LEPTONS

e

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

Mass $m = (548.57990943 \pm 0.00000023) \times 10^{-6}$ u
Mass $m = 0.510998910 \pm 0.000000013$ 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
$(g-2)/2 = (1159.65218073 \pm 0.00000028) \times 10^{-6}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
Electric dipole moment $d = (0.07 \pm 0.07) \times 10^{-26}$ e cm
Mean life $\tau > 4.6 \times 10^{26}$ yr, CL = 90% [a]

μ

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

Mass $m = 0.1134289256 \pm 0.0000000029$ u
Mass $m = 105.658367 \pm 0.000004$ MeV
Mean life $\tau = (2.197034 \pm 0.000021) \times 10^{-6}$ s (S = 1.2)
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.654$ 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]

$\rho = 0.7503 \pm 0.0004$
$\eta = 0.057 \pm 0.034$
$\delta = 0.7504 \pm 0.0006$
$\xi P_\mu = 1.0007 \pm 0.0035$ [c]
$\xi P_\mu \delta/\rho > 0.99682$, CL = 90% [c]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.7 \pm 0.4$
$\alpha/A = (0 \pm 4) \times 10^{-3}$
$\alpha'/A = (-10 \pm 20) \times 10^{-3}$
$\beta/A = (4 \pm 6) \times 10^{-3}$
$\beta'/A = (2 \pm 7) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

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*	$< 1.2 \times 10^{-11}$	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 $\tau = (290.6 \pm 1.0) \times 10^{-15}$ s
$c\tau = 87.11$ μm
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
$\text{Re}(d_\tau) = -0.22$ to 0.45×10^{-16} $e$cm, CL = 95%
$\text{Im}(d_\tau) = -0.25$ to 0.008×10^{-16} $e$cm, CL = 95%

Weak dipole moment

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

Weak anomalous magnetic dipole moment

$\text{Re}(\alpha_\tau^w) < 1.1 \times 10^{-3}$, CL = 95%
$\text{Im}(\alpha_\tau^w) < 2.7 \times 10^{-3}$, CL = 95%

Decay parameters

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

$\rho(e \text{ or } \mu) = 0.745 \pm 0.008$
$\rho(e) = 0.747 \pm 0.010$
$\rho(\mu) = 0.763 \pm 0.020$
$\xi(e \text{ or } \mu) = 0.985 \pm 0.030$
$\xi(e) = 0.994 \pm 0.040$
$\xi(\mu) = 1.030 \pm 0.059$
$\eta(e \text{ or } \mu) = 0.013 \pm 0.020$
$\eta(\mu) = 0.094 \pm 0.073$
$(\delta\xi)(e \text{ or } \mu) = 0.746 \pm 0.021$
$(\delta\xi)(e) = 0.734 \pm 0.028$

$(\delta\xi)(\mu) = 0.778 \pm 0.037$
$\xi(\pi) = 0.993 \pm 0.022$
$\xi(\rho) = 0.994 \pm 0.008$
$\xi(a_1) = 1.001 \pm 0.027$
ξ(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")		(85.36±0.08) %	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]	(17.36±0.05) %		885
$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[e]	(3.6 ±0.4) × 10^{-3}		885
$e^- \overline{\nu}_e \nu_\tau$	[g]	(17.85±0.05) %		888
$e^- \overline{\nu}_e \nu_\tau \gamma$	[e]	(1.75±0.18) %		888
$h^- \geq 0 K^0_L \nu_\tau$		(12.13±0.07) %	S=1.1	883
$h^- \nu_\tau$		(11.61±0.06) %	S=1.1	883
$\pi^- \nu_\tau$	[g]	(10.91±0.07) %	S=1.1	883
$K^- \nu_\tau$	[g]	(6.96±0.23) × 10^{-3}	S=1.1	820
$h^- \geq 1$ neutrals ν_τ		(37.06±0.10) %	S=1.2	–
$h^- \geq 1 \pi^0 \nu_\tau$ (ex. K^0)		(36.54±0.11) %	S=1.2	–
$h^- \pi^0 \nu_\tau$		(25.94±0.09) %	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g]	(25.51±0.09) %	S=1.1	878
$\pi^- \pi^0$ non-$\rho(770) \nu_\tau$		(3.0 ±3.2) × 10^{-3}		878
$K^- \pi^0 \nu_\tau$	[g]	(4.29±0.15) × 10^{-3}		814
$h^- \geq 2 \pi^0 \nu_\tau$		(10.85±0.12) %	S=1.3	–
$h^- 2\pi^0 \nu_\tau$		(9.51±0.11) %	S=1.2	862
$h^- 2\pi^0 \nu_\tau$ (ex. K^0)		(9.35±0.11) %	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g]	(9.29±0.11) %	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0), scalar		< 9 × 10^{-3}	CL=95%	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0), vector		< 7 × 10^{-3}	CL=95%	862
$K^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g]	(6.5 ±2.3) × 10^{-4}		796
$h^- \geq 3 \pi^0 \nu_\tau$		(1.34±0.07) %	S=1.1	–
$h^- \geq 3 \pi^0 \nu_\tau$ (ex. K^0)		(1.25±0.07) %	S=1.1	–
$h^- 3\pi^0 \nu_\tau$		(1.18±0.08) %		836
$\pi^- 3\pi^0 \nu_\tau$ (ex. K^0)	[g]	(1.04±0.07) %		836
$K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	[g]	(4.9 ±2.3) × 10^{-4}	S=1.1	765

$h^- 4\pi^0 \nu_\tau$ (ex. K^0)		(1.5 ±0.4) × 10^{-3}		800
$h^- 4\pi^0 \nu_\tau$ (ex. K^0,η)	[g]	(1.1 ±0.4) × 10^{-3}		800
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma\ \nu_\tau$		(1.57±0.04) %	S=1.1	820
$K^- \geq 1$ (π^0 or K^0 or γ) ν_τ		(8.72±0.32) × 10^{-3}	S=1.1	–

Modes with K^0's

K^0_S (particles)$^- \nu_\tau$		(9.2 ±0.4) × 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 ±0.4) × 10^{-3}	S=2.1	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-$) ν_τ		(5.4 ±2.1) × 10^{-4}		812
$K^- K^0 \nu_\tau$	[g]	(1.59±0.16) × 10^{-3}		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		(3.18±0.24) × 10^{-3}		737
$h^- \overline{K}^0 \pi^0 \nu_\tau$		(5.5 ±0.4) × 10^{-3}		794
$\pi^- \overline{K}^0 \pi^0 \nu_\tau$	[g]	(4.0 ±0.4) × 10^{-3}		794
$\overline{K}^0 \rho^- \nu_\tau$		(2.2 ±0.5) × 10^{-3}		612
$K^- K^0 \pi^0 \nu_\tau$	[g]	(1.59±0.20) × 10^{-3}		685
$\pi^- \overline{K}^0 \geq 1\pi^0 \nu_\tau$		(3.2 ±1.0) × 10^{-3}		–
$\pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$		(2.6 ±2.4) × 10^{-4}		763
$K^- K^0 \pi^0 \pi^0 \nu_\tau$		< 1.6 × 10^{-4}	CL=95%	619
$\pi^- K^0 \overline{K}^0 \nu_\tau$		(1.7 ±0.4) × 10^{-3}	S=1.6	682
$\pi^- K^0_S K^0_S \nu_\tau$	[g]	(2.4 ±0.5) × 10^{-4}		682
$\pi^- K^0_S K^0_L \nu_\tau$	[g]	(1.2 ±0.4) × 10^{-3}	S=1.7	682
$\pi^- K^0 \overline{K}^0 \pi^0 \nu_\tau$		(3.1 ±2.3) × 10^{-4}		614
$\pi^- K^0_S K^0_S \pi^0 \nu_\tau$		< 2.0 × 10^{-4}	CL=95%	614
$\pi^- K^0_S K^0_L \pi^0 \nu_\tau$		(3.1 ±1.2) × 10^{-4}		614
$K^0 h^+ h^- h^- \geq 0$ neutrals ν_τ		< 1.7 × 10^{-3}	CL=95%	760
$K^0 h^+ h^- h^- \nu_\tau$		(2.3 ±2.0) × 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")		(14.56±0.08) %	S=1.3	861
$h^- h^- h^+ \nu_\tau$		(9.80±0.08) %	S=1.4	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0)		(9.46±0.07) %	S=1.3	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0,ω)		(9.42±0.07) %	S=1.3	861
$\pi^- \pi^+ \pi^- \nu_\tau$		(9.32±0.07) %	S=1.2	861
$\pi^- \pi^+ \pi^- \nu_\tau$ (ex.K^0)		(9.03±0.06) %	S=1.2	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]	(9.00±0.06) %	S=1.2	861
$h^- h^- h^+ \geq 1$ neutrals ν_τ		(5.38±0.07) %	S=1.2	–
$h^- h^- h^+ \geq 1\pi^0 \nu_\tau$ (ex. K^0)		(5.08±0.06) %	S=1.1	–
$h^- h^- h^+ \pi^0 \nu_\tau$		(4.75±0.06) %	S=1.2	834

$h^-h^-h^+\pi^0\nu_\tau$ (ex.K^0)		(4.56±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=1.1	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)		(5.18±0.33) $\times 10^{-3}$		–
$h^-h^-h^+2\pi^0\nu_\tau$		(5.06±0.32) $\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$ (ex.K^0)		(4.95±0.32) $\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$ (ex.K^0,ω,η)	[g]	(10 ±4) $\times 10^{-4}$		797
$h^-h^-h^+3\pi^0\nu_\tau$	[g]	(2.3 ±0.7) $\times 10^{-4}$	S=1.3	749
$K^-h^+h^- \geq 0$ neutrals ν_τ		(6.24±0.24) $\times 10^{-3}$	S=1.5	794
$K^-h^+\pi^-\nu_\tau$ (ex.K^0)		(4.27±0.20) $\times 10^{-3}$	S=2.4	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		(4.78±0.21) $\times 10^{-3}$	S=1.3	794
$K^-\pi^+\pi^- \geq 0\pi^0\nu_\tau$ (ex.K^0)		(3.68±0.20) $\times 10^{-3}$	S=1.4	794
$K^-\pi^+\pi^-\nu_\tau$		(3.42±0.17) $\times 10^{-3}$	S=1.8	794
$K^-\pi^+\pi^-\nu_\tau$ (ex.K^0)	[g]	(2.87±0.16) $\times 10^{-3}$	S=2.1	794
$K^-\rho^0\nu_\tau \rightarrow K^-\pi^+\pi^-\nu_\tau$		(1.4 ±0.5) $\times 10^{-3}$		–
$K^-\pi^+\pi^-\pi^0\nu_\tau$		(1.36±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]	(7.7 ±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		(1.46±0.06) $\times 10^{-3}$	S=1.6	685
$K^-K^+\pi^-\nu_\tau$	[g]	(1.40±0.05) $\times 10^{-3}$	S=1.7	685
$K^-K^+\pi^-\pi^0\nu_\tau$	[g]	(6.1 ±2.5) $\times 10^{-5}$	S=1.4	618
$K^-K^+K^- \geq 0$ neut. ν_τ		$< 2.1 \times 10^{-3}$	CL=95%	471
$K^-K^+K^-\nu_\tau$		(1.58±0.18) $\times 10^{-5}$		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±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
$3h^-2h^+\pi^0\nu_\tau$ (ex.K^0)	[g]	(1.78±0.27) $\times 10^{-4}$		746
$3h^-2h^+2\pi^0\nu_\tau$		$< 3.4 \times 10^{-6}$	CL=90%	687

Miscellaneous other allowed modes

$(5\pi)^-\nu_\tau$		$(\ 7.6\ \pm0.5\ )\times10^{-3}$		800
$4h^-3h^+\geq0$ neutrals ν_τ ("7-prong")		$<\ 3.0\ \times10^{-7}$	CL=90%	682
$4h^-3h^+\nu_\tau$		$<\ 4.3\ \times10^{-7}$	CL=90%	682
$4h^-3h^+\pi^0\nu_\tau$		$<\ 2.5\ \times10^{-7}$	CL=90%	612
$X^-(S=-1)\nu_\tau$		$(\ 2.86\pm0.07)$ %	S=1.3	–
$K^*(892)^-\ \geq$ 0 neutrals $\geq 0K^0_L\nu_\tau$		$(\ 1.42\pm0.18)$ %	S=1.4	665
$K^*(892)^-\nu_\tau$		$(\ 1.20\pm0.07)$ %	S=1.8	665
$K^*(892)^-\nu_\tau\ \rightarrow\ \pi^-\overline{K}^0\nu_\tau$		$(\ 7.8\ \pm0.5\ )\times10^{-3}$		–
$K^*(892)^0K^-\geq0$ neutrals ν_τ		$(\ 3.2\ \pm1.4\ )\times10^{-3}$		542
$K^*(892)^0K^-\nu_\tau$		$(\ 2.1\ \pm0.4\ )\times10^{-3}$		542
$\overline{K}^*(892)^0\pi^-\geq0$ neutrals ν_τ		$(\ 3.8\ \pm1.7\ )\times10^{-3}$		655
$\overline{K}^*(892)^0\pi^-\nu_\tau$		$(\ 2.2\ \pm0.5\ )\times10^{-3}$		655
$(\overline{K}^*(892)\pi)^-\nu_\tau\rightarrow\ \pi^-\overline{K}^0\pi^0\nu_\tau$		$(\ 1.0\ \pm0.4\ )\times10^{-3}$		–
$K_1(1270)^-\nu_\tau$		$(\ 4.7\ \pm1.1\ )\times10^{-3}$		433
$K_1(1400)^-\nu_\tau$		$(\ 1.7\ \pm2.6\ )\times10^{-3}$	S=1.7	335
$K^*(1410)^-\nu_\tau$		$(\ 1.5\ ^{+1.4}_{-1.0}\ )\times10^{-3}$		326
$K^*_0(1430)^-\nu_\tau$		$<\ 5\ \times10^{-4}$	CL=95%	317
$K^*_2(1430)^-\nu_\tau$		$<\ 3\ \times10^{-3}$	CL=95%	316
$\eta\pi^-\nu_\tau$		$<\ 1.4\ \times10^{-4}$	CL=95%	797
$\eta\pi^-\pi^0\nu_\tau$	[g]	$(\ 1.39\pm0.10)\times10^{-3}$	S=1.4	778
$\eta\pi^-\pi^0\pi^0\nu_\tau$		$(\ 1.5\ \pm0.5\ )\times10^{-4}$		746
$\eta K^-\nu_\tau$	[g]	$(\ 1.61\pm0.11)\times10^{-4}$	S=1.1	719
$\eta K^*(892)^-\nu_\tau$		$(\ 1.38\pm0.15)\times10^{-4}$		511
$\eta K^-\pi^0\nu_\tau$		$(\ 4.8\ \pm1.2\ )\times10^{-5}$		665
$\eta K^-\pi^0$(non-$K^*(892)$)ν_τ		$<\ 3.5\ \times10^{-5}$	CL=90%	–
$\eta\overline{K}^0\pi^-\nu_\tau$		$(\ 9.3\ \pm1.5\ )\times10^{-5}$		661
$\eta\overline{K}^0\pi^-\pi^0\nu_\tau$		$<\ 5.0\ \times10^{-5}$	CL=90%	590
$\eta K^-K^0\nu_\tau$		$<\ 9.0\ \times10^{-6}$	CL=90%	430
$\eta\pi^+\pi^-\pi^-\geq0$ neutrals ν_τ		$<\ 3\ \times10^{-3}$	CL=90%	743
$\eta\pi^-\pi^+\pi^-\nu_\tau$(ex.$K^0$)		$(\ 1.64\pm0.12)\times10^{-4}$		743
$\eta a_1(1260)^-\nu_\tau\ \rightarrow\ \eta\pi^-\rho^0\nu_\tau$		$<\ 3.9\ \times10^{-4}$	CL=90%	–
$\eta\eta\pi^-\nu_\tau$		$<\ 7.4\ \times10^{-6}$	CL=90%	637
$\eta\eta\pi^-\pi^0\nu_\tau$		$<\ 2.0\ \times10^{-4}$	CL=95%	559
$\eta\eta K^-\nu_\tau$		$<\ 3.0\ \times10^{-6}$	CL=90%	382
$\eta'(958)\pi^-\nu_\tau$		$<\ 7.2\ \times10^{-6}$	CL=90%	620
$\eta'(958)\pi^-\pi^0\nu_\tau$		$<\ 8.0\ \times10^{-5}$	CL=90%	591
$\phi\pi^-\nu_\tau$		$(\ 3.4\ \pm0.6\ )\times10^{-5}$		585
$\phi K^-\nu_\tau$		$(\ 3.70\pm0.33)\times10^{-5}$	S=1.3	445
$f_1(1285)\pi^-\nu_\tau$		$(\ 3.6\ \pm0.7\ )\times10^{-4}$		408

$f_1(1285)\pi^-\nu_\tau \rightarrow \eta\pi^-\pi^+\pi^-\nu_\tau$		$(\ 1.11\pm0.08)\times10^{-4}$			–
$\pi(1300)^-\nu_\tau \rightarrow (\rho\pi)^-\nu_\tau \rightarrow (3\pi)^-\nu_\tau$		$<\ 1.0$	$\times10^{-4}$	CL=90%	–
$\pi(1300)^-\nu_\tau \rightarrow ((\pi\pi)_{S-\text{wave}}\ \pi)^-\nu_\tau \rightarrow (3\pi)^-\nu_\tau$		$<\ 1.9$	$\times10^{-4}$	CL=90%	–
$h^-\omega \geq 0$ neutrals ν_τ		$(\ 2.41\pm0.09)$ %		S=1.2	708
$h^-\omega\nu_\tau$	[g]	$(\ 1.99\pm0.08)$ %		S=1.3	708
$K^-\omega\nu_\tau$		$(\ 4.1\ \pm0.9\ )\times10^{-4}$			610
$h^-\omega\pi^0\nu_\tau$	[g]	$(\ 4.1\ \pm0.4\ )\times10^{-3}$			684
$h^-\omega 2\pi^0\nu_\tau$		$(\ 1.4\ \pm0.5\ )\times10^{-4}$			644
$h^-2\omega\nu_\tau$		$<\ 5.4$	$\times10^{-7}$	CL=90%	249
$2h^-h^+\omega\nu_\tau$		$(\ 1.20\pm0.22)\times10^{-4}$			641

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

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

$e^-\gamma$	*LF*	$<$	3.3	$\times10^{-8}$	CL=90%	888
$\mu^-\gamma$	*LF*	$<$	4.4	$\times10^{-8}$	CL=90%	885
$e^-\pi^0$	*LF*	$<$	8.0	$\times10^{-8}$	CL=90%	883
$\mu^-\pi^0$	*LF*	$<$	1.1	$\times10^{-7}$	CL=90%	880
$e^-K^0_S$	*LF*	$<$	3.3	$\times10^{-8}$	CL=90%	819
$\mu^-K^0_S$	*LF*	$<$	4.0	$\times10^{-8}$	CL=90%	815
$e^-\eta$	*LF*	$<$	9.2	$\times10^{-8}$	CL=90%	804
$\mu^-\eta$	*LF*	$<$	6.5	$\times10^{-8}$	CL=90%	800
$e^-\rho^0$	*LF*	$<$	4.6	$\times10^{-8}$	CL=90%	719
$\mu^-\rho^0$	*LF*	$<$	2.6	$\times10^{-8}$	CL=90%	715
$e^-\omega$	*LF*	$<$	1.1	$\times10^{-7}$	CL=90%	716
$\mu^-\omega$	*LF*	$<$	8.9	$\times10^{-8}$	CL=90%	711
$e^-K^*(892)^0$	*LF*	$<$	5.9	$\times10^{-8}$	CL=90%	665
$\mu^-K^*(892)^0$	*LF*	$<$	5.9	$\times10^{-8}$	CL=90%	659
$e^-\overline{K}^*(892)^0$	*LF*	$<$	4.6	$\times10^{-8}$	CL=90%	665
$\mu^-\overline{K}^*(892)^0$	*LF*	$<$	7.3	$\times10^{-8}$	CL=90%	659
$e^-\eta'(958)$	*LF*	$<$	1.6	$\times10^{-7}$	CL=90%	630
$\mu^-\eta'(958)$	*LF*	$<$	1.3	$\times10^{-7}$	CL=90%	625
$e^-f_0(980) \rightarrow e^-\pi^+\pi^-$	*LF*	$<$	3.2	$\times10^{-8}$	CL=90%	–
$\mu^-f_0(980) \rightarrow \mu^-\pi^+\pi^-$	*LF*	$<$	3.4	$\times10^{-8}$	CL=90%	–
$e^-\phi$	*LF*	$<$	3.1	$\times10^{-8}$	CL=90%	596
$\mu^-\phi$	*LF*	$<$	1.3	$\times10^{-7}$	CL=90%	590
$e^-e^+e^-$	*LF*	$<$	3.6	$\times10^{-8}$	CL=90%	888
$e^-\mu^+\mu^-$	*LF*	$<$	3.7	$\times10^{-8}$	CL=90%	882

$e^+\mu^-\mu^-$	*LF*	$<$	2.3	$\times 10^{-8}$	CL=90%	882
$\mu^-e^+e^-$	*LF*	$<$	2.7	$\times 10^{-8}$	CL=90%	885
$\mu^+e^-e^-$	*LF*	$<$	2.0	$\times 10^{-8}$	CL=90%	885
$\mu^-\mu^+\mu^-$	*LF*	$<$	3.2	$\times 10^{-8}$	CL=90%	873
$e^-\pi^+\pi^-$	*LF*	$<$	4.4	$\times 10^{-8}$	CL=90%	877
$e^+\pi^-\pi^-$	*L*	$<$	8.8	$\times 10^{-8}$	CL=90%	877
$\mu^-\pi^+\pi^-$	*LF*	$<$	3.3	$\times 10^{-8}$	CL=90%	866
$\mu^+\pi^-\pi^-$	*L*	$<$	3.7	$\times 10^{-8}$	CL=90%	866
$e^-\pi^+K^-$	*LF*	$<$	5.8	$\times 10^{-8}$	CL=90%	813
$e^-\pi^-K^+$	*LF*	$<$	5.2	$\times 10^{-8}$	CL=90%	813
$e^+\pi^-K^-$	*L*	$<$	6.7	$\times 10^{-8}$	CL=90%	813
$e^-K^0_SK^0_S$	*LF*	$<$	2.2	$\times 10^{-6}$	CL=90%	736
$e^-K^+K^-$	*LF*	$<$	5.4	$\times 10^{-8}$	CL=90%	738
$e^+K^-K^-$	*L*	$<$	6.0	$\times 10^{-8}$	CL=90%	738
$\mu^-\pi^+K^-$	*LF*	$<$	1.6	$\times 10^{-7}$	CL=90%	800
$\mu^-\pi^-K^+$	*LF*	$<$	1.0	$\times 10^{-7}$	CL=90%	800
$\mu^+\pi^-K^-$	*L*	$<$	9.4	$\times 10^{-8}$	CL=90%	800
$\mu^-K^0_SK^0_S$	*LF*	$<$	3.4	$\times 10^{-6}$	CL=90%	696
$\mu^-K^+K^-$	*LF*	$<$	6.8	$\times 10^{-8}$	CL=90%	699
$\mu^+K^-K^-$	*L*	$<$	9.6	$\times 10^{-8}$	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
$\overline{p}\gamma$	*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 $\mu < 0.54 \times 10^{-10}\ \mu_B$, CL = 90% (solar)

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*.

$\sin^2(2\theta_{12}) = 0.87 \pm 0.03$
$\Delta m^2_{21} = (7.59 \pm 0.20) \times 10^{-5}$ eV^2
$\sin^2(2\theta_{23}) > 0.92$ [i]
$\Delta m^2_{32} = (2.43 \pm 0.13) \times 10^{-3}$ eV^2 [j]
$\sin^2(2\theta_{13}) < 0.15$, CL = 90%

Heavy Neutral Leptons, Searches for

For excited leptons, see Compositeness Limits below.

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 limit quoted corresponds to the projection onto the $\sin^2(2\theta_{23})$ axis of the 90% CL contour in the $\sin^2(2\theta_{23})-\Delta m^2_{32}$ plane.

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