Tree Level FCNC from Models with a Flavored Peccei-Quinn Symmetry

Work in progress, in collaboration with E. Rojas, R. Martínez and J. C. Salazar,

based in part on arXiv:2007.05653 [hep-ph]

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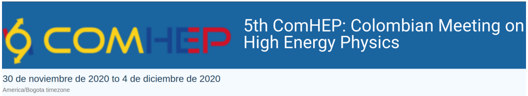


Overview

The five texture-zero mass matrices

- Texture zeros $\rightarrow$ simplify the number of free parameters$\rightarrow$ zeros will have predictions.
- The following five-zero textures gets a good fit for the quark and lepton masses and mixing parameters.
- Quark mass matrices (Yithsbey et al, J.Phys.G47,11,115002(2020)):

$$\underbrace{M^U = \begin{pmatrix} 0 & 0 & C_u \\ 0 & A_u & B_u \\ C_u^* & B_u^* & D_u \end{pmatrix}, \quad M^D = \begin{pmatrix} 0 & C_d & 0 \\ C_d^* & 0 & B_d \\ 0 & B_d^* & A_d \end{pmatrix},}_{\text{Hermitian matrices}} \quad \underset{\text{WBT}}{\Longrightarrow} \quad M^U = \begin{pmatrix} 0 & 0 & |C_u|e^{i\phi_{C_u}} \\ 0 & A_u & |B_u|e^{i\phi_{B_u}} \\ |C_u|e^{-i\phi_{C_u}} & |B_u|e^{-i\phi_{B_u}} & D_u \end{pmatrix}, \quad M^D = \begin{pmatrix} 0 & |C_d| & 0 \\ |C_d| & 0 & |B_d| \\ 0 & |B_d| & A_d \end{pmatrix}.$$

- Lepton mass matrices (Yithsbey,Phys.Rev.D86,093021(2012)):

$$\underbrace{M^N = \begin{pmatrix} 0 & |C_\nu|e^{ic_\nu} & 0 \\ |C_\nu|e^{-ic_\nu} & E_\nu & |B_\nu|e^{ib_\nu} \\ 0 & |B_\nu|e^{-ib_\nu} & A_\nu \end{pmatrix}, \quad M^E = \begin{pmatrix} 0 & |C_\ell| & 0 \\ |C_\ell| & 0 & |B_\ell| \\ 0 & |B_\ell| & A_\ell \end{pmatrix}.}_{\text{Hermitian matrices}}$$

$\Leftarrow$ Dirac mass neutrinos

The five texture-zero mass matrices

Diagonalization matrices for the quark sector:

$$U^{U\dagger} = \begin{pmatrix} e^{i(\phi_{C_u}+\theta_{1u})}\sqrt{\frac{m_c m_t (A_u - m_u)}{A_u(m_c+m_u)(m_t-m_u)}} & -e^{i(\phi_{C_u}+\theta_{2u})}\sqrt{\frac{(A_u+m_c)m_t m_u}{A_u(m_c+m_t)(m_c+m_u)}} & e^{i(\phi_{C_u}+\theta_{3u})}\sqrt{\frac{m_c(m_t-A_u)m_u}{A_u(m_c+m_t)(m_t-m_u)}} \\ -e^{i(\phi_{B_u}+\theta_{1u})}\sqrt{\frac{(A_u+m_c)(m_t-A_u)m_u}{A_u(m_c+m_u)(m_t-m_u)}} & -e^{i(\phi_{B_u}+\theta_{2u})}\sqrt{\frac{m_c(m_t-A_u)(A_u-m_u)}{A_u(m_c+m_t)(m_c+m_u)}} & e^{i(\phi_{B_u}+\theta_{3u})}\sqrt{\frac{(A_u+m_c)m_t(A_u-m_u)}{A_u(m_c+m_t)(m_t-m_u)}} \\ e^{i\theta_{1u}}\sqrt{\frac{m_u(A_u-m_u)}{(m_c+m_u)(m_t-m_u)}} & e^{i\theta_{2u}}\sqrt{\frac{m_c(A_u+m_c)}{(m_c+m_t)(m_c+m_u)}} & e^{i\theta_{3u}}\sqrt{\frac{m_t(m_t-A_u)}{(m_c+m_t)(m_t-m_u)}} \end{pmatrix},$$

$$U^{D\dagger} = \begin{pmatrix} e^{i\theta_{1d}}\sqrt{\frac{m_b(m_b-m_s)m_s}{(m_b-m_d)(m_d+m_s)(m_b+m_d-m_s)}} & -e^{i\theta_{2d}}\sqrt{\frac{m_b(m_b+m_d)m_d}{(m_d+m_s)(m_b+m_d-m_s)(m_b+m_s)}} & \sqrt{\frac{m_d(m_s-m_d)m_s}{(m_b-m_d)(m_b+m_d-m_s)(m_b+m_s)}} \\ e^{i\theta_{1d}}\sqrt{\frac{m_d(m_b-m_s)}{(m_b-m_d)(m_d+m_s)}} & e^{i\theta_{2d}}\sqrt{\frac{(m_b+m_d)m_s}{(m_d+m_s)(m_b+m_s)}} & \sqrt{\frac{m_b(m_s-m_d)}{(m_b-m_d)(m_b+m_s)}} \\ -e^{i\theta_{1d}}\sqrt{\frac{m_d(m_b+m_d)(m_s-m_d)}{(m_b-m_d)(m_d+m_s)(m_b+m_d-m_s)}} & -e^{i\theta_{2d}}\sqrt{\frac{(m_b-m_s)m_s(m_s-m_d)}{(m_d+m_s)(m_b+m_d-m_s)(m_b+m_s)}} & \sqrt{\frac{m_b(m_b+m_d)(m_b-m_s)}{(m_b-m_d)(m_b+m_d-m_s)(m_b+m_s)}} \end{pmatrix}.$$

$m_u \leq A_u \leq m_t$.

The five texture-zero mass matrices

Diagonalization matrices for the lepton sector:

$$U^{N\dagger}=\begin{pmatrix} e^{i(\theta_{1\nu}+c_\nu)}\sqrt{\frac{m_2m_3(A_\nu-m_1)}{A_\nu(m_2+m_1)(m_3-m_1)}} & -e^{i(\theta_{2\nu}+c_\nu)}\sqrt{\frac{m_1m_3(m_2+A_\nu)}{A_\nu(m_2+m_1)(m_3+m_2)}} & e^{i(\theta_{3\nu}+c_\nu)}\sqrt{\frac{m_1m_2(m_3-A_\nu)}{A_\nu(m_3-m_1)(m_3+m_2)}} \\ e^{i\theta_{1\nu}}\sqrt{\frac{m_1(A_\nu-m_1)}{(m_1+m_2)(m_3-m_1)}} & e^{i\theta_{2\nu}}\sqrt{\frac{m_2(A_\nu+m_2)}{(m_2+m_1)(m_3+m_2)}} & e^{i\theta_{3\nu}}\sqrt{\frac{m_3(m_3-A_\nu)}{(m_3-m_1)(m_3+m_2)}} \\ -e^{i(\theta_{1\nu}-b_\nu)}\sqrt{\frac{m_1(A_\nu+m_2)(m_3-A_\nu)}{A_\nu(m_1+m_2)(m_3-m_1)}} & -e^{i(\theta_{2\nu}-b_\nu)}\sqrt{\frac{m_2(A_\nu-m_1)(m_3-A_\nu)}{A_\nu(m_2+m_1)(m_3+m_2)}} & e^{i(\theta_{3\nu}-b_\nu)}\sqrt{\frac{m_3(A_\nu-m_1)(A_\nu+m_2)}{A_\nu(m_3-m_1)(m_3+m_2)}} \end{pmatrix},$$

$$U^{E\dagger}=\begin{pmatrix} e^{i\theta_{1\ell}}\sqrt{\frac{m_\mu m_\tau(m_\tau-m_\mu)}{(m_e-m_\mu+m_\tau)(m_\mu+m_e)(m_\tau-m_e)}} & -e^{i\theta_{2\ell}}\sqrt{\frac{m_e m_\tau(m_e+m_\tau)}{(m_e-m_\mu+m_\tau)(m_\mu+m_e)(m_\tau+m_\mu)}} & \sqrt{\frac{m_e m_\mu(m_\mu-m_e)}{(m_e-m_\mu+m_\tau)(m_\tau-m_e)(m_\tau+m_\mu)}} \\ e^{i\theta_{1\ell}}\sqrt{\frac{m_e(m_\tau-m_\mu)}{(m_\mu+m_e)(m_\tau-m_e)}} & e^{i\theta_{2\ell}}\sqrt{\frac{m_\mu(m_e+m_\tau)}{(m_\mu+m_e)(m_\tau+m_\mu)}} & \sqrt{\frac{m_\tau(m_\mu-m_e)}{(m_\tau-m_e)(m_\tau+m_\mu)}} \\ -e^{i\theta_{1\ell}}\sqrt{\frac{m_e(m_e+m_\tau)(m_\mu-m_e)}{(m_e-m_\mu+m_\tau)(m_\mu+m_e)(m_\tau-m_e)}} & -e^{i\theta_{2\ell}}\sqrt{\frac{m_\mu(m_\tau-m_\mu)(m_\mu-m_e)}{(m_e-m_\mu+m_\tau)(m_\mu+m_e)(m_\tau+m_\mu)}} & \sqrt{\frac{m_\tau(m_\tau-m_\mu)(m_e+m_\tau)}{(m_e-m_\mu+m_\tau)(m_\tau-m_e)(m_\tau+m_\mu)}} \end{pmatrix}.$$

$m_1\leq A_\nu\leq m_3.$

Yukawa Lagrangian and the PQ symmetry

$$\mathcal{L} \supset -\left(\bar{q}_{Li} y_{ij}^{D\alpha} \Phi^{\alpha} d_{Rj} + \bar{q}_{Li} y_{ij}^{U\alpha} \tilde{\Phi}^{\alpha} u_{Rj} + \bar{\ell}_{Li} y_{ij}^{E\alpha} \Phi^{\alpha} e_{Rj} + \bar{\ell}_{Li} y_{ij}^{N\alpha} \tilde{\Phi}^{\alpha} \nu_{Rj} + \text{h.c}\right),$$

$$M^N = \begin{pmatrix} 0 & x & 0 \\ x & x & x \\ 0 & x & x \end{pmatrix} \longrightarrow \begin{pmatrix} S_{11}^{N\alpha} \neq 0 & S_{12}^{N\alpha} = 0 & S_{13}^{N\alpha} \neq 0 \\ S_{21}^{N\alpha} = 0 & S_{22}^{N\alpha} = 0 & S_{23}^{N\alpha} = 0 \\ S_{31}^{N\alpha} \neq 0 & S_{32}^{N\alpha} = 0 & S_{33}^{N\alpha} = 0 \end{pmatrix},$$

$$M^E = \begin{pmatrix} 0 & x & 0 \\ x & 0 & x \\ 0 & x & x \end{pmatrix} \longrightarrow \begin{pmatrix} S_{11}^{E\alpha} \neq 0 & S_{12}^{E\alpha} = 0 & S_{13}^{E\alpha} \neq 0 \\ S_{21}^{E\alpha} = 0 & S_{22}^{E\alpha} \neq 0 & S_{23}^{E\alpha} = 0 \\ S_{31}^{E\alpha} \neq 0 & S_{32}^{E\alpha} = 0 & S_{33}^{E\alpha} = 0 \end{pmatrix},$$

where $S_{ij}^{N\alpha} = \underbrace{(-x_{\ell_i} + x_{\nu_j} - x_{\phi_\alpha})}_{\text{Peccei Quinn Charges}}$ and $S_{ij}^{E\alpha} = \underbrace{(-x_{\ell_i} + x_{e_j} + x_{\phi_\alpha})}_{\text{PQ charges}}$.

Yukawa Lagrangian and the PQ symmetry

Particle content and their respective PQ charges:

Particles	Spin	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$Q_{\text{PQ}}(i=1)$	$Q_{\text{PQ}}(i=2)$	$Q_{\text{PQ}}(i=3)$	$U(1)_{\text{PQ}}$
q_{Li}	1/2	3	2	1/6	$-2s_1+2s_2+\alpha$	$-s_1+s_2+\alpha$	α	x_{q_i}
u_{Ri}	1/2	3	1	2/3	$s_1+\alpha$	$s_2+\alpha$	$-s_1+2s_2+\alpha$	x_{u_i}
d_{Ri}	1/2	3	1	−1/3	$2s_1-3s_2+\alpha$	$s_1-2s_2+\alpha$	$-s_2+\alpha$	x_{d_i}
ℓ_{Li}	1/2	1	2	−1/2	$-2s_1+2s_2+\alpha'$	$-s_1+s_2+\alpha'$	α'	x_{ℓ_i}
e_{Ri}	1/2	1	1	−1	$2s_1-3s_2+\alpha'$	$s_1-2s_2+\alpha'$	$-s_2+\alpha'$	x_{e_i}
ν_{Ri}	1/2	1	1	0	$-4s_1+5s_2+\alpha'$	$-s_1+2s_2+\alpha'$	$s_2+\alpha'$	x_{ν_i}

- The subindex $i=1,2,3$ stand for the family number in the interaction basis.
- The columns 6-8 are the peccei-Quinn Q_{PQ} charges for the standard model quark in each family.
- The parameters s_1, s_2 and α are reals, with $s_1 \neq s_2$. Here: $s_1 = \frac{N}{9}\hat{s}_1$ and $s_2 = \frac{N}{9}(\epsilon + \hat{s}_1)$. Where N is the QCD anomaly.

Yukawa Lagrangian and the PQ symmetry

Beyond standard model scalar and fermion fields and their respective PQ charges:

Particles	Spin	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	Q_{PQ}	$U(1)_{\text{PQ}}$
ϕ_1	0	1	2	1/2	s_1	x_{ϕ_1}
ϕ_2	0	1	2	1/2	s_2	x_{ϕ_2}
ϕ_3	0	1	2	1/2	$-s_1+2s_2$	x_{ϕ_3}
ϕ_4	0	1	2	1/2	$-3s_1+4s_2$	x_{ϕ_4}
S	0	1	1	0	$x_S \neq 0$	x_S
Q_L	1/2	3	0	0	$x_{Q_L} - x_{Q_R} \neq 0$	x_{Q_L}
Q_R	1/2	3	0	0		x_{Q_R}

- $\epsilon = (1 - A_Q/N)$ and $A_Q = x_{Q_L} - x_{Q_R}$ is the contribution to the anomaly of a heavy quark Q singlet under the electroweak gauge group, with left (right)-handed Peccei-Quinn charges $x_{Q_{L,R}}$, respectively.
- To solve the strong CP problem $N = 2\Sigma q - \Sigma u - \Sigma d + A_Q \neq 0$ and to generate the texture-zeros in the mass matrices it is necessary to keep $\epsilon \neq 0$.

Naturalness of Yukawa couplings

- Quark sector:

$$M^U=\hat{v}_\alpha y_{ij}^{U\alpha}=\begin{pmatrix}0 & 0 & y_{13}^{U1}\hat{v}_1\\ 0 & y_{22}^{U1}\hat{v}_1 & y_{23}^{U2}\hat{v}_2\\ y_{13}^{U1^*}\hat{v}_1 & y_{23}^{U2^*}\hat{v}_2 & y_{33}^{U3}\hat{v}_3\end{pmatrix},\ M^D=\hat{v}_\alpha y_{ij}^{D\alpha}=\begin{pmatrix}0 & |y_{12}^{D4}|\hat{v}_4 & 0\\ |y_{12}^{D4}|\hat{v}_4 & 0 & |y_{23}^{D3}|\hat{v}_3\\ 0 & |y_{23}^{D3}|\hat{v}_3 & y_{33}^{D2}\hat{v}_2\end{pmatrix}.$$

$$\hat{v}_1=1.71\,\text{GeV},\qquad \hat{v}_2=2.91\,\text{GeV},\qquad \hat{v}_3=174.085\,\text{GeV},\qquad \hat{v}_4=13.3\,\text{MeV}.$$

- Lepton sector:

$$M^N=\hat{v}_\alpha y_{ij}^{N\alpha}=\begin{pmatrix}0 & y_{12}^{N1}\hat{v}_1 & 0\\ y_{21}^{N4}\hat{v}_4 & y_{22}^{N2}\hat{v}_2 & y_{23}^{N1}\hat{v}_1\\ 0 & y_{32}^{N3}\hat{v}_3 & y_{33}^{N2}\hat{v}_2\end{pmatrix},\ M^E=\hat{v}_\alpha y_{ij}^{E\alpha}=\begin{pmatrix}0 & |y_{12}^{E4}|\hat{v}_4 & 0\\ |y_{12}^{E4}|\hat{v}_4 & 0 & |y_{23}^{E3}|\hat{v}_3\\ 0 & |y_{23}^{E3}|\hat{v}_3 & y_{33}^{E2}\hat{v}_2\end{pmatrix}.$$

$$\begin{aligned}&|y_{12}^{E4}|=0.569582, && |y_{23}^{E3}|=0.00248291, && y_{33}^{E2}=0.574472,\\ &|y_{12}^{N1}|=4.74362\times10^{-6}, && |y_{21}^{N4}|=0.000609894, && y_{22}^{N2}=6.68808\times10^{-6},\\ &|y_{23}^{N1}|=0.0000159881, && |y_{32}^{N3}|=1.57047\times10^{-7}, && y_{33}^{N2}=8.65364\times10^{-6}.\end{aligned}$$

The Effective Lagrangian

$$\mathcal{L} = \underbrace{(D_\mu \Phi^\alpha)^\dagger D^\mu \Phi^\alpha + \sum_\psi i\bar{\psi}\gamma^\mu D_\mu \psi}_{\text{Kinectic terms}} + \underbrace{\frac{1}{2}\partial_\mu a \partial^\mu a - \frac{1}{2} m_a^2 a^2}_{\text{Axion particle}}$$

$$\underbrace{-\left(\bar{q}_{Li} y_{ij}^{D\alpha} \Phi^\alpha d_{Rj} + \bar{q}_{Li} y_{ij}^{U\alpha} \tilde{\Phi}^\alpha u_{Rj} + \bar{\ell}_{Li} y_{ij}^{E\alpha} \Phi^\alpha e_{Rj} + \bar{\ell}_{Li} y_{ij}^{N\alpha} \tilde{\Phi}^\alpha \nu_{Rj} + \text{h.c}\right)}_{\text{Yukawa Lagrangian}}$$

$$+ \underbrace{c_{a\Phi^\alpha} O_{a\Phi^\alpha} + c_1 \frac{\alpha_1}{8\pi} O_B + c_2 \frac{\alpha_2}{8\pi} O_W + c_3 \frac{\alpha_3}{8\pi} O_G}_{\text{Axion-gauge-scalar effective interaction. Wilson coefficients.}},$$

- Effective operators:

$$O_{a\Phi} = i\frac{\partial^\mu a}{\Lambda}\left((D_\mu \Phi^\alpha)^\dagger \Phi^\alpha - \Phi^{\alpha\dagger}(D_\mu \Phi^\alpha)\right), \qquad O_B = -\frac{a}{\Lambda} B_{\mu\nu} \tilde{B}^{\mu\nu},$$

$$O_W = -\frac{a}{\Lambda} W_{\mu\nu}^a \tilde{W}^{a\mu\nu}, \qquad O_G = -\frac{a}{\Lambda} G_{\mu\nu}^a \tilde{G}^{a\mu\nu}.$$

Where $\Lambda = f_a c_3^{\text{eff}}$, $c_3^{\text{eff}} = c_3 - 2\Sigma q + \Sigma u + \Sigma d - A_Q = -N$ and f_a axion decay constant.

The Effective Lagrangian

- Redefining the fields

$$\Phi^{\alpha} \longrightarrow e^{i\frac{x_{\Phi^{\alpha}}}{\Lambda}a}\Phi^{\alpha},$$
$$\psi_L \longrightarrow e^{i\frac{x_{\psi_L}}{\Lambda}a}\psi_L,$$
$$\psi_R \longrightarrow e^{i\frac{x_{\psi_R}}{\Lambda}a}\psi_R,$$

$$\mathcal{L} \longrightarrow \mathcal{L} + \Delta\mathcal{L}_{\text{LO}},$$

where

$$\Delta\mathcal{L}_{\text{LO}} = \Delta\mathcal{L}_{K^{\Phi}} + \Delta\mathcal{L}_{K^{\psi}} + \Delta\mathcal{L}_{\text{ Yukawa}} + \Delta\mathcal{L}(F_{\mu\nu}).$$

The Effective Lagrangian

- FCNC:

$$
\begin{aligned}
\Delta\mathcal{L}_{K^\psi} =& \frac{\partial_\mu a}{2\Lambda}\sum_\psi (x_{\psi_L}-x_{\psi_R})\bar\psi\gamma^\mu\gamma^5\psi - (x_{\psi_L}+x_{\psi_R})\bar\psi\gamma^\mu\psi,\\
\Delta\mathcal{L}_{Y} =& \frac{ia}{\Lambda}\bar q_{Li}\left(y_{ij}^{D\alpha}x_{d_j} - x_{q_i}y_{ij}^{D\alpha} + x_{\Phi^\alpha}y_{ij}^{D\alpha}\right)\Phi^\alpha d_{Rj}\\
&+\frac{ia}{\Lambda}\bar q_{Li}\left(y_{ij}^{U\alpha}x_{u_j} - x_{q_i}y_{ij}^{U\alpha} - x_{\Phi^\alpha}y_{ij}^{U\alpha}\right)\tilde\Phi^\alpha u_{Rj}\\
&+\frac{ia}{\Lambda}\bar l_{Li}\left(y_{ij}^{E\alpha}x_{e_j} - x_{l_i}y_{ij}^{E\alpha} + x_{\Phi^\alpha}y_{ij}^{E\alpha}\right)\Phi^\alpha e_{Rj}\\
&+\frac{ia}{\Lambda}\bar l_{Li}\left(y_{ij}^{N\alpha}x_{\nu_j} - x_{l_i}y_{ij}^{N\alpha} - x_{\Phi^\alpha}y_{ij}^{N\alpha}\right)\tilde\Phi^\alpha \nu_{Rj} + \text{h.c.}
\end{aligned}
$$

Low energy constraints and experimental bounds

The general form of the vector and axial coupligns:

$$g_{af_i f_j}^{V,A} = \frac{1}{2 f_a c_3^{\text{eff}}} \left(2\Delta_{V,A}^{Fij} - 2\,T_3^F \frac{\hat{v}\Delta_{\Phi}^{\gamma 1} Y_{V,A}^{F\gamma ij}}{(m_i^F \mp m_j^F)} \right),$$

where $\Delta_{V,A}^{Fij} = \Delta_{RR}^{Fij}(d) \pm \Delta_{LL}^{Dij}(q)$ with $\Delta_{LL}^{Fij}(q) = \left(U_L^F x_q \; U_L^{F\dagger}\right)^{ij}$ and $\Delta_{RR}^{Fij}(d) = \left(U_R^F x_d \; U_R^{F\dagger}\right)^{ij}$. $T_3^F = \pm 1/2$.

- The parameters associated with the FCNC due to the differences between the Higgs charges are: $\Delta_{\Phi}^{\gamma\beta} = (R x_{\Phi} R^T)^{\gamma\beta}$, $\hat{v} = v/\sqrt{2}$ and $Y_{V,A}^{F\gamma ij} = \left(Y_{ij}^{F\gamma} \mp Y_{ij}^{F\gamma\dagger}\right)$.
- The term with $\gamma = 1$ does not contribute to the FCNC since $Y^{F1} = \frac{2}{v} m^F$ is a diagonal matrix but there are off-diagonal contributions for $\gamma = 2, 3, 4$. The Yukawa matrix in the mass basis is given by $Y_{ij}^{F\gamma} = \left(U_L^F R_{\gamma\alpha} y^{F\alpha} U_R^{F\dagger}\right)_{ij}$.
- The factor 2 in front of $\Delta_{V,A}^{Fij}$ and the second term inside the brackets are a new contributions with respect to the existing literature.
- For normalized charges $c_3^{\text{eff}} = 1$.

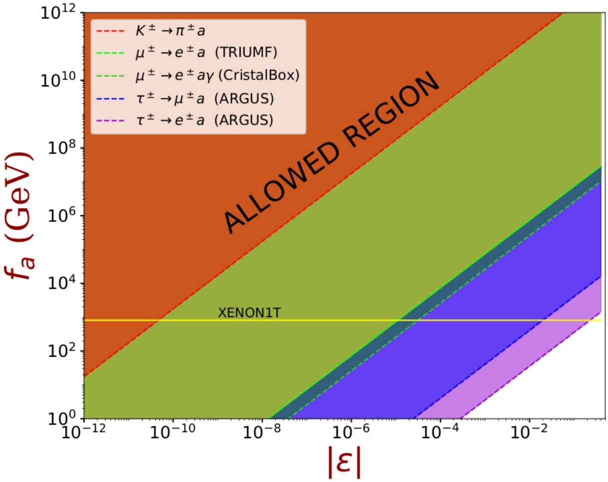
Low energy constraints and experimental bounds

- Branching ratio: $\mathrm{Br}(\ell_1 \to \ell_2\, a) = \frac{m_{\ell_1}^3}{16\pi\Gamma(\ell_1)} \left(1 - \frac{m_{\ell_2}^2}{m_{\ell_1}^2}\right)^3 |g_{a\ell_1\ell_2}|^2.$

Collaboration	Upper bound
E949+E787	$\mathcal{B}\left(K^+ \to \pi^+ a\right) < 0.73 \times 10^{-10}$
CLEO	$\mathcal{B}\left(B^\pm \to \pi^\pm a\right) < 4.9 \times 10^{-5}$
CLEO	$\mathcal{B}\left(B^\pm \to K^\pm a\right) < 4.9 \times 10^{-5}$
BELLE	$\mathcal{B}\left(B^\pm \to \rho^\pm a\right) < 21.3 \times 10^{-5}$
BELLE	$\mathcal{B}\left(B^\pm \to K^{*\pm} a\right) < 4.0 \times 10^{-5}$
TRIUMF	$\mathcal{B}\left(\mu^+ \to e^+ a\right) < 2.6 \times 10^{-6}$
Crystal Box	$\mathcal{B}\left(\mu^+ \to e^+ \gamma a\right) < 1.1 \times 10^{-9}$
ARGUS	$\mathcal{B}\left(\tau^+ \to e^+ a\right) < 1.5 \times 10^{-2}$
ARGUS	$\mathcal{B}\left(\tau^+ \to \mu^+ a\right) < 2.6 \times 10^{-2}$

These inequalities come from the window for new physics in the branching ratio uncertainty of the meson and lepton decay.

Experimental bounds



Summary and conclusions

1. A model is proposed where the fermionic and scalar fields are charged under a Peccei-Queen PQ symmetry.
2. The PQ charges are chosen in such a way that they can reproduce mass matrices with five texture zeros that can reproduce the masses of the standard model (SM) fermions, the CKM matrix and the PMNS matrix.
3. To obtain this result, at least 4 Higgs doublets are needed.
4. This model shows a route to understand the different scales of the SM by extending it with a Higgs sector and a PQ symmetry.
5. Since the PQ charges are not universal, the model presents flavor changing neutral currents (FCNC) at the tree level, a feature that constitutes the main source of restrictions on the parameter space.
6. If we include a heavy quark it is possible to fit the anomaly reported by xenon as a consequence of light axions.
7. In our work, we have normalized the PQ charges with the QCD anomaly $-N$ in such a way that keeping the parameter $\epsilon = 1 - A_Q/N \neq 0$ the textures of the mass matrices that allow us to tackle the flavor problem are obtained and the problem of strong CP is solved.
8. We report the regions of the parameter space allowed by lepton decays and compare the strength of these constraints with those coming from the semileptonic decays $K^{\pm} \longrightarrow \pi\bar{\nu}\nu$.

THANK YOU!