Polarized τ and μ Lepton Flavor Violation in the Littlest Higgs Model with T-parity.

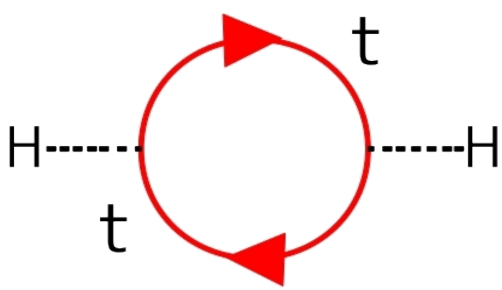
15 Apr. 2011 @ ULB

Yasuhiro Yamamoto (Sokendai/KEK)

with T. Goto (KEK) and Y. Okada (KEK/Sokendai)

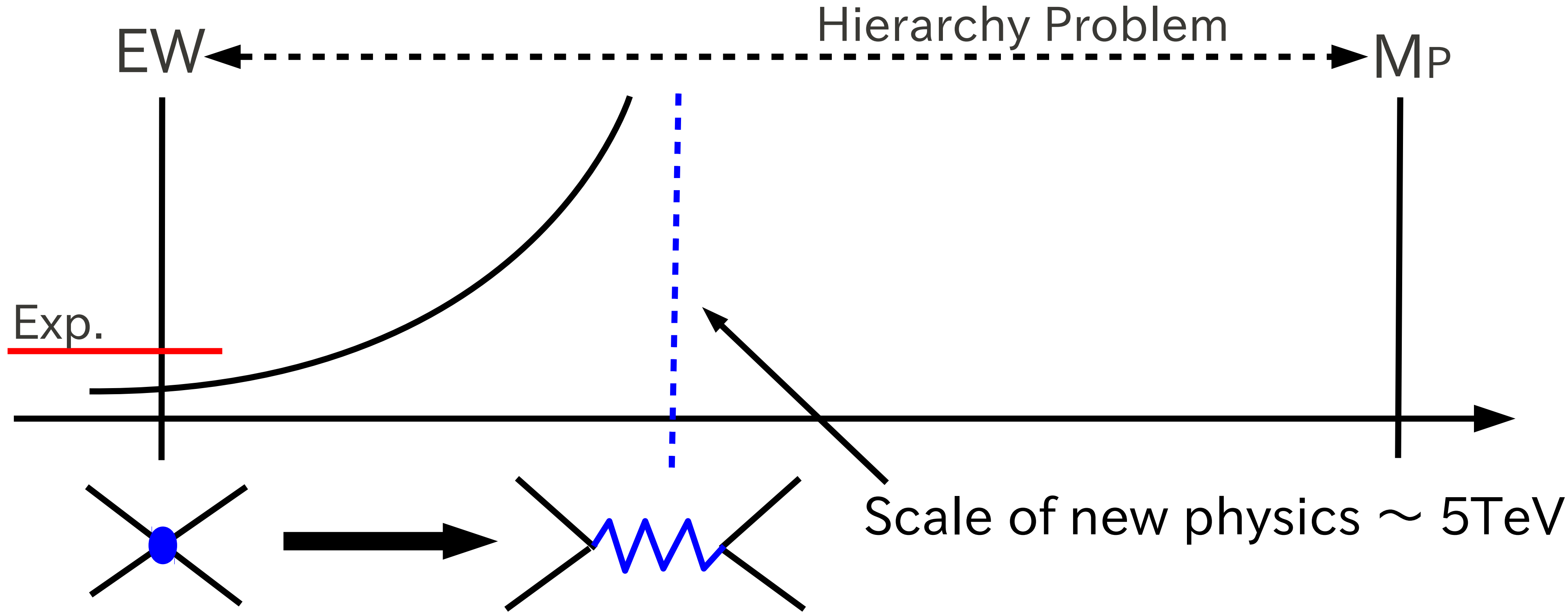
Based on arXiv:1012.4385[hep-ph]

The Hierarchy Problem



$$\sim \frac{\Delta m_H^2}{m_{EW}^2} \sim \left(0.3\frac{\mathrm{M}_P}{100\mathrm{GeV}}\right)^2 > 10^{33}$$

The Little Hierarchy Problem



$$\frac{\Delta m_H^2}{m_{EW}^2} \sim \left(0.3\frac{\Lambda_{\text{cut off}}}{100\text{GeV}}\right)^2 > 200$$

Unnatural hierarchy

'99 R.Barbieri, A.Strumia

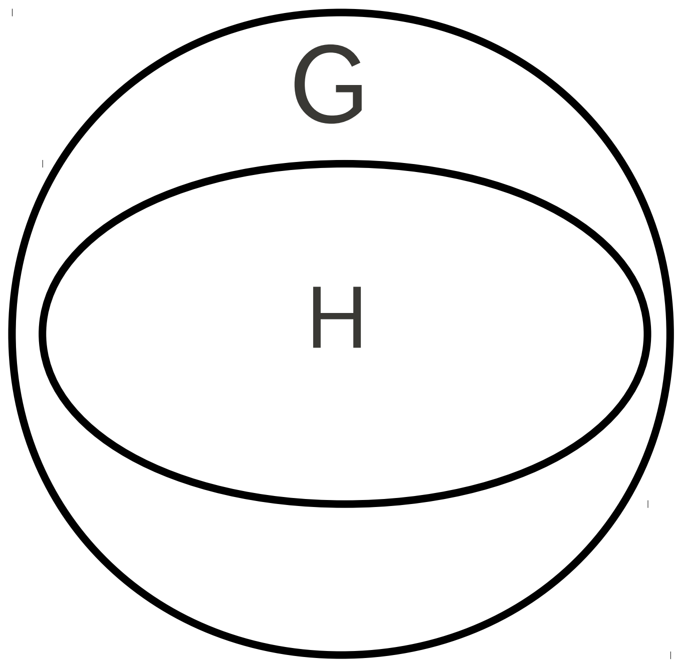
Canceled @1-loop

Little Higgs models

Little Higgs Models

The BEH doublet is embedded in a part of NG bosons.

$$\mathcal{L}_{\mathrm{BEH}} = \mathcal{L}_{G/H} + \mathcal{L}_{G1} + \mathcal{L}_{G2}$$



'01 N.Arkani-Hamed, A.G.Cohen, H.Georgi

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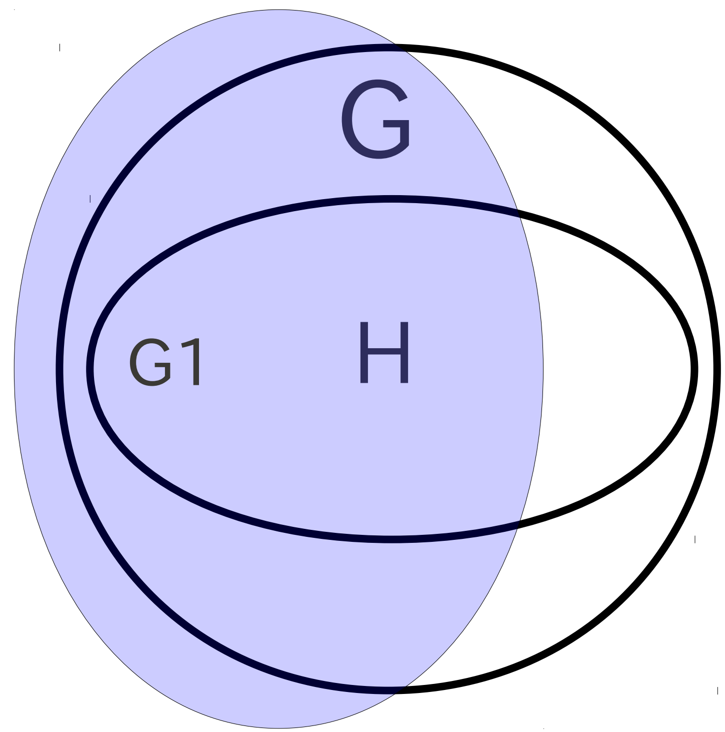

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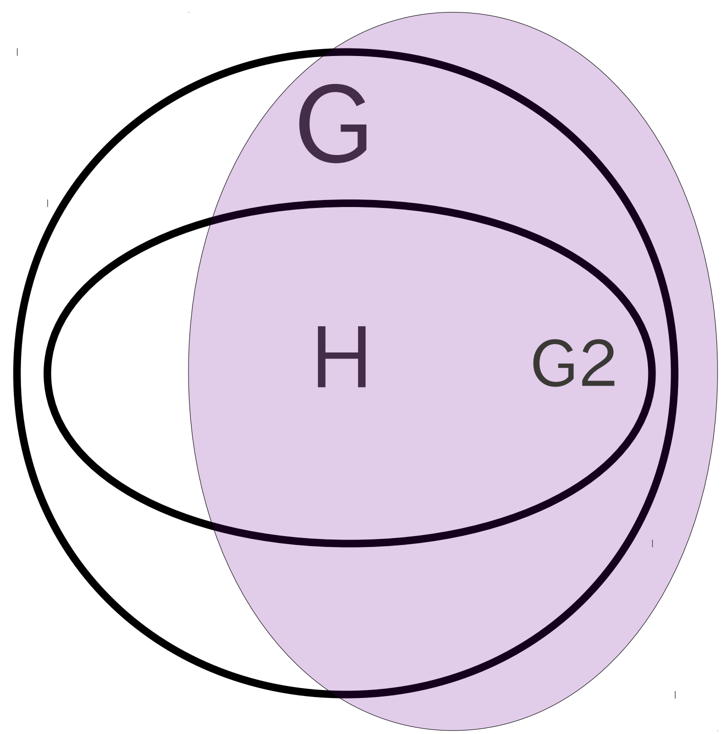

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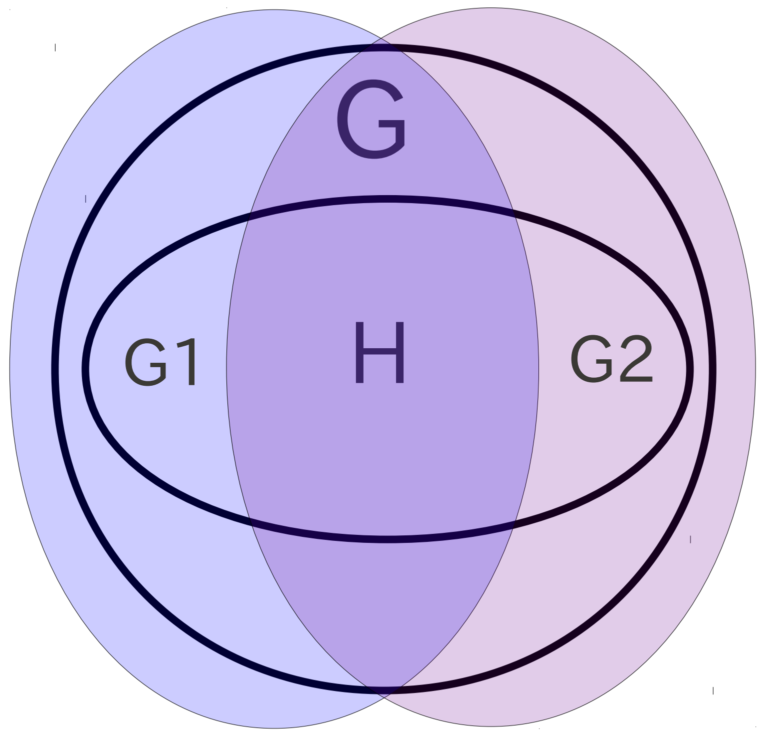


$$\mathcal{L}_{\mathrm{mass}} = g_1 g_2 \langle O_1 O_2 \rangle H^\dagger H$$

Quadratic divergences are suppressed at 1-loop.

'01 N.Arkani-Hamed, A.G.Cohen, H.Georgi

The Littlest Higgs Model

$SU(5) \supset [SU(2) \times U(1)]_1 \times [SU(2) \times U(1)]_2$

BEH ←

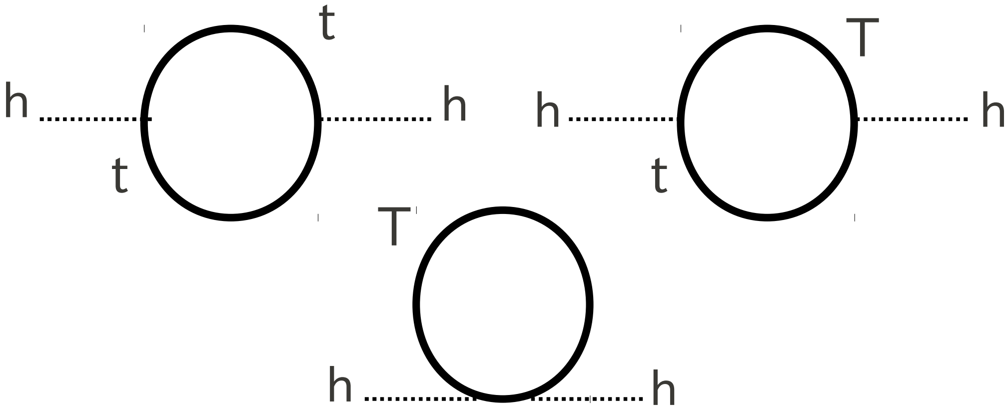
$SO(5) \supset SU(2)_L \times U(1)_Y$

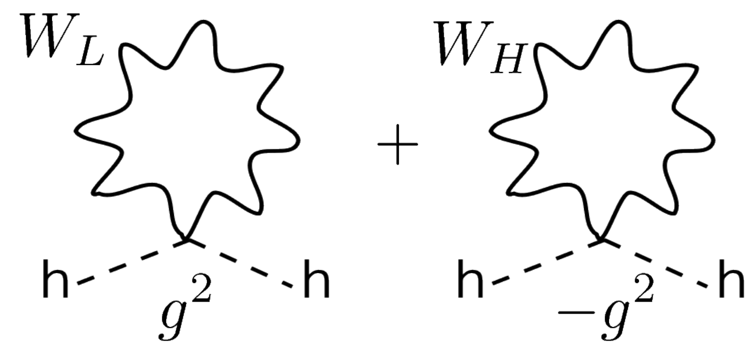
t ⇄ T

top — top partner

A, W, Z ⇄ A_H, W_H, Z_H

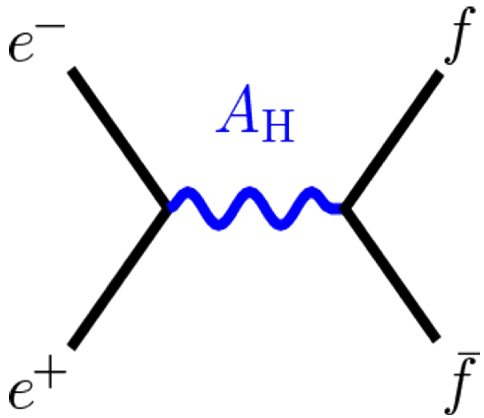
gauge bosons — heavy gauge bosons





'02 N.Arkani-Hamed, A.G.Cohen, E.Katz, A.E.Nelson

T-parity

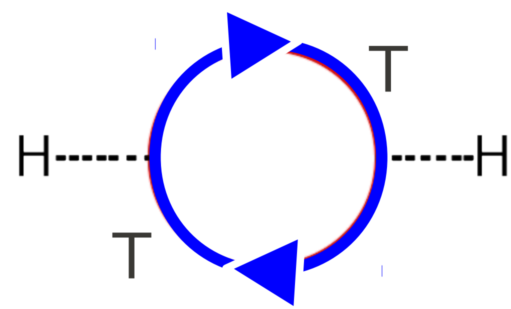


$$\simeq \frac{g'^2}{M_{AH}^2}(\bar{e}\gamma^\mu e)(\bar{f}\gamma_\mu f)$$

EWPM imply large M_{AH}

$$\Delta m_{\mathrm{H}} \sim \underline{m_{\mathrm{T}}} \ln \Lambda$$

Too Large!!



Forbidden by Z2 symmetry:T-parity

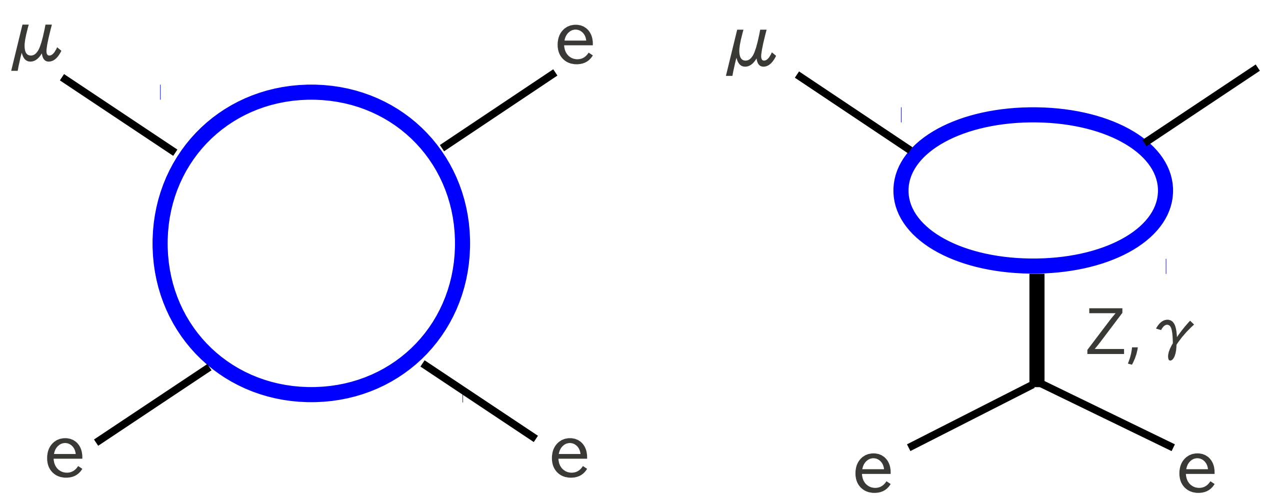
'03 C.H.Chen, I.Low

✓ New particles and mixing matrices are introduced

→ Investigate flavor signals in LHT!

Flavor Changing Neutral Current (FCNC)

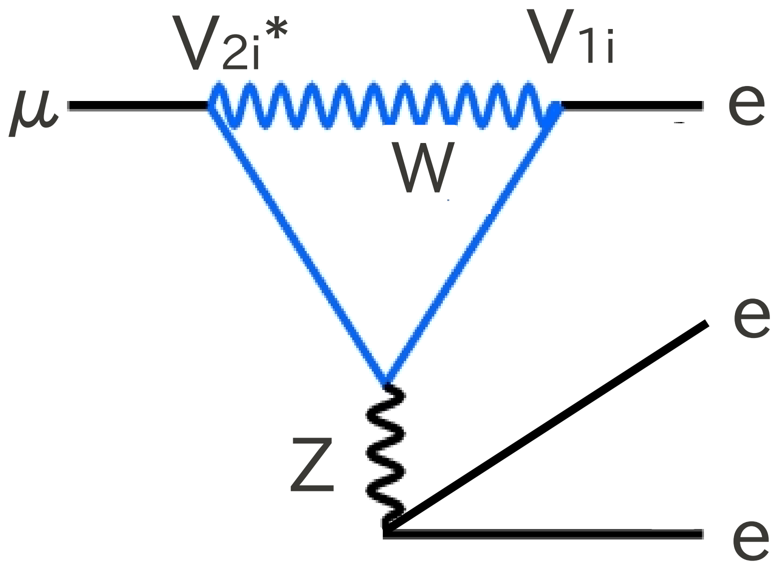
Don't exist at tree level in the SM



$$\frac{\mathrm{Br}_{\mathrm{loop}}}{\mathrm{Br}_{\mathrm{tree}}} < \left(\frac{g^2}{(4\pi)^2}\right)^2 \sim O(10^{-5})$$

- ✓ Contributions of new physics are relatively large.
- ✓ New physics is strongly constrained (c.f. K^0-$\overline{K^0}$ mixing → 1 PeV).
- ✓ Parity structure is good friend with loop induced proceses.

Lepton Flavor Violation (LFV)



$$\mathrm{Br} \sim \left| \frac{g^2}{(4\pi)^2} \sum_i V_{2i} V_{1i}^* \frac{m_{\nu i}^2}{m_W^2} \right|^2 \sim \mathcal{O}(10^{-53})$$

Negligibly small in the SM

- Only new physics contribute to the processes.
- QCD contamination is suppressed.

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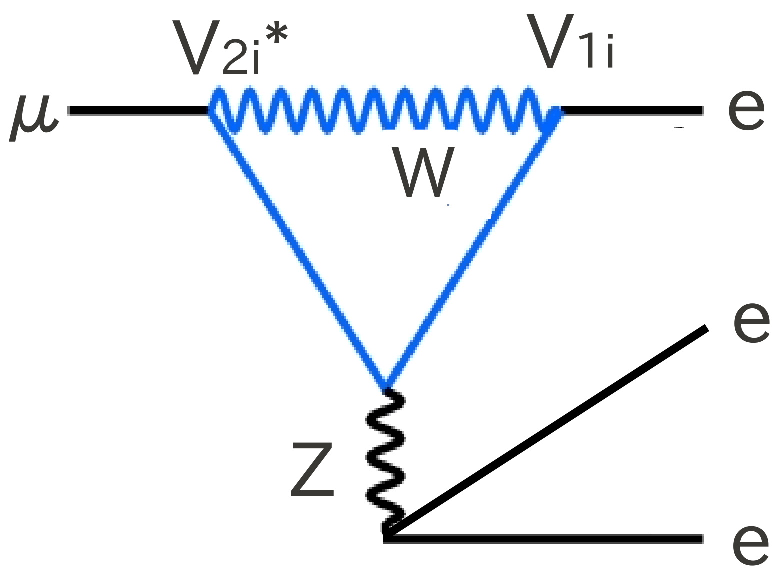

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The number of silicon atom in the earth $\sim \mathcal{O}(10^{53})$

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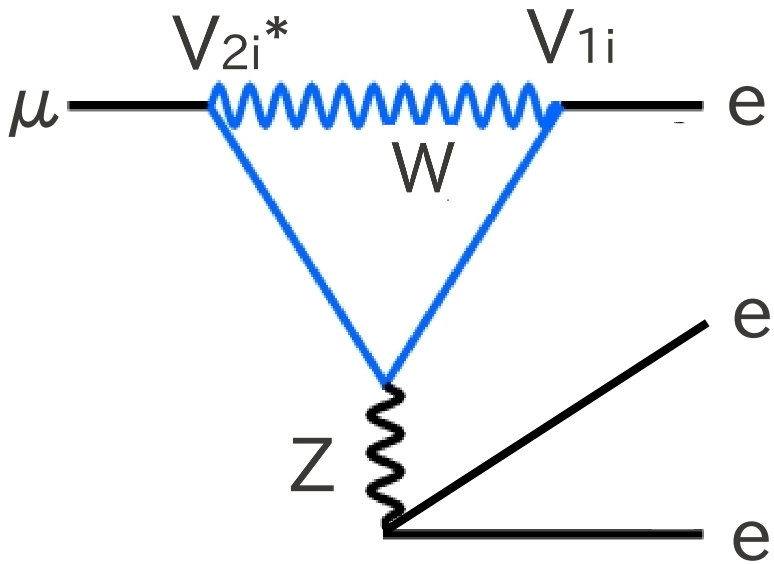

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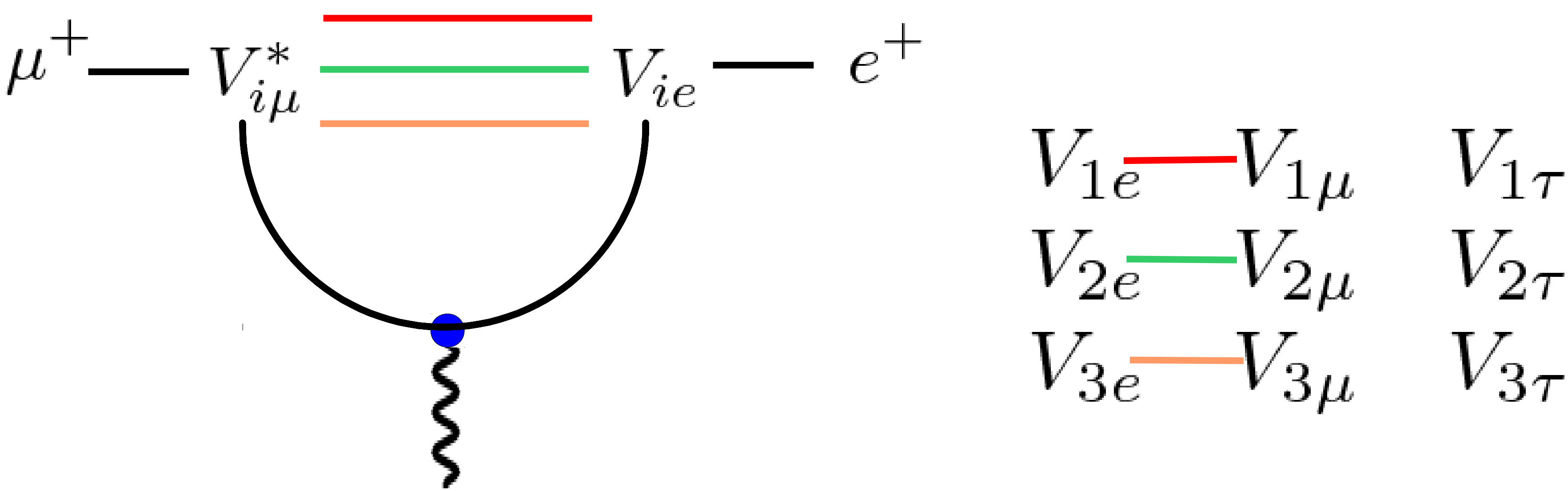
- QCD contamination is suppressed.

It difficult to study detail structure of models.

Asymmetry



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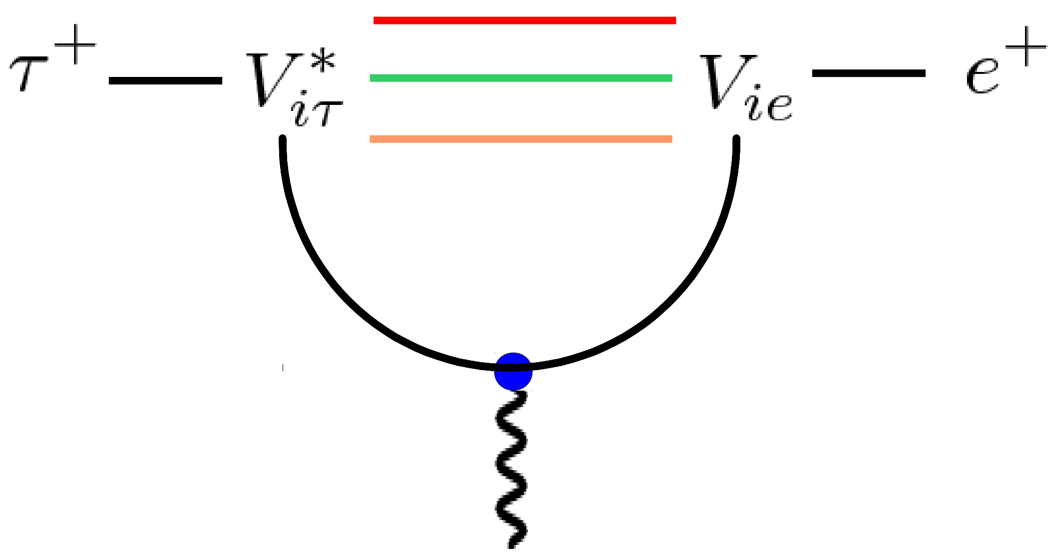
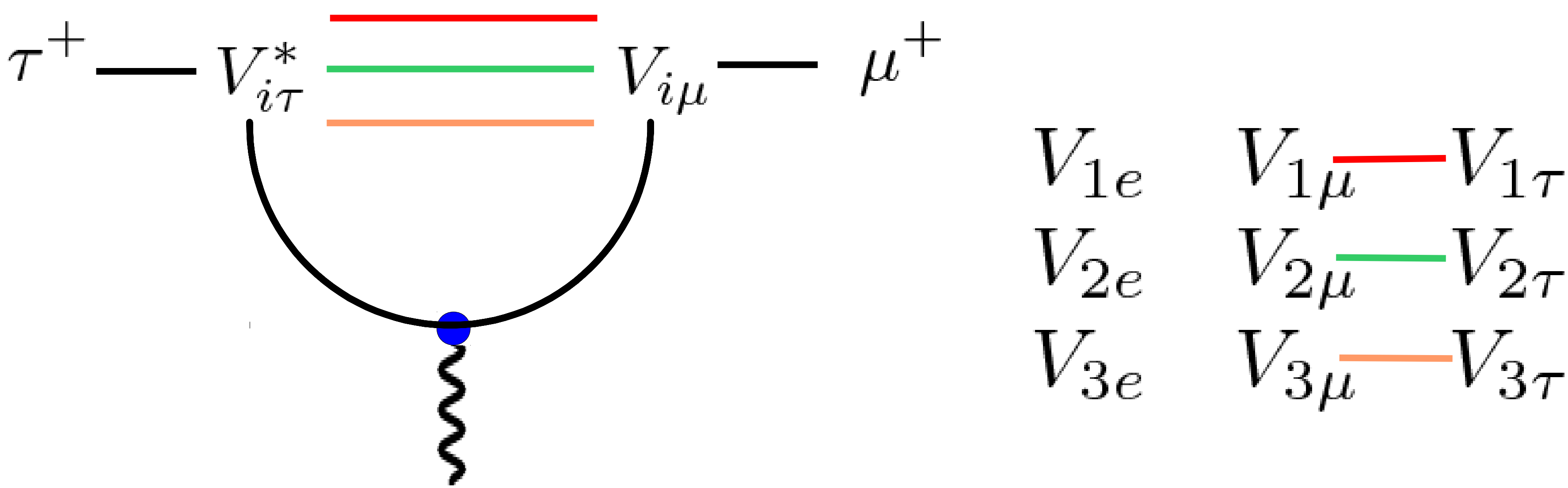


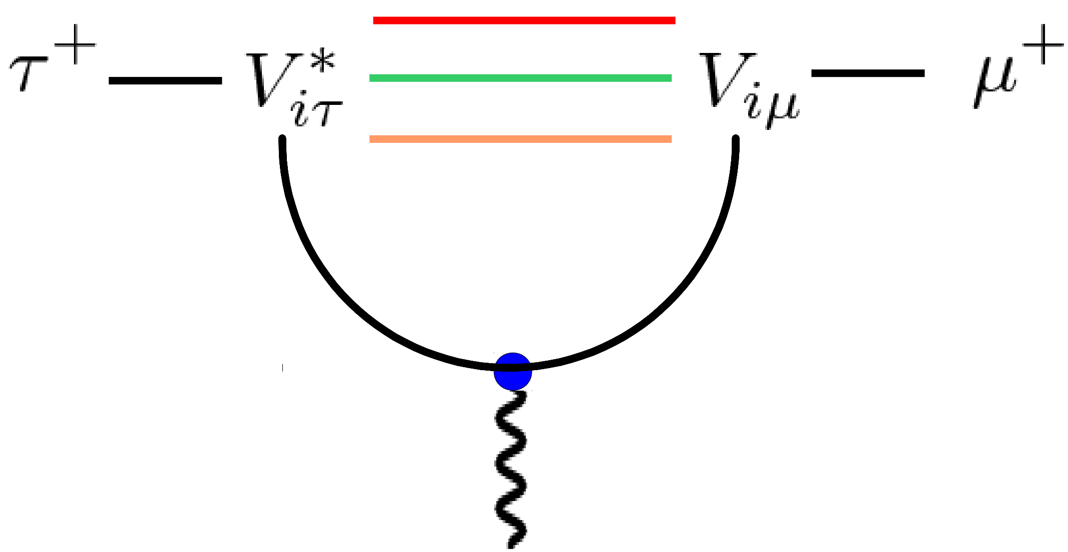
$$\begin{matrix} V_{1e} & V_{1\mu} & V_{1\tau} \\ V_{2e} & V_{2\mu} & V_{2\tau} \\ V_{3e} & V_{3\mu} & V_{3\tau} \end{matrix}$$

Asymmetry



τ^+
$V_{i\tau}^*$
$V_{i\mu}$
μ^+
V_{1e} $V_{1\mu}$ $V_{1\tau}$
V_{2e} $V_{2\mu}$ $V_{2\tau}$
V_{3e} $V_{3\mu}$ $V_{3\tau}$

Asymmetry



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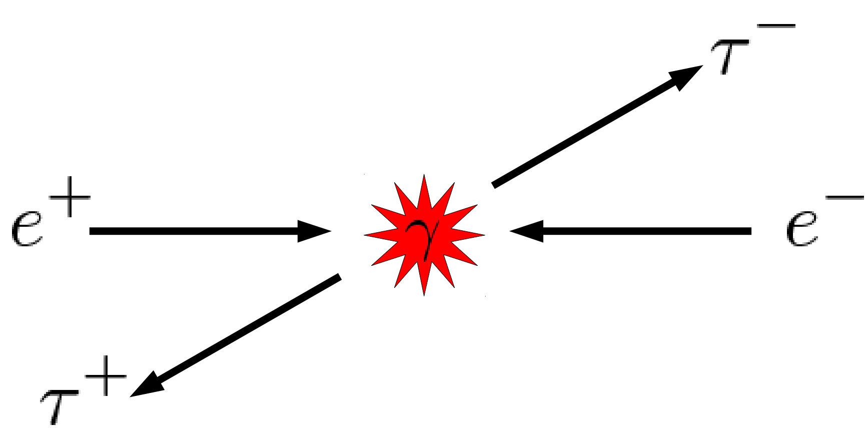
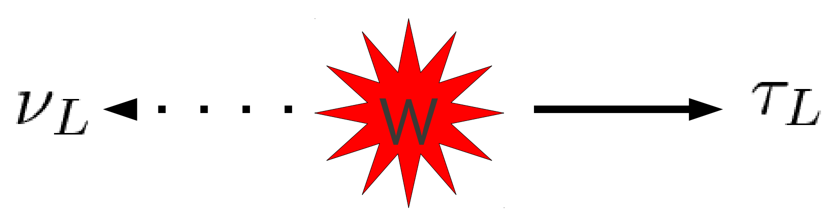
✓ τ polarization is easily measured.





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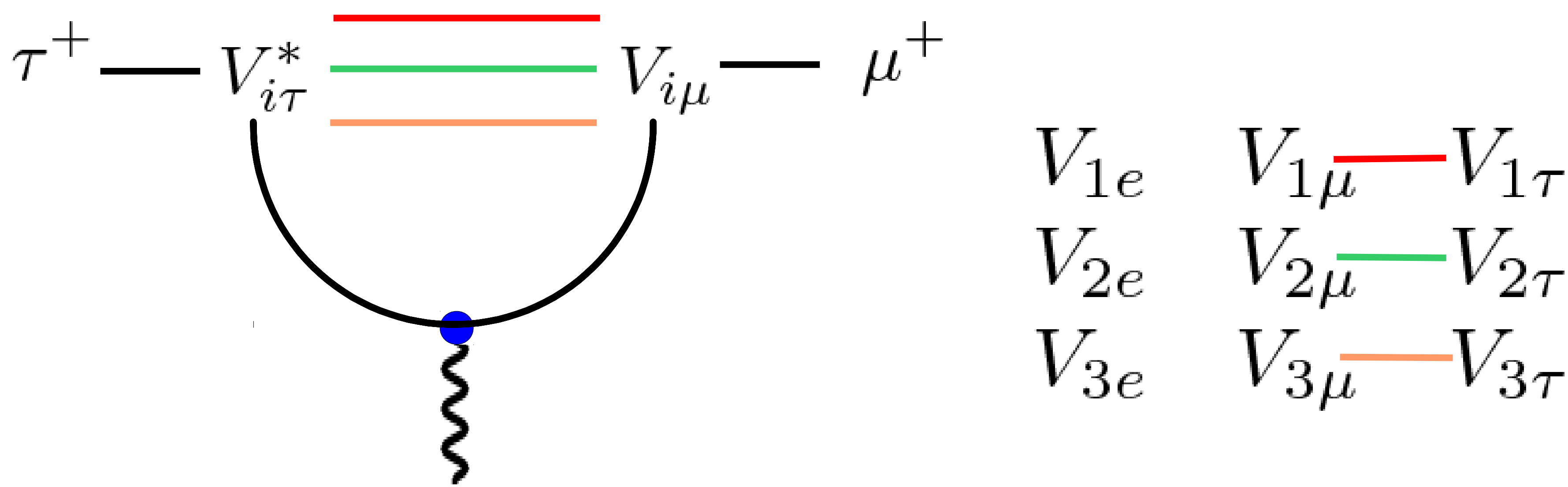

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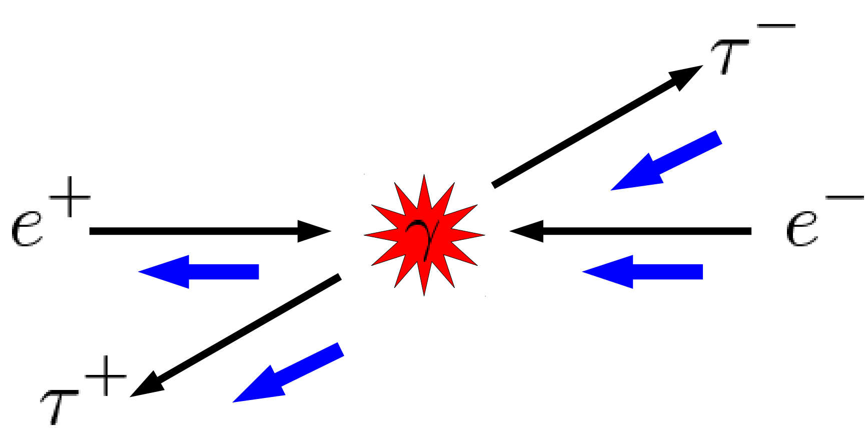

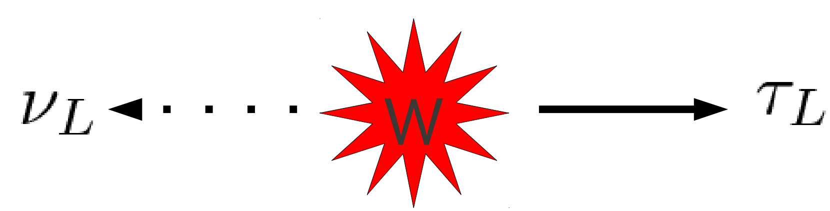

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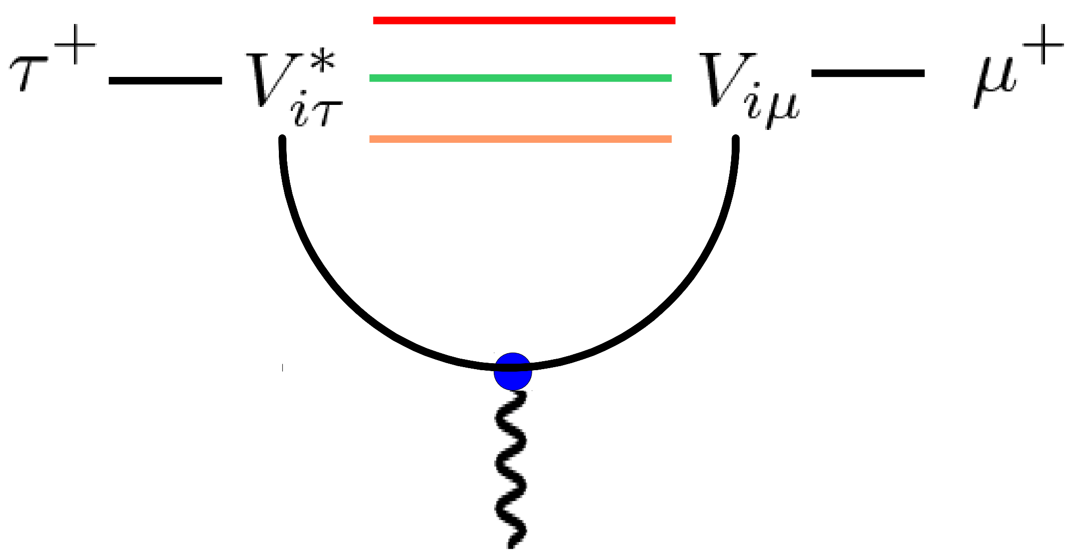

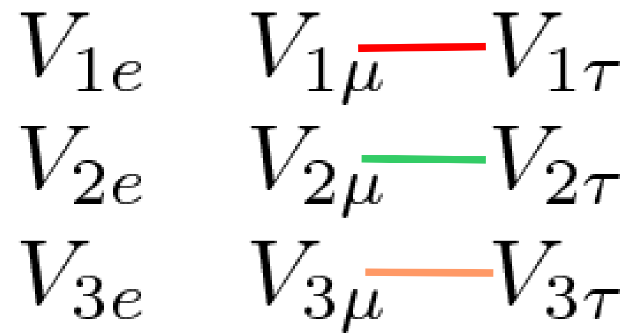

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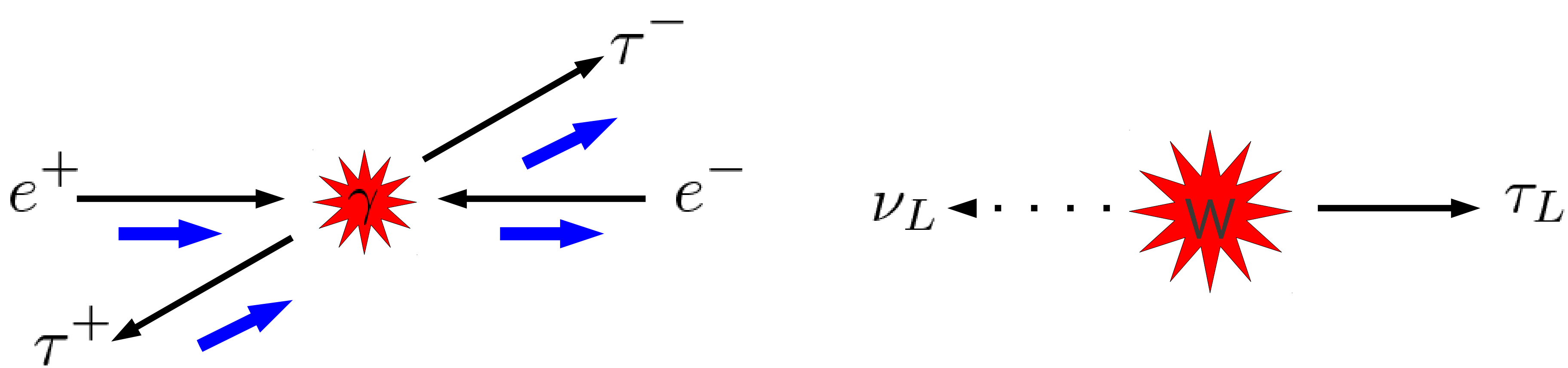

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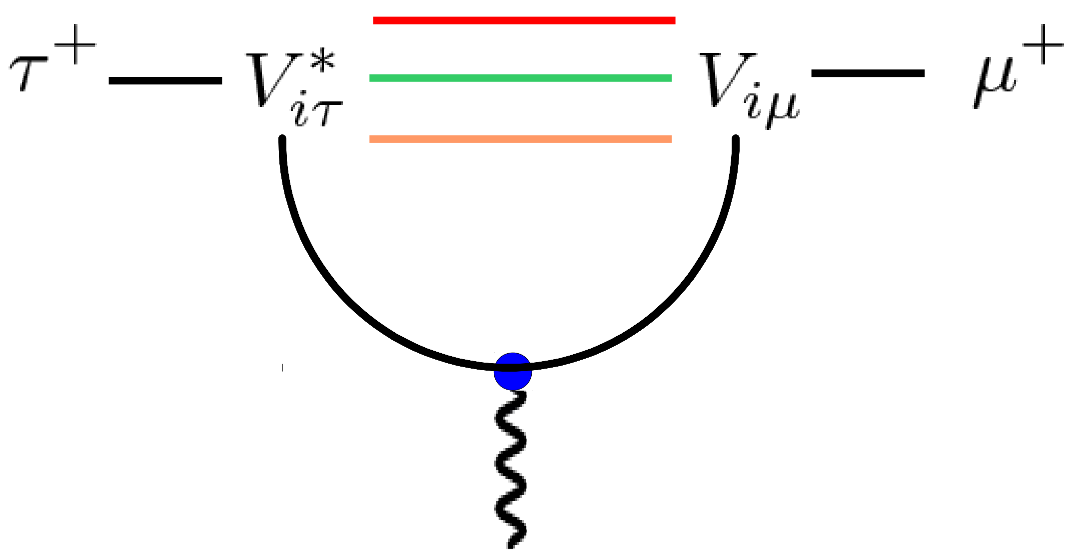

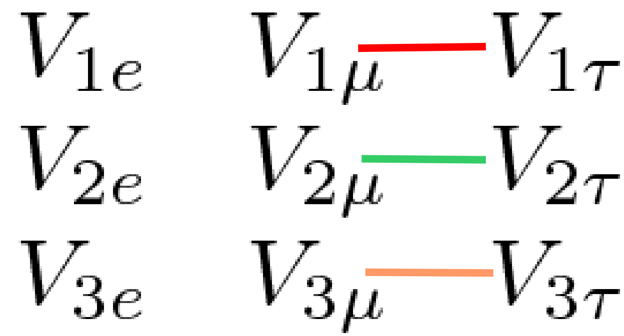

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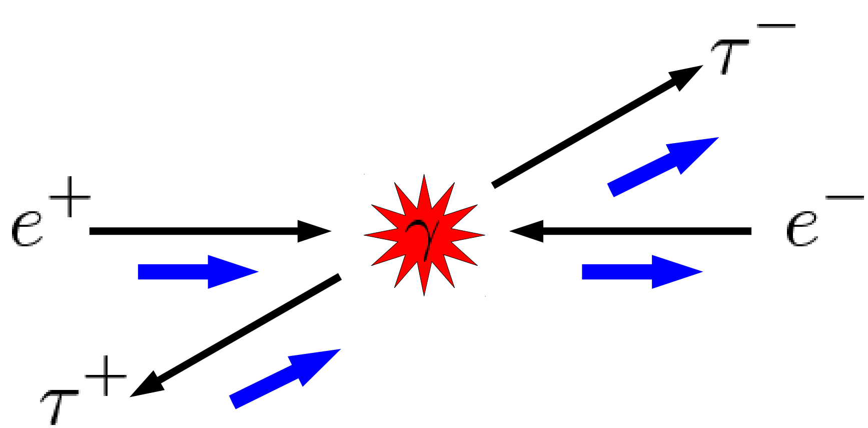

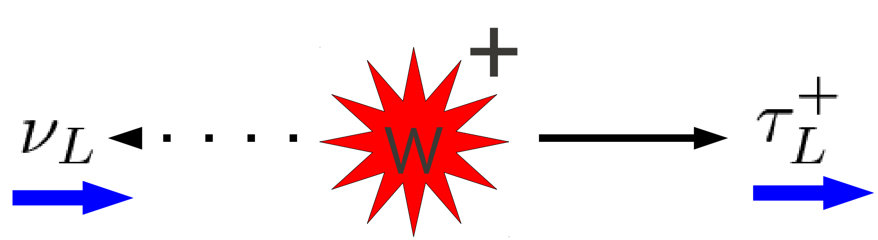

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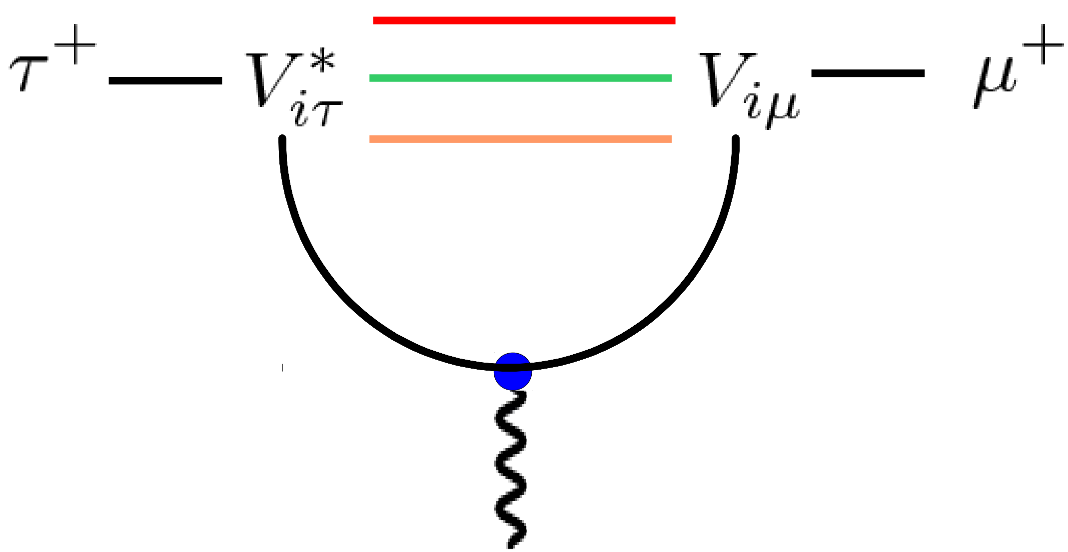

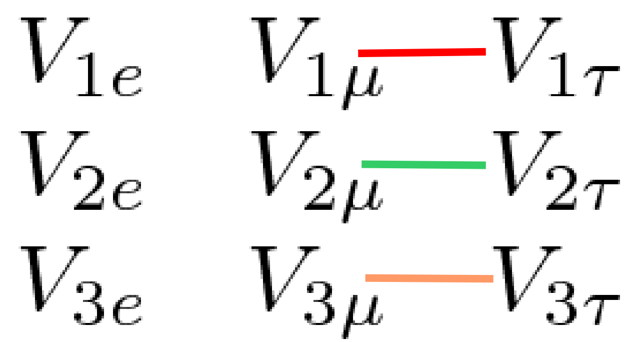

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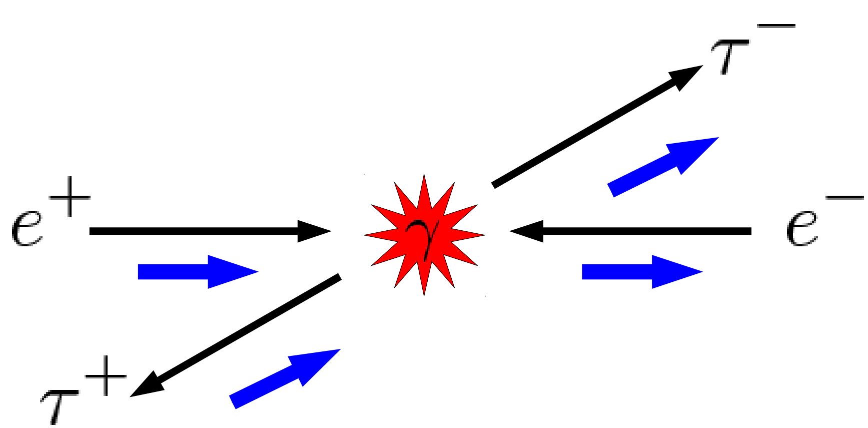

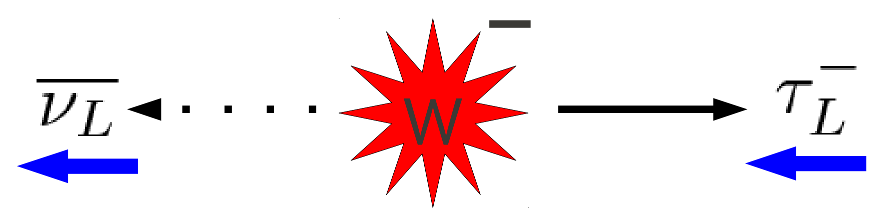

Work Done up to Now

Neutral meson mixings '05 J.Hubisz, S.J.Lee, G.Paz

Various FCNC processes '06~09 M.Blanke, A.J.Buras, C.Tarantino et al.

$K \to \pi\nu\nu$ '08 T.Goto, Y.Okada, Y.Y.

μ- LFV '08,10 F.del Aguila, J.I.Illana, M.D.Jenkins

✔ Lepton flavor violating decays of polarized τ and μ.

✔ Nuclide dependence of μ- e conversion.

"τ and μ lepton flavor violation in the littlest Higgs model with T-parity",
arXiv: 1012.4385, T. Goto, Y. Okada, Y.Y.

Contents

- The Littlest Higgs Model with T-parity
  Symmetry, particle contents and new flavor mixing.
- Lepton Flavor Violation and Asymmetry
  Current status and asymmetries of LFV.
- Numerical Results
  Correlations among branching ratios and asymmetries.
- Conclusion

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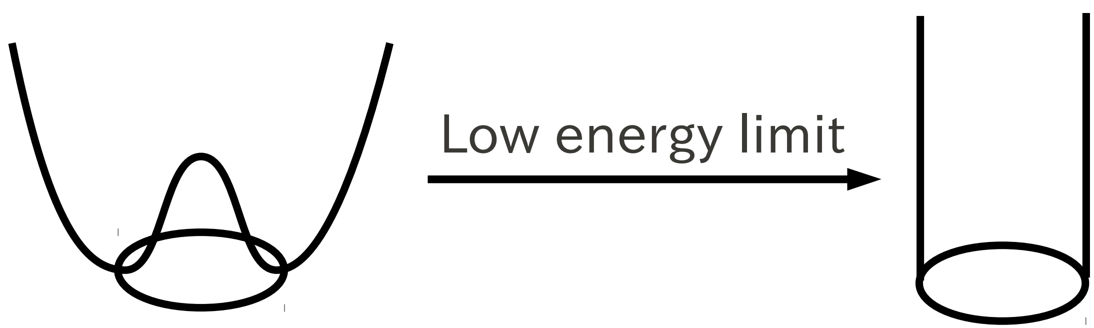
Global Symmetry of the LHT

$$\boxed{\begin{array}{c} SU(5) \\ \Big\downarrow \\ SO(5) \end{array}} \begin{array}{c} \supset \\ \\ \supset \end{array} \begin{array}{c} [SU(2) \times U(1)]_1 \times [SU(2) \times U(1)]_2 \\ \Big\downarrow \\ SU(2)_L \times U(1)_Y \end{array}$$

SU(5) → SO(5): 14 NG bosons



Linear σ model　　Non-linear σ model

$$\mathcal{L}_{\rm NG} = \frac{f^2}{8} {\rm tr}[(D_\mu \Sigma)^\dagger D^\mu \Sigma] : \Sigma = e^{i\frac{\pi^a T^a}{f}}$$

Gauge Symmetry of the LHT

$$\begin{array}{ccc} SU(5) & \supset & \boxed{\begin{array}{c} [SU(2) \times U(1)]_1 \times [SU(2) \times U(1)]_2 \\ \downarrow \\ SU(2)_L \times U(1)_Y \end{array}} \\ \downarrow & & \\ SO(5) & \supset & \end{array}$$

$$\mathcal{L}_{\text{gauge}} = \sum_{i=1,2} -\frac{1}{4}(W^a_{i\mu\nu} W_i^{a\mu\nu} + B_{i\mu\nu} B_i{}^{\mu\nu})$$

T-parity : 1 ↔ 2

$$Q_1^a = \frac{1}{2}\begin{pmatrix} \sigma^a & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \qquad Q_2^a = \frac{1}{2}\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -\sigma^{a*} \end{pmatrix},$$

$$Y_1 = \frac{1}{10}\text{diag}(3,3,-2,-2,-2), \quad Y_2 = \frac{1}{10}\text{diag}(2,2,2,-3,-3)$$

$$W_{\text{L, H}} = \frac{W_1 \pm W_2}{\sqrt{2}} \longrightarrow \begin{array}{l} M_{\text{WH, ZH}} = fg\left(1 - \dfrac{v^2}{8f^2}\right) \\ M_{\text{AH}} = \dfrac{fg'}{\sqrt{5}}\left(1 - \dfrac{5v^2}{8f^2}\right) \end{array}$$

Gauge Symmetry of the LHT

$$\begin{array}{ccc} SU(5) & \supset & [SU(2) \times U(1)]_1 \times [SU(2) \times U(1)]_2 \\ \downarrow & & \downarrow \\ SO(5) & \supset & SU(2)_L \times U(1)_Y \end{array}$$

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$$\xi = \exp\left[\frac{i}{f}\begin{pmatrix} \omega & H & \Phi \\ H^\dagger & \eta & H^T \\ \Phi^\dagger & H^* & \omega \end{pmatrix}\right]$$

Physical Scalar

SM BEH doublet

Eaten by
heavy gauge bosons

Fermions in the LHT

$$\mathcal{L}_{\mathrm{L}} = \bar{\Psi}_1 i \not{D} \Psi_1 + \bar{\Psi}_2 i \not{D} \Psi_2$$

$$\Psi_1 = (L_1,\, 0,\, 0_2),\;\; \Psi_2 = (0_2,\, 0,\, L_2) \qquad (L_i = (-\ell_i,\, \nu_i))$$

$$L_{\pm} = \frac{L_1 \mp L_2}{\sqrt{2}}$$

$$\mathcal{L}_{\mathrm{HR}} = \bar{\Psi}_{\mathrm{R}} \xi^{\dagger} (i \not{\partial} - g \not{A}) \xi \Psi_{\mathrm{R}}$$

$$\Psi_{\mathrm{R}} = (L_{\mathrm{HR}}, \chi_{\mathrm{R}}, \psi_{\mathrm{R}}) \qquad (L_{\mathrm{HR}} = (-\ell_{\mathrm{HR}}, \nu_{\mathrm{HR}}))$$

$$\xi \mapsto U \xi V^{\dagger},\;\; \Psi_{\mathrm{R}} \mapsto V \Psi_{\mathrm{R}} \qquad (U \in \mathrm{SU}(5),\; V \in \mathrm{SO}(5))$$

$$\mathcal{L}_{\mathrm{HY}} = -\kappa_{ij} f (\bar{\Psi}_2^i \xi + \bar{\Psi}_1^i \Sigma_0 \Omega \xi^{\dagger} \Omega) \Psi_{\mathrm{R}}^j + \mathrm{H.c.}$$

$$m_{\mathrm{H}i}^{\nu} = \sqrt{2} \kappa_i f \left(1 - \frac{v^2}{8 f^2} \right), \;\; m_{Hi}^{\ell} = \sqrt{2} \kappa_i f$$

Summary of the LHT

SU(5) ⊃ [SU(2) x U(1)]₁ x [SU(2) x U(1)]₂

Higgs

SO(5) ⊃ SU(2)$_L$ x U(1)$_Y$

T-even

$\gamma \; W^{\pm} \; Z \; h$

$\nu_i \; e_i \; u_i \; d_i \; T_+$

$V_{Hu} \quad V_{Hd}$

$V_{H\nu} \quad V_{H\ell}$

3 angles
3 phases

T-odd

$A_H \; W_H^{\pm} \; Z_H \; \Phi$

$\nu_{Hi} \; e_{Hi} \; u_{Hi} \; d_{Hi} \; T_-$

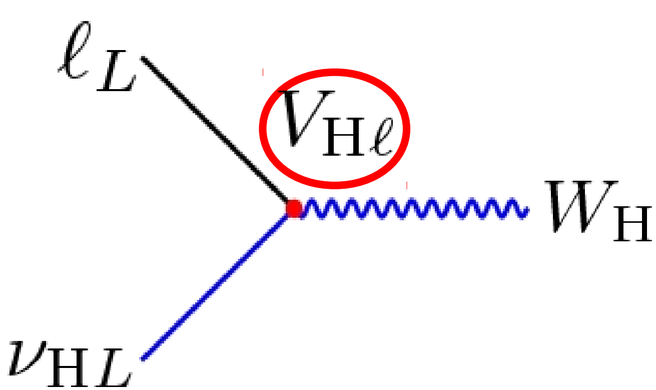
V_{CKM}

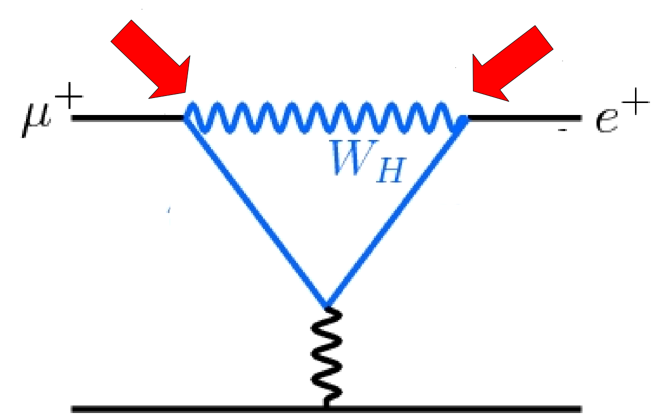
V_{MNS}

3 angles
1 phase

'05 J.Hubisz, S.J.Lee, G.Paz

'08 M.Blanke, A.J.Buras, C.Tarantino et al.





Summary of the LHT

$SU(5) \supset [SU(2) \times U(1)]_1 \times [SU(2) \times U(1)]_2$

Higgs $\leftarrow$

$SO(5) \supset \quad SU(2)_L \times U(1)_Y$

T-even

$\gamma \; W^{\pm} \; Z \; h$

$\nu_i \; e_i \; u_i \; d_i \; T_+$

$\cancel{V_{Hu}} \quad V_{Hd}$

$\cancel{V_{H\nu}} \quad V_{H\ell}$

3 angles
3 phases

T-odd

$A_H \; W_H^{\pm} \; Z_H \; \Phi$

$\nu_{Hi} \; e_{Hi} \; u_{Hi} \; d_{Hi} \; T_-$

V_{CKM}
V_{MNS}

3 angles
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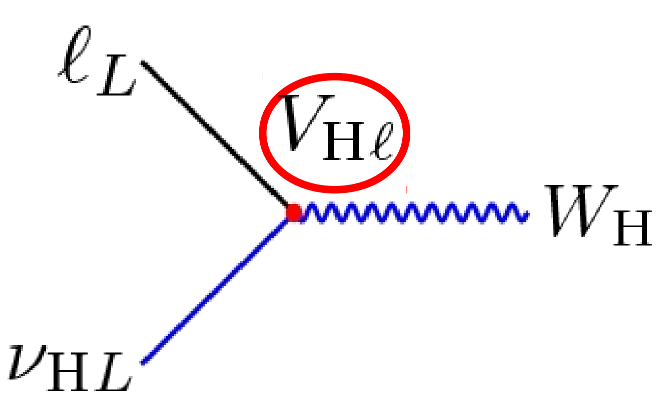
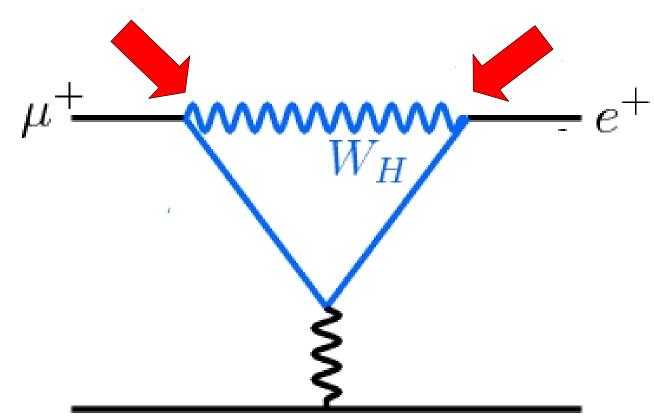




Contents

μ-LFV

✓ $\mathrm{Br}(\mu^+ \to e^+\gamma) \leq 1.2 \times 10^{-11}$ by MEGA

MEG(@PSI) is in progress: $1.5 \times 10^{-11} \to 10^{-13}$

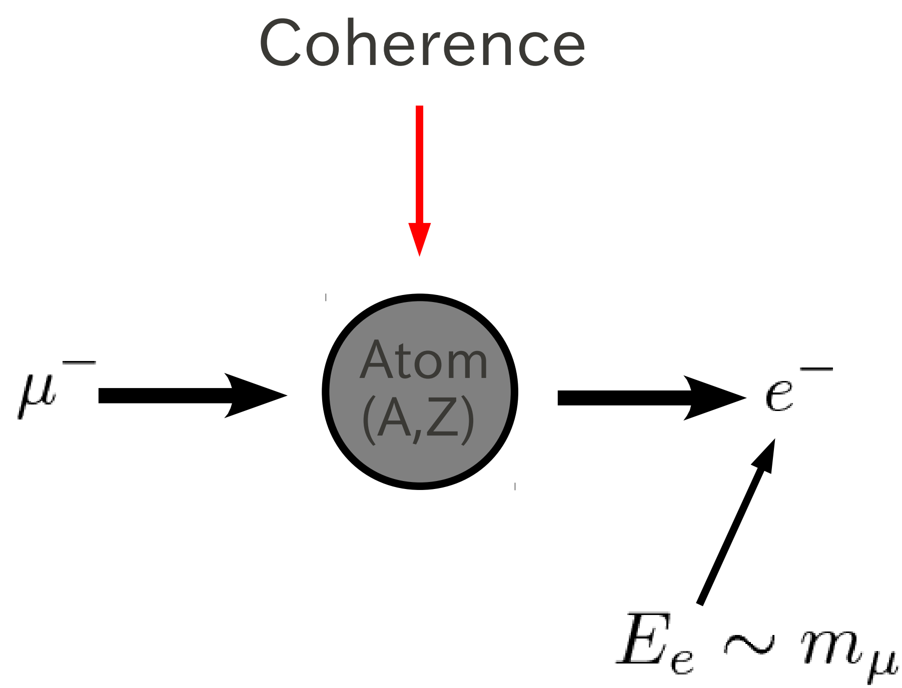
✓ $\mathrm{Br}(\mu^+ \to e^+e^+e^-) \leq 1.0 \times 10^{-12}$ by SINDRUM

✓ $\mathrm{R}(\mu^- A \to e^- A) \leq \begin{cases} 4.3 \times 10^{-12} \ (\mathrm{Ti}) \\ 0.7 \times 10^{-12} \ (\mathrm{Au}) \\ 4.6 \times 10^{-11} \ (\mathrm{Pb}) \end{cases}$ by SINDRUM II

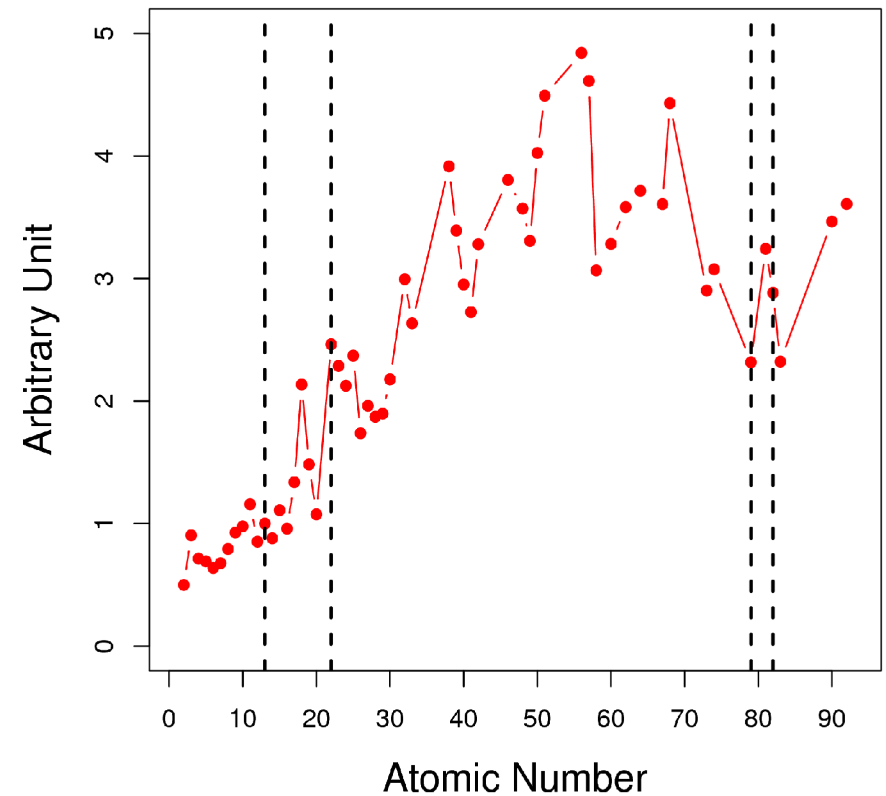
COMET(@J-PARC) and mu2e(@FNAL) are planned:

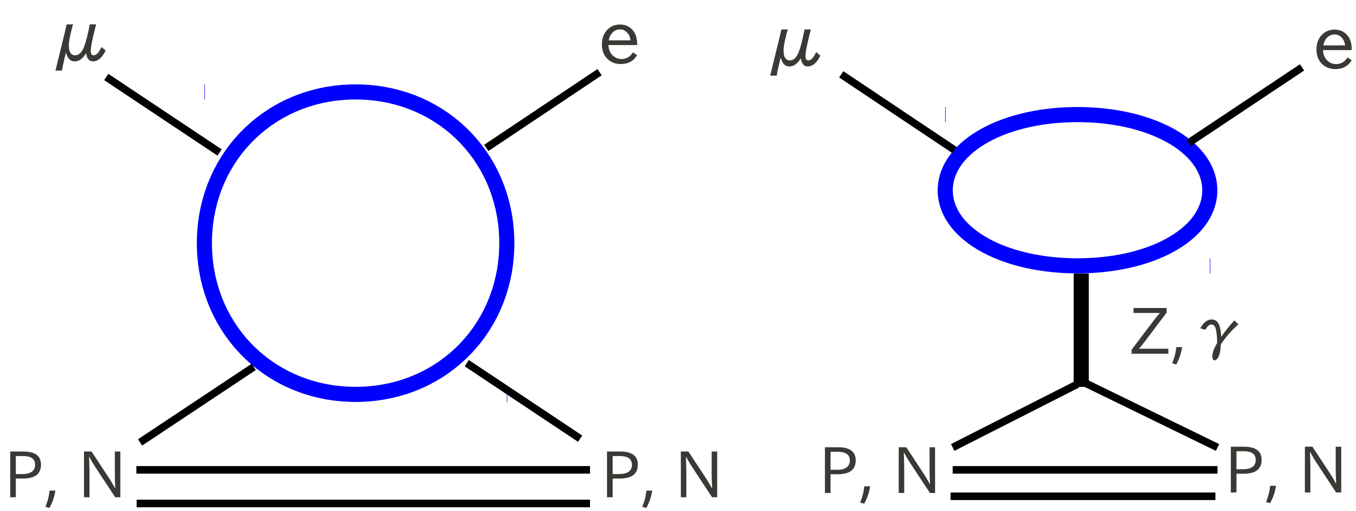
$\to 10^{-16}$ with Al

μ - e Conversion



Atomic number dependence of conversion rate in the LHT





'02 R.Kitano,M.Koike,Y.Okada

τ - LFV

✓ $\tau^+ \to \ell^+ \gamma \lesssim \mathcal{O}(10^{-8})$

✓ $\tau^+ \to \mu^+ \mu^+ \mu^-,\ \tau^+ \to \mu^+ e^+ e^-,\ \tau^+ \to \mu^+ \mu^+ e^- \lesssim \mathcal{O}(10^{-8})$

✓ $\tau^+ \to \ell^+ \pi^0,\ \eta\,\mathrm{or}\,\eta',\ \tau^+ \to \ell^+ \rho^0,\ \omega\,\mathrm{or}\,\phi \lesssim \mathcal{O}(10^{-8})$

by Belle @ KEK and BaBar @ SLAC

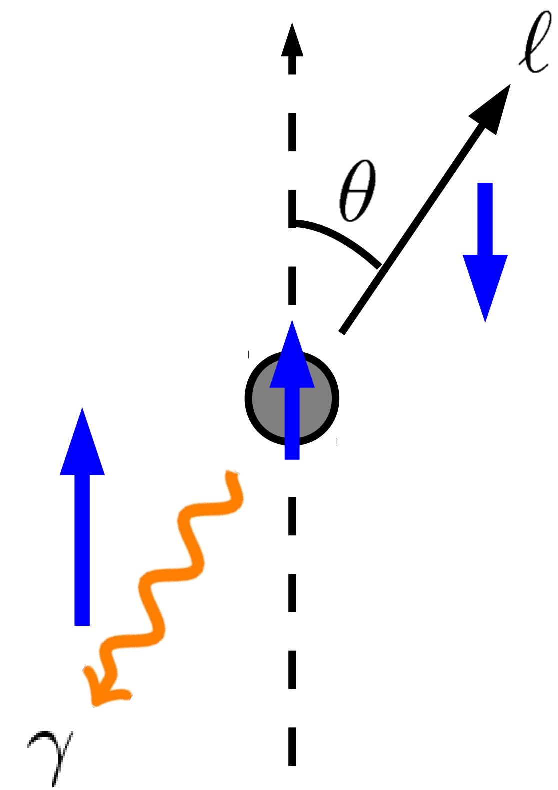
$$\left.\begin{array}{l}\text{Belle II(@KEK) and SuperB(@INFN) are planned} \\ \tau \to 3\mu \text{ and } \tau \to l\phi \text{ can be tested in LHC}\end{array}\right\} \to 10^{-9}$$

Asymmetry for 2 Body Decays

$\ell \to \ell' \gamma, \tau \to \ell P, \tau \to \ell V$

$$\mathcal{L}_\gamma = -\frac{4G_F}{\sqrt{2}}\left[m_a A_R \bar{\ell}_{aR}\sigma^{\mu\nu}\ell_{bL}F_{\mu\nu} + m_a A_L \bar{\ell}_{aL}\sigma^{\mu\nu}\ell_{bR}F_{\mu\nu}\right],$$

$$\Rightarrow \frac{d\Gamma}{d\cos\theta} \propto |A_L|^2(1+\cos\theta) + |A_R|^2(1-\cos\theta),$$

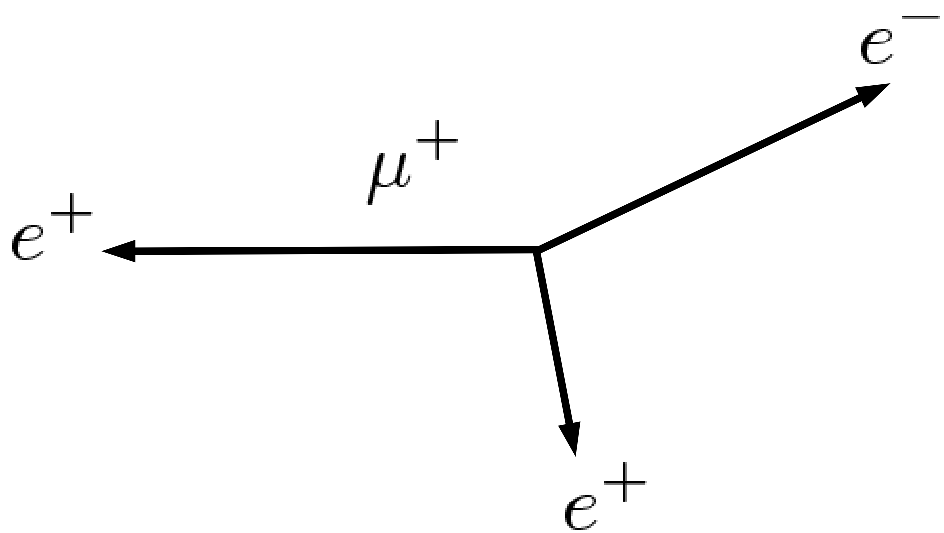


$$\mathrm{Br}(\ell \to \ell' \gamma) \propto |A_L|^2 + |A_R|^2$$

$$A_\gamma = \frac{1}{2}\frac{|A_L|^2 - |A_R|^2}{|A_L|^2 + |A_R|^2}$$

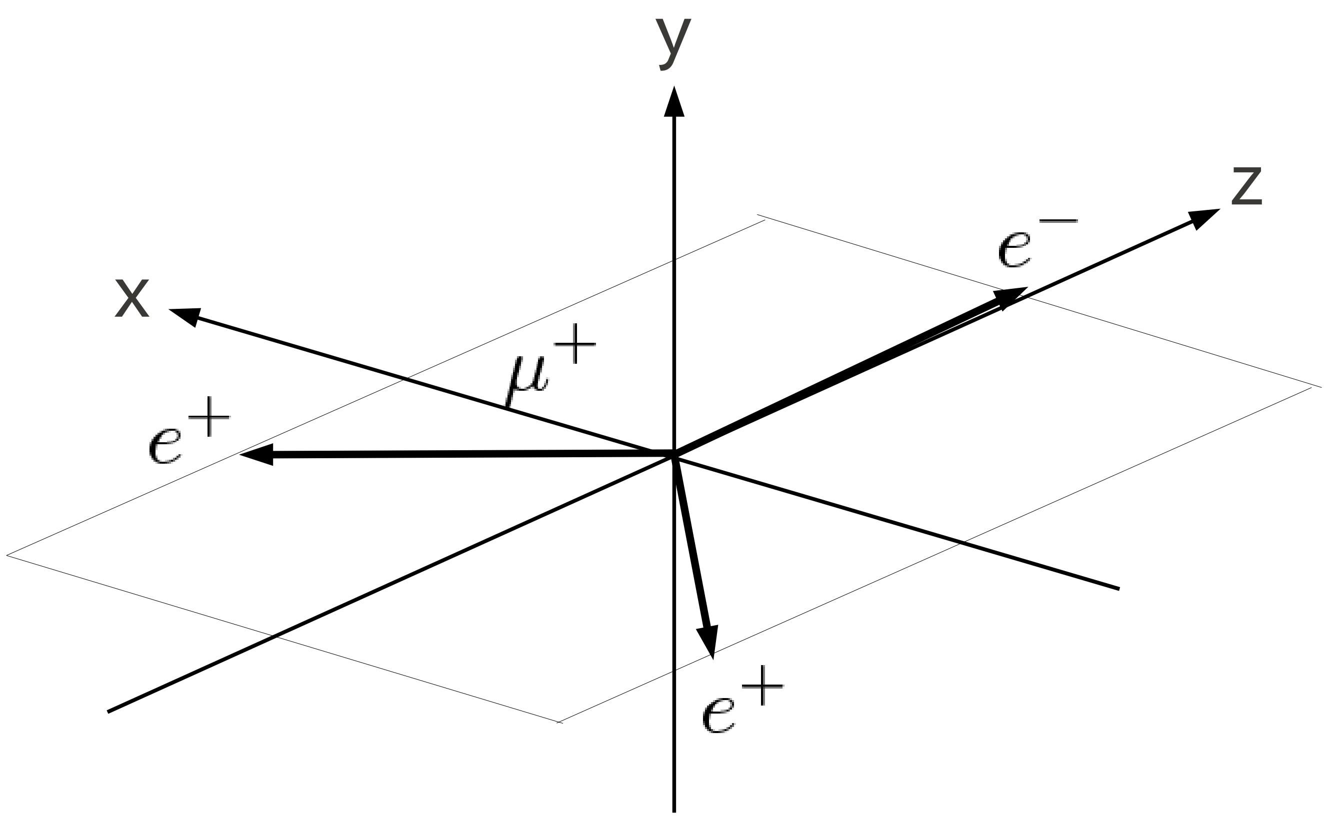
Parity asymmetry

Asymmetries for 3 Body Decays



'00 Y.Okada, K.Okumura, Y.Shimizu

Asymmetries for 3 Body Decays



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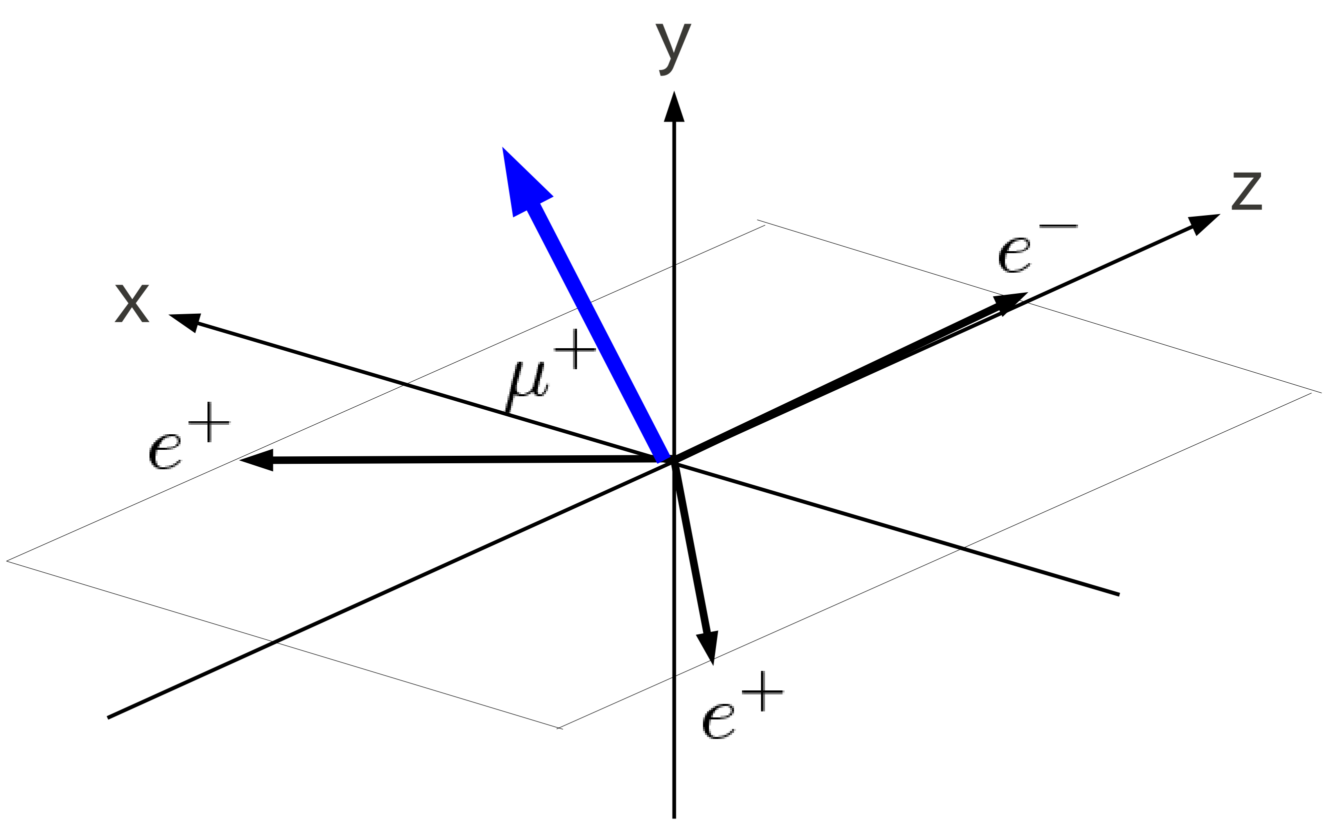
Asymmetries for 3 Body Decays



$$\hat{z} : \cos\theta \sim \vec{s}\cdot\vec{p}_a$$

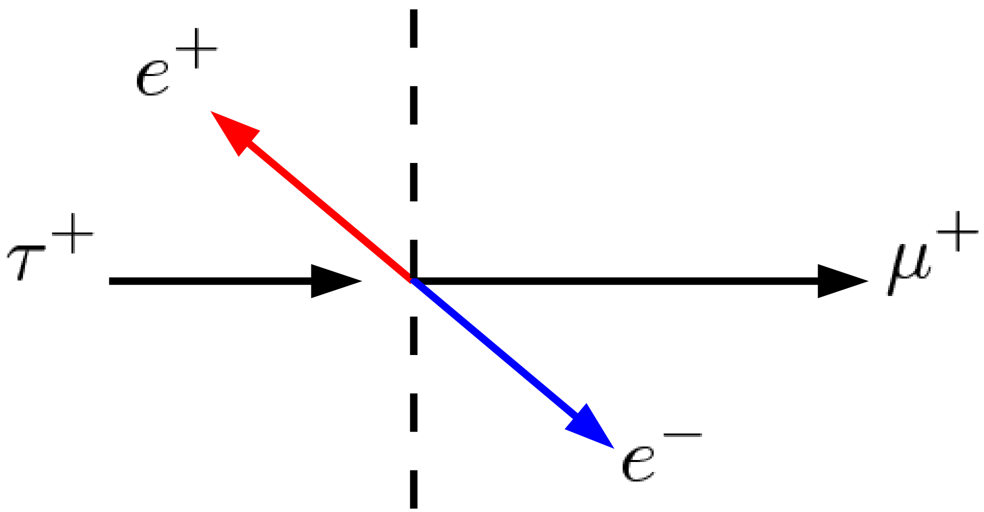
$$\hat{x} : \sin\theta\cos\phi \sim \vec{s}\cdot((\vec{p}_a\times\vec{p}_b)\times\vec{p}_a)$$

$$\hat{y} : \sin\theta\sin\phi \sim \vec{s}\cdot(\vec{p}_a\times\vec{p}_b)$$

'00 Y.Okada, K.Okumura, Y.Shimizu

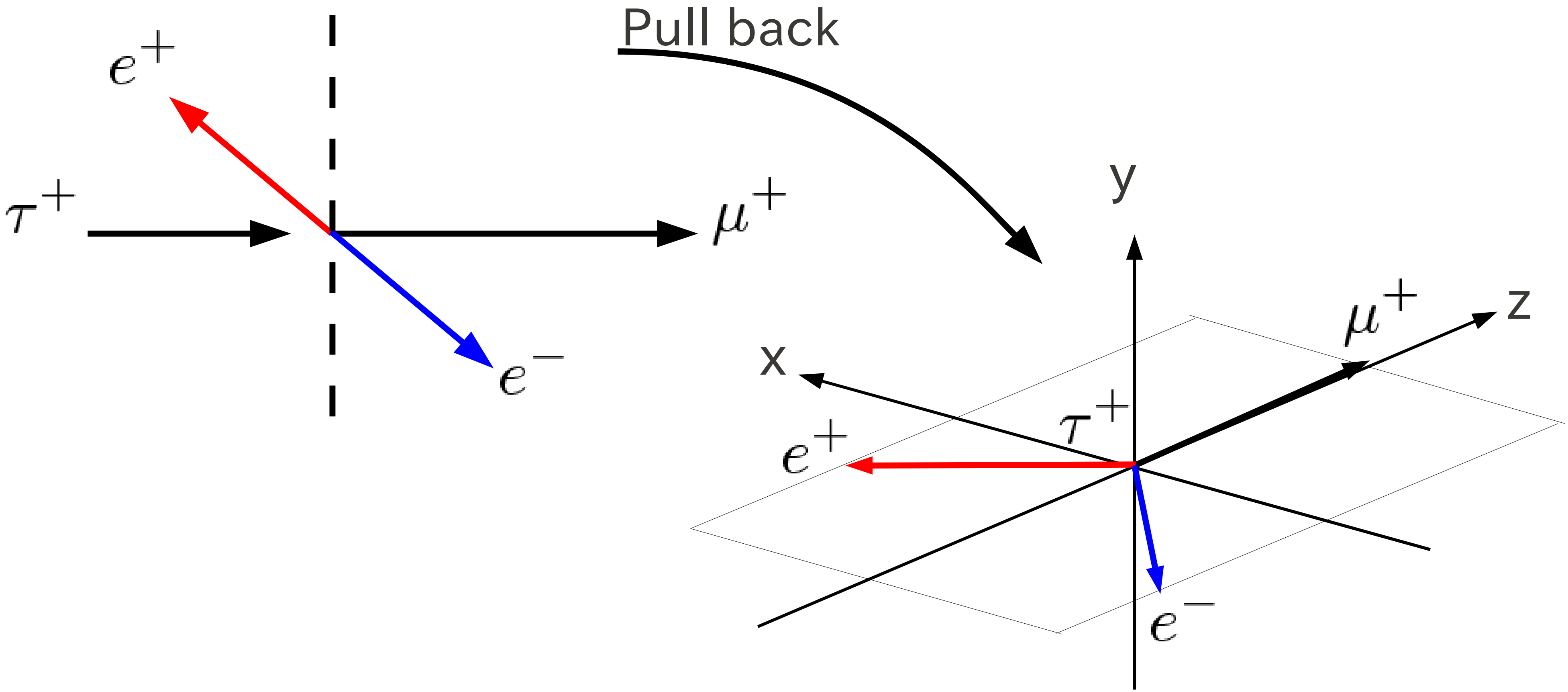
Asymmetries for 3 Body Decays

$\tau^+ \to \mu^+ e^+ e^-$



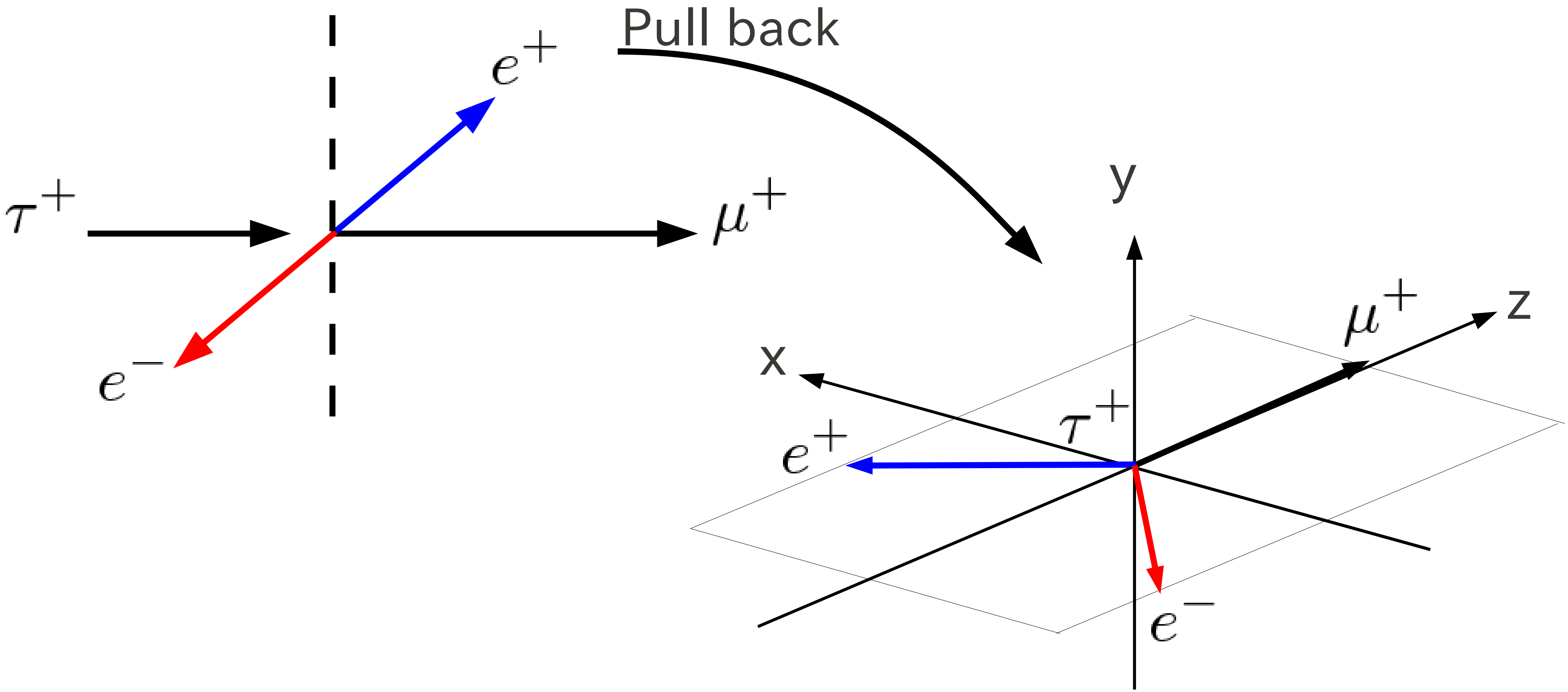
Asymmetries for 3 Body Decays

$\tau^+ \to \mu^+ e^+ e^-$



Asymmetries for 3 Body Decays

$$\tau^+ \to \mu^+ e^+ e^-$$



	Br	A_X	A_Y	A_Z
~~FB~~	Br	A_X	A_Y	A_Z
FB	A_{FB}	$A_{X,FB}$	$A_{Y,FB}$	$A_{Z,FB}$

Chirality Structure

Only the left handed SM leptons interact with the T-odd leptons

$\boxed{V_{\mathrm{H}\ell}}$

$$\mathcal{L}_{\mathrm{LHT}} = -\frac{4G_F}{\sqrt{2}}\left[m_\tau \underline{A_{\mathrm{R}}}\bar{\tau}_{\mathrm{R}}\sigma^{\mu\nu}\mu_{\mathrm{L}}F_{\mu\nu} + \underline{g_{\mathrm{Ll}}}(\tau_{\mathrm{L}}\gamma^{\mu}\mu_{\mathrm{L}})(\mu_{\mathrm{L}}\gamma_{\mu}\mu_{\mathrm{L}}) + \underline{g_{\mathrm{Lr}}}(\tau_{\mathrm{L}}\gamma^{\mu}\mu_{\mathrm{L}})(\mu_{\mathrm{R}}\gamma_{\mu}\mu_{\mathrm{R}}) + \mathrm{H.c.}\right]$$

➡ Some asymmetries are independent of the Wilson coefficients.

$$A_\gamma(\ell \to \ell'\gamma) = -\frac{1}{2}, \qquad A_P(\tau \to \ell P) = \frac{1}{2},$$

$$A_X(\tau^+ \to \mu^+\mu^+e^-) = 0, \quad A_Z(\tau^+ \to \mu^+\mu^+e^-) = -\frac{1}{2},$$

$$A_X(\tau^+ \to \mu^+e^+e^-) : A_{FB} : A_{Z,FB} = -\frac{4\pi}{35} : -\frac{1}{4} : \frac{1}{8}.$$

Contents

Parameters

There are 19 relevant parameters.

✓ Decay Constant (1): $f = 500\ \mathrm{GeV}$

✓ Masses of T-odd leptons and quarks (6): $m^i_{H\ell},\ m^i_{Hq}$

$$100\ \mathrm{GeV} \leq m^i_{H\ell} \leq 1\ \mathrm{TeV},\ m^i_{Hq} = 500\ \mathrm{GeV}$$

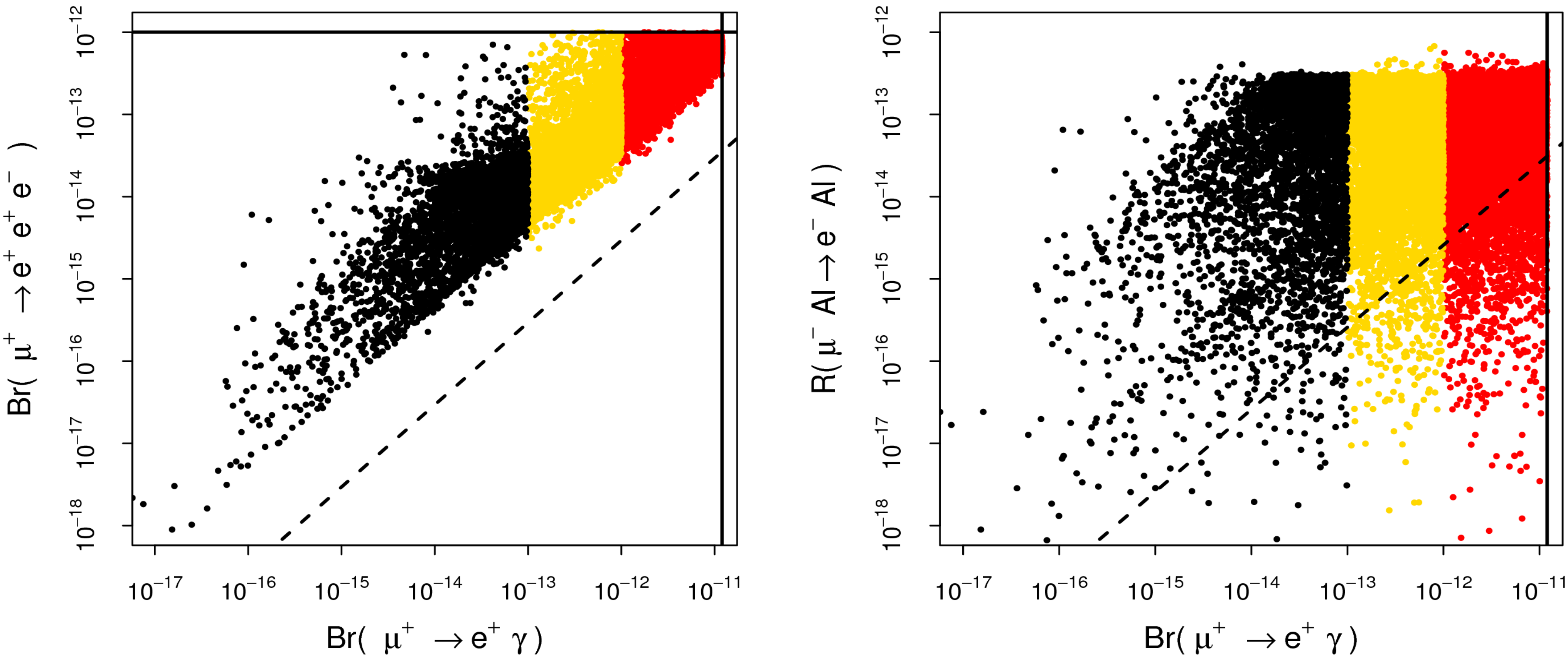
✓ New mixing angles and phases (12): $\theta^\ell_{ij},\ \phi^\ell_{ij},\ \theta^q_{ij},\ \phi^q_{ij}$

$$0 \leq \theta^\ell_{ij},\ \phi^\ell_{ij} < 2\pi$$

➡ Scatter plots on 7 parameters.

$\mathrm{Br}(\mu\to e\gamma)<10^{-13}<\mathrm{Br}(\mu\to e\gamma)<10^{-12}<\mathrm{Br}(\mu\to e\gamma)<1.2\times10^{-11}$

Branching Ratios of μ LFV

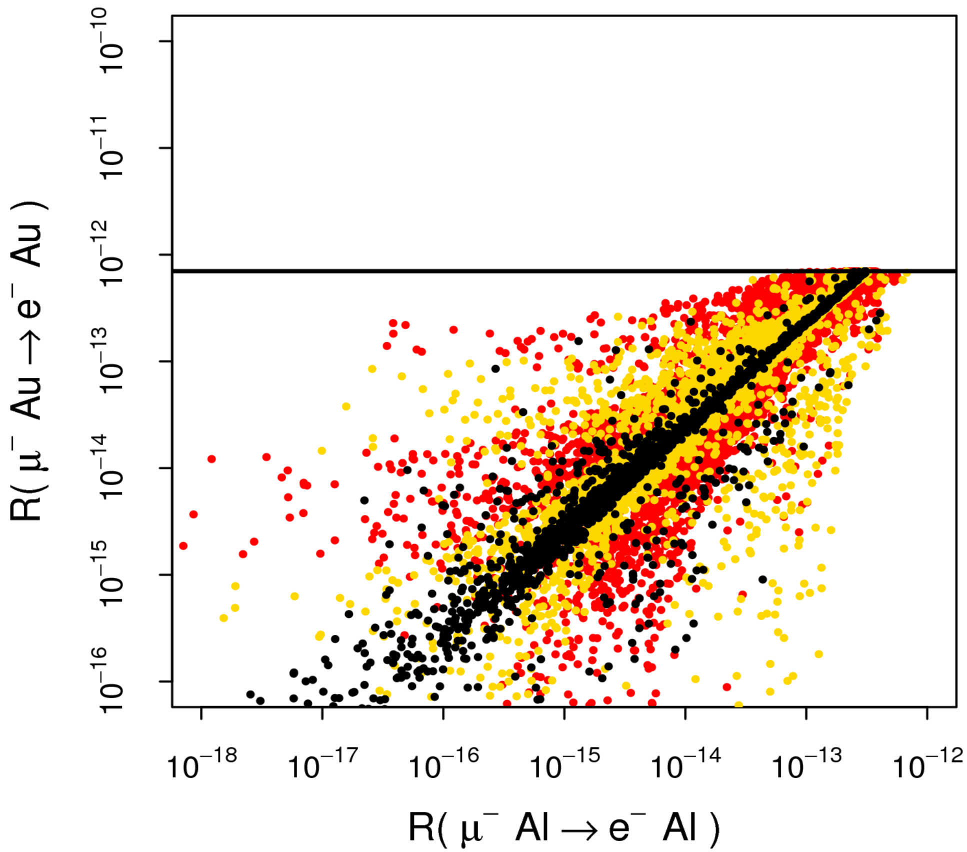


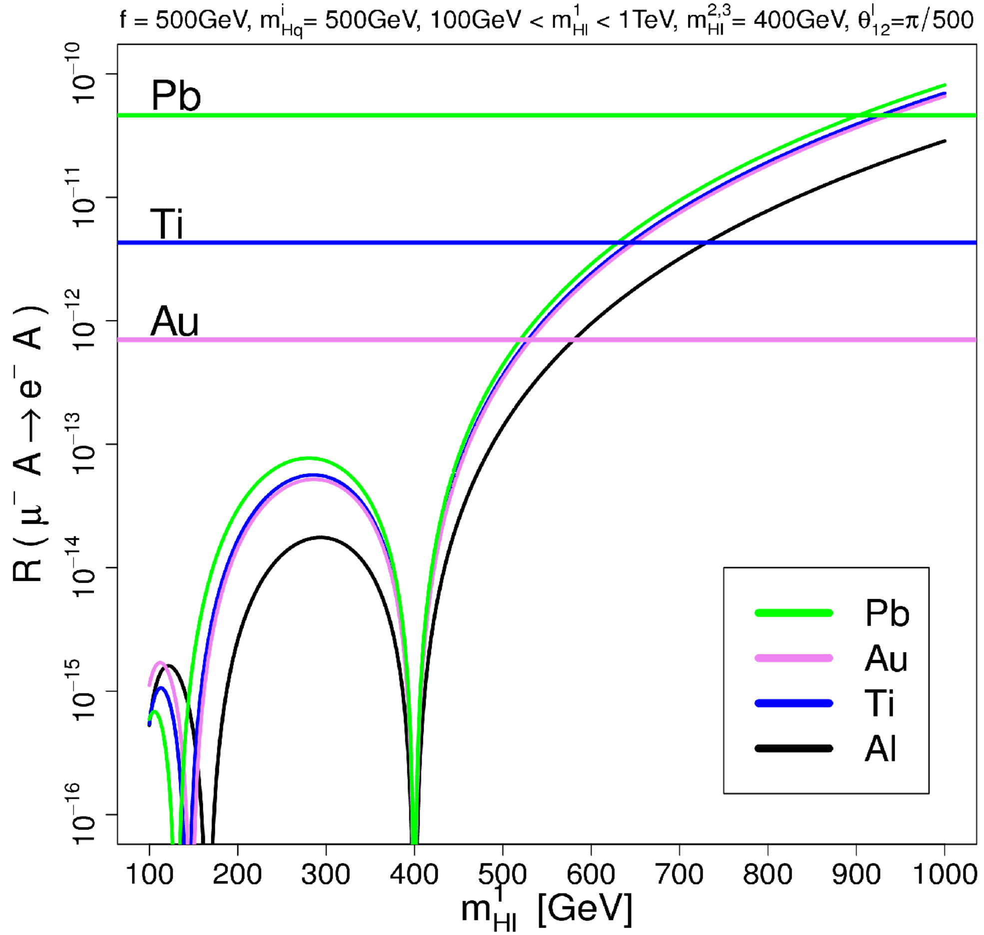
'07 M.Blanke, A.J.Buras, B.Duling, A.Poschenrieder, C.Tarantino

'08 F.del Aguila, J.I.Illana, M.D.Jenkins

- Dipole dominant signal is not favored in $\mu \to e\gamma$ vs $\mu \to 3e$.
- $\mu \to e\gamma$ is independent of μ-e conversion.

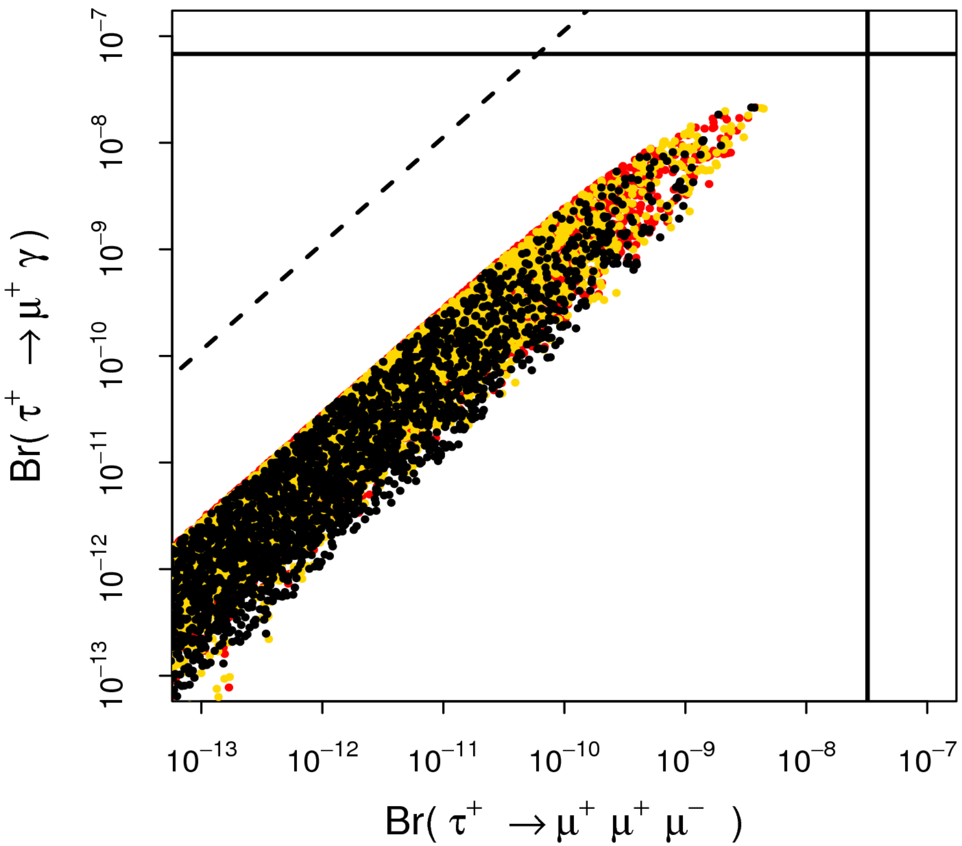
μ - e Conversion

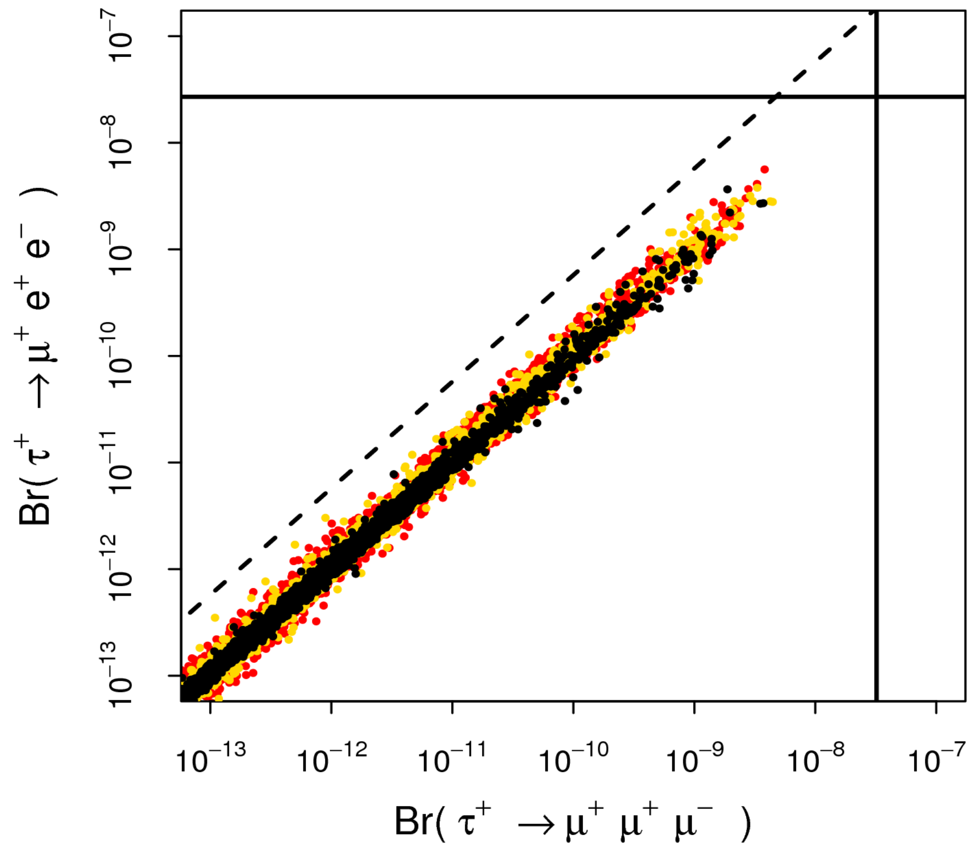




✔ μ -e conversion should be test with various atoms.

Branching Ratios of τ LFV

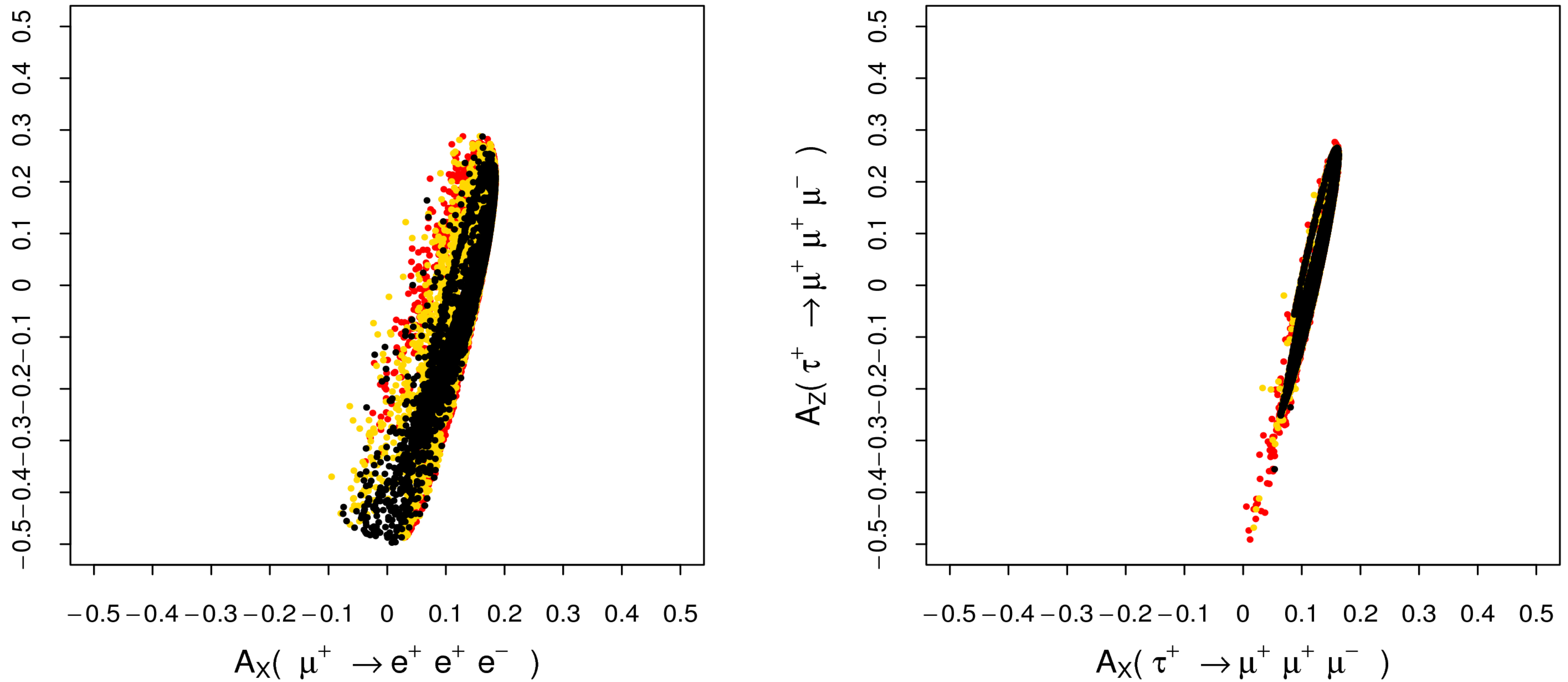




'07 M.Blanke, A.J.Buras, B.Duling, A.Poschenrieder, C.Tarantino

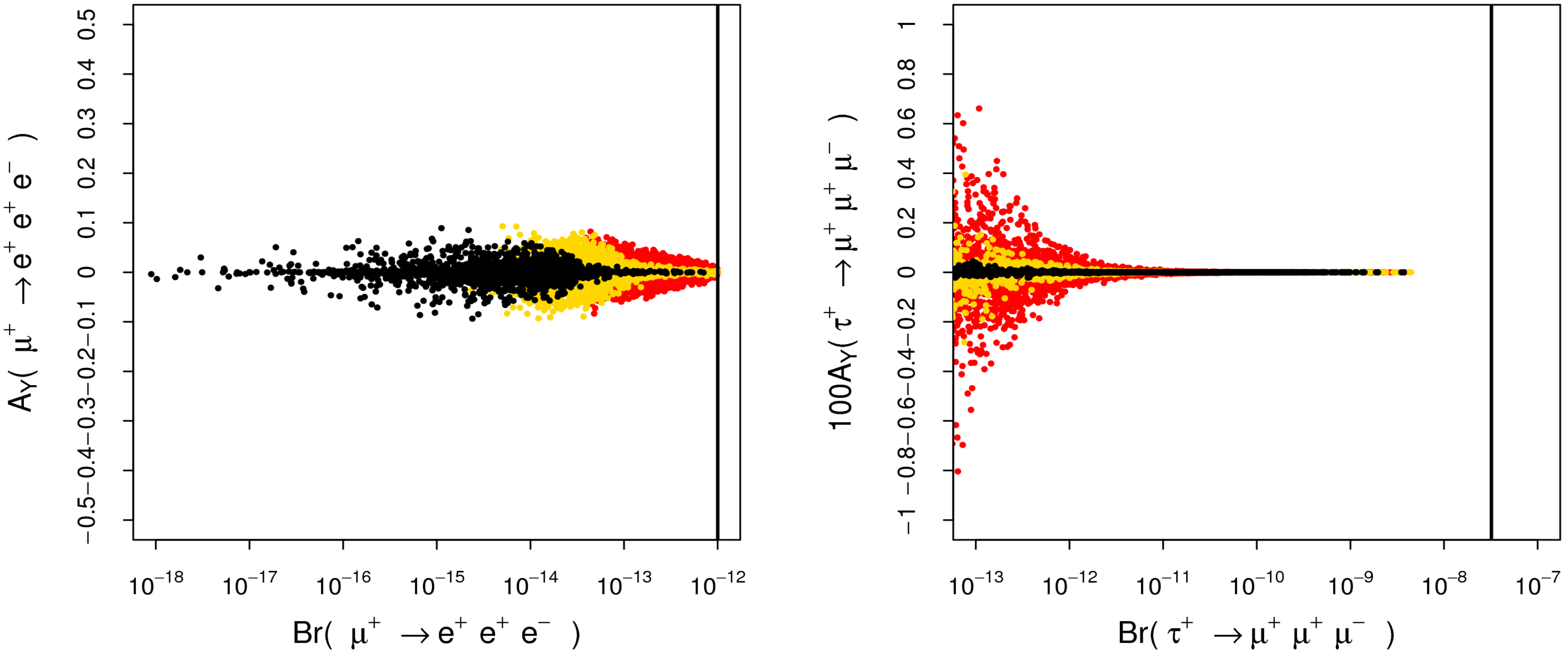
✓ Dipole dominant signals are not favored.

Parity Asymmetry



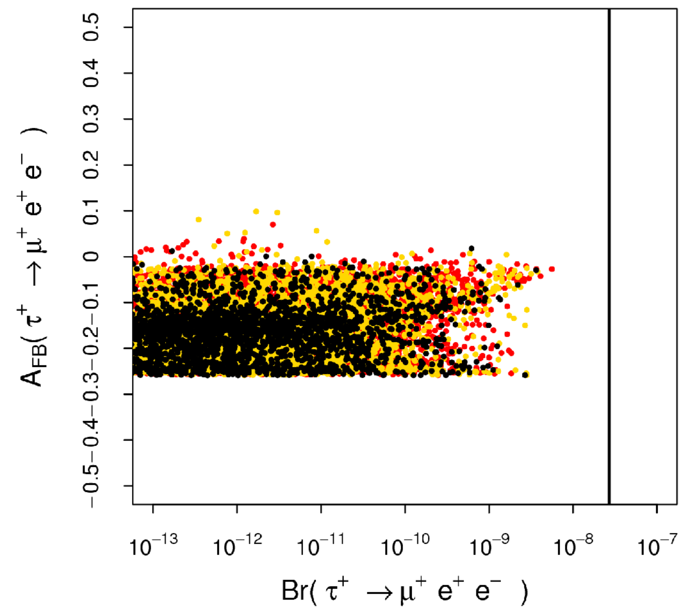
✔ Large parity asymmetries are allowed.

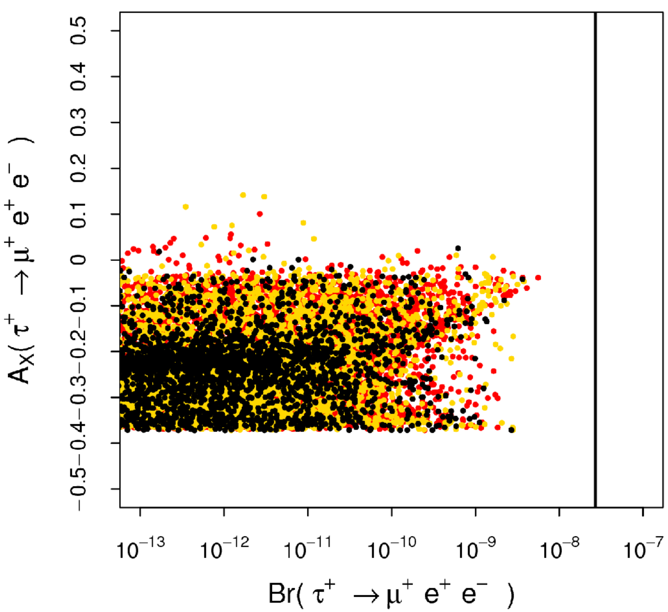
Time Reversal Asymmetry

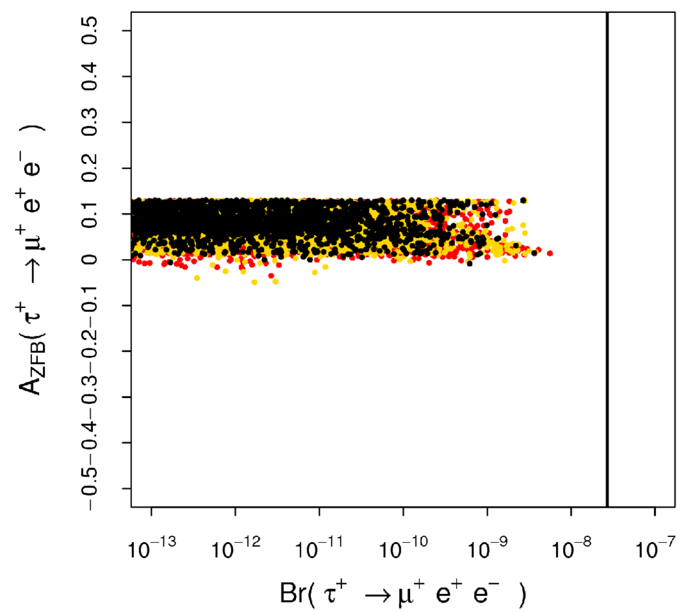


✓ Large time reversal asymmetry is allowed in μ-LFV.

Proportional Relation

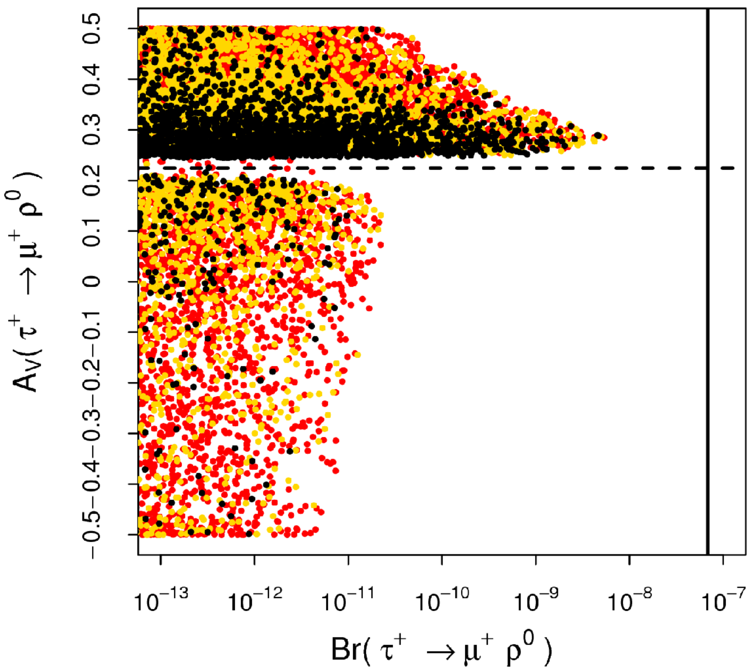


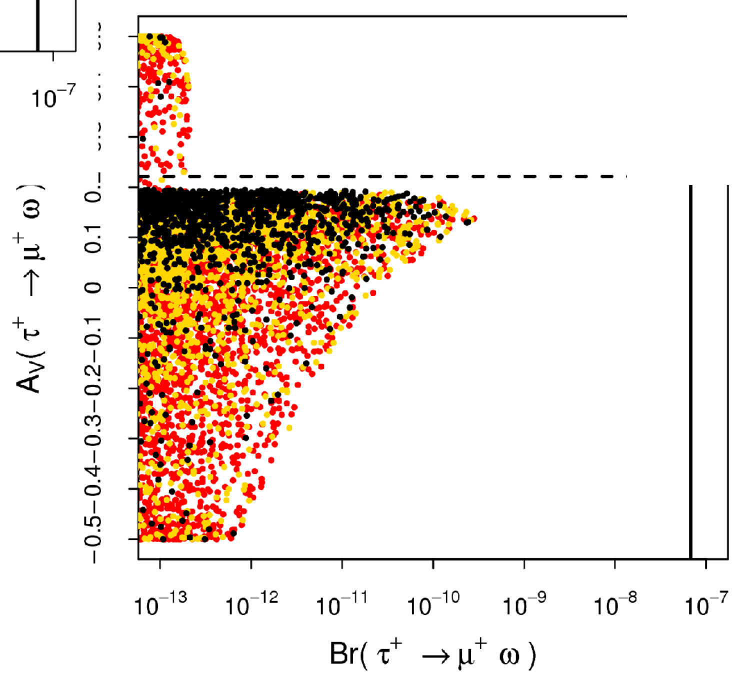


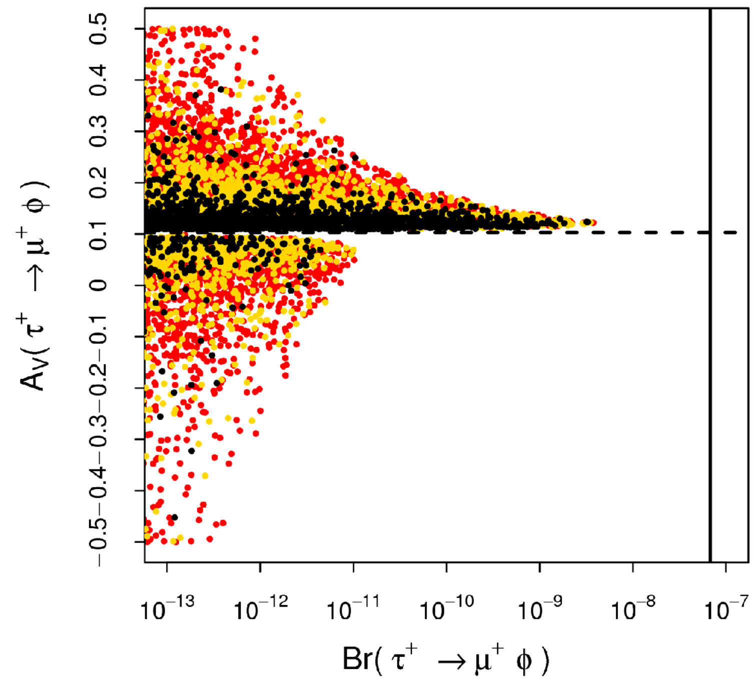


$$A_X(\tau^+ \to \mu^+ e^+ e^-) : A_{FB} : A_{Z,FB} = -\frac{4\pi}{35} : -\frac{1}{4} : \frac{1}{8}.$$

Vector Meson Emission







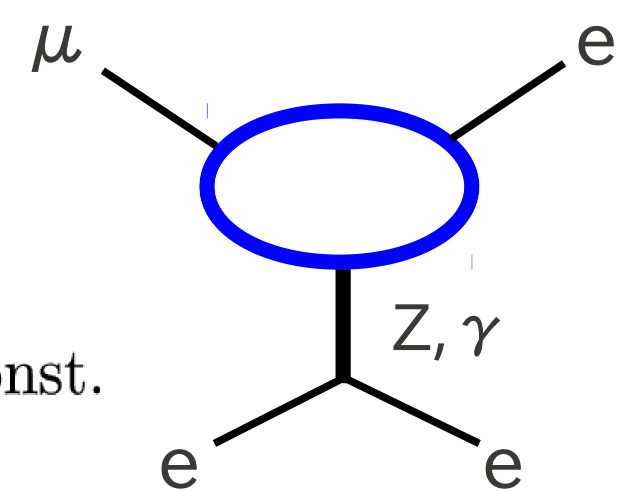
✓Parity asymmetries are positive if we can measure them.

Consistency of the Model

$$\mathcal{L}_{\mathrm{LHT}} = -\frac{4G_F}{\sqrt{2}}\left[m_\tau A_{\mathrm{R}} \underline{\bar{\tau}_{\mathrm{R}} \sigma^{\mu\nu} \mu_{\mathrm{L}}} F_{\mu\nu} + g_{\mathrm{Ll}} \underline{(\tau_{\mathrm{L}} \gamma^\mu \mu_{\mathrm{L}})} (\mu_{\mathrm{L}} \gamma_\mu \mu_{\mathrm{L}}) \right.$$

$$\left. + g_{\mathrm{Lr}} \underline{(\tau_{\mathrm{L}} \gamma^\mu \mu_{\mathrm{L}})} (\mu_{\mathrm{R}} \gamma_\mu \mu_{\mathrm{R}}) + \mathrm{H.c.}\right]$$

$$\frac{g_{Lr}}{eA_R} = -z, \qquad \frac{g_{Ll}}{eA_R} = -z + \Delta$$



$$\frac{\mathrm{Br}_{3l}}{\mathrm{Br}_\gamma} \propto |z|^2 + 2|-z+\Delta|^2 + 8\mathrm{Re}[-3z + 2\Delta] + \mathrm{const.}$$

$$\frac{A_{Z3l}}{\mathrm{Br}_\gamma} \propto \frac{1}{6}|z|^2 - |-z+\Delta|^2 - 4\mathrm{Re}[-z + 2\Delta] + \mathrm{const.}$$

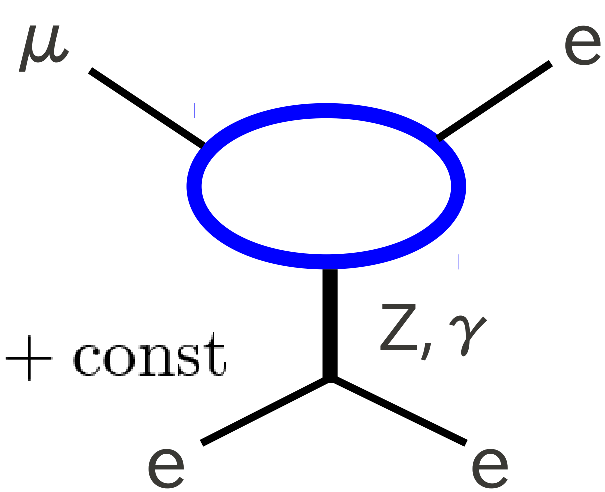
$$\frac{A_{X3l}}{\mathrm{Br}_\gamma} \propto \frac{1}{12}|z|^2 - \mathrm{Re}[-z + 3\Delta] + \mathrm{const.}$$

$$\frac{A_{Y3l}}{\mathrm{Br}_\gamma} \propto \mathrm{Im}[-z + 3\Delta]$$

Consistency of the Model

$$\mathcal{L}_{\mathrm{LHT}} = -\frac{4G_F}{\sqrt{2}}\left[m_\tau A_{\mathrm{R}} \underline{\bar{\tau}_{\mathrm{R}} \sigma^{\mu\nu} \mu_{\mathrm{L}}} F_{\mu\nu} + g_{\mathrm{Ll}} \underline{(\tau_{\mathrm{L}} \gamma^\mu \mu_{\mathrm{L}})} (\mu_{\mathrm{L}} \gamma_\mu \mu_{\mathrm{L}}) \right.$$
$$\left. + g_{\mathrm{Lr}} \underline{(\tau_{\mathrm{L}} \gamma^\mu \mu_{\mathrm{L}})} (\mu_{\mathrm{R}} \gamma_\mu \mu_{\mathrm{R}}) + \mathrm{H.c.}\right]$$

$$\frac{g_{Lr}}{eA_R} = Q_f z, \qquad \frac{g_{Ll}}{eA_R} = Q_f z + \Delta$$



$$\frac{\mathrm{Br}_{\mu ee}}{\mathrm{Br}_\gamma} \propto |z|^2 + |-z + \Delta'|^2 + 8\mathrm{Re}[-2z + \Delta'] + \mathrm{const}$$

$$\frac{\mathrm{A}_{FB\mu ee}}{\mathrm{Br}_\gamma} \propto -|z|^2 + |-z + \Delta'|^2 + 16\mathrm{Re}[\Delta']$$

$$\frac{\mathrm{Br}_\rho}{\mathrm{Br}_\gamma} \propto |2z + \Delta_u - \Delta_d + \mathrm{const}| + \mathrm{const}$$

$$\frac{\mathrm{A}_\rho}{\mathrm{Br}_\gamma} \propto |2z + \Delta_u - \Delta_d + \mathrm{const}| + \mathrm{const}$$

Conclusion

Model x Process

Conclusion

T-even

$\gamma \; W^{\pm} \; Z \; h$

$\nu_i \; e_i \; u_i \; d_i \; T_+$

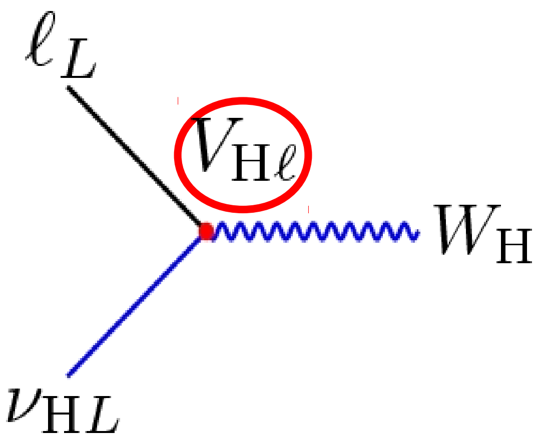
$V_{Hu} \quad V_{Hd}$

$V_{H\nu} \quad V_{H\ell}$

T-odd

$A_H \; W_H^{\pm} \; Z_H \; \Phi$

$\nu_{Hi} \; e_{Hi} \; u_{Hi} \; d_{Hi} \; T_-$



LHT x Process

Conclusion

T-even

$\gamma\ W^{\pm}\ Z\ h$

$\nu_i\ e_i\ u_i\ d_i\ T_+$

$V_{Hu}\quad V_{Hd}$

$V_{H\nu}\quad V_{H\ell}$

T-odd

$A_H\ W_H^{\pm}\ Z_H\ \Phi$

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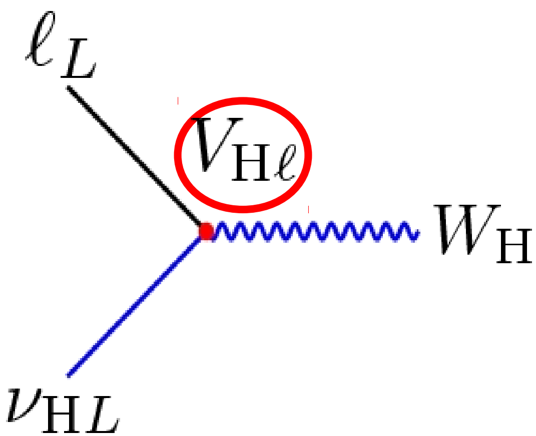
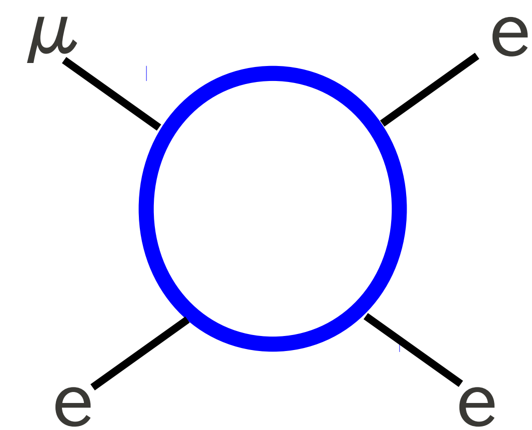
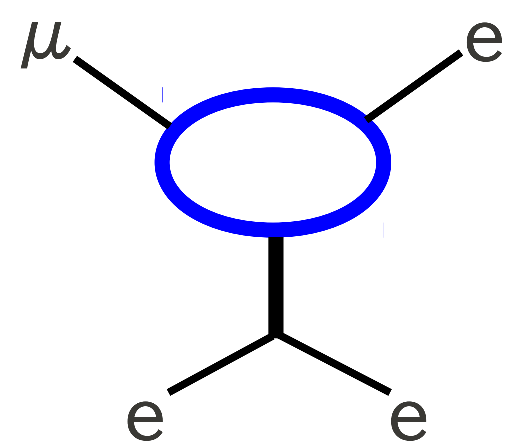


LHT x LFV





Conclusion

T-even

$\gamma\ W^{\pm}\ Z\ h$

$\nu_i\ e_i\ u_i\ d_i\ T_+$

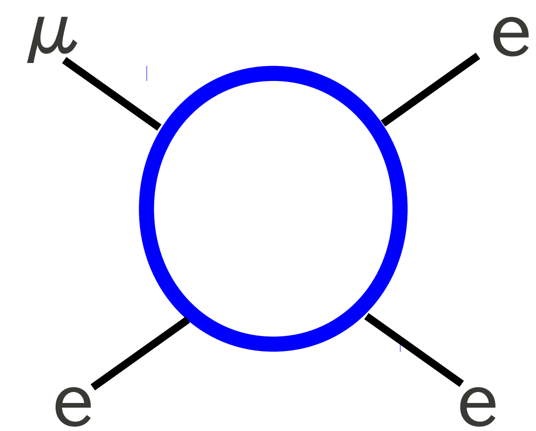
$V_{Hu}\quad V_{Hd}$

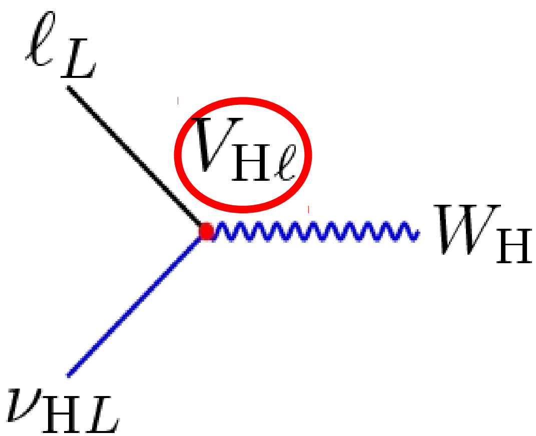
$V_{H\nu}\quad V_{H\ell}$

T-odd

$A_H\ W_H^{\pm}\ Z_H\ \Phi$

$\nu_{Hi}\ e_{Hi}\ u_{Hi}\ d_{Hi}\ T_-$





LHT x LFV

+ Asymmetry