

LEPTONS

e

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

Mass $m = (548.579909070 \pm 0.000000016) \times 10^{-6}$ u

Mass $m = 0.5109989461 \pm 0.0000000031$ MeV

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

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

Magnetic moment anomaly

$(g-2)/2 = (1159.65218091 \pm 0.00000026) \times 10^{-6}$

$(g_{e^+} - g_{e^-}) / g_{\text{average}} = (-0.5 \pm 2.1) \times 10^{-12}$

Electric dipole moment $d < 0.11 \times 10^{-28}$ e cm, CL = 90%

Mean life $\tau > 6.6 \times 10^{28}$ yr, CL = 90% [a]

 μ

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

Mass $m = 0.1134289257 \pm 0.0000000025$ u

Mass $m = 105.6583745 \pm 0.0000024$ 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 $(g-2)/2 = (11659209 \pm 6) \times 10^{-10}$

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

Electric diapole moment $|d| < 1.8 \times 10^{-19}$ 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]

$\xi' = 1.00 \pm 0.04$

$\xi'' = 0.98 \pm 0.04$

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

$\alpha'/A = (-10 \pm 20) \times 10^{-3}$

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

$\beta'/A = (2 \pm 7) \times 10^{-3}$

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

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

μ^- DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c) <i>p</i>
$e^- \bar{\nu}_e \nu_\mu$	$\approx 100\%$		53
$e^- \bar{\nu}_e \nu_\mu \gamma$	[d] $(6.0 \pm 0.5) \times 10^{-8}$		53
$e^- \bar{\nu}_e \nu_\mu e^+ e^-$	[e] $(3.4 \pm 0.4) \times 10^{-5}$		53
Lepton Family number (<i>LF</i>) violating modes			
$e^- \nu_e \bar{\nu}_\mu$	<i>LF</i> [f] < 1.2 %	90%	53
$e^- \gamma$	<i>LF</i> $< 4.2 \times 10^{-13}$	90%	53
$e^- e^+ e^-$	<i>LF</i> $< 1.0 \times 10^{-12}$	90%	53
$e^- 2\gamma$	<i>LF</i> $< 7.2 \times 10^{-11}$	90%	53

T

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

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

$$c\tau = 87.03 \mu\text{m}$$

Magnetic moment anomaly > -0.052 and < 0.013 , CL = 95%

$\text{Re}(d_\tau) = -0.220$ to 0.45×10^{-16} ecm, CL = 95%

$\text{Im}(d_\tau) = -0.250$ to 0.0080×10^{-16} ecm, CL = 95%

Weak dipole moment

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

$\text{Im}(d_\tau^w) < 1.1 \times 10^{-17}$ ecm, 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%

$\tau^\pm \rightarrow \pi^\pm K_S^0 \nu_\tau$ (RATE DIFFERENCE) / (RATE SUM) = $(-0.36 \pm 0.25)\%$

Decay parameters

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

$$\rho(e \text{ or } \mu) = 0.745 \pm 0.008$$

$$\rho(e) = 0.747 \pm 0.010$$

$$\rho(\mu) = 0.763 \pm 0.020$$

$$\xi(e \text{ or } \mu) = 0.985 \pm 0.030$$

$$\xi(e) = 0.994 \pm 0.040$$

$$\xi(\mu) = 1.030 \pm 0.059$$

$$\eta(e \text{ or } \mu) = 0.013 \pm 0.020$$

$$\begin{aligned}
\eta(\mu) &= 0.094 \pm 0.073 \\
(\delta\xi)(e \text{ or } \mu) &= 0.746 \pm 0.021 \\
(\delta\xi)(e) &= 0.734 \pm 0.028 \\
(\delta\xi)(\mu) &= 0.778 \pm 0.037 \\
\xi(\pi) &= 0.993 \pm 0.022 \\
\xi(\rho) &= 0.994 \pm 0.008 \\
\xi(a_1) &= 1.001 \pm 0.027 \\
\xi(\text{all hadronic modes}) &= 0.995 \pm 0.007 \\
\bar{\eta}(\mu) \text{ PARAMETER} &= -1.3 \pm 1.7 \\
\xi_\kappa(e) \text{ PARAMETER} &= -0.4 \pm 1.2 \\
\xi_\kappa(\mu) \text{ PARAMETER} &= 0.8 \pm 0.6
\end{aligned}$$

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	(MeV/c)
Modes with one charged particle			
particle ≥ 0 neutrals	$\geq 0 K^0 \nu_\tau$	(85.24 \pm 0.06) %	-
(“1-prong”)			
particle ≥ 0 neutrals	$\geq 0 K_L^0 \nu_\tau$	(84.58 \pm 0.06) %	-
$\mu^- \bar{\nu}_\mu \nu_\tau$	[g]	(17.39 \pm 0.04) %	885
$\mu^- \bar{\nu}_\mu \nu_\tau \gamma$	[e]	(3.67 \pm 0.08) $\times 10^{-3}$	885
$e^- \bar{\nu}_e \nu_\tau$	[g]	(17.82 \pm 0.04) %	888
$e^- \bar{\nu}_e \nu_\tau \gamma$	[e]	(1.83 \pm 0.05) %	888
$h^- \geq 0 K_L^0 \nu_\tau$		(12.03 \pm 0.05) %	883
$h^- \nu_\tau$		(11.51 \pm 0.05) %	883
$\pi^- \nu_\tau$	[g]	(10.82 \pm 0.05) %	883
$K^- \nu_\tau$	[g]	(6.96 \pm 0.10) $\times 10^{-3}$	820
$h^- \geq 1$ neutrals ν_τ		(37.01 \pm 0.09) %	-
$h^- \geq 1 \pi^0 \nu_\tau$ (ex. K^0)		(36.51 \pm 0.09) %	-
$h^- \pi^0 \nu_\tau$		(25.93 \pm 0.09) %	878
$\pi^- \pi^0 \nu_\tau$	[g]	(25.49 \pm 0.09) %	878
$\pi^- \pi^0$ non- $\rho(770) \nu_\tau$		(3.0 \pm 3.2) $\times 10^{-3}$	878
$K^- \pi^0 \nu_\tau$	[g]	(4.33 \pm 0.15) $\times 10^{-3}$	814
$h^- \geq 2 \pi^0 \nu_\tau$		(10.81 \pm 0.09) %	-
$h^- 2 \pi^0 \nu_\tau$		(9.48 \pm 0.10) %	862
$h^- 2 \pi^0 \nu_\tau$ (ex. K^0)		(9.32 \pm 0.10) %	862
$\pi^- 2 \pi^0 \nu_\tau$ (ex. K^0)	[g]	(9.26 \pm 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 \pm 2.2) $\times 10^{-4}$	796
$h^- \geq 3\pi^0 \nu_\tau$		(1.34 \pm 0.07) %	—
$h^- \geq 3\pi^0 \nu_\tau$ (ex. K^0)		(1.25 \pm 0.07) %	—
$h^- 3\pi^0 \nu_\tau$		(1.18 \pm 0.07) %	836
$\pi^- 3\pi^0 \nu_\tau$ (ex. K^0)	[g]	(1.04 \pm 0.07) %	836
$K^- 3\pi^0 \nu_\tau$ (ex. K^0 , η)	[g]	(4.8 \pm 2.1) $\times 10^{-4}$	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
$a_1(1260)\nu_\tau \rightarrow \pi^- \gamma \nu_\tau$		(3.8 \pm 1.5) $\times 10^{-4}$	—
$K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \nu_\tau$		(1.552 \pm 0.029) %	820
$K^- \geq 1 (\pi^0 \text{ or } K^0 \text{ or } \gamma) \nu_\tau$		(8.59 \pm 0.28) $\times 10^{-3}$	—
Modes with K^0's			
K_S^0 (particles) $^- \nu_\tau$		(9.43 \pm 0.28) $\times 10^{-3}$	—
$h^- \bar{K}^0 \nu_\tau$		(9.87 \pm 0.14) $\times 10^{-3}$	812
$\pi^- \bar{K}^0 \nu_\tau$	[g]	(8.38 \pm 0.14) $\times 10^{-3}$	812
$\pi^- \bar{K}^0$		(5.4 \pm 2.1) $\times 10^{-4}$	812
$(\text{non-}K^*(892)^-) \nu_\tau$			
$K^- K^0 \nu_\tau$	[g]	(1.486 \pm 0.034) $\times 10^{-3}$	737
$K^- K^0 \geq 0\pi^0 \nu_\tau$		(2.99 \pm 0.07) $\times 10^{-3}$	737
$h^- \bar{K}^0 \pi^0 \nu_\tau$		(5.32 \pm 0.13) $\times 10^{-3}$	794
$\pi^- \bar{K}^0 \pi^0 \nu_\tau$	[g]	(3.82 \pm 0.13) $\times 10^{-3}$	794
$\bar{K}^0 \rho^- \nu_\tau$		(2.2 \pm 0.5) $\times 10^{-3}$	612
$K^- K^0 \pi^0 \nu_\tau$	[g]	(1.50 \pm 0.07) $\times 10^{-3}$	685
$\pi^- \bar{K}^0 \geq 1\pi^0 \nu_\tau$		(4.08 \pm 0.25) $\times 10^{-3}$	—
$\pi^- \bar{K}^0 \pi^0 \pi^0 \nu_\tau$ (ex. K^0)	[g]	(2.6 \pm 2.3) $\times 10^{-4}$	763
$K^- K^0 \pi^0 \pi^0 \nu_\tau$		< 1.6 $\times 10^{-4}$ CL=95%	619
$\pi^- K^0 \bar{K}^0 \nu_\tau$		(1.55 \pm 0.24) $\times 10^{-3}$	682
$\pi^- K_S^0 K_S^0 \nu_\tau$	[g]	(2.35 \pm 0.06) $\times 10^{-4}$	682
$\pi^- K_S^0 K_L^0 \nu_\tau$	[g]	(1.08 \pm 0.24) $\times 10^{-3}$	682
$\pi^- K_L^0 K_L^0 \nu_\tau$		(2.35 \pm 0.06) $\times 10^{-4}$	682
$\pi^- K^0 \bar{K}^0 \pi^0 \nu_\tau$		(3.6 \pm 1.2) $\times 10^{-4}$	614
$\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$	[g]	(1.82 \pm 0.21) $\times 10^{-5}$	614
$K^{*-} K^0 \pi^0 \nu_\tau \rightarrow$ $\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(1.08 \pm 0.21) $\times 10^{-5}$	—
$f_1(1285)\pi^- \nu_\tau \rightarrow$ $\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(6.8 \pm 1.5) $\times 10^{-6}$	—
$f_1(1420)\pi^- \nu_\tau \rightarrow$ $\pi^- K_S^0 K_S^0 \pi^0 \nu_\tau$		(2.4 \pm 0.8) $\times 10^{-6}$	—
$\pi^- K_S^0 K_L^0 \pi^0 \nu_\tau$	[g]	(3.2 \pm 1.2) $\times 10^{-4}$	614
$\pi^- K_L^0 K_L^0 \pi^0 \nu_\tau$		(1.82 \pm 0.21) $\times 10^{-5}$	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
$K^0 h^+ h^- h^- \nu_\tau$	[g] (2.5 ± 2.0)	$\times 10^{-4}$		760
Modes with three charged particles				
$h^- h^- h^+ \geq 0$ neutrals $\geq 0 K_L^0 \nu_\tau$	(15.20 ± 0.06)	%		861
$h^- h^- h^+ \geq 0$ neutrals ν_τ (ex. $K_S^0 \rightarrow \pi^+ \pi^-$) ("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, ω)	[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)	(1.95 ± 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 , $\omega, f_1(1285)$)	[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 \pm 0.07) $\times 10^{-3}$	794
$K^-\rho^0\nu_\tau \rightarrow$		(1.4 \pm 0.5) $\times 10^{-3}$	-
$K^-\pi^+\pi^-\nu_\tau$			
$K^-\pi^+\pi^-\pi^0\nu_\tau$		(1.31 \pm 0.12) $\times 10^{-3}$	763
$K^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0)		(7.9 \pm 1.2) $\times 10^{-4}$	763
$K^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0,η)		(7.6 \pm 1.2) $\times 10^{-4}$	763
$K^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0,ω)		(3.7 \pm 0.9) $\times 10^{-4}$	763
$K^-\pi^+\pi^-\pi^0\nu_\tau$ (ex. K^0,ω,η)	[g]	(3.9 \pm 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 \pm 0.033) $\times 10^{-3}$	685
$K^-K^+\pi^-\nu_\tau$	[g]	(1.435 \pm 0.027) $\times 10^{-3}$	685
$K^-K^+\pi^-\pi^0\nu_\tau$	[g]	(6.1 \pm 1.8) $\times 10^{-5}$	618
$K^-K^+K^-\nu_\tau$		(2.2 \pm 0.8) $\times 10^{-5}$	S=5.4
$K^-K^+K^-\nu_\tau$ (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
$\mu^-e^-e^+\bar{\nu}_\mu\nu_\tau$		< 3.2 $\times 10^{-5}$ CL=90%	885
$\pi^-\mu^-\mu^+\nu_\tau$		< 1.14 $\times 10^{-5}$ CL=90%	870

Modes with five charged particles

$3h^-2h^+ \geq 0$ neutrals ν_τ		(9.9 \pm 0.4) $\times 10^{-4}$	794
(ex. $K_S^0 \rightarrow \pi^-\pi^+$)			
("5-prong")			
$3h^-2h^+\nu_\tau$ (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. $K^0, \omega,$	[g]	(7.75 \pm 0.30) $\times 10^{-4}$	-
$f_1(1285))$			
$K^-2\pi^-2\pi^+\nu_\tau$ (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)		(1.63 \pm 0.11) $\times 10^{-4}$	746
$3\pi^-2\pi^+\pi^0\nu_\tau$ (ex. $K^0, \eta,$		(1.11 \pm 0.10) $\times 10^{-4}$	-
$f_1(1285))$			
$3\pi^-2\pi^+\pi^0\nu_\tau$ (ex. $K^0, \eta,$	[g]	(3.8 \pm 0.9) $\times 10^{-5}$	-
$\omega, f_1(1285))$			
$K^-2\pi^-2\pi^+\pi^0\nu_\tau$ (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

		(7.8 \pm 0.5) $\times 10^{-3}$	800
$(5\pi)^-\nu_\tau$		$< 3.0 \times 10^{-7}$ CL=90%	682
$4h^-3h^+ \geq 0$ neutrals ν_τ ("7-prong")		$< 4.3 \times 10^{-7}$ CL=90%	682
$4h^-3h^+\nu_\tau$		$< 2.5 \times 10^{-7}$ CL=90%	612
$X^-(S=-1)\nu_\tau$		(2.92 \pm 0.04) %	—
$K^*(892)^- \geq 0$ neutrals $\geq 0K_L^0\nu_\tau$		(1.42 \pm 0.18) %	S=1.4
$K^*(892)^-\nu_\tau$		(1.20 \pm 0.07) %	S=1.8
$K^*(892)^-\nu_\tau \rightarrow \pi^-\bar{K}^0\nu_\tau$		(7.82 \pm 0.26) $\times 10^{-3}$	—
$K^*(892)^0 K^- \geq 0$ 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) $\times 10^{-3}$	447
$K_1(1400)^-\nu_\tau$		(1.7 \pm 2.6) $\times 10^{-3}$	S=1.7
$K^*(1410)^-\nu_\tau$		(1.5 \pm 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%	315
$\eta\pi^-\nu_\tau$		$< 9.9 \times 10^{-5}$ CL=95%	797
$\eta\pi^-\pi^0\nu_\tau$	[g]	(1.39 \pm 0.07) $\times 10^{-3}$	778
$\eta\pi^-\pi^0\pi^0\nu_\tau$	[g]	(2.0 \pm 0.4) $\times 10^{-4}$	746
$\eta K^-\nu_\tau$	[g]	(1.55 \pm 0.08) $\times 10^{-4}$	719
$\eta K^*(892)^-\nu_\tau$		(1.38 \pm 0.15) $\times 10^{-4}$	511
$\eta K^-\pi^0\nu_\tau$	[g]	(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%	—
$\eta\bar{K}^0\pi^-\nu_\tau$	[g]	(9.4 \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
$\eta\pi^+\pi^-\pi^- \geq 0$ neutrals ν_τ		$< 3 \times 10^{-3}$ CL=90%	744
$\eta\pi^-\pi^+\pi^-\nu_\tau (\text{ex. } K^0)$	[g]	(2.20 \pm 0.13) $\times 10^{-4}$	744
$\eta\pi^-\pi^+\pi^-\nu_\tau (\text{ex. } K^0, f_1(1285))$		(9.9 \pm 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 \pm 0.6) $\times 10^{-5}$	585

$\phi K^- \nu_\tau$	[g]	(4.4 \pm 1.6) $\times 10^{-5}$	445
$f_1(1285)\pi^-\nu_\tau$		(3.9 \pm 0.5) $\times 10^{-4}$	S=1.9
$f_1(1285)\pi^-\nu_\tau \rightarrow \eta\pi^-\pi^+\pi^-\nu_\tau$		(1.18 \pm 0.07) $\times 10^{-4}$	S=1.3
$f_1(1285)\pi^-\nu_\tau \rightarrow 3\pi^-2\pi^+\nu_\tau$	[g]	(5.2 \pm 0.4) $\times 10^{-5}$	-
$\pi(1300)^-\nu_\tau \rightarrow (\rho\pi)^-\nu_\tau \rightarrow (3\pi)^-\nu_\tau$	<	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%
$h^-\omega \geq 0 \text{ neutrals } \nu_\tau$		(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) $\times 10^{-4}$	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
$\pi^-\omega 2\pi^0\nu_\tau$	[g]	(7.2 \pm 1.6) $\times 10^{-5}$	644
$h^-\omega 2\nu_\tau$	<	5.4	$\times 10^{-7}$ CL=90%
$2h^- h^+\omega\nu_\tau$		(1.20 \pm 0.22) $\times 10^{-4}$	641
$2\pi^-\pi^+\omega\nu_\tau$ (ex. K^0)	[g]	(8.4 \pm 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. $\tau^- \rightarrow e^+ \pi^- \pi^-$). 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>	< 3.3	$\times 10^{-8}$ CL=90%	888
$\mu^-\gamma$	<i>LF</i>	< 4.4	$\times 10^{-8}$ 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>	< 2.6	$\times 10^{-8}$ CL=90%	819
$\mu^-K_S^0$	<i>LF</i>	< 2.3	$\times 10^{-8}$ 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
$e^-\rho^0$	<i>LF</i>	< 1.8	$\times 10^{-8}$ CL=90%	719
$\mu^-\rho^0$	<i>LF</i>	< 1.2	$\times 10^{-8}$ CL=90%	715
$e^-\omega$	<i>LF</i>	< 4.8	$\times 10^{-8}$ CL=90%	716
$\mu^-\omega$	<i>LF</i>	< 4.7	$\times 10^{-8}$ CL=90%	711
$e^-K^*(892)^0$	<i>LF</i>	< 3.2	$\times 10^{-8}$ CL=90%	665
$\mu^-K^*(892)^0$	<i>LF</i>	< 5.9	$\times 10^{-8}$ CL=90%	659
$e^-\overline{K}^*(892)^0$	<i>LF</i>	< 3.4	$\times 10^{-8}$ CL=90%	665
$\mu^-\overline{K}^*(892)^0$	<i>LF</i>	< 7.0	$\times 10^{-8}$ CL=90%	659
$e^-\eta'(958)$	<i>LF</i>	< 1.6	$\times 10^{-7}$ CL=90%	630

$\mu^- \eta'(958)$	<i>LF</i>	< 1.3	$\times 10^{-7}$ CL=90%	625
$e^- f_0(980) \rightarrow e^- \pi^+ \pi^-$	<i>LF</i>	< 3.2	$\times 10^{-8}$ CL=90%	—
$\mu^- f_0(980) \rightarrow \mu^- \pi^+ \pi^-$	<i>LF</i>	< 3.4	$\times 10^{-8}$ CL=90%	—
$e^- \phi$	<i>LF</i>	< 3.1	$\times 10^{-8}$ CL=90%	596
$\mu^- \phi$	<i>LF</i>	< 8.4	$\times 10^{-8}$ CL=90%	590
$e^- e^+ e^-$	<i>LF</i>	< 2.7	$\times 10^{-8}$ CL=90%	888
$e^- \mu^+ \mu^-$	<i>LF</i>	< 2.7	$\times 10^{-8}$ CL=90%	882
$e^+ \mu^- \mu^-$	<i>LF</i>	< 1.7	$\times 10^{-8}$ CL=90%	882
$\mu^- e^+ e^-$	<i>LF</i>	< 1.8	$\times 10^{-8}$ CL=90%	885
$\mu^+ e^- e^-$	<i>LF</i>	< 1.5	$\times 10^{-8}$ CL=90%	885
$\mu^- \mu^+ \mu^-$	<i>LF</i>	< 2.1	$\times 10^{-8}$ CL=90%	873
$e^- \pi^+ \pi^-$	<i>LF</i>	< 2.3	$\times 10^{-8}$ CL=90%	877
$e^+ \pi^- \pi^-$	<i>L</i>	< 2.0	$\times 10^{-8}$ CL=90%	877
$\mu^- \pi^+ \pi^-$	<i>LF</i>	< 2.1	$\times 10^{-8}$ CL=90%	866
$\mu^+ \pi^- \pi^-$	<i>L</i>	< 3.9	$\times 10^{-8}$ CL=90%	866
$e^- \pi^+ K^-$	<i>LF</i>	< 3.7	$\times 10^{-8}$ CL=90%	813
$e^- \pi^- K^+$	<i>LF</i>	< 3.1	$\times 10^{-8}$ CL=90%	813
$e^+ \pi^- K^-$	<i>L</i>	< 3.2	$\times 10^{-8}$ CL=90%	813
$e^- K_S^0 K_S^0$	<i>LF</i>	< 7.1	$\times 10^{-8}$ CL=90%	736
$e^- K^+ K^-$	<i>LF</i>	< 3.4	$\times 10^{-8}$ CL=90%	738
$e^+ K^- K^-$	<i>L</i>	< 3.3	$\times 10^{-8}$ CL=90%	738
$\mu^- \pi^+ K^-$	<i>LF</i>	< 8.6	$\times 10^{-8}$ CL=90%	800
$\mu^- \pi^- K^+$	<i>LF</i>	< 4.5	$\times 10^{-8}$ CL=90%	800
$\mu^+ \pi^- K^-$	<i>L</i>	< 4.8	$\times 10^{-8}$ CL=90%	800
$\mu^- K_S^0 K_S^0$	<i>LF</i>	< 8.0	$\times 10^{-8}$ CL=90%	696
$\mu^- K^+ K^-$	<i>LF</i>	< 4.4	$\times 10^{-8}$ CL=90%	699
$\mu^+ K^- K^-$	<i>L</i>	< 4.7	$\times 10^{-8}$ CL=90%	699
$e^- \pi^0 \pi^0$	<i>LF</i>	< 6.5	$\times 10^{-6}$ CL=90%	878
$\mu^- \pi^0 \pi^0$	<i>LF</i>	< 1.4	$\times 10^{-5}$ CL=90%	867
$e^- \eta \eta$	<i>LF</i>	< 3.5	$\times 10^{-5}$ CL=90%	699
$\mu^- \eta \eta$	<i>LF</i>	< 6.0	$\times 10^{-5}$ CL=90%	653
$e^- \pi^0 \eta$	<i>LF</i>	< 2.4	$\times 10^{-5}$ CL=90%	798
$\mu^- \pi^0 \eta$	<i>LF</i>	< 2.2	$\times 10^{-5}$ CL=90%	784
$p \mu^- \mu^-$	<i>L,B</i>	< 4.4	$\times 10^{-7}$ CL=90%	618
$\bar{p} \mu^+ \mu^-$	<i>L,B</i>	< 3.3	$\times 10^{-7}$ CL=90%	618
$\bar{p} \gamma$	<i>L,B</i>	< 3.5	$\times 10^{-6}$ CL=90%	641
$\bar{p} \pi^0$	<i>L,B</i>	< 1.5	$\times 10^{-5}$ CL=90%	632
$\bar{p} 2\pi^0$	<i>L,B</i>	< 3.3	$\times 10^{-5}$ CL=90%	604
$\bar{p} \eta$	<i>L,B</i>	< 8.9	$\times 10^{-6}$ CL=90%	475
$\bar{p} \pi^0 \eta$	<i>L,B</i>	< 2.7	$\times 10^{-5}$ CL=90%	360
$\Lambda \pi^-$	<i>L,B</i>	< 7.2	$\times 10^{-8}$ CL=90%	525

$\Lambda\pi^-$	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 $m < 1.1$ 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 $\mu < 0.28 \times 10^{-10} \mu_B$, 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.”

$$\sin^2(\theta_{12}) = 0.307 \pm 0.013$$

$$\Delta m_{21}^2 = (7.53 \pm 0.18) \times 10^{-5} \text{ eV}^2$$

$$\sin^2(\theta_{23}) = 0.547 \pm 0.021 \quad (\text{Inverted order})$$

$$\sin^2(\theta_{23}) = 0.545 \pm 0.021 \quad (\text{Normal order})$$

$$\Delta m_{32}^2 = (-2.546^{+0.034}_{-0.040}) \times 10^{-3} \text{ eV}^2 \quad (\text{Inverted order})$$

$$\Delta m_{32}^2 = (2.453 \pm 0.034) \times 10^{-3} \text{ eV}^2 \quad (\text{Normal order})$$

$$\sin^2(\theta_{13}) = (2.18 \pm 0.07) \times 10^{-2}$$

δ , CP violating phase = $1.36 \pm 0.17 \pi$ rad

$$\langle \Delta m_{21}^2 - \Delta \bar{m}_{21}^2 \rangle < 1.1 \times 10^{-4} \text{ eV}^2, \text{ CL} = 99.7\%$$

$$\langle \Delta m_{32}^2 - \Delta \bar{m}_{32}^2 \rangle = (-0.12 \pm 0.25) \times 10^{-3} \text{ eV}^2$$

NOTES

- [a] This is the best limit for the mode $e^- \rightarrow \nu \gamma$. The best limit for Nuclear de-excitation experiments is 6.4×10^{24} yr.
- [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 $e^- \bar{\nu}_e \nu_\mu$ 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.