LEPTONS

e

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

Mass $m = (548.57990945 \pm 0.00000024) \times 10^{-6}$ u
Mass $m = 0.51099892 \pm 0.00000004$ 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 $\mu = 1.0011596521859 \pm 0.0000000000038\ \mu_B$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
Electric dipole moment $d = (0.07 \pm 0.07) \times 10^{-26}\ e\,\text{cm}$
Mean life $\tau > 4.6 \times 10^{26}$ yr, CL = 90% [a]

μ

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

Mass $m = 0.1134289264 \pm 0.0000000030$ u
Mass $m = 105.658369 \pm 0.000009$ MeV
Mean life $\tau = (2.19703 \pm 0.00004) \times 10^{-6}$ s
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$c\tau = 658.654$ m
Magnetic moment $\mu = 1.0011659208 \pm 0.0000000006\ e\hbar/2m_\mu$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-2.6 \pm 1.6) \times 10^{-8}$
Electric dipole moment $d = (3.7 \pm 3.4) \times 10^{-19}\ e\,\text{cm}$

Decay parameters [b]

$\rho = 0.7509 \pm 0.0010$
$\eta = 0.001 \pm 0.024$ (S = 2.0)
$\delta = 0.7495 \pm 0.0012$
$\xi P_\mu = 1.003 \pm 0.008$ [c]
$\xi P_\mu \delta/\rho > 0.99682$, CL = 90% [c]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.7 \pm 0.4$
$\alpha/A = (0 \pm 4) \times 10^{-3}$
$\alpha'/A = (0 \pm 4) \times 10^{-3}$
$\beta/A = (4 \pm 6) \times 10^{-3}$
$\beta'/A = (1 \pm 5) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

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	$< 1.2\times10^{-11}$	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 $m = 1776.99^{+0.29}_{-0.26}$ MeV
$(m_{\tau^+} - m_{\tau^-})/m_{\text{average}} < 3.0\times10^{-3}$, CL = 90%
Mean life $\tau = (290.6 \pm 1.0)\times10^{-15}$ s
$c\tau = 87.11\ \mu$m
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
$\text{Re}(d_\tau) = -0.22$ to $0.45\times10^{-16}\ e$cm, CL = 95%
$\text{Im}(d_\tau) = -0.25$ to $0.008\times10^{-16}\ e$cm, CL = 95%

Weak dipole moment

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

Weak anomalous magnetic dipole moment

$\text{Re}(\alpha^w_\tau) < 1.1\times10^{-3}$, CL = 95%
$\text{Im}(\alpha^w_\tau) < 2.7\times10^{-3}$, CL = 95%

Decay parameters

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

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

$(\delta\xi)^\tau(\mu) = 0.778 \pm 0.037$
$\xi^\tau(\pi) = 0.993 \pm 0.022$
$\xi^\tau(\rho) = 0.994 \pm 0.008$
$\xi^\tau(a_1) = 1.001 \pm 0.027$
$\xi^\tau(\text{all hadronic modes}) = 0.995 \pm 0.007$

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")		(85.33±0.08) %	S=1.4	–
particle$^- \geq 0$ neutrals $\geq 0 K^0_L \nu_\tau$		(84.69±0.09) %	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]	(17.84±0.05) %		888
$e^- \overline{\nu}_e \nu_\tau \gamma$	[e]	(1.75±0.18) %		888
$h^- \geq 0 K^0_L \nu_\tau$		(12.14±0.07) %	S=1.1	883
$h^- \nu_\tau$		(11.59±0.06) %	S=1.1	883
$\pi^- \nu_\tau$	[g]	(10.90±0.07) %	S=1.1	883
$K^- \nu_\tau$	[g]	(6.91±0.23) × 10^{-3}		820
$h^- \geq 1$ neutrals ν_τ		(37.05±0.12) %	S=1.3	–
$h^- \geq 1 \pi^0 \nu_\tau$ (ex. K^0)		(36.51±0.12) %	S=1.3	–
$h^- \pi^0 \nu_\tau$		(25.95±0.10) %	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g]	(25.50±0.10) %	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]	(4.52±0.27) × 10^{-3}		814
$h^- \geq 2 \pi^0 \nu_\tau$		(10.81±0.14) %	S=1.5	–
$h^- 2\pi^0 \nu_\tau$		(9.47±0.12) %	S=1.3	862
$h^- 2\pi^0 \nu_\tau$ (ex. K^0)		(9.31±0.12) %	S=1.3	862
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g]	(9.25±0.12) %	S=1.3	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]	(5.8 ±2.3) × 10^{-4}		796
$h^- \geq 3 \pi^0 \nu_\tau$		(1.33±0.07) %	S=1.1	–
$h^- \geq 3 \pi^0 \nu_\tau$ (ex. K^0)		(1.25±0.07) %	S=1.1	–
$h^- 3\pi^0 \nu_\tau$		(1.17±0.08) %	S=1.1	836
$\pi^- 3\pi^0 \nu_\tau$ (ex. K^0)	[g]	(1.04±0.08) %	S=1.1	836
$K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	[g]	(4.2 ±2.1) × 10^{-4}		766

$h^- 4\pi^0 \nu_\tau$ (ex. K^0)		(1.6 ±0.4) × 10^{-3}		800
$h^- 4\pi^0 \nu_\tau$ (ex. K^0,η)	[g]	(1.0 ±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		(8.78±0.33) × 10^{-3}		–

Modes with K^0's

K^0_S (particles)$^- \nu_\tau$		(9.27±0.34) × 10^{-3}	S=1.1	–
$h^- \overline{K}^0 \nu_\tau$		(1.05±0.04) %	S=1.1	812
$\pi^- \overline{K}^0 \nu_\tau$	[g]	(9.0 ±0.4) × 10^{-3}	S=1.1	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-$) ν_τ		< 1.7 × 10^{-3}	CL=95%	812
$K^- K^0 \nu_\tau$	[g]	(1.53±0.16) × 10^{-3}		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		(3.07±0.24) × 10^{-3}		737
$h^- \overline{K}^0 \pi^0 \nu_\tau$		(5.3 ±0.4) × 10^{-3}		794
$\pi^- \overline{K}^0 \pi^0 \nu_\tau$	[g]	(3.8 ±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]	(1.54±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
$\pi^- K^0 \overline{K}^0 \nu_\tau$		(1.60±0.31) × 10^{-3}	S=1.2	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]	(1.12±0.30) × 10^{-3}	S=1.2	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 $\geq 0K^0_L \nu_\tau$		(15.22±0.09) %	S=1.4	861
$h^- h^- h^+ \geq 0$ neutrals ν_τ (ex. $K^0_S \to \pi^+\pi^-$) ("3-prong")		(14.59±0.08) %	S=1.4	861
$h^- h^- h^+ \nu_\tau$		(9.87±0.08) %	S=1.3	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0)		(9.51±0.08) %	S=1.3	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0,ω)		(9.47±0.08) %	S=1.3	861
$\pi^- \pi^+ \pi^- \nu_\tau$		(9.33±0.08) %	S=1.3	861
$\pi^- \pi^+ \pi^- \nu_\tau$ (ex.K^0)		(9.02±0.08) %	S=1.3	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±0.08) %	S=1.3	861
$h^- h^- h^+ \geq 1$ neutrals ν_τ		(5.34±0.06) %	S=1.1	–
$h^- h^- h^+ \geq 1\pi^0 \nu_\tau$ (ex. K^0)		(5.06±0.06) %	S=1.1	–
$h^- h^- h^+ \pi^0 \nu_\tau$		(4.73±0.07) %	S=1.2	834

$h^-\,h^-\,h^+\,\pi^0\,\nu_\tau$ (ex.K^0)		(4.55±0.06) %	S=1.2	834
$h^-\,h^-\,h^+\,\pi^0\,\nu_\tau$ (ex. K^0, ω)		(2.78±0.08) %	S=1.2	834
$\pi^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$		(4.59±0.07) %	S=1.2	834
$\pi^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$ (ex.K^0)		(4.46±0.06) %	S=1.2	834
$\pi^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$ (ex.K^0,ω)	[g]	(2.69±0.08) %	S=1.2	834
$h^-\,h^-\,h^+\,\geq\,2\pi^0\,\nu_\tau$ (ex. K^0)		(5.14±0.34) $\times 10^{-3}$	S=1.1	–
$h^-\,h^-\,h^+\,2\pi^0\,\nu_\tau$		(5.02±0.34) $\times 10^{-3}$	S=1.1	797
$h^-\,h^-\,h^+\,2\pi^0\,\nu_\tau$ (ex.K^0)		(4.92±0.34) $\times 10^{-3}$	S=1.1	797
$h^-\,h^-\,h^+\,2\pi^0\,\nu_\tau$ (ex.K^0,ω,η)	[g]	(9 ±4) $\times 10^{-4}$		797
$h^-\,h^-\,h^+\,3\pi^0\,\nu_\tau$	[g]	(2.2 ±0.5) $\times 10^{-4}$		749
$K^-\,h^+\,h^-\,\geq 0$ neutrals ν_τ		(6.79±0.35) $\times 10^{-3}$	S=1.3	794
$K^-\,h^+\,\pi^-\,\nu_\tau$ (ex.K^0)		(4.86±0.32) $\times 10^{-3}$	S=1.4	794
$K^-\,h^+\,\pi^-\,\pi^0\,\nu_\tau$ (ex.K^0)		(8.5 ±1.2) $\times 10^{-4}$		763
$K^-\,\pi^+\,\pi^-\,\geq 0$ neutrals ν_τ		(5.2 ±0.4) $\times 10^{-3}$	S=1.5	794
$K^-\,\pi^+\,\pi^-\,\geq\,0\pi^0\,\nu_\tau$ (ex.K^0)		(4.1 ±0.4) $\times 10^{-3}$	S=1.5	794
$K^-\,\pi^+\,\pi^-\,\nu_\tau$		(3.9 ±0.4) $\times 10^{-3}$	S=1.6	794
$K^-\,\pi^+\,\pi^-\,\nu_\tau$ (ex.K^0)	[g]	(3.33±0.35) $\times 10^{-3}$	S=1.6	794
$K^-\,\rho^0\,\nu_\tau \rightarrow K^-\,\pi^+\,\pi^-\,\nu_\tau$		(1.6 ±0.6) $\times 10^{-3}$		–
$K^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$		(1.32±0.14) $\times 10^{-3}$		763
$K^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$ (ex.K^0)		(7.9 ±1.2) $\times 10^{-4}$		763
$K^-\,\pi^+\,\pi^-\,\pi^0\,\nu_\tau$ (ex.K^0,η)	[g]	(7.3 ±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		(1.59±0.10) $\times 10^{-3}$	S=1.4	685
$K^-\,K^+\,\pi^-\,\nu_\tau$	[g]	(1.53±0.10) $\times 10^{-3}$	S=1.4	685
$K^-\,K^+\,\pi^-\,\pi^0\,\nu_\tau$	[g]	(6.1 ±2.0) $\times 10^{-5}$	S=1.1	618
$K^-\,K^+\,K^-\,\geq 0$ neut. ν_τ		$< 2.1 \times 10^{-3}$	CL=95%	472
$K^-\,K^+\,K^-\,\nu_\tau$		$< 3.7 \times 10^{-5}$	CL=90%	472
$K^-\,K^+\,K^-\,\pi^0\,\nu_\tau$		$< 4.8 \times 10^{-6}$	CL=90%	346
$\pi^-\,K^+\,\pi^-\,\geq 0$ 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]	(8.38±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
$3h^-\,2h^+\,2\pi^0\,\nu_\tau$		$< 1.1 \times 10^{-4}$	CL=90%	687

Miscellaneous other allowed modes

$(5\pi)^-\nu_\tau$		(7.6 ±0.5) $\times 10^{-3}$		S=1.1	800
$4h^-3h^+ \geq 0$ neutrals ν_τ ("7-prong")	<	3.0	$\times 10^{-7}$	CL=90%	683
$4h^-3h^+\nu_\tau$	<	4.3	$\times 10^{-7}$	CL=90%	683
$4h^-3h^+\pi^0\nu_\tau$	<	2.5	$\times 10^{-7}$	CL=90%	612
$X^-(S{=}-1)\nu_\tau$		(2.95±0.07) %		S=1.1	–
$K^*(892)^- \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$		(1.42±0.18) %		S=1.4	665
$K^*(892)^-\nu_\tau$		(1.29±0.05) %			665
$K^*(892)^0K^- \geq 0$ neutrals ν_τ		(3.2 ±1.4) $\times 10^{-3}$			542
$K^*(892)^0K^-\nu_\tau$		(2.1 ±0.4) $\times 10^{-3}$			542
$\overline{K}^*(892)^0\pi^- \geq 0$ neutrals ν_τ		(3.8 ±1.7) $\times 10^{-3}$			656
$\overline{K}^*(892)^0\pi^-\nu_\tau$		(2.2 ±0.5) $\times 10^{-3}$			656
$(\overline{K}^*(892)\pi)^-\nu_\tau \to \pi^-\overline{K}^0\pi^0\nu_\tau$		(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%	326
$K^*_2(1430)^-\nu_\tau$	<	3	$\times 10^{-3}$	CL=95%	317
$\eta\pi^-\nu_\tau$	<	1.4	$\times 10^{-4}$	CL=95%	798
$\eta\pi^-\pi^0\nu_\tau$	[g]	(1.77±0.24) $\times 10^{-3}$			778
$\eta\pi^-\pi^0\pi^0\nu_\tau$		(1.5 ±0.5) $\times 10^{-4}$			746
$\eta K^-\nu_\tau$	[g]	(2.7 ±0.6) $\times 10^{-4}$			720
$\eta K^*(892)^-\nu_\tau$		(2.9 ±0.9) $\times 10^{-4}$			511
$\eta K^-\pi^0\nu_\tau$		(1.8 ±0.9) $\times 10^{-4}$			665
$\eta\overline{K}^0\pi^-\nu_\tau$		(2.2 ±0.7) $\times 10^{-4}$			661
$\eta\pi^+\pi^-\pi^- \geq 0$ neutrals ν_τ	<	3	$\times 10^{-3}$	CL=90%	744
$\eta\pi^-\pi^+\pi^-\nu_\tau$		(2.3 ±0.5) $\times 10^{-4}$			744
$\eta a_1(1260)^-\nu_\tau \to \eta\pi^-\rho^0\nu_\tau$	<	3.9	$\times 10^{-4}$	CL=90%	–
$\eta\eta\pi^-\nu_\tau$	<	1.1	$\times 10^{-4}$	CL=95%	637
$\eta\eta\pi^-\pi^0\nu_\tau$	<	2.0	$\times 10^{-4}$	CL=95%	559
$\eta'(958)\pi^-\nu_\tau$	<	7.4	$\times 10^{-5}$	CL=90%	620
$\eta'(958)\pi^-\pi^0\nu_\tau$	<	8.0	$\times 10^{-5}$	CL=90%	591
$\phi\pi^-\nu_\tau$	<	2.0	$\times 10^{-4}$	CL=90%	585
$\phi K^-\nu_\tau$	<	6.7	$\times 10^{-5}$	CL=90%	445
$f_1(1285)\pi^-\nu_\tau$		(4.1 ±0.8) $\times 10^{-4}$			408
$f_1(1285)\pi^-\nu_\tau \to \eta\pi^-\pi^+\pi^-\nu_\tau$		(1.3 ±0.4) $\times 10^{-4}$			–
$\pi(1300)^-\nu_\tau \to (\rho\pi)^-\nu_\tau \to (3\pi)^-\nu_\tau$	<	1.0	$\times 10^{-4}$	CL=90%	–

$\pi(1300)^- \nu_\tau \rightarrow$ $((\pi\pi)_{S-\text{wave}}\ \pi)^- \nu_\tau \rightarrow$ $(3\pi)^- \nu_\tau$		$<$	1.9	$\times 10^{-4}$	CL=90%	–
$h^- \omega \geq 0$ neutrals ν_τ			(2.39±0.09) %		S=1.2	708
$h^- \omega \nu_\tau$	[g]		(1.99±0.08) %		S=1.2	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
$2h^- h^+ \omega \nu_\tau$			(1.20±0.22) $\times 10^{-4}$			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*	$<$	1.1	$\times 10^{-7}$	CL=90%	888
$\mu^-\gamma$	*LF*	$<$	6.8	$\times 10^{-8}$	CL=90%	885
$e^-\pi^0$	*LF*	$<$	1.9	$\times 10^{-7}$	CL=90%	883
$\mu^-\pi^0$	*LF*	$<$	4.1	$\times 10^{-7}$	CL=90%	880
$e^- K^0_S$	*LF*	$<$	9.1	$\times 10^{-7}$	CL=90%	819
$\mu^- K^0_S$	*LF*	$<$	9.5	$\times 10^{-7}$	CL=90%	815
$e^-\eta$	*LF*	$<$	2.4	$\times 10^{-7}$	CL=90%	804
$\mu^-\eta$	*LF*	$<$	1.5	$\times 10^{-7}$	CL=90%	800
$e^-\rho^0$	*LF*	$<$	2.0	$\times 10^{-6}$	CL=90%	719
$\mu^-\rho^0$	*LF*	$<$	6.3	$\times 10^{-6}$	CL=90%	715
$e^- K^*(892)^0$	*LF*	$<$	5.1	$\times 10^{-6}$	CL=90%	665
$\mu^- K^*(892)^0$	*LF*	$<$	7.5	$\times 10^{-6}$	CL=90%	660
$e^- \overline{K}^*(892)^0$	*LF*	$<$	7.4	$\times 10^{-6}$	CL=90%	665
$\mu^- \overline{K}^*(892)^0$	*LF*	$<$	7.5	$\times 10^{-6}$	CL=90%	660
$e^-\eta'(958)$	*LF*	$<$	1.0	$\times 10^{-6}$	CL=90%	630
$\mu^-\eta'(958)$	*LF*	$<$	4.7	$\times 10^{-7}$	CL=90%	625
$e^-\phi$	*LF*	$<$	6.9	$\times 10^{-6}$	CL=90%	596
$\mu^-\phi$	*LF*	$<$	7.0	$\times 10^{-6}$	CL=90%	590
$e^- e^+ e^-$	*LF*	$<$	2.0	$\times 10^{-7}$	CL=90%	888
$e^-\mu^+\mu^-$	*LF*	$<$	2.0	$\times 10^{-7}$	CL=90%	882
$e^+\mu^-\mu^-$	*LF*	$<$	1.3	$\times 10^{-7}$	CL=90%	882
$\mu^- e^+ e^-$	*LF*	$<$	1.9	$\times 10^{-7}$	CL=90%	885
$\mu^+ e^- e^-$	*LF*	$<$	1.1	$\times 10^{-7}$	CL=90%	885
$\mu^-\mu^+\mu^-$	*LF*	$<$	1.9	$\times 10^{-7}$	CL=90%	873
$e^-\pi^+\pi^-$	*LF*	$<$	1.2	$\times 10^{-7}$	CL=90%	877
$e^+\pi^-\pi^-$	*L*	$<$	2.7	$\times 10^{-7}$	CL=90%	877
$\mu^-\pi^+\pi^-$	*LF*	$<$	2.9	$\times 10^{-7}$	CL=90%	866
$\mu^+\pi^-\pi^-$	*L*	$<$	7	$\times 10^{-8}$	CL=90%	866
$e^-\pi^+ K^-$	*LF*	$<$	3.2	$\times 10^{-7}$	CL=90%	813

$e^-\pi^-K^+$	*LF*	$<$	1.7	$\times 10^{-7}$	CL=90%	813
$e^+\pi^-K^-$	*L*	$<$	1.8	$\times 10^{-7}$	CL=90%	813
$e^-K^0_S K^0_S$	*LF*	$<$	2.2	$\times 10^{-6}$	CL=90%	736
$e^-K^+K^-$	*LF*	$<$	1.4	$\times 10^{-7}$	CL=90%	739
$e^+K^-K^-$	*L*	$<$	1.5	$\times 10^{-7}$	CL=90%	739
$\mu^-\pi^+K^-$	*LF*	$<$	2.6	$\times 10^{-7}$	CL=90%	800
$\mu^-\pi^-K^+$	*LF*	$<$	3.2	$\times 10^{-7}$	CL=90%	800
$\mu^+\pi^-K^-$	*L*	$<$	2.2	$\times 10^{-7}$	CL=90%	800
$\mu^-K^0_S K^0_S$	*LF*	$<$	3.4	$\times 10^{-6}$	CL=90%	696
$\mu^-K^+K^-$	*LF*	$<$	2.5	$\times 10^{-7}$	CL=90%	699
$\mu^+K^-K^-$	*L*	$<$	4.8	$\times 10^{-7}$	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%	700
$\mu^-\eta\eta$	*LF*	$<$	6.0	$\times 10^{-5}$	CL=90%	654
$e^-\pi^0\eta$	*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%	526
$\overline{\Lambda}\pi^-$	*L,B*	$<$	1.4	$\times 10^{-7}$	CL=90%	526
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 $\mu < 0.9 \times 10^{-10}\ \mu_B$, CL = 90% (reactor)

Number of Neutrino Types

Number $N = 2.994 \pm 0.012$ (Standard Model fits to LEP data)
Number $N = 2.92 \pm 0.06$ (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 flavor change" by B. Kayser in this *Review*.

$\sin^2(2\theta_{12}) = 0.86^{+0.03}_{-0.04}$
$\Delta m^2_{21} = (8.0^{+0.4}_{-0.3}) \times 10^{-5}$ eV^2

The ranges below for $\sin^2(2\theta_{23})$ and Δm^2_{32} correspond to the projections onto the appropriate axes of the 90% CL contours in the $\sin^2(2\theta_{23})$-Δm^2_{32} plane.

$\sin^2(2\theta_{23}) > 0.92$
$\Delta m^2_{32} = 1.9$ to 3.0×10^{-3} eV^2 [i]

$\sin^2(2\theta_{13}) < 0.19$, 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 sign of Δm^2_{32} is not known at this time. The range quoted is for the absolute value.