«Additional Symmetries in 2HDM-III as a tool for the search of New Physics effects»

Pseudoscalar in the phenomenology of B

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Plan

Symmetries

- Flavor Symmetries (Family)
- Generalized CP Conservation

2HDM

- Version III as a tool
- $SU(3)$ Yukawa Matrices

Phenomenology of U-Spin case

- τ decays
- B meson decay

Flavor problem

- 3 Families
- Hierachy of fermions mixings
- Origin of masses
- Hierarchy of masses

Dark matter is the key to solve this problem

Yukawa sector for Multi-Higgs Models

$$\mathcal{L}_Y = -\sqrt{N}\bar{f}_{Li}\left[\frac{\delta_{ij}m_j^f}{v_0}\phi_0^0 + \sum_{a=1}^{N}\left(\frac{v_a}{v_0}e^{i\alpha_a}\phi_0^0 + \phi_a\right)\tilde{y}_{a,ij}^f\right]f_{Rj}$$

We consider transformations of the form

$$\begin{aligned} f'_{Li} &= e^{i\theta_{Li}}f_{Li} \\ f'_{Ri} &= e^{i\theta_{Ri}}f_{Ri} \\ \phi'_a &= S_{ab}\phi_b \end{aligned}$$

Invariance is reached when

$$y'^f_{a,ij} = e^{-i(\theta_{iL}-\theta_{iR})}S_{ab}^{-1}y_{b,ij}^f$$

FCNC at tree level is the main signature of non-standard scalar interactions

Yukawa Sector with 2 Doublets

$$\mathcal{L}_Y^{2HDM} = -\overline{Q}_L \sum_{a=1}^{2} (Y_a^d \Phi_a d_R + Y_a^u \tilde{\Phi}_a u_R) - \overline{L}_L \sum_{a=1}^{2} Y_a^l \Phi_a l_R + h.c.$$

$$\Phi_a = \left(\begin{array}{c} \varphi_a^+ \\ \varphi_a^0 e^{i\theta_a} \end{array} \right) ; \; \varphi_a^0 = v_a + \frac{\rho_a + i\eta_a}{\sqrt{2}} \; ; \; a = 1, 2$$

Mass Matrices

$$M_f = \frac{1}{\sqrt{2}} (v_1 Y_1^f + v_2 Y_2^f) \quad ; \quad f = u, d, l$$

- Same symmetries as SM
- 4 NEW scalars : H^0, $H^\pm$ and A^0
- New sources of CP violation (θ_a and phases in $Y_a^{u,d,l}$)
- FCNC at tree level

Versión III: Motivations

- Effective couplings at 1−loop level in SUSY models contains FCNC: decoupling limit scenario at low energies
- Minimal framework to parameterized flavor physics: a few free parameters
- Versions with NFC can no explain simultaneously: $B \to D\tau\nu$, $B \to D^*\tau\nu$ y $B \to \tau\nu$
- Analysis with non correlated V_{CKM} elements leads to: $(\chi^f_{ij} \lesssim 10^{-3})$

At the Higgs basis

$$\mathcal{L}_Y = \eta^u \bar{Q}_L \tilde{H}_1 u_R + \eta^d \bar{Q}_L H_1 d_R + \eta^\ell \bar{L}_L H_1 \ell_R$$
$$+ \hat{Y}^u \bar{Q}_L \tilde{H}_2 u_R + \hat{Y}^d \bar{Q}_L H_2 d_R + \hat{Y}^\ell$$

FCNC Suppression

- "Non elegant"way: $m_{H,A} \sim \mathcal{O}(10^3\text{TeV})$

$$g_{Sff} \sim 1/m_S^2$$

- Alignment:

$$Y_2^f = \gamma^f Y_1^f \text{ con } \gamma^f \in \mathbb{C}$$

- Textures compatible with V_{CKM}:

$$M_f = \begin{pmatrix} 0 & C_f & 0 \\ C_f^* & D_f & B_f \\ 0 & B_f^* & A_f \end{pmatrix}$$

where $|C^f| << |B^f| << |D^f| << |A^f|$

Partially aligment of the 2HDM

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Same texture, different scale: for 4-zeros

$$Y_2^f = \begin{pmatrix} 0 & c_2 C_f & 0 \\ c_2^* C_f^* & d_2 D_f & b_2 B_f \\ 0 & b_2^* B_f^* & A_f \end{pmatrix}$$

$$\tilde{\chi}_{ij}^f = \tilde{\chi}_{ij}^f (b_2, c_2, d_2, a_2, \phi_C, \phi_B)$$

Bilinear flavor transformations

$$Y^f = a' \cdot A_L M_{f'} A_R$$

where

$$|m_{f1}(\widetilde{A}_L^f)_{i1}(\widetilde{A}_R^f)_{1j} + m_{f2}(\widetilde{A}_L^f)_{i2}(\widetilde{A}_R^f)_{2j} + m_{f1}(\widetilde{A}_L^f)_{i3}(\widetilde{A}_R^f)_{3j}| \leq \sqrt{m_{fi} m_{fj}} |\widetilde{\chi}_{ij}^f|$$

Bilinear flavor transformations

$$\boxed{Y^f = a' \cdot A_L M^{f'} A_R}$$

- Less restrictive than direct alignment (FCFN y LFV)
- Works for Multihiggs models
- Starting point for flavor symmetries
- Suitable scenarios reproduce previous versions

Versión	A_L^u	A_R^u	A_L^d	A_R^d
I	$\sqrt{\frac{3M_W}{v}}\lambda_0$	$\sqrt{\frac{3M_W}{v}}\lambda_0$	$\sqrt{\frac{3M_W}{v}}\lambda_0$	$\sqrt{\frac{3M_W}{v}}\lambda_0$
II	$\sqrt{\frac{3M_W}{v}}\lambda_0$	$\sqrt{\frac{3M_W}{v}}\lambda_0$	$0_{3\times 3}$	$0_{3\times 3}$
III	$\sum_{a=0,3,8} C_a^u \lambda_a$	$(\sum_{a=0,3,8} C_a^u \lambda_a)^\dagger$	$\sum_{a=0,3,8} C_a^d \lambda_a$	$(\sum_{a=0,3,8} C_a^u \lambda_a)^\dagger$
A2HDM	$C_0^u \lambda_0$	$\widetilde{C}_0^{u*} \lambda_0$	$C_0^d \lambda_0$	$\widetilde{C}_0^{d*} \lambda_0$

Unitary Transformations $A_L^\dagger = A_R = U \in SU(3)$

$$Y_f = a' U^\dagger M_f U$$

$$U = \sum_a C_a \lambda_a \qquad ; \qquad C_{ab} \equiv C_a^* \cdot C_b$$

- Hermitian case: $C_{ab} = C_{ba}^*$.
- Phenomenology is given by

$$\mathrm{Tr}(\lambda_a Y^f \lambda_b) = \sum_{c,d} C_{cd} \mathrm{Tr}(\lambda_a \lambda_c M_f \lambda_d \lambda_b)$$

- Textures is preserved when U only have λ_3, λ_8 contributions.

Generalized CP symmetries

- On scalars
  - Family symmetries for Higgs doublets

$$\Phi_a \to S_{ab}(\theta)\Phi_b$$

  - Generalized Symmetries

$$\Phi_a \to X_{ab}\Phi_b^*$$

S_{ab} and X_{ab} are $SU(2)$ matrices

- $SU(3)$ Fermion symmetries (*Isospin*)

$$\begin{aligned} Q_L &\to X_\alpha \gamma^0 C Q_l^* \\ u_L &\to X_\beta \gamma^0 C u_l^* \\ d_L &\to X_\gamma \gamma^0 C d_l^* \end{aligned}$$

Restricctions on Yukawa matrices

GCP symmetries

$$\begin{aligned} X_\alpha Y_1^{*f} - (\cos\theta Y_1^f - \sin\theta Y_2^f) X_\beta &= 0 \\ X_\alpha Y_2^{*f} - (\sin\theta Y_1^f + \cos\theta Y_2^f) X_\beta &= 0 \end{aligned}$$

For $\boxed{0 < \theta < \frac{\pi}{2}}$

$$Y_1^f = \begin{pmatrix} ia_{11} & ia_{12} & a_{13} \\ ia_{12} & -ia_{11} & a_{23} \\ a_{31} & ia_{32} & 0 \end{pmatrix} \quad ; \quad Y_2^f = \begin{pmatrix} ia_{12} & -ia_{11} & -a_{13} \\ -ia_{11} & -ia_{12} & a_{13} \\ -a_{31} & a_{31} & 0 \end{pmatrix}$$

At the mass basis and Higgs basis

$$H^d = \frac{v^2}{2} Y_1^f (Y_1^f)^\dagger = U_L^f \left[\mathrm{diag}(m_1^f, m_2^f, m_3^f)\right] U_L^{f\dagger}$$

Using mass matrix

$$Y_2^f = \frac{1}{v_2}\left(\sqrt{2} M^f - v_1 Y_1^f\right)$$

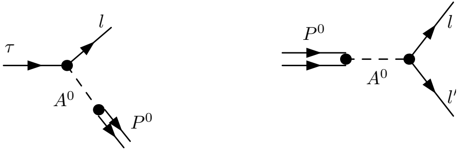
Invariant subgroups of $SU(3)$

$$U_L^f = a_0\lambda_0 + \mathrm{Re}(A_X)\lambda_i + \mathrm{Im}(A_X)\lambda_j + B_X\lambda_k$$

Subgroup	Generators	U_{XL}^f
Isospin	$\lambda_1, \lambda_2, \lambda_3$	$\begin{pmatrix} a_0+B_S & A_S^* & 0 \\ A_S & a_0-B_S & 0 \\ 0 & 0 & a_0 \end{pmatrix}$
U-Spin	$\lambda_4, \lambda_5, \frac{1}{4}(\sqrt{3}\lambda_3+\lambda_8)$	$\begin{pmatrix} a_0+B_U & 0 & A_U^* \\ 0 & a_0 & 0 \\ A_U & 0 & a_0-B_U \end{pmatrix}$
V-Spin	$\lambda_6, \lambda_7, \frac{1}{4}(\sqrt{3}\lambda_3-\lambda_8)$	$\begin{pmatrix} a_0 & 0 & 0 \\ 0 & a_0+B_V & A_V^* \\ 0 & A_V & a_0-B_V \end{pmatrix}$

$$\begin{aligned}
\tilde{Y}_{X2}^d &= (\sqrt{2}G_F)^{\frac{1}{2}} U_{XL}^d D^d U_{XL}^{d\dagger} \\
\tilde{Y}_{X2}^u &= (\sqrt{2}G_F)^{\frac{1}{2}} U_{XL}^d V_{\mathrm{CKM}}^\dagger D^u V_{\mathrm{CKM}} U_{XL}^{d\dagger} \\
\tilde{Y}_{X'2}^\ell &= (\sqrt{2}G_F)^{\frac{1}{2}} U_{X'L}^{\ell\dagger} D^\ell U_{X'L}^\ell
\end{aligned}$$

2HDM with CP conservation



(a) (b)

- Free parameters: M_A, $\tan\beta$, a_0 , A_X y B_X

$$-\mathcal{L}_{\rm eff}^{XX'} = \sqrt{2}G_F \frac{M_W^2}{M_{A^0}^2} g^X_{A^0\ell_i\ell_j} \left(\bar{\ell}_i\gamma^5\ell_j\right)\left[\sum_{q_n,q_m} g^{X'}_{A^0 q_m q_n}\bar{q}_n\gamma^5 q_m\right]$$

$$\begin{aligned}
g^X_{A^0\ell_i\ell_j} &= \frac{1}{M_W}\left[-m_i\tan\beta\delta_{ij} + \frac{1}{\sqrt{2}\cos\beta}\left(U^{\ell\dagger}_{X\,L} D^d U^{\ell}_{X\,L}\right)_{ij}\right]\\
g^X_{A^0 d_i d_j} &= \frac{1}{M_W}\left[-m_{d_i}\tan\beta\delta_{ij} + \frac{1}{\sqrt{2}\cos\beta}\left(U^{d\dagger}_{X\,L} D^d U^{\ell}_{X\,L}\right)_{ij}\right]\\
g^X_{A^0 u_i u_j} &= \frac{1}{M_W}\left[-m_i\cot\beta\delta_{ij} + \frac{1}{\sqrt{2}\sin\beta}\left(U^{d}_{X\,L} V^\dagger_{\rm CKM} D^u V_{\rm CKM} U^{d\dagger}_{X\,L}\right)_{ij}\right].
\end{aligned}$$

B mixing as a bound for M_A

$$\mathcal{H}_{A^0} = \sqrt{2} G_F \frac{m_W^2}{M_{A^0}^2} |g_{Asb}|^2 (\bar{q}_s \gamma^5 q_b)(\bar{q}_b \gamma^5 q_s)$$

$$g_{Asb} = \frac{i}{2\sqrt{2}\cos\beta} \frac{\sqrt{m_s m_b}}{m_W} \tilde{\chi}_{ij}^d$$

$$\Delta m_s \simeq \frac{2}{m_{B_s^0}} \left(\langle B_s^0 | \mathcal{H}_{\rm SM} | \bar{B}_s^0 \rangle + \langle B_s^0 | \mathcal{H}_{A^0} | \bar{B}_s^0 \rangle \right)$$

Taking only the pseudoscalar contribution

$$\langle B_s^0 | \mathcal{H}_{A^0} | \bar{B}_s^0 \rangle = \sqrt{2} G_F \frac{m_W^2}{M_{A^0}^2} |g_{Asb}|^2 \frac{|f_{B_s}|^2 m_{B_s^0}^4}{(m_b + m_s)^2}$$

That can be explicitly cast in the form

$$\Delta m_s \simeq \Delta m_s^{\rm SM} + \left(9.6030 \times 10^{-7} {\rm GeV}^3\right) \frac{|\chi_{sb}^d|^2}{M_{A^0}^2} (1 + \tan^2\beta)$$

Minimizing the function with non correlated CKM matrix elements

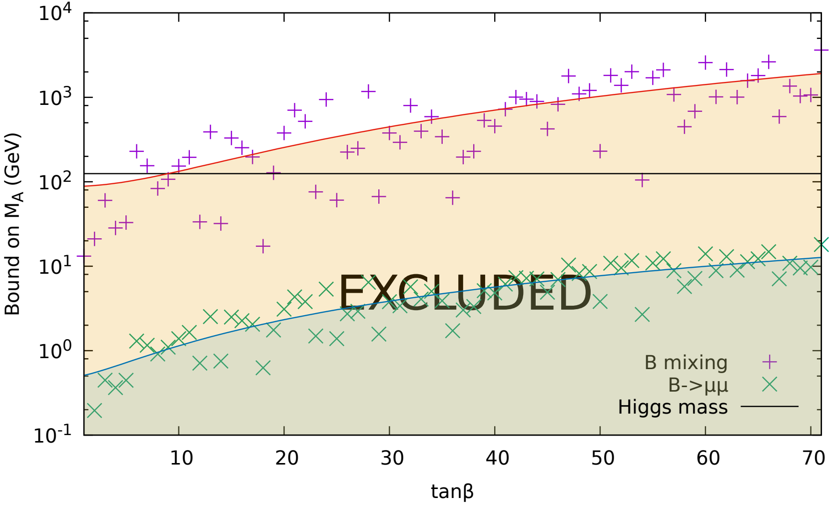
$$\chi^2 = \sum_{i=d,s,b} \frac{\left(\left|V_{ui}^{th}(\chi_{ij})\right| - |V_{ui}^{ex}|\right)^2}{\sigma_{V_{ui}}^2} + \frac{\left(\left|V_{cb}^{th}(\chi_{ij})\right| - |V_{cb}^{ex}|\right)^2}{\sigma_{V_{cb}}^2},$$

O. Félix-Beltrán, et.al. , Phys. Lett. B742, 347 (2015)

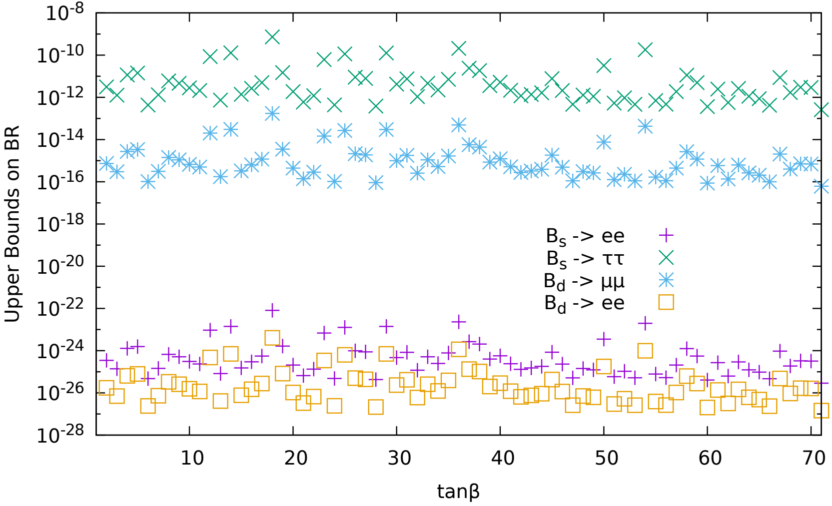
$$|V_{ud}^{ex}| = 0.97425 \pm 0.00022, \quad |V_{us}^{ex}| = 0.22523 \pm 0.00080,$$
$$|V_{ub}^{ex}| = 0.00413 \pm 0.00049, \quad |V_{cb}^{ex}| = 0.0411 \pm 0.00130.$$

With this calculation 2HDM-III is as predictive as versions with NFC

Lower Bound on M_A^0



Upper Bounds on FCNC in B decays



LFV in τ decays

$$\Gamma_{XX'}(\tau \to \ell P^0) = \frac{G_F^2}{8\pi}\left(\frac{M_W}{M_{A^0}}\right)^4 \left[(m_\tau - m_\ell)^2 - m_P^2\right] \frac{\lambda^{1/2}(m_\tau^2, m_\ell^2, m_P^2)}{m_\tau^3} \times |g^X_{A^0\tau\ell}|^2 \left|\langle P| \sum_{q_i,q_j} (g^{X'}_{A^0 q_i q_j})\bar{q}_i\gamma^5 q_j|0\rangle\right|^2$$

Channel	Upper bound [PDG]	$\frac{\lvert g^X_{A^0\tau\ell}\rvert}{M_A^2}\left\lvert\langle P\rvert \sum_{q_i,q_j}(g^{X'}_{A^0 q_i q_j})\bar{q}_i\gamma^5 q_j\lvert 0\rangle\right\rvert$
$\tau \to e^-\pi^0$	$< 8.0 \times 10^{-8}$	$< 2.13 \times 10^{-8}$
$\tau \to \mu^-\pi^0$	$< 1.1 \times 10^{-7}$	$< 2.67 \times 10^{-8}$
$\tau \to e^- K_s^0$	$< 2.6 \times 10^{-8}$	$< 1.31 \times 10^{-8}$
$\tau \to \mu^- K_s^0$	$< 2.3 \times 10^{-8}$	$< 1.32 \times 10^{-8}$
$\tau \to e^-\eta$	$< 9.2 \times 10^{-8}$	$< 2.52 \times 10^{-8}$
$\tau \to \mu^-\eta$	$< 6.5 \times 10^{-8}$	$< 2.27 \times 10^{-8}$
$\tau \to e^-\eta'$	$< 1.6 \times 10^{-7}$	$< 4.24 \times 10^{-8}$
$\tau \to \mu^-\eta'$	$< 1.3 \times 10^{-8}$	$< 1.32 \times 10^{-8}$

Pseudoscalars meson decays

$$\Gamma_{XX'}(P^0 \to \ell\ell) = \frac{G_F^2}{8\pi}\left(\frac{M_W}{M_{A^0}}\right)^4 \left[m_P^2 - (m_\ell - m_\ell)^2\right] \frac{\lambda^{1/2}(m_P^2, m_\ell^2, m_\ell^2)}{m_P^3} \times |g^X_{A^0\ell\ell}|^2 \left|\langle P|(g^{X'}_{A^0 q_i q_j})\bar{q}_i\gamma^5 q_j|0\rangle\right|^2$$

Channel	Upper Bound [PDG 2014]	$\frac{\lvert g^X_{A^0\ell\ell}\rvert}{M_A^2}\left\lvert\langle P\rvert(g^{X'}_{A^0 q_i q_j})\bar{q}_i\gamma^5 q_j\lvert 0\rangle\right\rvert$
$B_d^0 \to e^- e^+$	$< 8.3 \times 10^{-8}$	$< 9.7 \times 10^{-10}$
$B_d^0 \to \mu^- \mu^+$	$< 6.3 \times 10^{-10}$	$< 3.12 \times 10^{-9}$
$B_s^0 \to \tau^- \tau^+$	$< 4.1 \times 10^{-3}$	$< 2.20 \times 10^{-7}$
$B_s^0 \to e^- e^+$	$< 2.8 \times 10^{-7}$	$< 1.32 \times 10^{-10}$
$D^0 \to e^- e^+$	$< 7.9 \times 10^{-8}$	$< 2.52 \times 10^{-8}$
$D^0 \to \mu^- \mu^+$	$< 6.2 \times 10^{-9}$	$< 2.27 \times 10^{-7}$
$B_s^0 \to \mu^- \mu^+$	$= (3.1 \pm 0.7) \times 10^{-9}$	Compatible with SM

Isospin subgroup

$$Y_U^f = \begin{pmatrix} * & * & 0 \\ * & * & 0 \\ 0 & 0 & * \end{pmatrix} \qquad ; \qquad f = d, \ell$$

Couplings: $g^S_{A^0 \tau e} = 0,\ g^S_{A^0 \tau \mu} = 0$

$$g^S_{A^0 uu} = \frac{m_t}{\sqrt{2} M_W \sin\beta} \Big\{ (a^d_{S0})^2 V^2_{ub} + \Big[\Big(V_{ud}(a^d_{S0} + B^u_S) + V_{us} \Big) \Big(V_{ud}(a^d_{s0} + B^d_S) + V_{us} A^{d*}_S \Big) \Big] \Big($$

$$+ \Big(V_{us}(a^d_{s0} - B^d_S) + V_{ud} A^d_S \Big)^2 \left(\frac{m_c}{m_t} \right) \Big\}$$

$$g^S_{A^0 dd} = \frac{m_s}{\sqrt{2} M_W \cos\beta} \left[|A^d_S|^2 + \Big((a^d_{S0} + B^d_S)^2 - \sqrt{2} \sin\beta \Big) \left(\frac{m_d}{m_s} \right) \right]$$

$$g^S_{A^0 ss} = \frac{m_s}{\sqrt{2} M_W \cos\beta} \left[(a^d_{S0} - B^d_S)^2 - \sqrt{2} \sin\beta + |A^d_S|^2 \left(\frac{m_d}{m_s} \right) \right] .$$

$$g^S_{A^0 uc} = \frac{m_t}{\sqrt{2} M_W \sin\beta} \Big\{ (a^d_{S0})^2 V_{ub} V_{sb} + \Big(V_{us}(a^d_{s0} - B^d_S) + V_{ud} A^d_S \Big) \left(\frac{m_c}{m_t} \right)$$

$$+ \Big(V_{ud}(a^d_{S0} + B^d_S) + V_{us} A^d_S \Big) \Big(V_{cd}(a^d_0 + B^d_S) + V_{cs} A^{u*}_S \Big) \left(\frac{m_u}{m_t} \right) \Big\}$$

$$g^S_{A^0 sd} = \frac{m_s}{\sqrt{2} M_W \cos\beta} \left[A^d_S (a^d_{S0} - B^d_S) + (a^d_{S0} + B^d_S) A^{d*}_S \left(\frac{m_d}{m_s} \right) \right] .$$

U-Spin Subgroup

$$Y_U^f = \begin{pmatrix} * & 0 & * \\ 0 & * & 0 \\ * & 0 & * \end{pmatrix} \qquad ; \qquad f = d, \ell$$

Couplings: $g_{A^0\tau\mu} = 0$

$$g_{A^0\tau e} = \frac{m_\tau}{\sqrt{2} M_W \cos\beta} \left[A_U^\ell (a_{U0}^\ell - B_U^\ell) + (a_{S0}^\ell + B_U^\ell) A_U^{\ell *} \left(\frac{m_e}{m_\tau} \right) \right]$$

$$g^U_{A^0 uu} = \frac{m_t}{\sqrt{2} M_W \sin\beta} \left\{ \left[V_{ub}(a_{U0}^d - B_U^d) + A_U^d V_{ud} \right]^2 + (a_0^d)^2 V_{us}^2 \left(\frac{m_c}{m_t} \right) \right.$$
$$\left. + \left(\left[V_{ud}(a_{U0}^d + B_U^d) + A_U^d V_{ub} \right] \left[V_{ud}(a_{U0}^d + B_U^d) + V_{ub} A_U^d \right] - \sqrt{2}\cos\beta \right) \left(\frac{m_u}{m_\tau} \right) \right\}$$

$$g^U_{A^0 dd} = \frac{m_b}{\sqrt{2} M_W \cos\beta} \left[A_U^{d2} + \left((a_{U0}^d - B_U^d)^2 - \sqrt{2}\sin\beta \right) \left(\frac{m_d}{m_b} \right) \right]$$

$$g^U_{A^0 ss} = \frac{m_s}{\sqrt{2} M_W \cos\beta} \left[(a_{U0}^d)^2 - \sqrt{2}\sin\beta \right]$$

$$g^U_{A^0 uc} = \frac{m_t}{\sqrt{2} M_W \sin\beta} \left\{ \left[V_{ub}(a_{U0}^d - B_U^d) + A_U^d V_{ud} \right] \left[V_{cb}(a_{U0} - B) + A_U^d V_{cd} \right] \right.$$
$$+ \left[V_{ud}(a_{0U}^d + B_U^d) + A_U^d V_{ub} \right] \left[V_{cd}(a_{U0}^d + B_U^d) + V_{cb} A_U^{d*} \right] \left(\frac{m_u}{m_t} \right)$$
$$\left. + (a_{U0}^d)^2 V_{ud} V_{cs} \left(\frac{m_c}{m_t} \right) \right\}$$

$$Y_U^f = \begin{pmatrix} * & 0 & 0 \\ 0 & * & * \\ = & * & * \end{pmatrix} \quad ; \quad f = d, \ell$$

Couplings: $g^V_{A^0 \tau e} = 0 \; g_{A^0 \tau\mu} \frac{m_\tau}{\sqrt{2} M_W \cos\beta} \left[A^d_V (a^d_{V0} - B^d_V) + (a^d_{V0} + B^d_V) A^{d*}_V \left(\frac{m_\mu}{m_\tau}\right) \right]$

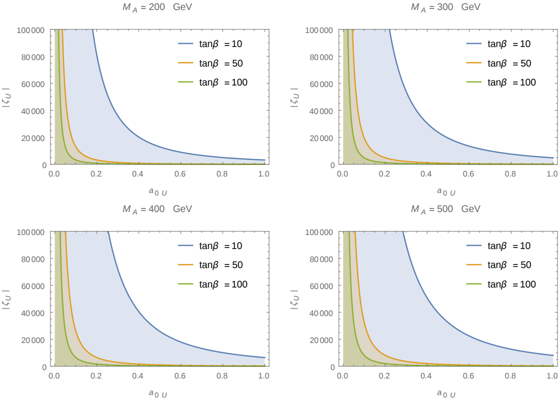
$$\begin{aligned}
g^V_{A^0 uu} &= \frac{m_u}{\sqrt{2} M_W \sin\beta} \left((a^d_{V0}) - \sqrt{2} \cos\beta \right) \\
g^V_{A^0 dd} &= \frac{m_b}{\sqrt{2} M_W \cos\beta} \Big\{ [V_{ub}(a_0 - B) + V_{us} A]^2 \\
&\quad + [V_{us}(a_0 + B) + A V_{ub}] \left[V_{us}(a_0 + B) + V_{ub} A^* \right] \left(\frac{m_s}{m_b} \right) \\
&\quad + \left((a_0)^2 V_{ud}^2 - \sqrt{2} \sin\beta \right) \left(\frac{m_d}{m_b} \right) \Big\} \\
g^V_{A^0 ss} &= \frac{m_b}{\sqrt{2} M_W \cos\beta} \left[A^2 + \left((a_0 + B)^2 - \sqrt{2} \sin\beta \right) \left(\frac{m_s}{m_b} \right) \right] \\
g^V_{A^0 uc} &= \frac{m_t}{\sqrt{2} M_W \sin\beta} \{ [V_{ub}(a_0 - B) + V_{us} A] [V_{cb}(a_0 - B) + A V_{cs}] \\
&\quad + [V_{us}(a_0 + B) + A V_{ub}] \left[V_{cs}(a_0 + B) + V_{cb} A^* \right] \left(\frac{m_c}{m_t} \right) + (a_0)^2 V_{ud} V_{cd} \left(\frac{m_u}{m_t} \right) \Big\} \\
g^V_{A^0 sd} &= 0 \, .
\end{aligned}$$

The U-Spin case

- $B_s^0 \to \mu^+\mu^-$ compatible with SM, thus U$-$Spin ($g_{Asb} = 0$) is a good possibility
- Isospin subgroup predicts the absence of LFV τ decay as in SM.
- The V$-$Spin effects are given at high energies and are very small given $B_s^0 \to \mu^+\mu^-$

And example with $\tau \to eK_s^0$ with U-Spin

$$\Gamma(\tau \to eK_s^0) \simeq (8.606 \times 10^{-15}\text{GeV}^5) \;\times\; \frac{|\zeta_U^\ell|^2 (a_{0U}^d)^4}{M_A^4}(1+\tan^2\beta)^2$$



$$g^U_{A^0\tau e} \simeq \frac{m_\tau \zeta_U^\ell}{\sqrt{2}M_W \cos\beta} \quad \text{and} \quad g^U_{A^0 sd} \simeq \frac{m_s (a_{U0}^d)^2}{\sqrt{2}M_W \cos\beta}$$

A general parametrization

$SU(3)$ Transformation

$$\boxed{\widetilde{Y}^{f'}_{\text{ext}}(t) = (\sqrt{2}G_F)^{1/2} e^{t\lambda} D^f e^{-t\lambda}}$$

with

$$\lambda = \frac{i}{2}\sum_{n=1}^{N_g} \theta_n \lambda_n \quad ; \quad D^f = \text{diag}(m_1^f, m_2^f, m_3^f)$$

- Perturbative Yukawa:

$$\widetilde{Y}^{f'}_{\text{ext}}(t) = \sqrt{2}G_F)^{1/2}(D^f + t\left[\lambda, D^f\right] + \frac{t^2}{2!}\left[\lambda\left[\lambda, D^f\right]\right] + \cdots)$$

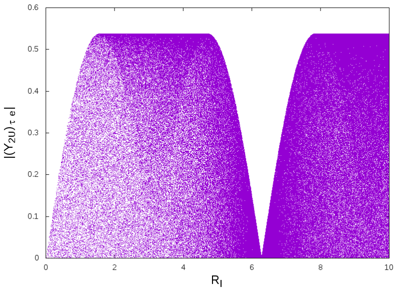
- Additional bound: $\det(U^f_{XL}) = 1$
- Framework for a dynamics of flavor

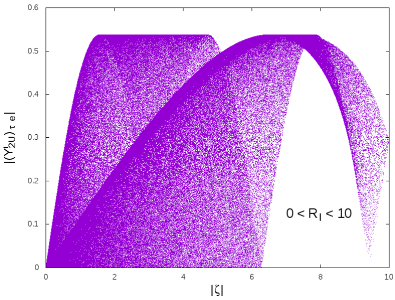
Yukawa Elements

Definimos los parámetros

- $R^2 = \theta_i^2 + \theta_j^2 + \theta_k^2$; Non standard contribution
- $|\zeta| = \sqrt{\theta_i^2 + \theta_j^2}$; Flavor violation parameter
- M_A is chosen in order to have no empty parameter space (~ 50 TeV)

U-Spin in leptonic sector

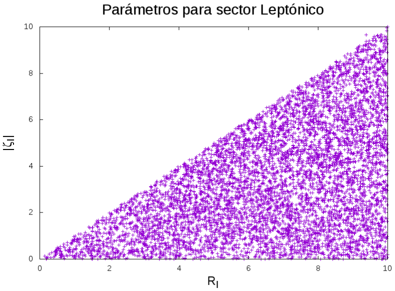


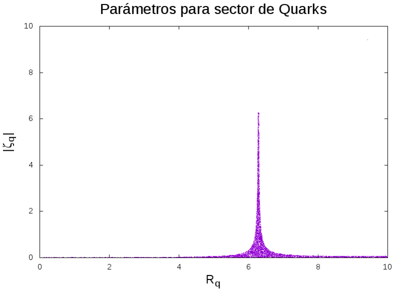


Parameters space

Channel	Upper Bound
$\tau \to e^- \pi^0$	$< 8.0 \times 10^{-8}$
$\tau \to \mu^- \pi^0$	$< 1.1 \times 10^{-7}$
$\tau \to e^- K_s^0$	$< 2.6 \times 10^{-8}$
$\tau \to \mu^- K_s^0$	$< 2.3 \times 10^{-8}$
$\tau \to e^- \eta$	$< 9.2 \times 10^{-8}$
$\tau \to \mu^- \eta$	$< 6.5 \times 10^{-8}$
$\tau \to e^- \eta'$	$< 1.6 \times 10^{-7}$
$\tau \to \mu^- \eta'$	$< 1.3 \times 10^{-8}$
$B^0 \to e^- e^+$	$< 8.3 \times 10^{-8}$
$B^0 \to \mu^- \mu^+$	$< 6.3 \times 10^{-10}$
$B^0 \to \tau^- \tau^+$	$< 4.1 \times 10^{-3}$
$B_s^0 \to e^- e^+$	$< 2.8 \times 10^{-7}$
$D^0 \to e^- e^+$	$< 7.9 \times 10^{-8}$
$D^0 \to \mu^- \mu^+$	$< 6.2 \times 10^{-9}$

$\mathbf{M_A} \geq \mathbf{50}\text{TeV}$





Bound using U-Spin parametrization

Bounds	Upper Limit
$\Gamma(\tau \to e^- \pi^0)$	$< 2.3 \times 10^{-19}$
$\Gamma(\tau \to e^- \eta)$	$< 4.5 \times 10^{-20}$
$\Gamma(\tau \to e^- \eta')$	$< 4.3 \times 10^{-20}$
$\Gamma(B_d^0 \to e^- e^+)$	$< 2.1 \times 10^{-21}$
$\Gamma(B_d^0 \to \mu^- \mu^+)$	$< 2.5 \times 10^{-22}$

Local flavor transformation

$$\boxed{Y^f(x) = \xi^f e^{t(x)\lambda^f} D e^{-t(x)\lambda^f}}$$

- $t(x)$: scalar field that leads to effective couplings
- The matrix D is diagonal in the mass basis
- Perturbative method

$$\frac{Y^f(x)}{\xi^f} = D + \frac{t(x)}{1!}[\lambda^f, D] + \frac{t^2(x)}{2!}[\lambda^f, [\lambda^f, D]] + \cdots$$

Final Comments

- 2HDM-III is a good frame to parameterized New Physics
- Invariants subgroups of $SU(3)$ reduce the nnumebr of free parameters and can shed light on flavor symmetries
- New restriction can be imposed on $\tau \to \ell P_1^0 P_2^0$ y $P_i^0 \to P_f^0 \ell_1 \ell_2$
- Textures can be seen as a consequence of suitable discret charges assigment for fermions
- Pseudoscalar is a WIMP