



B-anomalies: Model building attempts

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Based on
..., 1804.04642, 1802.04274, 1801.07641,
1708.08450, 1706.07808, 1704.09015,
1609.07138, 1603.04993,
1506.01705

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NP option?









BSM theorist toolbox

- SMEFT, Flavour symmetries
- Explicit models: Extended gauge sector, etc.





New mass scale?







Vector triplet model $W' = (\mathbf{1}, \mathbf{3}, 0)$

$$\mathcal{L} \supset W^{\prime a \mu} J^{a}_{\mu} + \dots \qquad T^{a} = \sigma^{a}/2$$

$$J^{a}_{\mu} = g_{q} \lambda^{q}_{ij} \left(\bar{Q}^{i}_{L} \gamma_{\mu} T^{a} Q^{j}_{L} \right) + g_{\ell} \lambda^{\ell}_{ij} \left(\bar{L}^{i}_{L} \gamma_{\mu} T^{a} L^{j}_{L} \right)$$

$$Q^{i}_{L} = \begin{pmatrix} V^{*}_{ii} u^{j}_{L} \\ d^{i}_{L} \end{pmatrix} \qquad L^{\alpha}_{L} = \begin{pmatrix} \nu^{\alpha}_{L} \\ \ell^{\alpha}_{L} \end{pmatrix}$$

$$\mathcal{L}^{d=6}_{eff} = -\frac{1}{2m_{V}^{2}} J^{a}_{\mu} J^{a}_{\mu} \longrightarrow \qquad \text{lepton x lepton}$$

$$quark x lepton$$

$$quark x quark$$

- Degenerate <u>charged</u> W'[±] and <u>neutral</u> Z' Quark FV controlled by a <u>single</u> matrix λ_{ij}^q

 $SU(3) \times SU(2)_{L} \times U(1)$

Fitting R(D^(*))





Challenges for Model Builders?

Working example I

'4321'

[Buttazzo, AG, Isidori, Marzocca] JHEP 1711 (2017) 044

> [Di Luzio, AG, Nardecchia] Phys.Rev. D96 (2017) 115011

> > [AG, Ben Stefanek] 1802.04274

Leptoquark option?

Strategy: Dynamical suppression in FCNC $B_s \leftrightarrow \bar{B}_s \qquad B \rightarrow K^{(*)} \nu_{\tau} \bar{\nu}_{\tau}$

Also loop?

[Buttazzo], 2017

Luca Di Luzio, Javier Fuentes Martin ... but I like W'. What was the problem?

Working example II

'3221' [AG, Robinson, Shakya, Zupan] 1804.04642

Matter content

	Field	$SU(3)_c$	$SU(2)_L$	$SU(2)_V$	U(1)'
	SM-like chiral fermions				
	$q_L'^i$	3	2	1	1/6
	$\ell_L'^i$	1	2	1	-1/2
	$u_R'^i$	3	1	1	2/3
	$d_R'^i$	3	1	1	-1/3
	$e_R'^i$	1	1	1	-1
	$ u_R'^i$	1	1	1	0
	Extra vector-like fermions				
	$Q_{L,R}'$	3	1	2	1/6
	$L'_{L,R}$	1	1	2	-1/2
	Scalars				
	H	1	2	1	1/2
	H_V	1	1	2	1/2
_	∧ SM	$\lambda i \overline{\frown} I$	TT 1/1	$\lambda i \overline{\Delta} I$	

$$\mathcal{L} \supset \mathcal{L}_{Yuk}^{SM} - \lambda_d^i \bar{Q}'_L H_V d_R'^i - \lambda_u^i \bar{Q}'_L \tilde{H}_V u_R'^i - \lambda_e^i \bar{L}'_L H_V e_R'^i - \lambda_\nu^i \bar{L}'_L \tilde{H}_V \nu_R'^i - M_Q \bar{Q}'_L Q_R' - M_L \bar{L}'_L L_R' + \text{h.c.}$$

[AG, Robinson, Shakya, Zupan] 1804.04642

: (Connection to R(K^(*))? [work in progress]

'3221' model

[AG, Robinson, Shakya, Zupan] 1804.04642

LHC exclusions: FL-23, 2 VL families

La fin

Hope for the best, but prepare for the worst

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$$\begin{array}{c} \hline \begin{array}{c} \hline \end{array} \\ \hline$$
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Other tree-level contributions

Coherent picture of B-anomalies

Energy	scale	Benchmar	k picture			
NP	$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} - \frac{1}{v^2} \lambda_{ij}^q \lambda_{\alpha\beta}^\ell \left[C_T \; (\bar{Q}_L^i \gamma_\mu \sigma^a Q_L^j) (\bar{L}_L^\alpha \gamma^\mu \sigma^a L_L^\beta) + C_S \; (\bar{Q}_L^i \gamma_\mu Q_L^j) (\bar{L}_L^\alpha \gamma^\mu L_L^\beta) \right]$					
			<u>Flavour basis</u> : $Q_i = (V_{ji}^* u_L^j, d_L^i)^T L_i = (v_L^i, \ell_L^i)^T$			
			$\begin{array}{l} \begin{array}{c} \underline{\text{Fit parameters}}\\ C_T,\ C_S,\ \lambda_{sb}^q,\ \text{and}\ \lambda_{\mu\mu}^\ell\\ \lambda_{bb}^q = \lambda_{\tau\tau}^\ell = 1 \end{array}$			
FW	• Global fi Observable	t to low-energy	data (RGE effects included)			
	$\Delta C_9^{\mu} = -\Delta C_{10}^{\mu}$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\frac{1 + 2C_T (1 - \lambda_{sb}^q V_{tb}^* / V_{ts}^*) (1 - \lambda_{\mu\mu}^\ell / 2)}{-\frac{\pi}{\alpha_{em} V_{tb} V_{ts}^*} \lambda_{\mu\mu}^\ell \lambda_{sb}^q (C_T + C_S)}$			
	$\begin{array}{c} B_{b \rightarrow c}^{\mu e} - 1 \\ B_{K^{(*)} \nu \bar{\nu}} \end{array}$	$\begin{array}{c} 0.00 \pm 0.02 \\ 0.0 \pm 2.6 \end{array}$	$\frac{2C_T(1-\lambda_{sb}^q V_{tb}^*/V_{ts}^*)\lambda_{\mu\mu}^{\ell}}{1+\frac{2}{3}\frac{\pi}{\alpha_{\rm em}V_{tb}V_{ts}^*C_{\nu}^{\rm SM}}(C_T-C_S)\lambda_{sb}^q(1+\lambda_{\mu\mu}^{\ell})}$			
	$\delta g^Z_{ au_L} \ \delta g^Z_{ u_ au}$	$\begin{array}{c} -0.0002 \pm 0.0006 \\ -0.0040 \pm 0.0021 \end{array}$	$\begin{array}{c} 0.033C_T - 0.043C_S \\ -0.033C_T - 0.043C_S \end{array}$			
QCD	$ g^W_ au/g^W_\ell $ $\mathcal{B}(au o 3\mu)$	$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	$\frac{1 - 0.084C_T}{2.5 \times 10^{-4} (C_S - C_T)^2 (\lambda_{\tau\mu}^{\ell})^2}$			
		26	Buttazzo, AG, Isidori, Marzocca], JHEP 1711 (2017) 044			

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Zhong], 1706.05033