Universidade do Minho
Escola de Ciências

Hints of new physics from composite Higgs models

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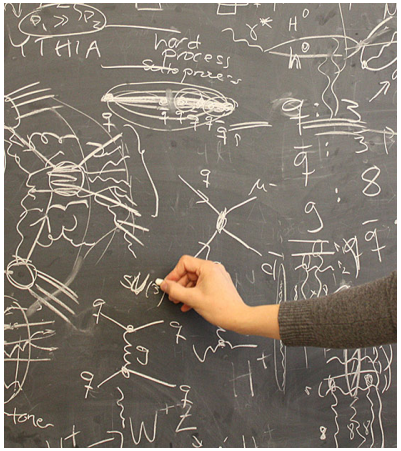
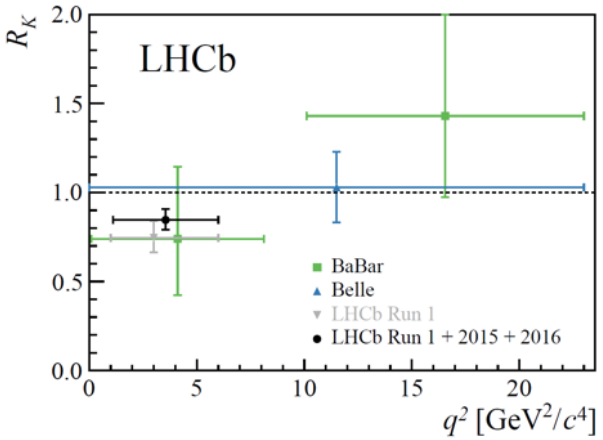
Based on 2005.09594 and 2005.09655

Where is NP?



Null results so far.

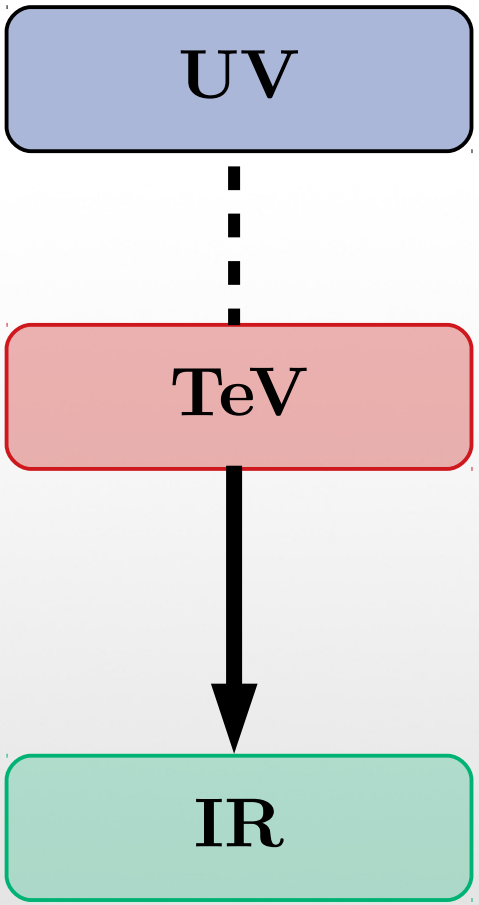
There should be NP near the TeV.



Look somewhere else:

(i) non-minimal predictions (ii) new signal regions (iii) experimental prospects

Composite phenomenology



$$\mathcal{L}_{E\leftrightarrow C} = \lambda q \overline{Q}$$

$\sim \rho_{\rm QCD}$ V_μ, B, T

$\sim \pi_{\rm QCD}$ $H,\ S,\ \eta^2,\ \ldots$

$m_h^2 \sim \lambda^2 m_T^2/(4\pi)^2$

Non-minimal signatures

1. There can be extra d.o.f. below the EW scale. (Pseudo-) scalar singlets are promising candidates.

Novel top decays; RGEs of SM+a EFT.* *ongoing work

2. Heavy vector-light scalar couplings naturally arise.

Exotic B-decays. [1907.13151]

3. New exotic channels open for the heavy quarks and leptons of the composite sector.

New collider signals of VLL.

VLL EFT and its collider signals

M.Chala, P Kozów, **M.R.**, A.Titov

Search for type-III Seesaw heavy leptons in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector

The ATLAS Collaboration

Abstract

A search for the pair-production of heavy leptons ($N^0, L^\pm$) predicted by the type-III seesaw theory formulated to explain the origin of small neutrino masses is presented. The decay channels $N^0 \to W^\pm l^\mp$ ($\ell = e, \mu, \tau$) and $L^\pm \to W^\pm \nu$ ($\nu = \nu_e, \nu_\mu, \nu_\tau$) are considered. The analysis is performed using the final state that contains two leptons (electrons or muons), two jets from a hadronically decaying W boson, and large missing transverse momentum. The data used in the measurement correspond to an integrated luminosity of $20.3\,\text{fb}^{-1}$ of pp collisions at $\sqrt{s} = 8$ TeV collected by the ATLAS detector at the LHC. No evidence of heavy lepton pair-production is observed. Heavy leptons with masses below 325–540 GeV are excluded at the 95% confidence level, depending on the theoretical scenario considered.

1506.01839 (ATLAS), 1511.01407 (CMS), 1506.01291 (ATLAS), 1905.10853 (CMS), 1911.04968 (CMS)...

Unlike most searches assume, it can be that the VLLs:

(i) are mostly single produced;

(ii) populate mainly the p.s. of large E;

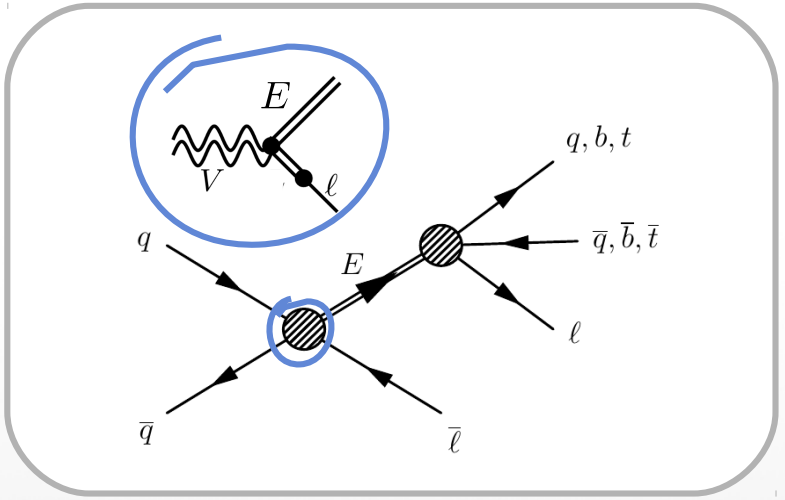
(iii) do not decay into SM gauge bosons.

We study these signatures in an EFT.

VLL EFT and its collider signals

$y<0.1$ by EWPD.

$$\mathcal{L} = y\overline{l_L} H E + \frac{c_i}{\Lambda^2} \left(\overline{q}\gamma^\mu q\right) \left(\overline{\ell}\gamma_\mu E\right)$$



Single production is the key:

$$\sigma_{EFT} \sim \frac{E^2}{\Lambda^4} \quad \text{vs} \quad \sigma_{SM} \sim \frac{1}{E^2}$$

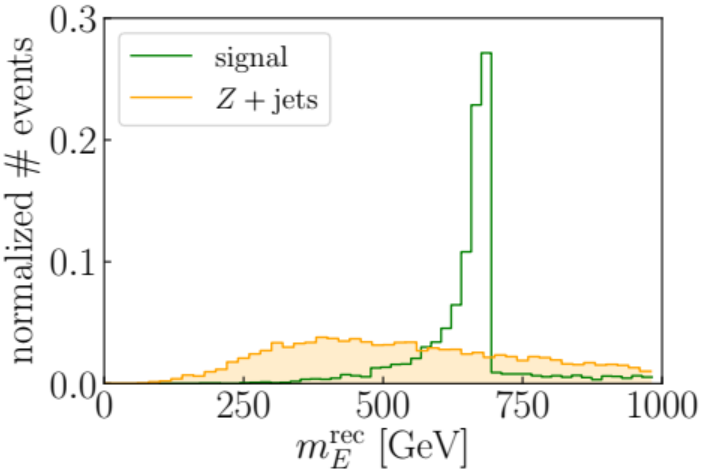
$$\frac{d\sigma}{d\theta} = \frac{\sin\theta}{32\pi s}\left(1-\frac{m_E^2}{s}\right)\frac{1}{3\Lambda^4}\left[s\left(s-m_E^2\right)\left(\frac{c_{qul}^2}{4}+c_{ue}^2\right)+t\left(t-m_E^2\right)\left(\frac{c_{luq}^2}{4}+c_{ue}^2+c_{qe}^2\right)+\ldots\right]$$

Master equation: $$N = \frac{1}{\Lambda^4}\left[I_1^u\left(\frac{c_{qul}^2}{4}+c_{ue}^2\right)+I_2^u\left(\frac{c_{luq}^2}{4}+c_{ue}^2+c_{qe}^2\right)+\ldots\right]$$

by recasting search for excited lepton to l+jj [CMS, 2001.04521]

Overcome of current limitations

2. Improved analysis by cutting on a new observable and including 3rd generation quarks.

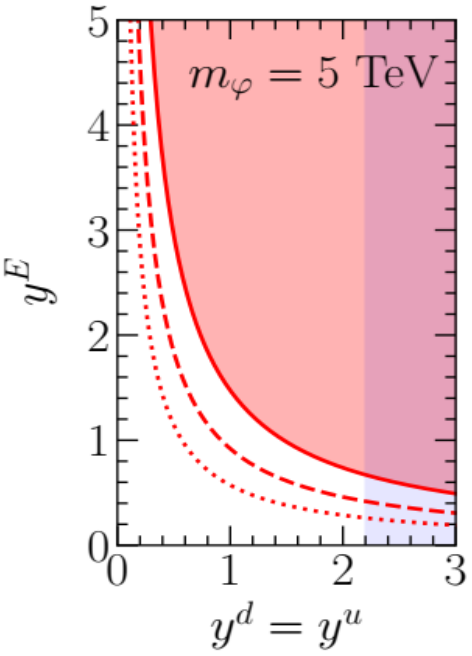


3. The validity of the EFT is assured for NP scales below 10 TeV (and ops. involving only sea-quarks).

The most constrained Wilsons reach 0.05 TeV^{-2}.

1. All operators can be taken into account.

$$J_\varphi = y^E \overline{E} l_L + y^d \overline{d_R} q_L + y^u i\sigma_2 \overline{q_L}^T u_R$$



Novel signatures of rare top decays

N.Castro, M.Chala, A.Peixoto, **M.R.**

$$t \to Sc/u, \; S \to \ell^+\ell^-$$

Top: huge production rate @LHC and @HL-LHC.

Pseudoscalar: very hard to detect (singlet & EDM constraints).

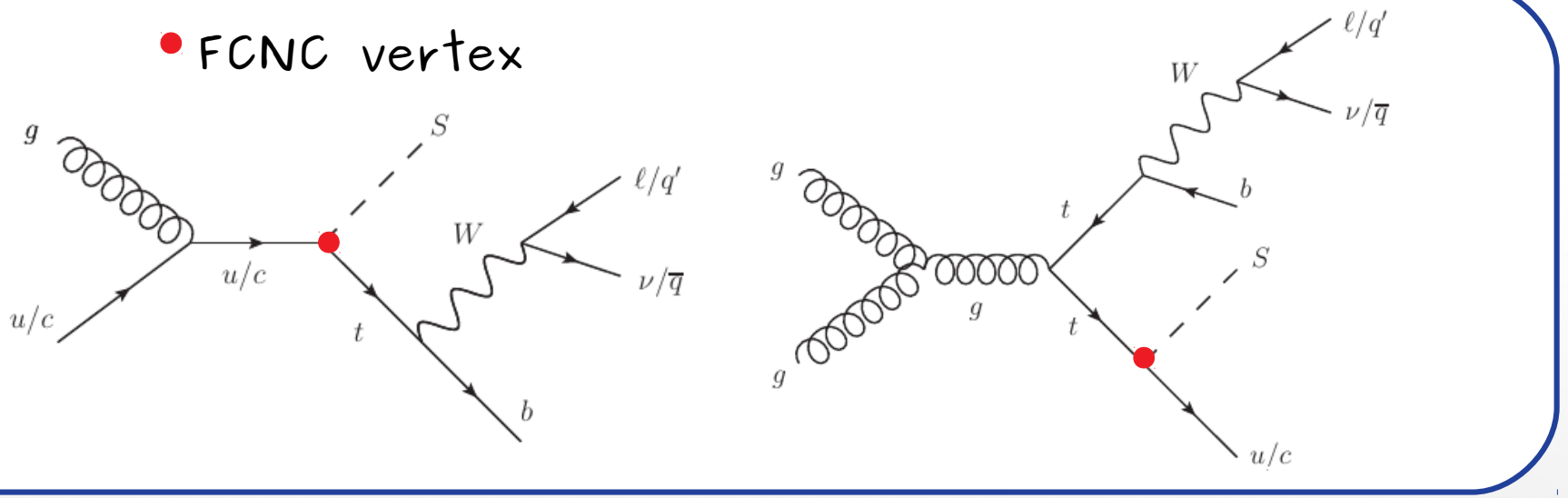
Why rare?

FCNCs are highly suppressed in the SM (by loops & CKM & GIM).
Therefore, the ideal place to search NP.

$$\mathcal{L} \supset \frac{1}{\sqrt{2}} \overline{u_L^I} h u_R^J \left[y_{IJ}^{(1)} \left(-1 + i\gamma \frac{S}{\Lambda} + \frac{h^2}{2\Lambda^2} + \frac{S^2}{2\Lambda^2} \right) + y_{IJ}^{(2)} + \ldots \right]$$

Production and analysis strategy

*muons channel

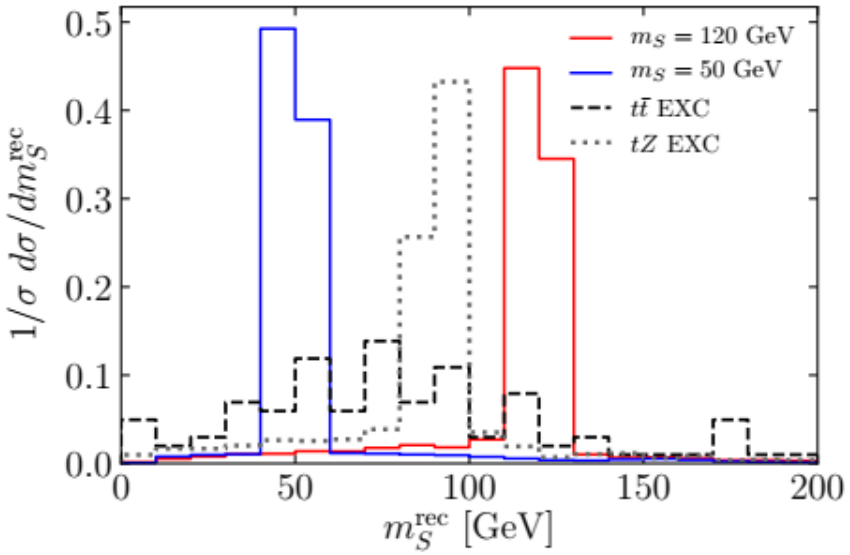


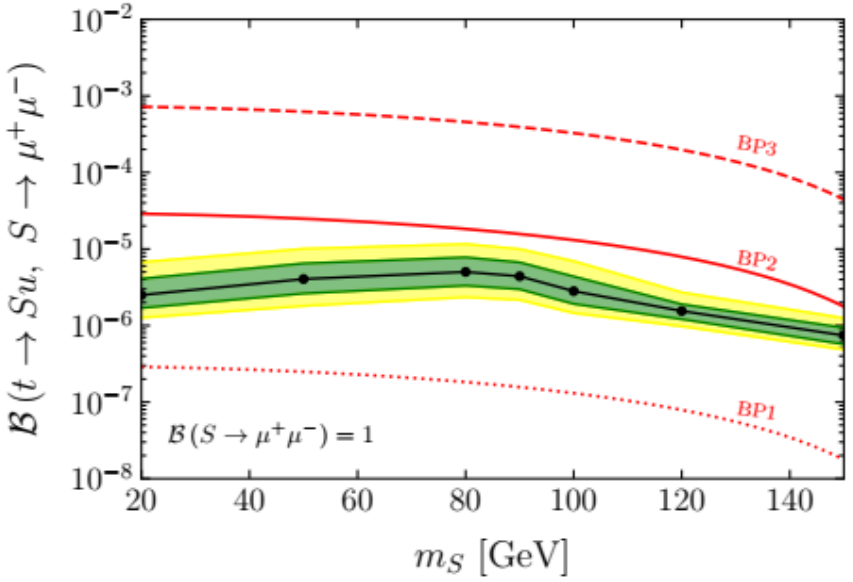
1. We require three light leptons and at least one jet (one of them b-tagged).

2. We reconstruct the scalar mass from the hardest muon pair. We reconstruct the leptonic top invariant mass.

3. The mass of the total system is required to be **below 1 TeV**.

Upper limits on BR with L=150/fb





NP scales as large as 90 (75) TeV can be probed with 95 % CL in the muons (taus) channel.

Recasting the search for top to Zq [*ATLAS*, 1803.09923], $O(20)$ TeV scales are ruled out.

Conclusions

- CHMs are a rich and predictive framework with important **low-energy consequences**.

- VLLs can be mostly single produced and decay via dim-6 four fermions interactions. **New dedicated analyses** (with b and t) are important, as well as a multiple-operator interpretation.

- Top FCNCs via extra scalars are promising channels to search NP. In the leptonic channel, $O(100)$ TeV scales could be probed @HL-LHC. Prospects are also presented for the motivated $t \to SSq$ decay.*backup

- Almost none of the non-minimal predictions have been searched for experimentally.

This is an important time to find motivation for new signal searches.

Thank you!

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Backup slide

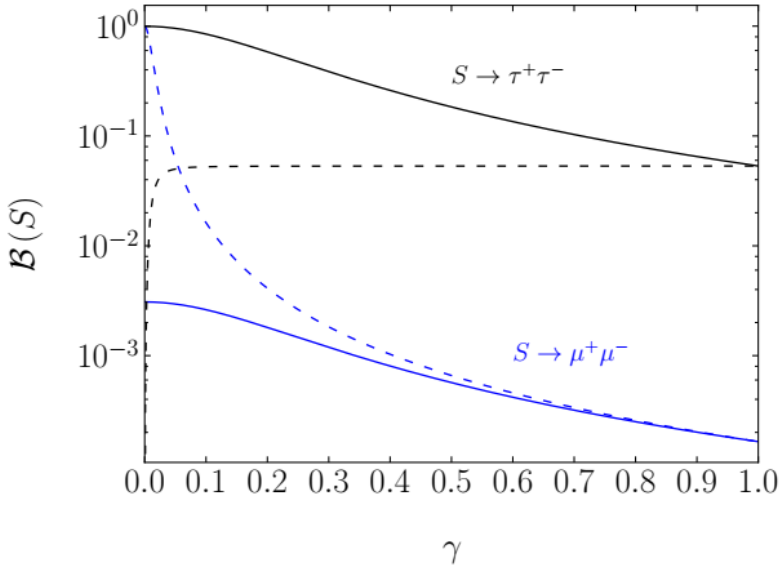
Motivation for SS decays

Assuming leptonic decay & top production is NOT generic.

(Requires that only $\mathbf{Y}^{q}_{i3,}$ $\mathbf{Y}^{q}_{3i}$ and $\mathbf{Y}^{l}_{jj}$ are non-zero.)

Prospects are very different if the shift symmetry is only (mostly) broken in the lepton sector. Then:

$$t \to q^i SS$$



Scales as large as 2 TeV can be probed with 150 fb^{-1}.