Higgs LFV decays in generalzed DFSZ type axion models

in progress

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Summary

- We discuss if the two LFV decay modes of h(125) can be enhanced or not in generalized DFSZ axion models.
- In the case of non-chiral alignment Yukawa couplings ($\Gamma^R_{\ell\ell'} \neq \Gamma^R_{\ell'\ell}$), $h \to e\tau$ and $h \to \mu\tau$ can be large simultaneously.
- The parameter region where hLFVs are enhanced can be explored by the searches of axion LFV couplings.

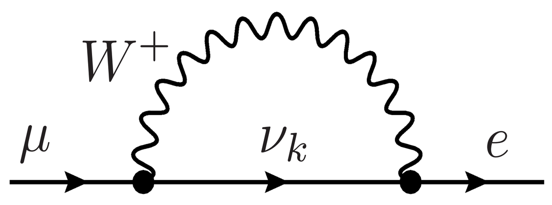
Lepton Flavor violation (LFV)

- Representative process
  - Lepton flavor violating (cLFV) decays : $e \to \mu\gamma, \quad \mu \to 3e, \quad \ldots$
  - Higgs LFV decays: $h \to e\tau, \quad h \to \mu\tau, \quad h \to e\tau$
- In the framework of the SM $+m_\nu \bar{\nu}_L^c \nu_L$
  - Lepton current appears in the charged current:

$$-\mathcal{L}_{cc} = \frac{g}{\sqrt{2}}(\bar{e}_L, \bar{\mu}_L, \bar{\tau}_L)\gamma^\mu U_{\rm PMNS}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix} W^+_\mu$$

  - Due to the GIM mechanism, LFV appears at 1-loop level

e.g.) $\mu \to e\gamma$



$$\mathrm{BR} = \frac{3\alpha}{32\pi}\left|\sum_{k=1}^{3}\frac{(U)_{\mu k}(U)^*_{ek}m^2_{\nu_k}}{m_W^2}\right|^2 = \mathcal{O}(10^{-54})$$

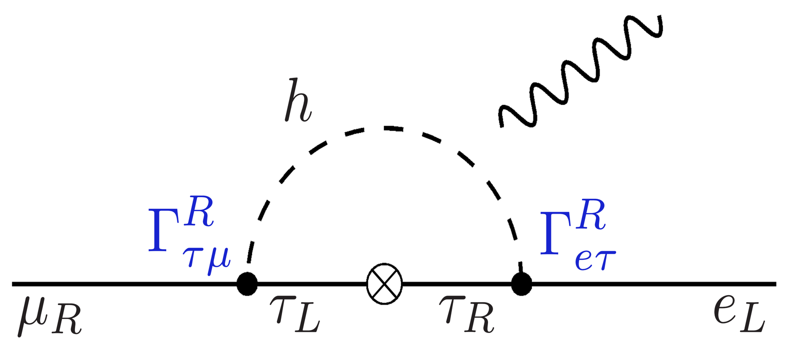
→ Clear evidence of new physics if LFV is discovered.

Motivations

- In Ref. [1], it is shown that due to the bound of cLFV, only one of $h \to e\tau$ or $h \to \mu\tau$ can be large:

$$\Gamma^R_{\tau\mu}\Gamma^R_{e\tau},\ \Gamma^R_{\mu\tau}\Gamma^R_{\tau e} \lesssim 10^{-8} \quad \text{(from } \mathrm{BR}^{\rm exp}_{\mu\to e\gamma} < 4.2\times 10^{-13}\text{)}$$

$$\left(\ \mathcal{L} = \bar{\ell}'_L\,\Gamma^R_{\ell'\ell}\,\ell_R h + \mathrm{h.c.}\ \right)$$



$$\sim \frac{m_\tau \Gamma^R_{\tau\mu}\Gamma^R_{e\tau} e}{16\pi^2 m_h^2}\left(-9 - 6\log\left(\frac{m_\tau^2}{m_h^2}\right)\right)$$

- They assumed that $\Gamma^R_{\ell\ell'} = \Gamma^R_{\ell'\ell}$. However, if it's not the case, $\mu \to e\gamma$ is not so severe.
- Can two Higgs LFV decay modes be enhanced at the same time?
  - This possibility isn't studied much in the framework of general structure of the Yukawa couplings.
  - Excess of 2.1 σ in $h \to \mu\tau$ and $h \to \mu\tau$ in ATLAS [2].

Generalized DFSZ axion models

- The original motivation of the model is the realization of "nucleophobic" axion [3].
  - Bounds from Neutron star cooling and SN 1987A for $m_a < 20$meV [4]

$$|g_{an}|, |g_{ap}| \lesssim 10^{-9}$$

- These couplings can be suppressed by specific conditions for g_{au} and g_{ad}.

$$C_p + C_n = 0.50(5)(C_u + C_d - 1) - 2\delta\,,$$
$$C_p - C_n = 1.273(2)\left(C_u - C_d - \frac{1-z}{1+z}\right)\,,$$

⇨

$$C_u + C_d = 1\,,\qquad C_u = \frac{1}{1+z} \sim 2/3\,.$$

$$C_u + C_d = N_1/(\sum_i^3 N_i) = 1$$

N_i : Anomaly coefficient for the i th generation quarks

⇨ $N_2 + N_3 = 0$ $\qquad N_1 = (X_{u_L} + X_{u_R} - X_{d_L} - X_{d_R})/2$

➡ Nucleophobic axion induces Flavor violation.

- (2+1) flavor space $\quad Q(f_1) = Q(f_2) = X_{fa}, \quad Q(f_3) = X_{f_3}$

The quark couplings are given by $C_u = c_\beta^2, C_d = s_\beta^2$

Nucleophobia is realized $\tan\beta \sim 0.7$.

- Nonalignment Yukawa coupling [$\xi^{e_{L/R}}_{ii} \equiv (V_{eL/R})^*_{3i}(V_{eL/R})_{3i}$]

$$(\Gamma^R_{he_ie_i}) = -\left(\frac{m_{e_i}}{v}[s_{\beta-\alpha} + (-t_\beta + \frac{1}{c_\beta s_\beta})c_{\beta-\alpha}]\delta_{ij} - \frac{c_{\beta-\alpha}m_\tau}{c_\beta s_\beta v}\sqrt{\xi^{e_L}_{ii}\xi^{e_R}_{jj}}\right),$$

$(ii = 11, 22, 33)$

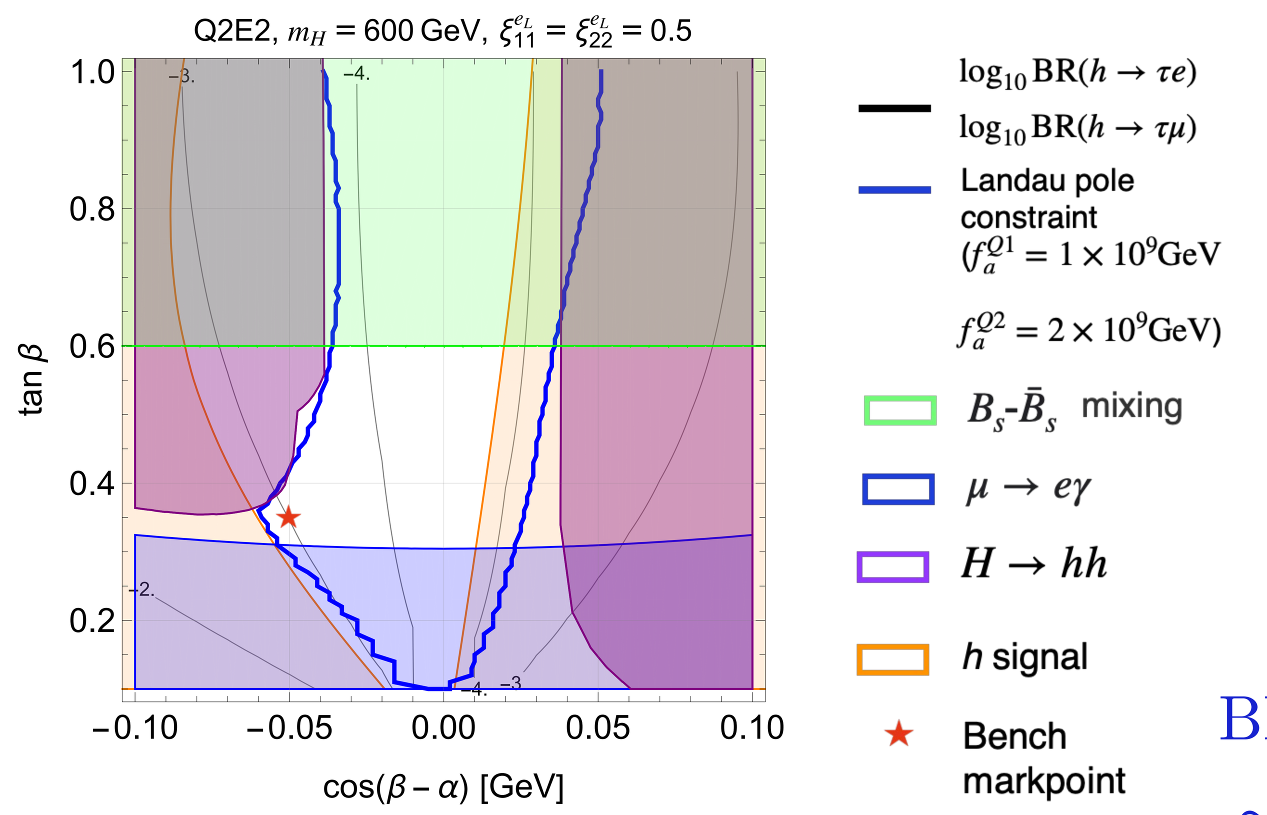
$$\xi^{e_R}_{11} = \xi^{e_R}_{22} = 0 \quad \longrightarrow \quad \Gamma^R_{he_ie_j} = \begin{pmatrix}\Gamma^R_{hee} & 0 & \Gamma^R_{he\tau}\\ 0 & \Gamma^R_{h\mu\mu} & \Gamma^R_{h\mu\tau}\\ 0 & 0 & \Gamma^R_{h\tau\tau}\end{pmatrix}$$

✓ cLFV bounds $\mu \to e\gamma$: $\Gamma^R_{\tau\mu}\Gamma^R_{e\tau},\ \Gamma^R_{\mu\tau}\Gamma^R_{\tau e} \lesssim 10^{-8}$

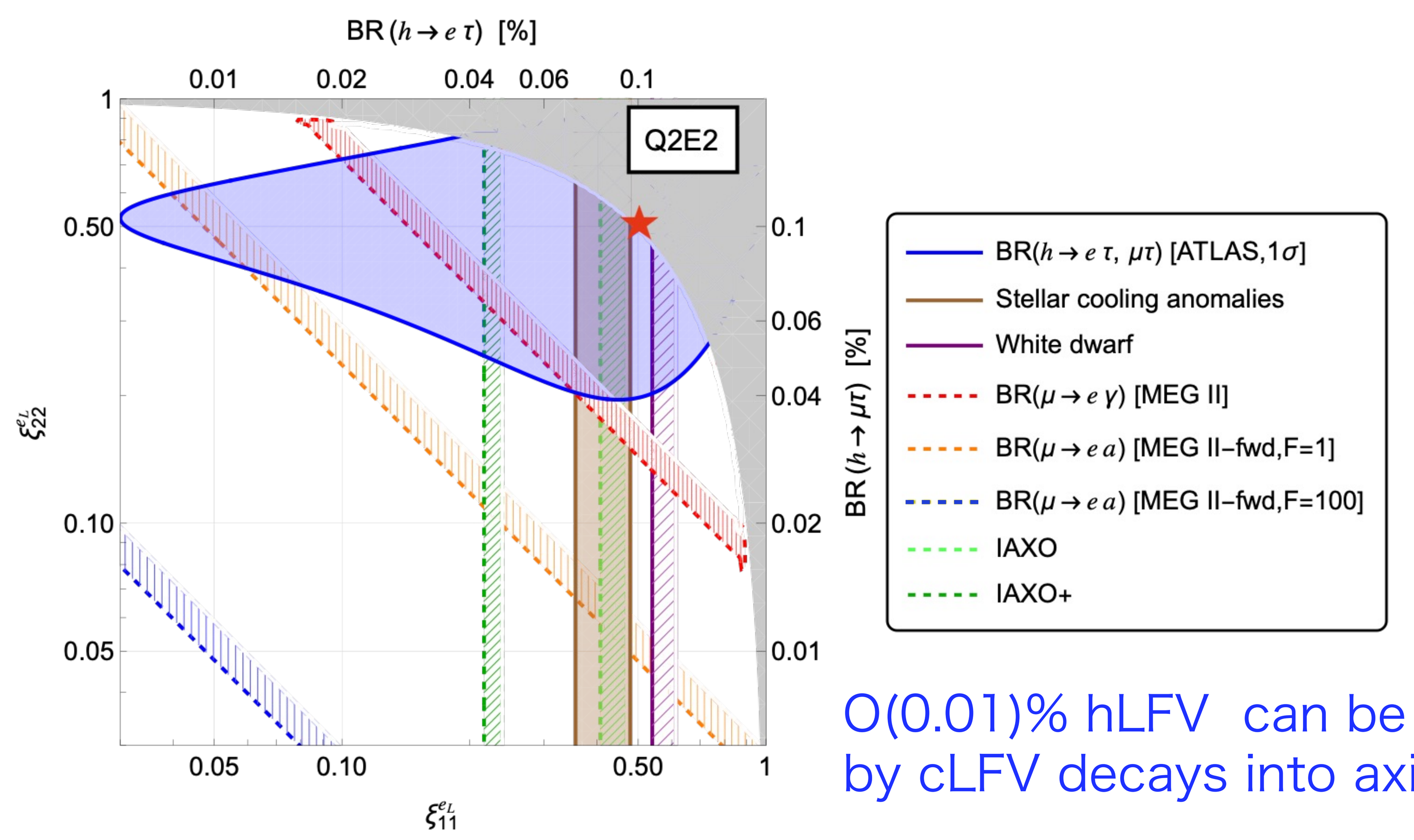
$\tau \to \ell\gamma$: $|\Gamma^R_{\tau\mu,\mu\tau}|^2,\ |\Gamma^R_{\tau e,e\tau}|^2 \lesssim 10^{-4}$

✓ Enhancement of $h \to \mu\tau$ and $h \to e\tau$

Numerical calcurations



$$\mathrm{BR}_{h\to\tau\mu}, \mathrm{BR}_{h\to\tau e} \sim 0.1\%$$



O(0.01)% hLFV can be surveyed by cLFV decays into axion.

Reference: [1]: Gianluca Blankenburg, John Ellis, Gino Isidori, Phys.Lett.B 712 (2012) 386-390. [2]: ATLAS Collaboration, JHEP 07 (2023) 166. [3]: Luca Di Luzio, Federico Mescia, Enrico Nardi, Paolo Panci, Robert Ziegler, Phys.Rev.Lett. 120 (2018) 26. [4]: https://cajohare.github.io/AxionLimits/