LEPTONS

e

$J = \frac{1}{2}$

Mass $m = (548.57990946 \pm 0.00000022) \times 10^{-6}$ u
Mass $m = 0.510998928 \pm 0.000000011$ MeV
$|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$, CL = 90%
$|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$
Magnetic moment anomaly
$(g-2)/2 = (1159.65218076 \pm 0.00000027) \times 10^{-6}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
Electric dipole moment $d < 0.87 \times 10^{-28}$ $e$cm, CL = 90%
Mean life $\tau > 4.6 \times 10^{26}$ yr, CL = 90% [a]

μ

$J = \frac{1}{2}$

Mass $m = 0.1134289267 \pm 0.0000000029$ u
Mass $m = 105.6583715 \pm 0.0000035$ MeV
Mean life $\tau = (2.1969811 \pm 0.0000022) \times 10^{-6}$ s
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.6384$ m
Magnetic moment anomaly $(g-2)/2 = (11659209 \pm 6) \times 10^{-10}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$
Electric dipole moment $d = (-0.1 \pm 0.9) \times 10^{-19}$ $e$cm

Decay parameters [b]

$\rho = 0.74979 \pm 0.00026$
$\eta = 0.057 \pm 0.034$
$\delta = 0.75047 \pm 0.00034$
$\xi P_\mu = 1.0009^{+0.0016}_{-0.0007}$ [c]
$\xi P_\mu \delta/\rho = 1.0018^{+0.0016}_{-0.0007}$ [c]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.98 \pm 0.04$
$\alpha/A = (0 \pm 4) \times 10^{-3}$
$\alpha'/A = (-10 \pm 20) \times 10^{-3}$
$\beta/A = (4 \pm 6) \times 10^{-3}$
$\beta'/A = (2 \pm 7) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

μ^+ modes are charge conjugates of the modes below.

μ^- DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$e^-\overline{\nu}_e\nu_\mu$		$\approx 100\%$		53
$e^-\overline{\nu}_e\nu_\mu\gamma$	[d]	(1.4 ± 0.4) %		53
$e^-\overline{\nu}_e\nu_\mu e^+e^-$	[e]	$(3.4\pm0.4)\times10^{-5}$		53
Lepton Family number (*LF*) violating modes				
$e^-\nu_e\overline{\nu}_\mu$	*LF*	[f] < 1.2 %	90%	53
$e^-\gamma$	*LF*	$< 5.7\times10^{-13}$	90%	53
$e^-e^+e^-$	*LF*	$< 1.0\times10^{-12}$	90%	53
$e^-2\gamma$	*LF*	$< 7.2\times10^{-11}$	90%	53

τ $J = \frac{1}{2}$

Mass $m = 1776.86 \pm 0.12$ MeV
$(m_{\tau^+} - m_{\tau^-})/m_{\text{average}} < 2.8\times10^{-4}$, CL = 90%
Mean life $\tau = (290.3 \pm 0.5)\times10^{-15}$ s
$c\tau = 87.03\ \mu$m
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
$\text{Re}(d_\tau) = -0.220$ to $0.45\times10^{-16}\ e$ cm, CL = 95%
$\text{Im}(d_\tau) = -0.250$ to $0.0080\times10^{-16}\ e$ cm, CL = 95%

Weak dipole moment

$\text{Re}(d_\tau^w) < 0.50\times10^{-17}\ e$ cm, CL = 95%
$\text{Im}(d_\tau^w) < 1.1\times10^{-17}\ e$ cm, CL = 95%

Weak anomalous magnetic dipole moment

$\text{Re}(\alpha_\tau^w) < 1.1\times10^{-3}$, CL = 95%
$\text{Im}(\alpha_\tau^w) < 2.7\times10^{-3}$, CL = 95%
$\tau^\pm \to \pi^\pm K_S^0\nu_\tau$ (RATE DIFFERENCE) / (RATE SUM) = (-0.36 ± 0.25)%

Decay parameters

See the τ Particle Listings for a note concerning τ-decay parameters.

$\rho(e \text{ or } \mu) = 0.745 \pm 0.008$
$\rho(e) = 0.747 \pm 0.010$
$\rho(\mu) = 0.763 \pm 0.020$
$\xi(e \text{ or } \mu) = 0.985 \pm 0.030$
$\xi(e) = 0.994 \pm 0.040$
$\xi(\mu) = 1.030 \pm 0.059$

$\eta(e \text{ or } \mu) = 0.013 \pm 0.020$
$\eta(\mu) = 0.094 \pm 0.073$
$(\delta\xi)(e \text{ or } \mu) = 0.746 \pm 0.021$
$(\delta\xi)(e) = 0.734 \pm 0.028$
$(\delta\xi)(\mu) = 0.778 \pm 0.037$
$\xi(\pi) = 0.993 \pm 0.022$
$\xi(\rho) = 0.994 \pm 0.008$
$\xi(a_1) = 1.001 \pm 0.027$
$\xi(\text{all hadronic modes}) = 0.995 \pm 0.007$

τ^+ modes are charge conjugates of the modes below. "$h^\pm$" stands for $\pi^\pm$ or $K^\pm$. "ℓ" stands for e or μ. "Neutrals" stands for γ's and/or π^0's.

τ^- DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Modes with one charged particle				
particle$^- \geq 0$ neutrals $\geq 0 K^0 \nu_\tau$ ("1-prong")		(85.35 ±0.07) %	S=1.3	–
particle$^- \geq 0$ neutrals $\geq 0 K^0_L \nu_\tau$		(84.72 ±0.08) %	S=1.4	–
$\mu^- \overline{\nu}_\mu \nu_\tau$	[g]	(17.41 ±0.04) %	S=1.1	885
$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[e]	(3.6 ±0.4) $\times 10^{-3}$		885
$e^- \overline{\nu}_e \nu_\tau$	[g]	(17.83 ±0.04) %		888
$e^- \overline{\nu}_e \nu_\tau \gamma$	[e]	(1.75 ±0.18) %		888
$h^- \geq 0 K^0_L \nu_\tau$		(12.05 ±0.06) %	S=1.2	883
$h^- \nu_\tau$		(11.53 ±0.06) %	S=1.2	883
$\pi^- \nu_\tau$	[g]	(10.83 ±0.06) %	S=1.2	883
$K^- \nu_\tau$	[g]	(7.00 ±0.10) $\times 10^{-3}$		820
$h^- \geq 1$ neutrals ν_τ		(37.11 ±0.10) %	S=1.2	–
$h^- \geq 1 \pi^0 \nu_\tau$ (ex. K^0)		(36.59 ±0.10) %	S=1.2	–
$h^- \pi^0 \nu_\tau$		(25.95 ±0.09) %	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g]	(25.52 ±0.09) %	S=1.1	878
$\pi^- \pi^0$ non-$\rho(770) \nu_\tau$		(3.0 ±3.2) $\times 10^{-3}$		878
$K^- \pi^0 \nu_\tau$	[g]	(4.30 ±0.15) $\times 10^{-3}$		814
$h^- \geq 2 \pi^0 \nu_\tau$		(10.88 ±0.11) %	S=1.2	–
$h^- 2\pi^0 \nu_\tau$		(9.53 ±0.11) %	S=1.1	862
$h^- 2\pi^0 \nu_\tau$ (ex. K^0)		(9.37 ±0.11) %	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g]	(9.30 ±0.11) %	S=1.1	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0), scalar		$< 9 \times 10^{-3}$	CL=95%	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0), vector		$< 7 \times 10^{-3}$	CL=95%	862
$K^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g]	(6.9 ±2.8) $\times 10^{-4}$	S=1.3	796
$h^- \geq 3 \pi^0 \nu_\tau$		(1.35 ±0.07) %	S=1.1	–

$h^- \geq 3\pi^0\nu_\tau$ (ex. K^0)		(1.27 ±0.07) %		S=1.1	–
$h^- 3\pi^0\nu_\tau$		(1.19 ±0.08) %			836
$\pi^- 3\pi^0\nu_\tau$ (ex.K^0)	[g]	(1.05 ±0.07) %			836
$K^- 3\pi^0\nu_\tau$ (ex.K^0, η)	[g]	(5.2 ±2.7)	$\times 10^{-4}$	S=1.3	765
$h^- 4\pi^0\nu_\tau$ (ex.K^0)		(1.6 ±0.4)	$\times 10^{-3}$		800
$h^- 4\pi^0\nu_\tau$ (ex.K^0,η)	[g]	(1.1 ±0.4)	$\times 10^{-3}$		800
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma\ \nu_\tau$		(1.563±0.034) %		S=1.2	820
$K^- \geq 1$ (π^0 or K^0 or γ) ν_τ		(8.63 ±0.33)	$\times 10^{-3}$	S=1.2	–

Modes with K^0's

K^0_S (particles)$^-\nu_\tau$		(9.1 ±0.5)	$\times 10^{-3}$	S=2.2	–
$h^- \overline{K}^0\nu_\tau$		(9.94 ±0.29)	$\times 10^{-3}$	S=1.8	812
$\pi^- \overline{K}^0\nu_\tau$	[g]	(8.45 ±0.28)	$\times 10^{-3}$	S=1.9	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-$)ν_τ		(5.4 ±2.1)	$\times 10^{-4}$		812
$K^- K^0\nu_\tau$	[g]	(1.49 ±0.05)	$\times 10^{-3}$		737
$K^- K^0 \geq 0\pi^0\nu_\tau$		(3.01 ±0.09)	$\times 10^{-3}$		737
$h^- \overline{K}^0\pi^0\nu_\tau$		(5.39 ±0.16)	$\times 10^{-3}$	S=1.1	794
$\pi^- \overline{K}^0\pi^0\nu_\tau$	[g]	(3.88 ±0.15)	$\times 10^{-3}$	S=1.1	794
$\overline{K}^0\rho^-\nu_\tau$		(2.2 ±0.5)	$\times 10^{-3}$		612
$K^- K^0\pi^0\nu_\tau$	[g]	(1.51 ±0.07)	$\times 10^{-3}$		685
$\pi^- \overline{K}^0 \geq 1\pi^0\nu_\tau$		(3.2 ±1.0)	$\times 10^{-3}$		–
$\pi^- \overline{K}^0\pi^0\pi^0\nu_\tau$		(2.6 ±2.4)	$\times 10^{-4}$		763
$K^- K^0\pi^0\pi^0\nu_\tau$		< 1.6	$\times 10^{-4}$	CL=95%	619
$\pi^- K^0\overline{K}^0\nu_\tau$		(1.7 ±0.5)	$\times 10^{-3}$	S=2.2	682
$\pi^- K^0_S K^0_S\nu_\tau$	[g]	(2.32 ±0.07)	$\times 10^{-4}$		682
$\pi^- K^0_S K^0_L\nu_\tau$	[g]	(1.2 ±0.5)	$\times 10^{-3}$	S=2.2	682
$\pi^- K^0\overline{K}^0\pi^0\nu_\tau$		(3.1 ±2.3)	$\times 10^{-4}$		614
$\pi^- K^0_S K^0_S\pi^0\nu_\tau$		(1.80 ±0.21)	$\times 10^{-5}$		614
$K^{*-} K^0\pi^0\nu_\tau \to \pi^- K^0_S K^0_S\pi^0\nu_\tau$		(1.08 ±0.21)	$\times 10^{-5}$		–
$f_1(1285)\pi^-\nu_\tau \to \pi^- K^0_S K^0_S\pi^0\nu_\tau$		(6.8 ±1.5)	$\times 10^{-6}$		–
$f_1(1420)\pi^-\nu_\tau \to \pi^- K^0_S K^0_S\pi^0\nu_\tau$		(2.4 ±0.8)	$\times 10^{-6}$		–
$\pi^- K^0_S K^0_L\pi^0\nu_\tau$		(3.1 ±1.2)	$\times 10^{-4}$		614
$K^- K^0_S K^0_S\nu_\tau$		< 6.3	$\times 10^{-7}$	CL=90%	466
$K^- K^0_S K^0_S\pi^0\nu_\tau$		< 4.0	$\times 10^{-7}$	CL=90%	337
$K^0 h^+ h^- h^- \geq 0$ neutrals ν_τ		< 1.7	$\times 10^{-3}$	CL=95%	760
$K^0 h^+ h^- h^-\nu_\tau$		(2.3 ±2.0)	$\times 10^{-4}$		760

Modes with three charged particles

$h^-h^-h^+ \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$		(15.19 ±0.08) %		S=1.4	861
$h^-h^-h^+ \geq 0$ neutrals ν_τ (ex. $K^0_S \to \pi^+\pi^-$) ("3-prong")		(14.57 ±0.07) %		S=1.3	861
$h^-h^-h^+\nu_\tau$		(9.80 ±0.06) %		S=1.2	861
$h^-h^-h^+\nu_\tau$(ex.K^0)		(9.46 ±0.06) %		S=1.2	861
$h^-h^-h^+\nu_\tau$(ex.K^0,ω)		(9.43 ±0.06) %		S=1.2	861
$\pi^-\pi^+\pi^-\nu_\tau$		(9.31 ±0.06) %		S=1.1	861
$\pi^-\pi^+\pi^-\nu_\tau$(ex.K^0)		(9.02 ±0.06) %		S=1.1	861
$\pi^-\pi^+\pi^-\nu_\tau$(ex.K^0), non-axial vector		< 2.4	%	CL=95%	861
$\pi^-\pi^+\pi^-\nu_\tau$(ex.K^0,ω)	[g]	(8.99 ±0.06) %		S=1.1	861
$h^-h^-h^+ \geq 1$ neutrals ν_τ		(5.38 ±0.07) %		S=1.3	–
$h^-h^-h^+ \geq 1\pi^0\nu_\tau$(ex. K^0)		(5.09 ±0.06) %		S=1.2	–
$h^-h^-h^+\pi^0\nu_\tau$		(4.75 ±0.06) %		S=1.2	834
$h^-h^-h^+\pi^0\nu_\tau$(ex.K^0)		(4.57 ±0.06) %		S=1.2	834
$h^-h^-h^+\pi^0\nu_\tau$(ex. K^0, ω)		(2.79 ±0.08) %		S=1.2	834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$		(4.61 ±0.06) %		S=1.2	834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$)		(4.48 ±0.06) %		S=1.2	834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$)	[g]	(2.70 ±0.08) %		S=1.2	834
$h^-h^-h^+ \geq 2\pi^0\nu_\tau$(ex. K^0)		(5.21 ±0.32)	$\times 10^{-3}$		–
$h^-h^-h^+2\pi^0\nu_\tau$		(5.08 ±0.32)	$\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$(ex.K^0)		(4.98 ±0.32)	$\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$(ex.K^0,ω,η)	[g]	(1.0 ±0.4)	$\times 10^{-3}$		797
$h^-h^-h^+3\pi^0\nu_\tau$	[g]	(2.3 ±0.7)	$\times 10^{-4}$	S=1.3	749
$2\pi^-\pi^+3\pi^0\nu_\tau$(ex.$K^0$)		(2.1 ±0.4)	$\times 10^{-4}$		749
$2\pi^-\pi^+3\pi^0\nu_\tau$(ex.$K^0$, η, $f_1(1285)$)		(1.7 ±0.4)	$\times 10^{-4}$		–
$2\pi^-\pi^+3\pi^0\nu_\tau$(ex.$K^0$, η, ω, $f_1(1285)$)		< 5.8	$\times 10^{-5}$	CL=90%	–
$K^-h^+h^- \geq 0$ neutrals ν_τ		(6.29 ±0.23)	$\times 10^{-3}$	S=1.7	794
$K^-h^+\pi^-\nu_\tau$(ex.K^0)		(4.38 ±0.19)	$\times 10^{-3}$	S=2.7	794
$K^-h^+\pi^-\pi^0\nu_\tau$(ex.K^0)		(8.7 ±1.2)	$\times 10^{-4}$	S=1.1	763
$K^-\pi^+\pi^- \geq 0$ neutrals ν_τ		(4.79 ±0.20)	$\times 10^{-3}$	S=1.4	794
$K^-\pi^+\pi^- \geq 0\pi^0\nu_\tau$(ex.$K^0$)		(3.75 ±0.19)	$\times 10^{-3}$	S=1.5	794
$K^-\pi^+\pi^-\nu_\tau$		(3.45 ±0.15)	$\times 10^{-3}$	S=2.2	794
$K^-\pi^+\pi^-\nu_\tau$(ex.K^0)	[g]	(2.94 ±0.15)	$\times 10^{-3}$	S=2.2	794
$K^-\rho^0\nu_\tau \to K^-\pi^+\pi^-\nu_\tau$		(1.4 ±0.5)	$\times 10^{-3}$		–
$K^-\pi^+\pi^-\pi^0\nu_\tau$		(1.33 ±0.12)	$\times 10^{-3}$		763
$K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$)		(8.1 ±1.2)	$\times 10^{-4}$		763

$K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\eta$)	[g]	(7.8	±1.2)	$\times 10^{-4}$		763
$K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$)		(3.7	±0.9)	$\times 10^{-4}$		763
$K^-\pi^+K^- \geq 0$ neut. ν_τ		< 9		$\times 10^{-4}$	CL=95%	685
$K^-K^+\pi^- \geq 0$ neut. ν_τ		(1.50	±0.06)	$\times 10^{-3}$	S=1.8	685
$K^-K^+\pi^-\nu_\tau$	[g]	(1.44	±0.05)	$\times 10^{-3}$	S=1.9	685
$K^-K^+\pi^-\pi^0\nu_\tau$	[g]	(6.1	±2.5)	$\times 10^{-5}$	S=1.4	618
$K^-K^+K^-\nu_\tau$		(2.1	±0.8)	$\times 10^{-5}$	S=5.4	472
$K^-K^+K^-\nu_\tau$(ex. ϕ)		< 2.5		$\times 10^{-6}$	CL=90%	–
$K^-K^+K^-\pi^0\nu_\tau$		< 4.8		$\times 10^{-6}$	CL=90%	345
$\pi^-K^+\pi^- \geq 0$ neut. ν_τ		< 2.5		$\times 10^{-3}$	CL=95%	794
$e^-e^-e^+\overline{\nu}_e\nu_\tau$		(2.8	±1.5)	$\times 10^{-5}$		888
$\mu^-e^-e^+\overline{\nu}_\mu\nu_\tau$		< 3.6		$\times 10^{-5}$	CL=90%	885

Modes with five charged particles

$3h^-2h^+ \geq 0$ neutrals ν_τ ("5-prong")		(1.02	±0.04)	$\times 10^{-3}$	S=1.1	794
$3h^-2h^+\nu_\tau$(ex.K^0)	[g]	(8.39	±0.35)	$\times 10^{-4}$	S=1.1	794
$3\pi^-2\pi^+\nu_\tau$(ex.K^0, ω)		(8.3	±0.4)	$\times 10^{-4}$		794
$3\pi^-2\pi^+\nu_\tau$(ex.K^0, ω, $f_1(1285)$)		(7.7	±0.4)	$\times 10^{-4}$		–
$K^-2\pi^-2\pi^+\nu_\tau$		< 2.4		$\times 10^{-6}$	CL=90%	716
$K^+3\pi^-\pi^+\nu_\tau$		< 5.0		$\times 10^{-6}$	CL=90%	716
$K^+K^-2\pi^-\pi^+\nu_\tau$		< 4.5		$\times 10^{-7}$	CL=90%	528
$3h^-2h^+\pi^0\nu_\tau$(ex.K^0)	[g]	(1.78	±0.27)	$\times 10^{-4}$		746
$3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$)		(1.65	±0.10)	$\times 10^{-4}$		746
$3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$, η, $f_1(1285)$)		(1.11	±0.10)	$\times 10^{-4}$		–
$3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$, η, ω, $f_1(1285)$)		(3.6	±0.9)	$\times 10^{-5}$		–
$K^-2\pi^-2\pi^+\pi^0\nu_\tau$		< 1.9		$\times 10^{-6}$	CL=90%	657
$K^+3\pi^-\pi^+\pi^0\nu_\tau$		< 8		$\times 10^{-7}$	CL=90%	657
$3h^-2h^+2\pi^0\nu_\tau$		< 3.4		$\times 10^{-6}$	CL=90%	687

Miscellaneous other allowed modes

$(5\pi)^-\nu_\tau$		(7.6	±0.5)	$\times 10^{-3}$		800
$4h^-3h^+ \geq 0$ neutrals ν_τ ("7-prong")		< 3.0		$\times 10^{-7}$	CL=90%	682
$4h^-3h^+\nu_\tau$		< 4.3		$\times 10^{-7}$	CL=90%	682
$4h^-3h^+\pi^0\nu_\tau$		< 2.5		$\times 10^{-7}$	CL=90%	612
$X^-(S{=}-1)\nu_\tau$		(2.87	±0.05)	%	S=1.4	–
$K^*(892)^- \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$		(1.42	±0.18)	%	S=1.4	665
$K^*(892)^-\nu_\tau$		(1.20	±0.07)	%	S=1.8	665
$K^*(892)^-\nu_\tau \rightarrow \pi^-\overline{K}^0\nu_\tau$		(7.88	±0.35)	$\times 10^{-3}$		–

$K^*(892)^0 K^- \geq 0$ neutrals ν_τ		(3.2	± 1.4)	$\times 10^{-3}$		542
$K^*(892)^0 K^- \nu_\tau$		(2.1	± 0.4)	$\times 10^{-3}$		542
$\overline{K}^*(892)^0 \pi^- \geq 0$ neutrals ν_τ		(3.8	± 1.7)	$\times 10^{-3}$		655
$\overline{K}^*(892)^0 \pi^- \nu_\tau$		(2.2	± 0.5)	$\times 10^{-3}$		655
$(\overline{K}^*(892)\pi)^- \nu_\tau \rightarrow$ $\pi^- \overline{K}^0 \pi^0 \nu_\tau$		(1.0	± 0.4)	$\times 10^{-3}$		–
$K_1(1270)^- \nu_\tau$		(4.7	± 1.1)	$\times 10^{-3}$		433
$K_1(1400)^- \nu_\tau$		(1.7	± 2.6)	$\times 10^{-3}$	S=1.7	335
$K^*(1410)^- \nu_\tau$		(1.5	$^{+1.4}_{-1.0}$)	$\times 10^{-3}$		326
$K_0^*(1430)^- \nu_\tau$		< 5		$\times 10^{-4}$	CL=95%	317
$K_2^*(1430)^- \nu_\tau$		< 3		$\times 10^{-3}$	CL=95%	317
$\eta \pi^- \nu_\tau$		< 9.9		$\times 10^{-5}$	CL=95%	797
$\eta \pi^- \pi^0 \nu_\tau$	[g]	(1.39	± 0.10)	$\times 10^{-3}$	S=1.4	778
$\eta \pi^- \pi^0 \pi^0 \nu_\tau$		(1.81	± 0.31)	$\times 10^{-4}$		746
$\eta K^- \nu_\tau$	[g]	(1.52	± 0.08)	$\times 10^{-4}$		719
$\eta K^*(892)^- \nu_\tau$		(1.38	± 0.15)	$\times 10^{-4}$		511
$\eta K^- \pi^0 \nu_\tau$		(4.8	± 1.2)	$\times 10^{-5}$		665
$\eta K^- \pi^0$ (non-$K^*(892)$) ν_τ		< 3.5		$\times 10^{-5}$	CL=90%	–
$\eta \overline{K}^0 \pi^- \nu_\tau$		(9.3	± 1.5)	$\times 10^{-5}$		661
$\eta \overline{K}^0 \pi^- \pi^0 \nu_\tau$		< 5.0		$\times 10^{-5}$	CL=90%	590
$\eta K^- K^0 \nu_\tau$		< 9.0		$\times 10^{-6}$	CL=90%	430
$\eta \pi^+ \pi^- \pi^- \geq 0$ neutrals ν_τ		< 3		$\times 10^{-3}$	CL=90%	744
$\eta \pi^- \pi^+ \pi^- \nu_\tau$ (ex. K^0)		(2.25	± 0.13)	$\times 10^{-4}$		744
$\eta \pi^- \pi^+ \pi^- \nu_\tau$ (ex. K^0, $f_1(1285)$)		(9.9	± 1.6)	$\times 10^{-5}$		–
$\eta a_1(1260)^- \nu_\tau \rightarrow \eta \pi^- \rho^0 \nu_\tau$		< 3.9		$\times 10^{-4}$	CL=90%	–
$\eta \eta \pi^- \nu_\tau$		< 7.4		$\times 10^{-6}$	CL=90%	637
$\eta \eta \pi^- \pi^0 \nu_\tau$		< 2.0		$\times 10^{-4}$	CL=95%	559
$\eta \eta K^- \nu_\tau$		< 3.0		$\times 10^{-6}$	CL=90%	382
$\eta'(958) \pi^- \nu_\tau$		< 4.0		$\times 10^{-6}$	CL=90%	620
$\eta'(958) \pi^- \pi^0 \nu_\tau$		< 1.2		$\times 10^{-5}$	CL=90%	591
$\eta'(958) K^- \nu_\tau$		< 2.4		$\times 10^{-6}$	CL=90%	495
$\phi \pi^- \nu_\tau$		(3.4	± 0.6)	$\times 10^{-5}$		585
$\phi K^- \nu_\tau$		(3.70	± 0.33)	$\times 10^{-5}$	S=1.3	445
$f_1(1285) \pi^- \nu_\tau$		(3.9	± 0.5)	$\times 10^{-4}$	S=1.9	408
$f_1(1285) \pi^- \nu_\tau \rightarrow$ $\eta \pi^- \pi^+ \pi^- \nu_\tau$		(1.18	± 0.07)	$\times 10^{-4}$	S=1.3	–
$f_1(1285) \pi^- \nu_\tau \rightarrow$ $3\pi^- 2\pi^+ \nu_\tau$		(5.2	± 0.5)	$\times 10^{-5}$		–
$\pi(1300)^- \nu_\tau \rightarrow (\rho\pi)^- \nu_\tau \rightarrow$ $(3\pi)^- \nu_\tau$		< 1.0		$\times 10^{-4}$	CL=90%	–
$\pi(1300)^- \nu_\tau \rightarrow$ $((\pi\pi)_{S-\text{wave}}\ \pi)^- \nu_\tau \rightarrow$ $(3\pi)^- \nu_\tau$		< 1.9		$\times 10^{-4}$	CL=90%	–

$h^-\omega \geq 0$ neutrals ν_τ		(	2.41	± 0.09) %		S=1.2	708
$h^-\omega\nu_\tau$	[g]	(	2.00	± 0.08) %		S=1.3	708
$K^-\omega\nu_\tau$		(	4.1	± 0.9)	$\times 10^{-4}$		610
$h^-\omega\pi^0\nu_\tau$	[g]	(	4.1	± 0.4)	$\times 10^{-3}$		684
$h^-\omega 2\pi^0\nu_\tau$		(	1.4	± 0.5)	$\times 10^{-4}$		644
$\pi^-\omega 2\pi^0\nu_\tau$		(	7.3	± 1.7)	$\times 10^{-5}$		644
$h^- 2\omega\nu_\tau$		$<$	5.4		$\times 10^{-7}$	CL=90%	250
$2h^- h^+\omega\nu_\tau$		(	1.20	± 0.22)	$\times 10^{-4}$		641
$2\pi^-\pi^+\omega\nu_\tau$		(	8.4	± 0.7)	$\times 10^{-5}$		641

Lepton Family number (LF), Lepton number (L), or Baryon number (B) violating modes

L means lepton number violation (*e.g.* $\tau^- \to e^+\pi^-\pi^-$). Following common usage, LF means lepton family violation *and not* lepton number violation (*e.g.* $\tau^- \to e^-\pi^+\pi^-$). B means baryon number violation.

$e^-\gamma$	LF	$<$	3.3	$\times 10^{-8}$		CL=90%	888
$\mu^-\gamma$	LF	$<$	4.4	$\times 10^{-8}$		CL=90%	885
$e^-\pi^0$	LF	$<$	8.0	$\times 10^{-8}$		CL=90%	883
$\mu^-\pi^0$	LF	$<$	1.1	$\times 10^{-7}$		CL=90%	880
$e^- K^0_S$	LF	$<$	2.6	$\times 10^{-8}$		CL=90%	819
$\mu^- K^0_S$	LF	$<$	2.3	$\times 10^{-8}$		CL=90%	815
$e^-\eta$	LF	$<$	9.2	$\times 10^{-8}$		CL=90%	804
$\mu^-\eta$	LF	$<$	6.5	$\times 10^{-8}$		CL=90%	800
$e^-\rho^0$	LF	$<$	1.8	$\times 10^{-8}$		CL=90%	719
$\mu^-\rho^0$	LF	$<$	1.2	$\times 10^{-8}$		CL=90%	715
$e^-\omega$	LF	$<$	4.8	$\times 10^{-8}$		CL=90%	716
$\mu^-\omega$	LF	$<$	4.7	$\times 10^{-8}$		CL=90%	711
$e^- K^*(892)^0$	LF	$<$	3.2	$\times 10^{-8}$		CL=90%	665
$\mu^- K^*(892)^0$	LF	$<$	5.9	$\times 10^{-8}$		CL=90%	659
$e^-\overline{K}^*(892)^0$	LF	$<$	3.4	$\times 10^{-8}$		CL=90%	665
$\mu^-\overline{K}^*(892)^0$	LF	$<$	7.0	$\times 10^{-8}$		CL=90%	659
$e^-\eta'(958)$	LF	$<$	1.6	$\times 10^{-7}$		CL=90%	630
$\mu^-\eta'(958)$	LF	$<$	1.3	$\times 10^{-7}$		CL=90%	625
$e^- f_0(980) \to e^-\pi^+\pi^-$	LF	$<$	3.2	$\times 10^{-8}$		CL=90%	–
$\mu^- f_0(980) \to \mu^-\pi^+\pi^-$	LF	$<$	3.4	$\times 10^{-8}$		CL=90%	–
$e^-\phi$	LF	$<$	3.1	$\times 10^{-8}$		CL=90%	596
$\mu^-\phi$	LF	$<$	8.4	$\times 10^{-8}$		CL=90%	590
$e^- e^+ e^-$	LF	$<$	2.7	$\times 10^{-8}$		CL=90%	888
$e^-\mu^+\mu^-$	LF	$<$	2.7	$\times 10^{-8}$		CL=90%	882
$e^+\mu^-\mu^-$	LF	$<$	1.7	$\times 10^{-8}$		CL=90%	882
$\mu^- e^+ e^-$	LF	$<$	1.8	$\times 10^{-8}$		CL=90%	885
$\mu^+ e^- e^-$	LF	$<$	1.5	$\times 10^{-8}$		CL=90%	885
$\mu^-\mu^+\mu^-$	LF	$<$	2.1	$\times 10^{-8}$		CL=90%	873
$e^-\pi^+\pi^-$	LF	$<$	2.3	$\times 10^{-8}$		CL=90%	877

$e^+\pi^-\pi^-$	L	$<$	2.0	$\times 10^{-8}$	CL=90%	877
$\mu^-\pi^+\pi^-$	LF	$<$	2.1	$\times 10^{-8}$	CL=90%	866
$\mu^+\pi^-\pi^-$	L	$<$	3.9	$\times 10^{-8}$	CL=90%	866
$e^-\pi^+K^-$	LF	$<$	3.7	$\times 10^{-8}$	CL=90%	813
$e^-\pi^-K^+$	LF	$<$	3.1	$\times 10^{-8}$	CL=90%	813
$e^+\pi^-K^-$	L	$<$	3.2	$\times 10^{-8}$	CL=90%	813
$e^-K^0_S K^0_S$	LF	$<$	7.1	$\times 10^{-8}$	CL=90%	736
$e^-K^+K^-$	LF	$<$	3.4	$\times 10^{-8}$	CL=90%	738
$e^+K^-K^-$	L	$<$	3.3	$\times 10^{-8}$	CL=90%	738
$\mu^-\pi^+K^-$	LF	$<$	8.6	$\times 10^{-8}$	CL=90%	800
$\mu^-\pi^-K^+$	LF	$<$	4.5	$\times 10^{-8}$	CL=90%	800
$\mu^+\pi^-K^-$	L	$<$	4.8	$\times 10^{-8}$	CL=90%	800
$\mu^-K^0_S K^0_S$	LF	$<$	8.0	$\times 10^{-8}$	CL=90%	696
$\mu^-K^+K^-$	LF	$<$	4.4	$\times 10^{-8}$	CL=90%	699
$\mu^+K^-K^-$	L	$<$	4.7	$\times 10^{-8}$	CL=90%	699
$e^-\pi^0\pi^0$	LF	$<$	6.5	$\times 10^{-6}$	CL=90%	878
$\mu^-\pi^0\pi^0$	LF	$<$	1.4	$\times 10^{-5}$	CL=90%	867
$e^-\eta\eta$	LF	$<$	3.5	$\times 10^{-5}$	CL=90%	699
$\mu^-\eta\eta$	LF	$<$	6.0	$\times 10^{-5}$	CL=90%	653
$e^-\pi^0\eta$	LF	$<$	2.4	$\times 10^{-5}$	CL=90%	798
$\mu^-\pi^0\eta$	LF	$<$	2.2	$\times 10^{-5}$	CL=90%	784
$p\mu^-\mu^-$	L,B	$<$	4.4	$\times 10^{-7}$	CL=90%	618
$\overline{p}\mu^+\mu^-$	L,B	$<$	3.3	$\times 10^{-7}$	CL=90%	618
$\overline{p}\gamma$	L,B	$<$	3.5	$\times 10^{-6}$	CL=90%	641
$\overline{p}\pi^0$	L,B	$<$	1.5	$\times 10^{-5}$	CL=90%	632
$\overline{p}2\pi^0$	L,B	$<$	3.3	$\times 10^{-5}$	CL=90%	604
$\overline{p}\eta$	L,B	$<$	8.9	$\times 10^{-6}$	CL=90%	475
$\overline{p}\pi^0\eta$	L,B	$<$	2.7	$\times 10^{-5}$	CL=90%	360
$\Lambda\pi^-$	L,B	$<$	7.2	$\times 10^{-8}$	CL=90%	525
$\overline{\Lambda}\pi^-$	L,B	$<$	1.4	$\times 10^{-7}$	CL=90%	525
e^- light boson	LF	$<$	2.7	$\times 10^{-3}$	CL=95%	–
μ^- light boson	LF	$<$	5	$\times 10^{-3}$	CL=95%	–

Heavy Charged Lepton Searches

$L^\pm$ – charged lepton

Mass $m >$ 100.8 GeV, CL = 95% [h] Decay to νW.

$L^\pm$ – stable charged heavy lepton

Mass $m >$ 102.6 GeV, CL = 95%

Neutrino Properties

See the note on "Neutrino properties listings" in the Particle Listings.

Mass $m < 2$ eV (tritium decay)
Mean life/mass, $\tau/m > 300$ s/eV, CL = 90% (reactor)
Mean life/mass, $\tau/m > 7 \times 10^9$ s/eV (solar)
Mean life/mass, $\tau/m > 15.4$ s/eV, CL = 90% (accelerator)
Magnetic moment $\mu < 0.29 \times 10^{-10}\ \mu_B$, CL = 90% (reactor)

Number of Neutrino Types

Number $N = 2.984 \pm 0.008$ (Standard Model fits to LEP data)
Number $N = 2.92 \pm 0.05$ (S = 1.2) (Direct measurement of invisible Z width)

Neutrino Mixing

The following values are obtained through data analyses based on the 3-neutrino mixing scheme described in the review "Neutrino Mass, Mixing, and Oscillations" by K. Nakamura and S.T. Petcov in this *Review*.

$\sin^2(\theta_{12}) = 0.304 \pm 0.014$
$\sin^2(2\theta_{12}) = 0.846 \pm 0.021$
$\Delta m^2_{21} = (7.53 \pm 0.18) \times 10^{-5}$ eV^2
$\sin^2(\theta_{23}) = 0.514^{+0.055}_{-0.056}$ (normal mass hierarchy)
$\sin^2(\theta_{23}) = 1.000^{+0.000}_{-0.017}$ (inverted mass hierarchy)
$\sin^2(2\theta_{23}) = 0.999^{+0.001}_{-0.018}$ (normal mass hierarchy)
$\sin^2(2\theta_{23}) = 1.000^{+0.000}_{-0.017}$ (inverted mass hierarchy)
$\Delta m^2_{32} = (2.44 \pm 0.06) \times 10^{-3}$ eV^2 [i] (normal mass hierarchy)
$\Delta m^2_{32} = (2.49 \pm 0.06) \times 10^{-3}$ eV^2 [i] (inverted mass hierarchy)
$\sin^2(\theta_{13}) = (2.19 \pm 0.12) \times 10^{-2}$
$\sin^2(2\theta_{13}) = (8.5 \pm 0.5) \times 10^{-2}$

Stable Neutral Heavy Lepton Mass Limits

Mass $m > 45.0$ GeV, CL = 95% (Dirac)
Mass $m > 39.5$ GeV, CL = 95% (Majorana)

Neutral Heavy Lepton Mass Limits

Mass $m > 90.3$ GeV, CL = 95%
(Dirac ν_L coupling to e, μ, τ; conservative case(τ))
Mass $m > 80.5$ GeV, CL = 95%
(Majorana ν_L coupling to e, μ, τ; conservative case(τ))

NOTES

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

[*b*] See the "Note on Muon Decay Parameters" in the μ Particle Listings for definitions and details.

[*c*] P_μ is the longitudinal polarization of the muon from pion decay. In standard $V-A$ theory, $P_\mu = 1$ and $\rho = \delta = 3/4$.

[*d*] This only includes events with the γ energy > 10 MeV. Since the $e^- \overline{\nu}_e \nu_\mu$ and $e^- \overline{\nu}_e \nu_\mu \gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.

[*e*] See the relevant Particle Listings for the energy limits used in this measurement.

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

[*g*] Basis mode for the τ.

[*h*] $L^\pm$ mass limit depends on decay assumptions; see the Full Listings.

[*i*] The sign of Δm^2_{32} is not known at this time. The range quoted is for the absolute value.