$\mu \to e\gamma$ and $\tau \to \ell\gamma$ decays in the in the type III seesaw model

Florian Bonnet

Laboratoire de Physique Théorique
Université Paris-Sud 11

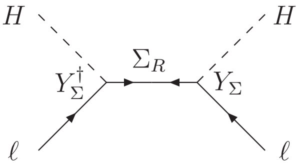
March 5^{th}, YSF 2, Rencontres de Moriond 2008

Based on : arXiv:0803.0481
A.Abada, C. Biggio, F.B., M.B. Gavela, T. Hambye

Type III Seesaw

We add extra fermions in the adjoint representation of SU(2) :

$$\Sigma_R = \begin{pmatrix} \Sigma_R^+ \\ \Sigma_R^0 \\ \Sigma_R^- \end{pmatrix} \sim (1,3,0)$$

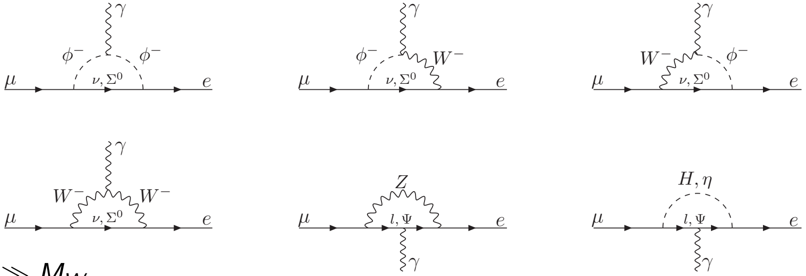


$$\mathcal{L}_\Sigma = i\overline{\vec{\Sigma}}_R \not{D} \vec{\Sigma}_R - \left[\frac{1}{2} \overline{\vec{\Sigma}}_R M_\Sigma \vec{\Sigma}_R^c + \overline{\vec{\Sigma}}_R Y_\Sigma \left(\tilde{\phi}^\dagger \vec{\tau} L_L \right) \right]$$

Source of mixing between ℓ and Σ

$\Rightarrow$ Can be constrained by Lepton Flavor Violation (LFV) processes

$\mu \longrightarrow e\gamma$, and $\tau \longrightarrow \ell\gamma$



$M_\Sigma \gg M_W$

$$BR(\mu \to e\gamma) = \frac{3}{32}\frac{\alpha}{\pi}\left| C.\,\epsilon_{e\mu} - \sum_i x_{\nu_i} (U_{PMNS})_{ei} \left((U_{PMNS})^\dagger\right)_{i\mu} + \mathcal{O}\left(\frac{1}{M_\Sigma^4}\right)\right|^2$$

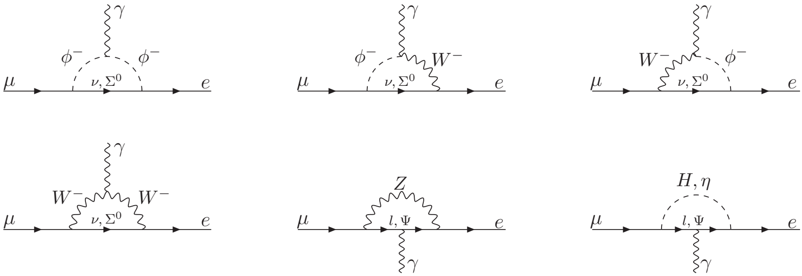
$C = -2.23$

$$\epsilon = \frac{v^2}{2} Y_\Sigma^\dagger \frac{1}{M_\Sigma^\dagger}\frac{1}{M_\Sigma} Y_\Sigma$$

$$x_{\nu_i} = \frac{m_{\nu_i}^2}{M_W^2}$$

lowest order ν mixing matrix

$\mu \to e\gamma$, and $\tau \to \ell\gamma$



$$BR\left(\mu \to e\gamma\right) = \frac{3}{32}\frac{\alpha}{\pi}\left| C.\,\epsilon_{e\mu} - \sum_i x_{\nu_i}\left(U_{PMNS}\right)_{ei}\left(\left(U_{PMNS}\right)^\dagger\right)_{i\mu} + \mathcal{O}\left(\frac{1}{M_\Sigma^4}\right)\right|^2$$

$$\begin{aligned} BR\left(\mu \to e\gamma\right) < 1.2 \cdot 10^{-11} &\to |\epsilon_{e\mu}| \lesssim 1.1 \cdot 10^{-4} \\ BR\left(\tau \to \mu\gamma\right) < 4.5 \cdot 10^{-8} &\to |\epsilon_{\mu\tau}| \lesssim 1.5 \cdot 10^{-2} \\ BR\left(\tau \to e\gamma\right) < 1.1 \cdot 10^{-7} &\to |\epsilon_{e\tau}| \lesssim 2.4 \cdot 10^{-2} \end{aligned}$$

PDG, Hayasaka et al. [Belle Collaboration]

One loop Vs. tree level LFV

Bounds on the same parameters ϵ coming from tree level LFV processes $\mu \to eee$ and $\tau \to \ell_1 \ell_2 \ell_3$:

$$|\epsilon_{e\mu}| < 1.1 \cdot 10^{-6}, \quad |\epsilon_{\mu\tau}| < 4.9 \cdot 10^{-4}, \quad |\epsilon_{e\tau}| < 5.1 \cdot 10^{-4}$$

Moreover we obtain fixed ratios between the branching ratios :

$$\underbrace{\begin{array}{l} Br(\mu \to e\gamma) \\ Br(\tau \to \mu\gamma) \\ Br(\tau \to e\gamma) \end{array}}_{\text{1-loop}} \begin{array}{c} = \\ = \\ = \end{array} \underbrace{\begin{array}{l} 1.3 \cdot 10^{-3} \cdot Br(\mu \to eee) \\ 1.3 \cdot 10^{-3} \cdot Br(\tau \to \mu\mu\mu) = 2.1 \cdot 10^{-3} \cdot Br(\tau^- \to e^- e^+ \mu^-) \\ 1.3 \cdot 10^{-3} \cdot Br(\tau \to eee) \ = 2.1 \cdot 10^{-3} \cdot Br(\tau^- \to \mu^- \mu^+ e^-) \end{array}}_{\text{Tree level}}$$

One loop Vs. tree level LFV

Using experimental bounds on $\ell \to 3\ell'$ decays (K.Abe et al. [Belle Collaboration]) we get :

$$Br(\mu \to e\gamma) < 10^{-15} \quad (exp. : < 1.2 \cdot 10^{-11})$$

$$Br(\tau \to \mu\gamma) < 4 \cdot 10^{-11} \quad (exp. : < 4.5 \cdot 10^{-8})$$

$$Br(\tau \to e\gamma) < 5 \cdot 10^{-11} \quad (exp. : < 1.1 \cdot 10^{-7})$$

The observation of a leptonic radiative decay rate close to the present bounds would contradict bounds which arise in this model from $l \to 3l$ decays. This would basically rule out the seesaw mechanism with only triplet of fermions, i.e. with no other source of lepton flavour changing processes.

BACKUP

Backup

We integrate out the heavy fields and get :

$$\delta\mathcal{L}^{d=6} = c^{d=6}_{\alpha\beta} \left(\overline{\ell_{L\alpha}}\vec{\tau}\tilde{\phi}\right) i\not{D}\left(\tilde{\phi}^{\dagger}\vec{\tau}\ell_{L\beta}\right)$$

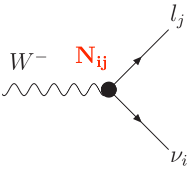
where the $d = 6$ operator coefficients are given in terms of the parameters of the high-energy Seesaw theory by

$$c^{d=6} = Y^{\dagger}_{\Sigma}\frac{1}{M^{\dagger}_{\Sigma}}\frac{1}{M_{\Sigma}}\,Y_{\Sigma}$$

while

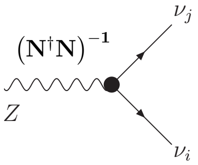
$$\epsilon = \frac{v^2}{2}\,c^{d=6}$$

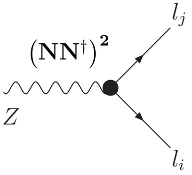
Charged current



$$N \equiv \Omega \, U_L^{l\,\dagger} \left(1 + \frac{\epsilon}{2}\right) \, U_{PMNS}$$

Neutral currents





$$\begin{aligned}
\mathrm{Br}(\mu^- \to e^+ e^- e^-) &\simeq \frac{\Gamma(\mu^- \to e^+ e^- e^-)}{\Gamma(\mu^- \to e^- \nu_\mu \overline{\nu}_e)} \\
&= |[(NN^\dagger)^2]_{e\mu}|^2 \left(3\sin^4\theta_W - 2\sin^2\theta_W + \frac{1}{2}\right) \\
&= 4.|\epsilon_{e\mu}|^2 \left(3\sin^4\theta_W - 2\sin^2\theta_W + \frac{1}{2}\right)
\end{aligned}$$

At order $\mathcal{O}\left(\left(\frac{Y_\Sigma v}{M_\Sigma}\right)^2\right)$,

$$\Gamma\left(\mu\rightarrow e\gamma\right) = \frac{{G_F^{SM}}^2 e^2 m_\mu^5}{8192\pi^5}\left| C.\epsilon_{e\mu} - \sum_i x_{\nu_i}\left(U_{PMNS}\right)_{ei}\left(\left(U_{PMNS}\right)^\dagger\right)_{i\mu} + \sum_i \frac{v^2}{2}\left(Y_\Sigma^\dagger M_\Sigma^{-1}\right)_{ei}\left(M_\Sigma^{-1} Y_\Sigma\right)_{i\mu}\left(A\left(x_{\Sigma_i}\right) + B\left(y_{\Sigma_i}\right) + C\left(z_{\Sigma_i}\right)\right)\right|^2$$

With :

$$A\left(x_{\Sigma_i} = \frac{M_{\Sigma_i}^2}{M_W^2}\right) = \frac{-30 + 153x_{\Sigma_i} - 198x_{\Sigma_i}^2 + 75x_{\Sigma_i}^3 + 18(4-3x_{\Sigma_i})x_{\Sigma_i}^2 \log x_{\Sigma_i}}{3(x_{\Sigma_i}-1)^4}$$

$$B\left(y_{\Sigma_i} = \frac{M_{\Sigma_i}^2}{M_Z^2}\right) = \frac{33 - 18y_{\Sigma_i} - 45y_{\Sigma_i}^2 + 30y_{\Sigma_i}^3 + 18(4-3y_{\Sigma_i})y_{\Sigma_i} \log y_{\Sigma_i}}{3(y_{\Sigma_i}-1)^4}$$

$$C\left(z_{\Sigma_i} = \frac{M_{\Sigma_i}^2}{M_H^2}\right) = \frac{-7 + 12z_{\Sigma_i} + 3z_{\Sigma_i}^2 - 8z_{\Sigma_i}^3 + 6(3z_{\Sigma_i}-2)z_{\Sigma_i} \log z_{\Sigma_i}}{3(z_{\Sigma_i}-1)^4}$$