



Leptophilic bosons and Muon g-2 in 2HDM

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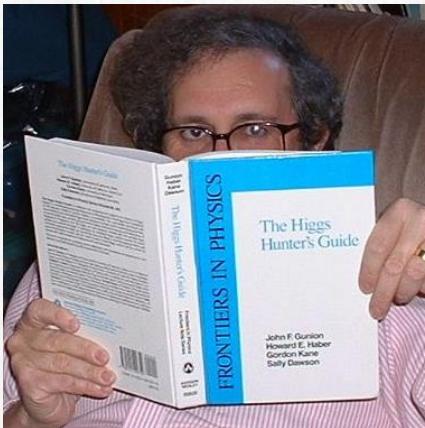
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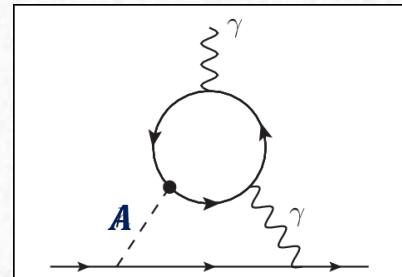
Outline

- Light leptophilic bosons in 2HDM of type-X

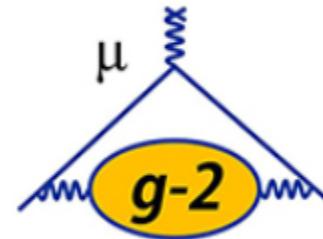
T.D. Lee, 1973
Glashow, Weinberg, 1977



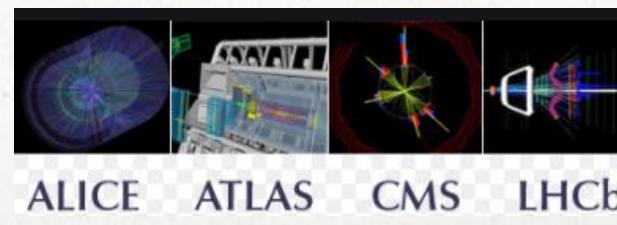
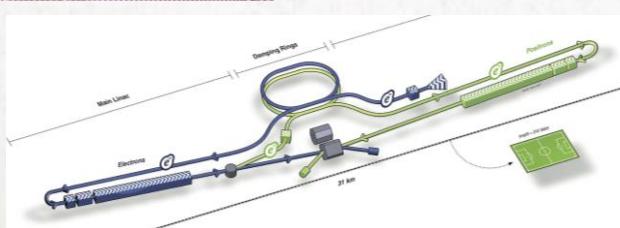
D. Chang, et.al, 2001



- Muon g-2 and Lepton Universality



- LHC and ILC tests



Leptophilic 2HDM

- 2HDM of type-X:

$$\mathcal{L}_Y = y_u \overline{q_L} \Phi_2^* u_R + y_d \overline{q_L} \Phi_2 d_R + y_l \overline{l_L} \Phi_1 e_R + h.c.$$

- 2HDM Higgs bosons: $h(125), H, H^\pm, A$

- In the alignment limit: $\sin(\beta - \alpha) \rightarrow 1; \cos(\beta - \alpha) \rightarrow 0, \text{ or } 2/t_\beta$

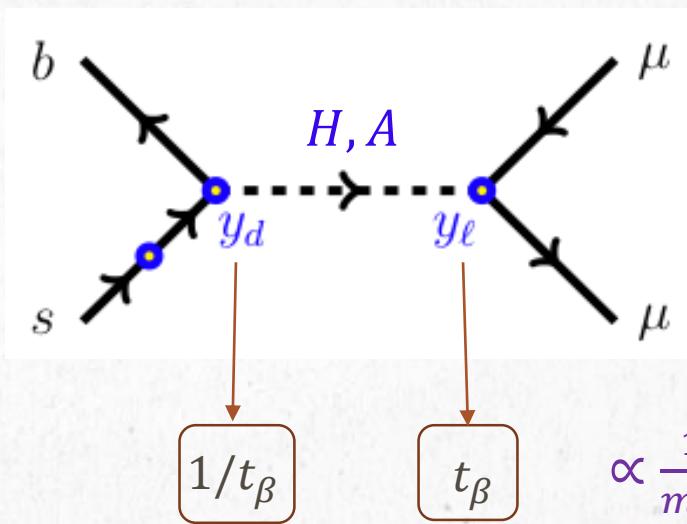
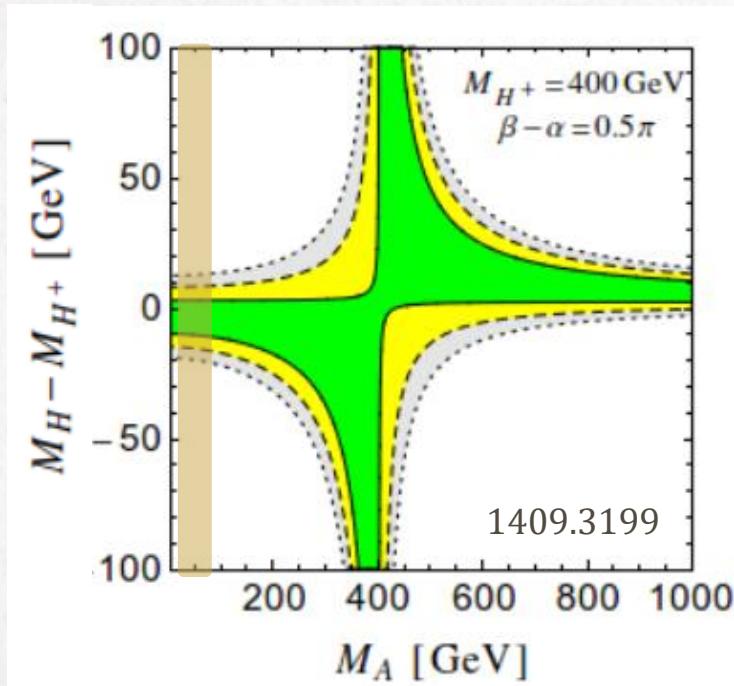
$$\begin{cases} \Phi_2 \rightarrow s_\beta(v + h) - c_\beta H - i c_\beta A \\ \Phi_1 \rightarrow c_\beta(v + h) + s_\beta H + i s_\beta A \end{cases}$$

$$\mathcal{L}_Y = \frac{m_f}{v} \bar{f} h f + \frac{m_q}{v} \frac{1}{t_\beta} \bar{q} (\mathbf{H} \pm i \gamma_5 \mathbf{A}) q + \frac{m_l}{v} t_\beta \bar{l} (\mathbf{H} + i \gamma_5 \mathbf{A}) l \rightarrow \text{Leptophilic at large } \tan\beta$$

- Muon g-2 favored (2σ): $m_H \approx m_{H^\pm} \gg m_A \gtrsim 10 \text{ GeV}, t_\beta \gtrsim 35$

with A. Broggio, M. Passera, K. M. Patel and S. K. Vempati: 1409.3199
J. Kim: 1605.06298

EWPT and $B_s \rightarrow \mu^+ \mu^-$

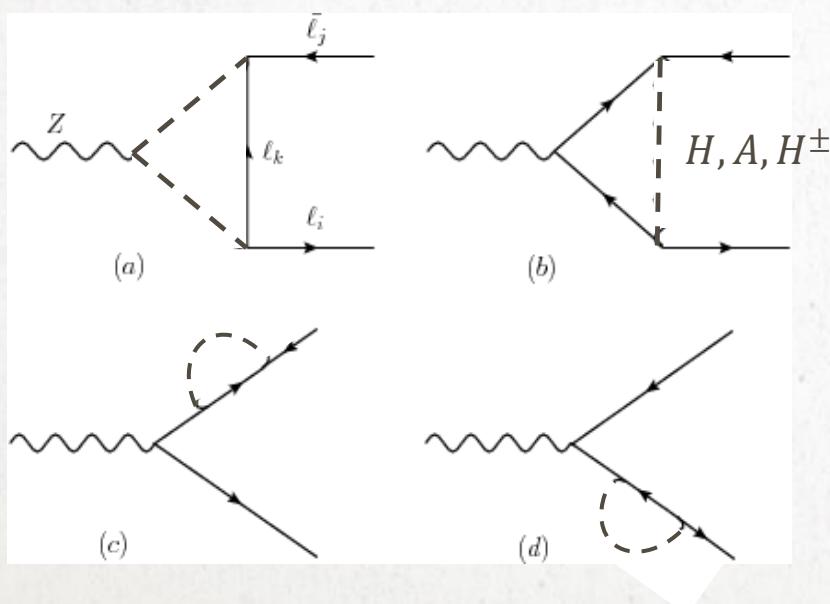


Wang, Han, 1412

LU in $Z \rightarrow ll$

- One-loop corrections mediated by extra Higgs bosons.

Hollik, Kuehn, 1991



LEP EWWG, 0509008

$$\frac{\Gamma_{Z \rightarrow \mu^+ \mu^-}}{\Gamma_{Z \rightarrow e^+ e^-}} = 1.0009 \pm 0.0028, \\ \frac{\Gamma_{Z \rightarrow \tau^+ \tau^-}}{\Gamma_{Z \rightarrow e^+ e^-}} = 1.0019 \pm 0.0032,$$

with correlation +0.63

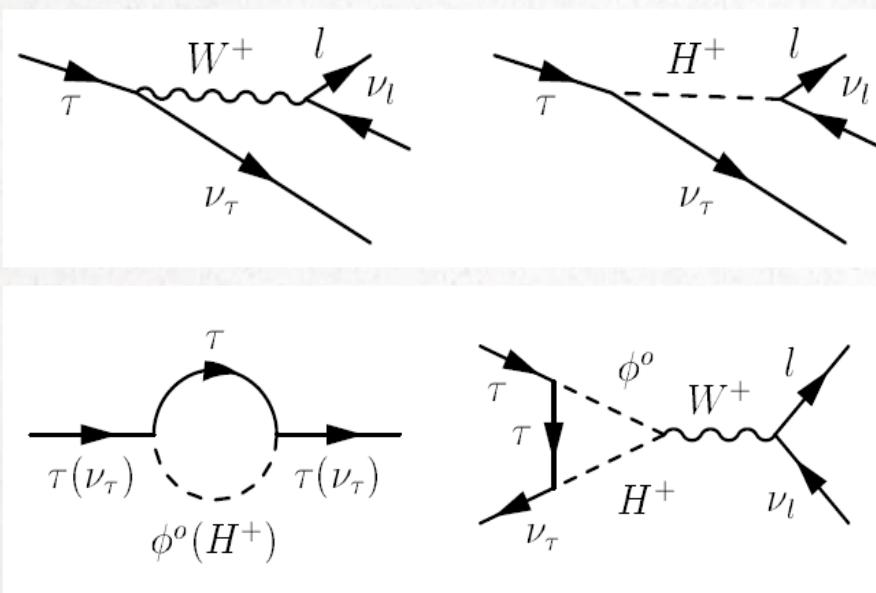
$$\delta_{\mu\mu} \simeq 0, \\ \delta_{\tau\tau} = \frac{2g_L^e \text{Re}(\delta g_L^{2\text{HDM}}) + 2g_R^e \text{Re}(\delta g_R^{2\text{HDM}})}{g_L^{e2} + g_R^{e2}},$$

Constraining large $\tan\beta$
and big hierarchy:
 $m_A \ll m_H \approx m_{H^\pm}$ and $m_\phi \gg m_Z$

LU in τ/μ Decays

- Tree-level contribution from H^\pm .
- One-loop corrections mediated by A, H, H^\pm .

Krawczyk, Temes, 0410248



HFAG, 1612.07233

$$\frac{\tau \rightarrow e\nu\nu}{\mu \rightarrow e\nu\nu}, \frac{\tau \rightarrow \mu\nu\nu}{\mu \rightarrow e\nu\nu}, \frac{\tau \rightarrow \mu\nu\nu}{\tau \rightarrow e\nu\nu} \quad \frac{(\tau \rightarrow \nu\pi/K)}{(\pi/K \rightarrow \mu\nu)}$$

$$\left(\frac{g_\tau}{g_\mu} \right) = 1.0011 \pm 0.0015$$

$$\left(\frac{g_\tau}{g_e} \right) = 1.0029 \pm 0.0015$$

$$\left(\frac{g_\mu}{g_e} \right) = 1.0018 \pm 0.0014$$

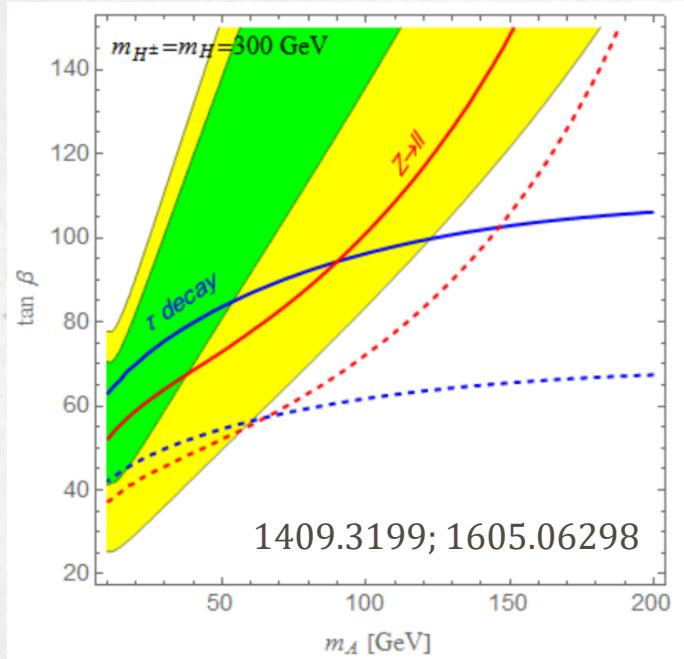
$$\left(\frac{g_\tau}{g_\mu} \right)_\pi = 0.9963 \pm 0.0027$$

$$\left(\frac{g_\tau}{g_\mu} \right)_K = 0.9858 \pm 0.0071$$

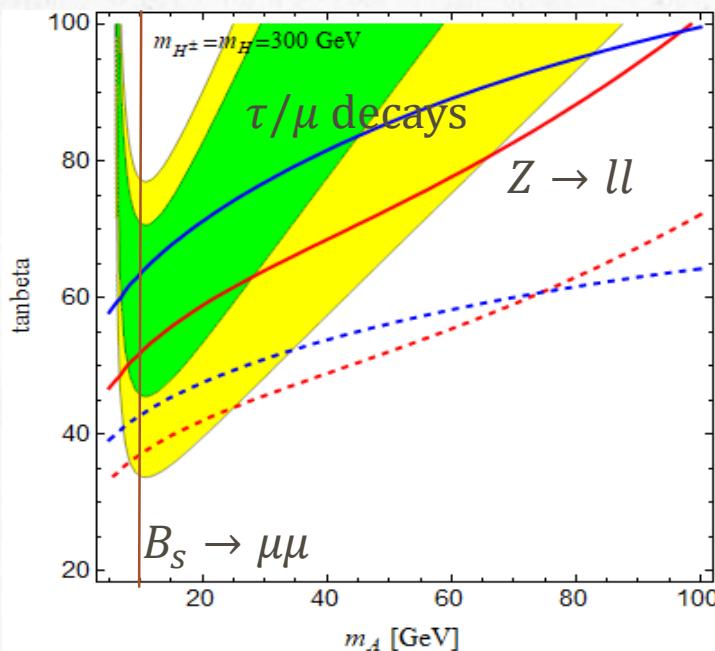
$$\left(\frac{g_\tau}{g_\mu} \right) = 1 + \delta_{\text{loop}}, \quad \left(\frac{g_\tau}{g_e} \right) = 1 + \delta_{\text{tree}} + \delta_{\text{loop}}, \quad \left(\frac{g_\mu}{g_e} \right) = 1 + \delta_{\text{tree}},$$

$$\left(\frac{g_\tau}{g_\mu} \right)_\pi = 1 + \delta_{\text{loop}}, \quad \left(\frac{g_\tau}{g_\mu} \right)_K = 1 + \delta_{\text{loop}}.$$

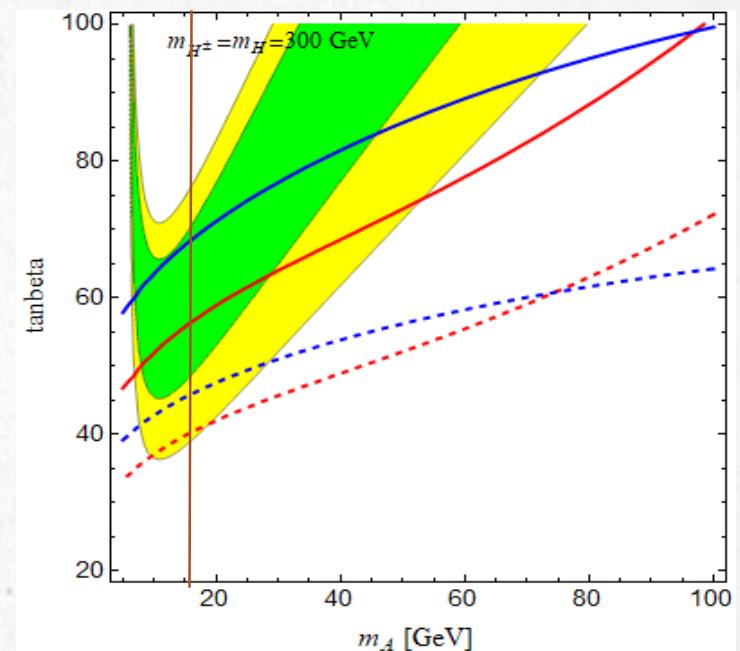
Muon g-2 in L2HDM



$$\Delta a_\mu = (262 \pm 85) \times 10^{-11}$$



$$\text{WP20: } \Delta a_\mu = (279 \pm 76) \times 10^{-11}$$



$$\text{FNAL: } \Delta a_\mu = (251 \pm 59) \times 10^{-11}$$

ϕ +L2HDM

- ϕ - H/h , ϕ - A mixing $\Rightarrow \theta_{\phi 1}, \theta_{\phi 2}, \theta_{\phi A}$

$$\mathcal{L}_{\phi h/H} = \phi (\mu_1 \Phi_1 \Phi_1^+ + \mu_2 \Phi_2 \Phi_2^+ + \mu_3 (\Phi_1 \Phi_2^+ + h.c.))$$

$$\mathcal{L}_{\phi A} = i\mu' \phi (\Phi_1 \Phi_2^+ - h.c.)$$

- Effective ϕff coupling:

(*) Leptophilic limit $\theta_{\phi 2} \rightarrow 0$: $\xi_l \equiv t_\beta \theta$, $\xi_q = \frac{\xi_l}{t_\beta^2}$

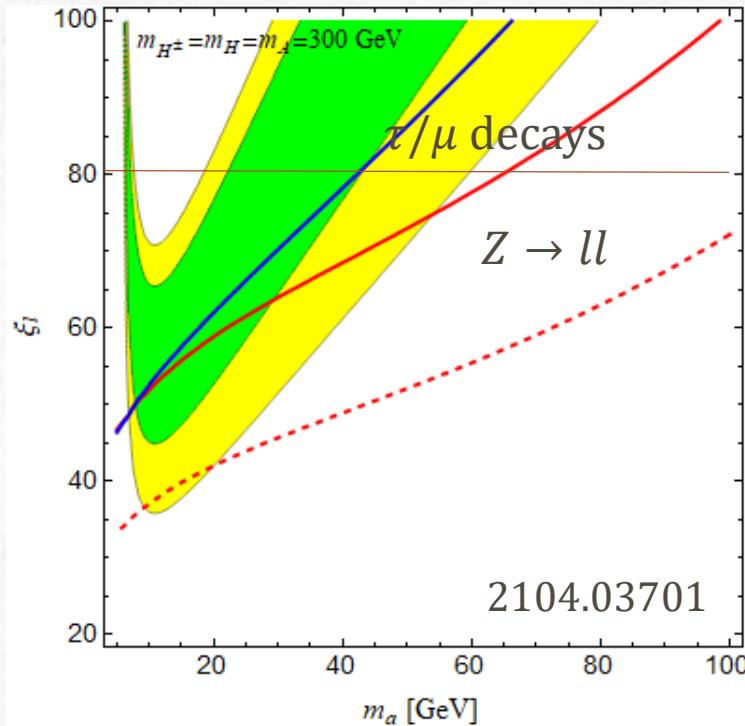
$$\mathcal{L}_{\phi ff} = \frac{m_q}{v} \phi \bar{q} \left[\left(\theta_{\phi 2} + \frac{\theta_{\phi 1}}{t_\beta} \right) \pm i\gamma_5 \frac{\theta_{\phi A}}{t_\beta} \right] q + \frac{m_l}{v} \phi \bar{l} \left[(\theta_{\phi 2} + t_\beta \theta_{\phi 2}) + i\gamma_5 t_\beta \theta_{\phi A} \right] l$$

- If allowed kinematically, generically sizable $h \rightarrow AA, \phi A, \phi \phi$

(*) ϕ as a portal to DM: $\mathcal{L}_{\phi \chi} = \phi \bar{\chi} (\textcolor{brown}{y}_\chi + i\gamma_5 \textcolor{brown}{y}'_\chi) \chi$

Muon g-2 with a singlet pseudoscalar

$$\xi_l = \sin\theta \tan\beta$$



FNAL: $\Delta a_\mu = (251 \pm 59) \times 10^{-11}$

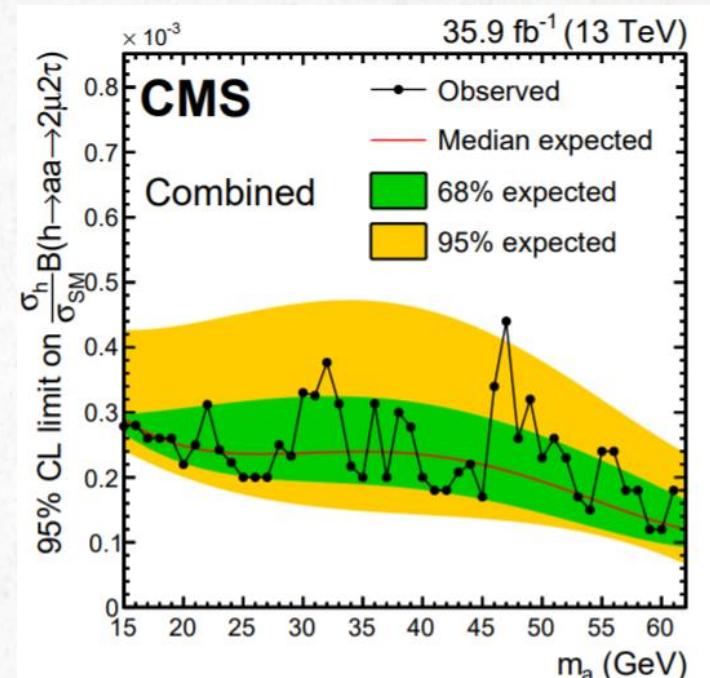
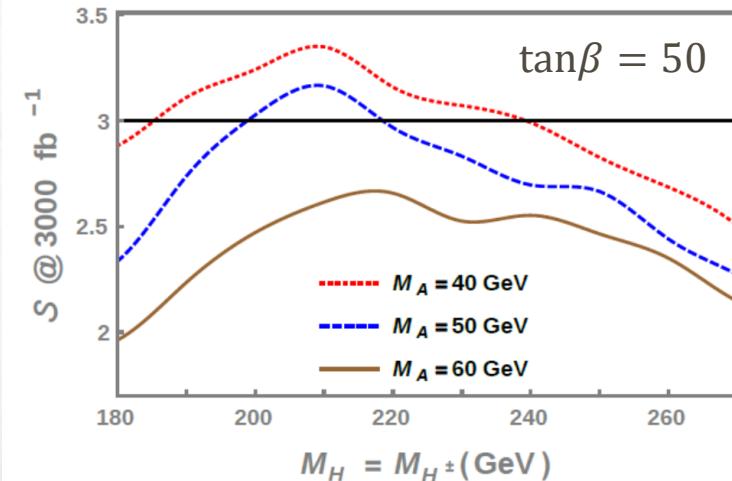
LHC Searches

- $pp \rightarrow H^\pm H + A \rightarrow 4\tau, 3\tau$ 1507.08067

- $pp \rightarrow h \rightarrow AA \rightarrow 2\tau 2\mu$ 1707.07928

$g_{hAA}/v \lesssim 0.008$ for $m_A = 15 - 62$ GeV CMS 1805.04865

- $pp \rightarrow H^\pm / H + A \rightarrow AA(2\tau 2\mu)$ 1807.05379



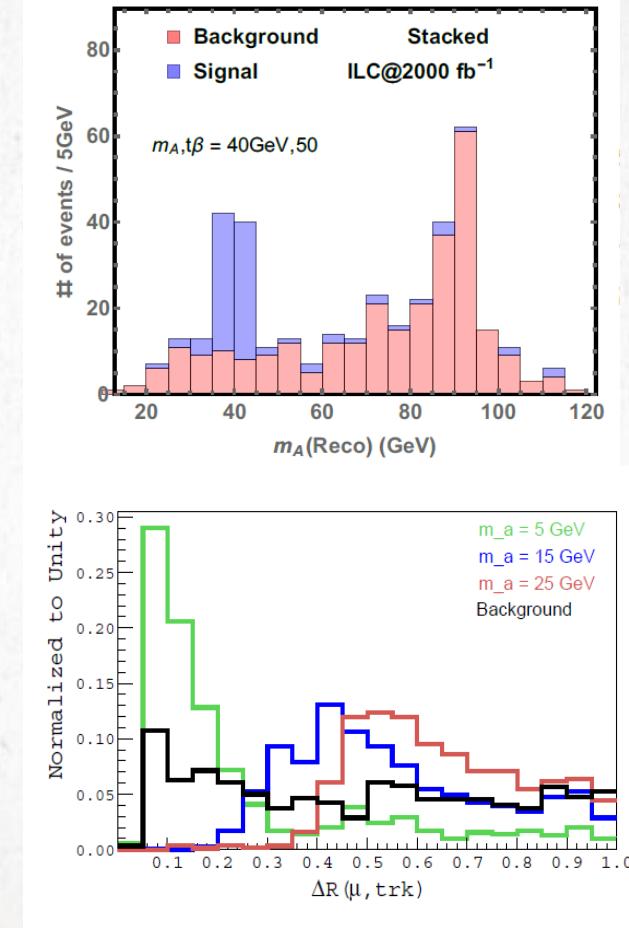
ILC Study

- $e^+e^- \rightarrow \tau^+\tau^-\phi \rightarrow \tau^+\tau^-(\tau^+\tau^-)$

1909.09515

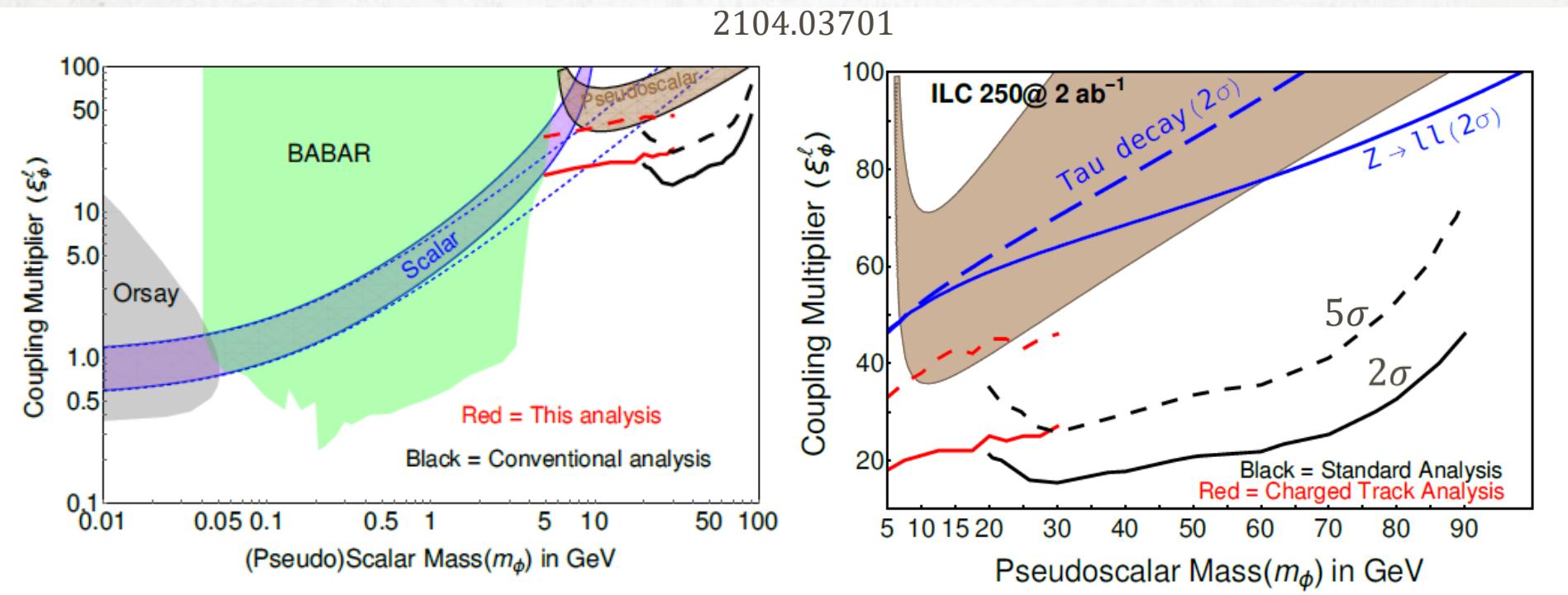
- $e^+e^- \rightarrow \tau^+\tau^-\phi(\tau\tau)$ 2104.03701

$$\phi(\tau\tau) = \mu^\pm + trk^\mp (\mu^\mp / e^\mp / h^\mp)$$



ILC Reach

2104.03701



Summary

- L2HDM can accommodate a light pseudoscalar which explains the muon g-2 anomaly.
- LHC searches from $pp \rightarrow \{h, H^\pm(H)A\} \rightarrow AA(2\tau 2\mu)$ for sizable g_{hAA} , or $\text{Br}(H^\pm(H) \rightarrow W^\pm(Z)A)$.
- Lepton Colliders will unambiguously rule out or discover such a leptophilic boson through the Yukawa production.