

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

$|m_{e^+} - m_{e^-}|/m < 8 \times 10^{-9}$, CL = 90%

$|q_{e^+} + q_{e^-}|/e < 4 \times 10^{-8}$

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 $(g-2)/2 = (11659208 \pm 6) \times 10^{-10}$

$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}} = (-0.11 \pm 0.12) \times 10^{-8}$

Electric dipole moment $d = (3.7 \pm 3.4) \times 10^{-19}$ e cm

Decay parameters [b]

$\rho = 0.7503 \pm 0.0004$

$\eta = 0.001 \pm 0.024$ (S = 2.0)

$\delta = 0.7504 \pm 0.0006$

$\xi P_{\mu} = 1.0007 \pm 0.0035$ [c]

$\xi P_{\mu} \delta / \rho > 0.99682$, CL = 90% [c]

$\xi' = 1.00 \pm 0.04$

$\xi'' = 0.7 \pm 0.4$

$\alpha/A = (0 \pm 4) \times 10^{-3}$

$\alpha'/A = (0 \pm 4) \times 10^{-3}$

$\beta/A = (4 \pm 6) \times 10^{-3}$

$\beta'/A = (1 \pm 5) \times 10^{-3}$

$\bar{\eta} = 0.02 \pm 0.08$

μ^+ modes are charge conjugates of the modes below.

μ^- DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$e^- \bar{\nu}_e \nu_\mu$	$\approx 100\%$		53
$e^- \bar{\nu}_e \nu_\mu \gamma$	[d] $(1.4 \pm 0.4)\%$		53
$e^- \bar{\nu}_e \nu_\mu e^+ e^-$	[e] $(3.4 \pm 0.4) \times 10^{-5}$		53
Lepton Family number (LF) violating modes			
$e^- \nu_e \bar{\nu}_\mu$	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



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

Mass $m = 1776.84 \pm 0.17$ 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

$$c\tau = 87.11 \mu\text{m}$$

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.

$$\begin{aligned} \rho(e \text{ or } \mu) &= 0.745 \pm 0.008 \\ \rho(e) &= 0.747 \pm 0.010 \\ \rho(\mu) &= 0.763 \pm 0.020 \\ \xi(e \text{ or } \mu) &= 0.985 \pm 0.030 \\ \xi(e) &= 0.994 \pm 0.040 \\ \xi(\mu) &= 1.030 \pm 0.059 \\ \eta(e \text{ or } \mu) &= 0.013 \pm 0.020 \\ \eta(\mu) &= 0.094 \pm 0.073 \\ (\delta\xi)(e \text{ or } \mu) &= 0.746 \pm 0.021 \\ (\delta\xi)(e) &= 0.734 \pm 0.028 \\ (\delta\xi)(\mu) &= 0.778 \pm 0.037 \\ \xi(\pi) &= 0.993 \pm 0.022 \\ \xi(\rho) &= 0.994 \pm 0.008 \\ \xi(a_1) &= 1.001 \pm 0.027 \\ \xi(\text{all hadronic modes}) &= 0.995 \pm 0.007 \end{aligned}$$

τ^+ modes are charge conjugates of the modes below. " h^\pm " stands for π^\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 ⁻ ≥ 0 neutrals $\geq 0K^0\nu_\tau$ ("1-prong")	(85.36 \pm 0.08) %	S=1.3	–
particle ⁻ ≥ 0 neutrals $\geq 0K_L^0\nu_\tau$	(84.72 \pm 0.08) %	S=1.4	–
$\mu^- \bar{\nu}_\mu \nu_\tau$	[g] (17.36 \pm 0.05) %		885
$\mu^- \bar{\nu}_\mu \nu_\tau \gamma$	[e] (3.6 \pm 0.4) $\times 10^{-3}$		885
$e^- \bar{\nu}_e \nu_\tau$	[g] (17.85 \pm 0.05) %		888
$e^- \bar{\nu}_e \nu_\tau \gamma$	[e] (1.75 \pm 0.18) %		888
$h^- \geq 0K_L^0 \nu_\tau$	(12.13 \pm 0.07) %	S=1.1	883
$h^- \nu_\tau$	(11.61 \pm 0.06) %	S=1.1	883
$\pi^- \nu_\tau$	[g] (10.91 \pm 0.07) %	S=1.1	883
$K^- \nu_\tau$	[g] (6.96 \pm 0.23) $\times 10^{-3}$	S=1.1	820
$h^- \geq 1$ neutrals ν_τ	(37.06 \pm 0.10) %	S=1.2	–
$h^- \geq 1\pi^0 \nu_\tau$ (ex. K^0)	(36.54 \pm 0.11) %	S=1.2	–
$h^- \pi^0 \nu_\tau$	(25.94 \pm 0.09) %	S=1.1	878
$\pi^- \pi^0 \nu_\tau$	[g] (25.51 \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] (4.29 \pm 0.15) $\times 10^{-3}$		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),	< 9 $\times 10^{-3}$	CL=95%	862
scalar			
$\pi^- 2\pi^0 \nu_\tau$ (ex. K^0),	< 7 $\times 10^{-3}$	CL=95%	862
vector			
$K^- 2\pi^0 \nu_\tau$ (ex. K^0)	[g] (6.5 ±2.3) $\times 10^{-4}$		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 ,	[g] (4.9 ±2.3) $\times 10^{-4}$	S=1.1	765
η)			
$h^- 4\pi^0 \nu_\tau$ (ex. K^0)	(1.5 ±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
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \nu_\tau$	(1.57±0.04) %	S=1.1	820
$K^- \geq 1 (\pi^0 \text{ or } K^0 \text{ or } \gamma) \nu_\tau$	(8.72±0.32) $\times 10^{-3}$	S=1.1	—

Modes with K^0 's

K_S^0 (particles) $^- \nu_\tau$	(9.2 ±0.4) $\times 10^{-3}$	S=1.5	—
$h^- \bar{K}^0 \nu_\tau$	(1.00±0.05) %	S=1.8	812
$\pi^- \bar{K}^0 \nu_\tau$	[g] (8.4 ±0.4) $\times 10^{-3}$	S=2.1	812
$\pi^- \bar{K}^0$	(5.4 ±2.1) $\times 10^{-4}$		812
(non- $K^*(892)^-$) ν_τ			
$K^- K^0 \nu_\tau$	[g] (1.59±0.16) $\times 10^{-3}$		737
$K^- K^0 \geq 0\pi^0 \nu_\tau$	(3.18±0.24) $\times 10^{-3}$		737
$h^- \bar{K}^0 \pi^0 \nu_\tau$	(5.5 ±0.4) $\times 10^{-3}$		794
$\pi^- \bar{K}^0 \pi^0 \nu_\tau$	[g] (4.0 ±0.4) $\times 10^{-3}$		794
$\bar{K}^0 \rho^- \nu_\tau$	(2.2 ±0.5) $\times 10^{-3}$		612
$K^- K^0 \pi^0 \nu_\tau$	[g] (1.59±0.20) $\times 10^{-3}$		685
$\pi^- \bar{K}^0 \geq 1\pi^0 \nu_\tau$	(3.2 ±1.0) $\times 10^{-3}$		—
$\pi^- \bar{K}^0 \pi^0 \pi^0 \nu_\tau$	(2.6 ±2.4) $\times 10^{-4}$		763
$K^- K^0 \pi^0 \pi^0 \nu_\tau$	< 1.6 $\times 10^{-4}$	CL=95%	619
$\pi^- K^0 \bar{K}^0 \nu_\tau$	(1.7 ±0.4) $\times 10^{-3}$	S=1.6	682
$\pi^- K_S^0 K_S^0 \nu_\tau$	[g] (2.4 ±0.5) $\times 10^{-4}$		682
$\pi^- K_S^0 K_L^0 \nu_\tau$	[g] (1.2 ±0.4) $\times 10^{-3}$	S=1.7	682
$\pi^- K^0 \bar{K}^0 \pi^0 \nu_\tau$	(3.1 ±2.3) $\times 10^{-4}$		614
$\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$	< 2.0 $\times 10^{-4}$	CL=95%	614
$\pi^- K_S^0 K_L^0 \pi^0 \nu_\tau$	(3.1 ±1.2) $\times 10^{-4}$		614
$K^0 h^+ h^- h^- \geq 0$ neutrals ν_τ	< 1.7 $\times 10^{-3}$	CL=95%	760
$K^0 h^+ h^- h^- \nu_\tau$	(2.3 ±2.0) $\times 10^{-4}$		760

Modes with three charged particles

$h^- h^- h^+ \geq 0$ neutrals $\geq 0 K_L^0 \nu_\tau$	(15.19±0.08) %	S=1.4	861
$h^- h^- h^+ \geq 0$ neutrals ν_τ (ex. $K_S^0 \rightarrow \pi^+ \pi^-$) ("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]	$(6.1 \pm 2.5) \times 10^{-5}$	S=1.4	618
$K^- K^+ K^- \geq 0$ neut. ν_τ		$< 2.1 \times 10^{-3}$	CL=95%	472
$K^- K^+ K^- \nu_\tau$		$(1.58 \pm 0.18) \times 10^{-5}$		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
$e^- e^- e^+ \bar{\nu}_e \nu_\tau$		$(2.8 \pm 1.5) \times 10^{-5}$		888
$\mu^- e^- e^+ \bar{\nu}_\mu \nu_\tau$		$< 3.6 \times 10^{-5}$	CL=90%	885

Modes with five charged particles

$3h^- 2h^+ \geq 0$ neutrals ν_τ (ex. $K_S^0 \rightarrow \pi^- \pi^+$) ("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
$3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	[g]	$(1.78 \pm 0.27) \times 10^{-4}$		746
$3h^- 2h^+ 2\pi^0 \nu_\tau$		$< 3.4 \times 10^{-6}$	CL=90%	687

Miscellaneous other allowed modes

$(5\pi)^- \nu_\tau$		$(7.6 \pm 0.5) \times 10^{-3}$		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
$X^-(S=-1) \nu_\tau$		$(2.86 \pm 0.07) \%$	S=1.3	—
$K^*(892)^- \geq 0$ neutrals \geq $0K_L^0 \nu_\tau$		$(1.42 \pm 0.18) \%$	S=1.4	665
$K^*(892)^- \nu_\tau$		$(1.20 \pm 0.07) \%$	S=1.8	665
$K^*(892)^- \nu_\tau \rightarrow \pi^- \bar{K}^0 \nu_\tau$		$(7.8 \pm 0.5) \times 10^{-3}$		—
$K^*(892)^0 K^- \geq 0$ 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
$\bar{K}^*(892)^0 \pi^- \geq 0$ neutrals ν_τ		$(3.8 \pm 1.7) \times 10^{-3}$		655
$\bar{K}^*(892)^0 \pi^- \nu_\tau$		$(2.2 \pm 0.5) \times 10^{-3}$		655
$(\bar{K}^*(892)\pi)^- \nu_\tau \rightarrow$ $\pi^- \bar{K}^0 \pi^0 \nu_\tau$		$(1.0 \pm 0.4) \times 10^{-3}$		—
$K_1(1270)^- \nu_\tau$		$(4.7 \pm 1.1) \times 10^{-3}$		433
$K_1(1400)^- \nu_\tau$		$(1.7 \pm 2.6) \times 10^{-3}$	S=1.7	335
$K^*(1410)^- \nu_\tau$		$(1.5 \pm_{-1.0}^{+1.4}) \times 10^{-3}$		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
$\eta \pi^- \nu_\tau$		$< 1.4 \times 10^{-4}$	CL=95%	797
$\eta \pi^- \pi^0 \nu_\tau$	[g]	$(1.39 \pm 0.10) \times 10^{-3}$	S=1.4	778
$\eta \pi^- \pi^0 \pi^0 \nu_\tau$		$(1.5 \pm 0.5) \times 10^{-4}$		746
$\eta K^- \nu_\tau$	[g]	$(1.61 \pm 0.11) \times 10^{-4}$	S=1.1	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%	—
$\eta \bar{K}^0 \pi^- \nu_\tau$		$(9.3 \pm 1.5) \times 10^{-5}$		661
$\eta \bar{K}^0 \pi^- \pi^0 \nu_\tau$		$< 5.0 \times 10^{-5}$	CL=90%	590
$\eta K^- K^0 \nu_\tau$		$< 9.0 \times 10^{-6}$	CL=90%	430
$\eta \pi^+ \pi^- \pi^- \geq 0 \text{ neutrals } \nu_\tau$		$< 3 \times 10^{-3}$	CL=90%	744
$\eta \pi^- \pi^+ \pi^- \nu_\tau (\text{ex.} K^0)$		$(1.64 \pm 0.12) \times 10^{-4}$		744
$\eta a_1(1260)^- \nu_\tau \rightarrow \eta \pi^- \rho^0 \nu_\tau$		$< 3.9 \times 10^{-4}$	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
$\eta'(958) \pi^- \nu_\tau$		$< 7.2 \times 10^{-6}$	CL=90%	620
$\eta'(958) \pi^- \pi^0 \nu_\tau$		$< 8.0 \times 10^{-5}$	CL=90%	591
$\phi \pi^- \nu_\tau$		$(3.4 \pm 0.6) \times 10^{-5}$		585
$\phi K^- \nu_\tau$		$(3.70 \pm 0.33) \times 10^{-5}$	S=1.3	445
$f_1(1285) \pi^- \nu_\tau$		$(3.6 \pm 0.7) \times 10^{-4}$		408
$f_1(1285) \pi^- \nu_\tau \rightarrow$ $\eta \pi^- \pi^+ \pi^- \nu_\tau$		$(1.11 \pm 0.08) \times 10^{-4}$		—
$\pi(1300)^- \nu_\tau \rightarrow (\rho \pi)^- \nu_\tau \rightarrow$ $(3\pi)^- \nu_\tau$		$< 1.0 \times 10^{-4}$	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%	—
$h^- \omega \geq 0 \text{ neutrals } \nu_\tau$		$(2.41 \pm 0.09) \%$	S=1.2	708
$h^- \omega \nu_\tau$	[g]	$(1.99 \pm 0.08) \%$	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
$h^- 2\omega \nu_\tau$		$< 5.4 \times 10^{-7}$	CL=90%	250
$2h^- h^+ \omega \nu_\tau$		$(1.20 \pm 0.22) \times 10^{-4}$		641

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.

$e^- \gamma$	<i>LF</i>	$< 1.1 \times 10^{-7}$	CL=90%	888
$\mu^- \gamma$	<i>LF</i>	$< 4.5 \times 10^{-8}$	CL=90%	885
$e^- \pi^0$	<i>LF</i>	$< 8.0 \times 10^{-8}$	CL=90%	883
$\mu^- \pi^0$	<i>LF</i>	$< 1.1 \times 10^{-7}$	CL=90%	880
$e^- K_S^0$	<i>LF</i>	$< 3.3 \times 10^{-8}$	CL=90%	819
$\mu^- K_S^0$	<i>LF</i>	$< 4.0 \times 10^{-8}$	CL=90%	815
$e^- \eta$	<i>LF</i>	$< 9.2 \times 10^{-8}$	CL=90%	804
$\mu^- \eta$	<i>LF</i>	$< 6.5 \times 10^{-8}$	CL=90%	800

$e^- \rho^0$	LF	< 6.3	$\times 10^{-8}$	CL=90%	719
$\mu^- \rho^0$	LF	< 6.8	$\times 10^{-8}$	CL=90%	715
$e^- \omega$	LF	< 1.1	$\times 10^{-7}$	CL=90%	716
$\mu^- \omega$	LF	< 8.9	$\times 10^{-8}$	CL=90%	711
$e^- K^*(892)^0$	LF	< 7.8	$\times 10^{-8}$	CL=90%	665
$\mu^- K^*(892)^0$	LF	< 5.9	$\times 10^{-8}$	CL=90%	659
$e^- \bar{K}^*(892)^0$	LF	< 7.7	$\times 10^{-8}$	CL=90%	665
$\mu^- \bar{K}^*(892)^0$	LF	< 1.0	$\times 10^{-7}$	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
$e^- f_0(980) \rightarrow e^- \pi^+ \pi^-$	LF	< 3.2	$\times 10^{-8}$	CL=90%	—
$\mu^- f_0(980) \rightarrow \mu^- \pi^+ \pi^-$	LF	< 3.4	$\times 10^{-8}$	CL=90%	—
$e^- \phi$	LF	< 7.3	$\times 10^{-8}$	CL=90%	596
$\mu^- \phi$	LF	< 1.3	$\times 10^{-7}$	CL=90%	590
$e^- e^+ e^-$	LF	< 3.6	$\times 10^{-8}$	CL=90%	888
$e^- \mu^+ \mu^-$	LF	< 3.7	$\times 10^{-8}$	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	< 1.2	$\times 10^{-7}$	CL=90%	877
$e^+ \pi^- \pi^-$	L	< 2.0	$\times 10^{-7}$	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	< 1.6	$\times 10^{-7}$	CL=90%	813
$e^+ \pi^- K^-$	L	< 1.8	$\times 10^{-7}$	CL=90%	813
$e^- K_S^0 K_S^0$	LF	< 2.2	$\times 10^{-6}$	CL=90%	736
$e^- K^+ K^-$	LF	< 1.4	$\times 10^{-7}$	CL=90%	738
$e^+ K^- K^-$	L	< 1.5	$\times 10^{-7}$	CL=90%	738
$\mu^- \pi^+ K^-$	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
$\mu^- K_S^0 K_S^0$	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	< 4.4	$\times 10^{-7}$	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%	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
$\bar{p} \gamma$	L,B	< 3.5	$\times 10^{-6}$	CL=90%	641
$\bar{p} \pi^0$	L,B	< 1.5	$\times 10^{-5}$	CL=90%	632

$\bar{p}2\pi^0$	L,B	< 3.3	$\times 10^{-5}$	CL=90%	604
$\bar{p}\eta$	L,B	< 8.9	$\times 10^{-6}$	CL=90%	475
$\bar{p}\pi^0\eta$	L,B	< 2.7	$\times 10^{-5}$	CL=90%	360
$\Lambda\pi^-$	L,B	< 7.2	$\times 10^{-8}$	CL=90%	525
$\bar{\Lambda}\pi^-$	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 flavor change” by B. Kayser in this *Review*.

$$\begin{aligned}\sin^2(2\theta_{12}) &= 0.87 \pm 0.03 \\ \Delta m_{21}^2 &= (7.59 \pm 0.20) \times 10^{-5} \text{ eV}^2 \\ \sin^2(2\theta_{23}) &> 0.92 \text{ [i]} \\ \Delta m_{32}^2 &= (2.43 \pm 0.13) \times 10^{-3} \text{ eV}^2 \text{ [j]} \\ \sin^2(2\theta_{13}) &< 0.19, \text{ CL} = 90\%\end{aligned}$$

Heavy Neutral Leptons, Searches for

For excited leptons, see Compositeness Limits below.

Stable Neutral Heavy Lepton Mass Limits

$$\begin{aligned}\text{Mass } m &> 45.0 \text{ GeV, CL} = 95\% \quad (\text{Dirac}) \\ \text{Mass } m &> 39.5 \text{ GeV, CL} = 95\% \quad (\text{Majorana})\end{aligned}$$

Neutral Heavy Lepton Mass Limits

$$\begin{aligned}\text{Mass } m &> 90.3 \text{ GeV, CL} = 95\% \\ &(\text{Dirac } \nu_L \text{ coupling to } e, \mu, \tau; \text{ conservative case}(\tau)) \\ \text{Mass } m &> 80.5 \text{ GeV, CL} = 95\% \\ &(\text{Majorana } \nu_L \text{ coupling to } e, \mu, \tau; \text{ conservative case}(\tau))\end{aligned}$$

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 $e^- \bar{\nu}_e \nu_\mu$ and $e^- \bar{\nu}_e \nu_\mu \gamma$ 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 $\sin^2(2\theta_{23})-\Delta m_{32}^2$ plane.
- [j] The sign of Δm_{32}^2 is not known at this time. The range quoted is for the absolute value.