GAUGED FLAVOUR SYMMETRY FOR B MESON ANOMALIES

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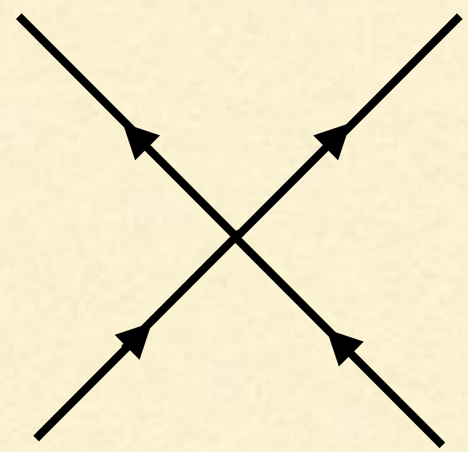
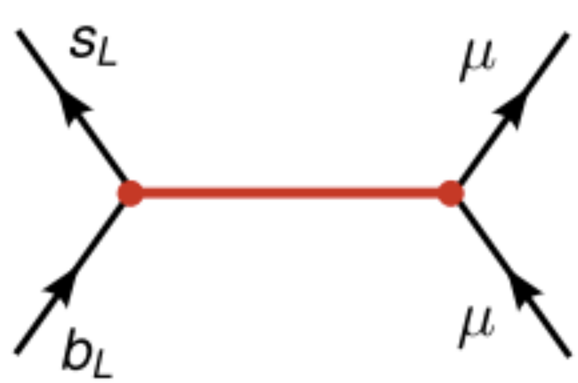
Rencontres de Moriond EW 2018

OPENING UP AN OPERATOR

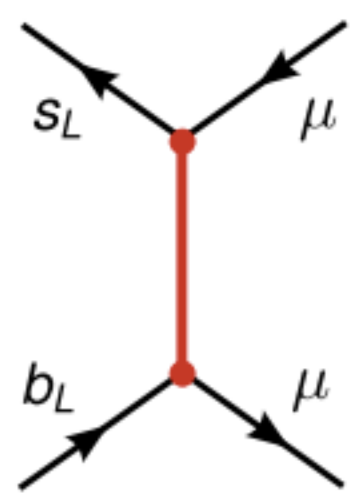
$\bar{s}\gamma_\rho b_L$



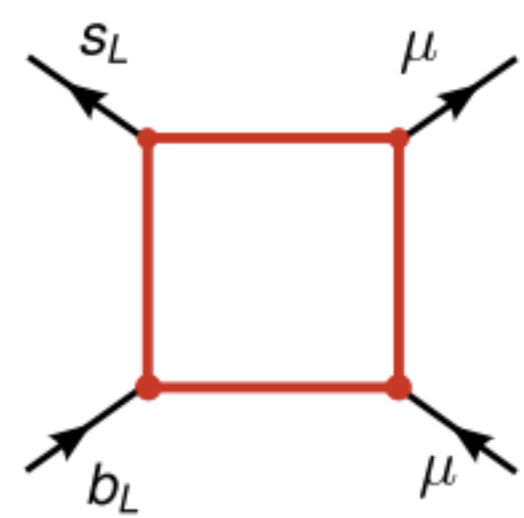
$\bar{\mu}\gamma^\rho \mu$



Z'



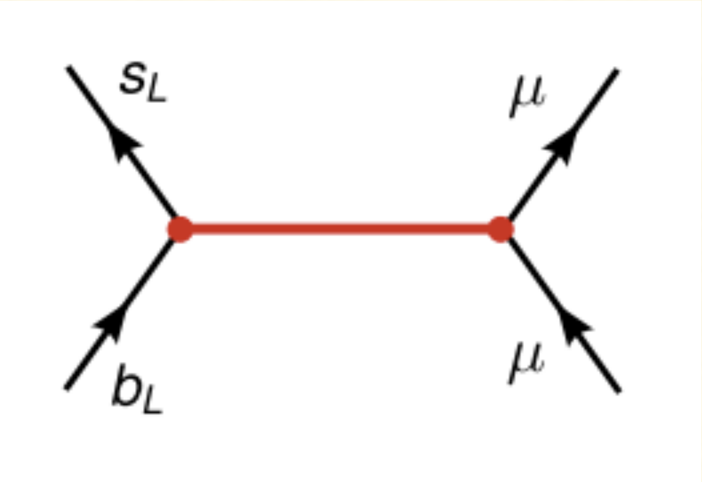
Lepto-quark



Loop

IN THIS TALK Z' MEDIATOR & $R_{K^{(*)}}$

$\bar{s}\gamma_\rho b_L$



$\bar{\mu}\gamma^\rho \mu$

$U(1)_{BGL}$ **Celis, Fuentes-Martin, Jung, Serodio 1505.03079**

$U(1) \subset U(1)_{B_1+B_2-2B_3} \times U(1)_{\mu-\tau}$ **Crivellin, Fuentes-Martin, Greljo & Isidori, 1611.02703**

$U(1)_X + \mathrm{VL\,fermions}$ **Aristizabal, Staub & Vicente 1503.06077**

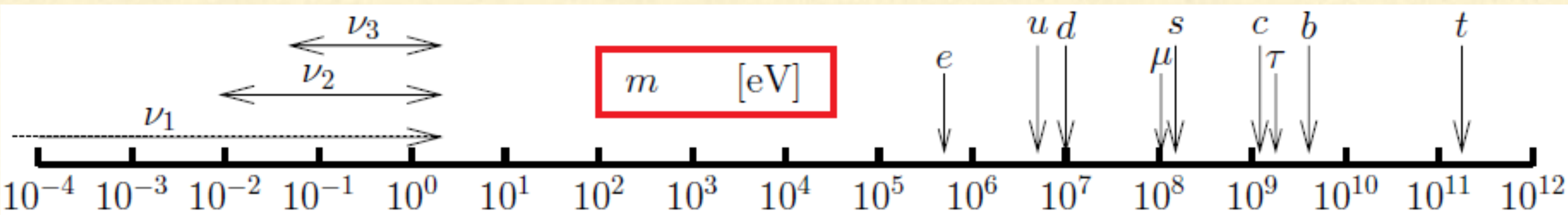
$U(1)_{\mu-\tau} + \mathrm{VL\,fermions}$ **Altmannshofer, Gori, Pospelov & Yavin 1403.1269**
Crivellin, D'Ambrosio & Heeck 1501.0093

$U(1)_{B_3-3L_\mu}$ **Bonilla, Modak, Srivastava & Valle, 1705.00915**

$U(1)_{(B-L)_3}$ **RA, Cox, Han & Yanagida, 1705.03858**

$\vdots$

THE FLAVOR STRUCTURE



Quarks | **Leptons**

$$V_{CKM} = \begin{pmatrix} \sim 1 & \lambda & \lambda^3 \\ \lambda & \sim 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & \sim 1 \end{pmatrix} \qquad U_{PMNS} = \begin{pmatrix} 0.8 & 0.5 & \sim 0.2 \\ -0.4 & 0.5 & -0.7 \\ -0.4 & 0.5 & 0.7 \end{pmatrix}$$

B anomalies is telling us:

i) QUARK FLAVOR VIOLATION

ii) LEPTON UNIVERSALITY VIOLATION

iii) QUARK-LEPTON CONNECTION

iv) FSB CONNECTION WITH MASSES AND MIXINGS

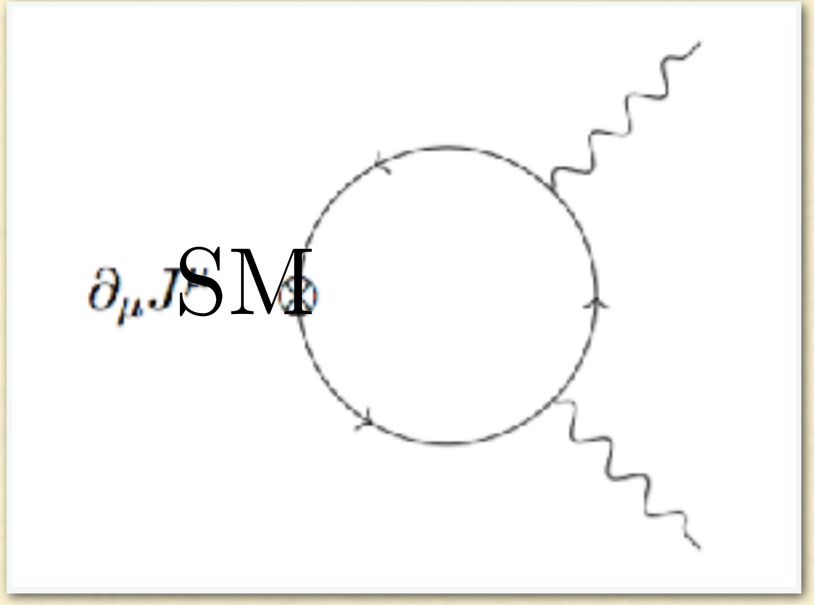
WHAT IS THE LARGEST FLAVOUR SYMMETRY IN SM?

$$U(1)^4 \times SU(3)^5$$

Minimal Flavour Violation

Georgi & Chivukula '87
D'Ambrosio, Giudice, Isidori & Strumia '02

However is this symmetry Gaugable?



NO → **Introduce fermions as many fermions as it takes**

Q - Grinstein, Redi, Villadoro '02
L - RA, Fernandez-Martinez, Gavela, Grinstein, Merlo & Quilez '15

NO → **Some diagonal combination of SU(3)'s, U(1)'s?**

$B - L?$

FLAVOR VIA SYMMETRY: 1-GEN

$$
\begin{array}{ccccccc}
 & q_L\,, & u_R\,, & d_R\,, & \ell_L\,, & e_R\,, & \nu_R \\
U(1)_{B-L} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & -1 & -1 & -1
\end{array}
$$

FLAVOR VIA SYMMETRY: **3**-GEN

	q_L^i	u_R^i	d_R^i	ℓ_L^i	e_R^i	ν_R^i
	q_L^3	t_R	b_R	ℓ_L^3	τ_R	ν_R^3
	q_L^2	c_R	s_R	ℓ_L^2	μ_R	ν_R^2
	q_L^1	u_R	d_R	ℓ_L^1	e_R	ν_R^1
$U(1)_{B-L}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	-1	-1	-1
$SU(3)_Q$	3	3	3	1	1	1
$SU(3)_L$	1	1	1	3	3	3

Flavour 'Horizontal' direction

The Largest Local Symmetry that the SM+3ν_R admits

RA, P. Cox, C. Han & T. T. Yanagida arXiv:1704.08158

FLAVOR VIA SYMMETRY: **3**-GEN

The Largest Local Symmetry that the SM+3ν_R admits

$$SU(3)_Q \times SU(3)_L \times U(1)_{B-L}$$

But the gauge bosons here act independently on quarks and leptons or have no flavor

Break the symmetry to mix the different sectors

$$\theta_{L-Q}$$

with e.g. a bi-fundamental

uncharted territory!

Quark-Lepton tied up in other way…
by a enlarged SM gauge group
GUT's, Pati Salam?

QUARK-LEPTON CONNECTION

Unify quark and lepton representations:

Pati, Salam '74

$$\psi_L = \begin{pmatrix} u_L & d_L \\ \nu_L & e_L \end{pmatrix} \qquad \psi_R = \begin{pmatrix} u_R & d_R \\ e_R & \nu_R \end{pmatrix}$$

$SU(3)_H$

$SU(4)$

$SU(2)$

$$\boxed{SU(4) \times SU(2)_L \times SU(2)_R \times SU(3)_H}$$

$U(1)_{B-L}$ No Landau poles

THE PATTERN OF FLAVOUR BREAKING

Yes, two very massive RH neutrinos are enough for Lepto-genesis and LH masses

$$\bar{\nu}_R^c \lambda_{ij} \phi_i^* \phi_j^\dagger \nu_R + h.c. \qquad i,j = 1,2$$

$$\boxed{SU(3)_H \times U(1)_{B-L} \to U(1)_h} \qquad @\ \Lambda_{\mathrm{Seesaw}}$$

$$J_\mu^h \equiv g_h \bar{\psi} \gamma_\mu T_\psi^h \psi$$

$$T_\psi^h = T_{\mathbb{C}S}^H + t_\omega Q_{B-L}\,,$$

Leptons

$$T_L^h = T_8^H - t_\omega \mathbf{1} = \frac{1}{2\sqrt{3}} \begin{pmatrix} 0 & & \\ & 0 & \\ & & -3 \end{pmatrix}$$

Quarks

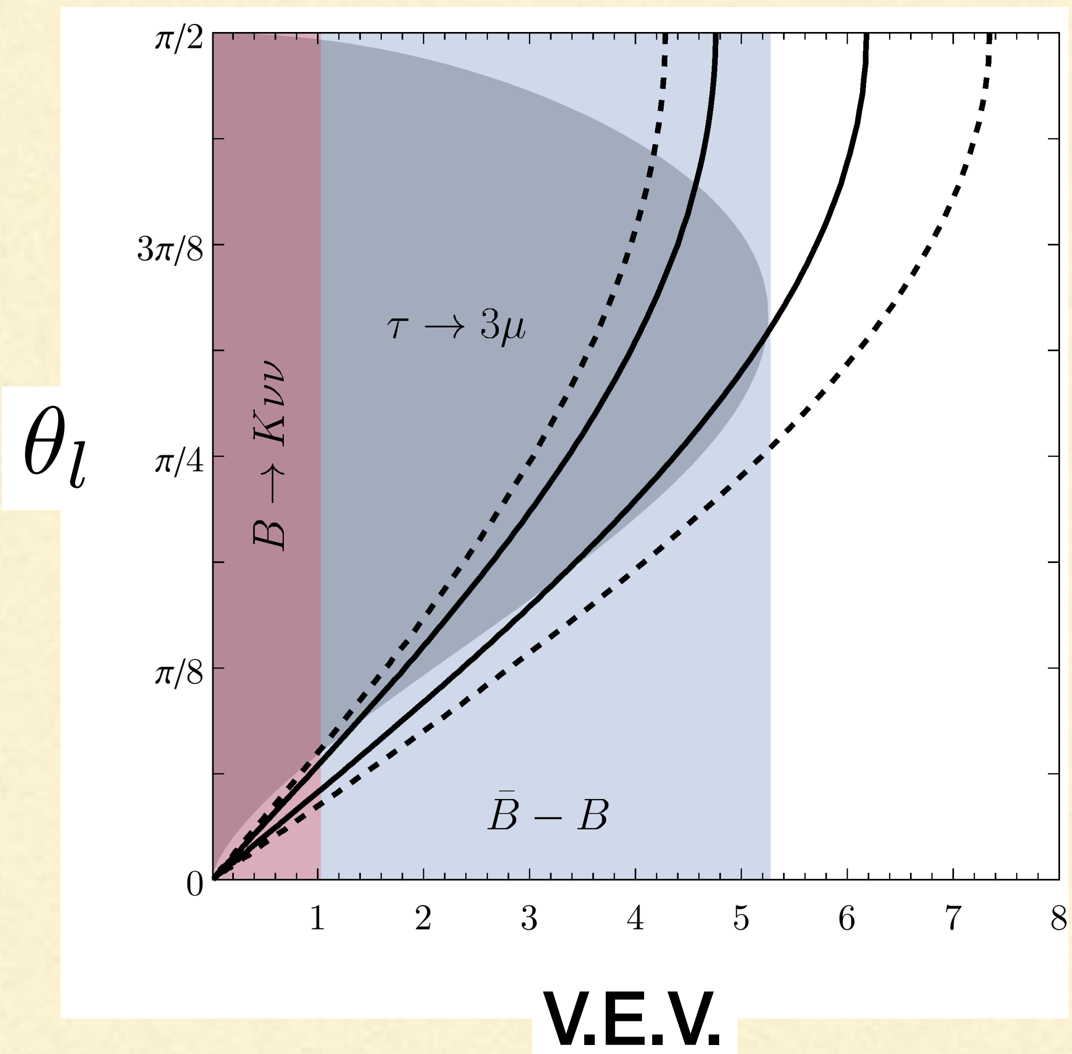
$$T_Q^h = T_8^H + \frac{1}{3} t_\omega \mathbf{1} = \frac{1}{2\sqrt{3}} \begin{pmatrix} \frac{4}{3} & & \\ & \frac{4}{3} & \\ & & -\frac{5}{3} \end{pmatrix}$$

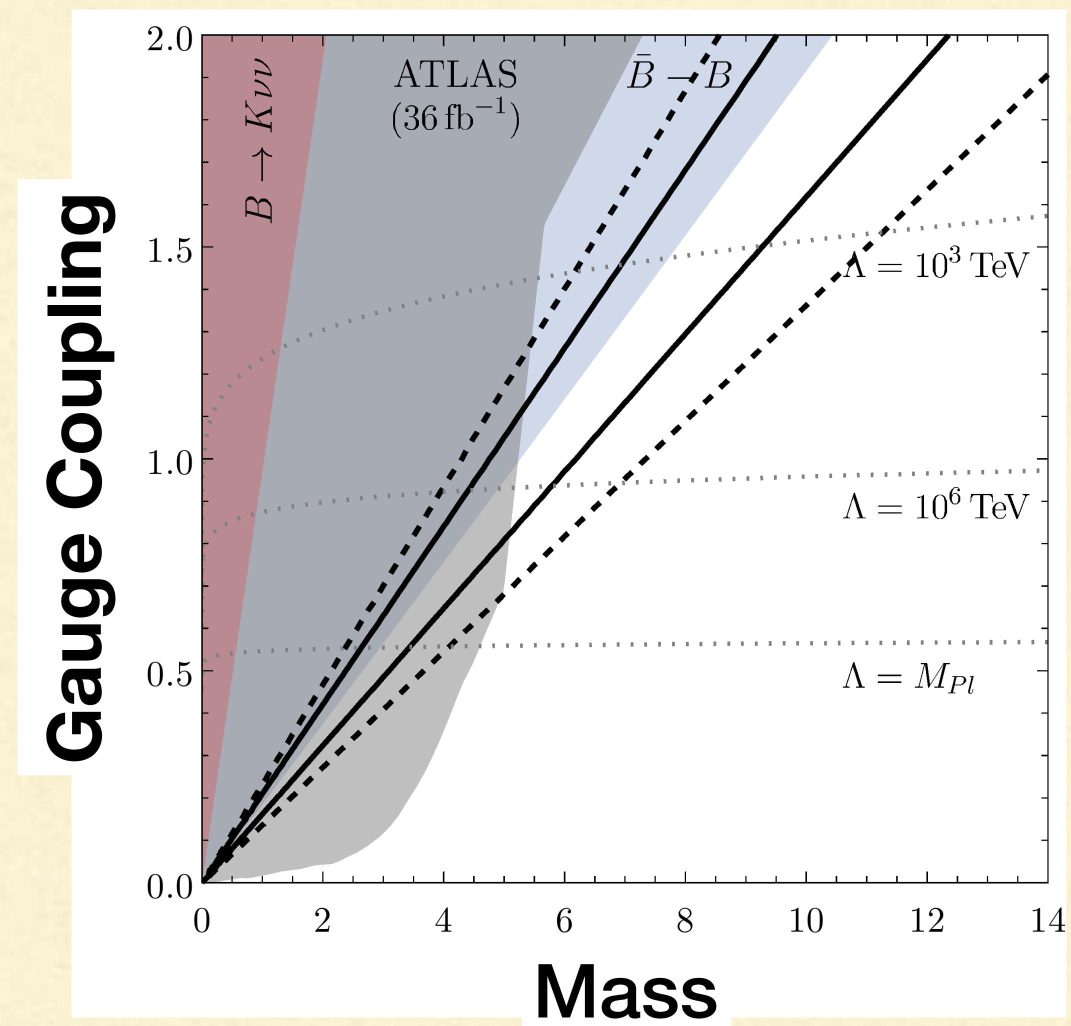
Rotation to mass basis:

$\mathrm{d_L}$ rotation $= V_{CKM}$, ν_L rotation $= R_{23} U_{PMNS}$ $\mathrm{e_L}$ rotation $= R_{23}$

RA, P. Cox, C. Han & T. T. Yanagida arXiv:1704.08158

CONSTRAINTS





Also 'TH constraints' $\beta(g_h) = \frac{269}{36}\frac{g_h^3}{(4\pi)^2}$,

CONCLUSIONS

- Experimental hints point towards flavor physics in Quarks&Leptons
- This could be the tip of a submerged
  `theory of gauged flavor'
- Or a theory of flavor to be formulated by... you