Flavour Anomalies

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Introduction to Flavour Physics

Flavour, Universality & Tests
The Standard Model

- **Gauge Group:** \( G_{\text{SM}} = SU(3)_C \times SU(2)_L \times U(1)_Y \)

- **Lagrangian:** \( \mathcal{L}_{\text{SM}} = \mathcal{L}_{\text{kin}} + \mathcal{L}_{\text{Higgs}} + \mathcal{L}_{\text{Yukawa}} \)

- **Fermions:** (in 3 generations \( i = 1, 2, 3 \))
  \( Q_{Li} \ (3, 2)_{1/6}^+ , \ U_{Ri} \ (3, 1)_{2/3}^+ , \ D_{Ri} \ (3, 1)_{-1/3}^- , \ L_{Li} \ (1, 2)_{-1/2}^-, \ E_{Ri} \ (1, 1)_{-1}^- \)
  with doublets \( Q_{Li} = (U_{Li}, D_{Li}) \) & \( L_{Li} = (\nu_{Li}, E_{Li}) \)

- **Higgs inducing SSB:** \( SU(2)_L \times U(1)_Y \rightarrow U(1)_{EM} \)
  \( \phi \ (1, 2)_{1/2}^+ \), \( \phi = \frac{1}{\sqrt{2}}(0, v + H) \)
Flavour (Physics)

- Flavour = species of fermion in SM: 6 quark and 6 lepton flavours: \( u, d, c, s, t, b, e, \mu, \tau, \nu_e, \nu_\mu, \nu_\tau \)

- Kinetic terms induce couplings of flavours to gauge bosons through gauge covariant derivative

- After SSB: (focus on \( W^\pm, Z \) and on coupling of left-handed fermions)

\[
\mathcal{L}_{\text{kin}}^q \supset \frac{g}{\sqrt{2}} \bar{U}_L i \gamma^\mu \delta_{ij} D_{Lj} W^+ + \text{h.c.}
\]

\[
+ \frac{g}{\sqrt{2}} \bar{U}_L i \gamma^\mu \delta_{ij} U_{Lj} Z + \frac{g}{\sqrt{2}} \bar{D}_L i \gamma^\mu \delta_{ij} D_{Lj} Z
\]

\( \Rightarrow \) \( W^\pm \) can induce \textbf{flavour change} (no \textit{flavour changing neutral current} (FCNC) via \( Z \) or gluons or photon), same holds true for lepton kinetic term
(Flavour) Universality

- **(Flavour) Universality** = flavour-independent coupling to all gauge bosons
  - for $E \gg m$, we have
    \[
    \Gamma(\text{\textit{Z}}\text{\textit{e}}\text{\textit{e}}) = \Gamma(\text{\textit{Z}}\text{\textit{\mu}}\text{\textit{\mu}})
    \]
    or
    \[
    \Gamma(\text{\textit{W}}^+\text{\textit{e}}\text{\textit{\nu}}_e) = \Gamma(\text{\textit{W}}^+\text{\textit{\mu}}\text{\textit{\nu}}_{\text{\mu}})
    \]
    (for finite energies: mass dependence)
- We focus on $SU(2)_L$-sector
  - For leptons it has been measured: $g_e = g_\mu = g_\tau$
- Compare previous form of gauge boson couplings: *looks* universal
  - But **universality is a basis independent property** \(\Rightarrow\) Go to mass eigenbasis
  - This is the basis we use when measuring particles
Quark vs Lepton Flavour Universality: Quarks

Diagonalize Yukawa interaction

\[ \mathcal{L}_{\text{Yukawa}}^q \supset Y_{ij}^U \bar{Q}_{Li} \phi U_{Rj} + Y_{ij}^D \bar{Q}_{Li} \phi D_{Rj} \rightarrow \text{diagonal mass terms} \]

Do this by \textit{unitary} field transformation of left-handed doublet

\[ U_{Li} \rightarrow V_{ij}^U U_{Lj}, \quad D_{Li} \rightarrow V_{ij}^D D_{Lj}, \quad (\text{some transf. of right-handed quarks}) \]

The (so far diagonal) coupling term to \( W, \overline{U}_{Li} \delta_{ij} D_{Lj} W^+ \), transforms to

\[ \delta_{ij} \rightarrow (V^U)_{ik}^{\dagger} \delta_{kl} (V^D)_{lj} = (V_{\text{CKM}})_{ij} \]

\[ \Rightarrow \text{Non-universal due to independent transf. of components of } SU(2)_L\text{-doublet} \]

Note that e.g. \( \overline{U}_{Li} \delta_{ij} U_{Lj} Z \) stays diagonal/universal (\( \rightarrow \) still no FCNC)
Quark vs Lepton Flavour Universality: Leptons

Repeat for lepton sector...

\[ \mathcal{L}_{\text{Yukawa}}^{l} \ni Y_{ij}^{l} \bar{L} L \phi E_{Rj} + \text{h.c.} \rightarrow \text{diagonal mass terms} \]

\[ L_{Li} \rightarrow V_{ij}^{L} L_{Lj}, \quad \text{(some transf. of right-handed leptons)} \]

Important difference: Components of doublet transformed together

(there is only one Yukawa matrix to be diagonalized)

Therefore the \( W^{\pm} \)-coupling transforms like

\[ \delta_{ij} \rightarrow (V^{l})^{\dagger}_{ik} \delta_{kl} (V^{l})_{lj} = \delta_{ij} \]

\[ \Rightarrow \text{Lepton Flavour Universality (LFU)} \text{ in the SM} \]
Testing LFU: B to D/K

Consider B-meson decays to D- or K-mesons:

where e.g.

$$\Gamma(B \rightarrow D \, l \, \bar{\nu}_l) = \Gamma(b \rightarrow c \, l \, \bar{\nu}_l) \cdot F_{QCD}$$

$\rightarrow F_{QCD}$ is independent of $l$ and $\bar{\nu}_l$

$\Rightarrow$ consider ratios such that lepton-independent factors drop out
Almost all the calculations of the branching ratios in flavour physics rely on the narrow width approximation (NWA):
Intermediate particle *created on-shell* with subsequent decay

Works well when:

- Mass peak is narrow: $\Gamma_m \ll m$.
- Propagator is separable from matrix element.
- Sub-processes are kinematically allowed: $\sqrt{s} \gg m + m_2$, $m \gg m_3 + m_4$.
- No interference.

\[ \Gamma(1 \rightarrow 234) = \Gamma(1 \rightarrow 2m) \times \text{Br}(m \rightarrow 34) \]
Testing LFU

\[
\frac{\Gamma(B \rightarrow D l \bar{\nu}_l)}{\Gamma(B \rightarrow D l' \bar{\nu}_{l'})} = \frac{Br(W \rightarrow l \bar{\nu}_l)}{Br(W \rightarrow l' \bar{\nu}_{l'})} \frac{\Gamma(b \rightarrow c W)}{\Gamma(b \rightarrow c W)} \frac{F_{QCD}}{F_{QCD}}
\]

\[
= \frac{Br(W \rightarrow l \bar{\nu}_l)}{Br(W \rightarrow l' \bar{\nu}_{l'})} \quad ? \quad 1
\]

Test: Ratios of decay rates that only differ by final lepton content (e.g. \( B \rightarrow D l \bar{\nu}_l \)) should be unity (up to lepton mass dependence).
Experimental Signatures of Flavour Anomalies
Signature Part - General Idea

- Measure B decays that only differ in final lepton content (Test LFU)

\[ B \to X l \nu_l \quad B \to X ll \]

where X is meson under study

\[ R_X \equiv \frac{BR(B \to Xll/\nu)}{BR(B \to Xl'l'/l'\nu')} \]

- rare loop induced b decays \( R_{K^*}(b \to s) \)
- tree-level tauonic decays \( R_{D^*}, R_{J/\psi}(b \to c) \)
FCNC (RK)

\[ R_{K(*)} \equiv \frac{BR(B \to K(*) \mu^+ \mu^-)}{BR(B \to K(*) e^+ e^-)} \]

- Loop process, rare in SM, good chance for new physics
- Theoretical uncertainties factor out and cancel
- In measurement: double ratio to J/Psi, first order systematic cancellation

From SM: \( RK(*) = 1 + \text{phase space corr.} \)
FCNC discrepancies

- Two bins:
  - low-$q^2$ 0.0045 GeV$^2$-1.1 GeV$^2$
  - central-$q^2$ 1.1 GeV$^2$ - 6 GeV$^2$
  - good theoretical description

$R_{K^*} = 0.66^{+0.11}_{-0.07}$ (stat) $\pm 0.03$ (syst) for $0.045 < q^2 < 1.1$ GeV$^2$/c$^4$

$R_{K^*} = 0.69^{+0.11}_{-0.07}$ (stat) $\pm 0.05$ (syst) for $1.1 < q^2 < 6.0$ GeV$^2$/c$^4$

- SM compatibility at 2.2-2.5σ level
Experimental Difficulties

- Muons very clean
- Electrons more problematic
Difficulties in electron reconstruction

- Electron reconstruction difficult
- Bremsstrahlung affects resolution & efficiencies
- Can be partially corrected

Also: Higher Trigger Threshold for e-
Outlook for the RK(*) anomaly

→ Higher statistics from LHCb

→ New experiment: Belle II

→ Improved resolution in electron channel
Angular Observable for FCNC

- angular observable $P_5^\prime$ -> form factor uncertainties cancel at leading order
- significant tension of 3.4 sigma
- J/Psi: theo. prediction difficult
Tree Level (RD, RD*)

\[
R_{D(*)} \equiv \frac{BR(B \to D(*) \tau \bar{\nu}_\tau)}{BR(B \to D(*) l \bar{\nu}_l)}, \quad \text{with } l = e, \mu
\]

\[\rightarrow R_D \approx 0.3, \quad R_{D*} \approx 0.25\]

Problem: \(\tau^- \to e^- \bar{\nu}_e \nu_\tau\) or \(\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau\)

\[\rightarrow\text{Similar final states in numerator & denominator}\]
Interlude: Advantages of Belle

→ Different $p_{\text{invisible}}$ for numerator (3 ν) and denominator (1 ν)
$M_{\text{miss}}$ distribution sg/bkg

$M^2_{\text{miss}} < 0.85$

dominated by denominator (1 $\nu$)

$M^2_{\text{miss}} > 0.85$ ( + neural net)

dominated by numerator (3 $\nu$)
Results \((R_D, R_{D^*})\) anomaly
Theory & Model-building

\[ b \to s \] anomalies

- Found by LHCb (and perhaps hinted by Belle)
- Many observables: global pattern
- Neutral current
- 1-loop (and CKM-suppressed) in the SM
- The New Physics can be heavy

\[ b \to c \] anomalies

- Found by several experiments (LHCb, BaBar and Belle)
- Two observables: R(D) and R(D*)
- Charged current
- Tree-level in the SM
- The New Physics must be light

[A. Vicente, Post-FPCP School 2018]
General consideration and remarks

- Angular and BR anomalies can be faked by hadronic uncertainties $\rightarrow$ QCD effect?
- LFU ratios are “clean” (cannot be mimicked by hadronic physics) $\rightarrow$ deviation still below 3 $\sigma$

Long list of experimental constraints:
- Other flavor observables: $B_s$-mixing, $\mathcal{B}(B \rightarrow K^{(*)}\bar{\nu}\nu)$, $b \rightarrow s\gamma$
- Direct LHC search: $pp \rightarrow \mu\mu, \tau\tau$
- Lepton universality test: $Z \rightarrow ll$
- Neutrino trident production
- Precision EW data

[A. Vicente, Post-FPCP School 2018]
EFT as model-independent approach

Assume:
1. Anomalies caused by New physics
2. new states are “heavy”: $\Lambda \gg m_b$

$$\frac{g^2}{8m_W^2} \rightarrow \frac{G_F}{\sqrt{2}}$$
weak EFT for (b-s) anomaly:

- non-renormalisable operators $O_i$ + Wilson coefficients $C_i$
- $C_i$ receive contributions from SM and NP
- SM reaction calculable and known with high precision
- important for anomaly: $C_9$, $C_{10}$

$$\mathcal{H}_{\text{eff}} = -\frac{4 G_F}{\sqrt{2}} \frac{e^2}{16\pi^2} V_{tb} V_{ts}^* \sum_i C_i O_i + \text{h.c.}$$

$$O_7^{(i)} = \frac{m_b}{e} (\bar{s} \sigma_{\mu\nu} \gamma^\mu P_{R(L)} b) F^{\mu\nu}$$

$$O_9^{(i)} = (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{\ell} \gamma^\mu \ell) \quad O_{10}^{(i)} = (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{\ell} \gamma^\mu \gamma_5 \ell)$$

$$O_S^{(i)} = (\bar{s} P_{R(L)} b) (\bar{\ell} \ell) \quad O_P^{(i)} = (\bar{s} P_{R(L)} b) (\bar{\ell} \gamma_5 \ell)$$
Gauge-invariant EFT approach: SMEFT

- non-gauge invariant EFTs **miss** relations among operators
- formulate EFT in terms of gauge-invariant operators
  - up to dim-6
  - 2499 real parameters
  - full 1-loop RGEs computed

<table>
<thead>
<tr>
<th>SMEFT operator</th>
<th>Definition</th>
<th>Matching</th>
<th>Order</th>
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<tr>
<td>([Q_{\ell\ell}^{(1)}]_{223})</td>
<td>((\bar{\ell}<em>a \gamma</em>\mu \ell_a) (\bar{q}_2 \gamma^\mu q_3))</td>
<td>(O_{9,10})</td>
<td>Tree</td>
</tr>
<tr>
<td>([Q_{\ell\ell}^{(3)}]_{223})</td>
<td>((\bar{\ell}<em>a \gamma</em>\mu \tau^l \ell_a) (\bar{q}_2 \gamma^\mu \tau^l q_3))</td>
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<td>([Q_{\varphi\ell\ell}]^{(1)}_{\ell\ell})</td>
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\[ Q_{\ell\ell}^{(1)} \mid_{223} = (\bar{\ell}_2 \gamma_\mu \ell_2) (\bar{q}_2 \gamma^\mu q_3) \]

EW scale \(\mu_{EW}\)

WET \(O_{9\mu} = (\bar{s} \gamma_\mu P_L b) (\bar{\mu} \gamma^\mu \mu)\)

[A. Vicente, Post-FPCP School 2018]
Global fits

- same Wilson coefficients enter several observables
- use pattern of deviations to extract “best” value

→ NP preferred over SM by more than 4-5σ!
→ $C_{9\mu}$ seems to be crucial!

Inclusive

\[ B \to X_s \gamma \ (BR) \quad \text{--------------------------------------} \quad C_{7}^{(t)} \]
\[ B \to X_s \ell^+\ell^- \ (dBR/dq^2) \quad \text{--------------------------------------} \quad C_{7}^{(t)}, C_{9}^{(t)}, C_{10}^{(t)} \]

Exclusive leptonic

\[ B_s \to \ell^+\ell^- \ (BR) \quad \text{--------------------------------------} \quad C_{10}^{(t)} \]

Exclusive radiative/semileptonic

\[ B \to K^* \gamma \ (BR, S, A_s) \quad \text{--------------------------------------} \quad C_{7}^{(t)} \]
\[ B \to K\ell^+\ell^- \ (dBR/dq^2) \quad \text{--------------------------------------} \quad C_{7}^{(t)}, C_{9}^{(t)}, C_{10}^{(t)} \]
\[ B \to K^*\ell^+\ell^- \ (dBR/dq^2, \text{angular obs.}) \quad \text{--------------------------------------} \quad C_{7}^{(t)}, C_{9}^{(t)}, C_{10}^{(t)} \]
\[ B_s \to \phi \ell^+\ell^- \ (dBR/dq^2, \text{angular obs.}) \quad \text{--------------------------------------} \quad C_{7}^{(t)}, C_{9}^{(t)}, C_{10}^{(t)} \]

\[\text{[A. Vicente, Post-FPCP School 2018]}\]

<table>
<thead>
<tr>
<th>1D Hyp.</th>
<th>Best fit</th>
<th>1 σ</th>
<th>2 σ</th>
<th>Pull$_{SM}$</th>
<th>p-value</th>
<th>Best fit</th>
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<th>2 σ</th>
<th>Pull$_{SM}$</th>
<th>p-value</th>
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<tr>
<td>$C_{9\mu}^{NP}$</td>
<td>-1.10</td>
<td>[-1.27, -0.92]</td>
<td>[-1.43, -0.74]</td>
<td>5.7</td>
<td>72</td>
<td>-1.76</td>
<td>[-2.36, -1.23]</td>
<td>[-3.04, -0.76]</td>
<td>3.9</td>
<td>69</td>
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<tr>
<td>$C_{9\mu}^{NP} = -C_{10\mu}^{NP}$</td>
<td>-0.61</td>
<td>[-0.73, -0.48]</td>
<td>[-0.87, -0.36]</td>
<td>5.2</td>
<td>61</td>
<td>-0.66</td>
<td>[-0.84, -0.48]</td>
<td>[-1.04, -0.32]</td>
<td>4.1</td>
<td>78</td>
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<tr>
<td>$C_{9\mu}^{NP} = -C_{9\mu}^{NP}$</td>
<td>-1.01</td>
<td>[-1.18, -0.84]</td>
<td>[-1.33, -0.65]</td>
<td>5.4</td>
<td>66</td>
<td>-1.64</td>
<td>[-2.12, -1.05]</td>
<td>[-2.52, -0.49]</td>
<td>3.2</td>
<td>31</td>
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<tr>
<td>$C_{9\mu}^{NP} = -3C_{9\mu}^{NP}$</td>
<td>-1.06</td>
<td>[-1.23, -0.89]</td>
<td>[-1.39, -0.71]</td>
<td>5.8</td>
<td>74</td>
<td>-1.35</td>
<td>[-1.82, -0.95]</td>
<td>[-2.38, -0.59]</td>
<td>4.0</td>
<td>71</td>
</tr>
</tbody>
</table>

[Capdevila et al, 1704.05340]
Model-independent fits to $C_{9,10}^{(')}$

e.g. in context of $R_K^{(\infty)}$

More observables needed for discrimination among different best-fit scenarios!

[D. Straub, Flavour anomalies, MPIK 2018]
UV models: difficulties & common features

- Loop suppression of neutral currents with respect to the charged ones.
- NP: $J_{\text{quark}} \times J_{\text{lepton}}$ with no traces in $J_{\text{quark}} \times J_{\text{quark}}$ (constraints from $B_s$ mixing) and $J_{\text{lepton}} \times J_{\text{lepton}}$ (constraints from pure LFV/LUV decays).
- Most models involve:
  - New charged (coloured) states.
  - Mass $\sim$TeV (to explain relatively large effects).
  - Significant coupling to the 3$^{\text{rd}}$-generation SM fermions (constraints from resonances decaying to $\tau \tau$ pairs).

Typical UV complete theory contains new states that are:

- Lorentz scalars/vectors
- $\text{SU}(3)_c$: singlet/triplet; $\text{SU}(2)_L$: singlet/doublet/triplet.
Example #1: $Z'$

Additional $U(1)_\chi$ generates $O_9$, $O_{10}$:

But also:

Explains $B \to K$ anomalies for $m_{Z'} \sim \text{TeV}$
Example #2: leptoquark

New scalar field: SU(3)$_c$-triplet, SU(2)$_L$- singlet.

Can it explain both $B \to K$ & $B \to D$ anomalies?

Requiring also electric charge equal to -$\frac{1}{3}$. ...
Example #2: leptoquark

\( B \to D^* \tau \nu: \) tree-level

\[ b \to c (s) \phi \to \mu \gamma \]

\( B \to K^* \ll: \) only at 1-loop level

\( B \to K^* \ll: \)

But also:

\( B \to K \& B \to D \) anomalies for \( m_\phi \sim \text{TeV} \)

(Bounds from \( B_S - B^-_S \) mixing, \( D \to \mu^+ \mu^- \), \( \tau \to \mu \gamma \))

*According to 1608.07583, accurate calculation of the loop-induced effects makes \( R^{\tau/l}_D \) inconsistent with data.
Mainstream models:

1. **Z’**
   - flavor-changing coupling to LH quarks
   - VL couplings to leptons
   - flavor violation or non-universality in lepton sector

2. **Leptoquarks**
   - scalar or vector
   - not simult. lepton non-universal and L conserving

3. **Compositeness**
   - neutral resonance, coupling to muons (part. composite)
   - lepton flavor violating couplings
   - constrained by LEP (Z-width) and B_s -B_s -mixing

[N. Mahmoudi, DM@LHC 2018]
Summary: Flavor could be around the corner!

- **SM prediction:** LFU!

- **Several anomalies in B physics**
  - $b\to s \mu\mu$ BR & $P_5'$ - hadr. uncertainties, but significant
  - $R_K^{(*)}$ - theo. clean but not too significant
  - $R_D^{(*)}$ - theo. clean and significant

- **NP highly constrained, but combined NP solution for all anomalies possible!**

- **More data and new experiments crucial**
  - LHC Run 2
  - Belle-II experiment
Backup
Angular observables

\[ \frac{d^4 \Gamma}{dq^2 \, d\cos \theta_K \, d\cos \theta_\ell \, d\phi} = \frac{9}{32\pi} \left[ J_{1s} \sin^2 \theta_K + J_{1c} \cos^2 \theta_K + (J_{2s} \sin^2 \theta_K + J_{2c} \cos^2 \theta_K) \cos 2\theta_\ell + J_3 \sin^2 \theta_K \sin^2 \theta_\ell \cos 2\phi + J_4 \sin 2\theta_K \sin 2\theta_\ell \cos \phi + J_5 \sin 2\theta_K \sin \theta_\ell \cos \phi + (J_{6s} \sin^2 \theta_K + J_{6c} \cos^2 \theta_K) \cos \theta_\ell + J_7 \sin 2\theta_K \sin \theta_\ell \sin \phi + J_8 \sin 2\theta_K \sin 2\theta_\ell \sin \phi + J_9 \sin^2 \theta_K \sin^2 \theta_\ell \sin 2\phi \right] \]

\( J_i \): functions of \( q^2, C_i, \) FF

Optimized observables

\[ P_5' = \frac{J_5}{2\sqrt{-J_{2s}J_{2c}}} \]

[Figure borrowed from Javier Virto]
weak EFT operators

Operator set for $b \to s$ transitions:

- **4-quark operators**
  \[ \mathcal{O}_{1,2} \propto (\bar{s} \Gamma_\mu c)(\bar{c} \Gamma^\mu b) \]
  \[ \mathcal{O}_{3,4} \propto (\bar{s} \Gamma_\mu b) \sum_q (\bar{q} \Gamma^\mu q) \]

- **Chromomagnetic dipole operator**
  \[ \mathcal{O}_8 \propto (\bar{s} \sigma^{\mu\nu} T^a P_R) G_{\mu\nu}^a \]

- **Electromagnetic dipole operator**
  \[ \mathcal{O}_7 \propto (\bar{s} \sigma^{\mu\nu} P_R) F_{\mu\nu}^a \]

- **Semileptonic operators**
  \[ \mathcal{O}_9 \propto (\bar{s} \gamma^\mu b_L)(\bar{\ell} \gamma_{\mu\nu} \ell) \]
  \[ \mathcal{O}_{10} \propto (\bar{s} \gamma^\mu b_L)(\bar{\ell} \gamma_{\mu\nu} \gamma_5 \ell) \]

+ the chirality flipped counter-parts of the above operators, $\mathcal{O}'_i$

[N. Mahmoudi, DM@LHC 2018]
Typical EFT scales

All scales $\Lambda_i$ probed so far appear to be rather large:

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<th>Order</th>
<th>Observable</th>
<th>New-physics scale for $g=O(1)$</th>
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<tr>
<td>D=5</td>
<td>Neutrino oscillations</td>
<td>$\Lambda \sim 10^9$ TeV</td>
</tr>
<tr>
<td>D=6</td>
<td>Proton decay</td>
<td>$\Lambda &gt; 10^{12}$ TeV</td>
</tr>
<tr>
<td>D=6</td>
<td>Flavor physics</td>
<td>$\Lambda &gt; 1-10^5$ TeV</td>
</tr>
<tr>
<td>D=6</td>
<td>EWPT</td>
<td>$\Lambda &gt; 1$ TeV</td>
</tr>
<tr>
<td>D=6</td>
<td>Higgs couplings</td>
<td>$\Lambda &gt; 0.5-1$ TeV</td>
</tr>
</tbody>
</table>

[M. Neubert, Exotic Hadrons & Flavor Physics 2018]
combination of measurements

- “orthogonal” systematic uncertainties
- test different regions of parameter space
- plot
- combined significance…
- future improvements and prospects
- projected uncertainty and limitations

-> final comment: LHCb+Belle -> final data samples will be sufficient to confirm discovery of anomalies or rule it out

-> hot topic that could guide us to new physics -> Theory consideration part
JHEP08(2017)055

- J/Psi & Y(2s) visible as horizontal lines
- Vertical line: B -> K^* l^+ l^-
Challenges on both sides ...

**Experimental measurements:**
- tbd
- tbd

**Theoretical calculations:**
- form factors: require non-perturbative calculations
- “non-factorisable” hadronic effects: problematic since easily generated at tree-level

[D.Straub, Flavour anomalies, MPIK 2018]