



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

K⁰ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
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497.614 ± 0.024 OUR FIT Error includes scale factor of 1.6.

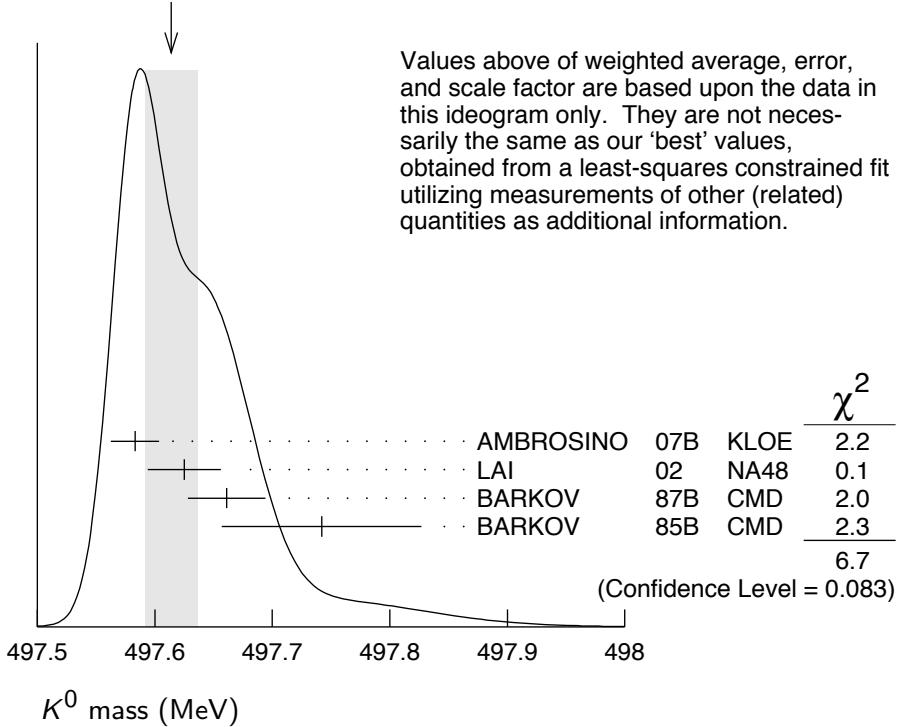
497.614 ± 0.022 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.

497.583 ± 0.005 ± 0.020	35k	AMBROSINO	07B	KLOE	e ⁺ e ⁻ → 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 ⁻ → K _L ⁰ K _S ⁰
497.742 ± 0.085	780	BARKOV	85B	CMD	e ⁺ e ⁻ → 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	

WEIGHTED AVERAGE
497.614 ± 0.022 (Error scaled by 1.5)



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

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>	
3.937±0.028 OUR FIT					Error includes scale factor of 1.8.	
					• • • We do not use the following data for averages, fits, limits, etc. • • •	
3.95 ±0.21	417	HILL	68B	DBC	+	$K^+ d \rightarrow K^0 p p$
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

<u>VALUE (fm²)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>	
-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 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 - \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±1.3±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) $4\text{Re}(\epsilon) = (6.2 \pm 1.4 \pm 1.0) \times 10^{-3}$.

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
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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.

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
2.3 ± 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: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ 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.

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

⁶ ANGELOPOULOS 98F use $\Delta S = \Delta Q$. If $\Delta S = \Delta Q$ is not assumed, they find $\text{Re}\delta = (3.0 \pm 3.3 \pm 0.6) \times 10^{-4}$.

⁷ 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>
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: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ 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.

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

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:

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

<u>VALUE (units 10^{-3})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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_L^0 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:

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

<u>VALUE (units 10^{-3})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
-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: $B(K_L^0 \rightarrow \pi^+ \pi^-)$ 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.
¹⁶ Uses PDG 04 for the K_L^0 semileptonic charge asymmetry and $\text{Re}(\delta)$ from CPLEAR, ANGELOPOULOS 98F.
¹⁷ Constrained by Bell-Steinberger (or unitarity) relation.

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

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 $\pi\pi$.

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
$<8 \times 10^{-19}$	90	PDG	10

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

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

¹⁸ 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.

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
$(7.8 \pm 8.4) \times 10^{-18}$	¹⁹ ANGELOPO... 99B	RVUE

¹⁹ ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR with other results. Correlated with $(m_{K^0} - m_{\bar{K}^0}) / m_{\text{average}}$ 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 $\text{Re}(x_-)$ section.

<u>VALUE (units 10^{-3})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
(-0.9 ± 3.0) OUR AVERAGE			
-2 ± 10		²⁰ BATLEY	07D NA48
-0.5 ± 3.6	13k	²¹ AMBROSINO	06E KLOE
-1.8 ± 6.1		²² ANGELOPO...	98D CPLR

²⁰ 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.

²¹ $\text{Re}(x_+)$ 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.

²² Obtained neglecting *CPT* violating amplitudes.

K^0 REFERENCES

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ABOUZAIID	06	PRL 96 101801	E. Abouzaid <i>et al.</i>	(KTeV Collab.)
AMBROSINO	06E	PL B636 173	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
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LAI	05A	PL B610 165	A. Lai <i>et al.</i>	(CERN NA48 Collab.)
PDG	04	PL B592 1	S. Eidelman <i>et al.</i>	(PDG Collab.)
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From YAF	58	1041.		
THOMSON	95	PR D51 1412	G.B. Thomson, Y. Zou	(RUTG)
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		Translated from YAF 46	1088.	
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FITCH	67	PR 164 1711	V.L. Fitch <i>et al.</i>	(PRIN)
BALTAY	66	PR 142 932	C. Baltay <i>et al.</i>	(YALE, BNL)
BURNSTEIN	65	PR 138 B895	R.A. Burnstein, H.A. Rubin	(UMD)
KIM	65B	PR 140B 1334	J.K. Kim, L. Kirsch, D. Miller	(COLU)
CHRISTENS...	64	PRL 13 138	J.H. Christenson <i>et al.</i>	(PRIN)
CRAWFORD	59	PRL 2 112	F.S. Crawford <i>et al.</i>	(LRL)
ROSENFELD	59	PRL 2 110	A.H. Rosenfeld, F.T. Solmitz, R.D. Tripp	(LRL)