCUMENT ID	TECN
1.596 ± 0.013	¹ AMBROSINO 06H	KLOE

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

1.664 ± 0.010	² LAI	05A NA48
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¹ 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.

² 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.

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
2.51 ± 2.25		¹ ABOUZOID 11	KTEV	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.3 ± 2.7		² AMBROSINO 06H	KLOE	
2.4 ± 2.8		³ APOSTOLA...	99B RVUE	
2.9 ± 2.6 ± 0.6	1.3M	⁴ ANGELOPO...	98F CPLR	
180 ± 200	6481	⁵ DEMIDOV 95		$K_{\ell 3}$ reanalysis

¹ ABOUZOID 11 uses Bell-Steinberger relations.

² 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.

³ APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

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

⁵ 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
– 1.5 ± 1.6		¹ ABOUZOID 11	KTEV	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.4 ± 2.1		² AMBROSINO 06H	KLOE	
– 0.2 ± 2.0		³ LAI 05A	NA48	
2.4 ± 5.0		⁴ APOSTOLA...	99B RVUE	
– 90 ± 290 ± 100	1.3M	⁵ ANGELOPO...	98F CPLR	
2100 ± 3700	6481	⁶ DEMIDOV 95		$K_{\ell 3}$ reanalysis

¹ ABOUZOID 11 uses Bell-Steinberger relations.

² 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.

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.

⁴ APOSTOLAKIS 99B assumes only unitarity and combines CPLEAR and other results.

⁵ If $\Delta S = \Delta Q$ is not assumed, ANGELOPOULOS 98F finds $\text{Im}\delta = (-15 \pm 23 \pm 3) \times 10^{-3}$.

⁶ 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. $\text{Re}(y)$ 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	¹ AMBROSINO 06E	KLOE

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

0.3 ± 3.1		² APOSTOLA... 99B	CPLR
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¹ They use the PDG 04 for the K_L^0 semileptonic charge asymmetry and PDG 04 (CPT review, CPT NOT ASSUMED) for $\text{Re}(\epsilon)$.

² 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 $\text{Re}(x_-)$, 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		¹ AMBROSINO 06H	KLOE	

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

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

¹ 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.

² Uses PDG 04 for the K_L^0 semileptonic charge asymmetry and $\text{Re}(\delta)$ from CPLEAR, ANGELOPOULOS 98F.

³ 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
$< 6 \times 10^{-19}$	90	PDG 12	

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

$(-3 \pm 4) \times 10^{-18}$		¹ ANGELOPO... 99B	RVUE
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¹ 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
$(7.8 \pm 8.4) \times 10^{-18}$	¹ ANGELOPO... 99B	RVUE

¹ 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 $\Delta S = \Delta Q$ RULERe(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		¹ BATLEY 07D	NA48
-0.5 ± 3.6	13k	² AMBROSINO 06E	KLOE
-1.8 ± 6.1		³ ANGELOPO... 98D	CPLR

¹ 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.

² 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.

³ Obtained neglecting *CPT* violating amplitudes.

 K^0 REFERENCES

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