Texturized Two Higgs Doublet Model (2HDM-Tx)

Enrique Díaz

FCFM-BUAP

June 26, 2013

Overview

Motivations for 2HDM

- Simplest Extension of the Standard Model.
- Connected with SUSY.
- Connected with Dark Matter.
- Connected with Flavor.

Versions of 2HDM

THDM-I

The model has the quarks and charged leptons obtain their mass from the VEV of one of the fields ϕ_1.

THDM-II

For this model the mass of the up quarks generated by the VEV of one of the ϕ_1, while the down quarks and the charged leptons are acquired by ϕ_2.

THDM-III

In this model ϕ_1 and ϕ_2 couple to both up and down type quarks and to the charged leptons.

FCNC are kept under control by MFV

Minimal Flavor Violation

$Y_1 \sim Y_2 \sim CKM$

or are absent

Alignment

$Y1 = KY_2$

Textures

Some of the models used so far assume that Y_1, Y_2 have the same form (parallel textures)

- 6-Textures

$$\begin{pmatrix} 0 & D & 0 \\ D^* & C & B \\ 0 & B^* & 0 \end{pmatrix}$$

- 4-Textures

$$\begin{pmatrix} 0 & D & 0 \\ D^* & C & B \\ 0 & B^* & A \end{pmatrix}$$

Our Proposal

Preprint: Marco Arroyo, Lorenzo Diaz-Cruz, Javier Orduz-Docuara. arXiv:1306.2343

Case 1:

$$Y_1 = \begin{pmatrix} 0 & d & 0 \\ d & c & b \\ 0 & b & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a \end{pmatrix};$$

Case 2:

$$Y_1 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & d & 0 \\ d & 0 & b \\ 0 & b & a \end{pmatrix}$$

Case 3:

$$Y_1 = \begin{pmatrix} 0 & d & 0 \\ d & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & c & b \\ 0 & b & a \end{pmatrix};$$

Case 4:

$$Y_1 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & b \\ 0 & b & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & d & 0 \\ d & c & 0 \\ 0 & 0 & a \end{pmatrix}$$

Case 5:

$$Y_1 = \begin{pmatrix} 0 & d & 0 \\ d & c & 0 \\ 0 & 0 & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & b \\ 0 & b & a \end{pmatrix};$$

Case 6:

$$Y_1 = \begin{pmatrix} 0 & d & 0 \\ d & 0 & b \\ 0 & b & 0 \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & a \end{pmatrix}$$

Case 7:

$$Y_1 = \begin{pmatrix} 0 & d & 0 \\ d & c & b \\ 0 & b & a \end{pmatrix}, Y_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a' \end{pmatrix}$$

We have formed "Complementary Textures"

$$Y_1 \sim \begin{pmatrix} X & 0 \\ 0 & 0 \end{pmatrix}, Y_2 \sim \begin{pmatrix} 0 & 0 \\ 0 & X \end{pmatrix}$$

The Yukawa Lagrangian in the THDM-III is given by

$$\begin{aligned}\mathcal{L} &= Y_1^u \overline{Q}_L \Phi_1 u_R + Y_2^u \overline{Q}_L \Phi_2 u_R \\ &+ Y_1^d \overline{Q}_L \Phi_1 d_R + Y_2^d \overline{Q}_L \Phi_2 d_R \\ &+ h.c.\end{aligned}$$

In order to transform to the quark mass eigenstate basis we perform the rotation d= Vd' with $\widetilde{Y}_i = V^\dagger Y_i V$.

$$\begin{aligned}
\mathcal{L}_N^d &= \overline{d'}\frac{1}{2}\left[\left(\widetilde{Y}_2^d \cos\alpha - \widetilde{Y}_1^d \sin\alpha\right) h^0\right. \\
&+ \left.\left(\widetilde{Y}_2^d \sin\alpha + \widetilde{Y}_1^d \cos\alpha\right) H^0\right] d' \\
&+ \frac{i}{2}\overline{d'}\left[\left(\widetilde{Y}_2^d \cos\beta - \widetilde{Y}_1^d \sin\beta\right) A^0\right]\gamma^5 d'
\end{aligned}$$

where the components of Y_1 and Y_2 are given by $\widetilde{Y}_{ij} = \frac{\sqrt{m_i m_j}}{\nu}\chi_{ij}$.

Using a more compact notation

$$\mathcal{L}_N^d = \left(g\frac{\sqrt{m_i m_j}}{\sqrt{2}M_W}\right)\overline{d_i'}\left[\left(\eta^{(1)}\right)_{ij} h^o + \left(\eta^{(2)}\right)_{ij} H^0 + i\left(\eta^{(3)}\right)_{ij} A^0\gamma^5\right] d_j'$$

where the η factors are defined as follows

$$\eta_{ij}^{(n)} = \chi_{ij}^{(1)} f_n(\alpha,\beta) + \chi_{ij}^{(2)} g_n(\alpha,\beta)$$

where

$$f_1(\alpha,\beta) = -\frac{\sin\alpha}{\cos\beta}, \qquad g_1(\alpha,\beta) = \frac{\cos\alpha}{\sin\beta},$$
$$f_2(\alpha,\beta) = \frac{\cos\alpha}{\cos\beta}, \qquad g_2(\alpha,\beta) = \frac{\sin\alpha}{\sin\beta},$$
$$f_3(\alpha,\beta) = -\tan\beta \qquad g_3(\alpha,\beta) = \cot\beta.$$

Low-Energy Constraints

- $K - \bar{K}$ mixing
- $B \longrightarrow \mu\mu$
- $\tau \longrightarrow \mu\bar{\mu}\mu$

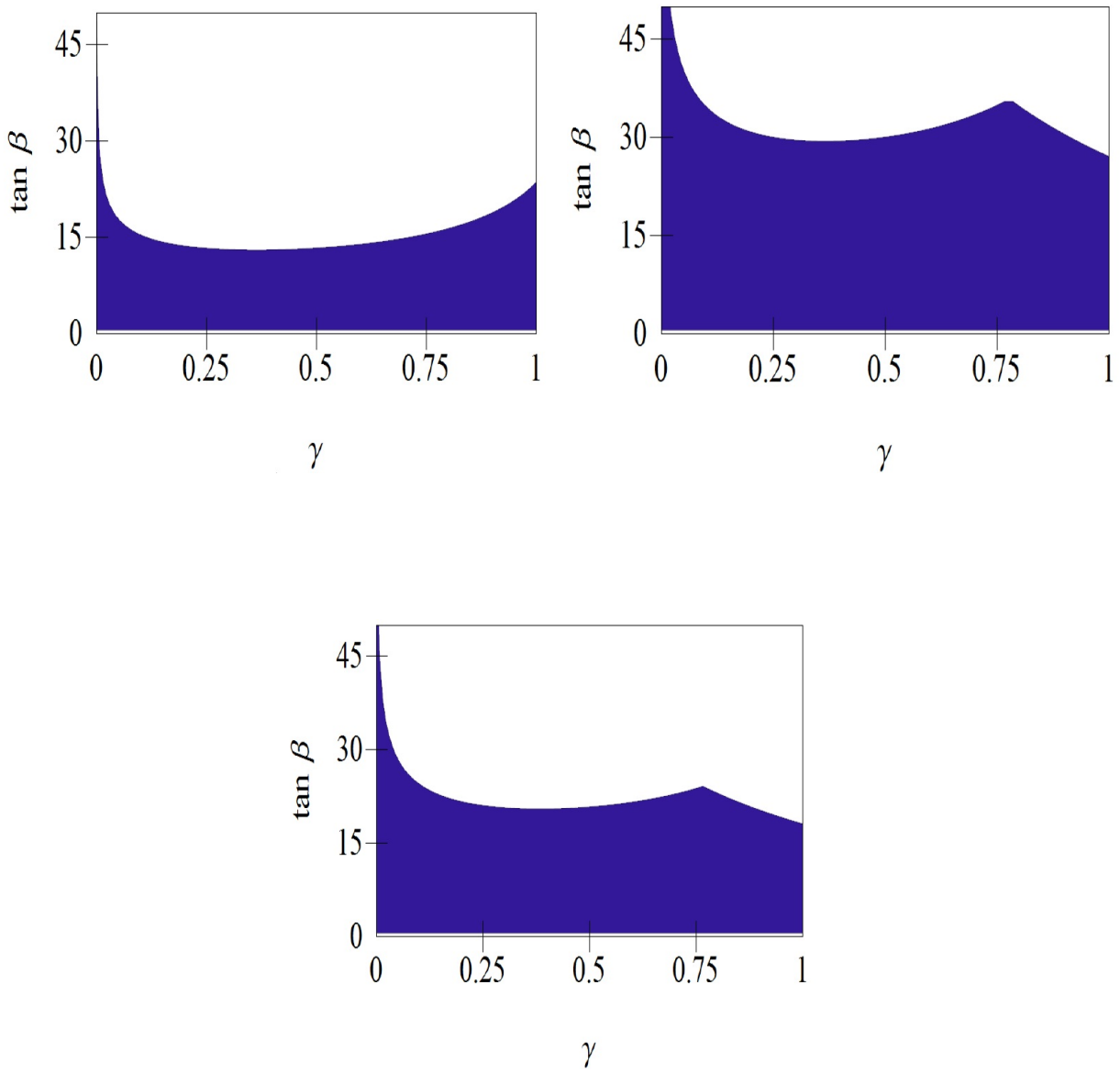

Figure: Allowed regions (blue) for Case 1.

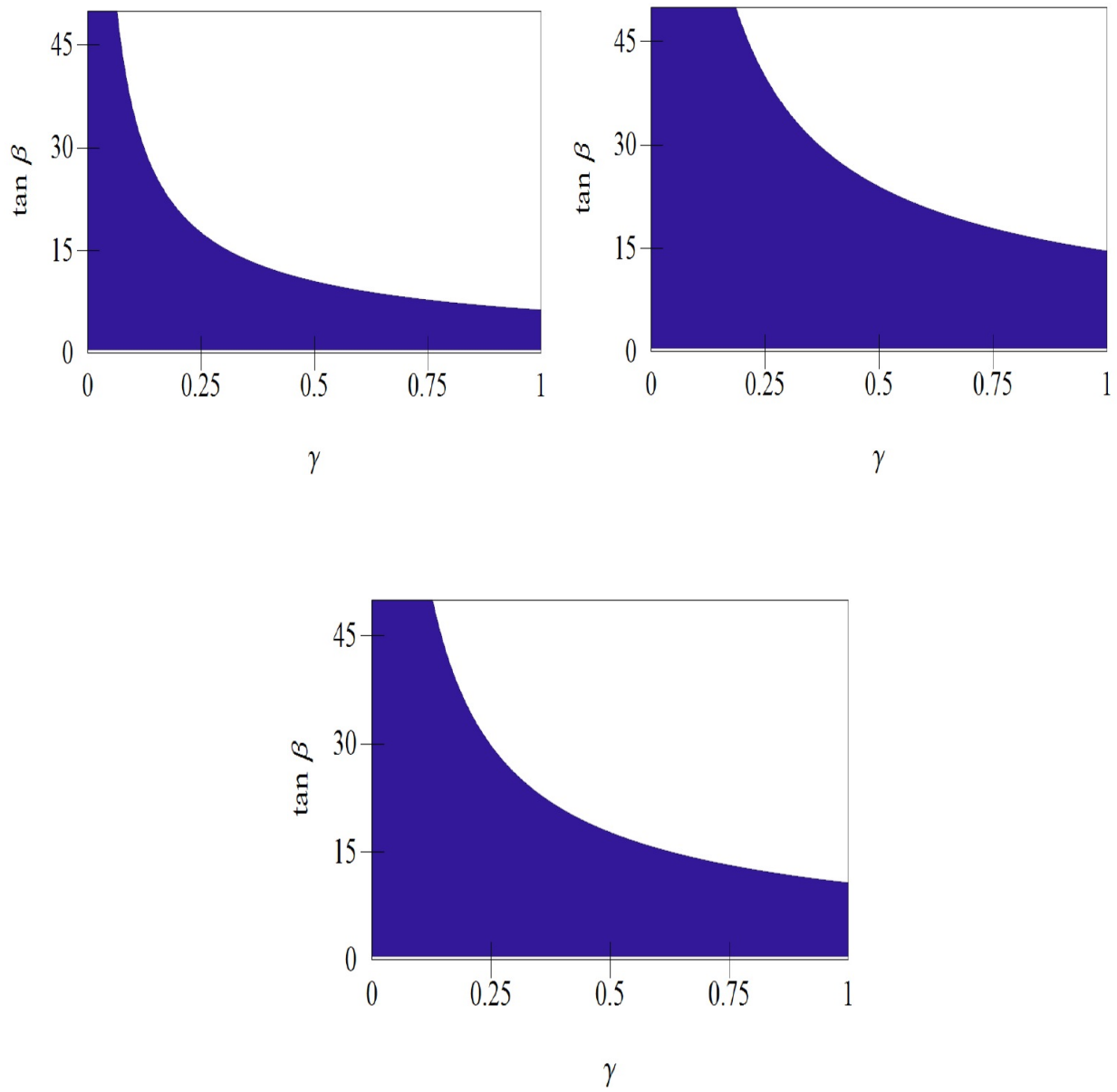

Figure: Allowed regions (blue) for Case 6.

LHC Higgs Constraints

Within the so called Narrow-width approximation, we can write the expression for R_{XX} as follows:

$$R_{XX} = \frac{\Gamma(h_1 \to gg)}{\Gamma(\phi_{sm} \to gg)} \frac{BR(h_1^0 \to XX)}{BR(\phi_{sm} \to XX)} \qquad (1)$$

we looked at the values of parameters that are consistent with both LHC Higgs data $R_{\gamma\gamma} = 1.56 \pm 0.43$ and $R_{ZZ} = 0.8^{+0.35}_{-0.28}$.

Predictions: $h \longrightarrow \tau\mu$ and $t \longrightarrow ch$

Cases	$h \longrightarrow \tau\mu$	$t \longrightarrow ch$
Case 1	8.1×10^{-3}	2.2×10^{-1}
Case 2	2.2×10^{-7}	1.6×10^{-7}
Case 3	6.7×10^{-6}	5.3×10^{-6}
Case 4	7.5×10^{-3}	4.4×10^{-1}
Case 5	4.2×10^{-5}	1.5×10^{-4}
Case 6	1.2×10^{-3}	5.4×10^{-2}
Case 7	5.0×10^{-4}	5.2×10^{-4}

Table: Sample of Branching ratios for our different Cases.

Conclusions

$\Rightarrow$ We find that current low energy constraints and LHC Higgs constraints are consistent with our model.

$\Rightarrow$ Our model is dependent on two free parameters: γ and $\tan\beta$ where $O < \gamma < 1$ and $tan\beta < 6$ from the Low energy constraints and LHC Higgs Constraints.

$\Rightarrow$ In each of our cases we are able to obtain predictions for $h \longrightarrow \tau\mu$ and $t \longrightarrow ch$.

Thank You