B-anomalies:
A Model Builder's Guide
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Based on
... , 1802.04274, 1801.07641,
1708.08450, 1706.07808, 1704.09015,
1609.07138, 1603.04993,
1506.01705
The plots in Fig. 1 show that the Wilson coefficients $C^0_{\alpha}$ and $C^0_{\mu}$ strongly correlate with the LFU observables, leading to a global fit that is strongly disfavored at $4\sigma$. This suggests that the Standard Model needs modifications to accommodate the observed LFU violation.

**Puzzles**

The $b \rightarrow s\mu\bar{\mu}$ decay is observed at $b > 4\sigma$, indicating a significant deviation from the Standard Model predictions.

**Predictions**

The $b \rightarrow cT\bar{\nu}_\tau$ decay is observed at $\sim 4\sigma$ with $\Delta\chi^2 = 1.0$ contours, suggesting that beyond the Standard Model (BSM) theories may be needed to explain these observations.

**BSM theorist**

The ATLAS and CMS collaborations are also working on these puzzles, with the LHCb and Belle collaborations contributing to the search for new physics.
$W'$ model for $b \rightarrow c \tau \nu$

$W' = (1, 3, 0)$

$B_s \leftrightarrow \bar{B}_s$

tree-level

[AG, Isidori, Marzocca]

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$pp \rightarrow \tau^+ \tau^-$

$B$-anomalies

$[\text{Faroughy, AG, F. Kamenik}]$

**MFV Z’ model for b \rightarrow s \mu \mu**

$\mathcal{L} \supset Z_{\mu} J_{\mu}$

$J_{\mu} = g_{Q}^{(1),ij}(\bar{Q}_{i} \gamma_{\mu} Q_{j}) + g_{L}^{(1),kl}(\bar{L}_{k} \gamma_{\mu} L_{l})$

$g_{Q}^{(1),ii} = g_{L}^{(1),22} = g_{*}$

$g_{Q}^{(1),23} = V_{ts} g_{*}$

- **R(K\textsuperscript{(*)})**
- **B-anomalies**

$pp \rightarrow \mu^{+} \mu^{-}$

Diagram:

```
q \rightarrow Z' \rightarrow \mu \mu
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**Lesson**

[AG, Marzocca]

The flavour structure in Eq. \( (2) \) is determined by the

- **Hint I**
  \[
  (\bar{Q}^i_L \gamma_\mu \sigma^a Q^j_L)(\bar{L}^\alpha_L \gamma_\mu \sigma^a L^\beta_L)
  \]

- **Hint II**

**Large NP**

- +15%

**Small NP**

- -15%

**Flavour puzzle?**
The discussion susceptibility the third-generation left-handed quarks and leptons.

Scale only four-fermion operators built in terms of left-handed quarks and leptons have non-vanishing Wilson coefficients.

The flavour structure is determined by the $U(2) \times U(2)$ flavour symmetry, minimally broken by two spurions $V \cdots V_2$, $V_1$. Operators containing flavour-blind contractions of the light fields have vanishing Wilson coefficients.

To consider two or more of them at the same time. For this reason, and also for illustrative purposes, we focus on simplified models.

We first discuss the consequences of these hypotheses on the structure of the relevant effective Lagrangian at the weak scale, $246 \text{ GeV}$. For simplicity, the definition of the EFT cut-off scale is presented in Appendix 1.

The complete set of single-mediator models with tree-level matching to the vector triplet, colour-triplet scalars $Z'$, $W'$, and $B'$, is contained in the Hermitian matrices $\sigma_{1 \sigma}, \sigma_{2 \sigma}, \sigma_{3 \sigma}$.

The normalisation of the relevant parameters is chosen to be $-0.06$, $-0.04$, $-0.02$, $0.00$, $0.02$, $0.04$, $0.06$.

The main points can be summarised as follows:

- **Semileptonic B-decays**
- **LFU and LFV in tau decays**
- **Z-pole precision**

**Lesson 3**

[Buttazzo, AG, Isidori, Marzocca]

JHEP 1711 (2017) 044
Lesson 4

Vector LQ: \textit{High-}p_T \textit{hunt}

- $g g \rightarrow \tau^+ \tau^-$ \(1609.07138\)
- $p p \rightarrow \tau^+ \tau^-$ \(300 \text{ fb}^{-1}\)

Vector LQ: \textit{Model building}

Gauge boson of an extended “4321” gauge symmetry

[[AG, Ben Stefanek]], 1802.04274

See also
[[Bordone, Cornella, Fuentes-Martin, Isidori]], 1712.01368


[Buttazzo, AG, Isidori, Marzocca] JHEP 1711 (2017) 044
LQ at the LHC

\[ \mathcal{L} \supset y q \ell q \ell \Phi + \text{h.c.} \]

\[ \sigma_{\text{single}} = \sigma_{\text{pair}} \]

LHC@13 TeV

\[ \mathcal{L} \supset y q \ell q \ell \Phi + \text{h.c.} \]

Scalar LQ

MadGraph5_aMC@NLO
PDF4LHC15_nlo_mc

LQ MC tool at NLO QCD:
http://lqnlo.hepforge.org

See also talk by Yuta Takahashi

Lesson 5

LQ physics review:
[Doršner, Fajfer, AG,
Košnik, F. Kamenik]
Phys.Rept. 641 (2016) 1-68
Thank you