# Lepton Flavour Universality tests @LHCb

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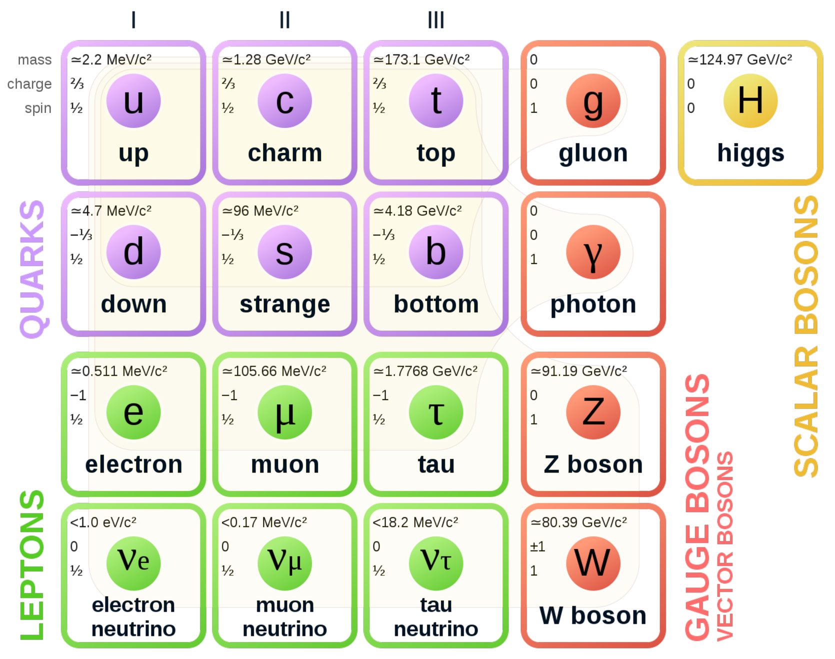
LHCb

## 1 - Standard Model and beyond




The most validated description of the sub-nuclear constituents of nature is the **Standard Model (SM)** of particle physics.

According to this theory, the elementary constituents can be divided into:

- *Bosons*, carries of the unified interactions (*weak, strong, electromagnetic*)
- *Quarks* and *Leptons*, the so-called *fermions* which are grouped in 3 families

In the SM, interactions of charged leptons differ only because of their different masses (**Lepton Flavour Universality**)

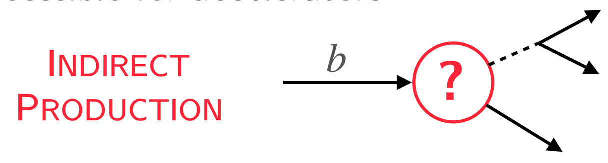
So far, at the LHC the only **deviations** from the SM have been found in the flavour sector, involving **B decays**.

If **confirmed**, they would discard the paradigm of Lepton Flavour Universality and thus reveal the presence of **new physics** beyond the SM

## 2 - The LHCb experiment

Located at one of the four interaction points at the LHC, the **LHCb** experiment is dedicated to precision measurements of **matter - antimatter asymmetries** and very **rare decays** of B mesons.

- It takes advantage of :
  - large $b(\bar{b})$ **cross section**, being the most copious source of B mesons in the world
  - **excellent detector** trigger, vertex and momentum resolution, to be able to cope with the hadronic environment
- It aims at providing ***indirect evidence*** of ***new physics***, probing energy scales now inaccessible for accelerators




## 3 - Flavour Anomalies

Both the experiments LHCb and Belle have found intriguing hints for Lepton Flavour Universality *violation* in :

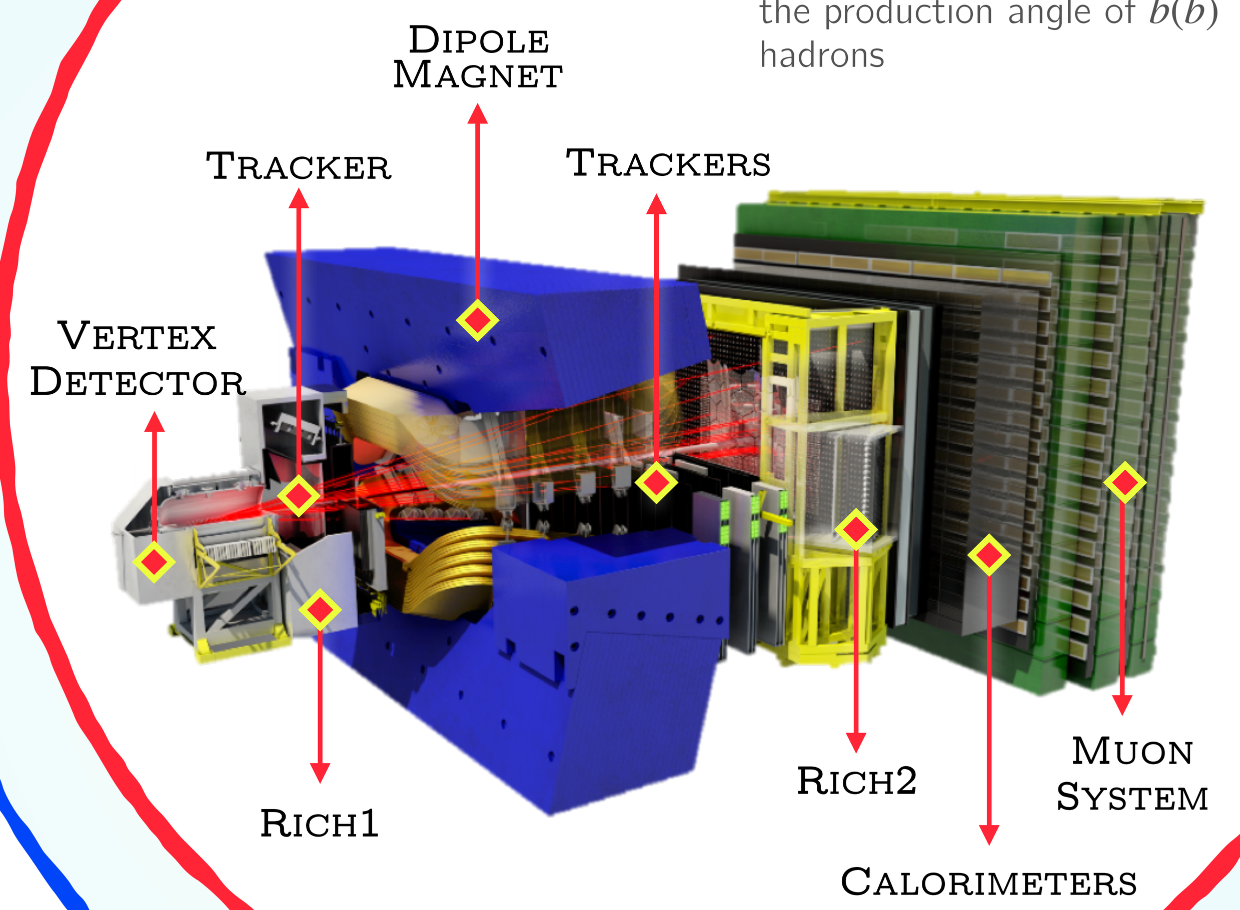
- Tree-mediated $b \to cl\nu_l$ transitions
  - *e.g.* $R(D^{(*)})$, $R(J/\psi)$
- Loop-mediated $b \to sll$ transitions
  - *e.g.* $R(K^{(*)})$

These ratio measurements have the advantage of being both **theoretically** and **experimentally** ***clean***

## LHCb detector

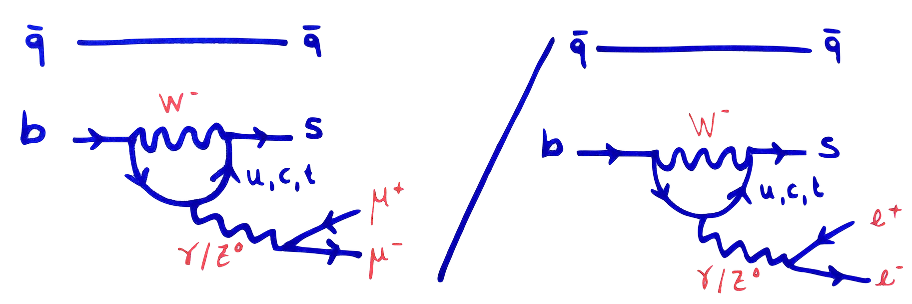
***Forward arm spectrometer***

choice of geometry due to the production angle of $b(\bar{b})$ hadrons




## 5 - Rare decays: $R(K^{(*)})$

*New particles* in Flavour Changing Neutral Current transitions can sensibly *influence* the SM *decay rates*

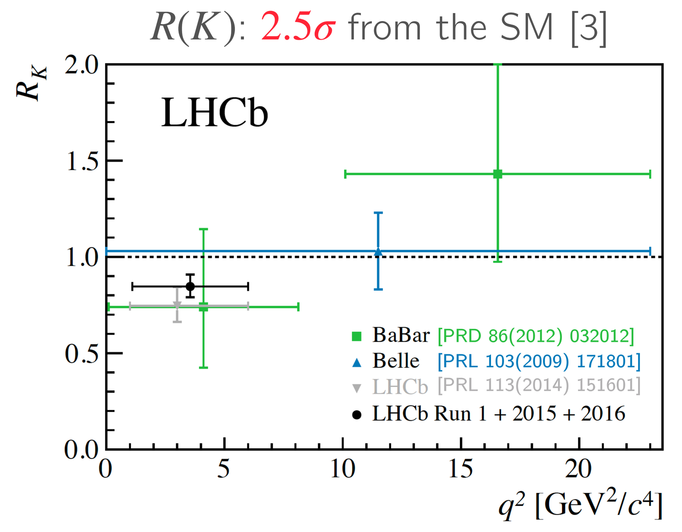



$$R(K^{(*)}) = \frac{BR(B^0 \to K^{(*)}\mu^+\mu^-)}{BR(B^0 \to K^{(*)}e^+e^-)}$$

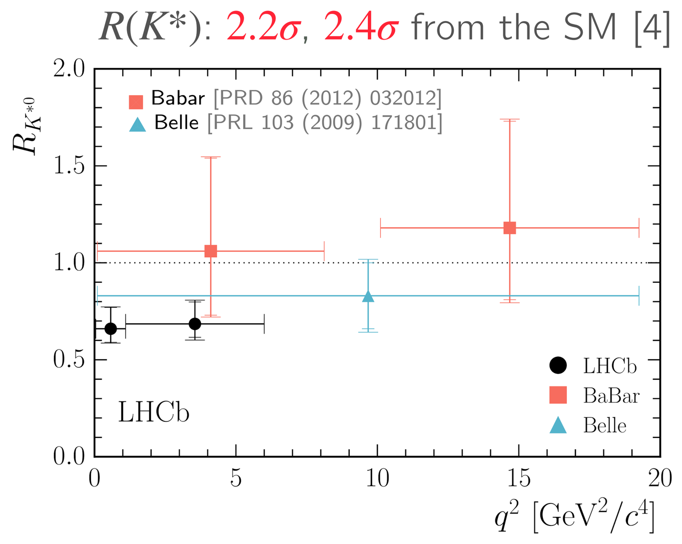
Bremsstrahlung radiation in the electron mode:

- ~ 5 times lower efficiency in trigger
- ~ 5 times lower efficiency in reconstruction
  - *experimentally challenging!*

$R(K)$: $2.5\sigma$ from the SM [3]

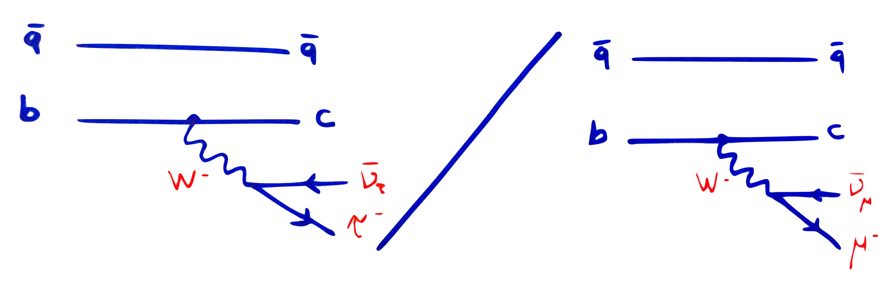



$R(K^*)$: $2.2\sigma$, $2.4\sigma$ from the SM [4]




## 4 - Semi-leptonic decays: $R(D^{(*)})$

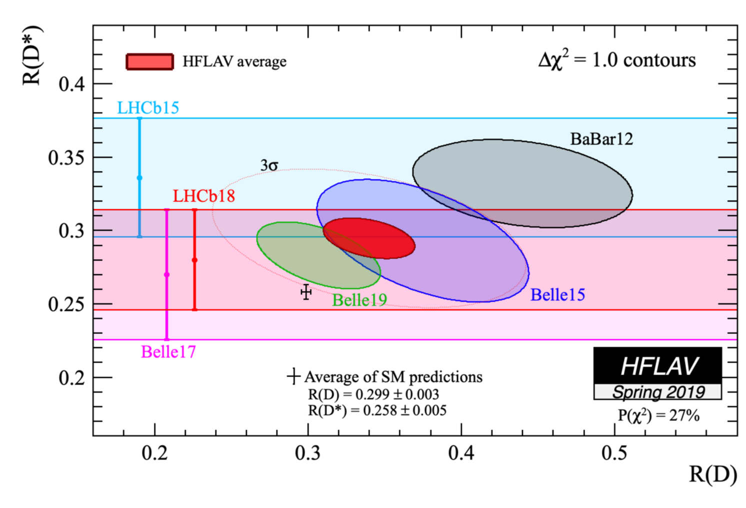
Any deviation in the decay rates would require ***large contributions*** from new particles

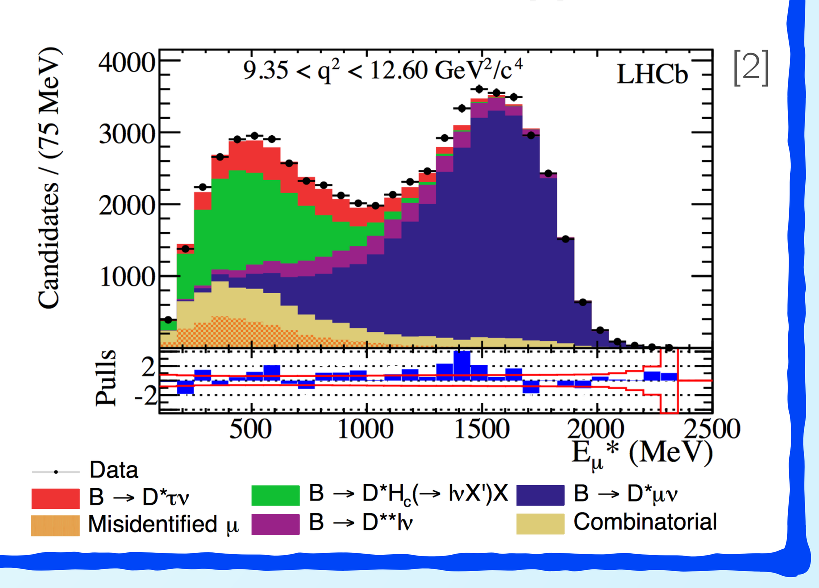



$$R(D^{(*)}) = \frac{BR(B^0 \to D^{(*)-}\tau^+\nu_\tau)}{BR(B^0 \to D^{(*)-}\mu^+\nu_\mu)} \quad \text{with} \quad \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$$

- 3 missing neutrinos in the final state
  - *experimentally challenging!*
- New physics in the 3rd generation ($\tau$)?

Combined $R(D^{(*)})$: **$3.1\sigma$ deviation** from the SM [1]

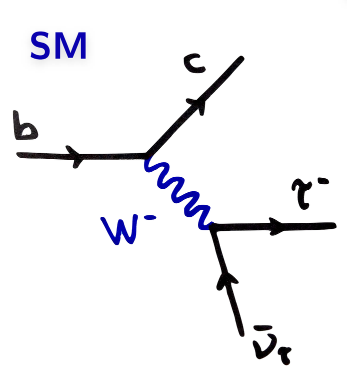


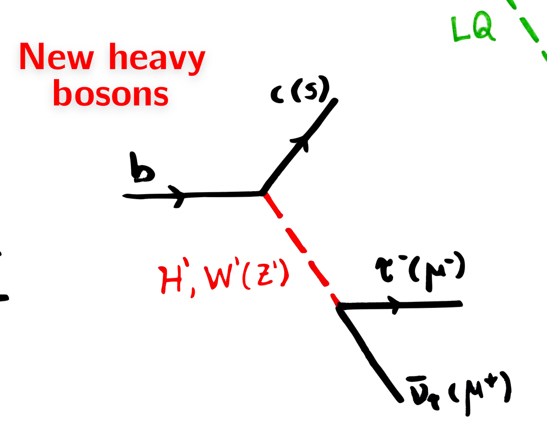



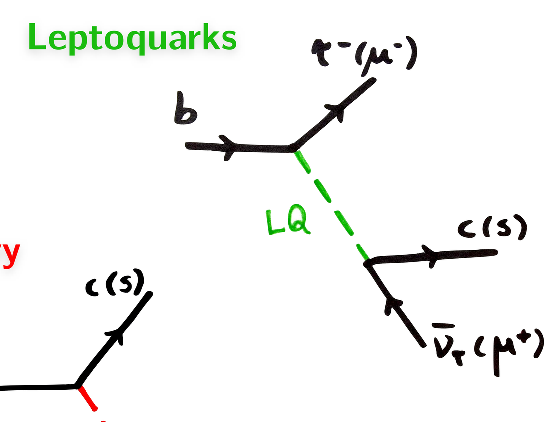

[2]

## 6 - Is there any new Physics?

- LFU breaking seems a feasible option and is so far suggested by the pattern of observed **deviations**, showing a coherent scheme
- If confirmed, the flavour anomalies would point to the existence of **New Particles** (many possible new physics interpretations)




The **Flavour physics group** at University of Zurich (**UZH**), lead by **Prof. Serra**, works to address these anomalies with multiple approaches in several analyses, in both rare and semi-leptonic decays. It profits from a multicultural environment of more than 20 members.

*In the next months new results will be available and a (hopefully) clearer scenario will get depicted. What is the future of SM going to be?*

### References and resources:

[1] Y. Amhis et al. [HFLAV Collaboration], Eur. Phys. J. C 77 (2017) no.12, 895 [arXiv:1612.07233]
[2] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. Lett. 115, 159901 (2015)
[3] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. Lett. **122**, 191801 (2019)
[4] R. Aaij *et al.* (LHCb collaboration), J. High Energ. Phys. (2017) 2017: 55. https://doi.org/10.1007/ JHEP08(2017) 055

- Nature Volume 546, pages 221-226 : https://www.nature.com/articles/nature21721.pdf
- Nature Volume 546, pages 227-233 : https://www.nature.com/articles/nature22346.pdf

→ *The Flavour Anomalies*

Group Serra Website