LEPTONS

e

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

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
$\quad (g-2)/2 = (1159.65218076 \pm 0.00000027) \times 10^{-6}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
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

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

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
$\tau_{\mu^+}/\tau_{\mu^-} = 1.00002 \pm 0.00008$
$\quad c\tau = 658.6384$ 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
$\quad e^- \overline{\nu}_e \nu_\mu \gamma$		[d] (1.4 ± 0.4) %			53
$e^- \overline{\nu}_e \nu_\mu e^+ e^-$		[e] $(3.4 \pm 0.4) \times 10^{-5}$			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

$\boxed{\tau}$ $\qquad\qquad\qquad\qquad\qquad J = \frac{1}{2}$

Mass $m = 1776.86 \pm 0.12$ 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
$\quad c\tau = 87.03$ μm
Magnetic moment anomaly > -0.052 and < 0.013, CL = 95%
$\text{Re}(d_\tau) = -0.220$ to 0.45×10^{-16} e cm, CL = 95%
$\text{Im}(d_\tau) = -0.250$ to 0.0080×10^{-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%
$\tau^\pm \to \pi^\pm K_S^0 \nu_\tau$ (RATE DIFFERENCE) / (RATE SUM) = $(-0.36 \pm 0.25)\%$

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")		$(85.35 \pm 0.07)\%$	S=1.3	–
particle$^- \geq 0$ neutrals $\geq 0 K_L^0 \nu_\tau$		$(84.72 \pm 0.08)\%$	S=1.4	–
$\mu^- \overline{\nu}_\mu \nu_\tau$	[g]	$(17.41 \pm 0.04)\%$	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]	$(17.83 \pm 0.04)\%$		888
$e^- \overline{\nu}_e \nu_\tau \gamma$	[e]	$(1.75 \pm 0.18)\%$		888
$h^- \geq 0 K_L^0 \nu_\tau$		$(12.05 \pm 0.06)\%$	S=1.2	883
$h^- \nu_\tau$		$(11.53 \pm 0.06)\%$	S=1.2	883
$\pi^- \nu_\tau$	[g]	$(10.83 \pm 0.06)\%$	S=1.2	883
$K^- \nu_\tau$	[g]	$(7.00 \pm 0.10) \times 10^{-3}$		820
$h^- \geq 1$ neutrals ν_τ		$(37.11 \pm 0.10)\%$	S=1.2	–
$h^- \geq 1\pi^0 \nu_\tau (\text{ex.} K^0)$		$(36.59 \pm 0.10)\%$	S=1.2	–
$h^- \pi^0 \nu_\tau$		$(25.95 \pm 0.09)\%$	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g]	$(25.52 \pm 0.09)\%$	S=1.1	878
$\pi^- \pi^0 \text{non-}\rho(770)\nu_\tau$		$(3.0 \pm 3.2) \times 10^{-3}$		878
$K^- \pi^0 \nu_\tau$	[g]	$(4.30 \pm 0.15) \times 10^{-3}$		814
$h^- \geq 2\pi^0 \nu_\tau$		$(10.88 \pm 0.11)\%$	S=1.2	–
$h^- 2\pi^0 \nu_\tau$		$(9.53 \pm 0.11)\%$	S=1.1	862
$h^- 2\pi^0 \nu_\tau (\text{ex.} K^0)$		$(9.37 \pm 0.11)\%$	S=1.2	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.} K^0)$	[g]	$(9.30 \pm 0.11)\%$	S=1.1	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.} K^0),$ scalar		$< 9 \quad \times 10^{-3}$	CL=95%	862
$\pi^- 2\pi^0 \nu_\tau (\text{ex.} K^0),$ vector		$< 7 \quad \times 10^{-3}$	CL=95%	862
$K^- 2\pi^0 \nu_\tau (\text{ex.} K^0)$	[g]	$(6.9 \pm 2.8) \times 10^{-4}$	S=1.3	796
$h^- \geq 3\pi^0 \nu_\tau$		$(1.35 \pm 0.07)\%$	S=1.1	–

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

Modes with K^0's

K_S^0 (particles)$^- \nu_\tau$		(9.1 $\pm$0.5) $\times 10^{-3}$	S=2.2	–
$h^- \overline{K}^0 \nu_\tau$		(9.94 $\pm$0.29) $\times 10^{-3}$	S=1.8	812
$\pi^- \overline{K}^0 \nu_\tau$	[g]	(8.45 $\pm$0.28) $\times 10^{-3}$	S=1.9	812
$\pi^- \overline{K}^0$ (non-$K^*(892)^-)\nu_\tau$		(5.4 $\pm$2.1) $\times 10^{-4}$		812
$K^- K^0 \nu_\tau$	[g]	(1.49 $\pm$0.05) $\times 10^{-3}$		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		(3.01 $\pm$0.09) $\times 10^{-3}$		737
$h^- \overline{K}^0 \pi^0 \nu_\tau$		(5.39 $\pm$0.16) $\times 10^{-3}$	S=1.1	794
$\pi^- \overline{K}^0 \pi^0 \nu_\tau$	[g]	(3.88 $\pm$0.15) $\times 10^{-3}$	S=1.1	794
$\overline{K}^0 \rho^- \nu_\tau$		(2.2 $\pm$0.5) $\times 10^{-3}$		612
$K^- K^0 \pi^0 \nu_\tau$	[g]	(1.51 $\pm$0.07) $\times 10^{-3}$		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$0.5) $\times 10^{-3}$	S=2.2	682
$\pi^- K_S^0 K_S^0 \nu_\tau$	[g]	(2.32 $\pm$0.07) $\times 10^{-4}$		682
$\pi^- K_S^0 K_L^0 \nu_\tau$	[g]	(1.2 $\pm$0.5) $\times 10^{-3}$	S=2.2	682
$\pi^- K^0 \overline{K}^0 \pi^0 \nu_\tau$		(3.1 $\pm$2.3) $\times 10^{-4}$		614
$\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(1.80 $\pm$0.21) $\times 10^{-5}$		614
$K^{*-} K^0 \pi^0 \nu_\tau \to \pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(1.08 $\pm$0.21) $\times 10^{-5}$		–
$f_1(1285)\pi^- \nu_\tau \to \pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(6.8 $\pm$1.5) $\times 10^{-6}$		–
$f_1(1420)\pi^- \nu_\tau \to \pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(2.4 $\pm$0.8) $\times 10^{-6}$		–
$\pi^- K_S^0 K_L^0 \pi^0 \nu_\tau$		(3.1 $\pm$1.2) $\times 10^{-4}$		614
$K^- K_S^0 K_S^0 \nu_\tau$		< 6.3 $\times 10^{-7}$	CL=90%	466
$K^- K_S^0 K_S^0 \pi^0 \nu_\tau$		< 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 $\geq 0 K^0_L \nu_\tau$		$(15.19 \pm 0.08)\ \%$	S=1.4	861
$h^- h^- h^+ \geq 0$ neutrals ν_τ (ex. $K^0_S \rightarrow \pi^+ \pi^-$) ("3-prong")		$(14.57 \pm 0.07)\ \%$	S=1.3	861
$h^- h^- h^+ \nu_\tau$		$(9.80 \pm 0.06)\ \%$	S=1.2	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0)		$(9.46 \pm 0.06)\ \%$	S=1.2	861
$h^- h^- h^+ \nu_\tau$ (ex.K^0,ω)		$(9.43 \pm 0.06)\ \%$	S=1.2	861
$\pi^- \pi^+ \pi^- \nu_\tau$		$(9.31 \pm 0.06)\ \%$	S=1.1	861
$\pi^- \pi^+ \pi^- \nu_\tau$ (ex.K^0)		$(9.02 \pm 0.06)\ \%$	S=1.1	861
$\pi^- \pi^+ \pi^- \nu_\tau$ (ex.K^0), non-axial vector		$< 2.4\qquad\ \%$	CL=95%	861
$\pi^- \pi^+ \pi^- \nu_\tau$ (ex.K^0,ω)	[g]	$(8.99 \pm 0.06)\ \%$	S=1.1	861
$h^- h^- h^+ \geq 1$ neutrals ν_τ		$(5.38 \pm 0.07)\ \%$	S=1.3	–
$h^- h^- h^+ \geq 1\pi^0 \nu_\tau$ (ex. K^0)		$(5.09 \pm 0.06)\ \%$	S=1.2	–
$h^- h^- h^+ \pi^0 \nu_\tau$		$(4.75 \pm 0.06)\ \%$	S=1.2	834
$h^- h^- h^+ \pi^0 \nu_\tau$ (ex.K^0)		$(4.57 \pm 0.06)\ \%$	S=1.2	834
$h^- h^- h^+ \pi^0 \nu_\tau$ (ex. K^0, ω)		$(2.79 \pm 0.08)\ \%$	S=1.2	834
$\pi^- \pi^+ \pi^- \pi^0 \nu_\tau$		$(4.61 \pm 0.06)\ \%$	S=1.2	834
$\pi^- \pi^+ \pi^- \pi^0 \nu_\tau$ (ex.K^0)		$(4.48 \pm 0.06)\ \%$	S=1.2	834
$\pi^- \pi^+ \pi^- \pi^0 \nu_\tau$ (ex.K^0,ω)	[g]	$(2.70 \pm 0.08)\ \%$	S=1.2	834
$h^- h^- h^+ \geq 2\pi^0 \nu_\tau$ (ex. K^0)		$(5.21 \pm 0.32) \times 10^{-3}$		–
$h^- h^- h^+ 2\pi^0 \nu_\tau$		$(5.08 \pm 0.32) \times 10^{-3}$		797
$h^- h^- h^+ 2\pi^0 \nu_\tau$ (ex.K^0)		$(4.98 \pm 0.32) \times 10^{-3}$		797
$h^- h^- h^+ 2\pi^0 \nu_\tau$ (ex.K^0,ω,η)	[g]	$(1.0 \pm 0.4) \times 10^{-3}$		797
$h^- h^- h^+ 3\pi^0 \nu_\tau$	[g]	$(2.3 \pm 0.7) \times 10^{-4}$	S=1.3	749
$2\pi^- \pi^+ 3\pi^0 \nu_\tau$ (ex.K^0)		$(2.1 \pm 0.4) \times 10^{-4}$		749
$2\pi^- \pi^+ 3\pi^0 \nu_\tau$ (ex.K^0, η, $f_1(1285)$)		$(1.7 \pm 0.4) \times 10^{-4}$		–
$2\pi^- \pi^+ 3\pi^0 \nu_\tau$ (ex.K^0, η, ω, $f_1(1285)$)		$< 5.8\qquad \times 10^{-5}$	CL=90%	–
$K^- h^+ h^- \geq 0$ neutrals ν_τ		$(6.29 \pm 0.23) \times 10^{-3}$	S=1.7	794
$K^- h^+ \pi^- \nu_\tau$ (ex.K^0)		$(4.38 \pm 0.19) \times 10^{-3}$	S=2.7	794
$K^- h^+ \pi^- \pi^0 \nu_\tau$ (ex.K^0)		$(8.7 \pm 1.2) \times 10^{-4}$	S=1.1	763
$K^- \pi^+ \pi^- \geq 0$ neutrals ν_τ		$(4.79 \pm 0.20) \times 10^{-3}$	S=1.4	794
$K^- \pi^+ \pi^- \geq 0\pi^0 \nu_\tau$ (ex.K^0)		$(3.75 \pm 0.19) \times 10^{-3}$	S=1.5	794
$K^- \pi^+ \pi^- \nu_\tau$		$(3.45 \pm 0.15) \times 10^{-3}$	S=2.2	794
$K^- \pi^+ \pi^- \nu_\tau$ (ex.K^0)	[g]	$(2.94 \pm 0.15) \times 10^{-3}$	S=2.2	794
$K^- \rho^0 \nu_\tau \rightarrow K^- \pi^+ \pi^- \nu_\tau$		$(1.4 \pm 0.5) \times 10^{-3}$		–
$K^- \pi^+ \pi^- \pi^0 \nu_\tau$		$(1.33 \pm 0.12) \times 10^{-3}$		763
$K^- \pi^+ \pi^- \pi^0 \nu_\tau$ (ex.K^0)		$(8.1 \pm 1.2) \times 10^{-4}$		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	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 (ex. $K^0_S \to \pi^-\pi^+$) ("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
$3\pi^-2\pi^+\nu_\tau$ (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
$K^*(892)^-\nu_\tau \to \pi^-\overline{K}^0\nu_\tau$	(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
$\eta K^- \pi^0 (\text{non-}K^*(892)) \nu_\tau$	< 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
$\eta \pi^- \pi^+ \pi^- \nu_\tau (\text{ex.}K^0)$	(2.25 ± 0.13) $\times 10^{-4}$			744
$\eta \pi^- \pi^+ \pi^- \nu_\tau (\text{ex.}K^0, f_1(1285))$	(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 $\pm$0.09) %	S=1.2		708
$h^- \omega \nu_\tau$	[g]	(2.00 $\pm$0.08) %	S=1.3		708
$K^- \omega \nu_\tau$		(4.1 $\pm$0.9) $\times 10^{-4}$			610
$h^- \omega \pi^0 \nu_\tau$	[g]	(4.1 $\pm$0.4) $\times 10^{-3}$			684
$h^- \omega 2\pi^0 \nu_\tau$		(1.4 $\pm$0.5) $\times 10^{-4}$			644
$\pi^- \omega 2\pi^0 \nu_\tau$		(7.3 $\pm$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 $\pm$0.22) $\times 10^{-4}$			641
$2\pi^- \pi^+ \omega \nu_\tau$		(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
$e^- K^0_S K^0_S$	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 $\mu < 0.29 \times 10^{-10}$ μ_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*.

$\sin^2(\theta_{12}) = 0.304 \pm 0.014$
$\sin^2(2\theta_{12}) = 0.846 \pm 0.021$
$\Delta m_{21}^2 = (7.53 \pm 0.18) \times 10^{-5}$ eV^2
$\sin^2(\theta_{23}) = 0.514^{+0.055}_{-0.056}$ (normal mass hierarchy)
$\sin^2(\theta_{23}) = 0.511 \pm 0.055$ (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)
$\Delta m_{32}^2 = (2.44 \pm 0.06) \times 10^{-3}$ eV^2 [i]   (normal mass hierarchy)
$\Delta m_{32}^2 = (2.49 \pm 0.06) \times 10^{-3}$ 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_{32}^2 is not known at this time. The range quoted is for the absolute value.