Leptophilic Dark Portals

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Washington University in St. Louis

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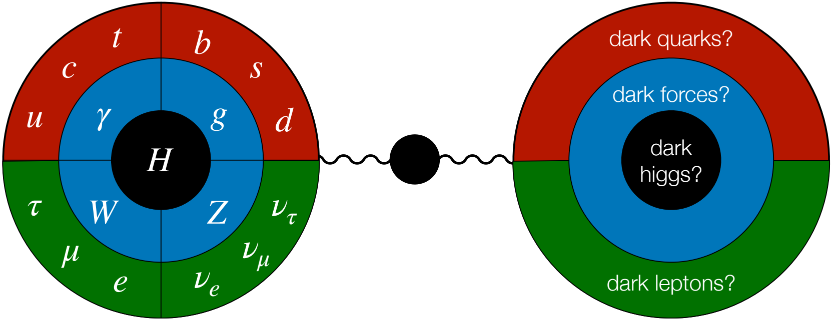
Voyage into the dark sector

(from *Symmetry* Magazine)

Portals to the Dark Sector



[Snowmass reports: 2207.06898, 2207.06905, 2209.04671]

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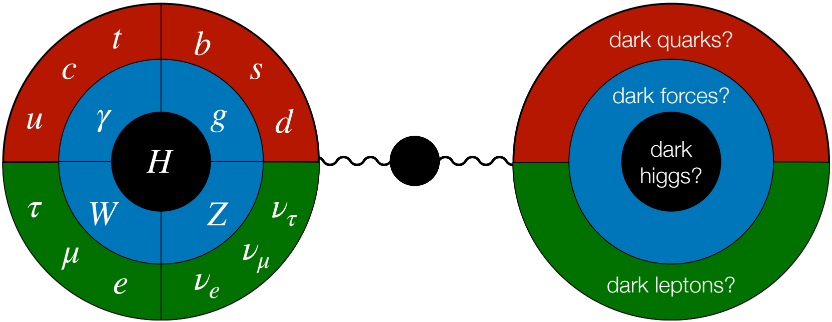

[Snowmass reports: 2207.06898, 2207.06905, 2209.04671]

In this talk,

- **Leptophilic** Higgs and vector portals.
- Possibility of interesting LFV signals.
- Complementarity between low and high-energy LFV searches.
- Connection to neutrino mass, gravitational waves, and more.

LFV is guaranteed!

- LFV is forbidden in the SM due to an accidental global symmetry: $U(1)_B \times U(1)_{L_e} \times U(1)_{L_\mu} \times U(1)_{L_\tau}$.
- Observed neutrino oscillations already imply LFV.
- But we haven't seen LFV in the *charged* lepton sector.

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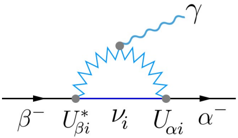
- Negligible in the SM(+neutrino mass) [Petcov '76]:

$$\ell_\beta^- \to \ell_\alpha^- \gamma : \frac{3\alpha}{32\pi} \left| \sum_i U_{\beta i}^* U_{\alpha i} \frac{m_{\nu_i}^2}{m_W^2} \right|^2 \lesssim \mathcal{O}(10^{-54})$$



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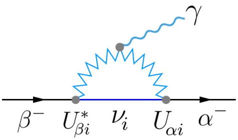

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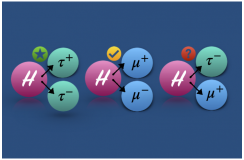
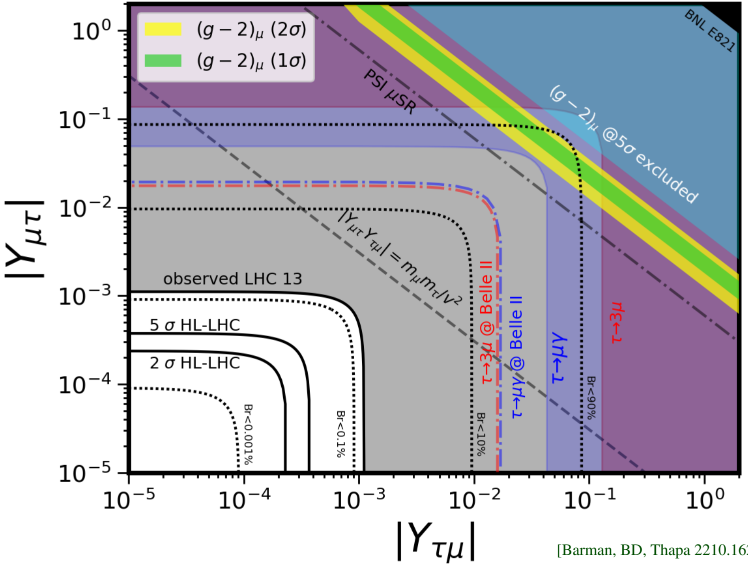
- Could be enhanced by orders of magnitude over the SM.

- Low-energy experiments are doing a great job.
- High-energy colliders provide a powerful complementary probe of LFV (e.g. via exotic decays of Higgs, Z and top).

  see talk by W. Altmannshofer



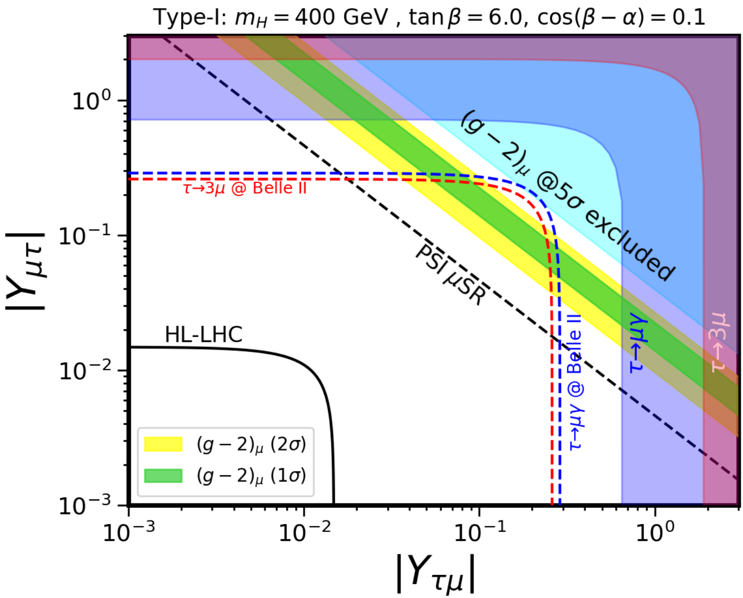
LFV decays of $h(125) \to \mu^\pm \tau^\mp$



[Barman, BD, Thapa 2210.16287 (PRD '23)]

see also [Harnik, Kopp, Zupan 1209.1397; Davidson, Verdier 1211.1248; Altmannshofer, Caillol, Dam, Xella, Zhang 2205.10576]

BSM Higgs $H \to \mu^{\pm}\tau^{\mp}$



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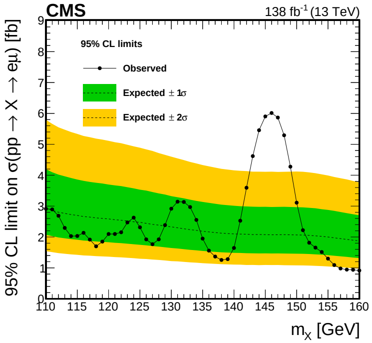
Leptophilic Higgs@LHC?



3.8σ (2.8σ) local (global) excess ☺

$$\sigma(pp \to H(146) \to e\mu)_{\rm CMS} = 3.89^{+1.25}_{-1.13}\ {\rm fb}$$

Hint of LFV? [2305.18106]

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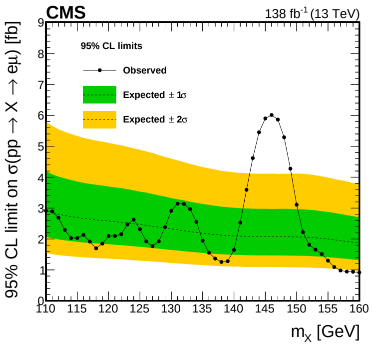

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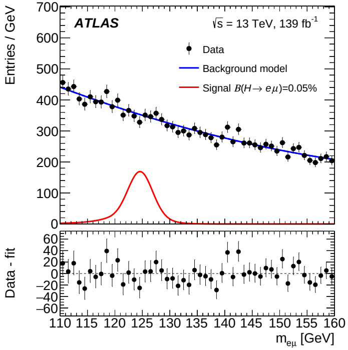

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$\sigma(pp \to H(146) \to e\mu)_{\rm ATLAS} \lesssim 3$ fb

(ballpark estimate only, not conclusive)

[1909.10235 and EW Moriond '23 talk by K. Leney]

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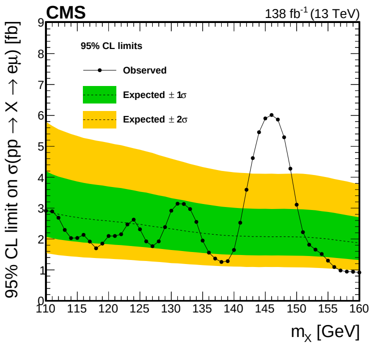

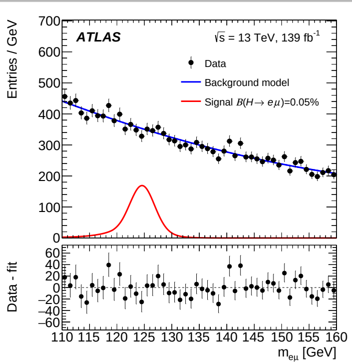

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[1909.10235 and EW Moriond '23 talk by K. Leney]

- If survives, simplest explanation: **Leptophilic (pseudo)scalar resonance**, e.g. in a leptophilic 2HDM.
- Use *lepton* PDF of the proton. [Bertone, Carrazza, Pagani, Zaro (JHEP '15); Buonocore, Nason, Tramontano, Zanderighi (JHEP '20, '21)]

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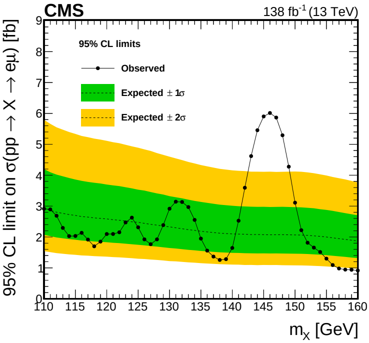

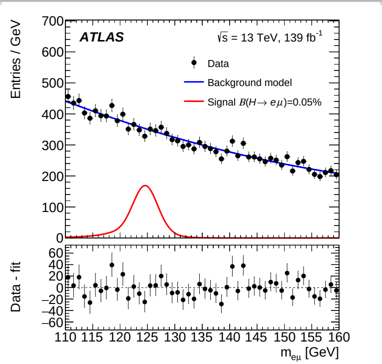

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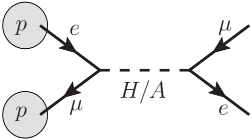
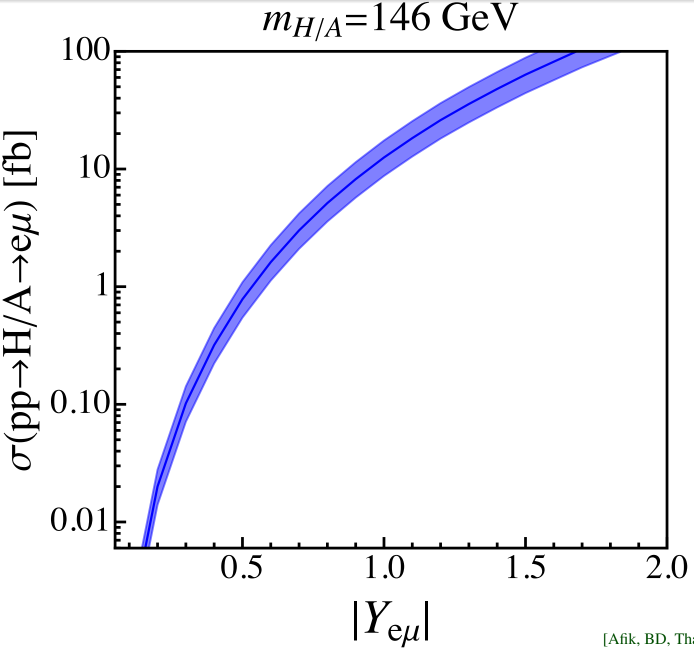
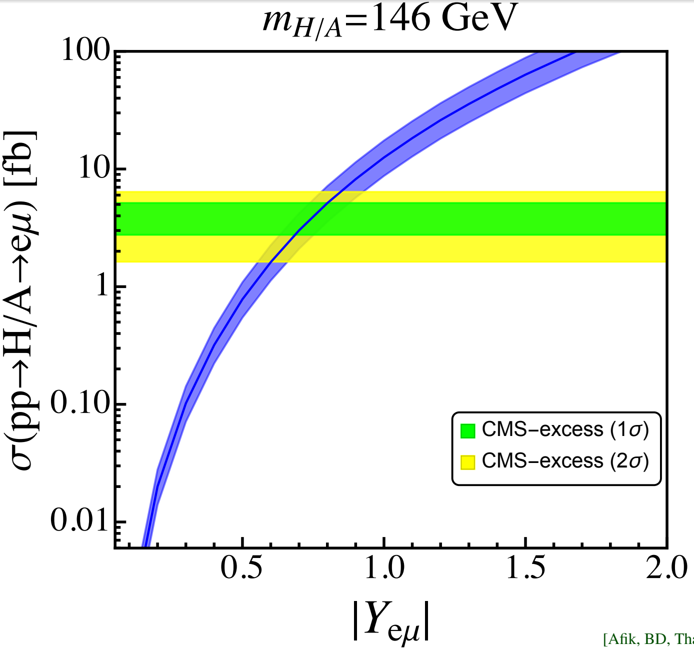




[Afik, BD, Thapa, 2305.19314]



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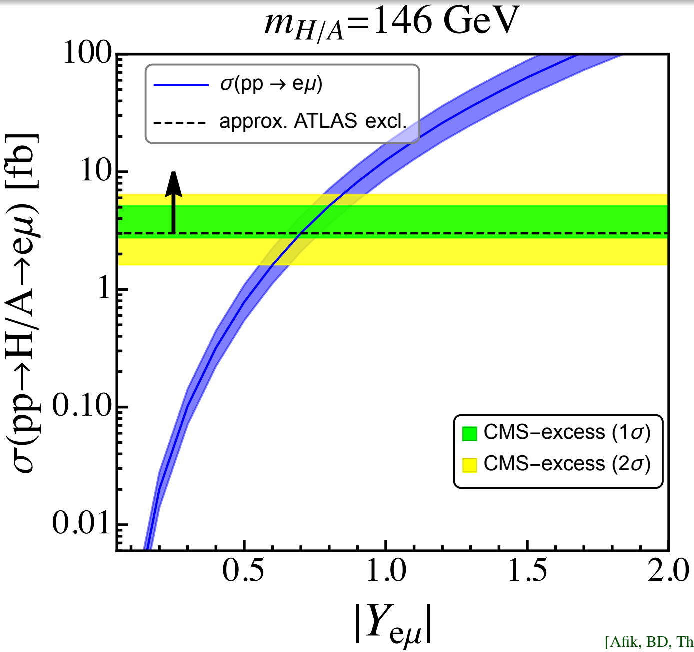

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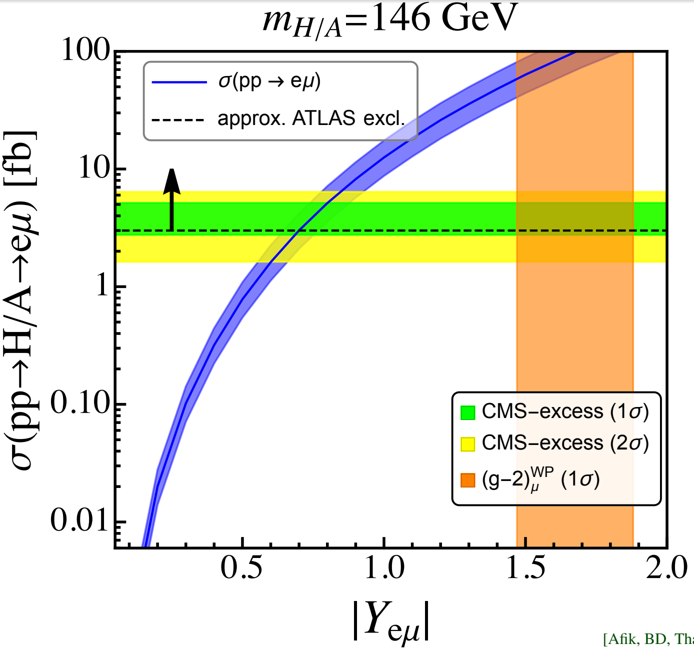
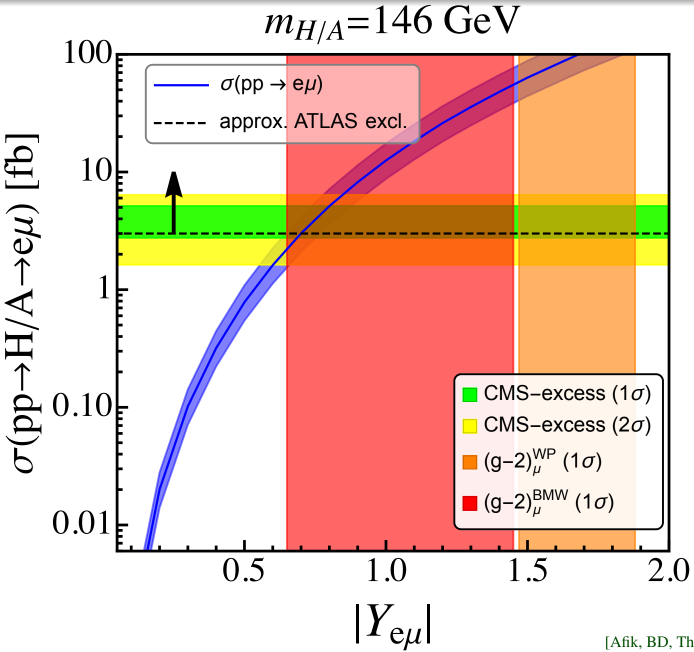
How about muon $g-2$?



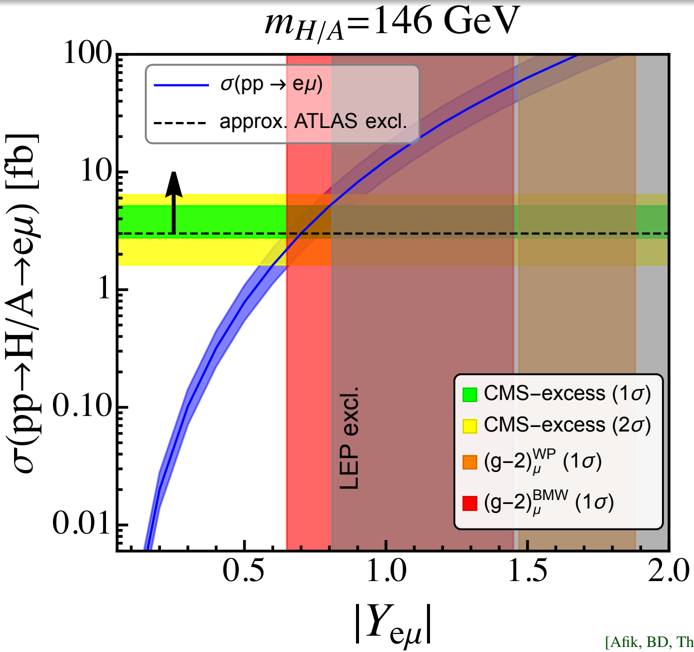
[Afik, BD, Thapa, 2305.19314]

BMW fits better than WP



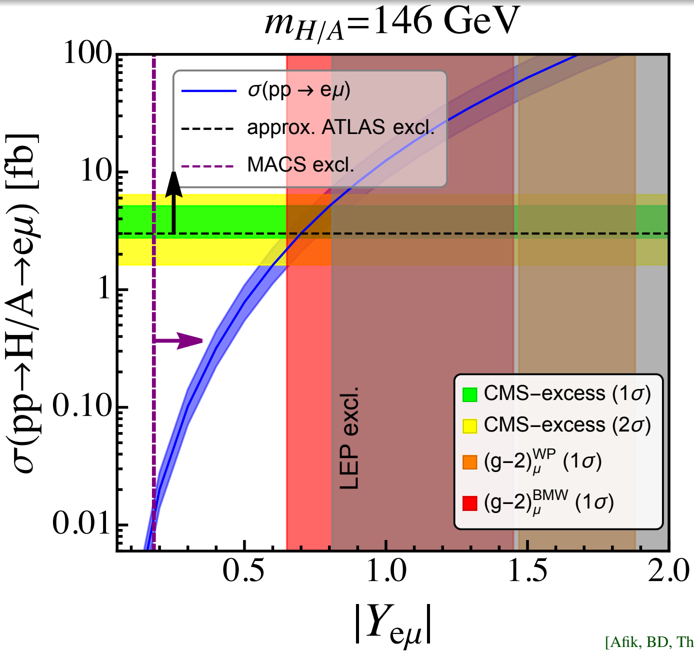
[Afik, BD, Thapa, 2305.19314]

LEP dimuon constraint



[Afik, BD, Thapa, 2305.19314]

Muonium-antimuonium oscillation is the killer



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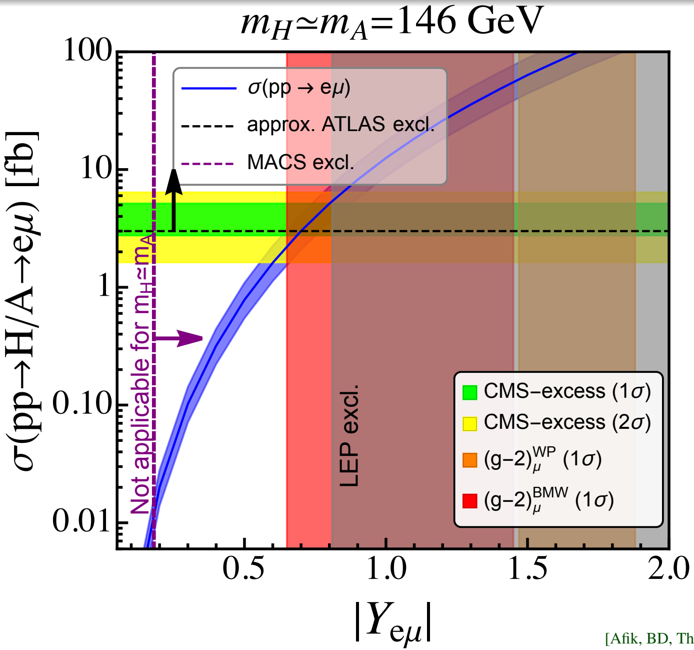
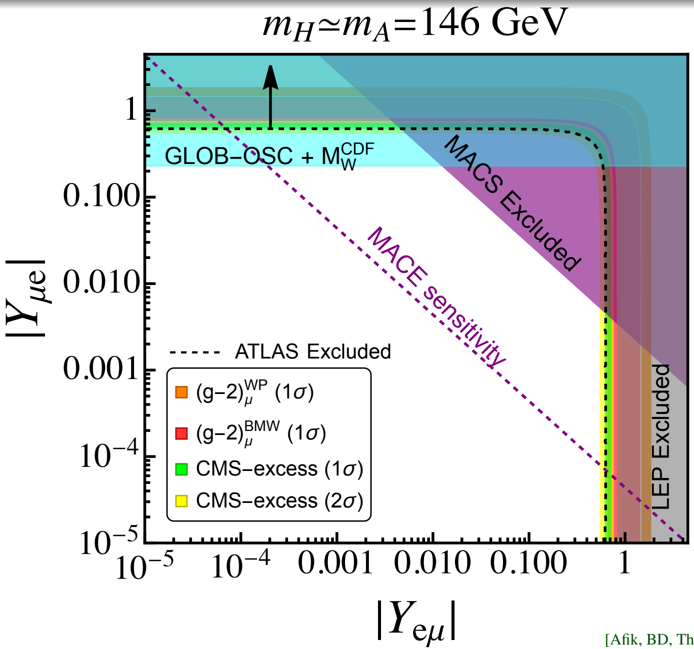
Can be evaded for a degenerate scalar spectrum



[Afik, BD, Thapa, 2305.19314]

LFV in the Higgs sector, but no cLFV at tree level



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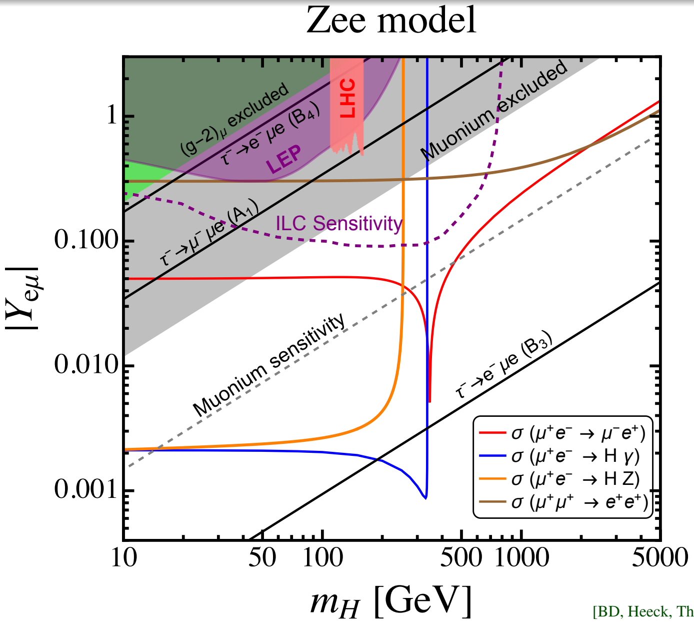
Future lepton collider prospects of leptophilic Higgs

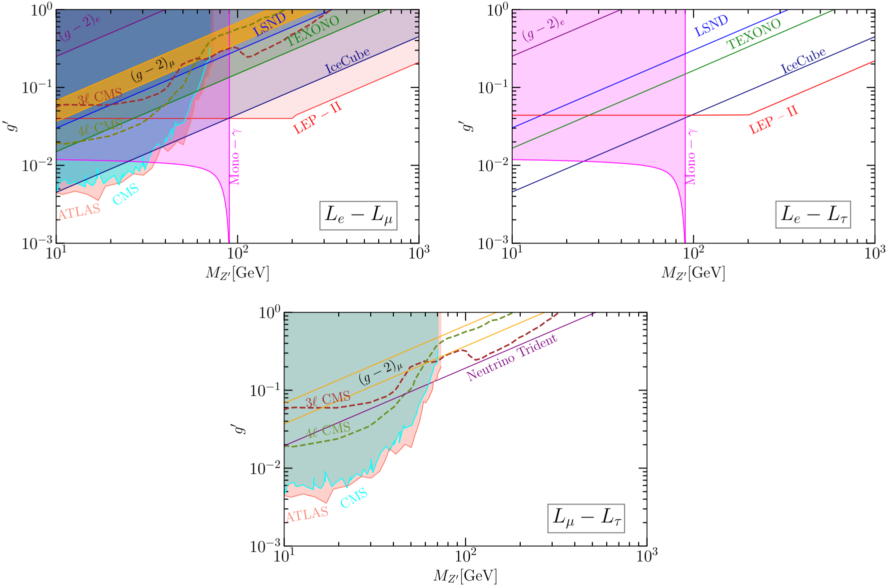


[BD, Heeck, Thapa, 2309.06463]

μTRISTAN [Hamada, Kitano, Matsudo, Takaura, Yoshida 2201.06664;]

LFV Z' in $U(1)_{L_\alpha - L_\beta}$: Current constraints

$$\mathcal{L} \supset g' Z'_\mu (\bar{L}_\alpha \gamma^\mu L_\alpha + \bar{e}_{R,\alpha}\gamma^\mu e_{R,\alpha} - \bar{L}_\beta \gamma^\mu L_\beta - \bar{e}_{R,\beta}\gamma^\mu e_{R,\beta}).$$



[Dasgupta, BD, Han, Padhan, Wang, Xie, 2308.12804 (JHEP '23)]

LFV Z' in $U(1)_{L_\alpha - L_\beta}$: Future collider prospects

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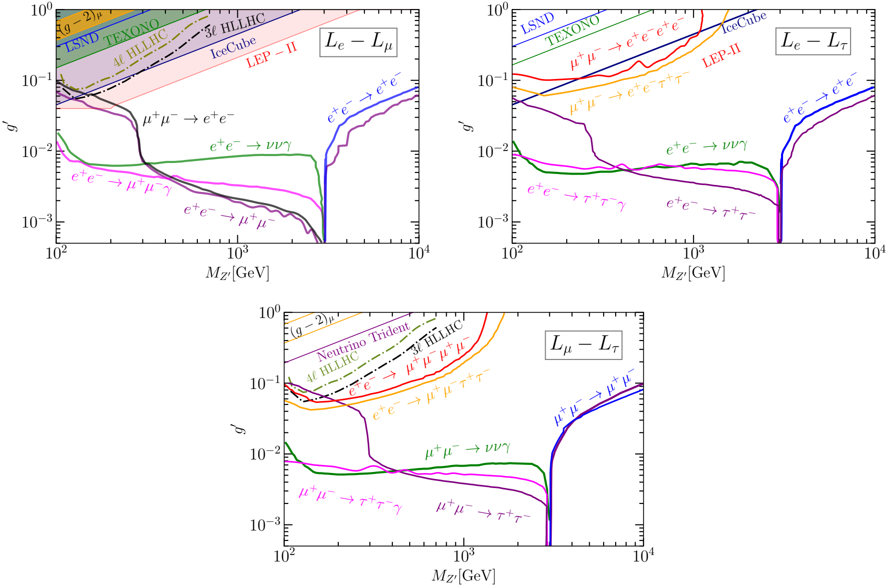
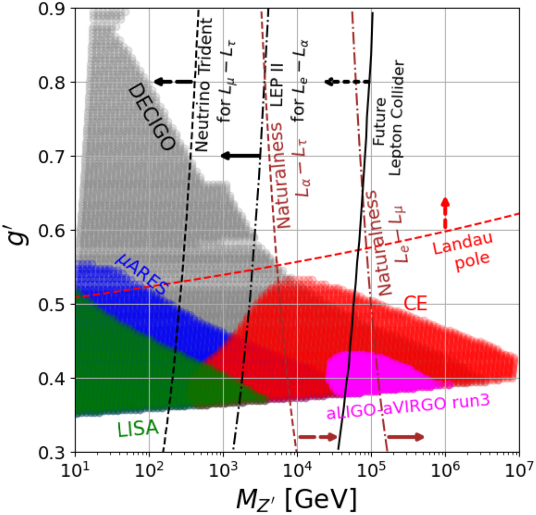


[Dasgupta, BD, Han, Padhan, Wang, Xie, 2308.12804 (JHEP '23)]

Gravitational wave signal

First-order phase transition if scalar sector is conformally invariant:

$$V_{\text{tree}} = \lambda_H (H^\dagger H)^2 + \lambda(\Phi^\dagger\Phi)^2 - \lambda'(\Phi^\dagger\Phi)(H^\dagger H)\,.$$



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Conclusions

- LFV is a ‘smoking gun’ signal of BSM physics.
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- We covered the possibility of LFV originating from the Higgs and vector portal scenarios.

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- We covered the possibility of LFV originating from the Higgs and vector portal scenarios.
- The recent CMS $e\mu$ excess is an intriguing hint of LFV. [Update at Moriond ’24?]
- A flavorful way to BSM physics?