Flavour Non-Universal Gauge Interactions

Joe Davighi, CERN

Flavour Path to New Physics, June 2024, University of Zurich

Flavour Deconstructing the Standard Model

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$$G_1 \times G_2 \times G_{3+\mathrm{H}}$$
$$\to G_{12} \times G_{3+\mathrm{H}}$$
$$\to G_{\mathrm{SM}}$$

Quark and charged lepton mass hierarchies

PMNS anarchy?

CKM hierarchies

$$G_1 \times G_2 \times G_{3+\mathrm{H}}$$
$$\rightarrow G_{12} \times G_{3+\mathrm{H}}$$
$$\rightarrow G_{\mathrm{SM}}$$

Hierarchy Problem?

Rich phenomenology

- High pT
- Flavour precision
- EW precision
- B anomalies via non-universal gauge U_1 LQ

Gauge Unification

The Flavour Path to New Physics

If you remove the Higgs, the Standard Model is completely natural - x3 gauge couplings $g_i = O(1)$

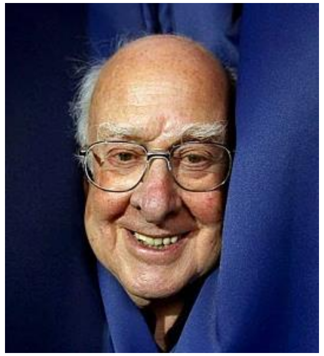
~~Hierarchy problem~~

~~Flavour puzzle~~

~~Strong CP problem~~ [massless quarks]

The Flavour Path to New Physics

Arguably, Higgs = key to (visible) BSM



The Flavour Path to New Physics

The Higgs has an unnaturally small mass parameter:

$\mu^2 \ll M_{\mathrm{Pl}}^2 \implies$ compositeness (or SUSY) as low scale as possible?

$\lambda \sim O(1)$ at $\mu = m_t$, but interestingly near-critical in the SM…

Most of the Higgs couplings are generating flavour:

$y_{q_3 t_3} \sim 1$; all other x12 physical $y_{ij} \ll 1$

$\implies \mathcal{L}_{\mathrm{SM}}$ has approx. $U(2)^n$ flavour symmetry

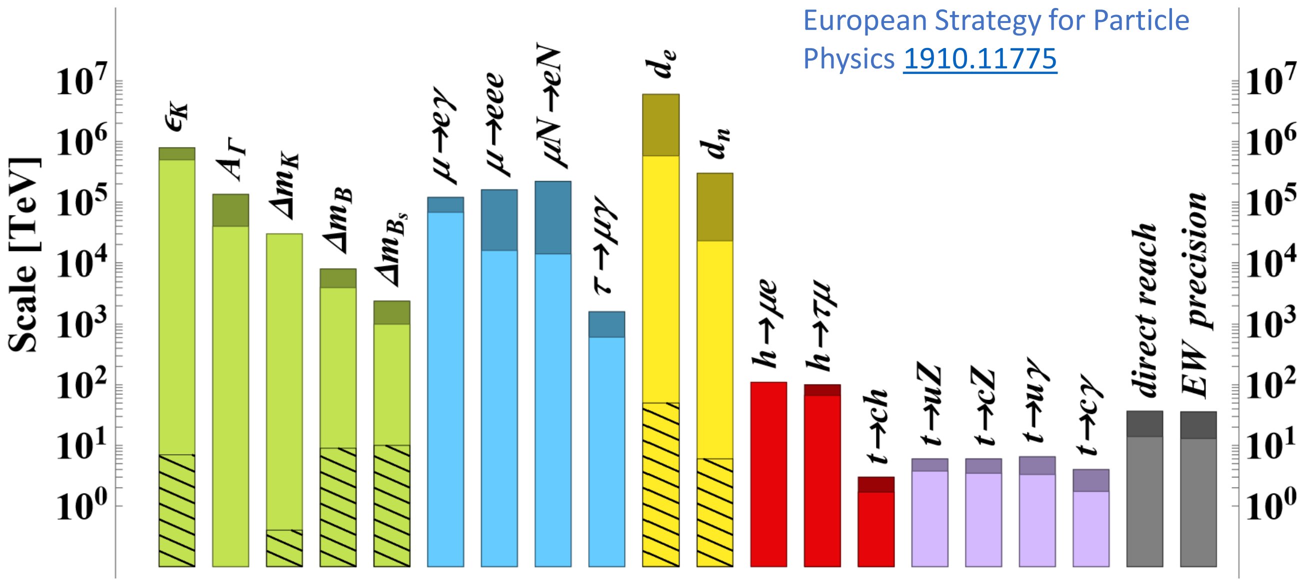
$$Y_u \sim \begin{pmatrix} & < 0.01 & 0.04 \\ & & 1 \end{pmatrix}$$

V_{cb} provides largest $U(2)$-breaking spurion
Then y_2/y_3

Maybe hierarchy problem + flavour puzzle have joint solution?

The Flavour Path to New Physics

We also know from precision flavour bounds (e.g. meson mixing) that $\mathcal{L}_{\text{SMEFT}}$ has approx. $U(2)^n$ flavour symmetry, at least – if $\Lambda < 10$ TeV or so



Global symmetries provide a clue

Bottom up: want $U(2)^n$ accidental symmetries

Origin: flavour non-universal [3 vs 1+2] gauge symmetry!

Global symmetries provide a clue

Bottom up: want $U(2)^n$ accidental symmetries

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One option is to gauge $U(2)^n$ directly, and break to nothing.

Gives a bunch of Z' bosons that can be decoupled from the Higgs (can take $g \ll 1$).

Important recent examples:
Darmé, Deandrea, Mahmoudi, 2307.09595
Greljo, Thomsen, 2309.11547
Greljo, Thomsen, Tiblom, 2406.02687 [TODAY!]

Global symmetries provide a clue

Bottom up: want $U(2)^n$ accidental symmetries

Origin: flavour non-universal [3 vs 1+2] gauge symmetry!

Another option is **flavour deconstruction**

$$G_1 \times G_2 \times G_{3+\mathrm{H}} \to G_{12} \times G_{3+\mathrm{H}} \qquad \sim 100(0\ldots)\ \mathrm{TeV}$$

$$\to G_{\mathrm{SM}} \qquad \sim 1(0\ldots)\ \mathrm{TeV}$$

Non-universal, charged heavy gauge bosons, gauge couplings $\gtrsim\ g_i = O(1)$

Rich phenomenology! *Cannot* be decoupled [g/M large] without wrecking naturalness $\delta m_h^2 \sim g^2 M^2 / 16\pi^2$

Not a new idea:

Gauge Model of Generation Nonuniversality

Xiao-yuan Li[a] and Ernest Ma
Department of Physics and Astronomy, University of Hawaii at Manoa, Honolulu, Hawaii 96822
(Received 13 October 1981)

An electroweak gauge model is discussed, where generations are associated with separate gauge groups with different couplings. The observed μ-e universality is the result of a mass-scale inequality, $v_{03} \ll v_{12}$, in much the same way as strong isospin is the result of $m_u, m_d \ll 1$ GeV. However, in contrast to the standard model, it is now possible to have (1) a longer τ lifetime, (2) an observable B^0-$\bar{B}^0$ mixing, and (3) many gauge bosons W_i, Z_i in place of W, Z with $M_{W_i} > M_W$ and $M_{Z_i} > M_Z$.

In conclusion, we have put forward in this pape a radical, if not heretical, point of view that both the observed μ-e universality and the known suppression of flavor-changing neutral-current kaon processes are in fact accidents, in much the same way that strong isospin is an accident. We thus predict a hierarchy of generations, in analogy with strong SU(2), SU(3), SU(4), etc., in which each succeeding generation breaks the universality of weak interactions more and more

Li, Ma, 1981

Modern incarnation revived by e.g.
Arkani-Hamed, Cohen, Georgi hep-th/0104005… Craig, Green, Katz 1103.3708 …

Then the B anomalies happened…

Flavour Deconstruction: the basics

$$G_1 \times G_2 \times G_{3+\mathrm{H}} \quad \to G_{12} \times G_{3+\mathrm{H}} \quad \langle \phi_{12} \rangle \sim 100(0\ldots)\ \mathrm{TeV}$$

$$\to G_{\mathrm{SM}} \quad \langle \phi_{23} \rangle \sim 1(0\ldots)\ \mathrm{TeV}$$

To connect 3rd family / Higgs to 2nd family, need ϕ_{23} insertion $\Longrightarrow \epsilon_{23} \coloneqq \frac{v_{23}}{\Lambda_{23}}$ suppression

To connect 3rd family / Higgs to 1st family, $\phi_{12}\phi_{23}$ insertion $\Longrightarrow \frac{v_{12}}{\Lambda_{12}}\frac{v_{23}}{\Lambda_{23}}$ suppression

Flavour Deconstruction: the basics

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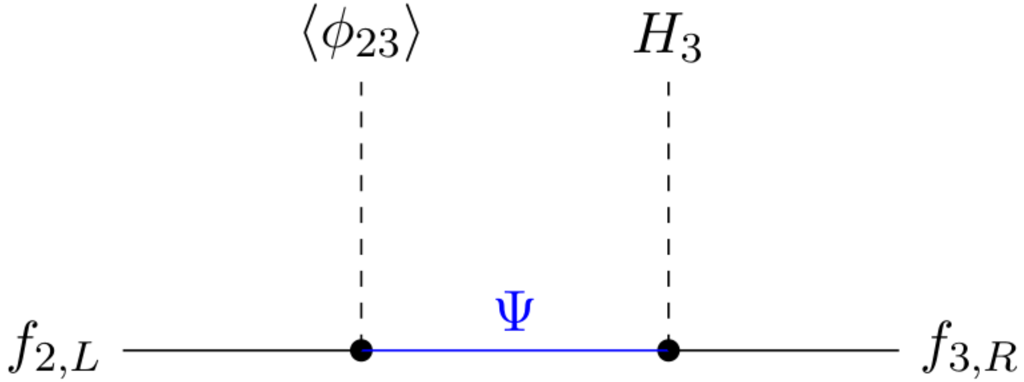
Example UV:



$y_{23} \sim \frac{v_{23}}{M_\Psi} = \epsilon_{23}$

Theoretical appeal

1. Charge assignment and anomaly-freedom inherited from SM by replicating the structure in one family* – no *ad hoc* choices

2. Breaking pattern $G_A \times G_B \to G_{A+B}$, given scalar condensate ϕ, is **generic** for simple G
   - for any choice of gauge couplings, and any scalar rep $\phi \sim (\boldsymbol{R}_{12} \neq 1, \boldsymbol{R}_3 \neq 1)$, you *always* break to the diagonal (ergo flavour-universal) subgroup
   - … because there is no other non-trivial subgroup embedding, by *Goursat's lemma*

Goursat, 1889
Craig, Garcia-Garcia, Sutherland, 1704.07831

3. Easy to find semi-simple UV completions with deconstruction approach
   - In contrast most $G_{\text{SM}} \times U(1)_X$, even anomaly-free, have no semi-simple completion

Davighi, Tooby-Smith, 2206.11271

*OR, we can split and rearrange families (e.g. to explain $y_t \gg y_{b,\tau}$), if we permit *anomalies* to be cancelled via couplings to a strong sector Fuentes-Martin, Lizana, 2402.09507

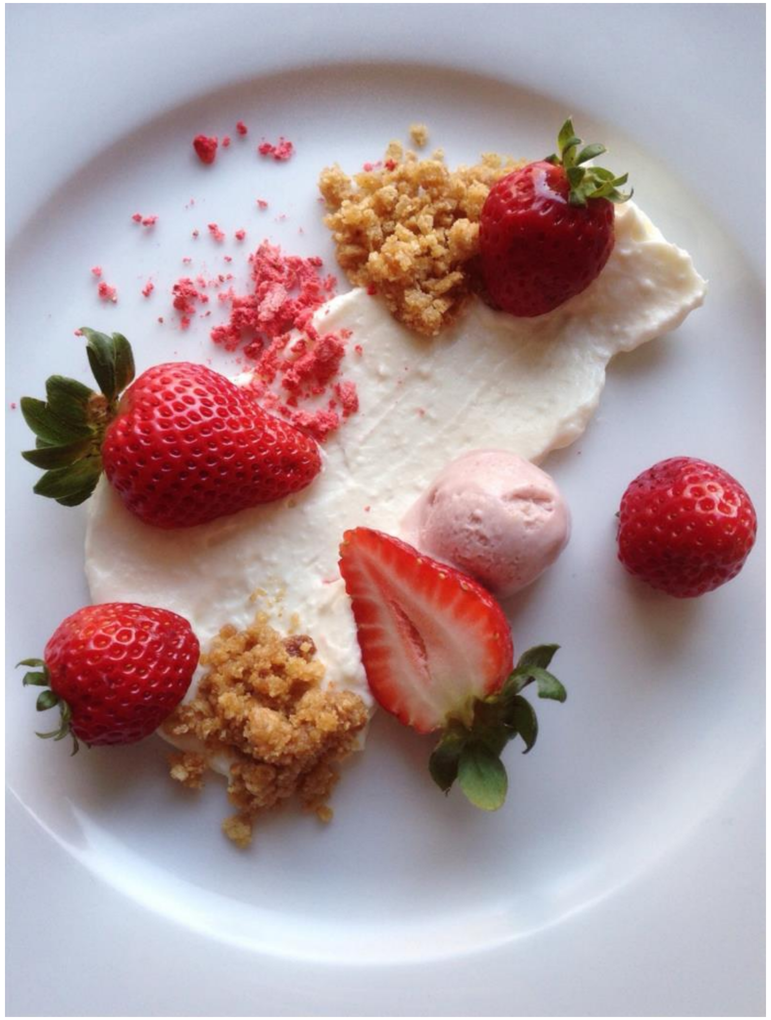
Flavour deconstruction provides a *class* of models

- What can these models explain?
- Which part of SM gauge symmetry should we deconstruct?
- What is the phenomenology, and at what scale?
- Are there “top down” UV motivations? Unification?

See also Mario Fernandez Navarro’s talk yesterday!

I will try to systematically survey the options that have been proposed in recent years, kick-started by B anomalies

- hugely indebted to Gino’s FLAY programme of work!



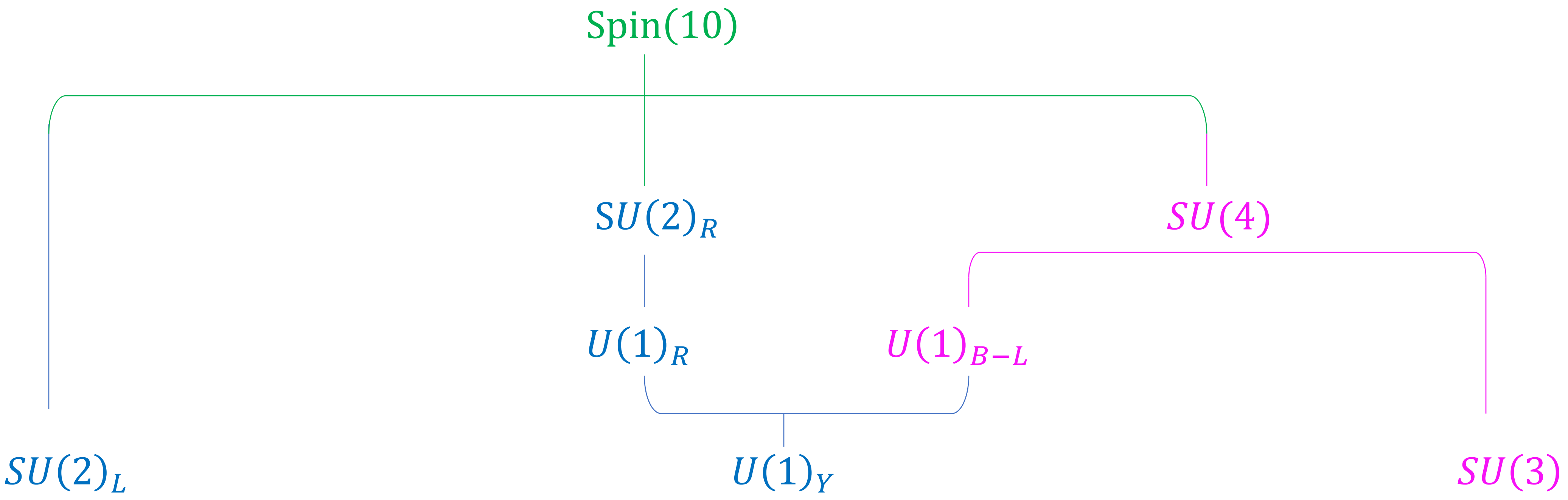
See Davighi, Isidori 2303.01520, which focussed on semi-simple UV completions but otherwise broad

Let me introduce a (horrible) shorthand notation:

$$\mathrm{D}[G] = \left\{G_1 \times G_2 \times G_{3+\mathrm{H}} \rightarrow G_{12} \times G_{3+\mathrm{H}} \rightarrow G_{123}\right\}$$

So e.g. $\mathrm{D}[SU(3)] \times SU(2)_L \times U(1)_Y$ refers to a model in which I deconstruct colour and leave EW symmetry alone

Start from the following chain of “vertical” embeddings in $\mathrm{Spin}(10)$



General consequences of deconstructing each SM force in turn:

$\mathrm{Spin}(10)$

$SU(2)_R$ $\quad$ $SU(4)$

$U(1)_R$ $\quad$ $U(1)_{B-L}$

$D[SU(2)_L]$ $\quad$ $U(1)_Y$ $\quad$ $SU(3)$

V_{cb}, V_{ub}

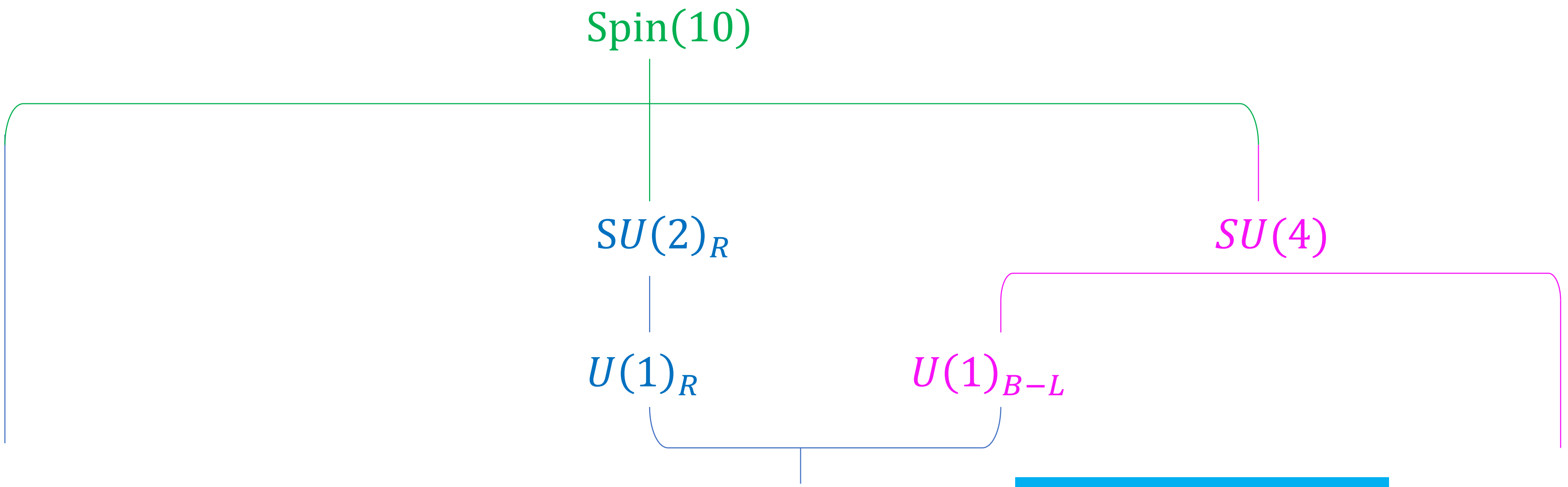
y_2, y_1 (ish)

1-loop δm_h^2

Tree EWPOs, $\delta m_W < 0$

$$Y \sim \begin{pmatrix} & & \\ & & \\ \times & \times & \times \end{pmatrix}$$

General consequences of deconstructing each SM force in turn:



$D[SU(2)_L]$

V_{cb}, V_{ub}

y_2, y_1 (ish)

1-loop δm_h^2

Tree EWPOs, $\delta m_W < 0$

$D[U(1)_Y]$

$Y \sim \left(\quad \times \right)$

V_{cb}, V_{ub}

y_2, y_1 (need 2 spurions)

1-loop δm_h^2

Tree EWPOs, $\delta m_W > 0$

$g_Y \sim \frac{1}{2} g_L \Longrightarrow$ x2 benefit for naturalness

$SU(3)$

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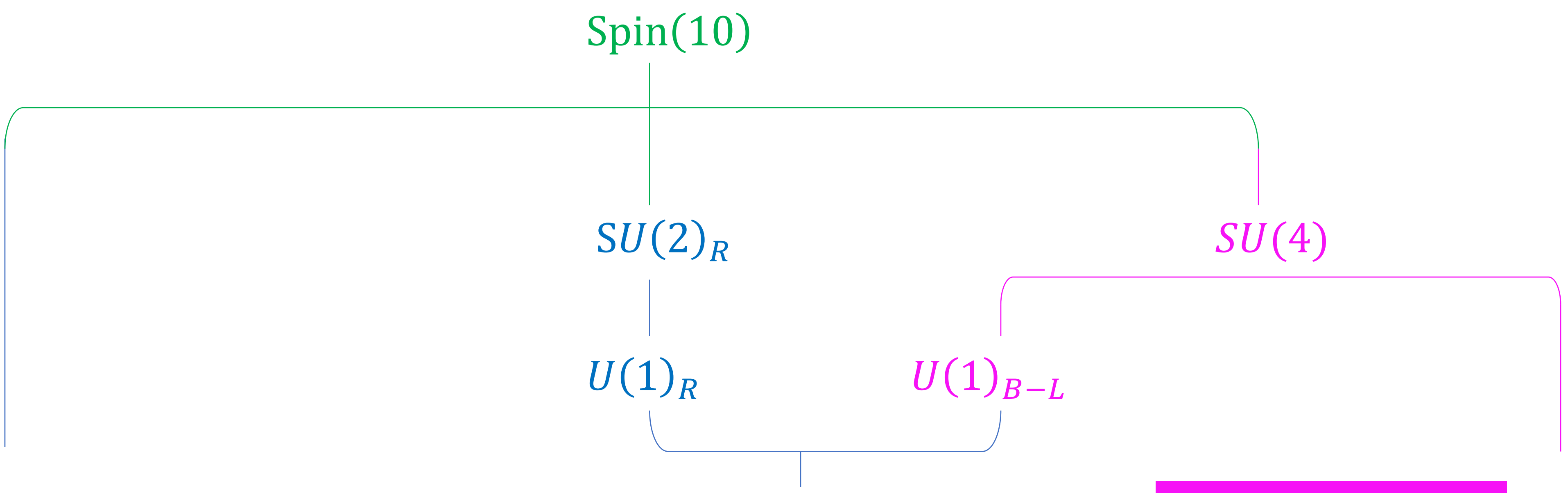

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$$Y \sim \begin{pmatrix} \times & & \\ & \times & \\ & & \times \end{pmatrix}$$

$D[SU(3)]$

V_{cb}, V_{ub}

No mass hierarchy

2-loop δm_h^2

1-loop EWPOs

Spin(10)

General Lesson

- Need to deconstruct part of the EW symmetry to explain the flavour puzzle (because Higgs is colourless)
- Automatically implies 1-loop δm_h^2 and tree-level δ EWPOs

$\mathrm{D}[SU(2)_L]$	$\mathrm{D}[U(1)_Y]$	$\mathrm{D}[SU(3)]$
V_{cb}, V_{ub}	V_{cb}, V_{ub}	V_{cb}, V_{ub}
y_2, y_1 (ish)	y_2, y_1 (need 2 spurions)	No mass hierarchy
1-loop δm_h^2	1-loop δm_h^2	2-loop δm_h^2
Tree EWPOs, $\delta m_W < 0$	Tree EWPOs, $\delta m_W > 0$	1-loop EWPOs
	$g_Y \sim \frac{1}{2} g_L \Longrightarrow$ x2 benefit for naturalness	

Need to deconstruct part of the EW symmetry to explain flavour puzzle
Automatically implies 1-loop δm_h^2 and tree-level δ EWPOs
Phenomenology is dramatic! Finite naturalness being pushed already…

Davighi, Gosnay, Miller, Renner 2312.13346
See also Capdevila, Crivellin, Lizana, Pokorski 2401.00848

$\mathbf{D}[SU(2)_L]$

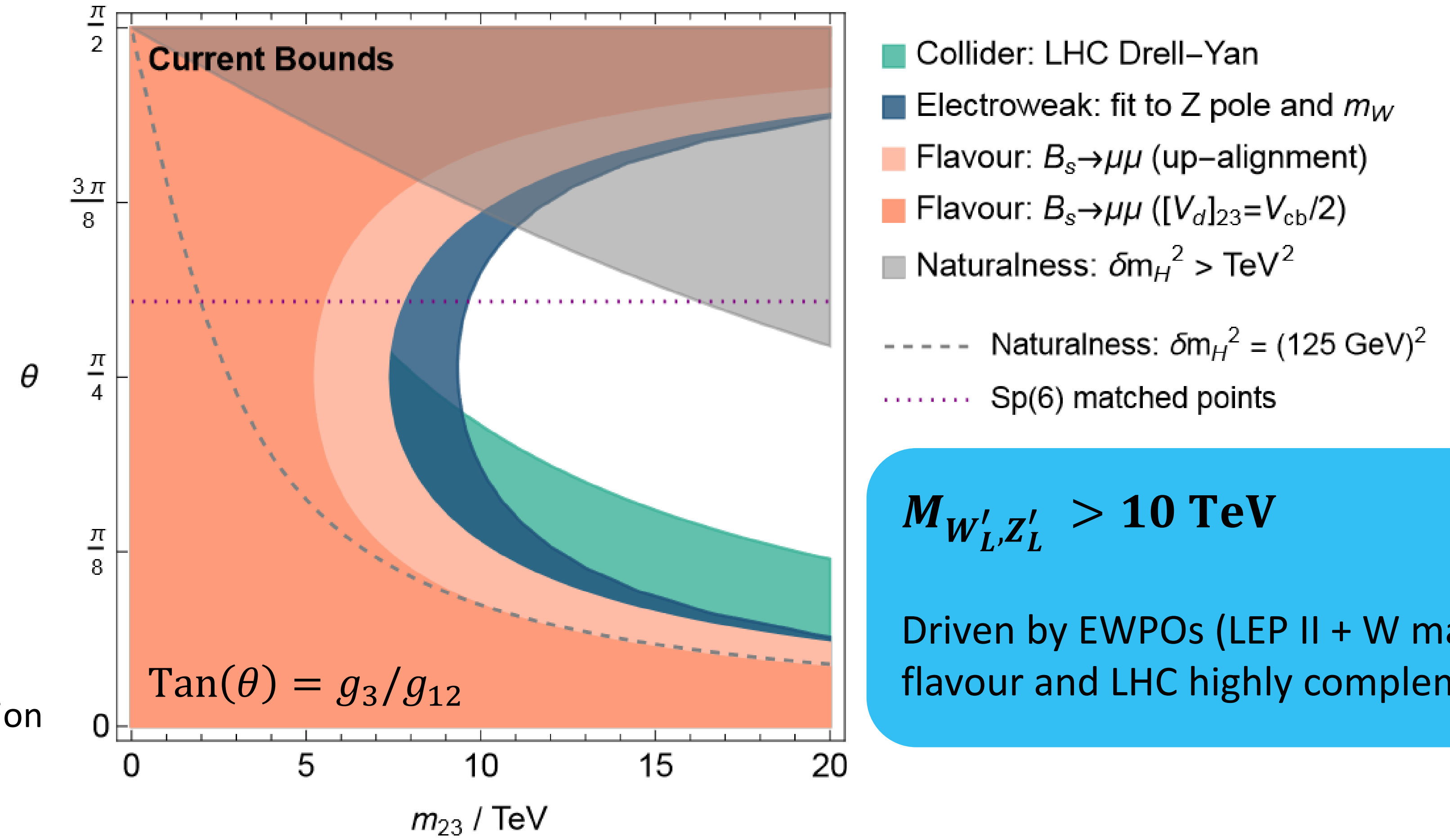
V_{cb}, V_{ub}

y_2, y_1 (ish)

1-loop δm_h^2

Tree EWPOs, $\delta m_W < 0$

Large $c_{10}^{e,\mu}$*



$M_{W'_L, Z'_L} > 10$ TeV

Driven by EWPOs (LEP II + W mass), with flavour and LHC highly complementary

*actually $c_{10}^{\tau} = 0$; exact cancellation between $C_{lq}^{\tau\tau bs}$ and C_{Hq}^{bs}…

Need to deconstruct part of the EW symmetry to explain flavour puzzle
Automatically implies 1-loop δm_h^2 and tree-level δ EWPOs
Phenomenology is dramatic! Deconstructing hypercharge **more natural**

$\mathbf{D}[\boldsymbol{U(1)_Y}]$

V_{cb}, V_{ub}

y_2, y_1 (2 spurions)

1-loop δm_h^2

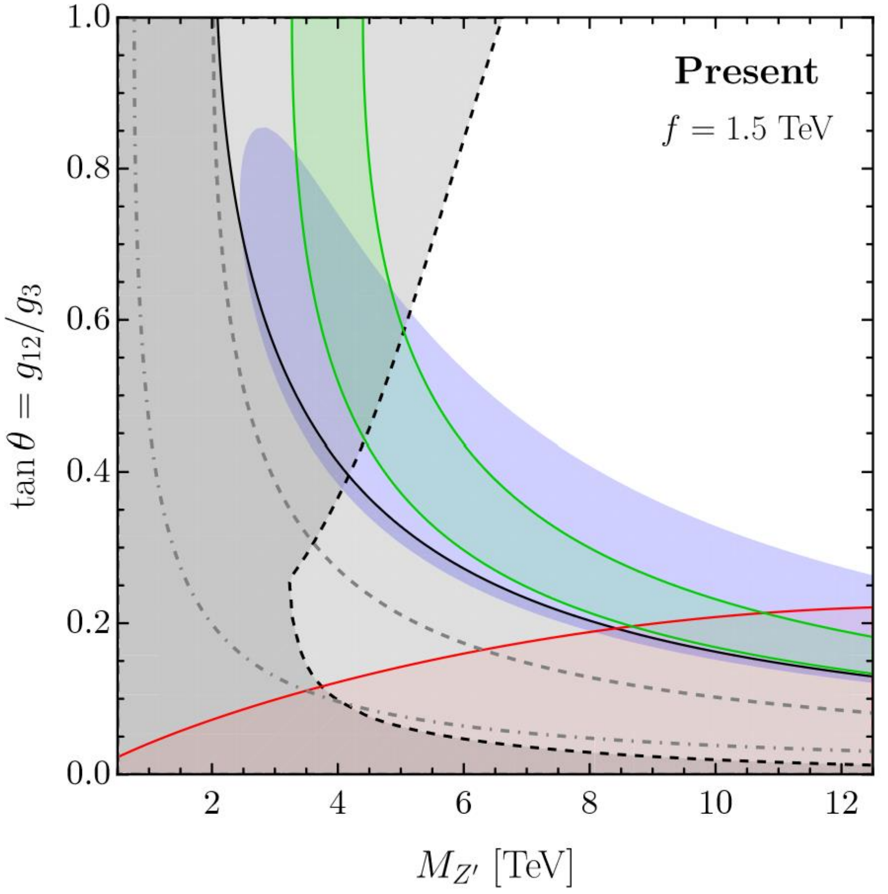
Tree EWPOs, $\boldsymbol{\delta m_W > 0}$

Large $c_{10}^{e,\mu}$*

$g_Y \sim \frac{1}{2} g_L$

*again $c_{10}^{\tau} = 0$ cancels

Davighi, Stefanek 2305.16280
See also Fernández Navarro, King 2305.07690, + Barbieri, Isidori, 2312.14004 for related model



B_s mixing (suppressed by $Y_Q g_Y$)

$B_s \to \mu\mu$ exclusion (strong-ish)

Electroweak fit (1 sigma)

Electroweak fit (2 sigma exclusion)

High p_T exclusion ($pp \to ee, \mu\mu, \tau\tau$ searches)

Percent tuning in M_h^2

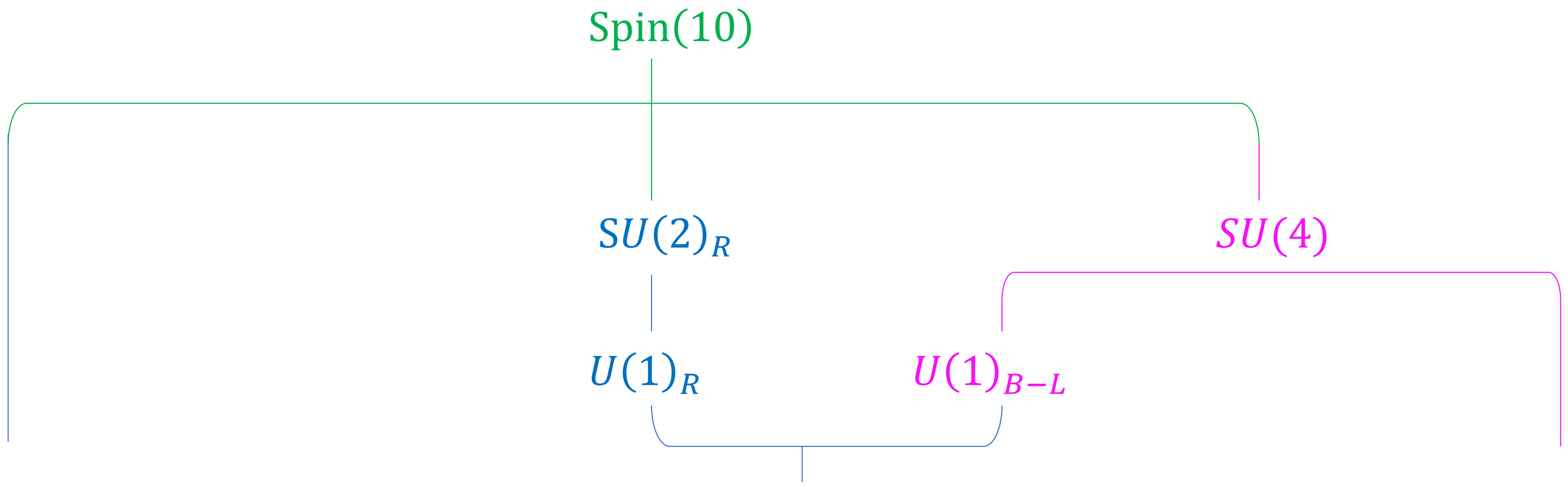
"Natural" explanation of y_c/y_t hierarchy

$\boldsymbol{M_{Z'_Y} \gtrsim 5}$ **TeV**

We will come back to the hierarchy problem (beyond just finite naturalness criteria) briefly at the end

Now, let’s continue our survey of deconstruction possibilities

What about going “upwards”, and considering **unification** + deconstruction?



$\mathrm{D}[SU(2)_L]$

V_{cb}, V_{ub}

y_2, y_1 (ish)

1-loop δm_h^2

Tree EWPOs, $\delta m_W < 0$

$\mathrm{D}[U(1)_Y]$

V_{cb}, V_{ub}

y_2, y_1 (need 2 spurions)

1-loop δm_h^2

Tree EWPOs, $\delta m_W > 0$

$g_Y \sim \frac{1}{2} g_L \implies$ x2 benefit for naturalness

$\mathrm{D}[SU(3)]$

V_{cb}, V_{ub}

No mass hierarchy

2-loop δm_h^2

1-loop EWPOs

4-3-2-1… where it all began!

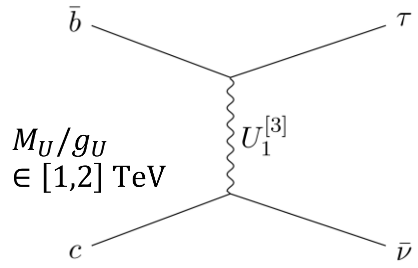
Just a few 4-3-2-1 references…

Buttazzo, Greljo, Isidori, Marzocca, 1706.07808; Di Luzio, Greljo, Nardecchia, 1708.08450; Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368; Greljo, Stefanek, 1802.04274; Di Luzio, Fuentes-Martin, Greljo, Nardecchia, Renner, 1808.00942; Fuentes-Martin, Stangl, 2004.11376 …

$\mathrm{Spin}(10)$

$SU(2)_R$

D$[SU(4)]$ + $R_{D^{(*)}}$, $bs\mu\mu$ ("4-3-2-1")



$U(1)_R$

$U(1)_{B-L}$

D$[SU(2)_L]$

V_{cb}, V_{ub}

y_2, y_1 (ish)

1-loop δm_h^2

Tree EWPOs, $\delta m_W < 0$

D$[U(1)_Y]$

V_{cb}, V_{ub}

y_2, y_1 (need 2 spurions)

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D$[SU(3)]$

V_{cb}, V_{ub}

No mass hierarchy

2-loop δm_h^2

1-loop EWPOs

Colour vs Electroweak

Deconstructing colour (or $SU(4)$) doesn't give huge effects in EWPOs, unlike deconstruction of $SU(2)_L$ or $U(1)_Y$.

Allwicher, Isidori, Lizana, Selimovic, Stefanek 2302.11584

So, in general, these "colour-deconstructed" gauge bosons can be lighter.

[Though remember, not enough on their own to explain the flavour puzzle]

Regardless of EW effects, **all** deconstructed models get strong bounds from LHC high pT data e.g. Drell-Yan $pp \to \ell\ell, \ell\nu$

$G_{\mathrm{SM},12} \times G_{\mathrm{SM},3} \to G_{\mathrm{SM}}$ gives heavy gauge bosons in adjoint, coupled to flavour-non-universal fermion current:

$$J^\mu \sim g_{12}^2 (J_1^\mu + J_2^\mu) - 2 g_3^2 J_3^\mu \,, \qquad J_3^\mu \supset D_{\mathrm{SM}}^\mu H$$

Can pump up the (relative) coupling to the heavy or light families by varying g_{12}/g_3

BUT we cannot decouple either completely, because there is a matching condition

$$\frac{1}{g^2} = \frac{1}{g_{12}^2} + \frac{1}{g_3^2} \quad \Rightarrow \quad g_{12}, g_3 > g$$

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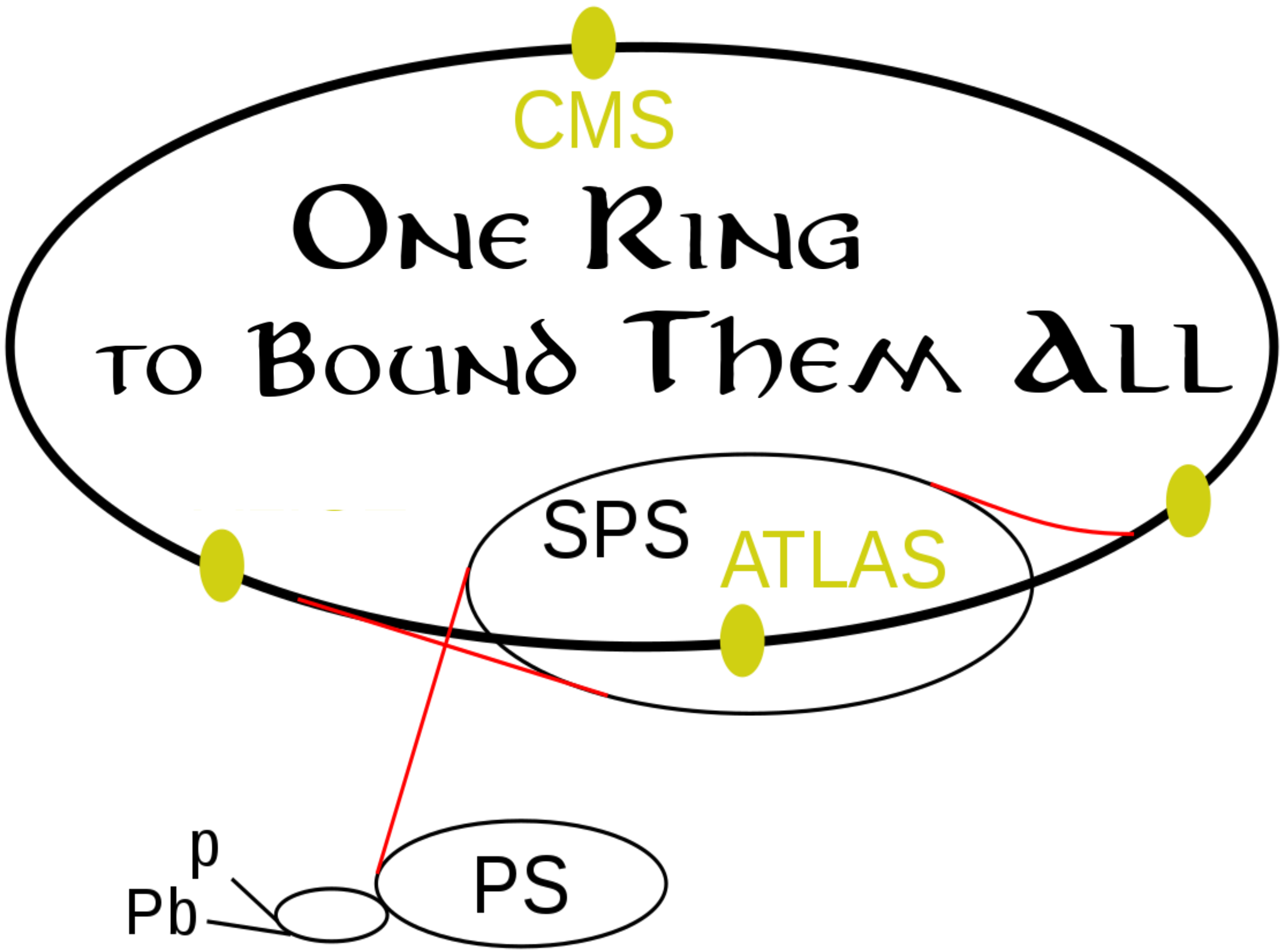
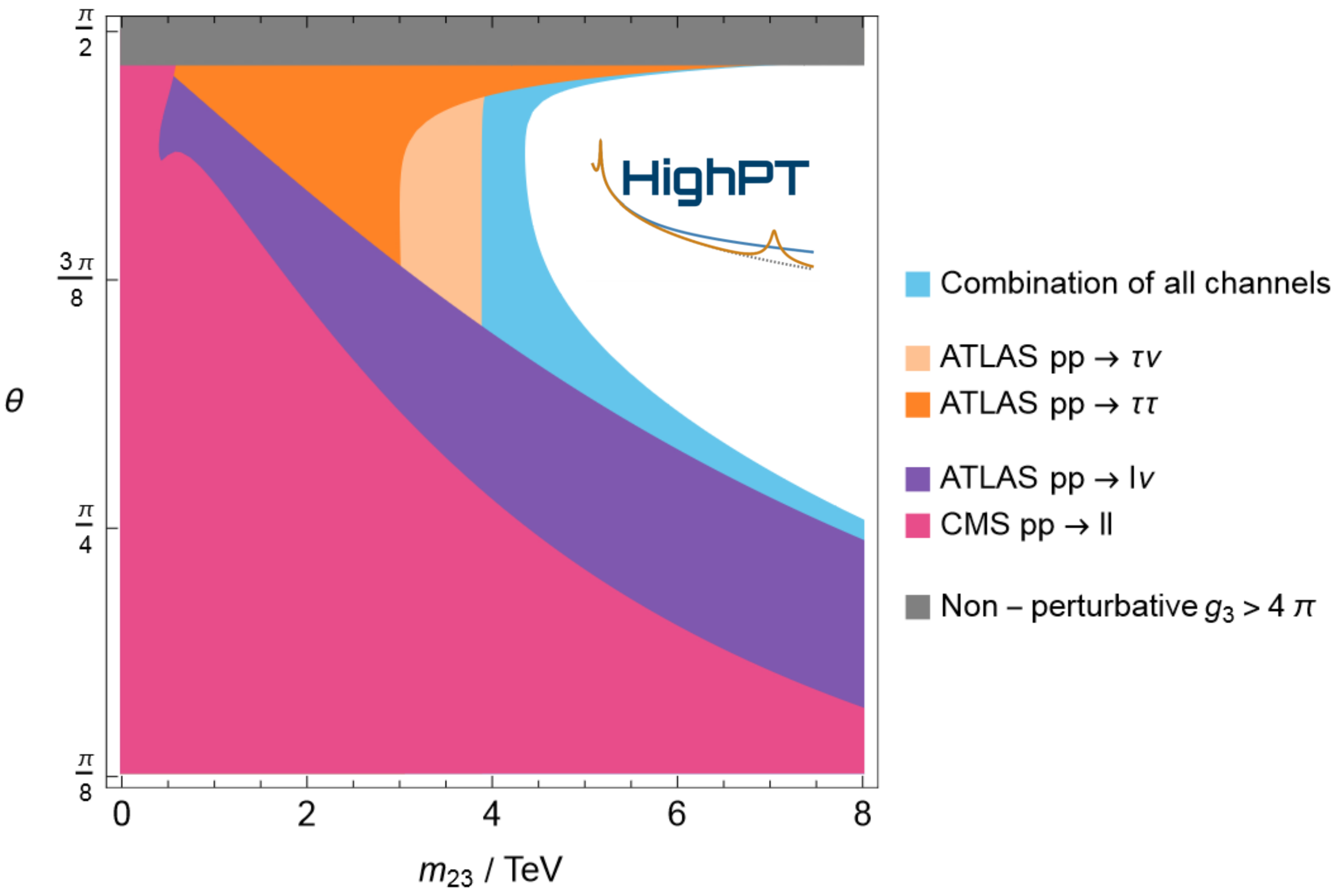


Example: the deconstructed $SU(2)_L$ model I showed before

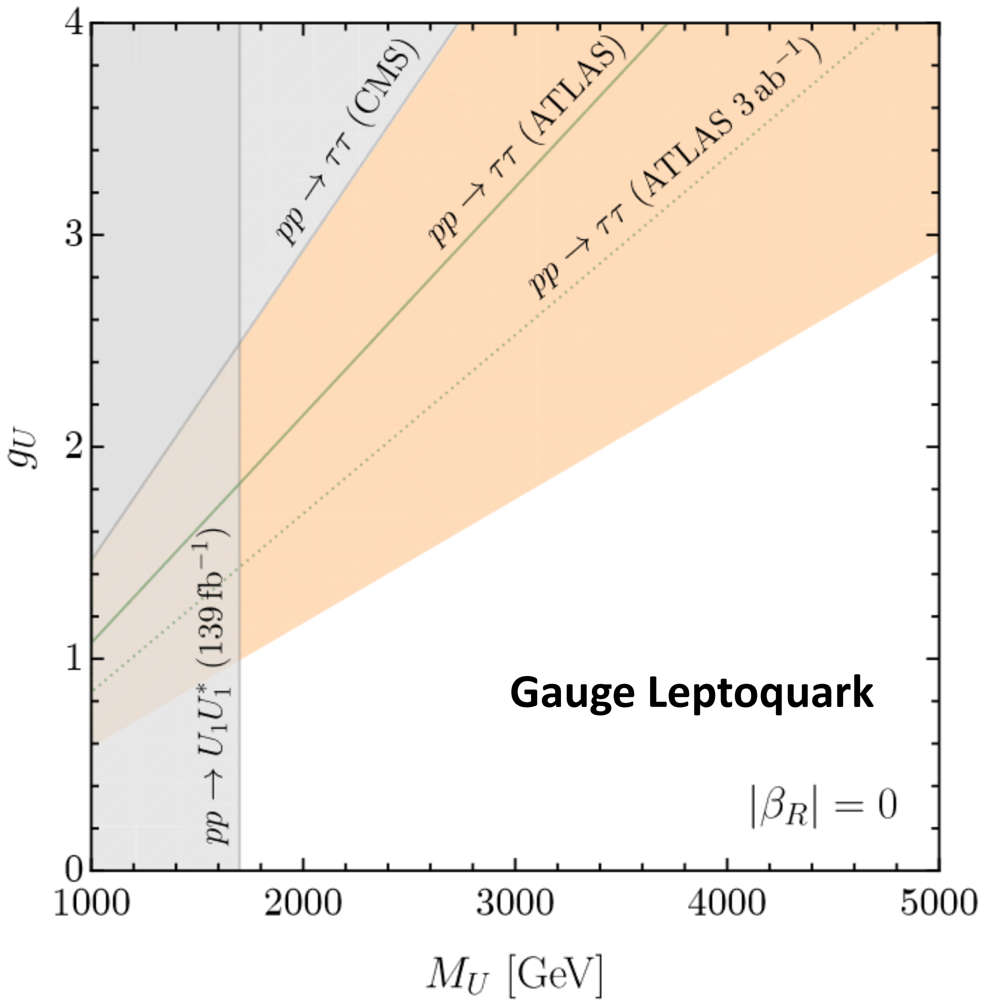
Computed using **HighPT** – another excellent FLAY by-product!
Allwicher et al, 2207.10756

LHC searches all using 139 fb^{-1}:
2002.12223, ATLAS-CONF-2021-025, **CMS**, 2103.02708, **ATLAS**, 1906.05609



And now for colour…

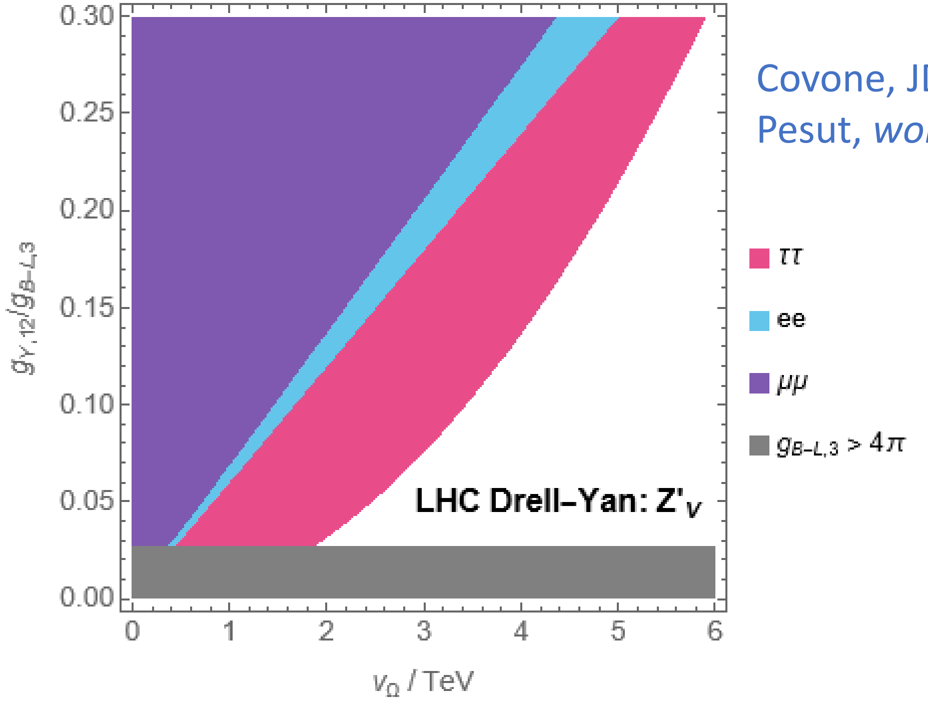
Faroughy, Greljo, Kamenik, 1609.07138 …
Aebischer, Isidori, Pesut, Stefanek, Wilsch, 2210.13422



For the "SM part" of deconstructed colour ($SU(3)$ or $U(1)_{B-L}$), there is less "wiggle room"

$$J^\mu \sim g_{12}^2 (J_1^\mu + J_2^\mu) - 2 g_3^2 J_3^\mu \,, \; J_3^\mu \supset D_{SM}^\mu H$$

where $\frac{1}{g^2} = \frac{1}{g_{12}^2} + \frac{1}{g_3^2} \quad \Rightarrow \quad g_{12}, g_3 > g$



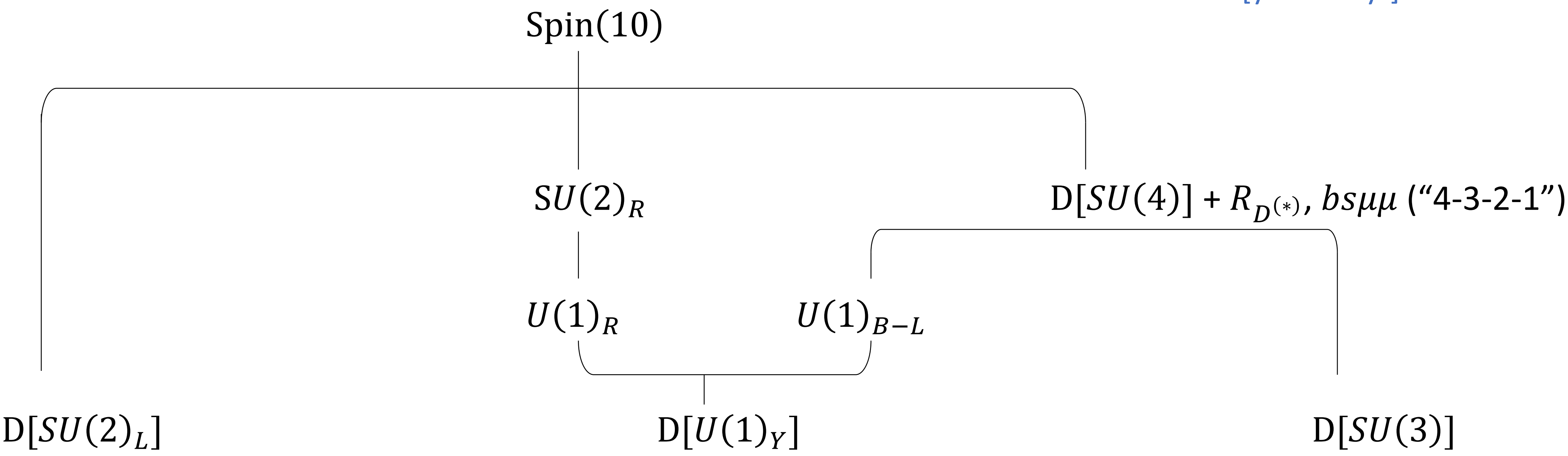
Covone, JD, Isidori, Pesut, *work in progress*

What about **neutrinos**?

Can we accommodate anarchic PMNS mixing, while preserving hierarchies in quark mixing (and in quark and charged lepton masses?)

What about **neutrinos**? Can we explain anarchic mixing angles?

Greljo, Isidori 2406.01696 [yesterday!]



Consider type 1 see-saw: $m_\nu \sim -Y_D\, M_M^{-1}\, Y_D^T$
RH ν is SM singlet; deconstruction **naively gives doubly hierarchical neutrino texture**
Insight: deconstruct $U(1)_R$ and/or $U(1)_{B-L}$ to get texture in M_M

Conditions for PMNS anarchy: $$M_M \sim \begin{pmatrix} \epsilon^4 & \epsilon^3 & \epsilon^2 \\ \epsilon^3 & \epsilon^2 & \epsilon \\ \epsilon^2 & \epsilon & 1 \end{pmatrix}, \qquad Y_D \sim \begin{pmatrix} \epsilon^2 & \lesssim \epsilon & \lesssim 1 \\ \lesssim \epsilon^2 & \epsilon & \lesssim 1 \\ \lesssim \epsilon^2 & \lesssim \epsilon & 1 \end{pmatrix}$$

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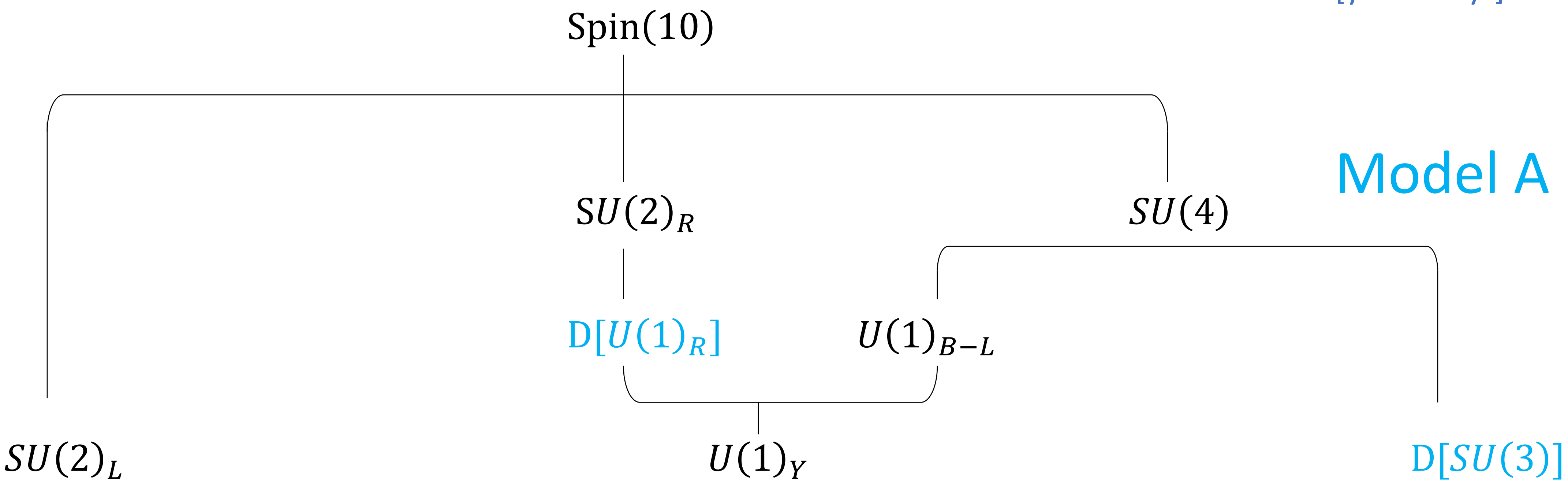
Greljo, Isidori 2406.01696 [yesterday!]

Model A



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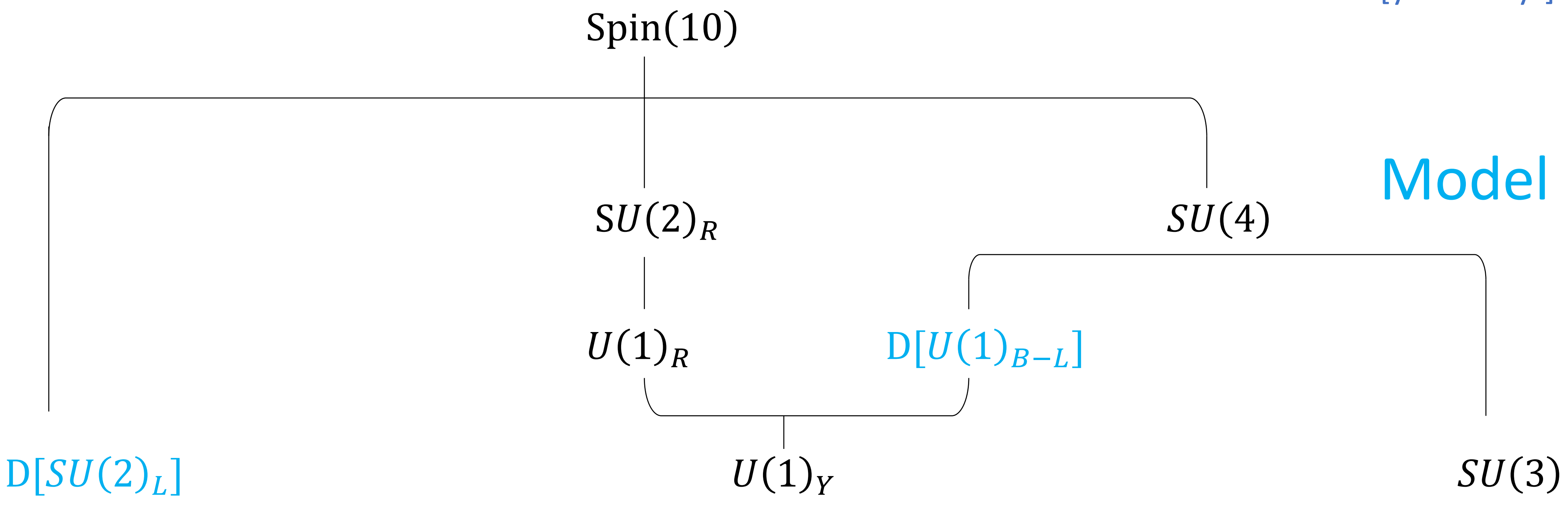
Greljo, Isidori 2406.01696
[yesterday!]

Model B



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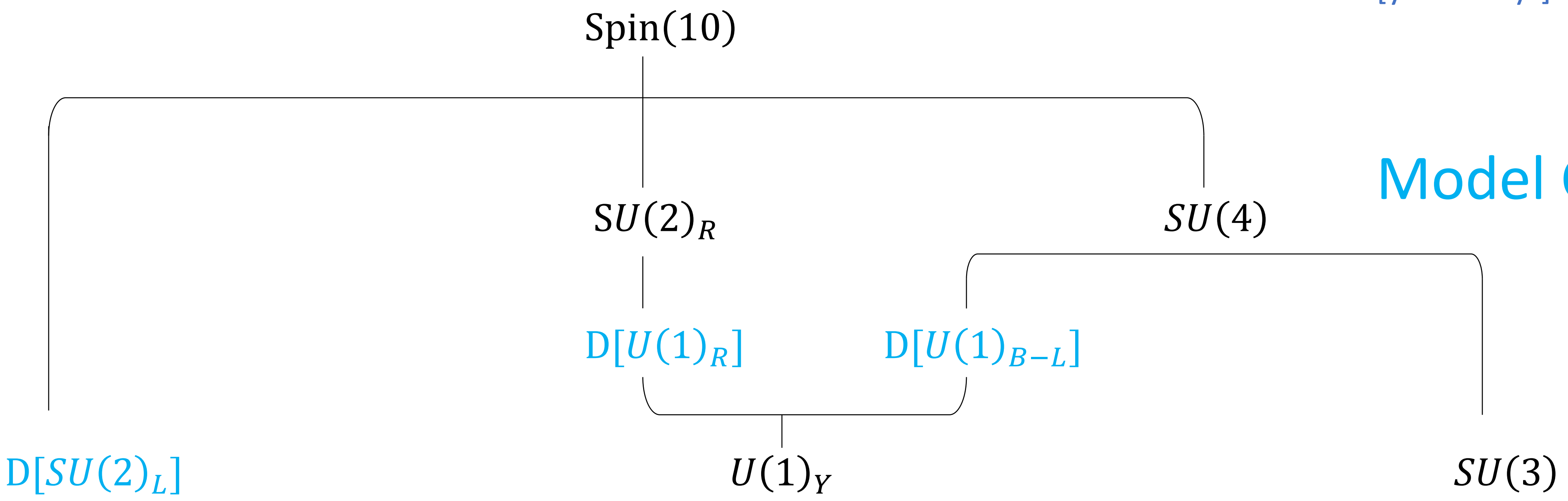
What about **neutrinos**? Can we explain anarchic mixing angles?

Greljo, Isidori 2406.01696 [yesterday!]

Model C



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RH ν is SM singlet; deconstruction **naively gives doubly hierarchical neutrino texture**
Insight: deconstruct $U(1)_R$ and/or $U(1)_{B-L}$ to get texture in M_M

Conditions for PMNS anarchy: $M_M \sim \begin{pmatrix} \epsilon^4 & \epsilon^3 & \epsilon^2 \\ \epsilon^3 & \epsilon^2 & \epsilon \\ \epsilon^2 & \epsilon & 1 \end{pmatrix}$, $Y_D \sim \begin{pmatrix} \epsilon^2 & \lesssim \epsilon & \lesssim 1 \\ \lesssim \epsilon^2 & \epsilon & \lesssim 1 \\ \lesssim \epsilon^2 & \lesssim \epsilon & 1 \end{pmatrix}$

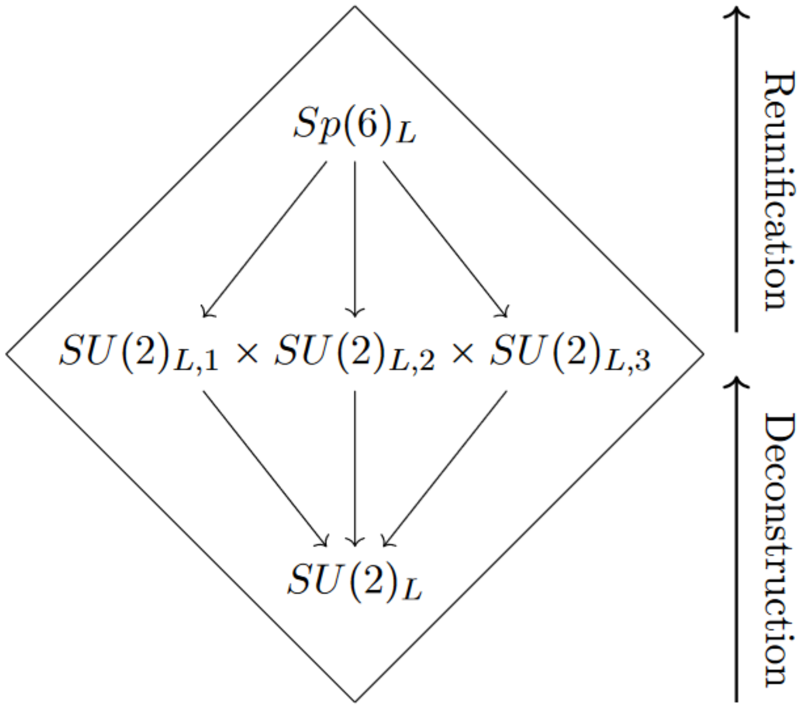
Is there a nice UV origin for flavour deconstruction?

One path is to *reunify* the deconstructed symmetry in the UV

Is there a nice UV origin for flavour deconstruction?

One path is to *reunify* the deconstructed symmetry in the UV

Also offers a gauge answer to: "why 3 generations"?



New options revealed by classification of all embeddings of 3-flavour SM gauge algebra from: Allanach, Gripaios, Tooby-Smith, 2104.14555

Davighi, Tooby-Smith, 2201.07245
Davighi, 2206.04482

Gauge Flavour Unification

Davighi, 2206.04482

$[Sp(6)_L \quad \vee \quad (Sp(6)_R \;\underline{\vee}\; SO(6)_R)] \quad \underline{\vee} \quad SU(12)$

Too much unification!
Expect $y_1 \sim y_2 \sim y_3$

$SU(2)_R$ $\quad$ $D[SU(4)]$

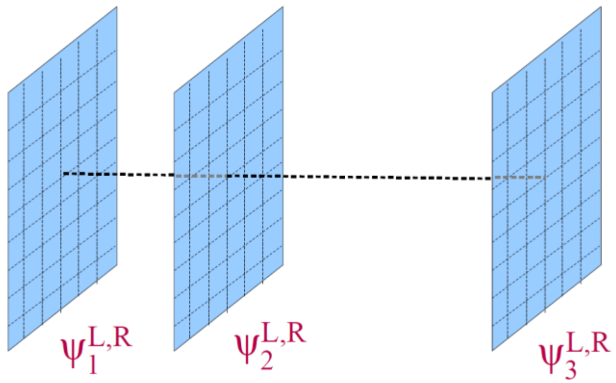
$U(1)_R$ $\quad$ $U(1)_{B-L}$

$D[SU(2)_L]$
V_{cb}, V_{ub}
y_2, y_1 (ish)
1-loop δm_h^2
Tree EWPOs, $\delta m_W < 0$

$D[U(1)_Y]$
V_{cb}, V_{ub}
y_2, y_1 (need 2 spurions)
1-loop δm_h^2
Tree EWPOs, $\delta m_W > 0$
$g_Y \sim \frac{1}{2} g_L \implies$ x2 benefit for naturalness

$D[SU(3)]$
V_{cb}, V_{ub}
No mass hierarchy
2-loop δm_h^2
1-loop EWPOs

Another possible origin is an extra “flavour” dimension



Fuentes-Martin, Isidori, Lizana, Selimovic, Stefanek, 2203.01952

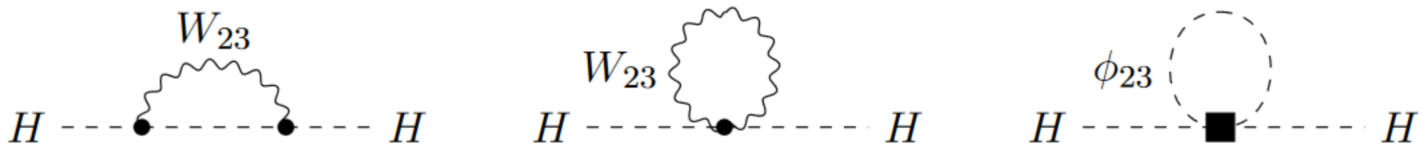
Finally, some more words about the hierarchy problem

Naturalness

We started by suggesting that flavour could be the path to new physics unlocking the Higgs sector – and possible *joint* explanation of hierarchy problem and flavour puzzle

See also Yi Chung's talk yesterday; Luca Vecchi's talk; round table discussion

So far, our considerations have been limited to **finite naturalness** estimates within flavour deconstruction models



$$\delta m_h^2 \sim \frac{1}{16\pi^2} g_L^2 M_X^2$$

To go further, we must embed flavour deconstruction within an actual solution to the hierarchy problem. Maybe deconstruction can even help *reduce* the little hierarchy?

Deconstructing the Composite Higgs

Covone, JD, Isidori, Pesut, *work in progress*

Higgs as a composite boson:

Compositeness scale cuts off quantum corrections to $V(h)$, c.f. QCD pions

Higgs as a pseudo Nambu Goldstone boson (pNGB):

Like pions, naturally lighter than other strong sector resonances

Minimal CHM:

break global $Sp(4) \rightarrow SU(2)_L \times SU(2)_R$, gives pNGBs $\sim (\mathbf{2}, \mathbf{2})$

Deconstructing the Composite Higgs

Covone, JD, Isidori, Pesut,
work in progress

Recall from our survey of deconstruction that the most natural starting point, which fully explains flavour puzzle, is **deconstructing hypercharge**

Custodial symmetry will help, so we promote

$$\mathrm{D}[U(1)_Y] \to D[SU(2)_R] \times D[U(1)_{B-L}]$$

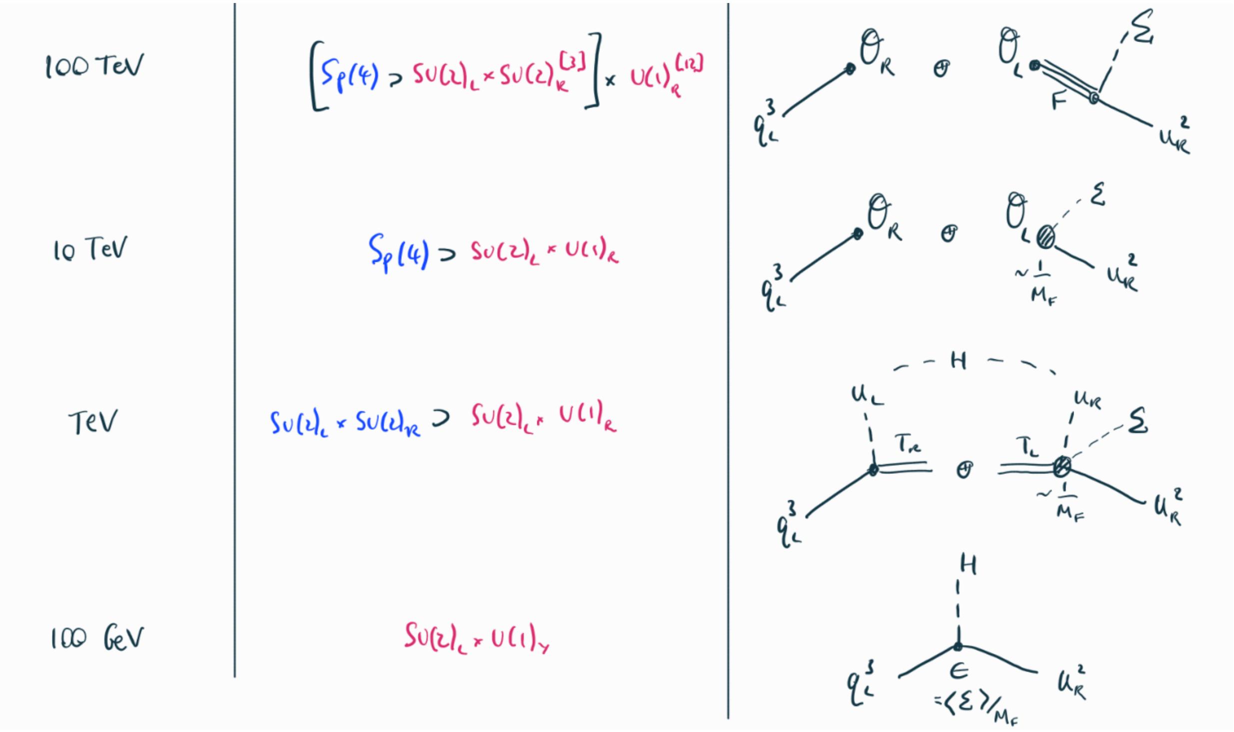
Deconstructing the Composite Higgs

Covone, JD, Isidori, Pesut,
work in progress

Embed $SU(2)_L \times SU(2)_R^3 \in Sp(4)_{\text{global}}$

$D[U(1)_{B-L}] \times SU(3) \times SU(2)_R^{12}$ purely elementary

Partial compositeness in **third family only**; light fermions elementary



Resolve heavy fermion responsible for preparing flavour structure at high scales (Higgs mass is shielded)

Higgs emerges as pNGB at low scales; top partner as composite state

Deconstructing the Composite Higgs

Covone, JD, Isidori, Pesut,
work in progress

Embed $SU(2)_L \times SU(2)_R^3 \in Sp(4)_{\text{global}}$

$D[U(1)_{B-L}] \times SU(3) \times SU(2)_R^{12}$ purely elementary

Partial compositeness in **third family only**; light fermions elementary

Some preliminary observations:

- Gauge explanation for accidental $U(2)$ symmetries needed to reconcile flavour bounds See Luca Vecchi's talk!
- Does not reduce the v/F little hierarchy (inferred e.g. from HWW couplings) See Gauthier Durieux's talk!
- However, gauge contribution to Higgs potential is naturally bigger; can more easily accommodate the requisite tuning between the (opposite sign) contributions to $V(h)$ from top + gauge loops

$$m_h^2 \sim \frac{1}{16\pi^2}[\#y_t^2 M_T^2 - \#g_{R,3}^2 M_\rho^2 + \#g_{R,3}^4 v_\phi^2],$$ T = top partner, ρ = spin-1 resonance

- To explain y_2/y_3 hierarchy, the heavy fermion is then 100s of TeV – but no contribution to Higgs mass! In contrast to the "fundamental Higgs" scenarios considered in [Davighi, Isidori 2303.01520]

The Flavour Path to New Physics

- Flavour deconstruction provides a playground of well-motivated (from bottom up and top down) BSM models that can address flavour puzzle, neutrino parameters, possible anomalies in flavour observables …

- Unavoidable Higgs mass corrections suggest the scale should be low, in which case hugely rich phenomenology: **high pT, flavour, EWP**

- Provide new paths to reducing the little hierarchy problem, by pursuing intrinsically flavour non-universal versions of e.g. compositeness / SUSY

The Flavour Path to New Physics

Alternative conclusion:

Arguably, Higgs (including FLAVOUR) = key to BSM.

Therefore, we should be excited to keep pushing (HL)-LHC and flavour factory experiments

… and extremely excited to eventually build FCC(ee+hh), CEPC, Muon Collider…

Thank you!