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

**Introduction**

Lepton Flavour Violating (LFV) processes are absent in the Standard Model (SM):  
\[ \mathcal{L}_{\text{SM}} = \sqrt{2} Y_i \phi L_i \nu R_j (1 + \frac{h}{v}) \equiv v_i L_i Y_{\text{diag}} R_j + i_{\text{diag}} \mathcal{L}_{\phi} \]

Yet, recently the CMS and ATLAS experiments have reported [1, 2, 3]:  
\[ \text{BR}(h \rightarrow \mu\tau) = 0.5 \% \]

**The Froggatt-Nielsen mechanism**

This mechanism generates the SM Yukawa interactions through higher dimensional operators consistent with some U(1) symmetry [4]  
\[ \mathcal{L}_{\phi} = \frac{c_{ij} \phi^R_{i\alpha} f_{Lj} f_{Rj}}{\Lambda} H + \text{h.c.} , \]

where $c_{ij}$ are order one coefficients, $\Lambda$ is the new physics scale and $f_{Lj}$, $f_{Rj}$ are SM fermions. Such operators are obtained by integrating out heavy states at the scale $\Lambda$. When $\Phi$ develops a VEV,  
\[ \phi = \frac{1}{\sqrt{2}} (v \phi + \phi) \]

with $\phi = \text{Re} \phi + i \text{Im} \phi$, the Yukawa couplings are given by  
\[ Y_{ij} = c_{ij} \left( \frac{v \phi}{\sqrt{2} \Lambda} \right)^n \equiv c_{ij} \epsilon^n_{ij} , \quad n_{ij} = -\frac{1}{2} (q_{L,i} + q_{R,j} + q_h) \]

**This work**

As the Higgs field develops a VEV, $H = \begin{pmatrix} 0 & v \phi \\ v \phi & 0 \end{pmatrix}$, the effective interaction takes the form  
\[ \mathcal{L}_{\text{eff}} = \frac{v}{\sqrt{2}} Y_i \phi \frac{1}{\sqrt{2}} i_{Lj} \phi f_{Lj} \]  

With $Y_{\text{diag}} = U_L Y U_R^\dagger$, where $U_{L,R}$ are unitary matrices, we get the following interactions in the mass eigenstate basis:  
\[ \mathcal{L}_{\text{eff}} \supset i_{Lj} \frac{v}{\sqrt{2}} Y_{\text{diag}} \phi f_{Lj} \frac{1}{\sqrt{2}} i_{Lj} \phi f_{Rj} \frac{1}{\sqrt{2}} i_{Lj} \phi f_{Rj} \]  

where the flavon vertex involves the matrix  
\[ \kappa = U_{Lj} (Y_{\text{ij}} q_{\text{ij}}) U_{Rj}^\dagger , \]

Setting $q_0 = -1$, $q_h = 0$, we have  
\[ \kappa_{ij} = y_j \sum_{k=1}^{3} q_{Lk} (U_L)_{ik} (U_L)_{jk}^* + y_j \sum_{k=1}^{3} q_{Rk} (U_R)_{ik} (U_R)_{jk}^* \]

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  
\[ V(H, \Phi) = -\mu^2 (H^2 (H^H)^2 + H^H (H_0^2) + \frac{1}{2} \kappa^2 (\Phi^0 \Phi)^2 + \mu^2 (H^H (H_0^2) + \frac{1}{2} \kappa^2 (\Phi^0 \Phi)^2 \text{h.c.} , \]

where  
\[ H_1 = \left( \begin{array}{c} \cos \theta \\ -\sin \theta \cos \theta \end{array} \right) \]

\[ H_2 = \left( \begin{array}{c} \sin \theta \cos \theta \\ \cos \theta \end{array} \right) \]

\[ \mu \]

**Results**

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

<table>
<thead>
<tr>
<th>Particle</th>
<th>$\epsilon L_i$</th>
<th>$\epsilon R_i$</th>
<th>$h$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U(1)$ charge</td>
<td>$q_{L,i}$</td>
<td>$q_{R,i}$</td>
<td>$q_h$</td>
<td>$q_{\phi}$</td>
</tr>
</tbody>
</table>

For a given $m_{H_1}$ and $m_{H_0}$, the region allowed by LFV constraints is shown on the left below. On the right, BR$_{\text{eff}}(H_1 \rightarrow \mu\tau)$ is shown.

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

**References**