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Higgs-flavon mixing and $h \to \mu\tau$

Introduction

Lepton Flavour Violating (LFV) processes are absent in the Standard Model (SM):

$$\mathcal{L}_{SM} \supset \frac{v_h}{\sqrt{2}}\, Y_{ij}\, \bar{l}'_{L,i} l'_{R,j}(1+\frac{h}{v_h}) \equiv v_h \bar{l}_L\, Y_{\rm diag}\, l_R + \bar{l}_L\, \frac{Y_{\rm diag}}{\sqrt{2}}\, l_R h$$

Yet, recently the CMS and ATLAS experiments have reported [1, 2, 3]:

$$\mathrm{BR}(h \to \mu\tau) = 0.55^{+0.28}_{-0.28}\ \% \ ,$$

The Froggatt-Nielsen mechanism

This mechanism generates the SM Yukawa interactions through higher dimensional operators consistent with some U(1) symmetry [4]

$$c_{ij}\, \frac{\Phi^{n_{ij}}}{\Lambda^{n_{ij}}} \bar{f}_{L,i} f_{R,j}\ H + \text{h.c.}\ ,$$

where c_{ij} are order one coefficients, Λ is the new physics scale and $f_{L,R}$ are SM fermions. Such operators are obtained by integrating out heavy states at the scale Λ. When Φ develops a VEV,

$$\Phi = \frac{1}{\sqrt{2}}(v_\phi + \phi)$$

with $\phi = \mathrm{Re}\phi + i\mathrm{Im}\phi$, the Yukawa couplings are given by

$$Y_{ij} = c_{ij}\, \left(\frac{v_\phi}{\sqrt{2}\Lambda}\right)^{n_{ij}} \equiv c_{ij}\, \epsilon^{n_{ij}}\ , \quad n_{ij} = -\frac{1}{q_\phi}(q_{\bar{L},i} + q_{R,j} + q_h)$$

Particle	$\bar{f}_{L,i}$	$f_{R,i}$	h	ϕ
$U(1)$ charge	$q_{\bar{L},i}$	$q_{R,i}$	q_h	q_ϕ

This work

As the Higgs field develops a VEV, $H = \begin{pmatrix} 0 \\ \frac{v+h}{\sqrt{2}} \end{pmatrix}$, the effective interaction takes the form

$$\mathcal{L}_{eff} \supset \frac{v}{\sqrt{2}}\, Y_{ij}\, \left(1 + \frac{h}{v} + n_{ij}\, \frac{\phi}{v_\phi}\right) \bar{l}'_{L,i} l'_{R,j}\ .$$

With $Y_{\rm diag} = U_L Y U_R^\dagger$, where $U_{L,R}$ are unitary matrices, we get the following interactions in the mass eigenstate basis:

$$\mathcal{L}_{eff} \supset \bar{l}_L\, \frac{v\, Y_{\rm diag}}{\sqrt{2}}\, l_R + \frac{h}{\sqrt{2}}\, \bar{l}_L\, Y_{\rm diag}\, l_R + \frac{\phi}{\sqrt{2}}\frac{v}{v_\phi}\, \bar{l}_L\, \kappa\, l_R + \text{h.c.},$$

where the flavon vertex involves the matrix

$$\kappa = U_L\, (Y_{ij} n_{ij})\, U_R^\dagger\ ,$$

Setting $q_\Phi = -1,\ q_h = 0$, we have

$$\kappa_{ij} = y_j \sum_{k=1}^{3} q_{\bar{L},k} (U_L)_{ik} (U_L)^*_{jk} + y_i \sum_{k=1}^{3} q_{R,k} (U_R)_{ik} (U_R)^*_{jk}\ ,$$

Upon the Higgs–flavon mixing, such flavor changing couplings also appear in the interactions of the physical Higgs–like boson. The softly broken U(1)–symmetric scalar potential is

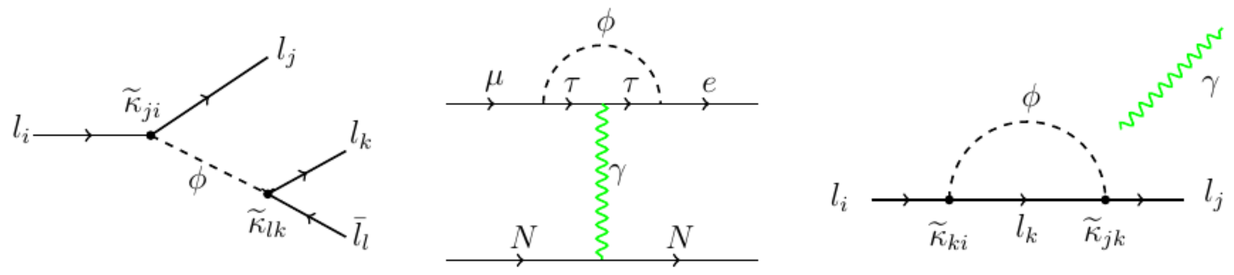
$$V(H,\Phi) = -\mu_h^2 (H^\dagger H) + \lambda_h (H^\dagger H)^2 - \mu_\phi^2 (\Phi^\dagger\Phi) + \lambda_\phi (\Phi^\dagger\Phi)^2 + \lambda_{h\phi} (H^\dagger H)(\Phi^\dagger\Phi) + \tilde{m}^2 \Phi^2 + \text{h.c.}\ ,$$

where

$$\begin{pmatrix} H_1 \\ H_2 \end{pmatrix} \equiv \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} h \\ \mathrm{Re}\phi \end{pmatrix}\ .$$

Bounds on LFV

The flavon interactions induce LFV processes, such as the three–body decay $l_i \to l_j l_k l_l$, magnetic transition $l_i \to l_j \gamma$ and $\mu \to e$ conversion processes which are strongly constrained by experiment.

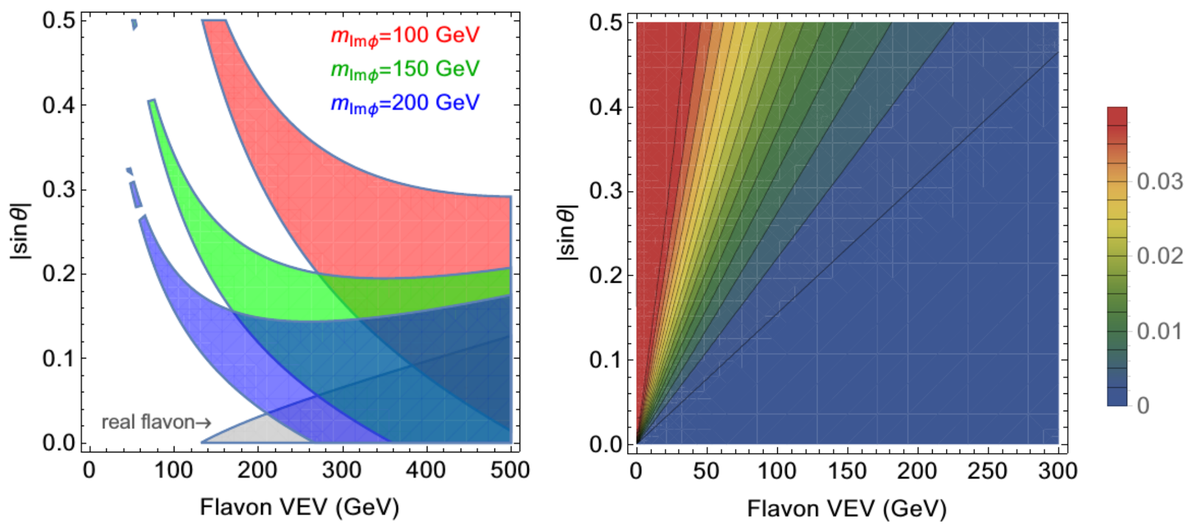


Results

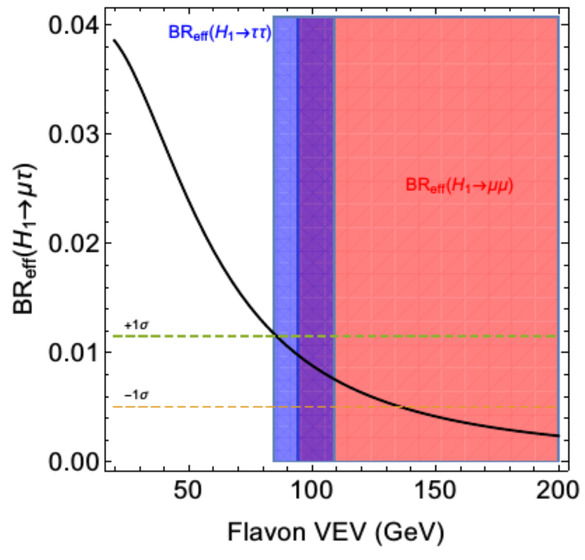
Our Yukawa texture with $\epsilon = 0.1$ is produced using the charges [5]:

Particle	e_L	e_R	μ_L	μ_R	τ_L	τ_R	H	ϕ
Charge	6	0	4	0	2	1	0	-1

For a given m_{H_2} and $m_{\mathrm{Im}\phi}$, the region allowed by LFV constraints is shown on the left below. On the right, $\mathrm{BR}_{\rm eff}(H_1 \to \mu\tau)$ is shown.



We show the $\mathrm{BR}_{\rm eff}(H_1 \to \mu\tau)$ vs v_ϕ (black curve) for $\sin\theta = -0.3$ where the red region is allowed by $\mathrm{BR}_{\rm eff}(H_1 \to \mu\mu)$ and the blue region is allowed by $\mathrm{BR}_{\rm eff}(H_1 \to \tau\tau)$, while their overlap (purple) is consistent with both. The dashed lines show the $\pm 1\sigma$ limits on the observed $\mathrm{BR}_{\rm eff}(H_1 \to \mu\tau)$.



References

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