LEPTON FLAVOUR VIOLATION IN THE SIMPLEST LITTLE HIGGS MODEL

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Tae 2013 Benasque

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$$\tau \longrightarrow \mu + Hadrons$$

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BELLE

Belle II

WHICH MODEL?

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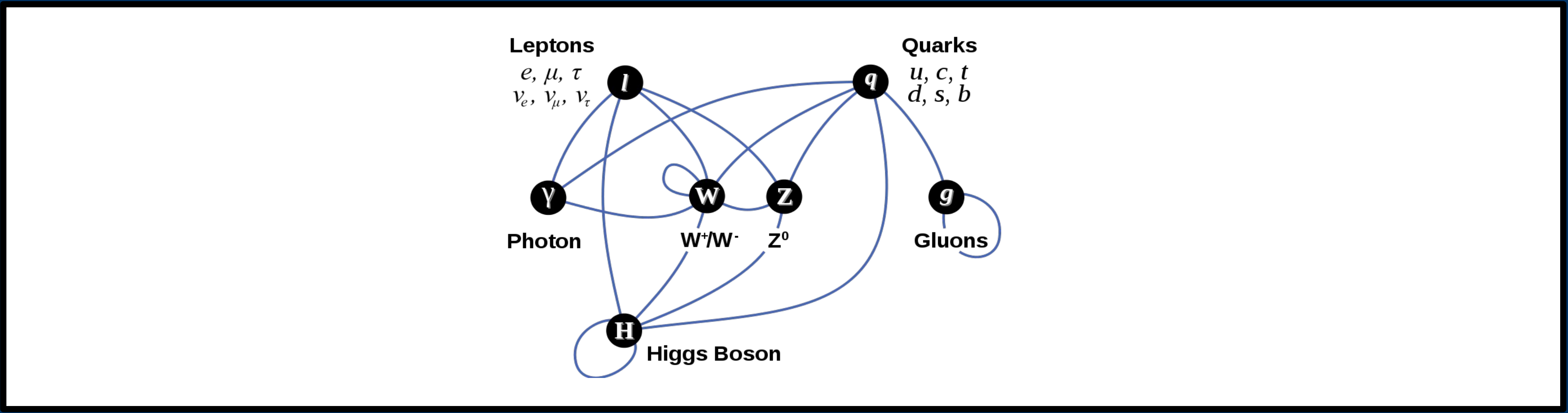

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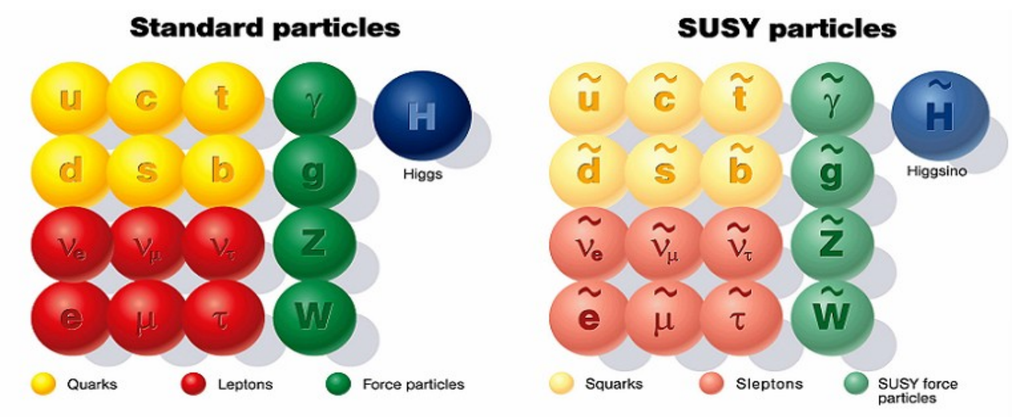

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Composite Higgs

COMPOSITE & EFFECTIVE

arXiv:1003.3251v J.R. Espinosa et all.

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- It has recently been obtained SILH with pseudoscalar Higgs

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Little Higgs Theories:

Model	Global group	Gauge group	Type	Comments
Minimal moose [7]	$SU(3)^8/SU(3)^4$	$SU(3)\times SU(2)\times U(1)$	t.s.	can contain extra light triplet and singlet scalars
Minimal moose with $SU(2)_C$ [8]	$SO(5)^8/SO(5)^4$	$SO(5)\times SU(2)\times U(1)$	t.s.	less constrained from electroweak precision tests (EWPT)
Moose with T-parity [9]	$SO(5)^{10}/SO(5)^5$	$(SU(2)\times U(1))^3$	t.s.	very few constraints from EWPT, larg spectrum, complicated plaquettes
Littlest Higgs [6]	$SU(5)/SO(5)$	$(SU(2)\times U(1))^2$	p.g.g	Minimal field content
SU(6)/Sp(6) model [10]	$SU(6)/Sp(6)$	$(SU(2)\times U(1))^2$	p.g.g	Small field content, contains a heavy vector-like quark doublet
Littlest Higgs with $SU(2)_C$ [11]	$SO(9)/(SO(5)\times SO(4))$	$SU(2)^3\times U(1)$	p.g.g.	less constraints from EWPT
Littlest Higgs with T-parity [12]	$SU(5)/SO(5)$	$(SU(2)\times U(1))^2$	p.g.g	Minimal field content, very few constraints from EWPT
SU(3) simple group [13, 14]	$(SU(3)\times U(1))^2/(SU(2)\times U(1))^2$	$SU(3)\times U(1)$	s.g.g.	no large quartic
SU(4) simple group [13]	$(SU(4)\times U(1))^4/(SU(3)\times U(1))^4$	$SU(4)\times U(1)$	s.g.g.	Two Higgs doublets, large quartic
SU(9)/SU(8) simple group [15]	$SU(9)/SU(8)$	$SU(3)\times U(1)$	s.g.g.	Two Higgs doublets, large quartic

SIMPLEST LITTLE HIGGS

arXiv: 1101.2936 Àguila et all.

- Solve the little hierarchy problem without the T-parity

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- E.W. Sector is in a group SU(3)xU(1)

- LHT and SLH are equivalent but the last have new sources of LFV

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- Every lepton family consists of an SU(3) left-handed triplet and 2 right-handed singlets

$$L_m^T = (\nu_L, \ell_L, \mathrm{i}N_L)_m \,, \quad \ell_{Rm} \,, \quad N_{Rm}$$

SIMPLEST LITTLE HIGGS

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- For the quarks we have 2 embedding

$$L_m^T = (\nu_L, \ell_L, \mathrm{i}N_L)_m \,, \quad \ell_{Rm} \,, \quad N_{Rm}$$

$$Q_m^T = (u_L, d_L, \mathrm{i}U_L)_m, \quad u_{Rm} \,, \quad d_{Rm} \,, \quad U_{Rm}$$

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$$L_m^T = (\nu_L, \ell_L, \mathrm{i}N_L)_m \,, \quad \ell_{Rm} \,, \quad N_{Rm}$$

$$Q_1^T = (d_L, -u_L, \mathrm{i}D_L) \,, \quad d_R \,, \quad u_R \,, \quad D_R$$

$$Q_2^T = (s_L, -c_L, \mathrm{i}S_L) \,, \quad s_R \,, \quad c_R \,, \quad S_R$$

$$Q_3^T = (t_L, b_L, \mathrm{i}T_L) \,, \quad t_R \,, \quad b_R \,, \quad T_R$$

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Universal embedding (U)							
Fermion	$Q_{1,2}$	Q_3	u_{Rm}, U_{Rm}	d_{Rm}	L_m	N_{Rm}	e_{Rm}
Q_x charge	$1/3$	$1/3$	$2/3$	$-1/3$	$-1/3$	0	-1
SU(3) rep.	$\mathbf{3}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$
Anomaly-free embedding (AF)							
Fermion	$Q_{1,2}$	Q_3	u_{Rm}, T_{Rm}	d_{Rm}, D_{Rm}, S_{Rm}	L_m	N_{Rm}	e_{Rm}
Q_x charge	0	$1/3$	$2/3$	$-1/3$	$-1/3$	0	-1
SU(3) rep.	$\bar{\mathbf{3}}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$	$\mathbf{3}$	$\mathbf{1}$	$\mathbf{1}$

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- Other basic fields and expansions

$$D_\mu = \partial_\mu - \mathrm{i} g A_\mu^a T_a + \mathrm{i} g_x Q_x B_\mu^x\,, \qquad g_x = \frac{g t_W}{\sqrt{1 - t_W^2/3}}$$

$$A^a T_a = \frac{A^3}{2}\begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix} + \frac{A^8}{2}\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix} + \frac{1}{\sqrt{2}}\begin{pmatrix} 0 & W^+ & Y^0 \\ W^- & 0 & X^- \\ Y^{0\dagger} & X^+ & 0 \end{pmatrix}$$

$$\Phi_1 = \exp\left(\frac{\mathrm{i}\Theta'}{f}\right)\exp\left(\frac{\mathrm{i} t_\beta \Theta}{f}\right)\begin{pmatrix} 0 \\ 0 \\ f c_\beta \end{pmatrix}$$

$$\Phi_2 = \exp\left(\frac{\mathrm{i}\Theta'}{f}\right)\exp\left(-\frac{\mathrm{i}\Theta}{t_\beta f}\right)\begin{pmatrix} 0 \\ 0 \\ f s_\beta \end{pmatrix}$$

$$\Theta = \begin{pmatrix} 0 & 0 & h^0 \\ 0 & 0 & h^- \\ h^{0\dagger} & h^+ & 0 \end{pmatrix}$$

$$h^0 = (v + H)/\sqrt{2} - i\chi \text{ and } h^\pm = -\phi^\pm.$$

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- Scalar Lagrangian and physical states

$$\mathcal{L}_\Phi = |D_\mu \Phi_1|^2 + |D_\mu \Phi_2|^2$$

$$W^\pm \to W^\pm \pm \frac{iv^3}{3\sqrt{2}f^3}\left(\frac{c_\beta^3}{s_\beta} - \frac{s_\beta^3}{c_\beta}\right) X^\pm$$

$$X^\pm \to X^\pm \pm \frac{iv^3}{3\sqrt{2}f^3}\left(\frac{c_\beta^3}{s_\beta} - \frac{s_\beta^3}{c_\beta}\right) W^\pm$$

$$\phi^\pm \to \mp i\left(1 + \frac{v^2}{12f^2}\left(\frac{c_\beta^4}{s_\beta^2} + \frac{s_\beta^4}{c_\beta^2}\right)\right)\phi^\pm$$

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- Scalar Lagrangian and physical states

$$\mathcal{L}_\Phi = |D_\mu \Phi_1|^2 + |D_\mu \Phi_2|^2$$

$$\begin{pmatrix} A^3 \\ A^8 \\ B_x \end{pmatrix} = \begin{pmatrix} 0 & c_W & -s_W \\ \frac{1}{\sqrt{3}}\sqrt{3-t_W^2} & \frac{s_W^2}{\sqrt{3}c_W} & \frac{s_W}{\sqrt{3}} \\ -\frac{t_W}{\sqrt{3}} & \frac{s_W}{\sqrt{3}}\sqrt{3-t_W^2} & \frac{c_W}{\sqrt{3}}\sqrt{3-t_W^2} \end{pmatrix} \begin{pmatrix} Z' \\ Z \\ A \end{pmatrix}$$

$$Z' \to Z' + \delta_Z Z\,,$$
$$Z \to Z - \delta_Z Z'\,,$$

$$\delta_Z = -\frac{(1-t_W^2)\sqrt{3-t_W^2}}{8c_W}\frac{v^2}{f^2}$$

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- Vector and Yukawa Lagrangians

$$\mathcal{L}_V = -\frac{1}{2}\mathrm{Tr}\{\widetilde{G}_{\mu\nu}\widetilde{G}^{\mu\nu}\} - \frac{1}{4}B_x^{\mu\nu}B_{x\,\mu\nu}\,, \qquad \widetilde{G}_{\mu\nu} = \frac{\mathrm{i}}{g}[D_\mu, D_\nu]$$

$$\mathcal{L}_Y \supset \mathrm{i}\lambda_N^m \bar{N}_{Rm}\Phi_2^\dagger L_m + \frac{\mathrm{i}\lambda_\ell^{mn}}{\Lambda}\bar{\ell}_{Rm}\epsilon_{ijk}\Phi_1^i\Phi_2^j L_n^k + \mathrm{h.c.}$$

$$\delta_\nu = -\frac{v}{\sqrt{2}ft_\beta} \qquad \begin{pmatrix}\nu_L \\ N_L\end{pmatrix}_m \to \left[\begin{pmatrix}1-\frac{\delta_\nu^2}{2} & -\delta_\nu \\ \delta_\nu & 1-\frac{\delta_\nu^2}{2}\end{pmatrix}\begin{pmatrix}V_\ell\nu_L \\ N_L\end{pmatrix}\right]_m \qquad \ell_{Lm} \to (V_\ell \ell_L)_m = V_\ell^{mi}\ell_{Li}$$

SIMPLEST LITTLE HIGGS

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- Fermion Lagrangian

$$\mathcal{L}_F = \bar{\psi}_m \mathrm{i} \not{D} \psi_m \,, \qquad \psi_m = \{L_m, \ell_{Rm}, N_{Rm}\}$$

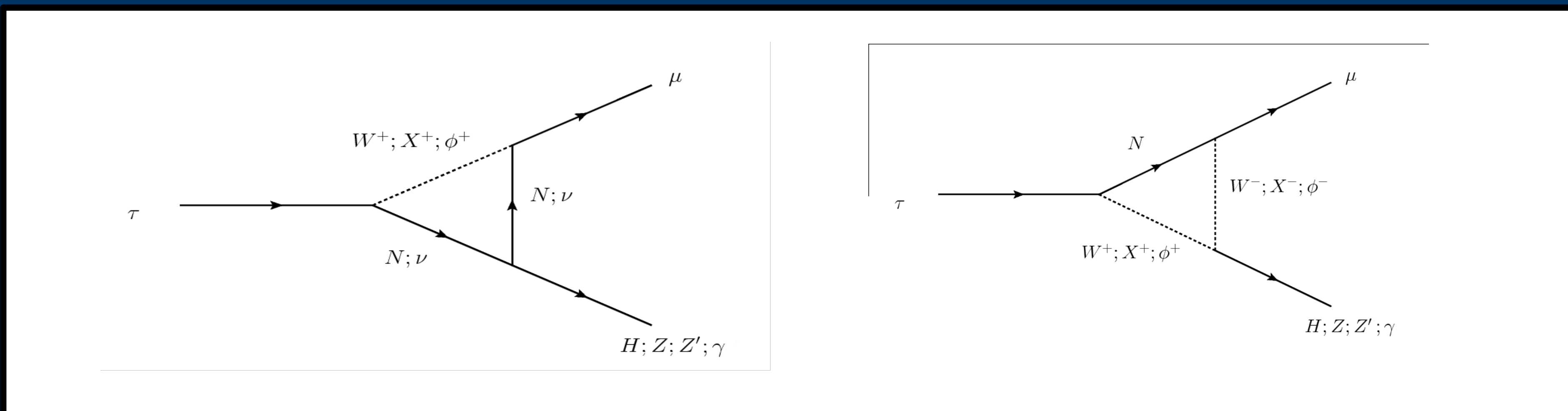
OUR WORK

- Finally we can write the Feynman rules for the channels of our interest

OUR WORK

$$\tau \longrightarrow \mu + H \longrightarrow \mu + P$$

$$\tau \longrightarrow \mu + Z; Z'; \gamma \longrightarrow \mu + V; PP$$



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- Then the parameters obtained should be compared with the results of tree-level hadronic processes

Muchas Gracias!