TESTS OF CONSERVATION LAWS

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In keeping with the current interest in tests of conservation laws, we collect together a Table of experimental limits on all weak and electromagnetic decays, mass differences, and moments, and on a few reactions, whose observation would violate conservation laws. The Table is given only in the full *Review of Particle Physics*, not in the Particle Physics Booklet. For the benefit of Booklet readers, we include the best limits from the Table in the following text. Limits in this text are for CL=90% unless otherwise specified. The Table is in two parts: "Discrete Space-Time Symmetries," *i.e.*, C, P, T, CP, and CPT; and "Number Conservation Laws," *i.e.*, lepton, baryon, hadronic flavor, and charge conservation. The references for these data can be found in the the Particle Listings in the *Review*. A discussion of these tests follows.

CPT INVARIANCE

General principles of relativistic field theory require invariance under the combined transformation CPT. The simplest tests of CPT invariance are the equality of the masses and lifetimes of a particle and its antiparticle. The best test comes from the limit on the mass difference between K^0 and $\overline{K}^0$. Any such difference contributes to the CP-violating parameter ϵ. Assuming CPT invariance, ϕ_ϵ, the phase of ϵ should be very close to 44°. (See the review "CP Violation in K_L decay" in this edition.) In contrast, if the entire source of CP violation in K^0 decays were a $K^0 - \overline{K}^0$ mass difference, ϕ_ϵ would be $44° + 90°$.

Assuming that there is no other source of CPT violation than this mass difference, it is possible to deduce that[1]

$$m_{\overline{K}^0} - m_{K^0} \approx \frac{2(m_{K_L^0} - m_{K_S^0})\,|\eta|\,(\frac{2}{3}\phi_{+-} + \frac{1}{3}\phi_{00} - \phi_{\rm SW})}{\sin\phi_{\rm SW}} \ ,$$

where $\phi_{\rm SW} = (43.51 \pm 0.05)°$, the superweak angle. Using our best values of the CP-violation parameters, we get $|(m_{\overline{K}^0} - m_{K^0})/m_{K^0}| \leq 10^{-18}$

at CL=95%. Limits can also be placed on specific CPT-violating decay amplitudes. Given the small value of $(1 - |\eta_{00}/\eta_{+-}|)$, the value of $\phi_{00} - \phi_{+-}$ provides a measure of CPT violation in $K^0_L \rightarrow 2\pi$ decay. Results from CERN[1] and Fermilab[2] indicate no CPT-violating effect.

CP AND T INVARIANCE

Given CPT invariance, CP violation and T violation are equivalent. The original evidence for CP violation came from the measurement of $|\eta_{+-}|$ $= |A(K^0_L \rightarrow \pi^+\pi^-)/A(K^0_S \rightarrow \pi^+\pi^-)| = (2.288 \pm 0.014) \times 10^{-3}$. This could be explained in terms of K^0–$\overline{K}^0$ mixing, which also leads to the asymmetry $[\Gamma(K^0_L \rightarrow \pi^- e^+ \nu) - \Gamma(K^0_L \rightarrow \pi^+ e^- \overline{\nu})]/[\mathrm{sum}] = (0.333 \pm 0.014)\%$. Evidence for CP violation in the kaon decay amplitide comes from the measurement of $(1 - |\eta_{00}/\eta_{+-}|)/3 = Re(\epsilon'/\epsilon) = (1.67 \pm 0.26) \times 10^{-3}$. In the Standard Model much larger CP-violating effects are expected. The first of these, which is associated with B–$\overline{B}$ mixing, is the parameter $sin(2\beta)$ now measured quite accurately to be 0.731 ± 0.056. A number of other CP-violating observables are being measured in B decays and preliminary results are available. Direct tests of T violation are much more difficult; a measurement by CPLEAR of the difference between the oscillation probabilities of K^0 to $\overline{K^0}$ and $\overline{K^0}$ to K^0 is related to T violation [3]. Other searches for CP or T violation involve effects that are expected to be unobservable in the Standard Model. The most sensitive are probably the searches for an electric dipole moment of the neutron, measured to be $< 6 \times 10^{-26}$ e cm, and the electron $(0.07 \pm 0.07) \times 10^{-26}$ e cm. A nonzero value requires both P and T violation.

CONSERVATION OF LEPTON NUMBERS

Present experimental evidence and the standard electroweak theory are consistent with the absolute conservation of three separate lepton numbers: electron number L_e, muon number L_μ, and tau number L_τ, except for the effect of neutrino mixing associated with neutrino masses. Searches for violations are of the following types:

a) $\Delta L = 2$ for one type of charged lepton. The best limit comes from the search for neutrinoless double beta decay $(Z, A) \to (Z+2, A) + e^- + e^-$. The best laboratory limit is $t_{1/2} > 1.9 \times 10^{25}$ yr (CL=90%) for ^{76}Ge.

b) Conversion of one charged-lepton type to another. For purely leptonic processes, the best limits are on $\mu \to e\gamma$ and $\mu \to 3e$, measured as $\Gamma(\mu \to e\gamma)/\Gamma(\mu \to \text{all}) < 1.2 \times 10^{-11}$ and $\Gamma(\mu \to 3e)/\Gamma(\mu \to \text{all}) < 1.0 \times 10^{-12}$. For semileptonic processes, the best limit comes from the coherent conversion process in a muonic atom, $\mu^- + (Z, A) \to e^- + (Z, A)$, measured as $\Gamma(\mu^-\text{Ti} \to e^-\text{Ti})/\Gamma(\mu^-\text{Ti} \to \text{all}) < 4 \times 10^{-12}$. Of special interest is the case in which the hadronic flavor also changes, as in $K_L \to e\mu$ and $K^+ \to \pi^+ e^- \mu^+$, measured as $\Gamma(K_L \to e\mu)/\Gamma(K_L \to \text{all}) < 4.7 \times 10^{-12}$ and $\Gamma(K^+ \to \pi^+ e^- \mu^+)/\Gamma(K^+ \to \text{all}) < 2.8 \times 10^{-11}$. Limits on the conversion of τ into e or μ are found in τ decay and are much less stringent than those for $\mu \to e$ conversion, *e.g.*, $\Gamma(\tau \to \mu\gamma)/\Gamma(\tau \to \text{all}) < 1.1 \times 10^{-6}$ and $\Gamma(\tau \to e\gamma)/\Gamma(\tau \to \text{all}) < 2.7 \times 10^{-6}$.

c) Conversion of one type of charged lepton into another type of charged antilepton. The case most studied is $\mu^- + (Z, A) \to e^+ + (Z-2, A)$, the strongest limit being $\Gamma(\mu^-\text{Ti} \to e^+\text{Ca})/\Gamma(\mu^-\text{Ti} \to \text{all}) < 3.6 \times 10^{-11}$.

d) Neutrino oscillations. If neutrinos have mass, then it is expected even in the standard electroweak theory that the lepton numbers are not separately conserved, as a consequence of lepton mixing analogous to Cabibbo quark mixing. However, if the only source of lepton-number violation is the mixing of low-mass neutrinos then processes such as $\mu \to e\gamma$ are expected to have extremely small unobservable probabilities. For small neutrino masses, the lepton-number violation would be observed first in neutrino oscillations, which have been the subject of extensive experimental searches. Strong evidence for neutrino mixing has come from atmospheric and solar neutrinos. The SNO experiment has detected the total flux of neutrinos from the sun measured via neutral current interactions and found it greater than the flux of ν_e. This confirms previous indications of a deficit of ν_e and can be explained by oscillations with $\Delta(m^2) = (7.1^{+1.2}_{-0.6})\times 10^{-5}$ eV^2. Evidence for such oscillations for reactor $\overline{\nu}$ has been found by the KAMLAND detector. In addition, underground detectors observing neutrinos produced by cosmic rays in the atmosphere have found a factor of 2 deficiency of upward going ν_μ compared to downward. This provides compelling evidence for ν_μ disappearance, for which the most probable explanation is $\nu_\mu \to \nu_\tau$ oscillations with nearly maximal mixing and $\Delta(m^2)$ of the order 0.0013–0.0030 eV^2.

CONSERVATION OF HADRONIC FLAVORS

In strong and electromagnetic interactions, hadronic flavor is conserved, *i.e.* the conversion of a quark of one flavor (d, u, s, c, b, t) into a quark of another flavor is forbidden. In the Standard Model, the weak interactions violate these conservation laws in a manner described by the Cabibbo-Kobayashi-Maskawa mixing (see the section "Cabibbo-Kobayashi-Maskawa Mixing Matrix"). The way in which these conservation laws are violated is tested as follows:

(a) $\Delta S = \Delta Q$ rule. In the strangeness-changing semileptonic decay of strange particles, the strangeness change equals the change in charge of the hadrons. Tests come from limits on decay rates such as $\Gamma(\Sigma^+ \to ne^+\nu)/\Gamma(\Sigma^+ \to \text{all}) < 5\times 10^{-6}$, and from a detailed analysis of $K_L \to \pi e \nu$, which yields the parameter x, measured to be $(\text{Re}\, x, \text{Im}\, x) = (-0.002 \pm 0.006,\ 0.0012 \pm 0.0021)$. Corresponding rules are $\Delta C = \Delta Q$ and $\Delta B = \Delta Q$.

(b) Change of flavor by two units. In the Standard Model this occurs only in second-order weak interactions. The classic example is $\Delta S = 2$ via $K^0 - \overline{K}^0$ mixing, which is directly measured by $m(K_L) - m(K_S) = (3.483 \pm 0.006) \times 10^{-12}$ MeV. There is now evidence for $B^0 - \overline{B}^0$ mixing $(\Delta B = 2)$, with the corresponding mass difference between the eigenstates $(m_{B^0_{\rm H}} - m_{B^0_{\rm L}}) = (0.751 \pm 0.012)\Gamma_{B^0} = (3.304 \pm 0.045)\times 10^{-10}$ MeV, and for B^0_s–$\overline{B}^0_s$ mixing, with $(m_{B^0_{sH}} - m_{B^0_{sL}}) > 20.6\,\Gamma_{B^0_s}$ or $> 9\times 10^{-9}$ MeV

(CL=95%). For $D^0 - \overline{D}^0$ mixing $m_{D^0_H} - m_{D^0_L} < 5 \times 10^{-11}$ MeV. All results are consistent with the second-order calculations in the Standard Model.

(c) Flavor-changing neutral currents. In the Standard Model the neutral-current interactions do not change flavor. The low rate $\Gamma(K_L \to \mu^+\mu^-)/\Gamma(K_L \to \text{all}) = (7.23 \pm 0.14) \times 10^{-9}$ puts limits on such interactions; the nonzero value for this rate is attributed to a combination of the weak and electromagnetic interactions. The best test should come from $K^+ \to \pi^+\nu\overline{\nu}$, which occurs in the Standard Model only as a second-order weak process with a branching fraction of (0.4 to 1.2)$\times 10^{-10}$. Recent results, including observation of two events, yields $\Gamma(K^+ \to \pi^+\nu\overline{\nu})/\Gamma(K^+ \to \text{all}) = (1.6^{+1.8}_{-0.8})\times 10^{-10}$[4]. Limits for charm-changing or bottom-changing neutral currents are much less stringent: $\Gamma(D^0 \to \mu^+\mu^-)/\Gamma(D^0 \to \text{all}) < 4 \times 10^{-6}$ and $\Gamma(B^0 \to \mu^+\mu^-)/\Gamma(B^0 \to \text{all}) < 1.6 \times 10^{-7}$. One cannot isolate flavor-changing neutral current (FCNC) effects in non leptonic decays. For example, the FCNC transition $s \to d + (\overline{u} + u)$ is equivalent to the charged-current transition $s \to u + (\overline{u} + d)$. Tests for FCNC are therefore limited to hadron decays into lepton pairs. Such decays are expected only in second-order in the electroweak coupling in the Standard Model.

References

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TESTS OF DISCRETE SPACE-TIME SYMMETRIES

CHARGE CONJUGATION (C) INVARIANCE

$\Gamma(\pi^0 \to 3\gamma)/\Gamma_{total}$		$<3.1 \times 10^{-8}$, CL = 90%
η C-nonconserving decay parameters		
$\pi^+\pi^-\pi^0$ left-right asymmetry parameter		$(0.09 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ sextant asymmetry parameter		$(0.18 \pm 0.16) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ quadrant asymmetry parameter		$(-0.17 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\gamma$ left-right asymmetry parameter		$(0.9 \pm 0.4) \times 10^{-2}$
$\pi^+\pi^-\gamma$ parameter β (D-wave)		-0.02 ± 0.07 (S = 1.3)
$\Gamma(\eta \to 3\gamma)/\Gamma_{total}$		$<5 \times 10^{-4}$, CL = 95%
$\Gamma(\eta \to \pi^0 e^+ e^-)/\Gamma_{total}$	[a]	$<4 \times 10^{-5}$, CL = 90%
$\Gamma(\eta \to \pi^0 \mu^+ \mu^-)/\Gamma_{total}$	[a]	$<5 \times 10^{-6}$, CL = 90%
$\Gamma(\omega(782) \to \eta\pi^0)/\Gamma_{total}$		$<1 \times 10^{-3}$, CL = 90%
$\Gamma(\omega(782) \to 3\pi^0)/\Gamma_{total}$		$<3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \to \pi^0 e^+ e^-)/\Gamma_{total}$	[a]	$<1.4 \times 10^{-3}$, CL = 90%
$\Gamma(\eta'(958) \to \eta e^+ e^-)/\Gamma_{total}$	[a]	$<2.4 \times 10^{-3}$, CL = 90%
$\Gamma(\eta'(958) \to 3\gamma)/\Gamma_{total}$		$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \to \mu^+\mu^-\pi^0)/\Gamma_{total}$	[a]	$<6.0 \times 10^{-5}$, CL = 90%
$\Gamma(\eta'(958) \to \mu^+\mu^-\eta)/\Gamma_{total}$	[a]	$<1.5 \times 10^{-5}$, CL = 90%

PARITY (P) INVARIANCE

e electric dipole moment	$(0.07 \pm 0.07) \times 10^{-26}$ e cm
μ electric dipole moment	$(3.7 \pm 3.4) \times 10^{-19}$ e cm
$\mathrm{Re}(d_\tau)$	-0.22 to 0.45×10^{-16} e cm, CL = 95%
$\Gamma(\eta \to \pi^+\pi^-)/\Gamma_{total}$	$<3.3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta \to \pi^0\pi^0)/\Gamma_{total}$	$<4.3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta \to 4\pi^0)/\Gamma_{total}$	$<6.9 \times 10^{-7}$, CL = 90%
$\Gamma(\eta'(958) \to \pi^+\pi^-)/\Gamma_{total}$	$<2 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \to \pi^0\pi^0)/\Gamma_{total}$	$<9 \times 10^{-4}$, CL = 90%
p electric dipole moment	$<0.54 \times 10^{-23}$ e cm
n electric dipole moment	$<0.63 \times 10^{-25}$ e cm, CL = 90%
Λ electric dipole moment	$<1.5 \times 10^{-16}$ e cm, CL = 95%

TIME REVERSAL (T) INVARIANCE

Limits on e, μ, τ, p, n, and Λ electric dipole moments under Parity Invariance above are also tests of Time Reversal Invariance.

μ decay parameters		
transverse e^+ polarization normal to plane of μ spin, e^+ momentum		0.007 ± 0.023
α'/A		$(0 \pm 4) \times 10^{-3}$
β'/A		$(2 \pm 6) \times 10^{-3}$
P_T in $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$		$(-4 \pm 5) \times 10^{-3}$
P_T in $K^+ \rightarrow \mu^+ \nu_\mu \gamma$		$(-0.6 \pm 1.9) \times 10^{-2}$
Im(ξ) in $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$ decay (from transverse μ pol.)		-0.014 ± 0.014
asymmetry A_T in K^0-$\overline{K}^0$ mixing		$(6.6 \pm 1.6) \times 10^{-3}$
Im(ξ) in $K^0_{\mu 3}$ decay (from transverse μ pol.)		-0.007 ± 0.026
$n \rightarrow p e^- \overline{\nu}_e$ decay parameters		
ϕ_{AV}, phase of g_A relative to g_V	[b]	$(180.08 \pm 0.10)^\circ$
triple correlation coefficient D		$(-0.6 \pm 1.0) \times 10^{-3}$
triple correlation coefficient D for $\Sigma^- \rightarrow n e^- \overline{\nu}_e$		0.11 ± 0.10

CP INVARIANCE

Re(d^W_τ)	$<0.50 \times 10^{-17}$ e cm, CL = 95%
Im(d^W_τ)	$<1.1 \times 10^{-17}$ e cm, CL = 95%
$\Gamma(\eta \rightarrow \pi^+ \pi^-)/\Gamma_{total}$	$<3.3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta \rightarrow \pi^0 \pi^0)/\Gamma_{total}$	$<4.3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta \rightarrow 4\pi^0)/\Gamma_{total}$	$<6.9 \times 10^{-7}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^+ \pi^-)/\Gamma_{total}$	$<2 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^0 \pi^0)/\Gamma_{total}$	$<9 \times 10^{-4}$, CL = 90%
$K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$ rate difference/average	(0.07 ± 0.12)%
$K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$ rate difference/average	(0.0 ± 0.6)%
$K^\pm \rightarrow \pi^\pm \pi^0 \gamma$ rate difference/average	(0.9 ± 3.3)%
$(g_{\tau^+} - g_{\tau^-}) / (g_{\tau^+} + g_{\tau^-})$ for $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$	(-0.7 ± 0.5)%
$\Delta(K^\pm_{\pi\mu\mu}) = \dfrac{\Gamma(K^+_{\pi\mu\mu}) - \Gamma(K^-_{\pi\mu\mu})}{\Gamma(K^+_{\pi\mu\mu}) + \Gamma(K^-_{\pi\mu\mu})}$	-0.02 ± 0.12
Im(η_{+-0}) = Im(A($K^0_S \rightarrow \pi^+ \pi^- \pi^0$, CP-violating) / A($K^0_L \rightarrow \pi^+ \pi^- \pi^0$))	-0.002 ± 0.009
Im(η_{000}) = Im($A(K^0_S \rightarrow \pi^0 \pi^0 \pi^0)/A(K^0_L \rightarrow \pi^0 \pi^0 \pi^0)$)	-0.05 ± 0.13
CP asymmetry A in $K^0_S \rightarrow \pi^+ \pi^- e^+ e^-$	(-1 ± 4)%

$\Gamma(K^0_S \to 3\pi^0)/\Gamma_{\text{total}}$		$<1.4 \times 10^{-5}$, CL = 90%
linear coefficient j for $K^0_L \to \pi^+\pi^-\pi^0$		0.0012 ± 0.0008
quadratic coefficient f for $K^0_L \to \pi^+\pi^-\pi^0$		0.004 ± 0.006
$\lvert\epsilon'_{+-\gamma}\rvert/\epsilon$ for $K^0_L \to \pi^+\pi^-\gamma$		<0.3, CL = 90%
$\Gamma(K^0_L \to \pi^0\mu^+\mu^-)/\Gamma_{\text{total}}$	[c]	$<3.8 \times 10^{-10}$, CL = 90%
$\Gamma(K^0_L \to \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	[c]	$<5.1 \times 10^{-10}$, CL = 90%
$\Gamma(K^0_L \to \pi^0\nu\overline{\nu})/\Gamma_{\text{total}}$	[d]	$<5.9 \times 10^{-7}$, CL = 90%
$A_{CP}(K^0_S\pi^\pm)$ in $D^\pm \to K^0_S\pi^\pm$		-0.016 ± 0.017
$A_{CP}(K^0_S K^\pm)$ in $D^\pm \to K^0_S K^\pm$		0.07 ± 0.06
$A_{CP}(K^+K^-\pi^\pm)$ in $D^\pm \to K^+K^-\pi^\pm$		0.002 ± 0.011
$A_{CP}(K^\pm K^{*0})$ in $D^+ \to K^+\overline{K}^{*0}$, $D^- \to K^- K^{*0}$		-0.02 ± 0.05
$A_{CP}(\phi\pi^\pm)$ in $D^\pm \to \phi\pi^\pm$		-0.014 ± 0.033
$A_{CP}(\pi^+\pi^-\pi^\pm)$ in $D^\pm \to \pi^+\pi^-\pi^\pm$		-0.02 ± 0.04
$A_{CP}(K^+K^-)$ in D^0, $\overline{D}^0 \to K^+K^-$		0.005 ± 0.016
$A_{CP}(K^0_S K^0_S)$ in D^0, $\overline{D}^0 \to K^0_S K^0_S$		-0.23 ± 0.19
$A_{CP}(\pi^+\pi^-)$ in D^0, $\overline{D}^0 \to \pi^+\pi^-$		0.021 ± 0.026
$A_{CP}(\pi^0\pi^0)$ in D^0, $\overline{D}^0 \to \pi^0\pi^0$		0.00 ± 0.05
$A_{CP}(K^0_S\phi)$ in D^0, $\overline{D}^0 \to K^0_S\phi$		-0.03 ± 0.09
$A_{CP}(K^0_S\pi^0)$ in D^0, $\overline{D}^0 \to K^0_S\pi^0$		0.001 ± 0.013
$A_{CP}(K^\pm\pi^\mp)$ in $D^0 \to K^+\pi^-$, $\overline{D}^0 \to K^-\pi^+$		0.08 ± 0.09
$A_{CP}(K^\mp\pi^\pm\pi^0)$ in $D^0 \to K^-\pi^+\pi^0$, $\overline{D}^0 \to K^+\pi^-\pi^0$		-0.03 ± 0.09
$A_{CP}(K^\pm\pi^\mp\pi^0)$ in $D^0 \to K^+\pi^-\pi^0$, $\overline{D}^0 \to K^-\pi^+\pi^0$		$0.09^{+0.25}_{-0.22}$
$A_{CP}(B^+ \to J/\psi(1S)K^+)$		-0.007 ± 0.019
$A_{CP}(B^+ \to J/\psi(1S)\pi^+)$		-0.01 ± 0.13
$A_{CP}(B^+ \to \psi(2S)K^+)$		-0.037 ± 0.025
$A_{CP}(B^+ \to \overline{D}^0 K^+)$		0.04 ± 0.07
$A_{CP}(B^+ \to D_{CP(+1)}K^+)$		0.06 ± 0.19
$A_{CP}(B^+ \to D_{CP(-1)}K^+)$		-0.19 ± 0.18
$A_{CP}(B^+ \to \pi^+\pi^0)$		0.05 ± 0.15
$A_{CP}(B^+ \to K^+\pi^0)$		-0.10 ± 0.08
$A_{CP}(B^+ \to K^0_S\pi^+)$		0.03 ± 0.08 (S = 1.1)
$A_{CP}(B^+ \to \pi^+\pi^-\pi^+)$		-0.39 ± 0.35
$A_{CP}(B^+ \to \rho^+\rho^0)$		-0.09 ± 0.16
$A_{CP}(B^+ \to K^+\pi^-\pi^+)$		0.01 ± 0.08
$A_{CP}(B^+ \to K^+K^-K^+)$		0.02 ± 0.08
$A_{CP}(B^+ \to K^+\eta')$		0.009 ± 0.035
$A_{CP}(B^+ \to \omega\pi^+)$		-0.21 ± 0.19
$A_{CP}(B^+ \to \omega K^+)$		-0.21 ± 0.28

$A_{CP}(B^+ \to \phi K^+)$	0.03 ± 0.07
$A_{CP}(B^+ \to \phi K^*(892)^+)$	0.09 ± 0.15
$A_{CP}(B^+ \to \rho^0 K^*(892)^+)$	0.20 ± 0.31
$\mathrm{Re}(\epsilon_{B^0})/(1+\lvert\epsilon_{B^0}\rvert^2)$	$(0.5 \pm 3.1) \times 10^{-3}$
$A_{T/CP}$	0.005 ± 0.018
$A_{CP}\ (B^0 \to K^+ \pi^-)$	-0.09 ± 0.04
$A_{CP}(B^0 \to \rho^+ \pi^-)$	-0.18 ± 0.09
$A_{CP}(B^0 \to \rho^+ K^-)$	0.28 ± 0.19
$A_{CP}(B^0 \to K^*(892)^+ \pi^-)$	0.26 ± 0.35
$A_{CP}(B^0 \to K^*(892)^0 \phi)$	0.05 ± 0.10
$A_{CP}(B^0 \to D^*(2010)^+ D^-)$	-0.03 ± 0.12
$C_{\pi\pi}\ (B^0 \to \pi^+ \pi^-)$	-0.51 ± 0.23 (S = 1.2)
$S_{\pi\pi}\ (B^0 \to \pi^+ \pi^-)$	-0.5 ± 0.6 (S = 2.3)
$C_{\rho\pi}\ (B^0 \to \rho^+ \pi^-)$	0.36 ± 0.18
$S_{\rho\pi}\ (B^0 \to \rho^+ \pi^-)$	0.19 ± 0.24
$C_{\eta'(958)K}\ (B^0 \to \eta'(958) K^0_S)$	0.04 ± 0.13
$S_{\eta'(958)K}\ (B^0 \to \eta'(958) K^0_S)$	0.27 ± 0.21
$C_{\phi K^0_S}\ (B^0 \to \phi K^0_S)$	0.15 ± 0.30
$S_{\phi K^0_S}\ (B^0 \to \phi K^0_S)$	-1.0 ± 0.5
$C_{K^+ K^- K^0_S}\ (B^0 \to K^+ K^- K^0_S)$	0.17 ± 0.16
$S_{K^+ K^- K^0_S}\ (B^0 \to K^+ K^- K^0_S)$	-0.51 ± 0.26
$C_{D^*(2010)^- D^+}\ (B^0 \to D^*(2010)^- D^+)$	-0.2 ± 0.4
$S_{D^*(2010)^- D^+}\ (B^0 \to D^*(2010)^- D^+)$	-0.2 ± 0.7
$C_{D^*(2010)^+ D^-}\ (B^0 \to D^*(2010)^+ D^-)$	-0.5 ± 0.4
$S_{D^*(2010)^+ D^-}\ (B^0 \to D^*(2010)^+ D^-)$	-0.8 ± 0.8
$C_{J/\psi(1S)\pi^0}\ (B^0 \to J/\psi(1S)\pi^0)$	0.4 ± 0.4
$S_{J/\psi(1S)\pi^0}\ (B^0 \to J/\psi(1S)\pi^0)$	0.1 ± 0.5
$\Delta C_{\rho\pi}\ (B^0 \to \rho^+ \pi^-)$	0.28 ± 0.19
$\Delta S_{\rho\pi}\ (B^0 \to \rho^+ \pi^-)$	0.15 ± 0.25
$\lvert\lambda\rvert\ (B^0 \to c\overline{c} K^0)$	0.949 ± 0.045
$\lvert\lambda\rvert\ (B^0 \to D^{*+} D^{*-})$	0.75 ± 0.19
$\mathrm{Im}(\lambda)\ (B^0 \to D^{*+} D^{*-})$	0.05 ± 0.31
$A_{CP}(B \to K^*(892)\gamma)$	-0.01 ± 0.07
$A_{CP}(B \to s\gamma)$	-0.08 ± 0.11
$[\alpha_-(\Lambda) + \alpha_+(\overline{\Lambda})]\ /\ [\alpha_-(\Lambda) - \alpha_+(\overline{\Lambda})]$	0.012 ± 0.021
$\frac{[\alpha(\Xi^-)\alpha_-(\Lambda) - \alpha(\overline{\Xi}^+)\alpha_+(\overline{\Lambda})]}{[\alpha(\Xi^-)\alpha_-(\Lambda) + \alpha(\overline{\Xi}^+)\alpha_+(\overline{\Lambda})]}$	0.012 ± 0.014

$[\alpha(\Omega^- \to \Lambda K^-)+\alpha(\overline{\Omega}^+ \to \overline{\Lambda} K^+)]/2$	-0.004 ± 0.040

CP VIOLATION OBSERVED

charge asymmetry in $K^0_{\ell 3}$ decays		
δ_L = weighted average of $\delta_L(\mu)$ and $\delta_L(e)$		$(0.327 \pm 0.012)\%$
$\delta_L(\mu) = [\Gamma(\pi^- \mu^+ \nu_\mu) - \Gamma(\pi^+ \mu^- \overline{\nu}_\mu)]/\text{sum}$		$(0.304 \pm 0.025)\%$
$\delta_L(e) = [\Gamma(\pi^- e^+ \nu_e) - \Gamma(\pi^+ e^- \overline{\nu}_e)]/\text{sum}$		$(0.333 \pm 0.014)\%$
parameters for $K^0_L \to 2\pi$ decay		
$\lvert\eta_{00}\rvert = \lvert A(K^0_L \to 2\pi^0) / A(K^0_S \to 2\pi^0)\rvert$		$(2.276 \pm 0.014) \times 10^{-3}$
$\lvert\eta_{+-}\rvert = \lvert A(K^0_L \to \pi^+\pi^-) / A(K^0_S \to \pi^+\pi^-)\rvert$		$(2.288 \pm 0.014) \times 10^{-3}$
$\lvert\epsilon\rvert = (2\lvert\eta_{+-}\rvert + \lvert\eta_{00}\rvert)/3$		$(2.284 \pm 0.014) \times 10^{-3}$
$\lvert\eta_{00}/\eta_{+-}\rvert$	[e]	0.9950 ± 0.0008 (S = 1.6)
$\mathrm{Re}(\epsilon'/\epsilon) = (1-\lvert\eta_{00}/\eta_{+-}\rvert)/3$	[e]	$(1.67 \pm 0.26) \times 10^{-3}$ (S = 1.6)
Assuming *CPT*		
ϕ_{+-}, phase of η_{+-}		$(43.52 \pm 0.06)^\circ$ (S = 1.3)
ϕ_{00}, phase of η_{00}		$(43.50 \pm 0.06)^\circ$ (S = 1.3)
$\phi_\epsilon = (2\phi_{+-} + \phi_{00})/3$		$(43.51 \pm 0.05)^\circ$ (S = 1.2)
Not assuming *CPT*		
ϕ_{+-}, phase of η_{+-}		$(43.4 \pm 0.7)^\circ$ (S = 1.3)
ϕ_{00}, phase of η_{00}		$(43.7 \pm 0.8)^\circ$ (S = 1.2)
$\phi_\epsilon = (2\phi_{+-} + \phi_{00})/3$		$(43.5 \pm 0.7)^\circ$ (S = 1.3)
CP asymmetry *A* in $K^0_L \to \pi^+\pi^- e^+ e^-$		$(13.8 \pm 2.2)\%$
β_{CP} from $K^0_L \to e^+ e^- e^+ e^-$		-0.23 ± 0.09
γ_{CP} from $K^0_L \to e^+ e^- e^+ e^-$		-0.09 ± 0.09
parameters for $K^0_L \to \pi^+\pi^-\gamma$ decay		
$\lvert\eta_{+-\gamma}\rvert = \lvert A(K^0_L \to \pi^+\pi^-\gamma, CP \text{ violating})/A(K^0_S \to \pi^+\pi^-\gamma)\rvert$		$(2.35 \pm 0.07) \times 10^{-3}$
$\phi_{+-\gamma}$ = phase of $\eta_{+-\gamma}$		$(44 \pm 4)^\circ$
$\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma_{\text{total}}$		$(2.090 \pm 0.025) \times 10^{-3}$ (S = 1.1)
$\Gamma(K^0_L \to \pi^0\pi^0)/\Gamma_{\text{total}}$		$(9.32 \pm 0.12) \times 10^{-4}$ (S = 1.1)
Parameters for $B^0 \to J/\psi K^0_S$		
$\sin(2\beta)$		0.731 ± 0.056

CPT INVARIANCE

$(m_{W^+} - m_{W^-}) / m_{\text{average}}$	-0.002 ± 0.007
$(m_{e^+} - m_{e^-}) / m_{\text{average}}$	$<8 \times 10^{-9}$, CL = 90%
$\lvert q_{e^+} + q_{e^-}\rvert/e$	$<4 \times 10^{-8}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}}$	$(-0.5 \pm 2.1) \times 10^{-12}$
$(\tau_{\mu^+} - \tau_{\mu^-}) / \tau_{\text{average}}$	$(2 \pm 8) \times 10^{-5}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}}$	$(-2.6 \pm 1.6) \times 10^{-8}$
$(m_{\pi^+} - m_{\pi^-}) / m_{\text{average}}$	$(2 \pm 5) \times 10^{-4}$
$(\tau_{\pi^+} - \tau_{\pi^-}) / \tau_{\text{average}}$	$(6 \pm 7) \times 10^{-4}$
$(m_{K^+} - m_{K^-}) / m_{\text{average}}$	$(-0.6 \pm 1.8) \times 10^{-4}$
$(\tau_{K^+} - \tau_{K^-}) / \tau_{\text{average}}$	(0.11 ± 0.09)% (S = 1.2)
$K^{\pm} \rightarrow \mu^{\pm}\nu_{\mu}$ rate difference/average	(-0.5 ± 0.4)%
$K^{\pm} \rightarrow \pi^{\pm}\pi^0$ rate difference/average	[*f*] (0.8 ± 1.2)%
δ in $K^0 - \overline{K}^0$ mixing	
real part of δ	$(2.9 \pm 2.7) \times 10^{-4}$
imaginary part of δ	$(0.02 \pm 0.05) \times 10^{-3}$
$\lvert m_{K^0} - m_{\overline{K}^0}\rvert / m_{\text{average}}$	[*g*] $<10^{-18}$, CL = 90%
$(\Gamma_{K^0} - \Gamma_{\overline{K}^0})/m_{\text{average}}$	$(8 \pm 8) \times 10^{-18}$
phase difference $\phi_{00} - \phi_{+-}$	$(0.2 \pm 0.4)^{\circ}$
$\mathrm{Re}(\frac{2}{3}\eta_{+-} + \frac{1}{3}\eta_{00}) - \frac{\delta_L}{2}$	$(-3 \pm 35) \times 10^{-6}$
$A_{CPT}(K^{\mp}\pi^{\pm})$ in $D^0 \rightarrow K^-\pi^+$, $\overline{D}^0 \rightarrow K^+\pi^-$	0.008 ± 0.008
$\lvert m_p - m_{\overline{p}}\rvert/m_p$	[*h*] $<1.0 \times 10^{-8}$, CL = 90%
$(\lvert\frac{q_{\overline{p}}}{m_{\overline{p}}}\rvert - \frac{q_p}{m_p})/\frac{q_p}{m_p}$	$(-9 \pm 9) \times 10^{-11}$
$\lvert q_p + q_{\overline{p}}\rvert/e$	[*h*] $<1.0 \times 10^{-8}$, CL = 90%
$(\mu_p + \mu_{\overline{p}}) / \mu_p$	$(-2.6 \pm 2.9) \times 10^{-3}$
$(m_n - m_{\overline{n}})/ m_n$	$(9 \pm 5) \times 10^{-5}$
$(m_{\Lambda} - m_{\overline{\Lambda}}) / m_{\Lambda}$	$(-0.1 \pm 1.1) \times 10^{-5}$ (S = 1.6)
$(\tau_{\Lambda} - \tau_{\overline{\Lambda}}) / \tau_{\Lambda}$	-0.001 ± 0.009
$(\tau_{\Sigma^+} - \tau_{\overline{\Sigma}^-}) / \tau_{\Sigma^+}$	$(-0.6 \pm 1.2) \times 10^{-3}$
$(\mu_{\Sigma^+} + \mu_{\overline{\Sigma}^-}) / \mu_{\Sigma^+}$	0.014 ± 0.015
$(m_{\Xi^-} - m_{\overline{\Xi}^+}) / m_{\Xi^-}$	$(1.1 \pm 2.7) \times 10^{-4}$
$(\tau_{\Xi^-} - \tau_{\overline{\Xi}^+}) / \tau_{\Xi^-}$	0.02 ± 0.18
$(\mu_{\Xi^-} + \mu_{\overline{\Xi}^+}) / \lvert\mu_{\Xi^-}\rvert$	$+0.01 \pm 0.05$
$(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\Omega^-}$	$(-1 \pm 8) \times 10^{-5}$
$(\tau_{\Omega^-} - \tau_{\overline{\Omega}^+}) / \tau_{\Omega^-}$	-0.002 ± 0.040

TESTS OF NUMBER CONSERVATION LAWS

LEPTON FAMILY NUMBER

Lepton family number conservation means separate conservation of each of L_e, L_μ, L_τ.

$\Gamma(Z \to e^{\pm}\mu^{\mp})/\Gamma_{\text{total}}$	[i]	$<1.7 \times 10^{-6}$, CL = 95%
$\Gamma(Z \to e^{\pm}\tau^{\mp})/\Gamma_{\text{total}}$	[i]	$<9.8 \times 10^{-6}$, CL = 95%
$\Gamma(Z \to \mu^{\pm}\tau^{\mp})/\Gamma_{\text{total}}$	[i]	$<1.2 \times 10^{-5}$, CL = 95%
limit on $\mu^- \to e^-$ conversion		
$\sigma(\mu^-\,{}^{32}\text{S} \to e^-\,{}^{32}\text{S})$ / $\sigma(\mu^-\,{}^{32}\text{S} \to \nu_\mu\,{}^{32}\text{P}^*)$		$<7 \times 10^{-11}$, CL = 90%
$\sigma(\mu^-\,\text{Ti} \to e^-\,\text{Ti})$ / $\sigma(\mu^-\,\text{Ti} \to \text{capture})$		$<4.3 \times 10^{-12}$, CL = 90%
$\sigma(\mu^-\,\text{Pb} \to e^-\,\text{Pb})$ / $\sigma(\mu^-\,\text{Pb} \to \text{capture})$		$<4.6 \times 10^{-11}$, CL = 90%
limit on muonium $\to$ antimuonium conversion $R_g = G_C / G_F$		<0.0030, CL = 90%
$\Gamma(\mu^- \to e^-\nu_e\overline{\nu}_\mu)/\Gamma_{\text{total}}$	[j]	$<1.2 \times 10^{-2}$, CL = 90%
$\Gamma(\mu^- \to e^-\gamma)/\Gamma_{\text{total}}$		$<1.2 \times 10^{-11}$, CL = 90%
$\Gamma(\mu^- \to e^-e^+e^-)/\Gamma_{\text{total}}$		$<1.0 \times 10^{-12}$, CL = 90%
$\Gamma(\mu^- \to e^-2\gamma)/\Gamma_{\text{total}}$		$<7.2 \times 10^{-11}$, CL = 90%
$\Gamma(\tau^- \to e^-\gamma)/\Gamma_{\text{total}}$		$<2.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\gamma)/\Gamma_{\text{total}}$		$<1.1 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^0)/\Gamma_{\text{total}}$		$<3.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^0)/\Gamma_{\text{total}}$		$<4.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-K^0_S)/\Gamma_{\text{total}}$		$<9.1 \times 10^{-7}$, CL = 90%
$\Gamma(\tau^- \to \mu^-K^0_S)/\Gamma_{\text{total}}$		$<9.5 \times 10^{-7}$, CL = 90%
$\Gamma(\tau^- \to e^-\eta)/\Gamma_{\text{total}}$		$<8.2 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\eta)/\Gamma_{\text{total}}$		$<9.6 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\rho^0)/\Gamma_{\text{total}}$		$<2.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\rho^0)/\Gamma_{\text{total}}$		$<6.3 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-K^*(892)^0)/\Gamma_{\text{total}}$		$<5.1 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-K^*(892)^0)/\Gamma_{\text{total}}$		$<7.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\overline{K}^*(892)^0)/\Gamma_{\text{total}}$		$<7.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\overline{K}^*(892)^0)/\Gamma_{\text{total}}$		$<7.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\phi)/\Gamma_{\text{total}}$		$<6.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\phi)/\Gamma_{\text{total}}$		$<7.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-e^+e^-)/\Gamma_{\text{total}}$		$<2.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\mu^+\mu^-)/\Gamma_{\text{total}}$		$<1.8 \times 10^{-6}$, CL = 90%

$\Gamma(\tau^- \to e^+\mu^-\mu^-)/\Gamma_{\text{total}}$		$<1.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- e^+ e^-)/\Gamma_{\text{total}}$		$<1.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^+ e^- e^-)/\Gamma_{\text{total}}$		$<1.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\mu^+\mu^-)/\Gamma_{\text{total}}$		$<1.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^+\pi^-)/\Gamma_{\text{total}}$		$<2.2 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^+\pi^-)/\Gamma_{\text{total}}$		$<8.2 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^+K^-)/\Gamma_{\text{total}}$		$<6.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^-K^+)/\Gamma_{\text{total}}$		$<3.8 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-K^0_S K^0_S)/\Gamma_{\text{total}}$		$<2.2 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to e^-K^+K^-)/\Gamma_{\text{total}}$		$<6.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^+K^-)/\Gamma_{\text{total}}$		$<7.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^-K^+)/\Gamma_{\text{total}}$		$<7.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-K^0_S K^0_S)/\Gamma_{\text{total}}$		$<3.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-K^+K^-)/\Gamma_{\text{total}}$		$<1.5 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^0\pi^0)/\Gamma_{\text{total}}$		$<6.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^0\pi^0)/\Gamma_{\text{total}}$		$<1.4 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to e^-\eta\eta)/\Gamma_{\text{total}}$		$<3.5 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\eta\eta)/\Gamma_{\text{total}}$		$<6.0 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to e^-\pi^0\eta)/\Gamma_{\text{total}}$		$<2.4 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to \mu^-\pi^0\eta)/\Gamma_{\text{total}}$		$<2.2 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to e^-\,\text{light boson})/\Gamma_{\text{total}}$		$<2.7 \times 10^{-3}$, CL = 95%
$\Gamma(\tau^- \to \mu^-\,\text{light boson})/\Gamma_{\text{total}}$		$<5 \times 10^{-3}$, CL = 95%

LEPTON FAMILY NUMBER VIOLATION IN NEUTRINOS

Solar Neutrinos

$\theta_\odot = 32.5^\circ\, {}^{+2.4^\circ}_{-2.3^\circ}$

$\Delta m^2_\odot = \left(7.1^{+1.2}_{-0.6}\right) \times 10^{-5}$ eV^2

Atmospheric Neutrinos

$36^\circ < \theta_{\text{atm}} < 54^\circ$, CL = 90%

1.3×10^{-3} eV^2 $< \Delta m^2_{\text{atm}} <$ 3.0×10^{-3} eV^2, CL = 90%

$\Gamma(\pi^+ \to \mu^+\nu_e)/\Gamma_{\text{total}}$	[k]	$<8.0 \times 10^{-3}$, CL = 90%
$\Gamma(\pi^+ \to \mu^- e^+ e^+ \nu)/\Gamma_{\text{total}}$		$<1.6 \times 10^{-6}$, CL = 90%
$\Gamma(\pi^0 \to \mu^+ e^-)/\Gamma_{\text{total}}$		$<3.8 \times 10^{-10}$, CL = 90%
$\Gamma(\pi^0 \to \mu^- e^+)/\Gamma_{\text{total}}$		$<3.4 \times 10^{-9}$, CL = 90%
$\Gamma(\pi^0 \to \mu^+ e^- + \mu^- e^+)/\Gamma_{\text{total}}$		$<1.72 \times 10^{-8}$, CL = 90%
$\Gamma(\eta \to \mu^+ e^- + \mu^- e^+)/\Gamma_{\text{total}}$		$<6 \times 10^{-6}$, CL = 90%
$\Gamma(\eta'(958) \to e\mu)/\Gamma_{\text{total}}$		$<4.7 \times 10^{-4}$, CL = 90%
$\Gamma(K^+ \to \mu^-\nu e^+ e^+)/\Gamma_{\text{total}}$		$<2.0 \times 10^{-8}$, CL = 90%
$\Gamma(K^+ \to \mu^+\nu_e)/\Gamma_{\text{total}}$	[k]	$<4 \times 10^{-3}$, CL = 90%
$\Gamma(K^+ \to \pi^+\mu^+ e^-)/\Gamma_{\text{total}}$		$<2.8 \times 10^{-11}$, CL = 90%
$\Gamma(K^+ \to \pi^+\mu^- e^+)/\Gamma_{\text{total}}$		$<5.2 \times 10^{-10}$, CL = 90%
$\Gamma(K^0_L \to e^\pm\mu^\mp)/\Gamma_{\text{total}}$	[i]	$<4.7 \times 10^{-12}$, CL = 90%
$\Gamma(K^0_L \to e^\pm e^\pm\mu^\mp\mu^\mp)/\Gamma_{\text{total}}$	[i]	$<4.12 \times 10^{-11}$, CL = 90%

$\Gamma(K^0_L \to \pi^0 \mu^\pm e^\mp)/\Gamma_{total}$	[i]	$<6.2 \times 10^{-9}$, CL = 90%
$\Gamma(D^+ \to \pi^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<3.4 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \to K^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<6.8 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \mu^\pm e^\mp)/\Gamma_{total}$	[i]	$<8.1 \times 10^{-6}$, CL = 90%
$\Gamma(D^0 \to \pi^0 e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<8.6 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \eta e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \pi^+ \pi^- e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.5 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \rho^0 e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<4.9 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \omega e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.2 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- K^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \phi e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<3.4 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \overline{K}^0 e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- \pi^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<5.53 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \overline{K}^*(892)^0 e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<8.3 \times 10^{-5}$, CL = 90%
$\Gamma(D^+_s \to \pi^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<6.1 \times 10^{-4}$, CL = 90%
$\Gamma(D^+_s \to K^+ e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<6.3 \times 10^{-4}$, CL = 90%
$\Gamma(B^+ \to \pi^+ e^+ \mu^-)/\Gamma_{total}$		$<6.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to \pi^+ e^- \mu^+)/\Gamma_{total}$		$<6.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to K^+ e^+ \mu^-)/\Gamma_{total}$		$<8 \times 10^{-7}$, CL = 90%
$\Gamma(B^+ \to K^+ e^- \mu^+)/\Gamma_{total}$		$<6.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^+ e^\pm \mu^\mp)/\Gamma_{total}$		$<7.9 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to \rho^- e^+ \mu^+)/\Gamma_{total}$		$<3.3 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^- e^+ \mu^+)/\Gamma_{total}$		$<4.4 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<1.7 \times 10^{-7}$, CL = 90%
$\Gamma(B^0 \to K^0 e^\pm \mu^\mp)/\Gamma_{total}$		$<4.0 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to K^*(892)^0 e^\pm \mu^\mp)/\Gamma_{total}$		$<3.4 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to e^\pm \tau^\mp)/\Gamma_{total}$	[i]	$<5.3 \times 10^{-4}$, CL = 90%
$\Gamma(B^0 \to \mu^\pm \tau^\mp)/\Gamma_{total}$	[i]	$<8.3 \times 10^{-4}$, CL = 90%
$\Gamma(B \to e^\pm \mu^\mp s)/\Gamma_{total}$	[i]	$<2.2 \times 10^{-5}$, CL = 90%
$\Gamma(B \to \pi e^\pm \mu^\mp)/\Gamma_{total}$		$<1.6 \times 10^{-6}$, CL = 90%
$\Gamma(B \to \rho e^\pm \mu^\mp)/\Gamma_{total}$		$<3.2 \times 10^{-6}$, CL = 90%
$\Gamma(B \to K e^\pm \mu^\mp)/\Gamma_{total}$		$<1.6 \times 10^{-6}$, CL = 90%
$\Gamma(B \to K^*(892) e^\pm \mu^\mp)/\Gamma_{total}$		$<6.2 \times 10^{-6}$, CL = 90%
$\Gamma(B^0_s \to e^\pm \mu^\mp)/\Gamma_{total}$	[i]	$<6.1 \times 10^{-6}$, CL = 90%
$\Gamma(J/\psi(1S) \to e^\pm \mu^\mp)/\Gamma_{total}$		$<1.1 \times 10^{-6}$, CL = 90%

TOTAL LEPTON NUMBER

Violation of total lepton number conservation also implies violation of lepton family number conservation.

$\Gamma(Z \rightarrow p e)/\Gamma_{\text{total}}$		$<1.8 \times 10^{-6}$, CL = 95%
$\Gamma(Z \rightarrow p \mu)/\Gamma_{\text{total}}$		$<1.8 \times 10^{-6}$, CL = 95%
limit on $\mu^- \rightarrow e^+$ conversion		
$\sigma(\mu^- \, {}^{32}\text{S} \rightarrow e^+ \, {}^{32}\text{Si}^*)$ / $\sigma(\mu^- \, {}^{32}\text{S} \rightarrow \nu_\mu \, {}^{32}\text{P}^*)$		$<9 \times 10^{-10}$, CL = 90%
$\sigma(\mu^- \, {}^{127}\text{I} \rightarrow e^+ \, {}^{127}\text{Sb}^*)$ / $\sigma(\mu^- \, {}^{127}\text{I} \rightarrow \text{anything})$		$<3 \times 10^{-10}$, CL = 90%
$\sigma(\mu^- \, \text{Ti} \rightarrow e^+ \, \text{Ca})$ / $\sigma(\mu^- \, \text{Ti} \rightarrow \text{capture})$		$<3.6 \times 10^{-11}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^+ \pi^- \pi^-)/\Gamma_{\text{total}}$		$<1.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^+ \pi^- \pi^-)/\Gamma_{\text{total}}$		$<3.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^+ \pi^- K^-)/\Gamma_{\text{total}}$		$<2.1 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^+ K^- K^-)/\Gamma_{\text{total}}$		$<3.8 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^+ \pi^- K^-)/\Gamma_{\text{total}}$		$<7.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^+ K^- K^-)/\Gamma_{\text{total}}$		$<6.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \overline{p} \gamma)/\Gamma_{\text{total}}$		$<3.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \overline{p} \pi^0)/\Gamma_{\text{total}}$		$<1.5 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \rightarrow \overline{p} 2\pi^0)/\Gamma_{\text{total}}$		$<3.3 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \rightarrow \overline{p} \eta)/\Gamma_{\text{total}}$		$<8.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \overline{p} \pi^0 \eta)/\Gamma_{\text{total}}$		$<2.7 \times 10^{-5}$, CL = 90%
$t_{1/2}({}^{76}\text{Ge} \rightarrow {}^{76}\text{Se} + 2\, e^-)$		$>1.9 \times 10^{25}$ yr, CL = 90%
$\Gamma(\pi^+ \rightarrow \mu^+ \overline{\nu}_e)/\Gamma_{\text{total}}$	[k]	$<1.5 \times 10^{-3}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^- \mu^+ e^+)/\Gamma_{\text{total}}$		$<5.0 \times 10^{-10}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}$		$<6.4 \times 10^{-10}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	[k]	$<3.0 \times 10^{-9}$, CL = 90%
$\Gamma(K^+ \rightarrow \mu^+ \overline{\nu}_e)/\Gamma_{\text{total}}$	[k]	$<3.3 \times 10^{-3}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^0 e^+ \overline{\nu}_e)/\Gamma_{\text{total}}$		$<3 \times 10^{-3}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}$		$<9.6 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<4.8 \times 10^{-6}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^- e^+ \mu^+)/\Gamma_{\text{total}}$		$<5.0 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \rightarrow \rho^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<5.6 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \rightarrow K^- e^+ e^+)/\Gamma_{\text{total}}$		$<1.2 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \rightarrow K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<1.3 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \rightarrow K^- e^+ \mu^+)/\Gamma_{\text{total}}$		$<1.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^+ \rightarrow K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}$		$<8.5 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \pi^- \pi^- e^+ e^+ + \text{c.c.})/\Gamma_{\text{total}}$		$<1.12 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \pi^- \pi^- \mu^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$		$<2.9 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \rightarrow K^- \pi^- e^+ e^+ + \text{c.c.})/\Gamma_{\text{total}}$		$<2.06 \times 10^{-4}$, CL = 90%

$\Gamma(D^0 \to K^- \pi^- \mu^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<3.9 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- K^- e^+ e^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<1.52 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- K^- \mu^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<9.4 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \pi^- \pi^- e^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<7.9 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to K^- \pi^- e^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<2.18 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- K^- e^+ \mu^+ + \text{c.c.})/\Gamma_{\text{total}}$	$<5.7 \times 10^{-5}$, CL = 90%
$\Gamma(D_s^+ \to \pi^- e^+ e^+)/\Gamma_{\text{total}}$	$<6.9 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<2.9 \times 10^{-5}$, CL = 90%
$\Gamma(D_s^+ \to \pi^- e^+ \mu^+)/\Gamma_{\text{total}}$	$<7.3 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^- e^+ e^+)/\Gamma_{\text{total}}$	$<6.3 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-5}$, CL = 90%
$\Gamma(D_s^+ \to K^- e^+ \mu^+)/\Gamma_{\text{total}}$	$<6.8 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<1.4 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to \pi^- e^+ e^+)/\Gamma_{\text{total}}$	$<1.6 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<1.4 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to \pi^- e^+ \mu^+)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to \rho^- e^+ e^+)/\Gamma_{\text{total}}$	$<2.6 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to \rho^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<5.0 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^- e^+ e^+)/\Gamma_{\text{total}}$	$<1.0 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^- e^+ \mu^+)/\Gamma_{\text{total}}$	$<2.0 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^- e^+ e^+)/\Gamma_{\text{total}}$	$<2.8 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<8.3 \times 10^{-6}$, CL = 90%
$\Gamma(\Xi^- \to p \mu^- \mu^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Lambda_c^+ \to \Sigma^- \mu^+ \mu^+)/\Gamma_{\text{total}}$	$<7.0 \times 10^{-4}$, CL = 90%

BARYON NUMBER

$\Gamma(Z \to p e)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-6}$, CL = 95%
$\Gamma(Z \to p \mu)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-6}$, CL = 95%
$\Gamma(\tau^- \to \overline{p} \gamma)/\Gamma_{\text{total}}$	$<3.5 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \overline{p} \pi^0)/\Gamma_{\text{total}}$	$<1.5 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to \overline{p} 2\pi^0)/\Gamma_{\text{total}}$	$<3.3 \times 10^{-5}$, CL = 90%
$\Gamma(\tau^- \to \overline{p} \eta)/\Gamma_{\text{total}}$	$<8.9 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \overline{p} \pi^0 \eta)/\Gamma_{\text{total}}$	$<2.7 \times 10^{-5}$, CL = 90%
p mean life	$>2.1 \times 10^{29}$ years, CL = 90%

A few examples of proton or bound neutron decay follow. For limits on many other nucleon decay channels, see the Baryon Summary Table.

$\tau(N \to e^+ \pi)$	$>$ 158 (n), $>$ 1600 (p) $\times 10^{30}$ years, CL = 90%
$\tau(N \to \mu^+ \pi)$	$>$ 100 (n), $>$ 473 (p) $\times 10^{30}$ years, CL = 90%

$\tau(N \to e^+ K)$		> 17 (n), > 150 (p) $\times 10^{30}$ years, CL = 90%
$\tau(N \to \mu^+ K)$		> 26 (n), > 120 (p) $\times 10^{30}$ years, CL = 90%
limit on $n\overline{n}$ oscillations (free n)		$>0.86 \times 10^{8}$ s, CL = 90%
limit on $n\overline{n}$ oscillations (bound n)	[l]	$>1.2 \times 10^{8}$ s, CL = 90%

ELECTRIC CHARGE (Q)

$e \to \nu_e \gamma$ and astrophysical limits	[m]	$>4.6 \times 10^{26}$ yr, CL = 90%
$\Gamma(n \to p \nu_e \overline{\nu}_e)/\Gamma_{\text{total}}$		$<8 \times 10^{-27}$, CL = 68%

$\Delta S = \Delta Q$ RULE

Violations allowed in second-order weak interactions.

$\Gamma(K^+ \to \pi^+ \pi^+ e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$<1.2 \times 10^{-8}$, CL = 90%
$\Gamma(K^+ \to \pi^+ \pi^+ \mu^- \overline{\nu}_\mu)/\Gamma_{\text{total}}$	$<3.0 \times 10^{-6}$, CL = 95%
$x = \text{A}(\overline{K}^0 \to \pi^- \ell^+ \nu)/\text{A}(K^0 \to \pi^- \ell^+ \nu) = \text{A}(\Delta S{=}-\Delta Q)/\text{A}(\Delta S{=}\Delta Q)$	
real part of x	-0.002 ± 0.006
imaginary part of x	0.0012 ± 0.0021
$\Gamma(\Sigma^+ \to n \ell^+ \nu)/\Gamma(\Sigma^- \to n \ell^- \overline{\nu})$	<0.043
$\Gamma(\Sigma^+ \to n e^+ \nu_e)/\Gamma_{\text{total}}$	$<5 \times 10^{-6}$, CL = 90%
$\Gamma(\Sigma^+ \to n \mu^+ \nu_\mu)/\Gamma_{\text{total}}$	$<3.0 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^0 \to \Sigma^- e^+ \nu_e)/\Gamma_{\text{total}}$	$<9 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^0 \to \Sigma^- \mu^+ \nu_\mu)/\Gamma_{\text{total}}$	$<9 \times 10^{-4}$, CL = 90%

$\Delta S = 2$ FORBIDDEN

Allowed in second-order weak interactions.

$\Gamma(\Xi^0 \to p \pi^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^0 \to p e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-3}$
$\Gamma(\Xi^0 \to p \mu^- \overline{\nu}_\mu)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-3}$
$\Gamma(\Xi^- \to n \pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^- \to n e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$<3.2 \times 10^{-3}$, CL = 90%
$\Gamma(\Xi^- \to n \mu^- \overline{\nu}_\mu)/\Gamma_{\text{total}}$	$<1.5 \times 10^{-2}$, CL = 90%
$\Gamma(\Xi^- \to p \pi^- \pi^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^- \to p \pi^- e^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^- \to p \pi^- \mu^- \overline{\nu}_\mu)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Omega^- \to \Lambda \pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-4}$, CL = 90%

$\Delta S = 2$ VIA MIXING

Allowed in second-order weak interactions, e.g. mixing.

$m_{K_L^0} - m_{K_S^0}$		$(0.5292 \pm 0.0010) \times 10^{10}\ \hbar\ s^{-1}$ (S = 1.2)
$m_{K_L^0} - m_{K_S^0}$		$(3.483 \pm 0.006) \times 10^{-12}$ MeV

$\Delta C = 2$ VIA MIXING

Allowed in second-order weak interactions, e.g. mixing.

$\lvert m_{D_1^0} - m_{D_2^0} \rvert$	[n]	$<7 \times 10^{10}\ \hbar\ s^{-1}$, CL = 95%
$(\Gamma_{D_1^0} - \Gamma_{D_2^0})/\Gamma = 2y$		0.016 ± 0.010
$\Gamma(D^0 \to K^+ \ell^- \overline{\nu}_\ell (\text{via } \overline{D}^0))/\Gamma_{\text{total}}$		$<1.7 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^+ \pi^- (\text{via } \overline{D}^0))/\Gamma_{\text{total}}$		$<1.6 \times 10^{-5}$, CL = 95%
$\Gamma(D^0 \to K^+ \pi^- \pi^+ \pi^- (\text{via } \overline{D}^0))/\Gamma_{\text{total}}$		$<4 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \mu^- \text{ anything } (\text{via } \overline{D}^0))/\Gamma_{\text{total}}$		$<4 \times 10^{-4}$, CL = 90%

$\Delta B = 2$ VIA MIXING

Allowed in second-order weak interactions, e.g. mixing.

χ_d	0.186 ± 0.004
$\Delta m_{B^0} = m_{B_H^0} - m_{B_L^0}$	$(0.502 \pm 0.007) \times 10^{12}\ \hbar\ s^{-1}$
$x_d = \Delta m_{B^0}/\Gamma_{B^0}$	0.771 ± 0.012
$\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0}$	$>14.4 \times 10^{12}\ \hbar\ s^{-1}$, CL = 95%
$x_s = \Delta m_{B_s^0}/\Gamma_{B_s^0}$	>20.6, CL = 95%
χ_s	>0.49883, CL = 95%

$\Delta S = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(K^+ \to \pi^+ e^+ e^-)/\Gamma_{\rm total}$		$(2.88 \pm 0.13) \times 10^{-7}$
$\Gamma(K^+ \to \pi^+ \mu^+ \mu^-)/\Gamma_{\rm total}$		$(8.1 \pm 1.4) \times 10^{-8}$ (S = 2.7)
$\Gamma(K^+ \to \pi^+ \nu\overline{\nu})/\Gamma_{\rm total}$		$(1.6^{+1.8}_{-0.8}) \times 10^{-10}$
$\Gamma(K^+ \to \pi^+ \pi^0 \nu\overline{\nu})/\Gamma_{\rm total}$		$<4.3 \times 10^{-5}$, CL = 90%
$\Gamma(K^0_S \to \mu^+ \mu^-)/\Gamma_{\rm total}$		$<3.2 \times 10^{-7}$, CL = 90%
$\Gamma(K^0_S \to e^+ e^-)/\Gamma_{\rm total}$		$<1.4 \times 10^{-7}$, CL = 90%
$\Gamma(K^0_S \to \pi^0 e^+ e^-)/\Gamma_{\rm total}$	[*o*]	$(3.0^{+1.5}_{-1.2}) \times 10^{-9}$
$\Gamma(K^0_L \to \mu^+ \mu^-)/\Gamma_{\rm total}$		$(7.27 \pm 0.14) \times 10^{-9}$
$\Gamma(K^0_L \to e^+ e^-)/\Gamma_{\rm total}$		$(9^{+6}_{-4}) \times 10^{-12}$
$\Gamma(K^0_L \to \pi^+ \pi^- e^+ e^-)/\Gamma_{\rm total}$	[*p*]	$(3.11 \pm 0.19) \times 10^{-7}$
$\Gamma(K^0_L \to \pi^0 \pi^0 e^+ e^-)/\Gamma_{\rm total}$		$<6.6 \times 10^{-9}$, CL = 90%
$\Gamma(K^0_L \to \mu^+ \mu^- e^+ e^-)/\Gamma_{\rm total}$		$(2.69 \pm 0.27) \times 10^{-9}$
$\Gamma(K^0_L \to e^+ e^- e^+ e^-)/\Gamma_{\rm total}$		$(3.75 \pm 0.27) \times 10^{-8}$
$\Gamma(K^0_L \to \pi^0 \mu^+ \mu^-)/\Gamma_{\rm total}$		$<3.8 \times 10^{-10}$, CL = 90%
$\Gamma(K^0_L \to \pi^0 e^+ e^-)/\Gamma_{\rm total}$		$<5.1 \times 10^{-10}$, CL = 90%
$\Gamma(K^0_L \to \pi^0 \nu\overline{\nu})/\Gamma_{\rm total}$		$<5.9 \times 10^{-7}$, CL = 90%
$\Gamma(\Sigma^+ \to p e^+ e^-)/\Gamma_{\rm total}$		$<7 \times 10^{-6}$

$\Delta C = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(D^+ \to \pi^+ e^+ e^-)/\Gamma_{\rm total}$	$<5.2 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \to \pi^+ \mu^+ \mu^-)/\Gamma_{\rm total}$	$<8.8 \times 10^{-6}$, CL = 90%
$\Gamma(D^+ \to \rho^+ \mu^+ \mu^-)/\Gamma_{\rm total}$	$<5.6 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \gamma\gamma)/\Gamma_{\rm total}$	$<2.8 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to e^+ e^-)/\Gamma_{\rm total}$	$<6.2 \times 10^{-6}$, CL = 90%
$\Gamma(D^0 \to \mu^+ \mu^-)/\Gamma_{\rm total}$	$<4.1 \times 10^{-6}$, CL = 90%
$\Gamma(D^0 \to \pi^0 e^+ e^-)/\Gamma_{\rm total}$	$<4.5 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \pi^0 \mu^+ \mu^-)/\Gamma_{\rm total}$	$<1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \eta e^+ e^-)/\Gamma_{\rm total}$	$<1.1 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \eta \mu^+ \mu^-)/\Gamma_{\rm total}$	$<5.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \pi^+ \pi^- e^+ e^-)/\Gamma_{\rm total}$	$<3.73 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \rho^0 e^+ e^-)/\Gamma_{\rm total}$	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \pi^+ \pi^- \mu^+ \mu^-)/\Gamma_{\rm total}$	$<3.0 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \rho^0 \mu^+ \mu^-)/\Gamma_{\rm total}$	$<2.2 \times 10^{-5}$, CL = 90%

$\Gamma(D^0 \to \omega e^+ e^-)/\Gamma_{\text{total}}$		$<1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \omega \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<8.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- K^+ e^+ e^-)/\Gamma_{\text{total}}$		$<3.15 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \phi e^+ e^-)/\Gamma_{\text{total}}$		$<5.2 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to K^- K^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<3.3 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \phi \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<3.1 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to K^- \pi^+ e^+ e^-)/\Gamma_{\text{total}}$		$<3.85 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to K^- \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<3.59 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \pi^+ \pi^- \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<8.1 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^+ e^+ e^-)/\Gamma_{\text{total}}$		$<1.6 \times 10^{-3}$, CL = 90%
$\Gamma(D_s^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<3.6 \times 10^{-5}$, CL = 90%
$\Gamma(D_s^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<1.4 \times 10^{-3}$, CL = 90%
$\Gamma(\Lambda_c^+ \to p \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<3.4 \times 10^{-4}$, CL = 90%

$\Delta B = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(B^+ \to \pi^+ e^+ e^-)/\Gamma_{\text{total}}$		$<3.9 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<9.1 \times 10^{-3}$, CL = 90%
$\Gamma(B^+ \to K^+ e^+ e^-)/\Gamma_{\text{total}}$		$(6.3^{+1.9}_{-1.7}) \times 10^{-7}$
$\Gamma(B^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$(4.5^{+1.4}_{-1.2}) \times 10^{-7}$
$\Gamma(B^+ \to K^+ \ell^+ \ell^-)/\Gamma_{\text{total}}$	[q]	$(5.3 \pm 1.1) \times 10^{-7}$
$\Gamma(B^+ \to K^+ \overline{\nu} \nu)/\Gamma_{\text{total}}$		$<2.4 \times 10^{-4}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^+ e^+ e^-)/\Gamma_{\text{total}}$		$<4.6 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<2.2 \times 10^{-6}$, CL = 90%
$\Gamma(B^+ \to K^*(892)^+ \ell^+ \ell)/\Gamma_{\text{total}}$	[q]	$<2.2 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to \gamma \gamma)/\Gamma_{\text{total}}$		$<1.7 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to e^+ e^-)/\Gamma_{\text{total}}$		$<1.9 \times 10^{-7}$, CL = 90%
$\Gamma(B^0 \to \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<1.6 \times 10^{-7}$, CL = 90%
$\Gamma(B^0 \to K^0 e^+ e^-)/\Gamma_{\text{total}}$		$<5.4 \times 10^{-7}$, CL = 90%
$\Gamma(B^0 \to K^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$		$(5.6^{+2.9}_{-2.4}) \times 10^{-7}$
$\Gamma(B^0 \to K^0 \ell^+ \ell^-)/\Gamma_{\text{total}}$	[q]	$<6.8 \times 10^{-7}$, CL = 90%
$\Gamma(B^0 \to K^*(892)^0 e^+ e^-)/\Gamma_{\text{total}}$		$<2.4 \times 10^{-6}$, CL = 90%
$\Gamma(B^0 \to K^*(892)^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$		$(1.3 \pm 0.4) \times 10^{-6}$
$\Gamma(B^0 \to K^*(892)^0 \nu \overline{\nu})/\Gamma_{\text{total}}$		$<1.0 \times 10^{-3}$, CL = 90%
$\Gamma(B^0 \to K^*(892)^0 \ell^+ \ell^-)/\Gamma_{\text{total}}$	[q]	$(1.17 \pm 0.30) \times 10^{-6}$
$\Gamma(B \to s e^+ e^-)/\Gamma_{\text{total}}$		$(5.0 \pm 2.6) \times 10^{-6}$
$\Gamma(B \to s \mu^+ \mu^-)/\Gamma_{\text{total}}$		$(7.9^{+3.0}_{-2.6}) \times 10^{-6}$
$\Gamma(B \to s \ell^+ \ell^-)/\Gamma_{\text{total}}$	[q]	$(6.1^{+2.0}_{-1.8}) \times 10^{-6}$

$\Gamma(B \to K e^+ e^-)/\Gamma_{\text{total}}$	$(4.8^{+1.5}_{-1.3}) \times 10^{-7}$
$\Gamma(B \to K^*(892) e^+ e^-)/\Gamma_{\text{total}}$	$(1.5 \pm 0.5) \times 10^{-6}$
$\Gamma(B \to K \mu^+ \mu^-)/\Gamma_{\text{total}}$	$(4.8 \pm 1.2) \times 10^{-7}$
$\Gamma(B \to K^*(892) \mu^+ \mu^-)/\Gamma_{\text{total}}$	$(1.17^{+0.37}_{-0.33}) \times 10^{-6}$
$\Gamma(B \to K \ell^+ \ell^-)/\Gamma_{\text{total}}$	$(5.4 \pm 0.8) \times 10^{-7}$
$\Gamma(B \to K^*(892) \ell^+ \ell^-)/\Gamma_{\text{total}}$	$(1.05 \pm 0.20) \times 10^{-6}$
$\Gamma(\overline{b} \to \mu^+ \mu^- \text{anything})/\Gamma_{\text{total}}$	$<3.2 \times 10^{-4}$, CL = 90%
$\Gamma(B^0_s \to \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<2.0 \times 10^{-6}$, CL = 90%
$\Gamma(B^0_s \to e^+ e^-)/\Gamma_{\text{total}}$	$<5.4 \times 10^{-5}$, CL = 90%
$\Gamma(B^0_s \to \phi(1020) \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<4.7 \times 10^{-5}$, CL = 90%
$\Gamma(B^0_s \to \phi \nu \overline{\nu})/\Gamma_{\text{total}}$	$<5.4 \times 10^{-3}$, CL = 90%

$\Delta T = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(t \to Z q (q{=}u,c))/\Gamma_{\text{total}}$	[*r*]	$<13.7 \times 10^{-2}$, CL = 95%

NOTES

[*a*] *C* parity forbids this to occur as a single-photon process.

[*b*] Time-reversal invariance requires this to be 0° or 180°.

[*c*] Allowed by higher-order electroweak interactions.

[*d*] Violates *CP* in leading order. Test of direct *CP* violation since the indirect *CP*-violating and *CP*-conserving contributions are expected to be suppressed.

[*e*] $\text{Re}(\epsilon'/\epsilon) = \epsilon'/\epsilon$ to a very good approximation provided the phases satisfy *CPT* invariance.

[*f*] Neglecting photon channels. See, *e.g.*, A. Pais and S.B. Treiman, Phys. Rev. **D12**, 2744 (1975).

[*g*] Derived from measured values of ϕ_{+-}, ϕ_{00}, $|\eta|$, $|m_{K^0_L} - m_{K^0_S}|$, and $\tau_{K^0_S}$, as described in the introduction to "Tests of Conservation Laws."

[*h*] These two results are not independent, and both use the more precise measurement of $|q_{\overline{p}}/m_{\overline{p}}|/(q_p/m_p)$.

[*i*] The value is for the sum of the charge states or particle/antiparticle states indicated.

[*j*] A test of additive vs. multiplicative lepton family number conservation.

[*k*] Derived from an analysis of neutrino-oscillation experiments.

[*l*] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The first limit here is from reactor experiments with free neutrons.

[*m*] This is the best limit for the mode $e^- \rightarrow \nu\gamma$. The best limit for "electron disappearance" is 6.4×10^{24} yr.

[*n*] This $D_1^0 - D_2^0$ limit is inferred from the D^0-$\overline{D}^0$ mixing ratio $\Gamma(K^+\pi^-$ (via $\overline{D}^0$)) / $\Gamma(K^-\pi^+)$ near the end of the D^0 Listings.

[*o*] See the K_S^0 Particle Listings for the energy limits used in this measurement.

[*p*] See the K_L^0 Particle Listings for the energy limits used in this measurement.

[*q*] An ℓ indicates an e or a μ mode, not a sum over these modes.

[*r*] This limit is for $\Gamma(t \rightarrow Zq)/\Gamma(t \rightarrow Wb)$.