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
$\left|m_{e^+} - m_{e^-}\right|/m < 8 \times 10^{-9}$, CL = 90%
$\left|q_{e^+} + q_{e^-}\right|/e < 4 \times 10^{-8}$
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 $d < 10.5 \times 10^{-28}$ 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]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.7 \pm 0.4$
$\alpha/\mathrm{A} = (0 \pm 4) \times 10^{-3}$
$\alpha'/\mathrm{A} = (-10 \pm 20) \times 10^{-3}$
$\beta/\mathrm{A} = (4 \pm 6) \times 10^{-3}$
$\beta'/\mathrm{A} = (2 \pm 7) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

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]	$(3.4\pm0.4) \times 10^{-5}$			53
Lepton Family number (*LF*) violating modes						
$e^- \nu_e \overline{\nu}_\mu$	*LF*	[f]	< 1.2	%	90%	53
$e^- \gamma$	*LF*		< 5.7	$\times 10^{-13}$	90%	53
$e^- e^+ e^-$	*LF*		< 1.0	$\times 10^{-12}$	90%	53
$e^- 2\gamma$	*LF*		< 7.2	$\times 10^{-11}$	90%	53

τ

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

Mass $m = 1776.82 \pm 0.16$ MeV
$(m_{\tau^+} - m_{\tau^-})/m_{\text{average}} < 2.8 \times 10^{-4}$, CL = 90%
Mean life $\tau = (290.3 \pm 0.5) \times 10^{-15}$ s
$c\tau = 87.03$ μm
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
Re$(d_\tau) = -0.220$ to 0.45×10^{-16} e cm, CL = 95%
Im$(d_\tau) = -0.250$ to 0.0080×10^{-16} e cm, CL = 95%

Weak dipole moment

Re$(d_\tau^w) < 0.50 \times 10^{-17}$ e cm, CL = 95%
Im$(d_\tau^w) < 1.1 \times 10^{-17}$ e cm, CL = 95%

Weak anomalous magnetic dipole moment

Re$(\alpha_\tau^w) < 1.1 \times 10^{-3}$, CL = 95%
Im$(\alpha_\tau^w) < 2.7 \times 10^{-3}$, 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 $\geq 0K^0\nu_\tau$ ("1-prong")		(85.35 ± 0.07) %	S=1.3	–
particle$^- \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$		(84.71 ± 0.08) %	S=1.3	–
$\mu^-\overline{\nu}_\mu\nu_\tau$	[g]	(17.41 ± 0.04) %	S=1.1	885
$\mu^-\overline{\nu}_\mu\nu_\tau\gamma$	[e]	$(3.6 \pm 0.4) \times 10^{-3}$		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
$h^- \geq 0K^0_L\ \nu_\tau$		(12.06 ± 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]	$(7.00 \pm 0.10) \times 10^{-3}$	S=1.1	820
$h^- \geq 1$ neutralsν_τ		(37.10 ± 0.10) %	S=1.2	–
$h^- \geq 1\pi^0\nu_\tau(\text{ex.}K^0)$		(36.58 ± 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-$\rho(770)\nu_\tau$		$(3.0 \pm 3.2) \times 10^{-3}$		878
$K^-\pi^0\nu_\tau$	[g]	$(4.29 \pm 0.15) \times 10^{-3}$		814
$h^- \geq 2\pi^0\nu_\tau$		(10.87 ± 0.11) %	S=1.2	–
$h^-2\pi^0\nu_\tau$		(9.52 ± 0.11) %	S=1.1	862
$h^-2\pi^0\nu_\tau(\text{ex.}K^0)$		(9.36 ± 0.11) %	S=1.2	862
$\pi^-2\pi^0\nu_\tau(\text{ex.}K^0)$	[g]	(9.30 ± 0.11) %	S=1.2	862
$\pi^-2\pi^0\nu_\tau(\text{ex.}K^0)$, scalar		$< 9 \times 10^{-3}$	CL=95%	862
$\pi^-2\pi^0\nu_\tau(\text{ex.}K^0)$, vector		$< 7 \times 10^{-3}$	CL=95%	862
$K^-2\pi^0\nu_\tau(\text{ex.}K^0)$	[g]	$(6.5 \pm 2.3) \times 10^{-4}$		796
$h^- \geq 3\pi^0\nu_\tau$		(1.35 ± 0.07) %	S=1.1	–
$h^- \geq 3\pi^0\nu_\tau(\text{ex. } K^0)$		(1.26 ± 0.07) %	S=1.1	–
$h^-3\pi^0\nu_\tau$		(1.19 ± 0.07) %		836
$\pi^-3\pi^0\nu_\tau(\text{ex.}K^0)$	[g]	(1.05 ± 0.07) %		836

$K^- 3\pi^0 \nu_\tau$ (ex.K^0, η)	[g]	$(4.8 \pm 2.2) \times 10^{-4}$		765
$h^- 4\pi^0 \nu_\tau$ (ex.K^0)		$(1.6 \pm 0.4) \times 10^{-3}$		800
$h^- 4\pi^0 \nu_\tau$ (ex.K^0,η)	[g]	$(1.1 \pm 0.4) \times 10^{-3}$		800
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma\ \nu_\tau$		(1.572 ± 0.033) %	S=1.1	820
$K^- \geq 1\ (\pi^0$ or K^0 or $\gamma)\ \nu_\tau$		$(8.72 \pm 0.32) \times 10^{-3}$	S=1.1	–

Modes with K^0's

K^0_S (particles)$^- \nu_\tau$		$(9.2 \pm 0.4) \times 10^{-3}$	S=1.5	–
$h^- \overline{K}^0 \nu_\tau$		(1.00 ± 0.05) %	S=1.8	812
$\pi^- \overline{K}^0 \nu_\tau$	[g]	$(8.4 \pm 0.4) \times 10^{-3}$	S=2.1	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-$) ν_τ		$(5.4 \pm 2.1) \times 10^{-4}$		812
$K^- K^0 \nu_\tau$	[g]	$(1.59 \pm 0.16) \times 10^{-3}$		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		$(3.18 \pm 0.23) \times 10^{-3}$		737
$h^- \overline{K}^0 \pi^0 \nu_\tau$		$(5.6 \pm 0.4) \times 10^{-3}$		794
$\pi^- \overline{K}^0 \pi^0 \nu_\tau$	[g]	$(4.0 \pm 0.4) \times 10^{-3}$		794
$\overline{K}^0 \rho^- \nu_\tau$		$(2.2 \pm 0.5) \times 10^{-3}$		612
$K^- K^0 \pi^0 \nu_\tau$	[g]	$(1.59 \pm 0.20) \times 10^{-3}$		685
$\pi^- \overline{K}^0 \geq 1\pi^0 \nu_\tau$		$(3.2 \pm 1.0) \times 10^{-3}$		–
$\pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$		$(2.6 \pm 2.4) \times 10^{-4}$		763
$K^- K^0 \pi^0 \pi^0 \nu_\tau$		$< 1.6 \times 10^{-4}$	CL=95%	619
$\pi^- K^0 \overline{K}^0 \nu_\tau$		$(1.7 \pm 0.4) \times 10^{-3}$	S=1.8	682
$\pi^- K^0_S K^0_S \nu_\tau$	[g]	$(2.31 \pm 0.17) \times 10^{-4}$	S=1.9	682
$\pi^- K^0_S K^0_L \nu_\tau$	[g]	$(1.2 \pm 0.4) \times 10^{-3}$	S=1.8	682
$\pi^- K^0 \overline{K}^0 \pi^0 \nu_\tau$		$(3.1 \pm 2.3) \times 10^{-4}$		614
$\pi^- K^0_S K^0_S \pi^0 \nu_\tau$		$(1.60 \pm 0.30) \times 10^{-4}$		614
$\pi^- K^0_S K^0_L \pi^0 \nu_\tau$		$(3.1 \pm 1.2) \times 10^{-4}$		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
$K^0 h^+ h^- h^- \nu_\tau$		$(2.3 \pm 2.0) \times 10^{-4}$		760

Modes with three charged particles

$h^- h^- h^+ \geq 0$ neutrals $\geq 0K^0_L \nu_\tau$		(15.20 ± 0.08) %	S=1.3	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 ± 0.07) %	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)		(9.42 ± 0.06) %	S=1.2	861
$\pi^- \pi^+ \pi^- \nu_\tau$		(9.31 ± 0.06) %	S=1.2	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		(5.39 ±0.07) %	S=1.2	–
$h^- h^- h^+ \geq 1\pi^0 \nu_\tau$ (ex. K^0)		(5.09 ±0.06) %	S=1.2	–
$h^- h^- h^+ \pi^0 \nu_\tau$		(4.76 ±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
$\pi^- \pi^+ \pi^- \pi^0 \nu_\tau$		(4.62 ±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,ω)	[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 ±0.6) $\times 10^{-4}$	S=1.2	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		(6.35 ±0.24) $\times 10^{-3}$	S=1.5	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		(4.85 ±0.21) $\times 10^{-3}$	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
$K^- \pi^+ \pi^- \nu_\tau$		(3.49 ±0.16) $\times 10^{-3}$	S=1.9	794
$K^- \pi^+ \pi^- \nu_\tau$ (ex.K^0)	[g]	(2.94 ±0.15) $\times 10^{-3}$	S=2.2	794
$K^- \rho^0 \nu_\tau \rightarrow K^- \pi^+ \pi^- \nu_\tau$		(1.4 ±0.5) $\times 10^{-3}$		–
$K^- \pi^+ \pi^- \pi^0 \nu_\tau$		(1.35 ±0.14) $\times 10^{-3}$		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,η)	[g]	(7.8 ±1.2) $\times 10^{-4}$		763
$K^- \pi^+ \pi^- \pi^0 \nu_\tau$ (ex.K^0,ω)		(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	471
$K^- K^+ K^- \nu_\tau$ (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 (ex. $K^0_S \rightarrow \pi^- \pi^+$) ("5-prong")		$(1.02 \pm 0.04) \times 10^{-3}$		S=1.1	794
$3h^- 2h^+ \nu_\tau$ (ex.K^0)	[g]	$(8.39 \pm 0.35) \times 10^{-4}$		S=1.1	794
$3\pi^- 2\pi^+ \nu_\tau$ (ex.K^0, ω)		$(8.3 \pm 0.4) \times 10^{-4}$			794
$3\pi^- 2\pi^+ \nu_\tau$ (ex.K^0, ω, $f_1(1285)$)		$(7.7 \pm 0.4) \times 10^{-4}$			–
$K^- 2\pi^- 2\pi^+ \nu_\tau$		$< 2.4 \times 10^{-6}$	CL=90%		715
$K^+ 3\pi^- \pi^+ \nu_\tau$		$< 5.0 \times 10^{-6}$	CL=90%		715
$K^+ K^- 2\pi^- \pi^+ \nu_\tau$		$< 4.5 \times 10^{-7}$	CL=90%		528
$3h^- 2h^+ \pi^0 \nu_\tau$ (ex.K^0)	[g]	$(1.78 \pm 0.27) \times 10^{-4}$			746
$3\pi^- 2\pi^+ \pi^0 \nu_\tau$ (ex.K^0)		$(1.65 \pm 0.10) \times 10^{-4}$			746
$3\pi^- 2\pi^+ \pi^0 \nu_\tau$ (ex.K^0, η, $f_1(1285)$)		$(1.11 \pm 0.10) \times 10^{-4}$			–
$3\pi^- 2\pi^+ \pi^0 \nu_\tau$ (ex.K^0, η, ω, $f_1(1285)$)		$(3.6 \pm 0.9) \times 10^{-5}$			–
$K^- 2\pi^- 2\pi^+ \pi^0 \nu_\tau$		$< 1.9 \times 10^{-6}$	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

$(5\pi)^- \nu_\tau$		$(7.6 \pm 0.5) \times 10^{-3}$			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 ± 0.07) %		S=1.3	–
$K^*(892)^- \geq 0$ neutrals $\geq 0 K^0_L \nu_\tau$		(1.42 ± 0.18) %		S=1.4	665
$K^*(892)^- \nu_\tau$		(1.20 ± 0.07) %		S=1.8	665
$K^*(892)^- \nu_\tau \rightarrow \pi^- \overline{K}^0 \nu_\tau$		$(7.9 \pm 0.5) \times 10^{-3}$			–
$K^*(892)^0 K^- \geq 0$ neutrals ν_τ		$(3.2 \pm 1.4) \times 10^{-3}$			542
$K^*(892)^0 K^- \nu_\tau$		$(2.1 \pm 0.4) \times 10^{-3}$			542
$\overline{K}^*(892)^0 \pi^- \geq 0$ neutrals ν_τ		$(3.8 \pm 1.7) \times 10^{-3}$			655
$\overline{K}^*(892)^0 \pi^- \nu_\tau$		$(2.2 \pm 0.5) \times 10^{-3}$			655
$(\overline{K}^*(892)\pi)^- \nu_\tau \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_\tau$		$(1.0 \pm 0.4) \times 10^{-3}$			–
$K_1(1270)^- \nu_\tau$		$(4.7 \pm 1.1) \times 10^{-3}$			433
$K_1(1400)^- \nu_\tau$		$(1.7 \pm 2.6) \times 10^{-3}$		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%		316
$\eta \pi^- \nu_\tau$		$< 9.9 \times 10^{-5}$	CL=95%		797

$\eta\pi^-\pi^0\nu_\tau$	[g]	$(1.39 \pm 0.10) \times 10^{-3}$	S=1.4	778
$\eta\pi^-\pi^0\pi^0\nu_\tau$		$(1.81 \pm 0.31) \times 10^{-4}$		746
$\eta K^-\nu_\tau$	[g]	$(1.52 \pm 0.08) \times 10^{-4}$		719
$\eta K^*(892)^-\nu_\tau$		$(1.38 \pm 0.15) \times 10^{-4}$		511
$\eta K^-\pi^0\nu_\tau$		$(4.8 \pm 1.2) \times 10^{-5}$		665
$\eta K^-\pi^0(\text{non-}K^*(892))\nu_\tau$		$< 3.5 \times 10^{-5}$	CL=90%	–
$\eta\overline{K}^0\pi^-\nu_\tau$		$(9.3 \pm 1.5) \times 10^{-5}$		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%	743
$\quad\eta\pi^-\pi^+\pi^-\nu_\tau(\text{ex.}K^0)$		$(2.25 \pm 0.13) \times 10^{-4}$		743
$\quad\quad\eta\pi^-\pi^+\pi^-\nu_\tau(\text{ex.}K^0, f_1(1285))$		$(9.9 \pm 1.6) \times 10^{-5}$		–
$\quad\eta a_1(1260)^-\nu_\tau \to \eta\pi^-\rho^0\nu_\tau$		$< 3.9 \times 10^{-4}$	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
$\phi\pi^-\nu_\tau$		$(3.4 \pm 0.6) \times 10^{-5}$		585
$\phi K^-\nu_\tau$		$(3.70 \pm 0.33) \times 10^{-5}$	S=1.3	445
$f_1(1285)\pi^-\nu_\tau$		$(3.9 \pm 0.5) \times 10^{-4}$	S=1.9	408
$\quad f_1(1285)\pi^-\nu_\tau \to \eta\pi^-\pi^+\pi^-\nu_\tau$		$(1.18 \pm 0.07) \times 10^{-4}$	S=1.3	–
$\quad f_1(1285)\pi^-\nu_\tau \to 3\pi^-2\pi^+\nu_\tau$		$(5.2 \pm 0.5) \times 10^{-5}$		–
$\pi(1300)^-\nu_\tau \to (\rho\pi)^-\nu_\tau \to (3\pi)^-\nu_\tau$		$< 1.0 \times 10^{-4}$	CL=90%	–
$\pi(1300)^-\nu_\tau \to ((\pi\pi)_{S-\text{wave}}\pi)^-\nu_\tau \to (3\pi)^-\nu_\tau$		$< 1.9 \times 10^{-4}$	CL=90%	–
$h^-\omega \geq 0$ neutrals ν_τ		(2.41 ± 0.09) %	S=1.2	708
$\quad h^-\omega\nu_\tau$	[g]	(2.00 ± 0.08) %	S=1.3	708
$\quad\quad K^-\omega\nu_\tau$		$(4.1 \pm 0.9) \times 10^{-4}$		610
$\quad h^-\omega\pi^0\nu_\tau$	[g]	$(4.1 \pm 0.4) \times 10^{-3}$		684
$\quad h^-\omega 2\pi^0\nu_\tau$		$(1.4 \pm 0.5) \times 10^{-4}$		644
$\quad\quad \pi^-\omega 2\pi^0\nu_\tau$		$(7.3 \pm 1.7) \times 10^{-5}$		644
$\quad h^-2\omega\nu_\tau$		$< 5.4 \times 10^{-7}$	CL=90%	249
$2h^-h^+\omega\nu_\tau$		$(1.20 \pm 0.22) \times 10^{-4}$		641
$\quad 2\pi^-\pi^+\omega\nu_\tau$		$(8.4 \pm 0.7) \times 10^{-5}$		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
$e^-K^0_SK^0_S$	*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, $\tau/m >$ 7×10^9 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*.

$\sin^2(2\theta_{12}) = 0.846 \pm 0.021$
$\Delta m^2_{21} = (7.53 \pm 0.18) \times 10^{-5}$ eV^2
$\sin^2(2\theta_{23}) = 0.999^{+0.001}_{-0.018}$ (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)
$\Delta m^2_{32} = (2.52 \pm 0.07) \times 10^{-3}$ eV^2 [i] (inverted mass hierarchy)
$\sin^2(2\theta_{13}) = (9.3 \pm 0.8) \times 10^{-2}$

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 $e^- \rightarrow \nu\gamma$. 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.