Lepton Flavour Violation in the Littlest Higgs Model with T-parity

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arXiv:1705.08827 [hep-ph]
arXiv:1709.xxxxx [hep-ph]

CENTRO ANDALUZ DE FISICA DE PARTICULAS ELEMENTALES
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There is a large literature, and excellent reviews, on Little Higgs models:

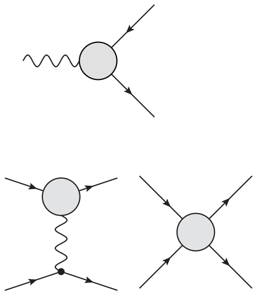
- N. Arkani-Hamed, A.G. Cohen, H. Georgi, hep-ph/0105239
- N. Arkani-Hamed, A.G. Cohen, E. Katz, A.E. Nelson, hep-ph/0206021
- H.C. Cheng, I. Low, hep-ph/0308199, hep-ph/0405243
- M. Schmaltz, D. Tucker-Smith, hep-ph/0502182
- T. Han, H.E. Logan, L.T. Wang, hep-ph/0506313
- M. Perelstein, hep-ph/0512128
- J. Hubisz, P. Meade, A. Noble, M. Perelstein, hep-ph/0506042
- C.R. Chen, K. Tobe, C.P. Yuan, hep-ph/0602211
- M. Blanke, A.J. Buras, A. Poschenrieder, C. Tarantino, S. Uhlig, A. Weiler, hep-ph/0605214

- Flavour anomalies discussion in the next three talks in Corfu 2017

Outline

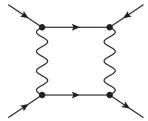
- Motivation
  - No large Flavour Violating effects
- Model
  - Short review
- Lepton Flavour Violation in the LHT
  - Higgs decays
  - Gauge boson mediated processes
- Results
- Conclusions

UPPER LIMITS



10^{-4}

	Branching Ratio		Branching Ratio
$\mu^- \to e^- \gamma$	5.7×10^{-13}	$\mu^- \to e^- e^+ e^-$	1.0×10^{-12}
	Conversion Rate		
$\mu^- \to e^-$	7.0×10^{-13}		
	Branching Ratio		
$\tau^- \to e^- \gamma$	1.2×10^{-7}	$\tau^- \to \mu^- e^+ \mu^-$	1.7×10^{-8}
$\tau^- \to \mu^- \gamma$	4.5×10^{-8}	$\tau^- \to e^- \mu^+ e^-$	1.5×10^{-8}
$\tau^+ \to e^+ \gamma$	3.3×10^{-8}	$\tau^- \to \mu^- e^+ e^-$	1.8×10^{-8}
$\tau^+ \to \mu^+ \gamma$	4.4×10^{-8}	$\tau^- \to e^- \mu^+ \mu^-$	2.7×10^{-8}
		$\tau^- \to e^- e^+ e^-$	2.7×10^{-8}
		$\tau^- \to \mu^- \mu^+ \mu^-$	2.1×10^{-8}
$Z \to \mu e$	7.5×10^{-7}	$h \to \mu e$	3.5×10^{-4}
$Z \to \tau e$	9.8×10^{-6}	$h \to \tau e$	6.1×10^{-3}
$Z \to \tau \mu$	1.2×10^{-5}	$h \to \tau \mu$	2.5×10^{-3}



universality violation $\sim 25\%$

$$\frac{1}{16\pi^2}\frac{1}{f^2}\overline{l_L}\phi\ell_R\phi^\dagger\phi$$

$$\left|\frac{1}{16\pi^2}\frac{v^2}{f^2}\right|^2 \sim 10^{-7}$$

$$\delta a_\mu \sim \frac{\alpha}{4\pi}\frac{m_\ell^2}{M_{W_H}^2} \sim 10^{-11}$$

No tree level anomalies

- Little Higgs models stabilise the Standard Model (SM) Higgs doublet making it part of the Goldstone bosons associated with the breaking of a large enough global symmetry above the electro-weak scale v ~ 246 GeV. In the littlest case SU(5) breaks down to SO(5) at f ~ few TeV.

- If the model can incorporate a Z_2 symmetry under which SM particles are even and the extra particles are odd, the latter must be pair produced and hence, their indirect effects are suppressed by at least one loop and the direct ones by the available energy -which must be larger than twice the lightest odd particle-.

- Such a discrete symmetry is realised in the Littlest Higgs model with T-parity (LHT). Hence, in this case Lepton Flavour Violating (LFV) amplitudes are suppressed by a factor $\frac{1}{16\pi^2}\frac{v^2}{f^2} \sim 4 \times 10^{-4}$. Smaller branching ratios can be accommodated allowing for small mixing angles.

- Previous studies of $\mu \to e\gamma, \mu \to e\bar{e}e, \mu N \to eN$ only include part of the T-odd spectrum. As recently noticed, Higgs decays are only one-loop finite if all T-odd particles are taken into account. What requires a reanalysis of all processes.

GLOBAL

$$SU(5) \to SO(5) : \Sigma_0 = \begin{pmatrix} \mathbf{0}_{2\times 2} & 0 & \mathbf{1}_{2\times 2} \\ 0 & 1 & 0 \\ \mathbf{1}_{2\times 2} & 0 & \mathbf{0}_{2\times 2} \end{pmatrix}$$

$$24 = 14 + 10$$

T − even (SM)

$$\Pi = \begin{pmatrix} -\frac{\omega^0}{2} - \frac{\eta}{\sqrt{20}} & -\frac{\omega^+}{\sqrt{2}} & -i\frac{\pi^+}{\sqrt{2}} & -i\Phi^{++} & -i\frac{\Phi^+}{\sqrt{2}} \\ -\frac{\omega^-}{\sqrt{2}} & \frac{\omega^0}{2} - \frac{\eta}{\sqrt{20}} & \frac{v+h+i\pi^0}{2} & -i\frac{\Phi^+}{\sqrt{2}} & \frac{-i\Phi^0+\Phi^P}{\sqrt{2}} \\ i\frac{\pi^-}{\sqrt{2}} & \frac{v+h-i\pi^0}{2} & \sqrt{\frac{4}{5}}\eta & -i\frac{\pi^+}{\sqrt{2}} & \frac{v+h+i\pi^0}{2} \\ i\Phi^{--} & i\frac{\Phi^-}{\sqrt{2}} & i\frac{\pi^-}{\sqrt{2}} & -\frac{\omega^0}{2} - \frac{\eta}{\sqrt{20}} & -\frac{\omega^-}{\sqrt{2}} \\ i\frac{\Phi^-}{\sqrt{2}} & \frac{i\Phi^0+\Phi^P}{\sqrt{2}} & \frac{v+h-i\pi^0}{2} & -\frac{\omega^+}{\sqrt{2}} & \frac{\omega^0}{2} - \frac{\eta}{\sqrt{20}} \end{pmatrix}$$

All the other bosons T − odd

GAUGE

$$SU(2)_1 \times U(1)_1 \times SU(2)_2 \times U(1)_2 \to SU(2)_{1+2} \times U(1)_{1+2}$$

$\gamma_H, Z_H, W_H^{\pm}$

T − even (SM) $\gamma, Z, W^{\pm}$

LEPTONS PER FAMILY

Left − handed

$l_L = \frac{1}{\sqrt{2}}(l_{1L} - l_{2L})$

T − even (SM)

$$\Psi_1[\bar{\mathbf{5}}] = \begin{pmatrix} -\mathrm{i}\sigma^2 l_{1L} \\ 0 \\ 0 \end{pmatrix} \quad \Psi_2[\mathbf{5}] = \begin{pmatrix} 0 \\ 0 \\ -\mathrm{i}\sigma^2 l_{2L} \end{pmatrix} \quad \Psi_R = \begin{pmatrix} -\mathrm{i}\sigma^2 \tilde{l}^c_L \\ \chi_R \\ -\mathrm{i}\sigma^2 l_{HR} \end{pmatrix} \text{T − even} \quad \Psi_L = \begin{pmatrix} -i\sigma^2 \tilde{l}^c_R \\ \chi_L \\ 0 \end{pmatrix}$$

Right − handed

ℓ_R

T − even (SM)

All the other leptons T − odd

Heavy masses $\sim f$

$$\mathcal{L}_{Y_H} = -\kappa f \left(\overline{\Psi}_2 \xi + \overline{\Psi}_1 \Sigma_0 \xi^\dagger\right) \Psi_R + \text{h.c.}$$

$$\xi = e^{i\Pi/f} \qquad \Sigma_0 = \begin{pmatrix} \mathbf{0}_{2\times 2} & 0 & \mathbf{1}_{2\times 2} \\ 0 & 1 & 0 \\ \mathbf{1}_{2\times 2} & 0 & \mathbf{0}_{2\times 2} \end{pmatrix}$$

$V_{i\ell}$ $\quad$ W_{ji}

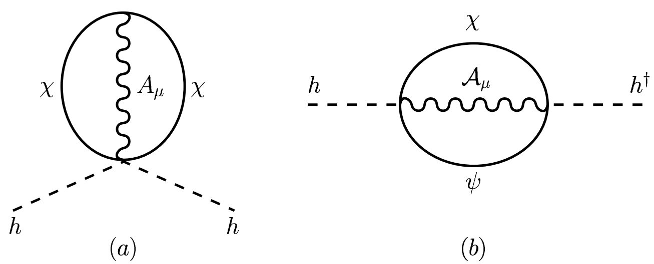
SM masses $\sim v$

$$\mathcal{L}_Y = \frac{i\lambda_\ell}{2\sqrt{2}} f \epsilon_{ij} \epsilon_{xyz} \left[(\overline{\Psi}'_2)_x \Sigma_{iy} \Sigma_{jz} X + \text{T-transformed} \right] \ell_R + \text{h.c.}$$

$$\Sigma(x) = e^{i\Pi/f} \Sigma_0 e^{i\Pi^T/f}$$

$$\Psi'_2 = \begin{pmatrix} 0 \\ 0 \\ l_{2L} \end{pmatrix}, \quad X = (\Sigma_{33})^{-\frac{1}{4}}$$

H.C. Cheng, I. Low, hep-ph/0405243



Large masses

$$\mathcal{L}_M = -M \bar{\tilde{l}}_R \tilde{l}_L + \text{h.c.}$$

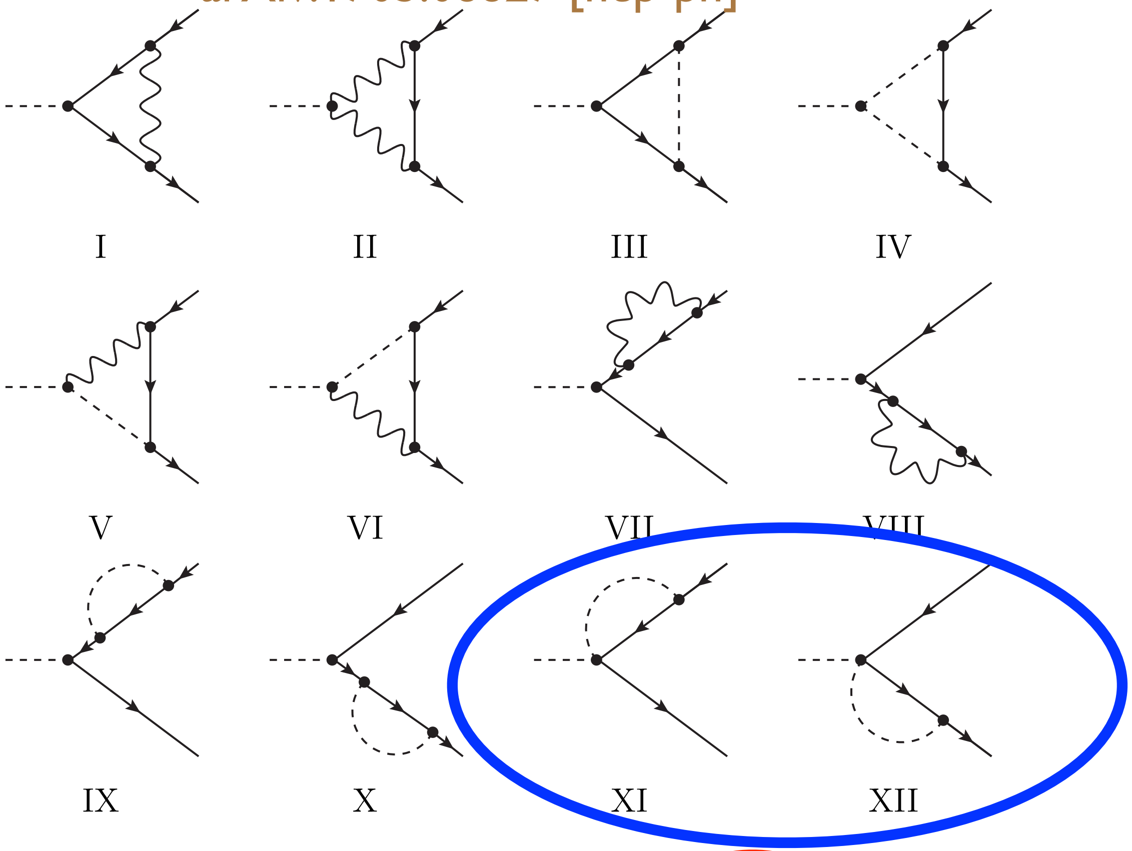


Figure 1. Topologies contributing to $h \to \ell\ell'$.

$$\frac{1}{16\pi^2}\left(C^{(1)}_{\rm UV} + \frac{v^2}{f^2} C^{(\frac{v^2}{f^2})}_{\rm UV}\right)\frac{1}{\epsilon}\sum_{i=1}^{3} V^\dagger_{\ell' i} V_{i\ell} \frac{m^2_{\ell_H i}}{f^2}\bar{u}(p', m_{\ell'})\left(\frac{m_{\ell'}}{v}P_L + \frac{m_\ell}{v}P_R\right)v(p, m_\ell)$$

$C^{(1)}_{\rm UV}$	I	II	III	IV	V+VI	VII+VIII	IX+X	XI+XII	Sum
ω, ν_H	–	–	•	•	–	–	1	-1	•
ω^0, ℓ_H	–	–	•	•	–	–	$\frac{1}{2}$	$-\frac{1}{2}$	•
η, ℓ_H	–	–	•	•	–	–	$\frac{1}{10}$	$-\frac{1}{10}$	•
Total	–	–	•	•	–	–	$\frac{8}{5}$	$-\frac{8}{5}$	•

Table 6. Divergent contributions proportional to $\frac{1}{\epsilon}$, with $\epsilon = 4 - d$ the extra dimensions in dimensional regularization, of each particle set running in the loop and topology in Figure 1 contributing at $\mathcal{O}(1)$. A dash means that the field set does not run in the diagram, whereas a dot indicates that the infinite and finite parts vanish.

$C_{\rm UV}^{(\frac{v^2}{f^2})}$	I	II	III	IV	V+VI	VII+VIII	IX+X	XI+XII	Sum
W_H, ν_H	0	0	–	–	–	•	–	–	0
W_H, ω, ν_H	–	–	–	–	0	–	–	–	0
ω, ν_H	–	–	$\frac{1}{4}$	$-\frac{1}{8}$	–	–	$-\frac{1}{6}$	$\frac{5}{24}$	$\frac{1}{6}$
Z_H, ℓ_H	•	0	–	–	–	•	–	–	0
Z_H, ω^0, ℓ_H	–	–	–	–	0	–	–	–	0
ω^0, ℓ_H	–	–	•	$-\frac{1}{16}$	–	–	$-\frac{13}{48} + x_H \frac{c_W}{s_W}$	$\frac{7}{16} - x_H \frac{c_W}{s_W}$	$\frac{5}{48}$
$A_H \ell_H$	•	0	–	–	–	•	–	–	0
A_H, η, ℓ_H	–	–	–	–	0	–	–	–	0
η, ℓ_H	–	–	•	$-\frac{1}{16}$	–	–	$-\frac{23}{240} - x_H \frac{s_W}{5c_W}$	$-\frac{17}{240} + x_H \frac{s_W}{5c_W}$	$-\frac{11}{48}$
Z_H, A_H, ℓ_H	–	0	–	–	–	–	–	–	0
ω^0, η, ℓ_H	–	–	–	$\frac{1}{8}$	–	–	–	–	$\frac{1}{8}$
W_H, Φ, ν_H	–	–	–	–	0	–	–	–	0
Φ, ν_H	–	–	•	•	–	–	$-\frac{1}{8}$	$\frac{1}{24}$	$-\frac{1}{12}$
ω, Φ, ν_H	–	–	–	$\frac{1}{6}$	–	–	–	–	$\frac{1}{6}$
ω^0, Φ^P, ℓ_H	–	–	–	$\frac{1}{24}$	–	–	–	–	$\frac{1}{24}$
η, Φ^P, ℓ_H	–	–	–	$-\frac{1}{24}$	–	–	–	–	$-\frac{1}{24}$
$\Phi, \tilde{\nu}^c, \nu_H$	–	–	$-\frac{1}{4}$	$\frac{1}{24}$	–	–	•	$-\frac{1}{24}$	$-\frac{1}{4}$
Total	0	0	0	$\frac{1}{12}$	0	•	$-\frac{49}{120}$	$\frac{39}{120}$	0

Table 7. As in Table 6 but to $\mathcal{O}(v^2/f^2)$. $x_H = \frac{5t_W}{4(5-t_W^2)}$ is defined in Eq. (2.33) with $t_W = \frac{s_W}{c_W}$.

F.A., M. Pérez-Victoria, J. Santiago, hep-ph/0007160

$$\mathcal{L}_{eff} = -\frac{\sqrt{2}}{v} m_{\ell_i} \bar{l}_{L\,i} \phi\, \ell_{R\,i} + \frac{c_{ij}}{f^2} |\phi|^2 \bar{l}_{L\,i} \phi\, \ell_{R\,j} + \text{h.c.} + \ldots$$

$$= \left[\left(-m_{\ell_i} \delta_{ij} + \frac{1}{2\sqrt{2}} \frac{v^3}{f^2} c_{ij} \right) + \frac{h}{v} \left(-m_{\ell_i} \delta_{ij} + \frac{3}{2\sqrt{2}} \frac{v^3}{f^2} c_{ij} \right) \right] \bar{\ell}_{L\,i}\, \ell_{R\,j} + \text{h.c.} + \ldots\ ,$$

$$\frac{c_{ij} v}{2\sqrt{2}} + (A_L)_{ij} m_{\ell_j} - m_{\ell_i} (A_R)_{ij} = 0\,, \quad (i \neq j,\ \text{physical basis})$$

$$\frac{v^2}{f^2} \left[\frac{3\, c_{ij}}{2\sqrt{2}} + (A_L)_{ij} \frac{m_{\ell_j}}{v} - \frac{m_{\ell_i}}{v} (A_R)_{ij} \right] h\, \bar{\ell}_{L\,i}\, \ell_{R\,j} + \ldots$$

$$= \frac{1}{\sqrt{2}} \frac{v^2}{f^2} c_{ij}\, h\, \bar{\ell}_{L\,i}\, \ell_{R\,j} + \ldots, \quad (i \neq j,\ \text{physical basis})$$

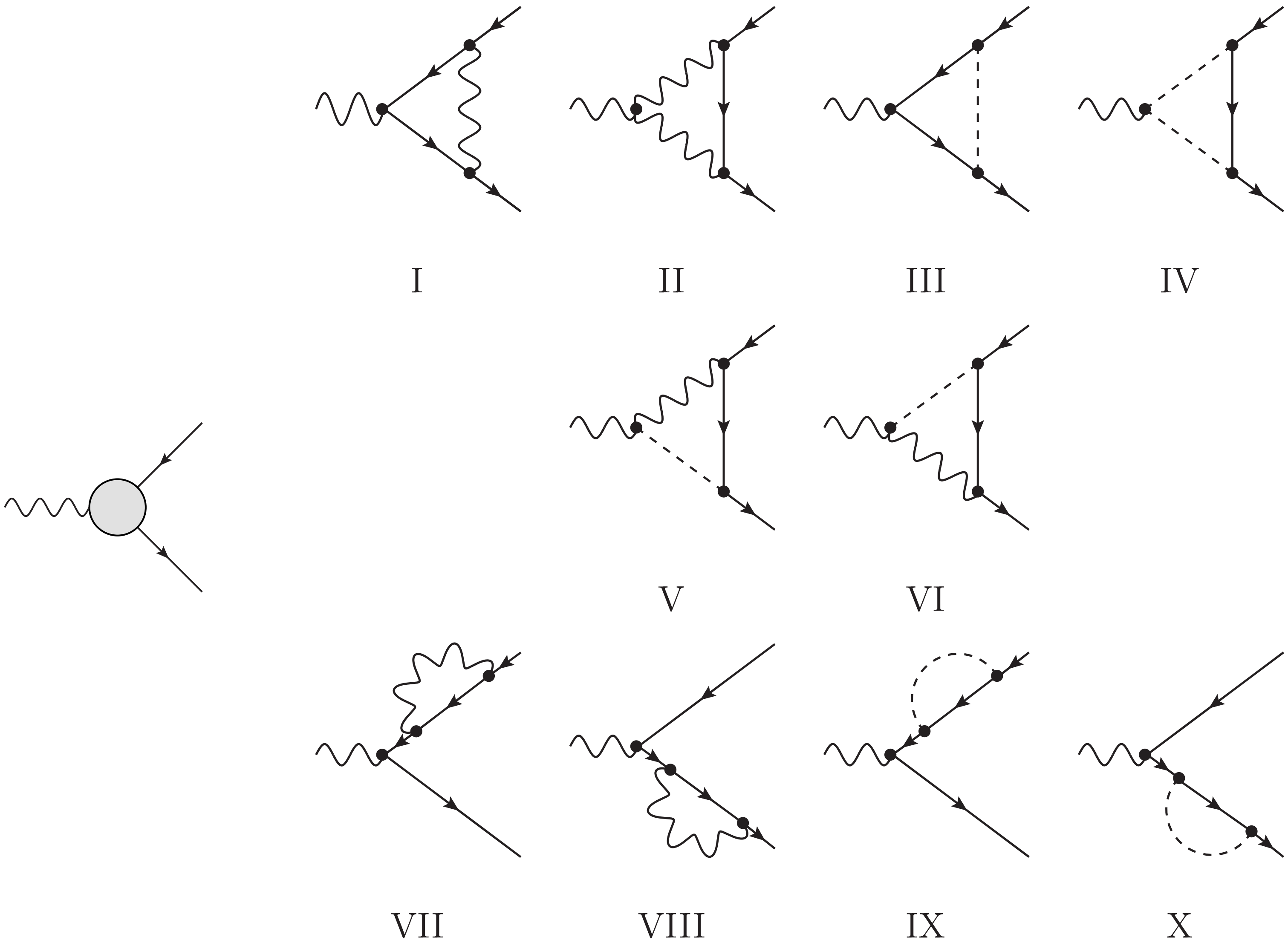


Figure 1: Topologies contributing to $\gamma, Z \to \bar{\ell}\ell'$.

S.R. Choudhury, A.S. Cornell, A. Deandrea, N. Gaur, A. Goyal, hep-ph/0612327
M. Blanke, A.J. Buras, B. Duling, A. Poschenrieder, C. Tarantino, hep-ph/0702136
T. Goto, Y. Okada, Y. Yamamoto, arXiv:0809.4753[hep-ph]
F.A., J.I. Illana, M.D. Jenkins, arXiv:0811.2891[hep-ph]

$C_{\rm UV}^{(1)}$	I	II	III	IV	V+VI	VII+VIII	IX+X	Sum
W_H	0	0	$\frac{1}{2}$	$-1+s_W^2$	•	–	$\frac{1}{2}-s_W^2$	•
Z_H	0	•	$-\frac{1}{4}+\frac{s_W^2}{2}$	•	–	0	$\frac{1}{4}-\frac{s_W^2}{2}$	•
A_H	0	•	$-\frac{1}{20}+\frac{s_W^2}{10}$	•	–	0	$\frac{1}{20}-\frac{s_W^2}{10}$	•
$\tilde{l}$	–	–	$\frac{1}{2}-2s_W^2$	$-2+5s_W^2$	–	–	$\frac{3}{2}-3s_W^2$	•
Total	0	0	$\frac{7}{10}-\frac{7s_W^2}{5}$	$-3+6s_W^2$	•	0	$\frac{23}{10}-\frac{23s_W^2}{5}$	•

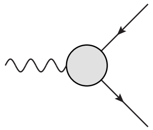
$C_{\rm UV}^{(\frac{v^2}{f^2})}$	I	II	III	IV	V+VI	VII+VIII	IX+X	Sum
W_H	0	0	$-\frac{1}{8}$	$\frac{1}{8}$	0	0	0	0
Z_H	0	•	$\frac{1}{8}-\frac{s_W^2}{4}-5c_W^2 y_H$	•	–	0	$-\frac{1}{8}+\frac{s_W^2}{4}+5c_W^2 y_H$	0
A_H	0	•	$\frac{1}{8}-\frac{s_W^2}{4}+s_W^2 y_H$	•	–	0	$-\frac{1}{8}+\frac{s_W^2}{4}-s_W^2 y_H$	0
$\tilde{l}$	–	–	$\frac{1}{8}$	$-\frac{1}{8}$	–	–	•	0
Total	0	0	$\frac{1}{8}-\frac{s_W^2}{4}$	0	0	0	$-\frac{1}{8}+\frac{s_W^2}{4}$	0

Table II: As in Table I but to $\mathcal{O}(\frac{v^2}{f^2})$. $y_H=\frac{1-t_W}{8(5-t_W^2)}$ with $t_W=\frac{s_W}{c_W}$.

arXiv:1709.xxxxx [hep-ph]

F.A., J.I. Illana, M.D. Jenkins, arXiv:0811.2891[hep-ph]

arXiv:1709.xxxxx [hep-ph]

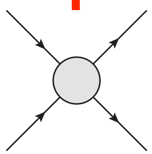


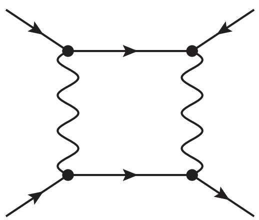
$$
\begin{aligned}
F_L^Z &= F_L^Z|_{W_H} + F_L^Z|_{A_H} + F_L^Z|_{Z_H} + F_L^Z|_{\tilde{\nu}^c} + F_L^Z|_{\tilde{\ell}^c} \\
&= \sum_i V^\dagger_{\ell' i} V_{i\ell} \frac{\alpha_W}{8\pi s_W c_W} \left\{ \frac{v^2}{8f^2} H_L^{W(0)}\left(\frac{m^2_{\ell_{Hi}}}{M^2_{W_H}}\right) + \frac{Q^2}{M^2_{W_H}} H_L^W\left(\frac{m^2_{\ell_{Hi}}}{M^2_{W_H}}\right) \right. \\
&\qquad \left. + (1-2c_W^2)\frac{Q^2}{M^2_{W_H}}\left[\frac{1}{5} H_L^{A/Z}\left(\frac{m^2_{\ell_{Hi}}}{M^2_{A_H}}\right) + H_L^{A/Z}\left(\frac{m^2_{\ell_{Hi}}}{M^2_{Z_H}}\right)\right]\right\} \\
&+ \sum_{ijk} V^\dagger_{\ell' i} \frac{m_{\ell_{Hi}}}{M_{W_H}} W^\dagger_{ij} W_{jk} \frac{m_{\ell_{Hk}}}{M_{W_H}} V_{k\ell} \frac{\alpha_W}{8\pi s_W c_W} \frac{Q^2}{M^2_\Phi}\left[H_L^{\tilde{\nu}}\left(\frac{m^2_{\tilde{\nu}^c_j}}{M^2_\Phi}\right) + (1-2c_W^2) H_L^{\tilde{\ell}}\left(\frac{m^2_{\tilde{\nu}^c_j}}{M^2_\Phi}\right)\right]
\end{aligned}
$$

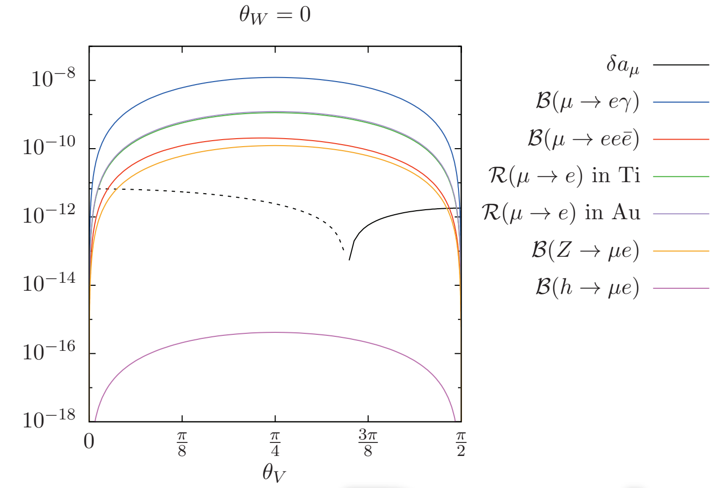
Inverse

Linear

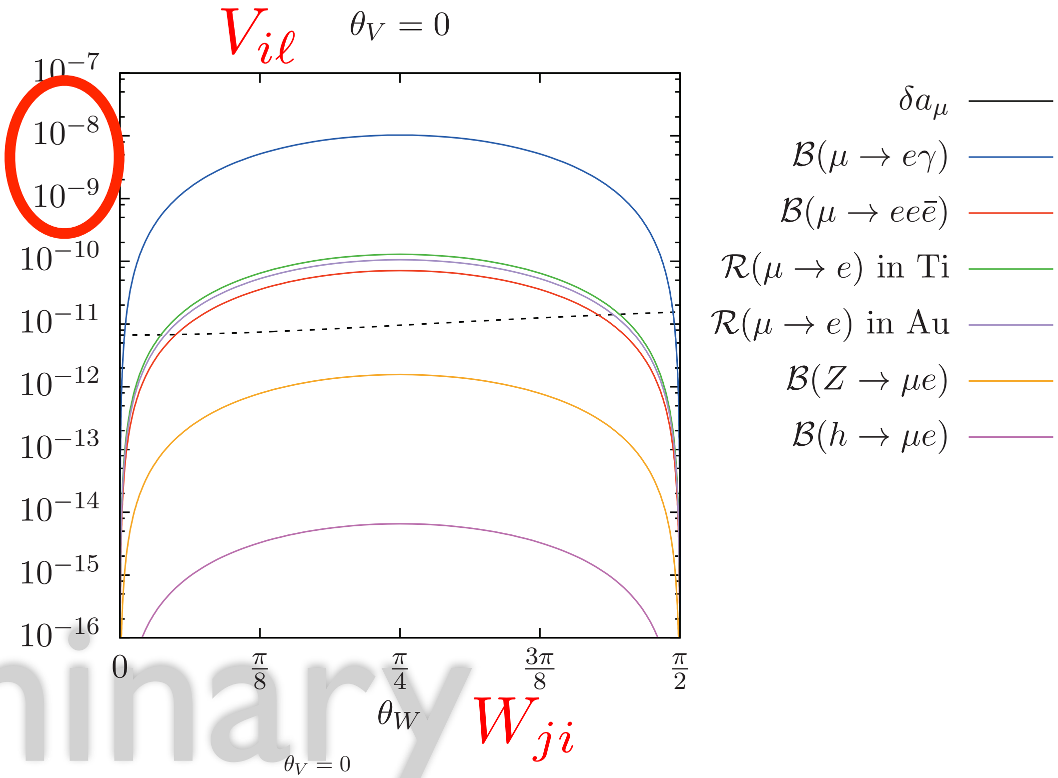
Constant



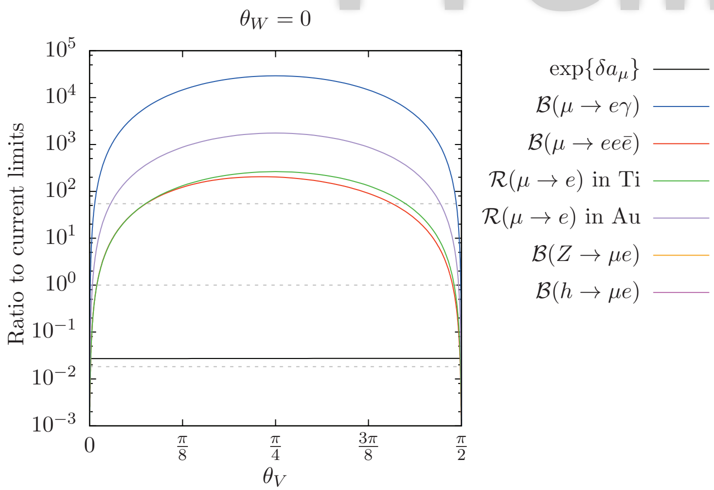




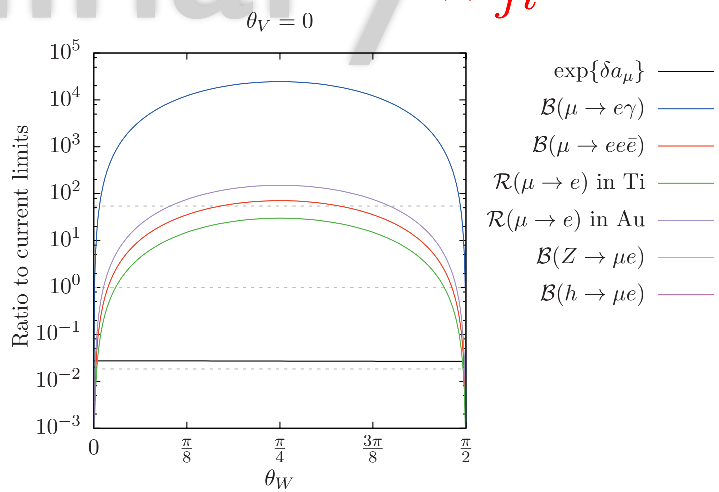
$\theta_W = 0$
θ_V
δa_μ
$\mathcal{B}(\mu \to e\gamma)$
$\mathcal{B}(\mu \to ee\bar{e})$
$\mathcal{R}(\mu \to e)$ in Ti
$\mathcal{R}(\mu \to e)$ in Au
$\mathcal{B}(Z \to \mu e)$
$\mathcal{B}(h \to \mu e)$



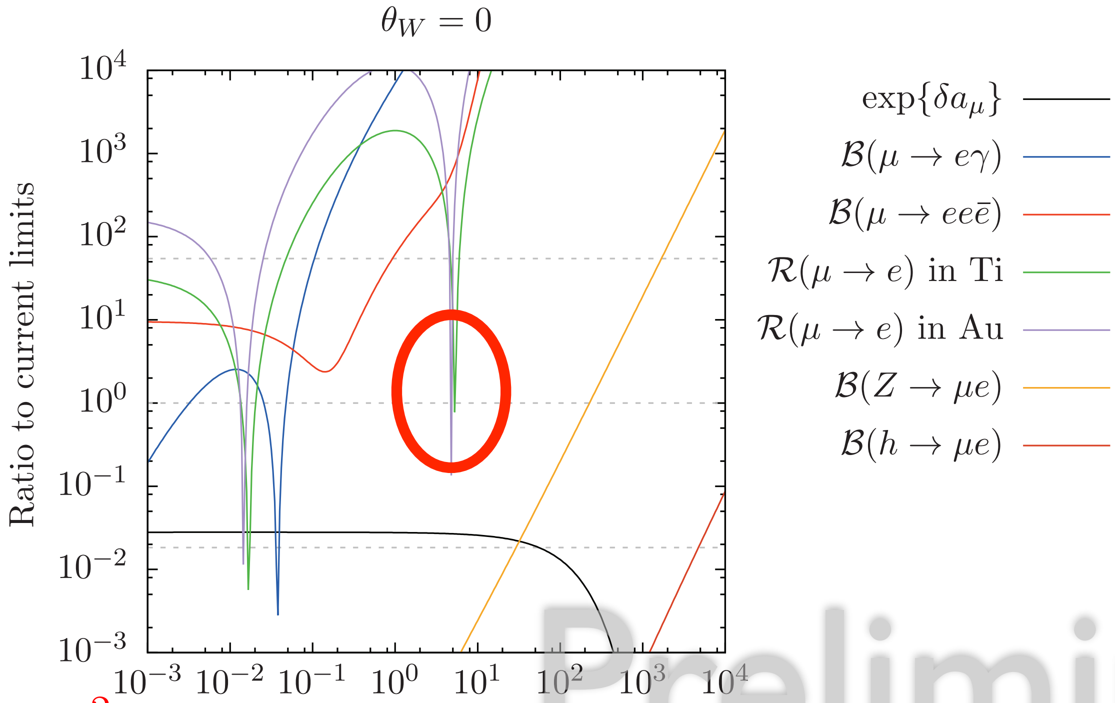
$V_{i\ell}$
$\theta_V = 0$
θ_W
W_{ji}
δa_μ
$\mathcal{B}(\mu \to e\gamma)$
$\mathcal{B}(\mu \to ee\bar{e})$
$\mathcal{R}(\mu \to e)$ in Ti
$\mathcal{R}(\mu \to e)$ in Au
$\mathcal{B}(Z \to \mu e)$
$\mathcal{B}(h \to \mu e)$



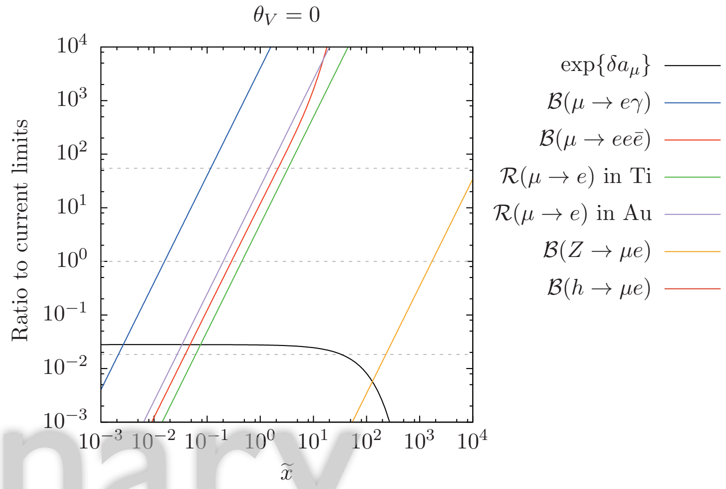
$\theta_W = 0$
Ratio to current limits
θ_V
$\exp\{\delta a_\mu\}$
$\mathcal{B}(\mu \to e\gamma)$
$\mathcal{B}(\mu \to ee\bar{e})$
$\mathcal{R}(\mu \to e)$ in Ti
$\mathcal{R}(\mu \to e)$ in Au
$\mathcal{B}(Z \to \mu e)$
$\mathcal{B}(h \to \mu e)$

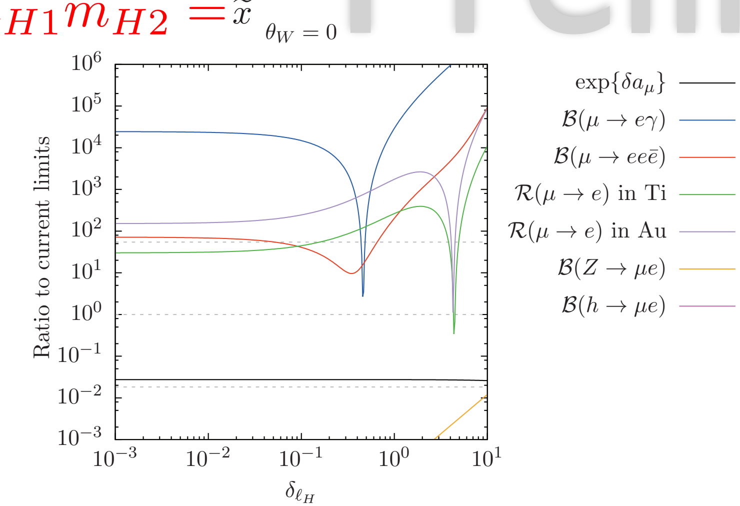


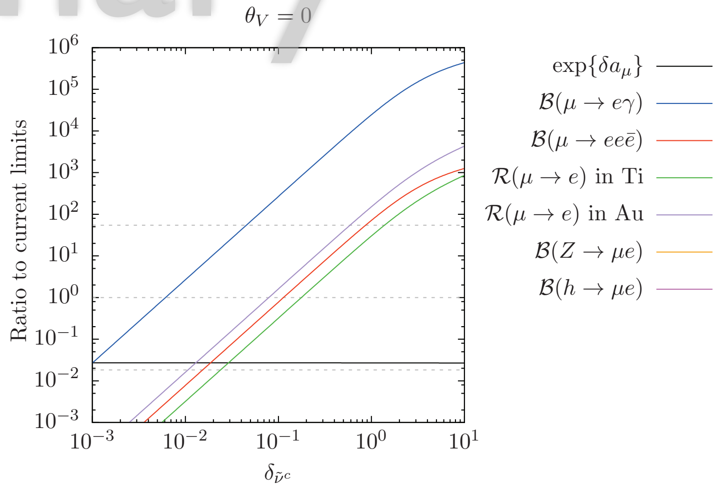
$\theta_V = 0$
Ratio to current limits
θ_W
$\exp\{\delta a_\mu\}$
$\mathcal{B}(\mu \to e\gamma)$
$\mathcal{B}(\mu \to ee\bar{e})$
$\mathcal{R}(\mu \to e)$ in Ti
$\mathcal{R}(\mu \to e)$ in Au
$\mathcal{B}(Z \to \mu e)$
$\mathcal{B}(h \to \mu e)$

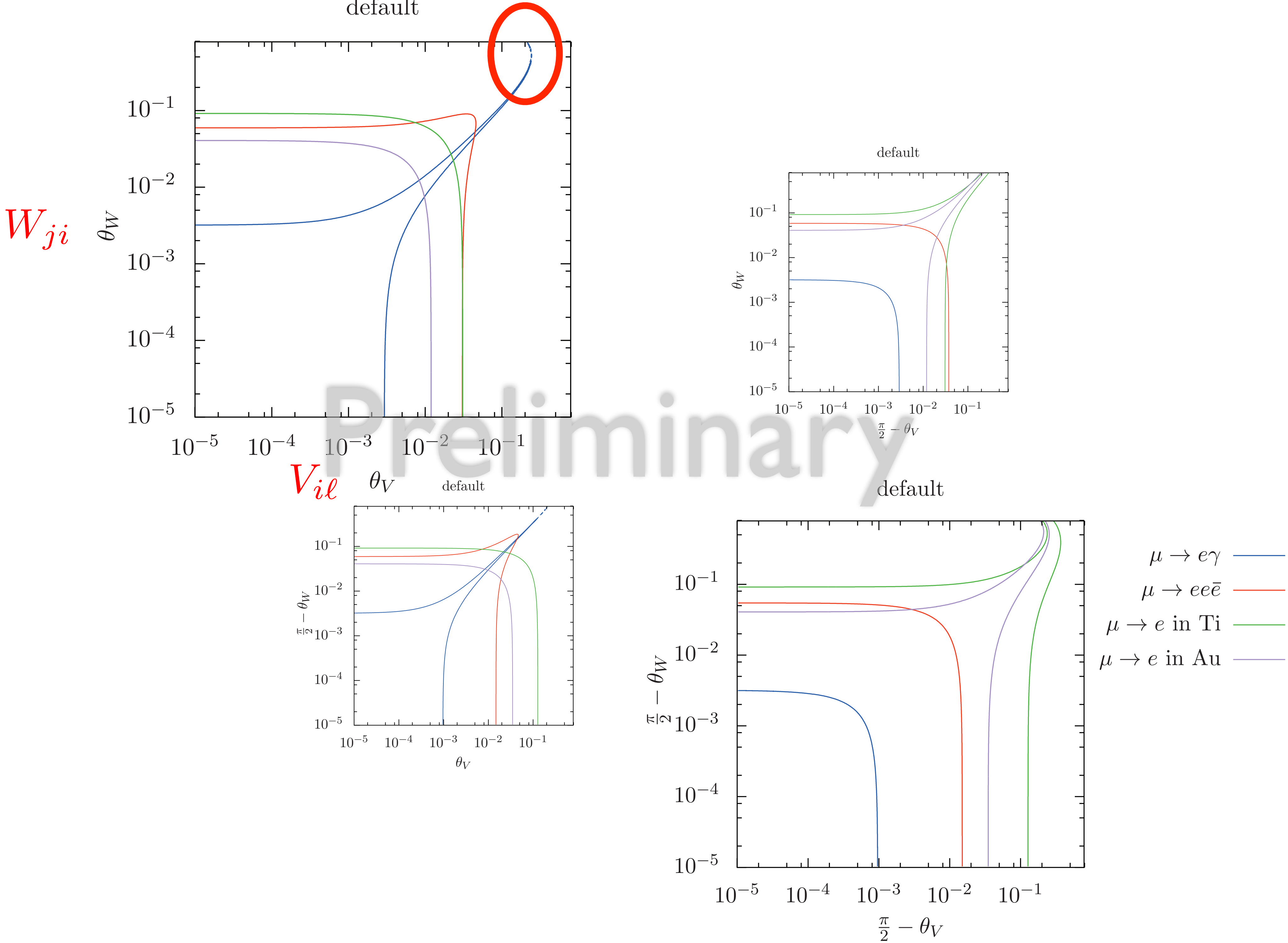


(TeV^2) $m_{H1} m_{H2} = \tilde{x}$



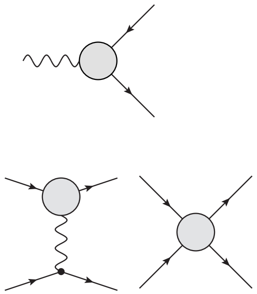






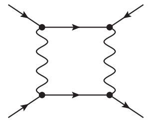
default
W_{ji}
θ_W
$V_{i\ell}$
θ_V
$\frac{\pi}{2} - \theta_V$
$\frac{\pi}{2} - \theta_W$
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1}
$\mu \to e\gamma$
$\mu \to ee\bar{e}$
$\mu \to e$ in Ti
$\mu \to e$ in Au
Preliminary

UPPER LIMITS



10^{-4}

	Branching Ratio		Branching Ratio
$\mu^- \to e^-\gamma$	5.7×10^{-13}	$\mu^- \to e^-e^+e^-$	1.0×10^{-12}
	Conversion Rate		
$\mu^- \to e^-$	7.0×10^{-13}		
	Branching Ratio		
$\tau^- \to e^-\gamma$	1.2×10^{-7}	$\tau^- \to \mu^-e^+\mu^-$	1.7×10^{-8}
$\tau^- \to \mu^-\gamma$	4.5×10^{-8}	$\tau^- \to e^-\mu^+e^-$	1.5×10^{-8}
$\tau^+ \to e^+\gamma$	3.3×10^{-8}	$\tau^- \to \mu^-e^+e^-$	1.8×10^{-8}
$\tau^+ \to \mu^+\gamma$	4.4×10^{-8}	$\tau^- \to e^-\mu^+\mu^-$	2.7×10^{-8}
		$\tau^- \to e^-e^+e^-$	2.7×10^{-8}
		$\tau^- \to \mu^-\mu^+\mu^-$	2.1×10^{-8}
$Z \to \mu e$	7.5×10^{-7}	$h \to \mu e$	3.5×10^{-4}
$Z \to \tau e$	9.8×10^{-6}	$h \to \tau e$	6.1×10^{-3}
$Z \to \tau\mu$	1.2×10^{-5}	$h \to \tau\mu$	2.5×10^{-3}



universality violation $\sim 25\%$

$$\frac{1}{16\pi^2}\frac{1}{f^2}\overline{l_L}\phi\ell_R\phi^\dagger\phi$$

$$\left|\frac{1}{16\pi^2}\frac{v^2}{f^2}\right|^2 \sim 10^{-7}$$

$$\delta a_\mu \sim \frac{\alpha}{4\pi}\frac{m_\ell^2}{M_{W_H}^2} \sim 10^{-11}$$

No tree level anomalies

Summary

- The Littlest Higgs model with T-parity allows for a lower scale of new physics because the new T-odd particles must be produced by pairs and then, they contribute to SM processes only at loop order. Thus, for example, LFV amplitudes are suppressed by a factor $(1/16\pi^2)\ v^2/f^2 \sim 10^{-7}$

- In order to keep Higgs amplitudes finite at one loop, all the T-odd spectrum must run in the loop, implying that all T-odd particles must have masses ~ f. In general, however, in definite processes some contributions may vanish (decouple) if the exchanged T-odd particles have masses going to infinity.

- LFV processes are one-loop finite in the LHT. Branching ratios $< 10^{-7}$ can be accommodated allowing for small mixing angles and/or correlated heavy masses.

Thanks for your attention

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