# 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]

## $\mu$

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

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

$\mu^+$ modes are charge conjugates of the modes below.

| $\mu^-$ DECAY MODES | | Fraction ($\Gamma_i/\Gamma$) | 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 |
| $e^-\gamma$ | $LF$ | $< 4.2\times10^{-13}$ | 90% | 53 |
| $e^-e^+e^-$ | $LF$ | $< 1.0\times10^{-12}$ | 90% | 53 |
| $e^-2\gamma$ | $LF$ | $< 7.2\times10^{-11}$ | 90% | 53 |

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

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
$c\tau = 87.03$ $\mu$m
Magnetic moment anomaly $= -0.057$ to 0.024, CL = 95%
$\text{Re}(d_\tau) = -0.185$ to $0.061\times10^{-16}$ $e$ cm, CL = 95%
$\text{Im}(d_\tau) = -0.103$ to $0.0230\times10^{-16}$ $e$ 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 $\tau$ Particle Listings for a note concerning $\tau$-decay parameters.

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

$(\delta\xi)(e \text{ or } \mu) = 0.746 \pm 0.021$
$(\delta\xi)(e) = 0.734 \pm 0.028$
$(\delta\xi)(\mu) = 0.778 \pm 0.037$
$\xi(\pi) = 0.993 \pm 0.022$
$\xi(\rho) = 0.994 \pm 0.008$
$\xi(a_1) = 1.001 \pm 0.027$
$\xi(\text{all hadronic modes}) = 0.995 \pm 0.007$
$\xi'(\mu) = 0.2 \pm 1.0$
$\overline{\eta}(\mu) = -1.3 \pm 1.7$
$(\xi\kappa)(e \text{ or } \mu) = 0.5 \pm 0.4$
$(\xi\kappa)(e) = -0.4 \pm 1.2$
$(\xi\kappa)(\mu) = 0.8 \pm 0.6$

$\tau^+$ modes are charge conjugates of the modes below. "$h^\pm$" stands for $\pi^\pm$ or $K^\pm$. "$\ell$" stands for $e$ or $\mu$. "Neutrals" stands for $\gamma$'s and/or $\pi^0$'s.

| $\tau^-$ DECAY MODES | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level | $p$ (MeV/$c$) |
|---|---|---|---|---|
| **Modes with one charged particle** | | | | |
| particle$^- \geq 0$ neutrals $\geq 0 K^0 \nu_\tau$ ("1-prong") | | (85.24 ± 0.06 ) % | | – |
| particle$^- \geq 0$ neutrals $\geq 0 K^0_L \nu_\tau$ | | (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 |
| $h^- \geq 0 K^0_L \nu_\tau$ | | (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 $\nu_\tau$ | | (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 ) × $10^{-4}$ | | 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.$K^0$, $\eta$) | [g] | ( 4.8 ± 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.$K^0$,$\eta$) | [g] | ( 1.1 ± 0.4 ) × $10^{-3}$ | | 800 |
| $a_1(1260)\nu_\tau \rightarrow \pi^- \gamma \nu_\tau$ | | ( 4.0 ± 1.5 ) × $10^{-4}$ | | – |
| $K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \ \nu_\tau$ | | ( 1.552± 0.029) % | | 820 |
| $K^- \geq 1$ ($\pi^0$ or $K^0$ or $\gamma$) $\nu_\tau$ | | ( 8.59 ± 0.28 ) × $10^{-3}$ | | – |

## 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-$K^*(892)^-$) $\nu_\tau$ | | ( 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 |
| $K^{*-} K^0 \pi^0 \nu_\tau \rightarrow \pi^- K^0_S K^0_S \pi^0 \nu_\tau$ | | ( 1.08 ± 0.21 ) × $10^{-5}$ | | – |
| $f_1(1285)\pi^- \nu_\tau \rightarrow \pi^- K^0_S K^0_S \pi^0 \nu_\tau$ | | ( 6.8 ± 1.5 ) × $10^{-6}$ | | – |
| $f_1(1420)\pi^- \nu_\tau \rightarrow \pi^- K^0_S K^0_S \pi^0 \nu_\tau$ | | ( 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 $\nu_\tau$ | | $< 1.7$ | $\times 10^{-3}$ | CL=95% | 760 |
| $K^0 h^+ h^- h^- \nu_\tau$ | [g] | $( 2.5 \pm 2.0 ) \times 10^{-4}$ | | | 760 |

## Modes with three charged particles

| | | | | | |
|---|---|---|---|---|---|
| $h^- h^- h^+ \geq 0$ neutrals $\geq 0 K^0_L \nu_\tau$ | | (15.20 ± 0.06 ) % | | | 861 |
| $h^- h^- h^+ \geq 0$ neutrals $\nu_\tau$ | | (14.55 ± 0.06 ) % | | | 861 |
| (ex. $K^0_S \to \pi^+\pi^-$) | | | | | |
| ("3-prong") | | | | | |
| $h^- h^- h^+ \nu_\tau$ | | ( 9.80 ± 0.05 ) % | | | 861 |
| $h^- h^- h^+ \nu_\tau$(ex.$K^0$) | | ( 9.46 ± 0.05 ) % | | | 861 |
| $h^- h^- h^+ \nu_\tau$(ex.$K^0$,$\omega$) | | ( 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.$K^0$), | | $< 2.4$ | % | CL=95% | 861 |
| non-axial vector | | | | | |
| $\pi^-\pi^+\pi^-\nu_\tau$(ex.$K^0$,$\omega$) | [g] | ( 8.99 ± 0.05 ) % | | | 861 |
| $h^- h^- h^+ \geq 1$ neutrals $\nu_\tau$ | | ( 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. $K^0$, $\omega$) | | ( 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. | | ( 5.17 ± 0.31 ) $\times 10^{-3}$ | | | – |
| $K^0$) | | | | | |
| $h^- h^- h^+ 2\pi^0 \nu_\tau$ | | ( 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.$K^0$,$\omega$,$\eta$) | [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.$K^0$, $\eta$, | | ( 1.7 ± 0.4 ) $\times 10^{-4}$ | | | – |
| $f_1(1285)$) | | | | | |
| $2\pi^-\pi^+ 3\pi^0 \nu_\tau$(ex.$K^0$, $\eta$, | [g] | ( 1.4 ± 2.7 ) $\times 10^{-5}$ | | | – |
| $\omega$, $f_1(1285)$) | | | | | |
| $K^- h^+ h^- \geq 0$ neutrals $\nu_\tau$ | | ( 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 $\nu_\tau$ | | ( 4.77 ± 0.14 ) $\times 10^{-3}$ | | | 794 |
| $K^-\pi^+\pi^- \geq$ | | ( 3.73 ± 0.13 ) $\times 10^{-3}$ | | | 794 |
| $0\pi^0\nu_\tau$(ex.$K^0$) | | | | | |
| $K^-\pi^+\pi^-\nu_\tau$ | | ( 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.$K^0$,$\omega$) | [g] | ( 2.93 ± 0.07 ) $\times 10^{-3}$ | | | 794 |

| | | | | |
|---|---|---|---|---|
| $K^-\rho^0\nu_\tau \rightarrow K^-\pi^+\pi^-\nu_\tau$ | | $(\ 1.4 \pm 0.5\ )\times10^{-3}$ | | – |
| $K^-\pi^+\pi^-\pi^0\nu_\tau$ | | $(\ 1.31 \pm 0.12\ )\times10^{-3}$ | | 763 |
| $K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$) | | $(\ 7.9 \pm 1.2\ )\times10^{-4}$ | | 763 |
| $K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\eta$) | | $(\ 7.6 \pm 1.2\ )\times10^{-4}$ | | 763 |
| $K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$) | | $(\ 3.7 \pm 0.9\ )\times10^{-4}$ | | 763 |
| $K^-\pi^+\pi^-\pi^0\nu_\tau$(ex.$K^0$,$\omega$,$\eta$) | [g] | $(\ 3.9 \pm 1.4\ )\times10^{-4}$ | | 763 |
| $K^-\pi^+K^-\geq0$ neut. $\nu_\tau$ | | $<\ 9\times10^{-4}$ | CL=95% | 685 |
| $K^-K^+\pi^-\geq0$ neut. $\nu_\tau$ | | $(\ 1.496\pm 0.033)\times10^{-3}$ | | 685 |
| $K^-K^+\pi^-\nu_\tau$ | [g] | $(\ 1.435\pm 0.027)\times10^{-3}$ | | 685 |
| $K^-K^+\pi^-\pi^0\nu_\tau$ | [g] | $(\ 6.1 \pm 1.8\ )\times10^{-5}$ | | 618 |
| $K^-K^+K^-\nu_\tau$ | | $(\ 2.2 \pm 0.8\ )\times10^{-5}$ | S=5.4 | 472 |
| $K^-K^+K^-\nu_\tau$(ex. $\phi$) | | $<\ 2.5\times10^{-6}$ | CL=90% | – |
| $K^-K^+K^-\pi^0\nu_\tau$ | | $<\ 4.8\times10^{-6}$ | CL=90% | 346 |
| $\pi^-K^+\pi^-\geq0$ neut. $\nu_\tau$ | | $<\ 2.5\times10^{-3}$ | CL=95% | 794 |
| $e^-e^-e^+\overline{\nu}_e\nu_\tau$ | | $(\ 2.8 \pm 1.5\ )\times10^{-5}$ | | 888 |
| $\mu^-e^-e^+\overline{\nu}_\mu\nu_\tau$ | | $<\ 3.2\times10^{-5}$ | CL=90% | 885 |
| $\pi^-e^-e^+\nu_\tau$ | | seen | | 883 |
| $\pi^-\mu^-\mu^+\nu_\tau$ | | $<\ 1.14\times10^{-5}$ | CL=90% | 870 |

## Modes with five charged particles

| | | | | |
|---|---|---|---|---|
| $3h^-2h^+\geq0$ neutrals $\nu_\tau$ (ex. $K^0_S\rightarrow\pi^-\pi^+$) ("5-prong") | | $(\ 9.9 \pm 0.4\ )\times10^{-4}$ | | 794 |
| $3h^-2h^+\nu_\tau$(ex.$K^0$) | | $(\ 8.29 \pm 0.31\ )\times10^{-4}$ | | 794 |
| $3\pi^-2\pi^+\nu_\tau$(ex.$K^0$, $\omega$) | | $(\ 8.27 \pm 0.31\ )\times10^{-4}$ | | 794 |
| $3\pi^-2\pi^+\nu_\tau$(ex.$K^0$, $\omega$, $f_1(1285)$) | [g] | $(\ 7.75 \pm 0.30\ )\times10^{-4}$ | | – |
| $K^-2\pi^-2\pi^+\nu_\tau$(ex.$K^0$) | [g] | $(\ 6 \pm 12\ )\times10^{-7}$ | | 716 |
| $K^+3\pi^-\pi^+\nu_\tau$ | | $<\ 5.0\times10^{-6}$ | CL=90% | 716 |
| $K^+K^-2\pi^-\pi^+\nu_\tau$ | | $<\ 4.5\times10^{-7}$ | CL=90% | 528 |
| $3h^-2h^+\pi^0\nu_\tau$(ex.$K^0$) | | $(\ 1.65 \pm 0.11\ )\times10^{-4}$ | | 746 |
| $3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$) | | $(\ 1.64 \pm 0.11\ )\times10^{-4}$ | | 746 |
| $3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$, $\eta$, $f_1(1285)$) | | $(\ 1.11 \pm 0.10\ )\times10^{-4}$ | | – |
| $3\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$, $\eta$, $\omega$, $f_1(1285)$) | [g] | $(\ 3.8 \pm 0.9\ )\times10^{-5}$ | | – |
| $K^-2\pi^-2\pi^+\pi^0\nu_\tau$(ex.$K^0$) | [g] | $(\ 1.1 \pm 0.6\ )\times10^{-6}$ | | 657 |
| $K^+3\pi^-\pi^+\pi^0\nu_\tau$ | | $<\ 8\times10^{-7}$ | CL=90% | 657 |
| $3h^-2h^+2\pi^0\nu_\tau$ | | $<\ 3.4\times10^{-6}$ | CL=90% | 687 |

## Miscellaneous other allowed modes

| | | | | |
|---|---|---|---|---|
| $(5\pi)^-\nu_\tau$ | | $(\ 7.8 \pm 0.5\ )\times10^{-3}$ | | 800 |
| $4h^-3h^+\geq0$ neutrals $\nu_\tau$ ("7-prong") | | $<\ 3.0\times10^{-7}$ | 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 | ± 0.04 ) | % | | – |
| $K^*(892)^-\ \geq$ 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 |
| $K^*(892)^-\nu_\tau \to \pi^-\overline{K}^0\nu_\tau$ | | ( | 7.82 | ± 0.26 ) | $\times 10^{-3}$ | | – |
| $K^*(892)^0K^-\geq 0$ neutrals $\nu_\tau$ | | ( | 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 $\nu_\tau$ | | ( | 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 ) | $\times 10^{-3}$ | | 447 |
| $K_1(1400)^-\nu_\tau$ | | ( | 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% | 315 |
| $\eta\pi^-\nu_\tau$ | | $<$ | 9.9 | | $\times 10^{-5}$ | CL=95% | 797 |
| $\eta\pi^-\pi^0\nu_\tau$ | [g] | ( | 1.39 | ± 0.07 ) | $\times 10^{-3}$ | | 778 |
| $\eta\pi^-\pi^0\pi^0\nu_\tau$ | [g] | ( | 1.9 | ± 0.4 ) | $\times 10^{-4}$ | | 746 |
| $\eta K^-\nu_\tau$ | [g] | ( | 1.55 | ± 0.08 ) | $\times 10^{-4}$ | | 720 |
| $\eta K^*(892)^-\nu_\tau$ | | ( | 1.38 | ± 0.15 ) | $\times 10^{-4}$ | | 511 |
| $\eta K^-\pi^0\nu_\tau$ | [g] | ( | 4.8 | ± 1.2 ) | $\times 10^{-5}$ | | 665 |
| $\eta K^-\pi^0$(non-$K^*(892)$)$\nu_\tau$ | | $<$ | 3.5 | | $\times 10^{-5}$ | CL=90% | – |
| $\eta\overline{K}^0\pi^-\nu_\tau$ | [g] | ( | 9.4 | ± 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 $\nu_\tau$ | | $<$ | 3 | | $\times 10^{-3}$ | CL=90% | 744 |
| $\eta\pi^-\pi^+\pi^-\nu_\tau$(ex.$K^0$) | [g] | ( | 2.20 | ± 0.13 ) | $\times 10^{-4}$ | | 744 |
| $\eta\pi^-\pi^+\pi^-\nu_\tau$(ex.$K^0$,$f_1(1285)$) | | ( | 9.9 | ± 1.6 ) | $\times 10^{-5}$ | | – |
| $\eta a_1(1260)^-\nu_\tau \to \eta\pi^-\rho^0\nu_\tau$ | | $<$ | 3.9 | | $\times 10^{-4}$ | CL=90% | – |
| $\eta\eta\pi^-\nu_\tau$ | | $<$ | 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 |
| $\phi K^-\nu_\tau$ | [g] | ( | 4.4 | ± 1.6 ) | $\times 10^{-5}$ | | 445 |
| $f_1(1285)\pi^-\nu_\tau$ | | ( | 3.9 | ± 0.5 ) | $\times 10^{-4}$ | S=1.9 | 408 |
| $f_1(1285)\pi^-\nu_\tau \to \eta\pi^-\pi^+\pi^-\nu_\tau$ | | ( | 1.18 | ± 0.07 ) | $\times 10^{-4}$ | S=1.3 | – |

| | | | | |
|---|---|---|---|---|
| $f_1(1285)\pi^-\nu_\tau \rightarrow 3\pi^-2\pi^+\nu_\tau$ | [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% | – |
| $h^-\omega \geq 0$ 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 |
| $h^-2\omega\nu_\tau$ | | $< 5.4$ | $\times 10^{-7}$ CL=90% | 250 |
| $2h^-h^+\omega\nu_\tau$ | | $(\ 1.20 \pm 0.22\ ) \times 10^{-4}$ | | 641 |
| $2\pi^-\pi^+\omega\nu_\tau$(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.

| | | | | |
|---|---|---|---|---|
| $e^-\gamma$ | *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 |
| $e^-f_0(980) \rightarrow e^-\pi^+\pi^-$ | *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* | < | 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* | < | 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% | 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 |
| $\mu^- K^0_S K^0_S$ | *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 |
| $p e^- e^-$ | *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* | < | 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* | < | 9 | $\times 10^{-4}$ CL=95% | – |
| $\mu^-$ 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 $\nu W$.

**$L^\pm$ – 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."

$\sin^2(\theta_{12}) = 0.307 \pm 0.013$
$\Delta m^2_{21} = (7.53 \pm 0.18) \times 10^{-5}$ eV$^2$
$\sin^2(\theta_{23}) = 0.553^{+0.016}_{-0.024}$ (S = 1.1) (Inverted order)
$\sin^2(\theta_{23}) = 0.558^{+0.015}_{-0.021}$ (Normal order)
$\Delta m^2_{32} = (-2.529 \pm 0.029) \times 10^{-3}$ eV$^2$ (Inverted order)
$\Delta m^2_{32} = (2.455 \pm 0.028) \times 10^{-3}$ eV$^2$ (Normal order)

$\sin^2(\theta_{13}) = (2.19 \pm 0.07) \times 10^{-2}$ (S = 1.2)
$\delta$, *CP* violating phase = $1.19 \pm 0.22\ \pi$ 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*] $P_\mu$ 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 $\tau$.

[*h*] $L^\pm$ mass limit depends on decay assumptions; see the Full Listings.