Texturized Two Higgs Doublet Model (2HDM-Tx)

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2HDM-Tx

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solutions to FCNC or THDM type III

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Simplest Extension of the Standard Model.

- Connected with SUSY.
- Connected with Dark Matter.
- Connected with Flavor.

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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.

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FCNC are kept under control by MFV

Minimal Flavor Violation

 $Y_1 \sim Y_2 \sim CKM$

or are absent

Alignment

 $Y1 = KY_2$

Solutions to ECNC

for THDM type III

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

6-Textures

$$\left(\begin{array}{ccc}
0 & D & 0 \\
D^* & C & B \\
0 & B^* & 0
\end{array}\right)$$

4-Textures

$$\left(\begin{array}{ccc}
0 & D & 0 \\
D^* & C & B \\
0 & B^* & A
\end{array}\right)$$

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

Case 1:

$$Y_1 = \left(\begin{array}{ccc} 0 & d & 0 \\ d & c & b \\ 0 & b & 0 \end{array}\right), Y_2 = \left(\begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a \end{array}\right);$$

Case 2:

$$Y_1 = \left(egin{array}{ccc} 0 & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & 0 \end{array}
ight), Y_2 = \left(egin{array}{ccc} 0 & d & 0 \\ d & 0 & b \\ 0 & b & a \end{array}
ight)$$

Case 3:

$$Y_1 = \left(\begin{array}{ccc} 0 & d & 0 \\ d & 0 & 0 \\ 0 & 0 & 0 \end{array}\right), Y_2 = \left(\begin{array}{ccc} 0 & 0 & 0 \\ 0 & c & b \\ 0 & b & a \end{array}\right);$$

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 $Y_1 = \left(\begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & b \\ 0 & b & 0 \end{array}\right), Y_2 = \left(\begin{array}{ccc} 0 & d & 0 \\ d & c & 0 \\ 0 & 0 & c \end{array}\right)$

Case 5:

$$Y_1 = \left(\begin{array}{ccc} 0 & d & 0 \\ d & c & 0 \\ 0 & 0 & 0 \end{array}\right), Y_2 = \left(\begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & b \\ 0 & b & a \end{array}\right);$$

Case 6:

$$Y_1 = \left(egin{array}{ccc} 0 & d & 0 \\ d & 0 & b \\ 0 & b & 0 \end{array}
ight), Y_2 = \left(egin{array}{ccc} 0 & 0 & 0 \\ 0 & c & 0 \\ 0 & 0 & a \end{array}
ight)$$

Case 7:

$$Y_1 = \left(\begin{array}{ccc} 0 & d & 0 \\ d & c & b \\ 0 & b & a \end{array}\right), Y_2 = \left(\begin{array}{ccc} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a' \end{array}\right)$$

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We have formed "Complementary Textures"

$$Y_1 \sim \left(\begin{array}{cc} X & 0 \\ 0 & 0 \end{array} \right), Y_2 \sim \left(\begin{array}{cc} 0 & 0 \\ 0 & X \end{array} \right)$$

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The Yukawa Lagrangian in the THDM-III is given by

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

Lagrangian

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

$$\mathcal{L}_{N}^{d} = \overline{d'} \frac{1}{2} \left[\left(\widetilde{Y}_{2}^{d} \cos \alpha - \widetilde{Y}_{1}^{d} \sin \alpha \right) h^{0} + \left(\widetilde{Y}_{2}^{d} \sin \alpha + \widetilde{Y}_{1}^{d} \cos \alpha \right) H^{0} \right] d' + \frac{i}{2} \overline{d'} \left[\left(\widetilde{Y}_{2}^{d} \cos \beta - \widetilde{Y}_{1}^{d} \sin \beta \right) A^{0} \right] \gamma^{5} d'$$

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

Using a more compact notation

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 $\mathcal{L}_{N}^{d} = \left(g\frac{\sqrt{m_{i}m_{j}}}{\sqrt{2}M_{\text{MA}}}\right)\overline{d_{i}^{\prime}}\left[\left(\eta^{(1)}\right)_{ij}h^{o} + \left(\eta^{(2)}\right)_{ij}H^{0} + i\left(\eta^{(3)}\right)_{ij}A^{0}\gamma^{5}\right] d_{j}^{\prime \text{S of 2HDM}}$

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

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

Lagrangian

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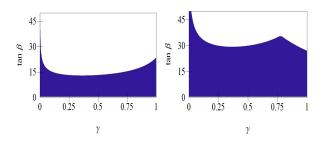
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- $ightharpoonup K \bar{K}$ mixing
- $ightharpoonup B
 ightarrow \mu \mu$
- $ightharpoonup au
 ightharpoonup \mu ar{\mu} \mu$



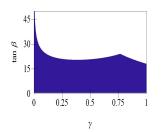


Figure: Allowed regions (blue) for Case 1.

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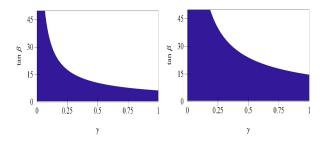
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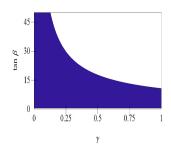


Figure: Allowed regions (blue) for Case 6.

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

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

we looked at the values of parameters that are consistent with both LHC Higgs data $R_{\gamma\gamma}=1.56\pm0.43$ and $R_{ZZ}=0.8^{+0.35}_{-0.28}$.

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

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

Table: Sample of Branching ratios for our different Cases.

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4 D > 4 P > 4 E > 4 E > 9 Q P

⇒ 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 β where $O < \gamma < 1$ and $tan\beta < 6$ from the Low energy constraints and LHC Higgs Constraints.

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

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Thank You