Anomalies in Bottom from New Physics in Top

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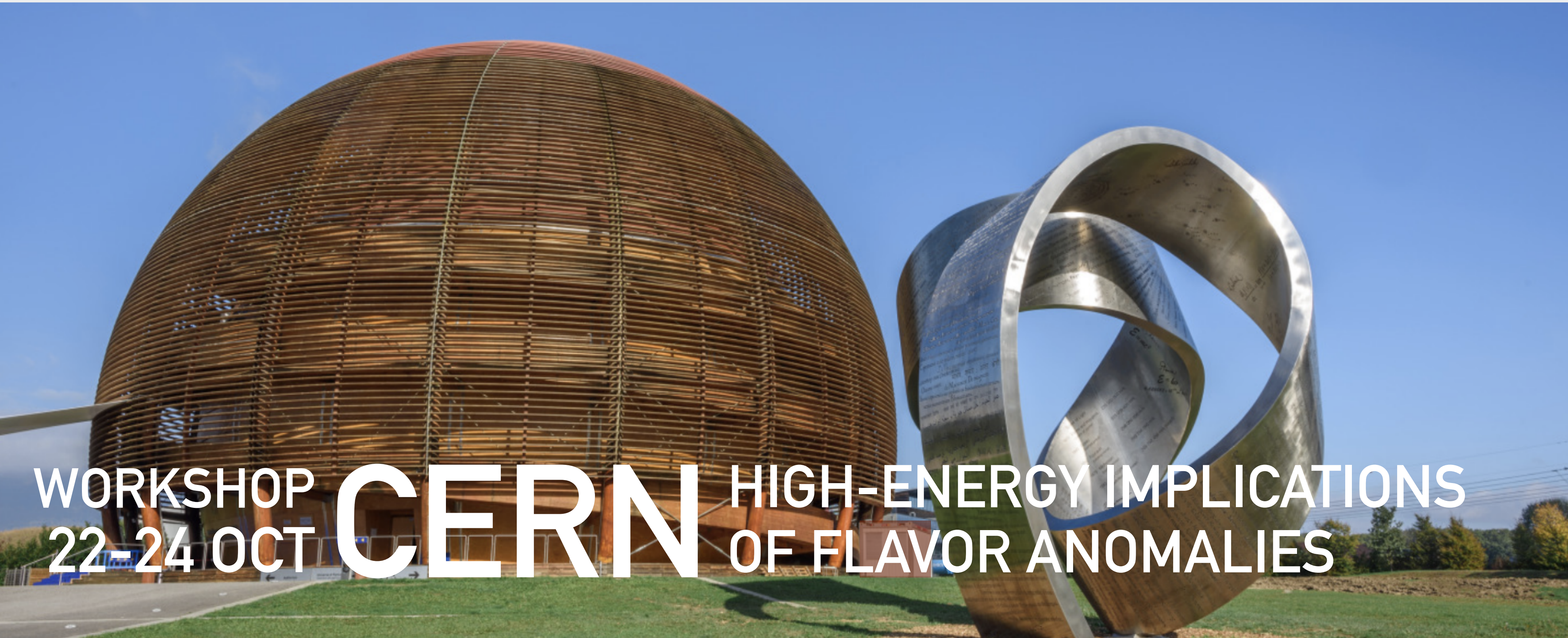
Based on: 1805.04917
Camargo-Molina, Celis, DAF



(Loop) New Physics in b→sll

Hints of Lepton Universality Violation (LFU) $R_{K^{(*)}}$

LFU ratio electron/ muon at LHCb

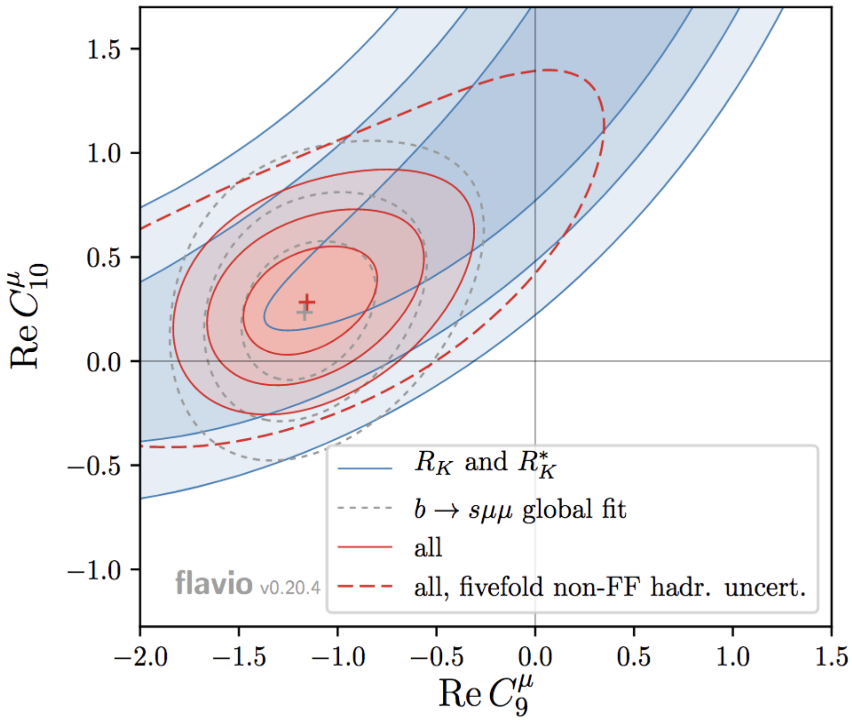
$\sim 4\,\sigma$ deviation

Semi-leptonic vectorial operators $B \to K^{(*)}\ell\bar{\ell}$

$$\mathcal{O}_9 = (\bar{s}_L\gamma^\mu b_L)\,(\bar{\ell}\gamma^\mu\ell) \qquad \mathcal{O}'_9 = (\bar{s}_L\gamma^\mu b_L)\,(\bar{\ell}\gamma^\mu\gamma_5\ell)$$
$$\mathcal{O}_{10} = (\bar{s}_R\gamma^\mu b_R)\,(\bar{\ell}\gamma^\mu\ell) \qquad \mathcal{O}'_{10} = (\bar{s}_R\gamma^\mu b_R)\,(\bar{\ell}\gamma^\mu\gamma_5\ell)$$

$$\mathcal{H}_{eff}^{NP} = -\frac{\alpha\, G_F}{\sqrt{2}\pi} V_{ts}^* V_{tb} \sum_i (\mathcal{C}_i\mathcal{O}_i + \mathcal{C}'_i\mathcal{O}'_i) + \text{h.c.}$$

New Physics (NP) preferentially in muons



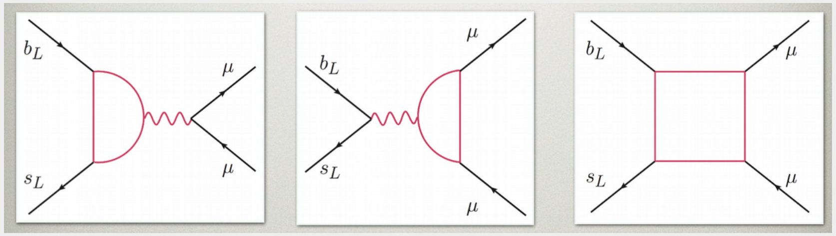
Loop-level solutions:

Low NP scale (loop suppression): $\Lambda \sim \mathcal{O}(1)\,\text{TeV}$

Strong case for LHC searches. ...maybe too strong?

Light NP more easily hidden in top sector.

This talk: top-philic 1-loop models.



Gripaios, Nardecchia, Renner [1509.05020]
Bauer, Neubert [1511.01900]
Bélanger, Delaunay [1603.03333]
Becirevic, Sumensari [1704.05835]
Kamenik, Soreq, Zupan [1704.06005]

B-anomaly from 'Top-philia'

Main assumptions:

- i) **Top-philia:** dominant NP couplings to right-handed tops in quark sector.
- ii) NP couples dominantly to muons in lepton sector.
- iii) NP scale at the TeV (LHC accessible)

SMEFT:

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{i,d} \frac{c_i}{\Lambda^{d-4}} \mathcal{O}_i$$

2 Fermi operators (LLRR RRRR)

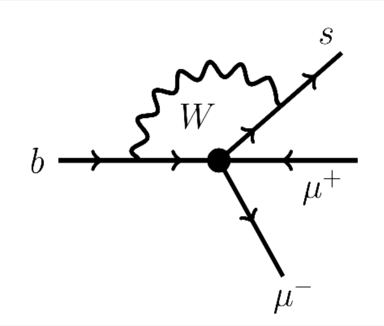
$$[\mathcal{O}_{eu}]_{\mu\mu tt} = (\bar{\mu}_R \gamma^\alpha \mu_R)(\bar{t}_R \gamma_\alpha t_R)$$

$$[\mathcal{O}_{\ell u}]_{\mu\mu tt} = (\bar{\ell}_\mu \gamma^\alpha \ell_\mu)(\bar{t}_R \gamma_\alpha t_R)$$

$$\ell_\mu = (\nu_\mu, \mu_L)^T$$

B-anomaly:

- Generates LFU violation at the 1-loop level
- Predicts 'V-A' stucture for quark current
- Only source of flavor violation is the CKM (MFV)



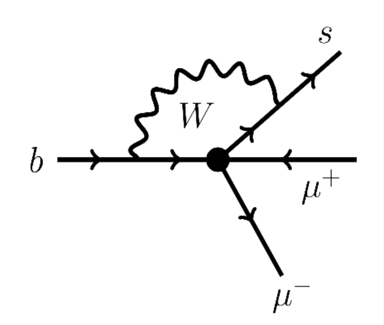
Low-energy phenomenology

$b \to s\mu\bar{\mu}$ from $\mathcal{O}_{\ell u}$ $\mathcal{O}_{eu}$

$$\mathcal{H}^{NP}_{eff} = -\frac{\alpha\, G_F}{\sqrt{2}\pi} V^*_{ts} V_{tb}\, [\mathcal{C}_9 (\bar{s}_L \gamma_\alpha b_L)(\bar{\mu}\gamma^\alpha \mu) + \mathcal{C}_{10} (\bar{s}_L \gamma_\alpha b_L)(\bar{\mu}\gamma^\alpha \gamma_5 \mu)] + \text{h.c.}$$

$$\mathcal{C}_9 \simeq \frac{\alpha}{8\pi}\left(\frac{m_t^2}{\Lambda^2}\right) \log\left(\frac{\Lambda}{M_W}\right) [\mathcal{C}_{eu} + \mathcal{C}_{\ell u}] \; + \; \ldots$$

$$\mathcal{C}_{10} \simeq \frac{\alpha}{8\pi}\left(\frac{m_t^2}{\Lambda^2}\right) \log\left(\frac{\Lambda}{M_W}\right) [\mathcal{C}_{eu} - \mathcal{C}_{\ell u}] \; + \; \ldots$$



Keeping the leading log from RGE

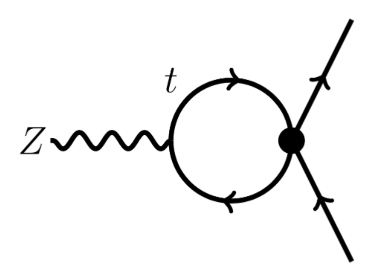
$Z \to \mu\bar{\mu}$

$$\mathcal{L} = \frac{g}{c_W} \bar{\mu}\gamma_\alpha (\delta g_L P_L + \delta g_R P_R)\mu Z^\alpha$$

Modified Z coupling to muons

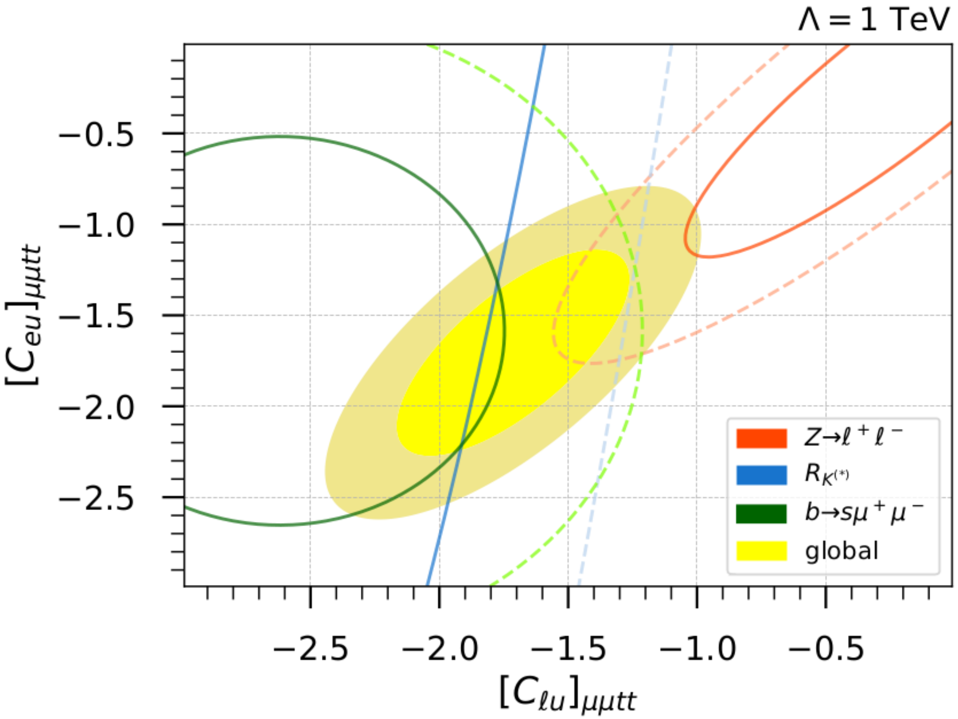
$$\delta g_L \simeq \frac{3}{4\pi^2}\left(\frac{m_t^2}{\Lambda^2}\right) \log\left(\frac{\Lambda}{m_t}\right) \mathcal{C}_{\ell u} \; + \; \ldots$$

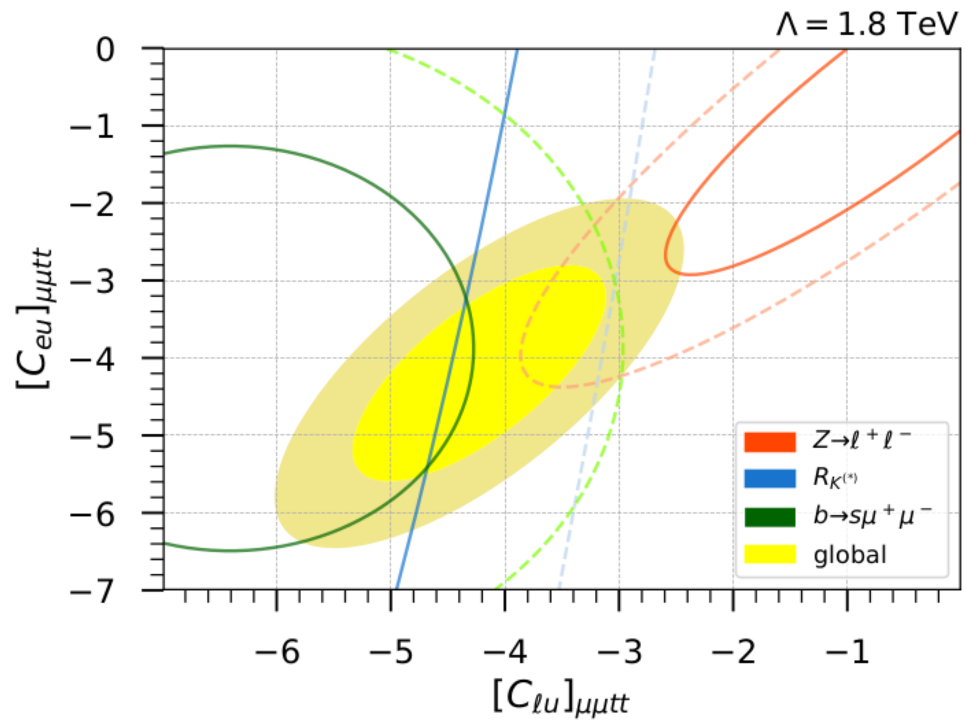
$$\delta g_R \simeq \frac{3}{4\pi^2}\left(\frac{m_t^2}{\Lambda^2}\right) \log\left(\frac{\Lambda}{m_t}\right) \mathcal{C}_{eu} \; + \; \ldots$$



Relevant constraints from LEP :
LFU tests & forward-background asymmetry measuerments.

Less relevant constraints from $b \to s\nu\nu$





Camargo-Molina, Celis, DAF 1805.04917

TABLE I. *Contribution to the χ^2 from each sector at the minimum of the global χ^2 and in the SM.*

χ^2	$b\to s\mu^+\mu^-$	$R_{K^{(*)}}$	$Z\to\ell^+\ell^-$
SM	25.8	22.5	0.5
$\Lambda = 1$ TeV	2.5	5	7.9
$\Lambda = 1.5$ TeV	2.5	5	7.8
$\Lambda = 1.8$ TeV	2.4	5	7.8

Prefered region: $\mathcal{C}_{\ell u} \sim \mathcal{C}_{eu} < 0$

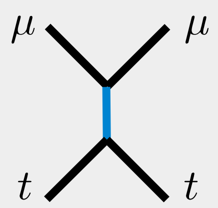
Vectorial coupling to muons!

Some tension with EWPT

LHC: simplified models

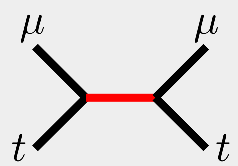
EFT description may break down at the LHC…
NP Mediators needed for more reliable studies.
Caution: not UV complete.

Colorless



Top-philic $Z' \sim (\mathbf{1},\mathbf{1},0)$

Colorful



Leptoquarks (LQ)
Leptotops

Leptoquark Bestiary:

$(SU(3), SU(2), U(1))$	Spin	Symbol
$(\bar{\mathbf{3}},\mathbf{3},1/3)$	0	S_3
$(\mathbf{3},\mathbf{2},7/6)$	0	R_2
$(\mathbf{3},\mathbf{2},1/6)$	0	$\tilde{R}_2$
$(\bar{\mathbf{3}},\mathbf{1},4/3)$	0	$\tilde{S}_1$
$(\bar{\mathbf{3}},\mathbf{1},1/3)$	0	S_1
$(\bar{\mathbf{3}},\mathbf{1},-2/3)$	0	$\bar{S}_1$
$(\mathbf{3},\mathbf{3},2/3)$	1	U_3
$(\bar{\mathbf{3}},\mathbf{2},5/6)$	1	V_2
$(\bar{\mathbf{3}},\mathbf{2},-1/6)$	1	$\tilde{V}_2$
$(\mathbf{3},\mathbf{1},5/3)$	1	$\tilde{U}_1$
$(\mathbf{3},\mathbf{1},2/3)$	1	U_1
$(\mathbf{3},\mathbf{1},-1/3)$	1	$\bar{U}_1$

Dorsner, Fajfer, Greljo, Kamenik, Kosnik
[Phys.Rept. 641 (2016) 1-68]

5 LQs couple to RH top

Which Top-philic Mediators?

	Z'	S_1	R_2	$\widetilde{U}_1$	$\widetilde{V}_2$
$[\mathcal{O}_{\ell u}]_{\mu\mu tt}$	✓	✗	✓	✗	✓
$[\mathcal{O}_{eu}]_{\mu\mu tt}$	✓	✓	✗	✓	✗
$\mathcal{C}_{\ell u}, \mathcal{C}_{eu} < 0$	✓	✗	✓	✓	✗

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Only one single mediator solution: Z'
Two LQ solution: 1 vector + 1 scalar

$\widetilde{U}_1^{\mu} \sim (\mathbf{3},\mathbf{1},5/3) \quad R_2 \sim (\mathbf{3},\mathbf{2},7/6)$

Do NOT confuse with Pati-Salam LQ! $U_1 \sim (\mathbf{3},\mathbf{1},2/3)$

Simplified Top-philic Z' model:

$$\mathcal{L}_{Z'} = \frac{1}{4} Z'_{\alpha\beta} Z'^{\alpha\beta} - \frac{1}{2} M_{Z'} Z'_{\alpha} Z'^{\alpha} + Z'_{\alpha} \Big[\epsilon_R^{tt} (\bar{t}_R \gamma^\alpha t_R) + \epsilon_R^{\mu\mu} (\bar{\mu}_R \gamma^\alpha \mu_R) + \epsilon_L^{\mu\mu} (\bar{\ell}_\mu \gamma^\alpha \ell_\mu) \Big]$$

1 mass + 3 couplings

$\ell_\mu \equiv (\nu_\mu, \mu_L)^T$

Matching conditions: $\mathcal{C}_{\ell u} = -\epsilon_R^{tt} \epsilon_L^{\mu\mu}\,, \quad \mathcal{C}_{eu} = -\epsilon_R^{tt} \epsilon_R^{\mu\mu}$

Fit prefers vectorial muonic couplings: $\epsilon_V^{\mu\mu} \equiv \epsilon_R^{\mu\mu} = \epsilon_L^{\mu\mu}$

UV completion: Top-philic U(1)’ models

Kamenik, Soreq, Zupan [1704.06005]
Fox, Low, Zhang [1801.03505]

Simplified Top-philic LQ model: $\widetilde{U}_1^\mu \sim (\mathbf{3}, \mathbf{1}, 5/3) \quad R_2 \sim (\mathbf{3}, \mathbf{2}, 7/6)$

$$\mathcal{L}_{\rm LQ} = (D_\alpha R_2)^\dagger (D^\alpha R_2) - \frac{1}{2} \widetilde{U}^\dagger_{\alpha\beta} \widetilde{U}^{\alpha\beta} - i g_s \widetilde{U}^\dagger_\alpha G^{\alpha\beta} \widetilde{U}_\beta + \kappa_S\, \bar{t}_R (R_2^T i\tau_2 \ell_\mu) + \kappa_V\, (\bar{t}_R \gamma^\alpha \mu_R) \widetilde{U}_\alpha + \text{h.c.}$$

2 masses + 2 couplings

$R_2 = (R_2^{(5/3)}, R_2^{(2/3)})^T$

$\ell_\mu \equiv (\nu_\mu, \mu_L)^T$

Matching conditions: $\mathcal{C}_{\ell u} = -|\kappa_S|^2/2\,, \quad \mathcal{C}_{eu} = -|\kappa_V|^2$

We forbid the Yukawa term: $\bar{\mu}_R R_2^\dagger Q_L^3$ (e.g. assume symmetry in the UV)

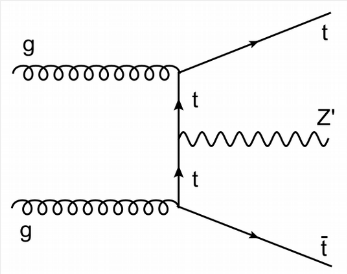
vector LQ: only RH couplings

UV completion: none yet...

Z' Phenomenology

Direct searches at Colliders:

$$pp \to t\bar{t}Z'$$



$$pp \to t\bar{t}t\bar{t}$$
$$pp \to t\bar{t}\mu\bar{\mu}$$
$$pp \to t\bar{t}\nu\bar{\nu}$$

4-tops at LHC:

CMS $35.9\,\text{fb}^{-1}$ Eur. Phys. J. C78 (2018) no.2, 140

$$\sigma^{\text{NP}}(t\bar{t}t\bar{t}) < 32\,\text{fb at } 95\%,\text{CL}$$

$tt\mu\bar{\mu}$ production: no search yet...

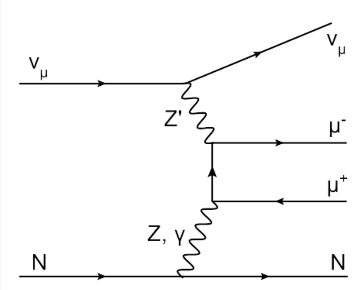
We recast Z' di-muon inclusive searches

ATLAS $36.1\,\text{fb}^{-1}$ $pp \to \mu^+\mu^- + X$

JHEP 10 (2017) 182

Low-energy:

neutrino tridents $\nu_\mu\gamma^* \to \nu_\mu\mu^+\mu^-$



Altmannshofer, Gori, Pospelov, Yavin [1406.2332]

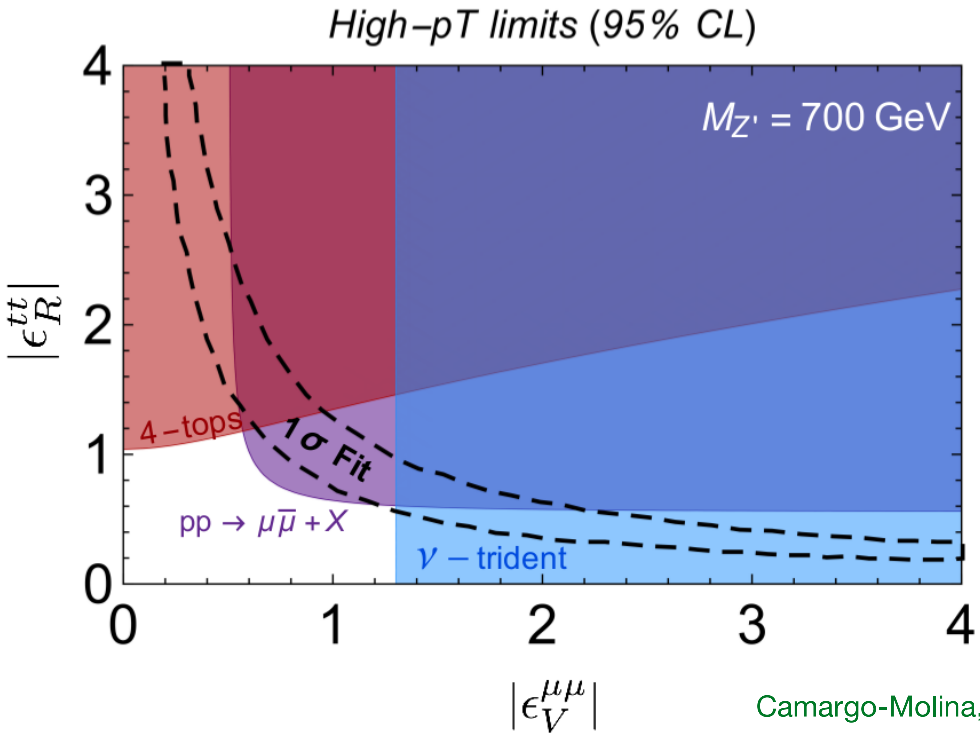
$$\frac{\sigma^{\text{NP}}_{\nu_\mu\mu\bar{\mu}}}{\sigma^{\text{SM}}_{\nu_\mu\mu\bar{\mu}}} = \frac{1 + \left(1 + 4s^2_{\theta_W} + \frac{2v^2\,(\epsilon_V^{\mu\mu})^2}{M^2_{Z'}}\right)^2}{1 + (1 + 4s^2_{\theta_W})^2}.$$

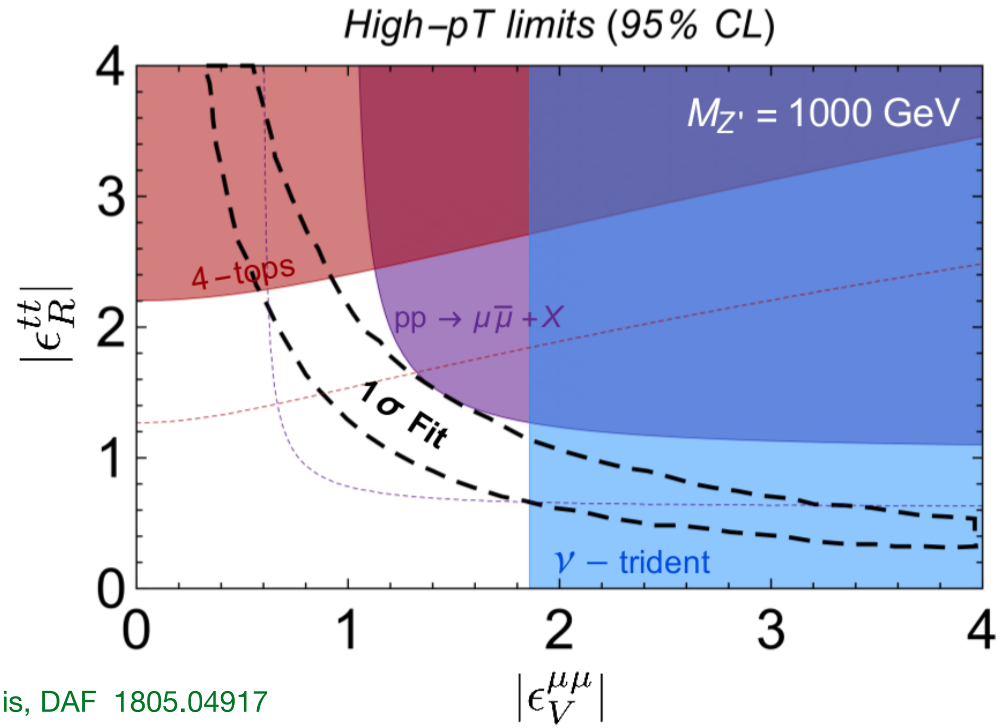
Probed at fixed target neutrino dump experiments

CCFR collaboration measurement

$$\sigma^{\text{NP}}_{\nu_\mu\mu\bar{\mu}}/\sigma^{\text{SM}}_{\nu_\mu\mu\bar{\mu}} = 0.82 \pm 0.28$$

Phys. Rev. Lett 66 (1991) 3117





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Nice high-pT / low-energy complementarity!

- For 4-top projections at 300/fb: $\sigma^{\rm NP}(t\bar{t}t\bar{t}) < 23\,{\rm fb~at~95\%~CL}$

  Alvarez, DAF, Kamenik, Morales, Szynkman [Nucl. Phys. B 915 19 (2017)]

- LHC can probe parameter space relevant for the B-anomaly

Request for experimentalist:
Perform dedicated search for $pp \to t\bar{t}Z' \to t\bar{t}\mu\bar{\mu}$ (low and high mass Z')

Four-tops for LHC

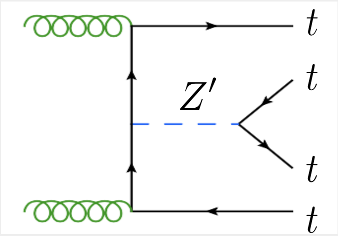
Alvarez, DAF, Kamenik, Morales, Szynkman [Nucl. Phys. B 915 19 (2017)]

What about light NP?

- 4 tops: probe for non-resonant top-philic forces

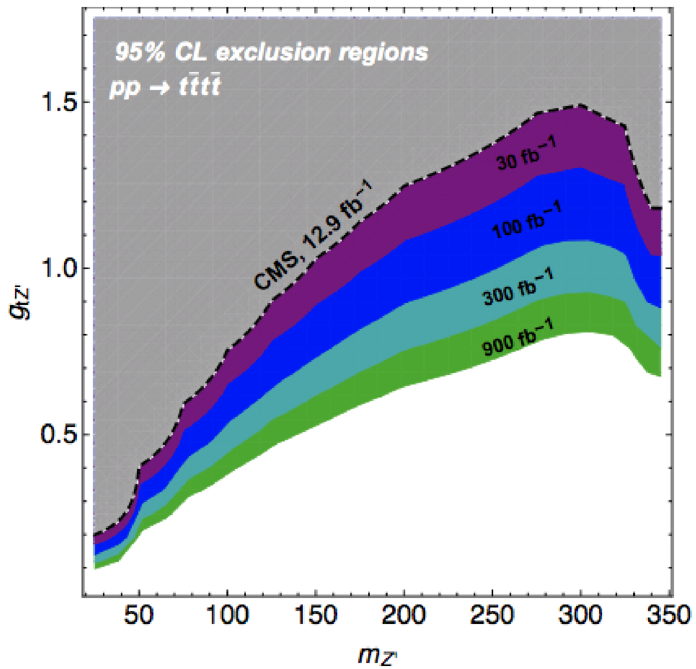
$$\mathcal{L} \supset -g_{tZ'} Z'_\mu \left(\bar{t}_R \gamma^\mu t_R\right)$$

$$m_{Z'} < 2m_t$$



- Large enhancment in 4-top cross-section $\sigma^{\rm SM}_{t\bar{t}t\bar{t}} = 12 \text{ fb}$

Request for experimentalist:
Recast SM 4-top search for top-philic Z' solution for B-anomaly. I can provide model files, etc...



[Nucl. Phys. B 915 19 (2017)]

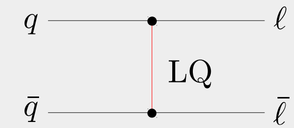
“Leptotop” Pheno: $R_2\,,\ \widetilde{U}_\mu$

- Main LQ production mechanisms at hadron colliders:

Pair production
$pp \to \mathrm{LQ}^\dagger \mathrm{LQ}$

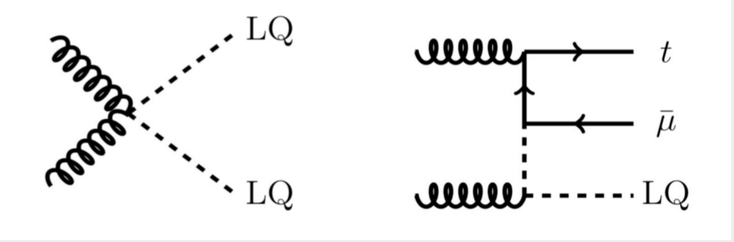
Single production
$pp \to \mathrm{LQ}\,\ell$

Drell-Yan
$pp \to \ell\bar{\ell}$



- Implication of no tops inside proton:

i) Pair production is completely QCD driven.
ii) No t-channel Drell-Yan production.
iii) No $2 \to 2$ single LQ production.



- Branching ratios in this model:

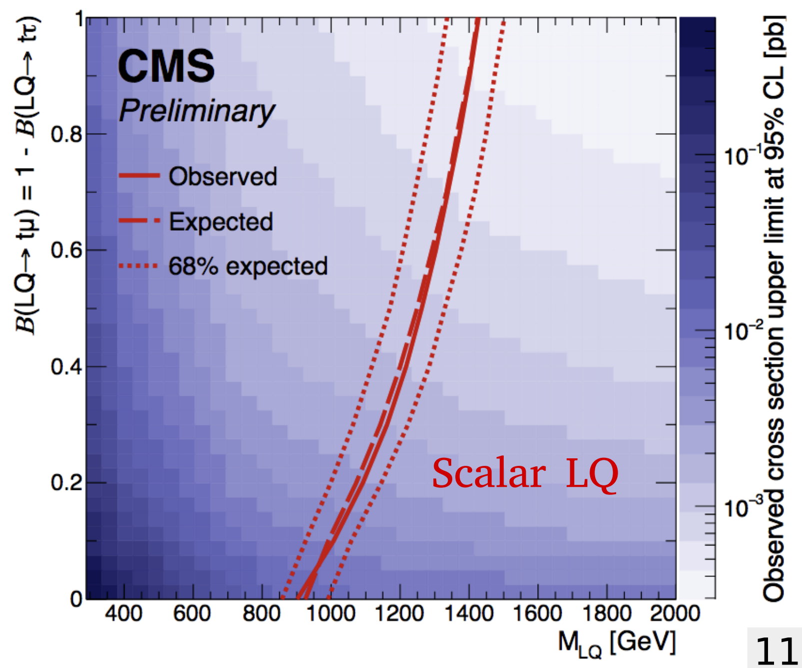
$\beta(\widetilde{U}_\mu \to t\mu) = 1 \qquad \beta(R_2^{(5/3)} \to t\mu) = 1 \qquad \beta(R_2^{(2/3)} \to t\nu_\mu) = 1$

Very recent search by CMS:

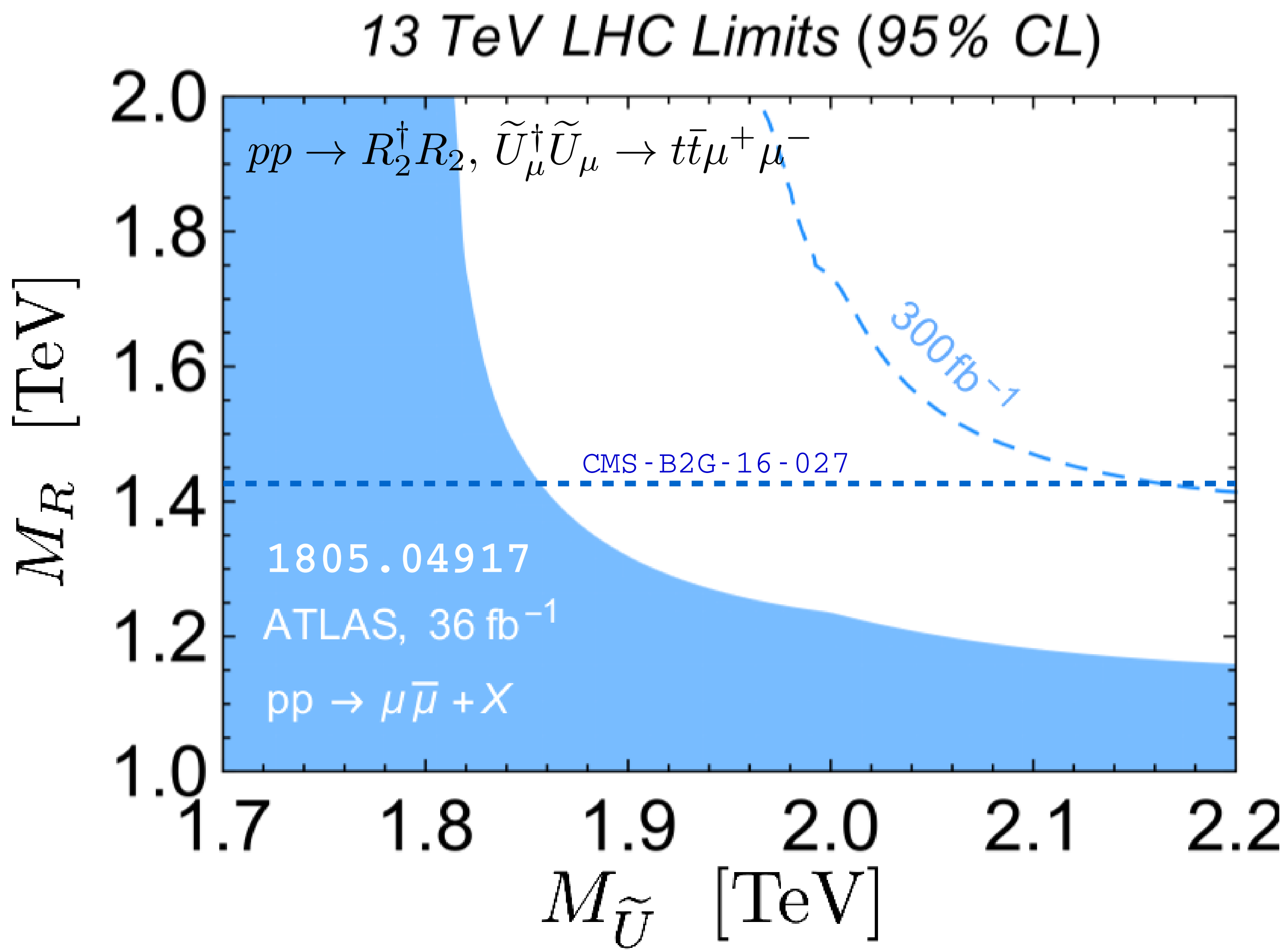
CMS-B2G-16-027, CERN-EP-2018-233

$M_{\mathrm{LQ}} > 1.4\,\mathrm{TeV}$ (scalars)

Request for experimentalist:
Please extend search to vector LQs $\widetilde{U}_\mu \sim (\mathbf{3}, \mathbf{1}, 5/3)$
I can provide material. Model files, etc...



Limits for top-philic LQ model:



Currently probing relevant portions of parameter space for the anomaly

Toward UV complete theories

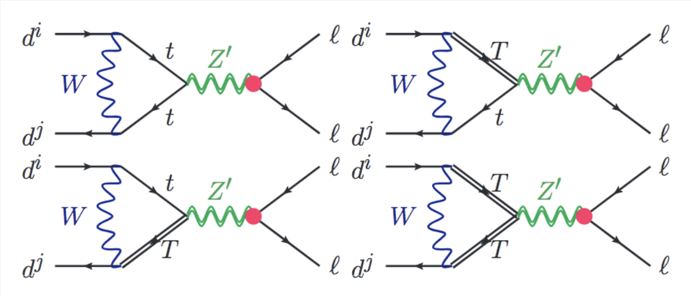
Abelian models:

Minimal Top-philic Z’ model Kamenik, Soreq, Zupan [1704.06005]

In a nut-shell: $\mathcal{G}_{\rm SM} \times {\rm U}(1)_{Y'}$

New vector-like top T charged under U(1)'.

All SM matter singlets under U(1)'.



After SSB top and muon couplings to Z' induced via fermion mixing.

Non-abelian models?

Top-philic SU(4) model Camargo-Molina, Celis, DAF [in preparation]

4321 Gauge group: ${\rm SU}(4) \times {\rm SU}(3)_{c'} \times {\rm SU}(2)_L \times {\rm U}(1)_{Y'}$

Many similarities with '4321' model for the Pati-Salam LQ.

Di Luzio, Greljo, Nardecchia
Diaz, Schmaltz, Zhong
See Di Luzio's talk

$\widetilde{U}_\mu \sim (\mathbf{3}, \mathbf{1}, 5/3)$ appears as a gauge boson of SU(4).

Also hidden sector with vector-like fermions plus exotic scalars.

fields	SU(4)	$SU(3)_{c'}$	$SU(2)_L$	$U(1)_{Y'}$
Q_L^i	1	$\mathbf{3}$	$\mathbf{2}$	1/6
L_L^i	1	1	$\mathbf{2}$	−1/2
u_R^i	1	$\mathbf{3}$	1	2/3
d_R^i	1	$\mathbf{3}$	1	−1/3
e_R^i	1	1	1	−1
$\Psi_{L,R}$	$\mathbf{4}$	1	1	1/4
Ω_3	$\bar{\mathbf{4}}$	$\mathbf{3}$	1	5/12
Ω_2	$\bar{\mathbf{4}}$	1	$\mathbf{2}$	−3/4
Ω_1	$\bar{\mathbf{4}}$	1	1	−5/4
H	1	1	$\mathbf{2}$	1/2

Would-be SM matter fields

1 Heavy vector fermion: SU(2) singlet

3 Heavy scalars

SM Higgs doublet

Heavy (top-philic) gauge bosons: $\widetilde{U}'_\mu$ Z'_μ G'_μ

fields	SU(4)	$SU(3)_{c'}$	$SU(2)_L$	$U(1)_{Y'}$
Q_L^i	1	$\mathbf{3}$	$\mathbf{2}$	1/6
L_L^i	1	1	$\mathbf{2}$	−1/2
u_R^i	1	$\mathbf{3}$	1	2/3
d_R^i	1	$\mathbf{3}$	1	−1/3
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$\Psi_{L,R}$	$\mathbf{4}$	1	1	1/4
Ω_3	$\bar{\mathbf{4}}$	$\mathbf{3}$	1	5/12
Ω_2	$\bar{\mathbf{4}}$	1	$\mathbf{2}$	−3/4
Ω_1	$\bar{\mathbf{4}}$	1	1	−5/4
H	1	1	$\mathbf{2}$	1/2

- 2 scalars induce SSB (like 'Pati-Salam 4321'):

$$\mathrm{SU}(4) \times \mathrm{SU}(3)_{c'} \times \mathrm{U}(1)_{Y'} \to \mathrm{SU}(3)_c \times \mathrm{U}(1)_Y$$

$$\langle \Omega_3 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} v_3 & 0 & 0 \\ 0 & v_3 & 0 \\ 0 & 0 & v_3 \\ 0 & 0 & 0 \end{pmatrix}, \quad \langle \Omega_1 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \\ 0 \\ v_1 \end{pmatrix},$$

$$\Omega_3 \sim (\mathbf{8}, \mathbf{1}, 0) \oplus \underline{(\mathbf{3}, \mathbf{1}, 5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

$$\Omega_1 \sim \underline{(\bar{\mathbf{3}}, \mathbf{1}, -5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

Would-be-Goldstone swollowed by $\widetilde{U}_\mu \sim (\mathbf{3}, \mathbf{1}, 5/3)$

fields	SU(4)	$SU(3)_{c'}$	$SU(2)_L$	$U(1)_{Y'}$
Q_L^i	1	$\mathbf{3}$	$\mathbf{2}$	1/6
L_L^i	1	1	$\mathbf{2}$	−1/2
u_R^i	1	$\mathbf{3}$	1	2/3
d_R^i	1	$\mathbf{3}$	1	−1/3
e_R^i	1	1	1	−1
$\Psi_{L,R}$	$\mathbf{4}$	1	1	1/4
Ω_3	$\bar{\mathbf{4}}$	$\mathbf{3}$	1	5/12
Ω_2	$\bar{\mathbf{4}}$	1	$\mathbf{2}$	−3/4
Ω_1	$\bar{\mathbf{4}}$	1	1	−5/4
H	1	1	$\mathbf{2}$	1/2

- 2 scalars induce SSB (like 'Pati-Salam 4321'):

$$\mathrm{SU}(4) \times \mathrm{SU}(3)_{c'} \times \mathrm{U}(1)_{Y'} \to \mathrm{SU}(3)_c \times \mathrm{U}(1)_Y$$

$$\langle \Omega_3 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} v_3 & 0 & 0 \\ 0 & v_3 & 0 \\ 0 & 0 & v_3 \\ 0 & 0 & 0 \end{pmatrix}, \quad \langle \Omega_1 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \\ 0 \\ v_1 \end{pmatrix},$$

$$\Omega_3 \sim (\mathbf{8}, \mathbf{1}, 0) \oplus \underline{(\mathbf{3}, \mathbf{1}, 5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

$$\Omega_1 \sim \underline{(\bar{\mathbf{3}}, \mathbf{1}, -5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

Would-be-Goldstone swollowed by $\widetilde{U}_\mu \sim (\mathbf{3}, \mathbf{1}, 5/3)$

- One VEV-less bi-fundamental scalar:

$$\langle \Omega_2 \rangle = 0 \qquad \Omega_2 \sim \underbrace{(\bar{\mathbf{3}}, \mathbf{2}, -7/6)}_{R_2^\dagger} \oplus (\mathbf{1}, \mathbf{2}, 1/2)$$

Scalar Leptoquark necesary for B-anomaly.

fields	SU(4)	$SU(3)_{c'}$	$SU(2)_L$	$U(1)_{Y'}$
Q_L^i	1	$\mathbf{3}$	$\mathbf{2}$	1/6
L_L^i	1	1	$\mathbf{2}$	−1/2
u_R^i	1	$\mathbf{3}$	1	2/3
d_R^i	1	$\mathbf{3}$	1	−1/3
e_R^i	1	1	1	−1
$\Psi_{L,R}$	$\mathbf{4}$	1	1	1/4
Ω_3	$\bar{\mathbf{4}}$	$\mathbf{3}$	1	5/12
Ω_2	$\bar{\mathbf{4}}$	1	$\mathbf{2}$	−3/4
Ω_1	$\bar{\mathbf{4}}$	1	1	−5/4
H	1	1	$\mathbf{2}$	1/2

- 2 scalars induce SSB (like ‘Pati-Salam 4321’):

$$SU(4) \times SU(3)_{c'} \times U(1)_{Y'} \to SU(3)_c \times U(1)_Y$$

$$\langle \Omega_3 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} v_3 & 0 & 0 \\ 0 & v_3 & 0 \\ 0 & 0 & v_3 \\ 0 & 0 & 0 \end{pmatrix}, \quad \langle \Omega_1 \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \\ 0 \\ v_1 \end{pmatrix},$$

$$\Omega_3 \sim (\mathbf{8}, \mathbf{1}, 0) \oplus \underline{(\mathbf{3}, \mathbf{1}, 5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

$$\Omega_1 \sim \underline{(\bar{\mathbf{3}}, \mathbf{1}, -5/3)} \oplus (\mathbf{1}, \mathbf{1}, 0)$$

Would-be-Goldstone swollowed by $\widetilde{U}_\mu \sim (\mathbf{3}, \mathbf{1}, 5/3)$

$\Psi_{L,R} = (T, E)^T_{L,R}$

T: top partner
E: muon partner

Fermion-Gauge LQ interactions:

$$\mathcal{L} \supset \frac{g_4}{\sqrt{2}} \widetilde{U}_\mu (\bar{T}_L \gamma^\mu E_L + \bar{T}_R \gamma^\mu E_R)$$

- One VEV-less bi-fundamental scalar:

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Yukawa interactions: $\mathcal{L}\supset\lambda_u^i\,(\bar{\Psi}_L\Omega_3^\dagger u_R^i)+\lambda_\ell^i(\bar{\ell}_i\Omega_2\Psi_R)+\lambda_e^i\,(\bar{\Psi}_L\Omega_1^\dagger e_R^i)$

Mass matrix and fermion mixing:

$$(\bar{t}_L,\bar{T}_L)\begin{pmatrix}\frac{y_t v}{\sqrt{2}} & 0\\ \frac{\lambda_t v_3}{\sqrt{2}} & M_\Psi\end{pmatrix}\begin{pmatrix}t_R\\T_R\end{pmatrix}$$

$M_\Psi\sim v_3,\ v_1>>v$ Large vector-like fermion mass

θ_R Large RH mixing angles.

$\theta_L\sim v/M_\Psi$ Suppressed LH mixing!

Conclusions

We explored the possibility of explaining the anomalies in $B \to K^{(*)}\ell\bar{\ell}$
from **Top-philic NP at 1-loop.**

Identified the SMEFT operators relevant for the B-anoamlies
as well as all possible mediators accomodating low energy data $Z', R_2, \widetilde{U}_\mu$

We discussed two interesting possibilies allowed by high- and low energy data:

- 1 colorless mediator : Z'
- 2 LQs: $R_2 + \widetilde{U}_\mu$

LHC are currently probing significant portions of parameter space and higher lumi will be relevant for these models.

We sketched a potential UV model: Top-philic SU(4)