LEPTONS

e

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

Mass $m = (548.579909065 \pm 0.000000016) \times 10^{-6}$ u
Mass $m = 0.51099895000 \pm 0.00000000015$ 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
$(g-2)/2 = (1159.65218062 \pm 0.00000012) \times 10^{-6}$
$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$
Electric dipole moment $d < 0.041 \times 10^{-28}$ e cm, CL = 90%
Mean life $\tau > 6.6 \times 10^{28}$ yr, CL = 90% [a]

μ

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

Mass $m = 0.1134289259 \pm 0.0000000025$ u
Mass $m = 105.6583755 \pm 0.0000023$ 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 $(g-2)/2 = (11659205.9 \pm 2.2) \times 10^{-10}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$
Electric dipole moment $\left|\text{d}\right| < 1.8 \times 10^{-19}$ e cm, CL = 95%

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]
$\xi' = 1.00 \pm 0.04$
$\xi'' = 0.98 \pm 0.04$
$\alpha/\text{A} = (0 \pm 4) \times 10^{-3}$
$\alpha'/\text{A} = (-10 \pm 20) \times 10^{-3}$
$\beta/\text{A} = (4 \pm 6) \times 10^{-3}$
$\beta'/\text{A} = (2 \pm 7) \times 10^{-3}$
$\overline{\eta} = 0.02 \pm 0.08$

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] $(6.0\pm0.5)\times10^{-8}$		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*	$< 3.1\times10^{-13}$	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 $m = 1776.93 \pm 0.09$ 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
$c\tau = 87.03$ μm
Magnetic moment anomaly $= -0.057$ to 0.024, CL = 95%
$\text{Re}(d_\tau) = -0.185$ to 0.061×10^{-16} e cm, CL = 95%
$\text{Im}(d_\tau) = -0.103$ to 0.0230×10^{-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) = $(-0.36 \pm 0.25)\%$

Decay parameters

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

$\rho(e \text{ or } \mu) = 0.745 \pm 0.008$
$\rho(e) = 0.747 \pm 0.010$
$\rho(\mu) = 0.763 \pm 0.020$
$\xi(e \text{ or } \mu) = 0.985 \pm 0.030$
$\xi(e) = 0.994 \pm 0.040$
$\xi(\mu) = 1.030 \pm 0.059$
$\eta(e \text{ or } \mu) = 0.013 \pm 0.020$
$\eta(\mu) = 0.094 \pm 0.073$
$(\delta\xi)(e \text{ or } \mu) = 0.746 \pm 0.021$
$(\delta\xi)(e) = 0.734 \pm 0.028$
$(\delta\xi)(\mu) = 0.778 \pm 0.037$
$\xi(\pi) = 0.993 \pm 0.022$
$\xi(\rho) = 0.994 \pm 0.008$
$\xi(a_1) = 1.001 \pm 0.027$
$\xi(\text{all hadronic modes}) = 0.995 \pm 0.007$
$\xi'(\mu) = 0.2 \pm 1.0$
$\overline{\eta}(\mu) = -1.3 \pm 1.7$
$(\xi\kappa)(e \text{ or } \mu) = 0.5 \pm 0.4$
$(\xi\kappa)(e) = -0.4 \pm 1.2$
$(\xi\kappa)(\mu) = 0.8 \pm 0.6$

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")		(85.24 ± 0.06) %		–
particle$^- \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$		(84.58 ± 0.06) %		–
$\mu^-\overline{\nu}_\mu\nu_\tau$	[g]	(17.39 ± 0.04) %		885
$\mu^-\overline{\nu}_\mu\nu_\tau\gamma$	[e]	(3.67 ± 0.08) $\times 10^{-3}$		885
$e^-\overline{\nu}_e\nu_\tau$	[g]	(17.82 ± 0.04) %		888
$e^-\overline{\nu}_e\nu_\tau\gamma$	[e]	(1.83 ± 0.05) %		888
$h^- \geq 0K^0_L\ \nu_\tau$		(12.03 ± 0.05) %		883
$h^-\nu_\tau$		(11.51 ± 0.05) %		883
$\pi^-\nu_\tau$	[g]	(10.82 ± 0.05) %		883
$K^-\nu_\tau$	[g]	(6.96 ± 0.10) $\times 10^{-3}$		820
$h^- \geq 1$ neutrals ν_τ		(37.00 ± 0.09) %		–
$h^- \geq 1\pi^0\nu_\tau$ (ex.K^0)		(36.50 ± 0.09) %		–
$h^-\pi^0\nu_\tau$		(25.93 ± 0.09) %		878
$\pi^-\pi^0\nu_\tau$	[g]	(25.49 ± 0.09) %		878
$\pi^-\pi^0$ non-$\rho(770)\nu_\tau$		(3.0 ± 3.2) $\times 10^{-3}$		878
$K^-\pi^0\nu_\tau$	[g]	(4.33 ± 0.15) $\times 10^{-3}$		814
$h^- \geq 2\pi^0\nu_\tau$		(10.81 ± 0.09) %		–
$h^-2\pi^0\nu_\tau$		(9.48 ± 0.10) %		862
$h^-2\pi^0\nu_\tau$ (ex.K^0)		(9.32 ± 0.10) %		862
$\pi^-2\pi^0\nu_\tau$ (ex.K^0)	[g]	(9.26 ± 0.10) %		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]	(6.5 ± 2.2) $\times 10^{-4}$		796
$h^- \geq 3\pi^0\nu_\tau$		(1.34 ± 0.07) %		–
$h^- \geq 3\pi^0\nu_\tau$ (ex. K^0)		(1.25 ± 0.07) %		–
$h^-3\pi^0\nu_\tau$		(1.18 ± 0.07) %		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]	(4.8 ± 2.1) $\times 10^{-4}$		766
$h^-4\pi^0\nu_\tau$ (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
$a_1(1260)\nu_\tau \to\ \pi^-\gamma\nu_\tau$		(4.0 ± 1.5) $\times 10^{-4}$		–
$K^- \geq 0\pi^0\ \geq 0K^0\ \geq 0\gamma\ \nu_\tau$		(1.552± 0.029) %		820
$K^- \geq 1$ (π^0 or K^0 or γ) ν_τ		(8.59 ± 0.28) $\times 10^{-3}$		–

Modes with K^0's

K^0_S (particles)$^-\,\nu_\tau$		(9.43 ± 0.28) × 10^{-3}	–
$h^-\,\overline{K}^0\,\nu_\tau$		(9.87 ± 0.14) × 10^{-3}	812
$\pi^-\,\overline{K}^0\,\nu_\tau$	[g]	(8.38 ± 0.14) × 10^{-3}	812
$\pi^-\,\overline{K}^0$ (non-$K^*(892)^-$) ν_τ		(5.4 ± 2.1) × 10^{-4}	812
$K^-\,K^0\,\nu_\tau$	[g]	(1.486 ± 0.034) × 10^{-3}	737
$K^-\,K^0 \geq 0\pi^0\,\nu_\tau$		(2.99 ± 0.07) × 10^{-3}	737
$h^-\,\overline{K}^0\,\pi^0\,\nu_\tau$		(5.32 ± 0.13) × 10^{-3}	794
$\pi^-\,\overline{K}^0\,\pi^0\,\nu_\tau$	[g]	(3.82 ± 0.13) × 10^{-3}	794
$\overline{K}^0\,\rho^-\,\nu_\tau$		(2.2 ± 0.5) × 10^{-3}	612
$K^-\,K^0\,\pi^0\,\nu_\tau$	[g]	(1.50 ± 0.07) × 10^{-3}	685
$\pi^-\,\overline{K}^0 \geq 1\pi^0\,\nu_\tau$		(4.08 ± 0.25) × 10^{-3}	–
$\pi^-\,\overline{K}^0\,\pi^0\,\pi^0\,\nu_\tau$ (ex.K^0)	[g]	(2.6 ± 2.3) × 10^{-4}	763
$K^-\,K^0\,\pi^0\,\pi^0\,\nu_\tau$		< 1.6 × 10^{-4} CL=95%	619
$\pi^-\,K^0\,\overline{K}^0\,\nu_\tau$		(1.55 ± 0.24) × 10^{-3}	682
$\pi^-\,K^0_S\,K^0_S\,\nu_\tau$	[g]	(2.35 ± 0.06) × 10^{-4}	682
$\pi^-\,K^0_S\,K^0_L\,\nu_\tau$	[g]	(1.08 ± 0.24) × 10^{-3}	682
$\pi^-\,K^0_L\,K^0_L\,\nu_\tau$		(2.35 ± 0.06) × 10^{-4}	682
$\pi^-\,K^0\,\overline{K}^0\,\pi^0\,\nu_\tau$		(3.6 ± 1.2) × 10^{-4}	614
$\pi^-\,K^0_S\,K^0_S\,\pi^0\,\nu_\tau$	[g]	(1.82 ± 0.21) × 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) × 10^{-5}	–
$f_1(1285)\,\pi^-\,\nu_\tau \to \pi^-\,K^0_S\,K^0_S\,\pi^0\,\nu_\tau$		(6.8 ± 1.5) × 10^{-6}	–
$f_1(1420)\,\pi^-\,\nu_\tau \to \pi^-\,K^0_S\,K^0_S\,\pi^0\,\nu_\tau$		(2.4 ± 0.8) × 10^{-6}	–
$\pi^-\,K^0_S\,K^0_L\,\pi^0\,\nu_\tau$	[g]	(3.2 ± 1.2) × 10^{-4}	614
$\pi^-\,K^0_L\,K^0_L\,\pi^0\,\nu_\tau$		(1.82 ± 0.21) × 10^{-5}	614
$K^-\,K^0_S\,K^0_S\,\nu_\tau$		< 6.3 × 10^{-7} CL=90%	466
$K^-\,K^0_S\,K^0_S\,\pi^0\,\nu_\tau$		< 4.0 × 10^{-7} CL=90%	337
$K^0\,h^+\,h^-\,h^- \geq 0$ neutrals ν_τ		< 1.7 × 10^{-3} CL=95%	760
$K^0\,h^+\,h^-\,h^-\,\nu_\tau$	[g]	(2.5 ± 2.0) × 10^{-4}	760

Modes with three charged particles

$h^-\,h^-\,h^+ \geq 0$ neutrals $\geq 0K^0_L\,\nu_\tau$		(15.20 ± 0.06) %	861
$h^-\,h^-\,h^+ \geq 0$ neutrals ν_τ (ex. $K^0_S \to \pi^+\pi^-$) ("3-prong")		(14.55 ± 0.06) %	861
$h^-\,h^-\,h^+\,\nu_\tau$		(9.80 ± 0.05) %	861
$h^-\,h^-\,h^+\,\nu_\tau$ (ex.K^0)		(9.46 ± 0.05) %	861
$h^-\,h^-\,h^+\,\nu_\tau$ (ex.K^0,ω)		(9.43 ± 0.05) %	861
$\pi^-\,\pi^+\,\pi^-\,\nu_\tau$		(9.31 ± 0.05) %	861
$\pi^-\,\pi^+\,\pi^-\,\nu_\tau$ (ex.K^0)		(9.02 ± 0.05) %	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	± 0.05)	%		861
$h^-h^-h^+ \geq 1$ neutrals ν_τ		(	5.29	± 0.05)	%		–
$h^-h^-h^+ \geq 1\pi^0\nu_\tau$(ex. K^0)		(	5.09	± 0.05)	%		–
$h^-h^-h^+\pi^0\nu_\tau$		(	4.76	± 0.05)	%		834
$h^-h^-h^+\pi^0\nu_\tau$(ex.K^0)		(	4.57	± 0.05)	%		834
$h^-h^-h^+\pi^0\nu_\tau$(ex. K^0, ω)		(	2.79	± 0.07)	%		834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$		(	4.62	± 0.05)	%		834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$)		(	4.49	± 0.05)	%		834
$\pi^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$)	[g]	(	2.74	± 0.07)	%		834
$h^-h^-h^+ \geq 2\pi^0\nu_\tau$(ex. K^0)		(	5.17	± 0.31)	$\times 10^{-3}$		–
$h^-h^-h^+2\pi^0\nu_\tau$		(	5.05	± 0.31)	$\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$(ex.K^0)		(	4.95	± 0.31)	$\times 10^{-3}$		797
$h^-h^-h^+2\pi^0\nu_\tau$(ex.K^0,ω,η)	[g]	(	10	± 4)	$\times 10^{-4}$		797
$h^-h^-h^+3\pi^0\nu_\tau$		(	2.13	± 0.30)	$\times 10^{-4}$		749
$2\pi^-\pi^+3\pi^0\nu_\tau$(ex.$K^0$)		(	1.94	± 0.30)	$\times 10^{-4}$		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, $f_1(1285)$)	[g]	(	1.4	± 2.7)	$\times 10^{-5}$		–
$K^-h^+h^- \geq 0$ neutrals ν_τ		(	6.29	± 0.14)	$\times 10^{-3}$		794
$K^-h^+\pi^-\nu_\tau$(ex.K^0)		(	4.37	± 0.07)	$\times 10^{-3}$		794
$K^-h^+\pi^-\pi^0\nu_\tau$(ex.K^0)		(	8.6	± 1.2)	$\times 10^{-4}$		763
$K^-\pi^+\pi^- \geq 0$ neutrals ν_τ		(	4.77	± 0.14)	$\times 10^{-3}$		794
$K^-\pi^+\pi^- \geq 0\pi^0\nu_\tau$(ex.$K^0$)		(	3.73	± 0.13)	$\times 10^{-3}$		794
$K^-\pi^+\pi^-\nu_\tau$		(	3.45	± 0.07)	$\times 10^{-3}$		794
$K^-\pi^+\pi^-\nu_\tau$(ex.K^0)		(	2.93	± 0.07)	$\times 10^{-3}$		794
$K^-\pi^+\pi^-\nu_\tau$(ex.K^0,ω)	[g]	(	2.93	± 0.07)	$\times 10^{-3}$		794
$K^-\rho^0\nu_\tau \rightarrow K^-\pi^+\pi^-\nu_\tau$		(	1.4	± 0.5)	$\times 10^{-3}$		–
$K^-\pi^+\pi^-\pi^0\nu_\tau$		(	1.31	± 0.12)	$\times 10^{-3}$		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.$K^0$,$\eta$)		(	7.6	± 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
$K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$,$\eta$)	[g]	(	3.9	± 1.4)	$\times 10^{-4}$		763
$K^-\pi^+K^- \geq 0$ neut. ν_τ		<	9		$\times 10^{-4}$	CL=95%	685
$K^-K^+\pi^- \geq 0$ neut. ν_τ		(	1.496	± 0.033)	$\times 10^{-3}$		685
$K^-K^+\pi^-\nu_\tau$	[g]	(	1.435	± 0.027)	$\times 10^{-3}$		685
$K^-K^+\pi^-\pi^0\nu_\tau$	[g]	(	6.1	± 1.8)	$\times 10^{-5}$		618
$K^-K^+K^-\nu_\tau$		(	2.2	± 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%	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 $\pm$ 1.5)	$\times 10^{-5}$		888
$\mu^-e^-e^+\overline{\nu}_\mu\nu_\tau$	$<$ 3.2	$\times 10^{-5}$	CL=90%	885
$\pi^-e^-e^+\nu_\tau$	seen			883
$\pi^-\mu^-\mu^+\nu_\tau$	$<$ 1.14	$\times 10^{-5}$	CL=90%	870

Modes with five charged particles

$3h^-2h^+ \geq 0$ neutrals ν_τ (ex. $K^0_S \to \pi^-\pi^+$) ("5-prong")	(9.9 $\pm$ 0.4)	$\times 10^{-4}$		794
$3h^-2h^+\nu_\tau$(ex.K^0)	(8.29 $\pm$ 0.31)	$\times 10^{-4}$		794
$3\pi^-2\pi^+\nu_\tau$(ex.K^0, ω)	(8.27 $\pm$ 0.31)	$\times 10^{-4}$		794
$3\pi^-2\pi^+\nu_\tau$(ex.K^0, ω, $f_1(1285)$) [g]	(7.75 $\pm$ 0.30)	$\times 10^{-4}$		–
$K^-2\pi^-2\pi^+\nu_\tau$(ex.K^0) [g]	(6 $\pm$12)	$\times 10^{-7}$		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)	(1.65 $\pm$ 0.11)	$\times 10^{-4}$		746
$3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$)	(1.64 $\pm$ 0.11)	$\times 10^{-4}$		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, $f_1(1285)$) [g]	(3.8 $\pm$ 0.9)	$\times 10^{-5}$		–
$K^-2\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$) [g]	(1.1 $\pm$ 0.6)	$\times 10^{-6}$		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

$(5\pi)^-\nu_\tau$	(7.8 $\pm$ 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
$X^-(S{=}-1)\nu_\tau$	(2.92 $\pm$ 0.04)	%			–
$K^*(892)^- \geq 0$ neutrals $\geq 0K^0_L\nu_\tau$	(1.42 $\pm$ 0.18)	%		S=1.4	665
$K^*(892)^-\nu_\tau$	(1.20 $\pm$ 0.07)	%		S=1.8	665
$K^*(892)^-\nu_\tau \to \pi^-\overline{K}^0\nu_\tau$	(7.82 $\pm$ 0.26)	$\times 10^{-3}$			–
$K^*(892)^0K^- \geq 0$ neutrals ν_τ	(3.2 $\pm$ 1.4)	$\times 10^{-3}$			542
$K^*(892)^0K^-\nu_\tau$	(2.1 $\pm$ 0.4)	$\times 10^{-3}$			542
$\overline{K}^*(892)^0\pi^- \geq 0$ neutrals ν_τ	(3.8 $\pm$ 1.7)	$\times 10^{-3}$			656
$\overline{K}^*(892)^0\pi^-\nu_\tau$	(2.2 $\pm$ 0.5)	$\times 10^{-3}$			656
$(\overline{K}^*(892)\pi)^-\nu_\tau \to \pi^-\overline{K}^0\pi^0\nu_\tau$	(1.0 $\pm$ 0.4)	$\times 10^{-3}$			–

$K_1(1270)^-\nu_\tau$		$(\ 4.7 \pm 1.1\ )\times10^{-3}$			447
$K_1(1400)^-\nu_\tau$		$(\ 1.7 \pm 2.6\ )\times10^{-3}$	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%		315
$\eta\pi^-\nu_\tau$		$<\ 9.9\times10^{-5}$	CL=95%		797
$\eta\pi^-\pi^0\nu_\tau$	[g]	$(\ 1.39 \pm 0.07\ )\times10^{-3}$			778
$\eta\pi^-\pi^0\pi^0\nu_\tau$	[g]	$(\ 1.9 \pm 0.4\ )\times10^{-4}$			746
$\eta K^-\nu_\tau$	[g]	$(\ 1.55 \pm 0.08\ )\times10^{-4}$			720
$\eta K^*(892)^-\nu_\tau$		$(\ 1.38 \pm 0.15\ )\times10^{-4}$			511
$\eta K^-\pi^0\nu_\tau$	[g]	$(\ 4.8 \pm 1.2\ )\times10^{-5}$			665
$\eta K^-\pi^0$ (non-$K^*(892)$)ν_τ		$<\ 3.5\times10^{-5}$	CL=90%		–
$\eta\overline{K}^0\pi^-\nu_\tau$	[g]	$(\ 9.4 \pm 1.5\ )\times10^{-5}$			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%		744
$\eta\pi^-\pi^+\pi^-\nu_\tau$ (ex.K^0)	[g]	$(\ 2.20 \pm 0.13\ )\times10^{-4}$			744
$\eta\pi^-\pi^+\pi^-\nu_\tau$ (ex.K^0,$f_1(1285)$)		$(\ 9.9 \pm 1.6\ )\times10^{-5}$			–
$\eta a_1(1260)^-\nu_\tau \to\ \eta\pi^-\rho^0\nu_\tau$		$<\ 3.9\times10^{-4}$	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
$\eta'(958)\pi^-\nu_\tau$		$<\ 4.0\times10^{-6}$	CL=90%		620
$\eta'(958)\pi^-\pi^0\nu_\tau$		$<\ 1.2\times10^{-5}$	CL=90%		591
$\eta'(958)K^-\nu_\tau$		$<\ 2.4\times10^{-6}$	CL=90%		495
$\phi\pi^-\nu_\tau$		$(\ 3.4 \pm 0.6\ )\times10^{-5}$			585
$\phi K^-\nu_\tau$	[g]	$(\ 4.4 \pm 1.6\ )\times10^{-5}$			445
$f_1(1285)\pi^-\nu_\tau$		$(\ 3.9 \pm 0.5\ )\times10^{-4}$	S=1.9		408
$f_1(1285)\pi^-\nu_\tau \to\ \eta\pi^-\pi^+\pi^-\nu_\tau$		$(\ 1.18 \pm 0.07\ )\times10^{-4}$	S=1.3		–
$f_1(1285)\pi^-\nu_\tau \to\ 3\pi^-2\pi^+\nu_\tau$	[g]	$(\ 5.2 \pm 0.4\ )\times10^{-5}$			–
$\pi(1300)^-\nu_\tau \to\ (\rho\pi)^-\nu_\tau \to\ (3\pi)^-\nu_\tau$		$<\ 1.0\times10^{-4}$	CL=90%		–
$\pi(1300)^-\nu_\tau \to\ ((\pi\pi)_{S-\text{wave}}\ \pi)^-\nu_\tau \to\ (3\pi)^-\nu_\tau$		$<\ 1.9\times10^{-4}$	CL=90%		–
$h^-\omega\geq0$ neutrals ν_τ		$(\ 2.40 \pm 0.08\ )\ \%$			708
$h^-\omega\nu_\tau$		$(\ 1.99 \pm 0.06\ )\ \%$			708
$\pi^-\omega\nu_\tau$	[g]	$(\ 1.95 \pm 0.06\ )\ \%$			708
$K^-\omega\nu_\tau$	[g]	$(\ 4.1 \pm 0.9\ )\times10^{-4}$			610
$h^-\omega\pi^0\nu_\tau$	[g]	$(\ 4.1 \pm 0.4\ )\times10^{-3}$			684
$h^-\omega2\pi^0\nu_\tau$		$(\ 1.4 \pm 0.5\ )\times10^{-4}$			644

$\pi^-\omega 2\pi^0\nu_\tau$	[g]	(7.2 ± 1.6) $\times 10^{-5}$		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
$2\pi^-\pi^+\omega\nu_\tau$(ex.$K^0$)	[g]	(8.4 ± 0.6) $\times 10^{-5}$		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
$e^-\gamma\gamma$	*LF*	< 2.5	$\times 10^{-4}$ CL=90%	888
$\mu^-\gamma$	*LF*	< 4.2	$\times 10^{-8}$ CL=90%	885
$\mu^-\gamma\gamma$	*LF*	< 5.8	$\times 10^{-4}$ 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*	< 2.2	$\times 10^{-8}$ CL=90%	719
$\mu^-\rho^0$	*LF*	< 1.7	$\times 10^{-8}$ CL=90%	715
$e^-\omega$	*LF*	< 2.4	$\times 10^{-8}$ CL=90%	716
$\mu^-\omega$	*LF*	< 3.9	$\times 10^{-8}$ CL=90%	711
$e^-K^*(892)^0$	*LF*	< 1.9	$\times 10^{-8}$ CL=90%	665
$\mu^-K^*(892)^0$	*LF*	< 2.9	$\times 10^{-8}$ CL=90%	659
$e^-\overline{K}^*(892)^0$	*LF*	< 1.7	$\times 10^{-8}$ CL=90%	665
$\mu^-\overline{K}^*(892)^0$	*LF*	< 4.3	$\times 10^{-8}$ 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*	< 2.0	$\times 10^{-8}$ CL=90%	596
$\mu^-\phi$	*LF*	< 2.3	$\times 10^{-8}$ 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*	< 1.9	$\times 10^{-8}$ 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%	739
$e^+K^-K^-$	*L*	<	3.3	$\times 10^{-8}$ CL=90%	739
$\mu^-\pi^+K^-$	*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
$\mu^-K^0_SK^0_S$	*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
pe^-e^-	*L*,*B*	<	3.0	$\times 10^{-8}$ CL=90%	641
$\overline{p}e^+e^-$	*L*,*B*	<	3.0	$\times 10^{-8}$ CL=90%	641
$\overline{p}e^+\mu^-$	*L*,*B*	<	2.0	$\times 10^{-8}$ CL=90%	635
$\overline{p}e^-\mu^+$	*L*,*B*	<	1.8	$\times 10^{-8}$ CL=90%	635
$p\mu^-\mu^-$	*L*,*B*	<	4.0	$\times 10^{-8}$ CL=90%	618
$\overline{p}\mu^+\mu^-$	*L*,*B*	<	1.8	$\times 10^{-8}$ 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*	<	4.7	$\times 10^{-8}$ CL=90%	525
$\overline{\Lambda}\pi^-$	*L*,*B*	<	4.3	$\times 10^{-8}$ CL=90%	525
e^- light boson	*LF*	<	9	$\times 10^{-4}$ CL=95%	–
μ^- light boson	*LF*	<	6	$\times 10^{-4}$ 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 $m <$ 0.8 eV, CL = 90% (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 $\mu < 0.064 \times 10^{-10}\ \mu_B$, CL = 90% (solar + radiochemical)

Number of Neutrino Types

Number $N = 2.996 \pm 0.007$ (Standard Model fits to LEP-SLC 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 Masses, Mixing, and Oscillations."

$\sin^2(\theta_{12}) = 0.307 \pm 0.012$
$\Delta m^2_{21} = (7.50 \pm 0.19) \times 10^{-5}$ eV^2
$\sin^2(\theta_{23}) = 0.537 \pm 0.020$ (S = 1.2) (Inverted order)
$\sin^2(\theta_{23}) = 0.534^{+0.015}_{-0.019}$ (Normal order)
$\Delta m^2_{32} = (-2.527 \pm 0.034) \times 10^{-3}$ eV^2 (S = 1.2) (Inverted order)
$\Delta m^2_{32} = (2.451 \pm 0.026) \times 10^{-3}$ eV^2 (Normal order)
$\sin^2(\theta_{13}) = (2.16 \pm 0.06) \times 10^{-2}$ (S = 1.2)
δ, CP violating phase $= 1.21^{+0.19}_{-0.22}\ \pi$ rad (S = 1.2)
$\langle \Delta m^2_{21} - \Delta \overline{m}^2_{21} \rangle < 1.1 \times 10^{-4}$ eV^2, CL = 99.7%
$\langle \Delta m^2_{32} - \Delta \overline{m}^2_{32} \rangle = (-0.12 \pm 0.25) \times 10^{-3}$ eV^2

NOTES

[*a*] This is the best limit for the mode $e^- \to \nu\gamma$.

[*b*] See the review on "Muon Decay Parameters" for definitions and details.

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

[*d*] This only includes events with energy of $e > 45$ MeV and energy of $\gamma > 40$ 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.