Flavour Anomalies
on the Eve of the Run-2 Verdict

Diego Guadagnoli
LAPTh Annecy (France)

Flavor anomalies

0 ***A first qualitative observation***

A whole range of $b \to s$ *measurements involving a* $\mu\mu$ *pair display a consistent pattern:*
Exp < SM

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LHCb 2014

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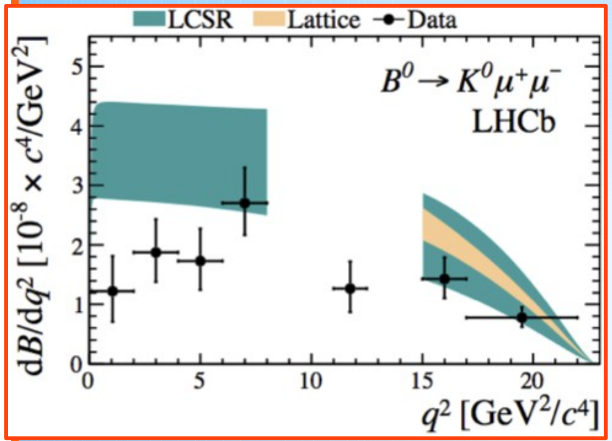

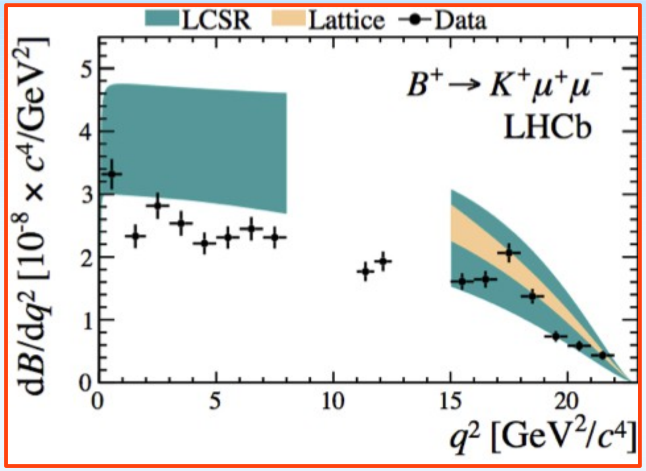

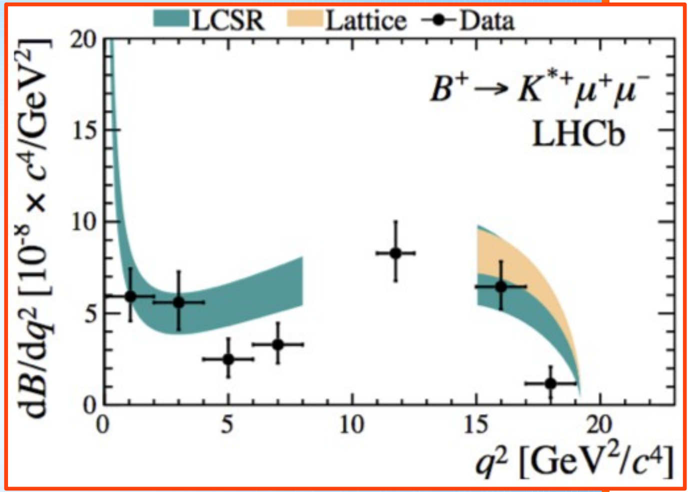

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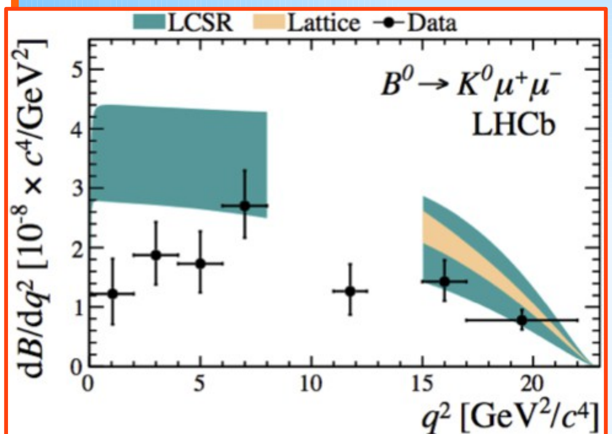

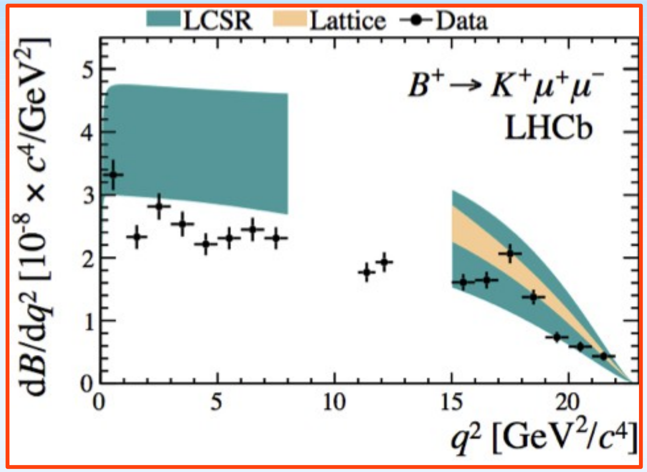

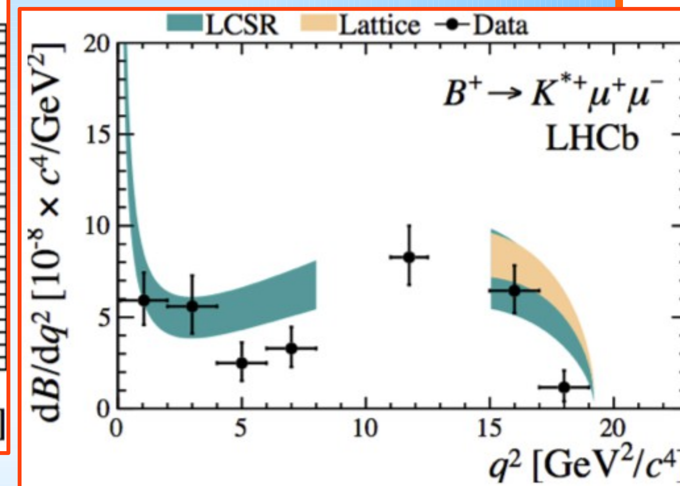

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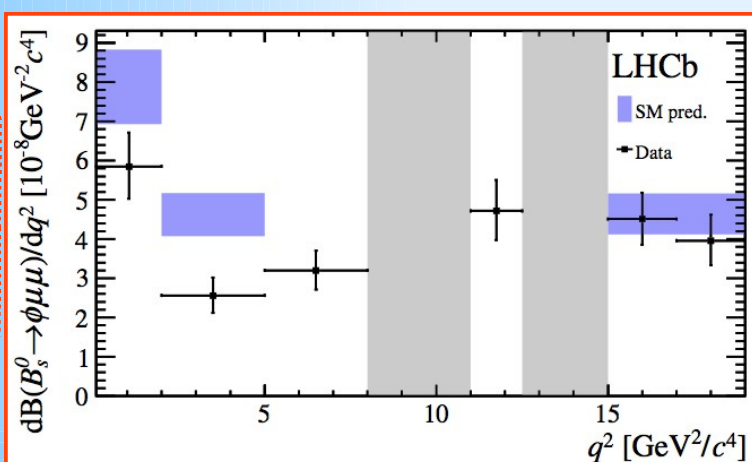

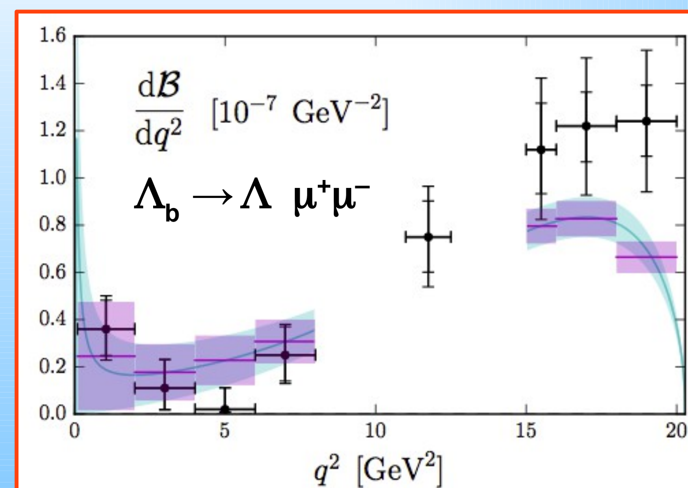

LHCb 2015 & Detmold+Meinel '16

b → s data

We know that BR measurements suffer from large f.f. uncertainties.
However, here's a clean quantity:

❶ $$R_K = \frac{BR(B^+ \to K^+ \mu\mu)_{[1,6]}}{BR(B^+ \to K^+ e e)_{[1,6]}} = 0.745 \cdot (1 \pm 13\%)$$

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❸ ***B → K* μμ angular analysis:*** *discrepancy in one combination of the angular expansion coefficients, known as P'_5*

❸ ***$B \to K^* \mu\mu$ angular analysis:***

The P'_5 anomaly

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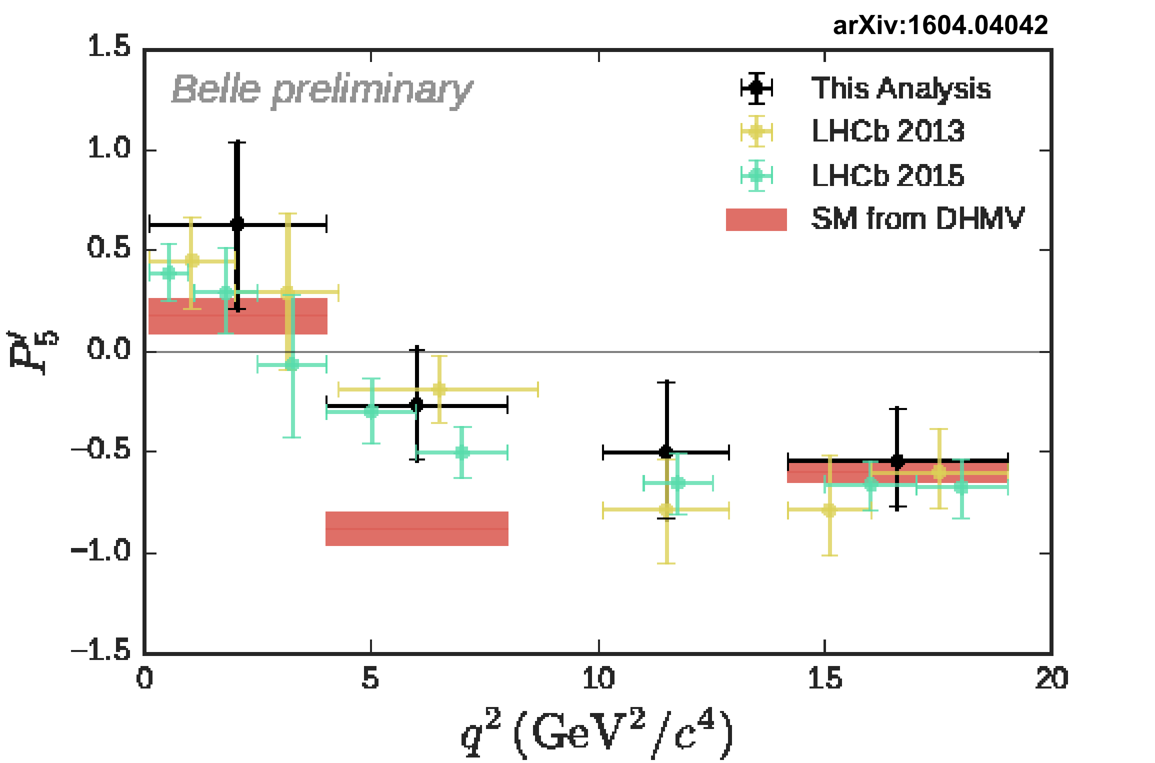

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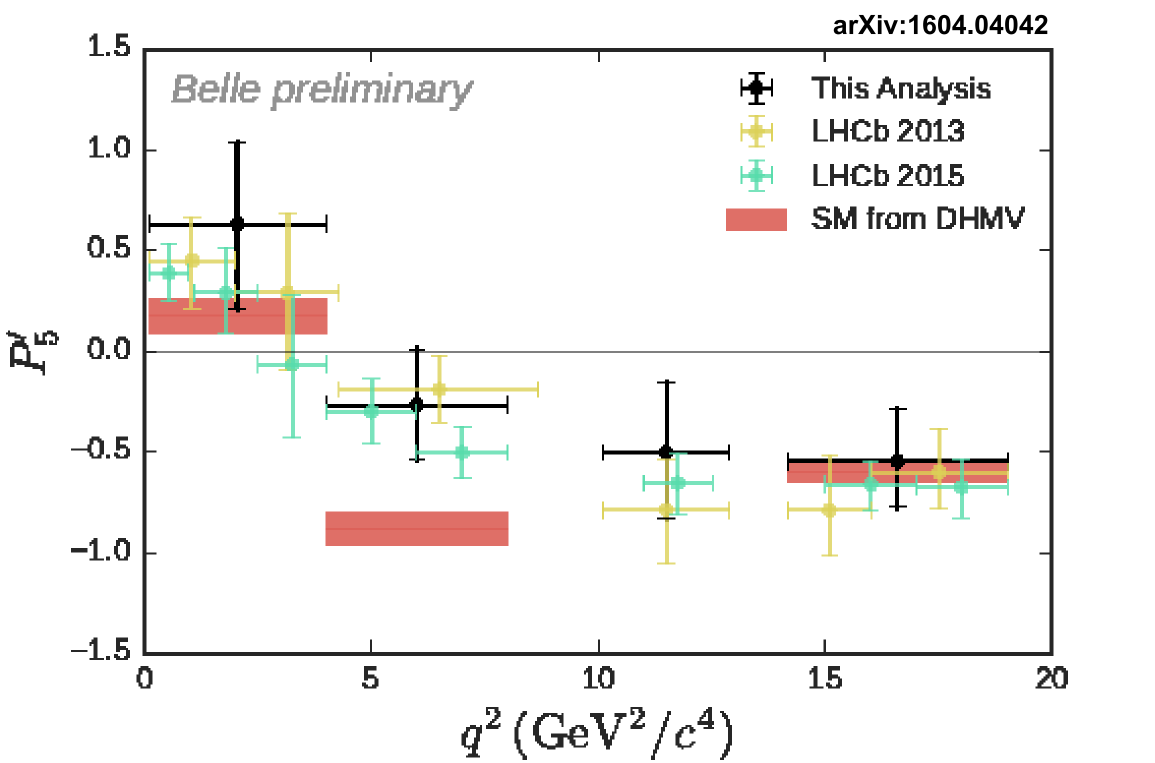

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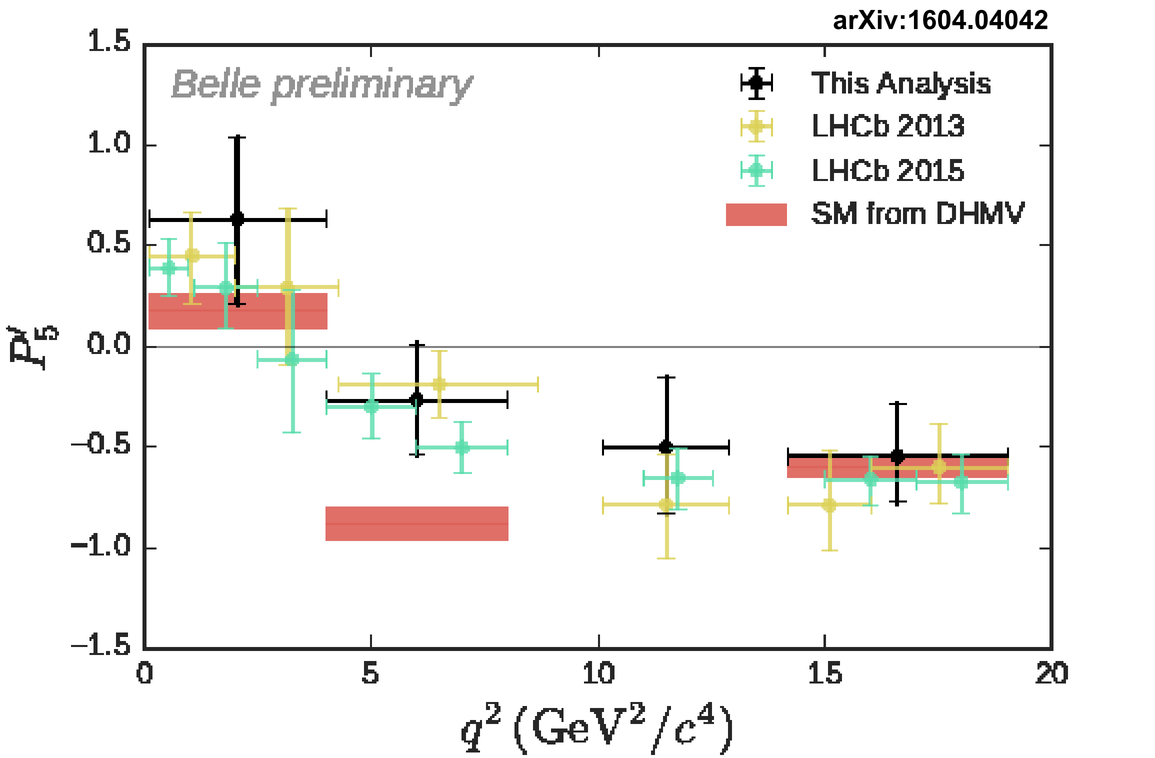

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- Crucial issue:

  How important departures from the infinite-m_b limit are, for q^2 approaching $4\,m_c^2$.

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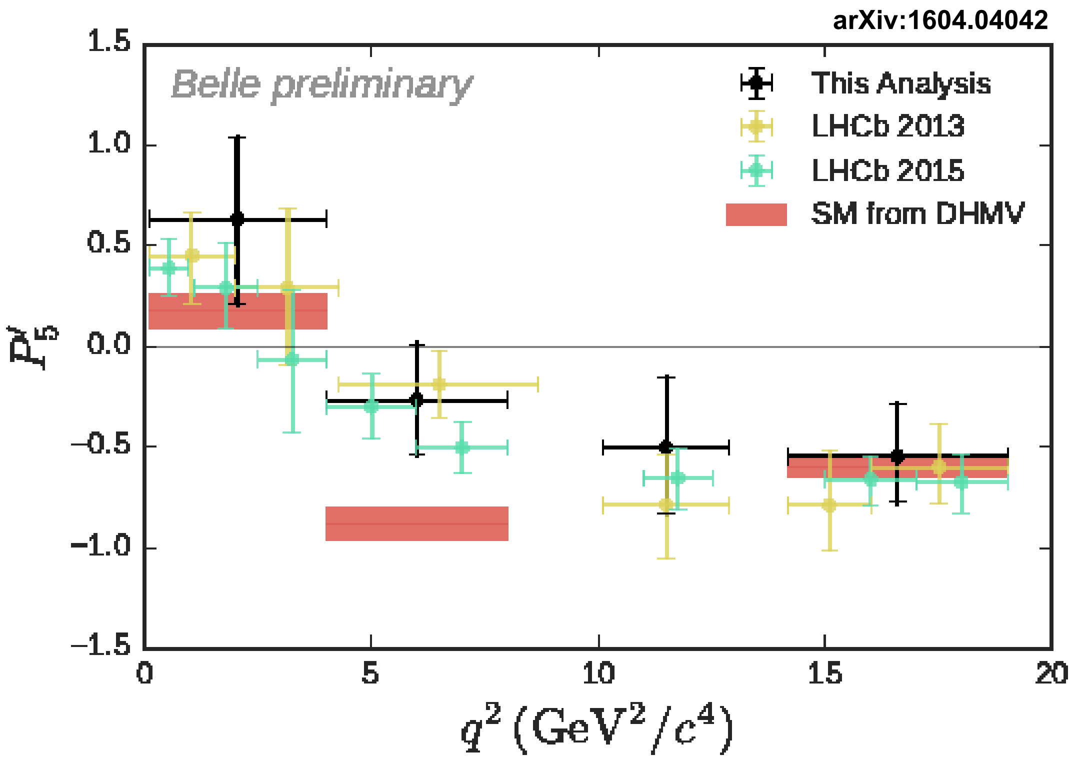

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But interesting nonetheless, because:

- *Effect is again in the same region:* $m^2_{\mu\mu} \in [1, 6]\ \mathrm{GeV}^2$
- *Compatibility between 1/fb and 3/fb LHCb analyses and a recent Belle analysis*

b → c data

There are long-standing discrepancies in b → c transitions as well.

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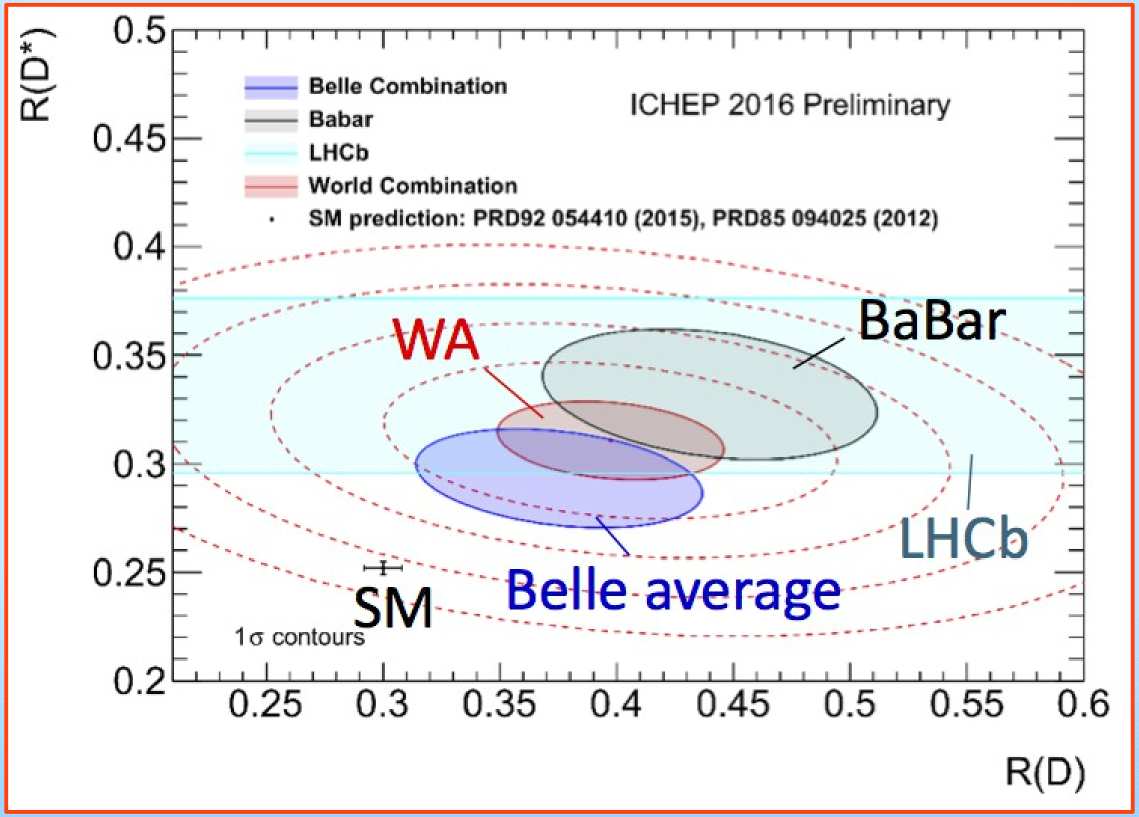

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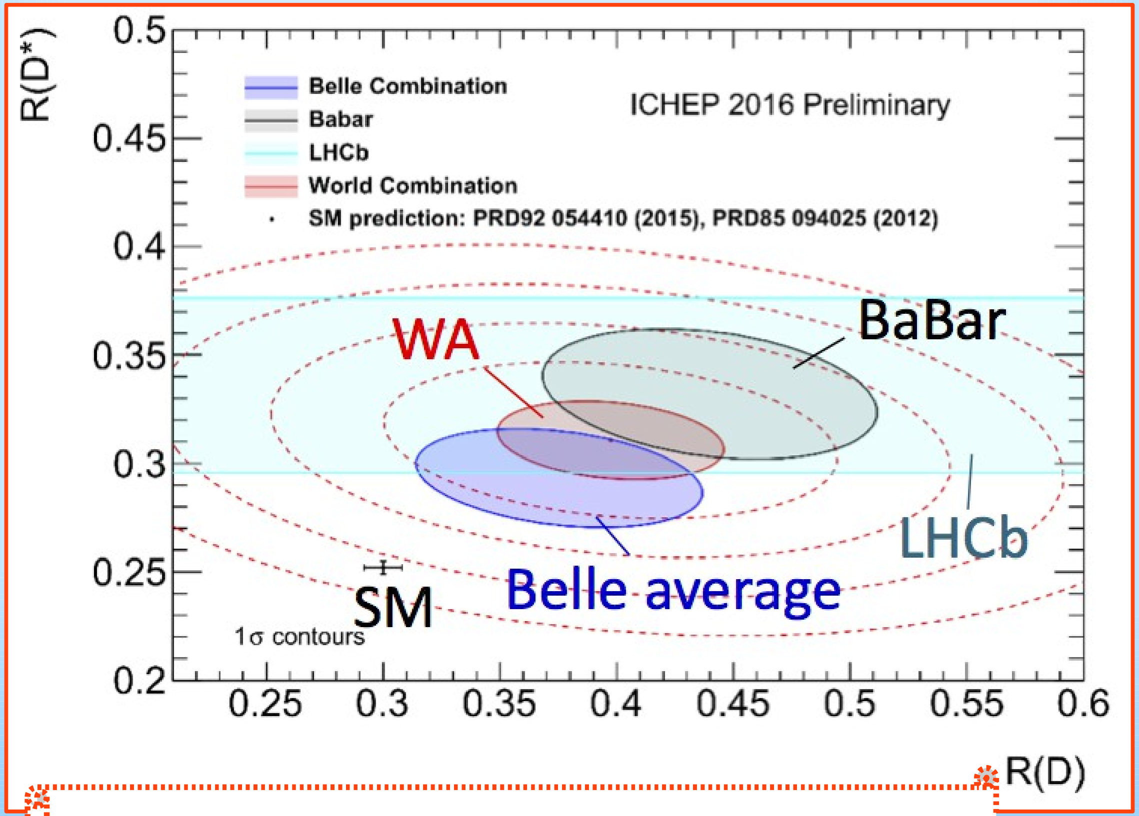

Simultaneous fit to R(D) & R(D*) about 4σ away from SM

Wrap-up

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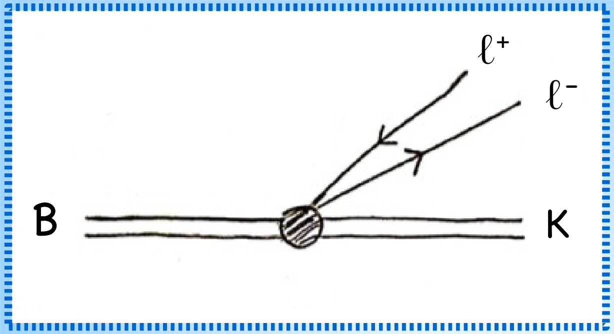
- Focusing for the moment on the $b \to s$ discrepancies

  - **Q1:** Can we (easily) make theoretical sense of data?
  - **Q2:** What are the most immediate signatures to expect ?

B → K(*) $\ell\ell$ decays: basic theory considerations



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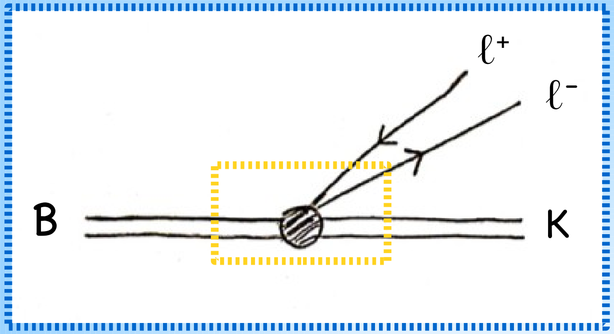

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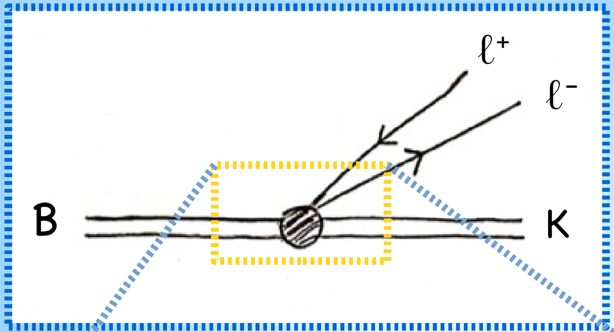

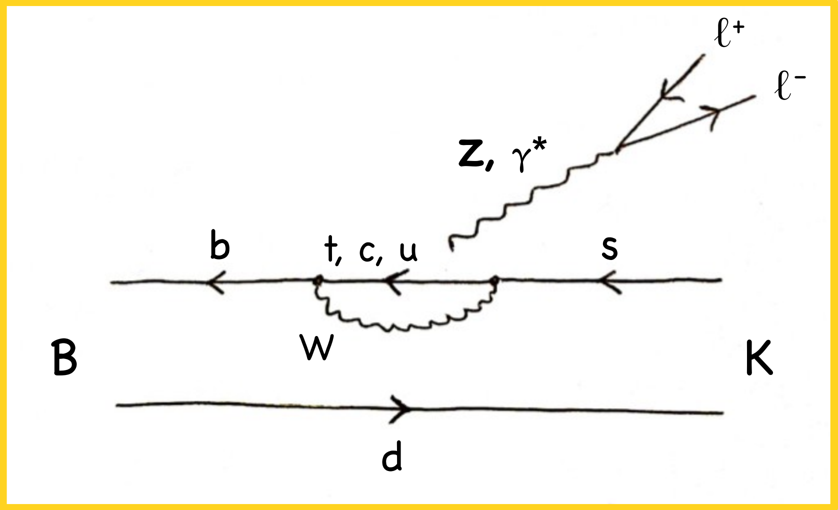

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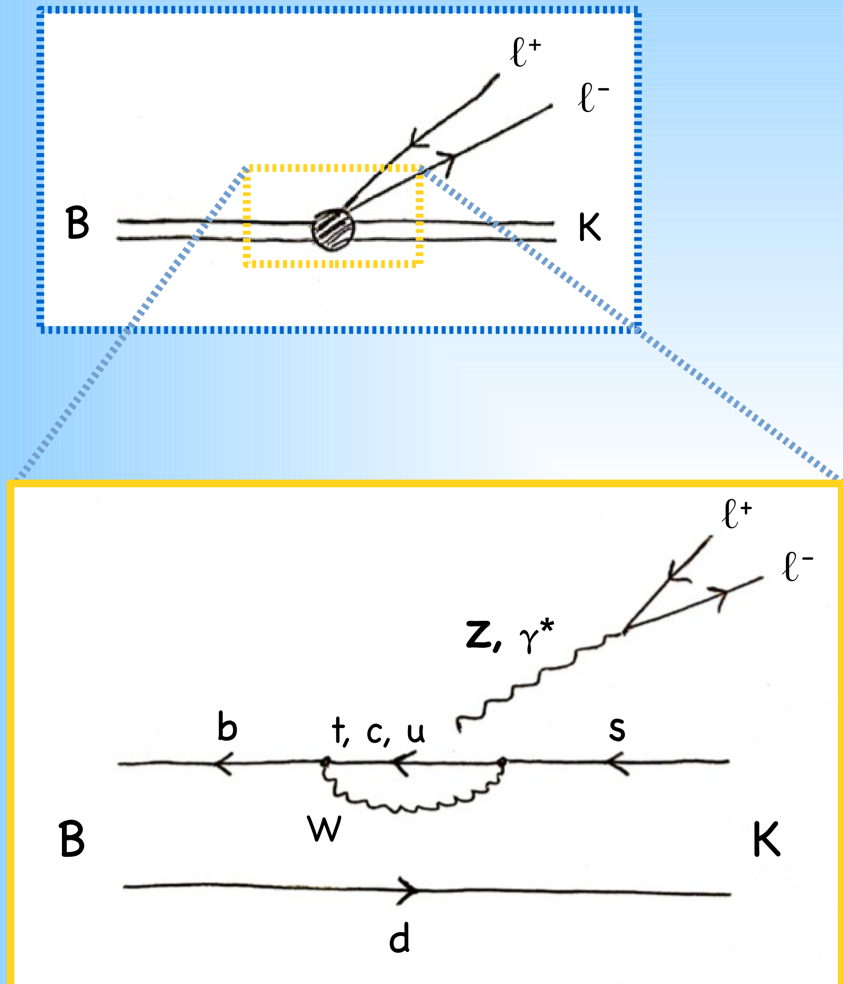

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In the SM:

- there's no tree-level contribution: it's an "FCNC"

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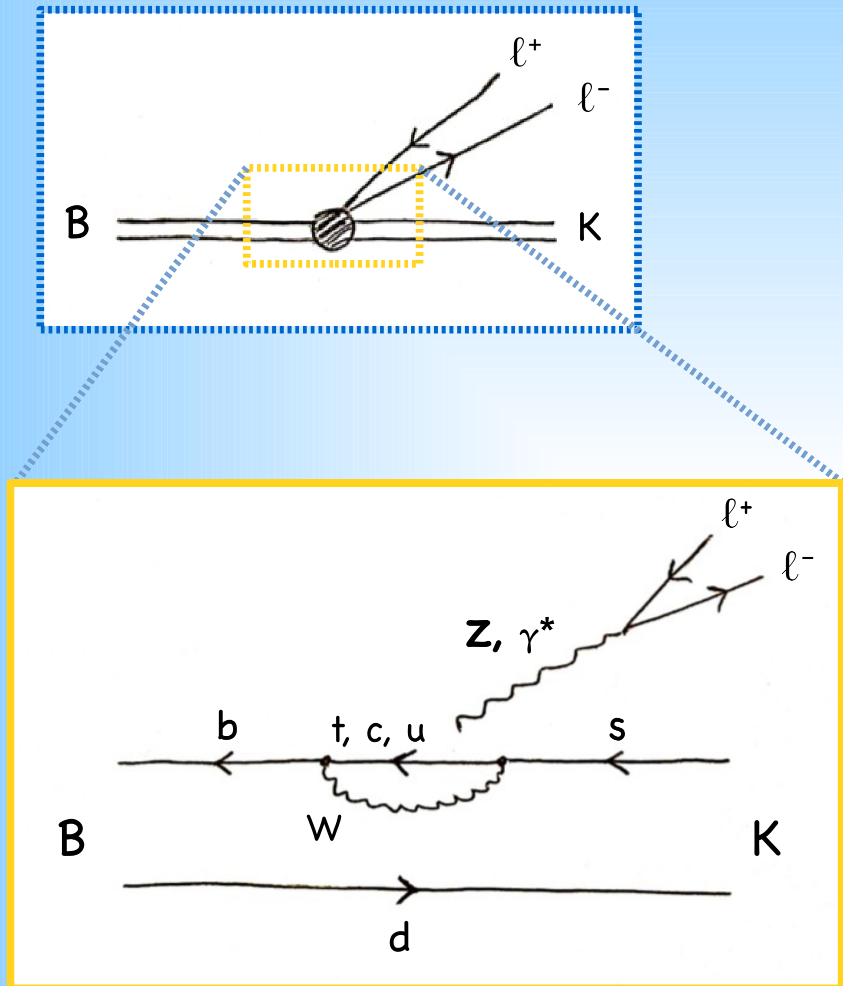

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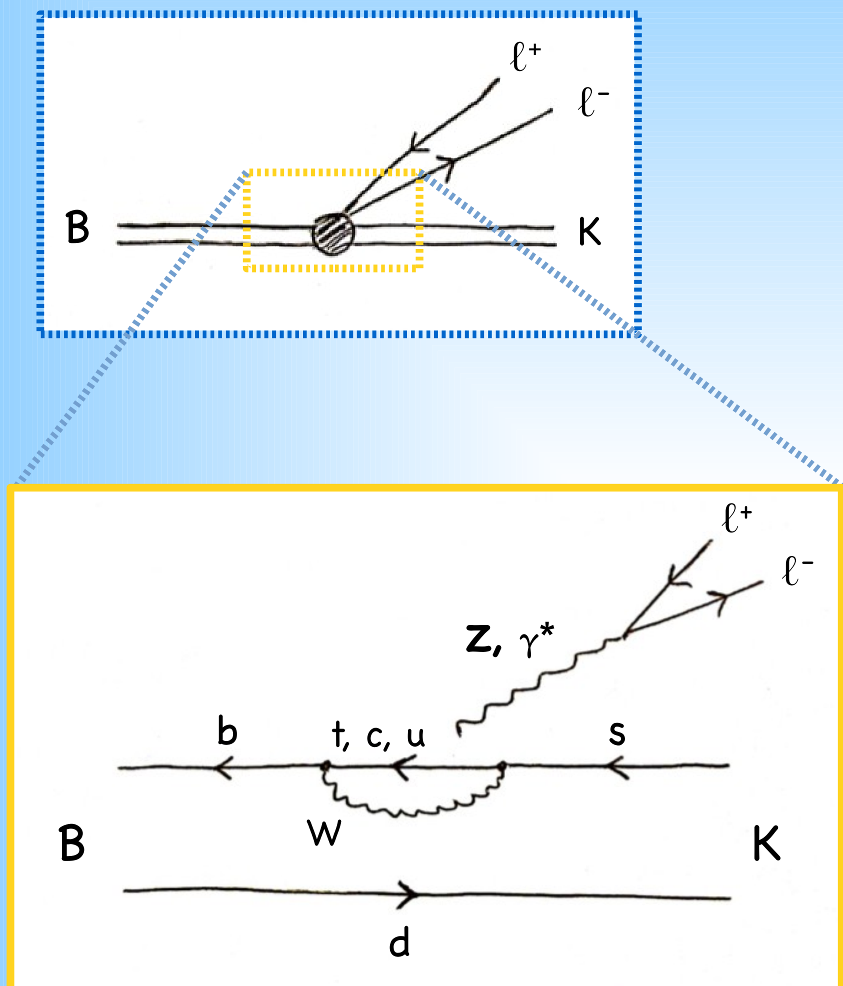

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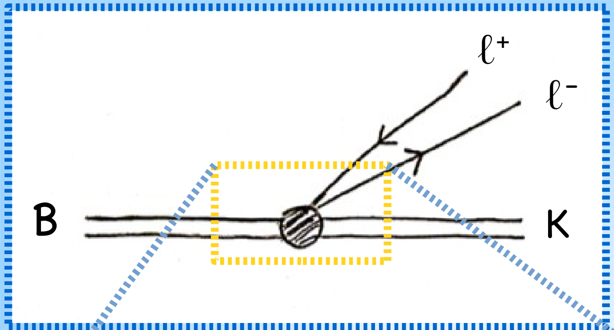

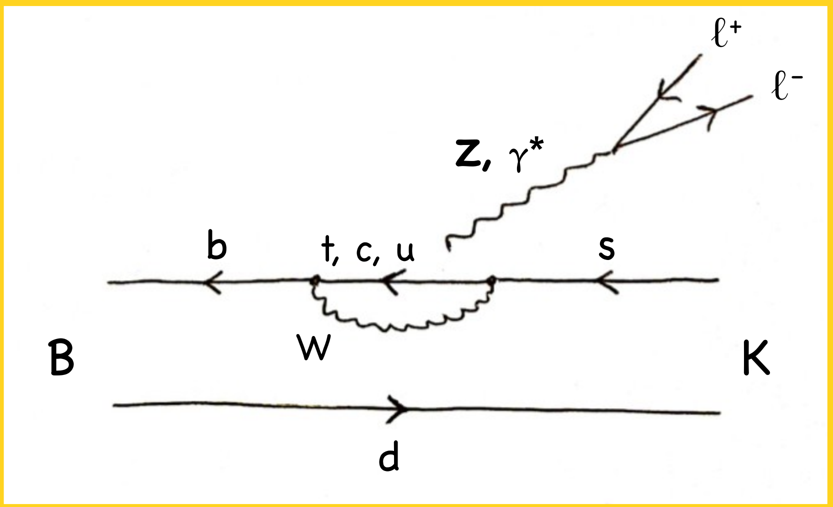

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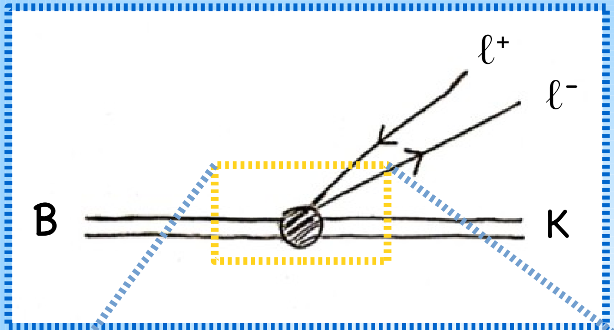

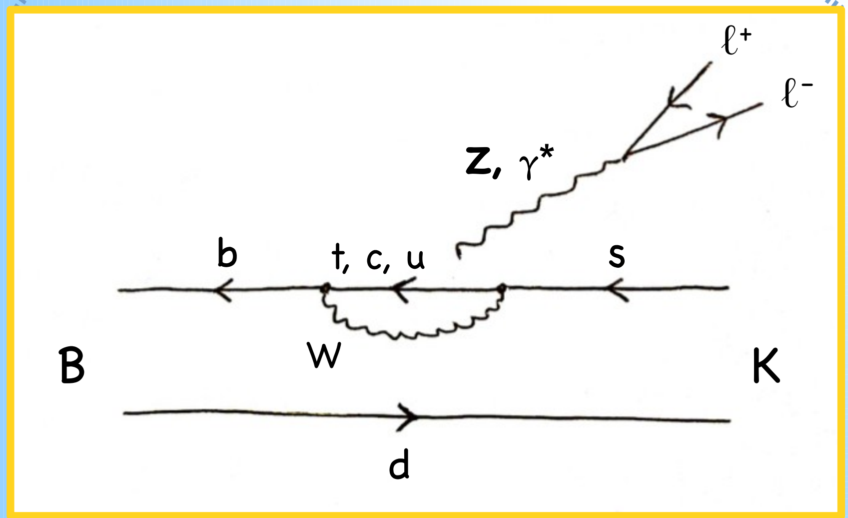

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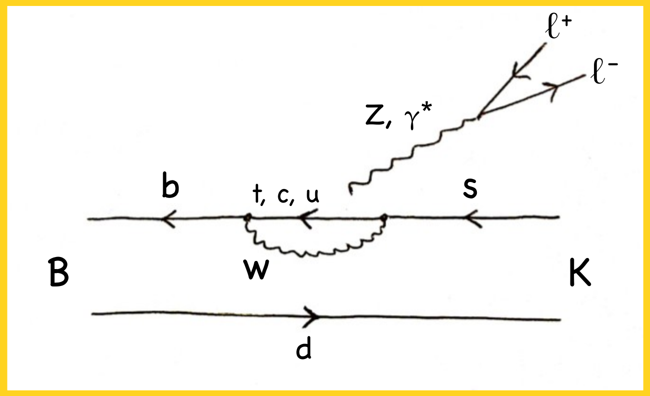

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$$\frac{m_t^2}{m_W^2} = O(1)$$

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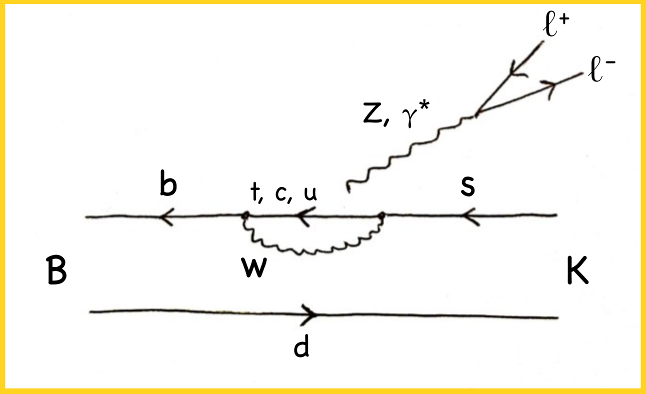

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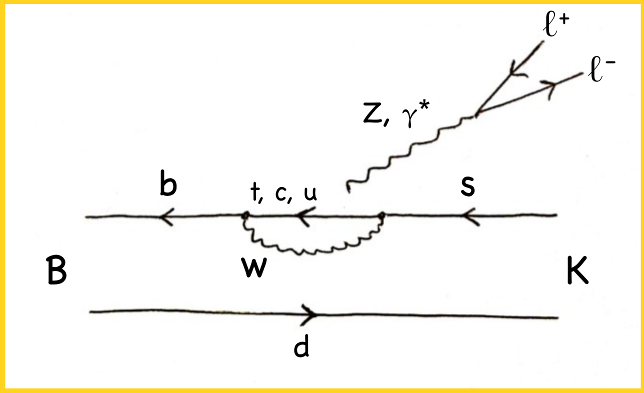

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Two consequences

☑ One can shrink the above diagram to a point, and describe the decay as an effective interaction of the kind

$$H = \sum_i \frac{C_i}{\Lambda^2} \left(\bar{b}\, \Gamma_q^{(i)} s\right) \left(\bar{\ell}\, \Gamma_\ell^{(i)} \ell\right)$$

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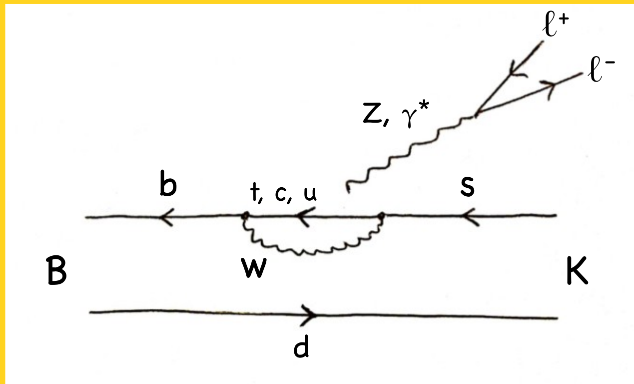

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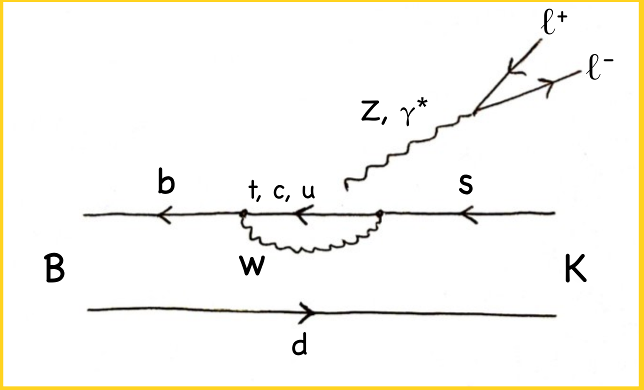

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- That the top mass be intriguingly close to the EW scale makes the top a candidate portal to new states.
- b → s decays then provide an indirect test of such physics

Concerning Q1: can we easily make theoretical sense of these data?

- *Yes we can. Consider the following Hamiltonian*

$$H_{\mathrm{SM+NP}}(\bar{b} \to \bar{s}\mu\mu) = -\frac{4G_F}{\sqrt{2}} V_{tb}^* V_{ts} \frac{\alpha_{\mathrm{em}}}{4\pi} \left[\bar{b}_L \gamma^\lambda s_L \cdot \left(C_9^{(\mu)} \bar{\mu}\gamma_\lambda \mu + C_{10}^{(\mu)} \bar{\mu}\gamma_\lambda \gamma_5 \mu \right) \right]$$

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- *Advocating the same (V – A) x (V – A) structure also for the corrections to $C_{9,10}^{SM}$ (in the μμ-channel only!) would account for:*
  - *R_K lower than 1*
  - *$b \to s\,\mu\mu$ BR data below predictions*
  - *the P_5' anomaly in $B \to K^*\,\mu\mu$*

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- *A fully quantitative test requires a global fit.*

new physics contributions to the Wilson coefficients. We find that the by far largest decrease in the χ^2 can be obtained either by a negative new physics contribution to C_9 (with $C_9^{\mathrm{NP}} \sim -30\% \times C_9^{\mathrm{SM}}$), or by new physics in the $SU(2)_L$ invariant direction $C_9^{\mathrm{NP}} = -C_{10}^{\mathrm{NP}}$, (with $C_9^{\mathrm{NP}} \sim -12\% \times C_9^{\mathrm{SM}}$). A positive NP contribution to C_{10} alone would also improve the fit, although to a lesser extent. [Altmannshofer, Straub, EPJC '15]

For analogous conclusions, see also [Ghosh, Nardecchia, Renner, JHEP '14]

Model example:
Glashow *et al.*, 2015

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- *This pattern can be generated from a purely 3rd-generation interaction of the kind*

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See:
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And yes they are!
See: [Greljo-Isidori-Marzocca]
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focused on models accounting for R_K & $R(D^{(*)})$

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Recap of model-building attempts

focused on models accounting for R_K & $R(D^{(*)})$

$SU(3)_c$ ↓ / $SU(2)_L$ →	1	2	3
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  Result: *BR compatible with previous measurements, and (again) smaller than SM*

What's the BR result for q^2 in [1, 6] GeV^2 ?

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- *So this measurement gives access to the ISR spectrum, to be compared with theory [Melikhov-Nikitin, '04]*

But LQCD calculation of $B \to \gamma$ f.f.'s required

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  Examples:
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  - *more LUV quantities*
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