Universität Zürich[UZH]

Lepton flavour universality tests at LHCb

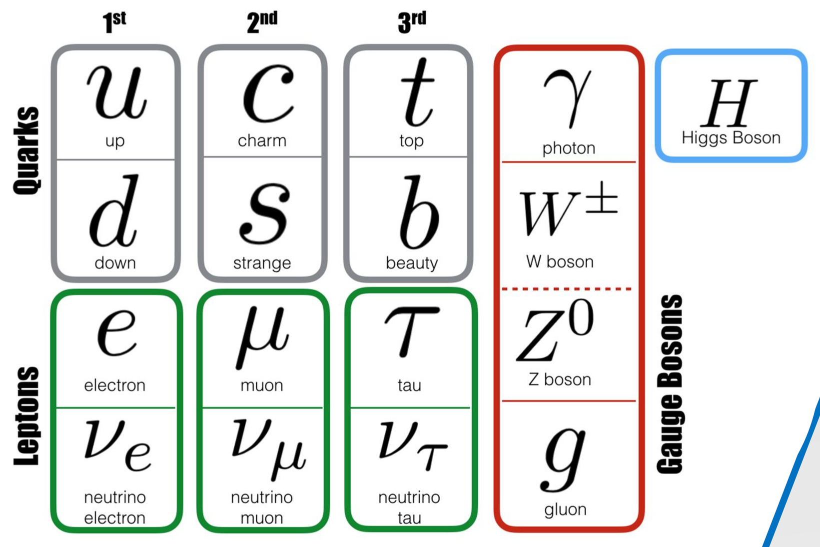
Michele Atzeni (michele.atzeni@cern.ch), Zhenzi Wang, Julián García Pardiñas
[Group Serra, UZH]

The Standard Model (SM) of Particle Physics

The **Standard Model** (SM) is a theory that describes in a common framework the **strong**, **weak** and **electromagnetic** interactions.

Its building blocks can be divided in two main categories:

- **Bosons**, the carriers of the fundamental forces
- **Fermions**, the matter content of the theory, constituted of **three generations** of quarks and leptons



Lepton Flavour Universality (LFU):
In the SM the three lepton generations are indistinguishable except for their masses.

Any exception would be a clear sign of New Physics (NP)!

Hints of LFU violation have been recently observed by LHCb, BaBar and Belle.

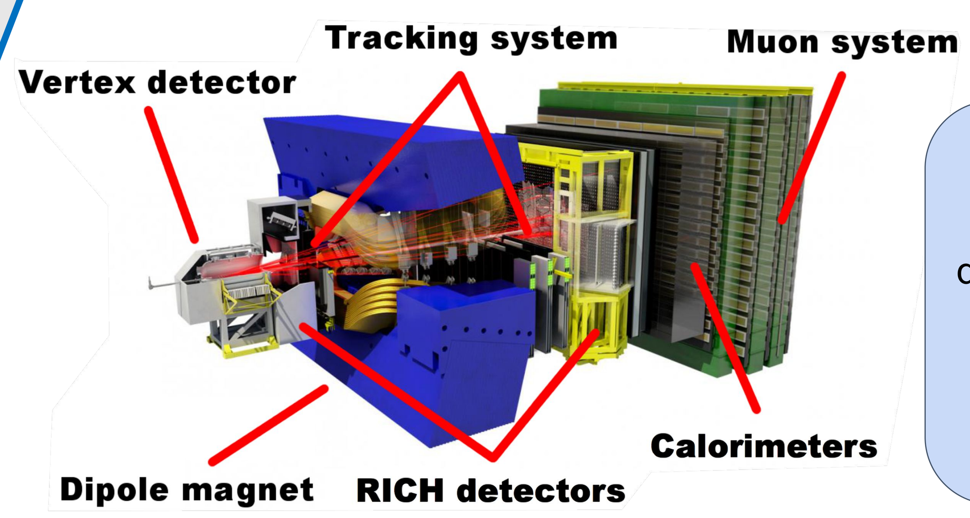
The LHCb Experiment

The **LHCb detector**, situated at one of the four proton-proton collision points of the LHC, is optimised for the study of the **decays of particles containing b or c quarks.**

Its **aim** is to search for **indirect evidence of NP** by measuring deviations from the SM.

LHCb benefits from the **unique combination** of:

- large b and c hadron production cross-sections,
- the production of many different species of b and c hadrons.



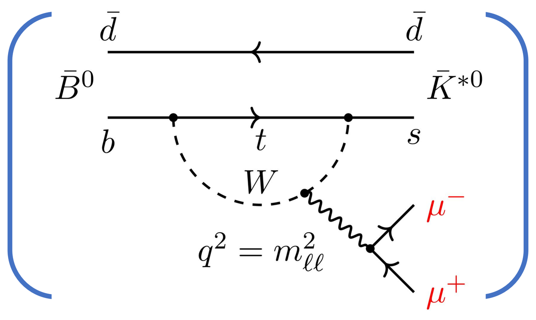
Indirect search for NP
Indirect searches are complementary to direct searches for new particles, and are capable of probing NP at energy scales higher than that which is currently accessible at particle accelerators

R ratios

Theoretically clean. Experimentally clean.

Electrons vs muons

$R(K^{(*)})$ =



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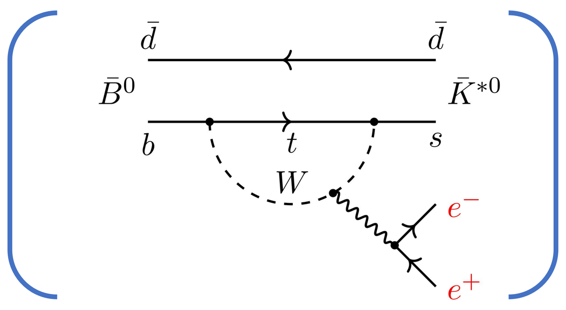
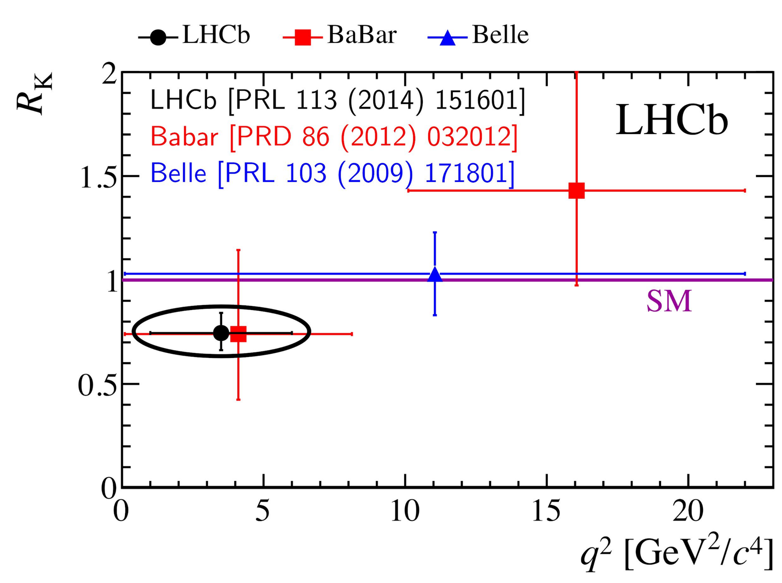
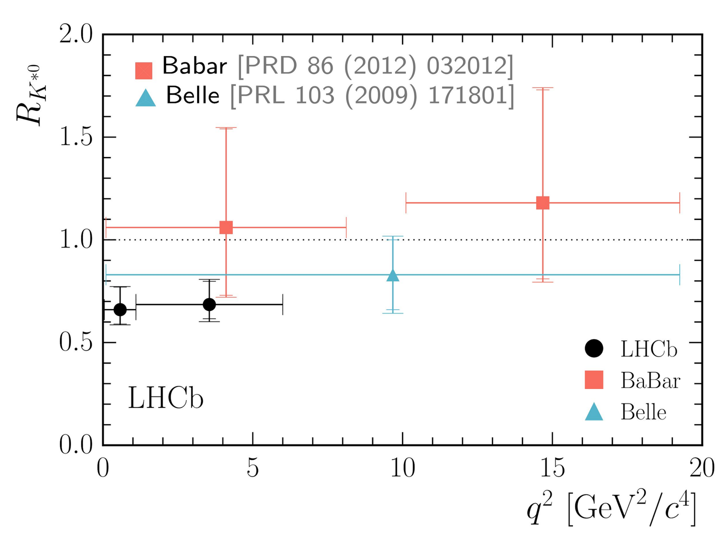


Flavour-changing neutral-current decays can only occur through **"loop"** diagrams in the SM, making them particularly **sensitive to** contributions from **new particles**.

The measurements





Current deviations:
- 2.6σ in $R(K)$ [PRL 113 (2014) 151601]
- 2.2σ and 2.4σ in $R(K^*)$ [JHEP 08 (2017) 055]

Experimental challenges

Bremsstrahlung

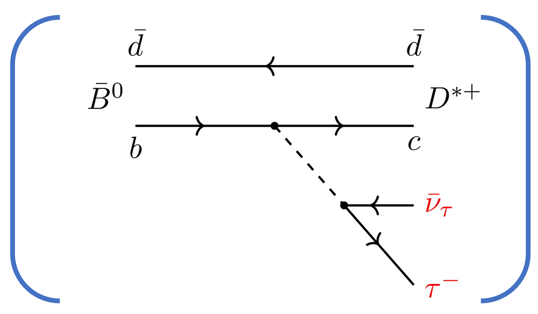
$$\frac{\sigma^e_{brem}}{\sigma^\mu_{brem}} \approx 4 \cdot 10^5$$

Trigger efficiency

$$\frac{\epsilon^e_{trig}}{\epsilon^\mu_{trig}} \approx \frac{1}{5}$$

Muons vs tauons

$R(D^{(*)})$ =



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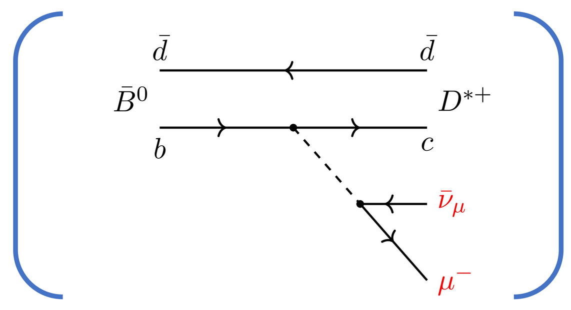
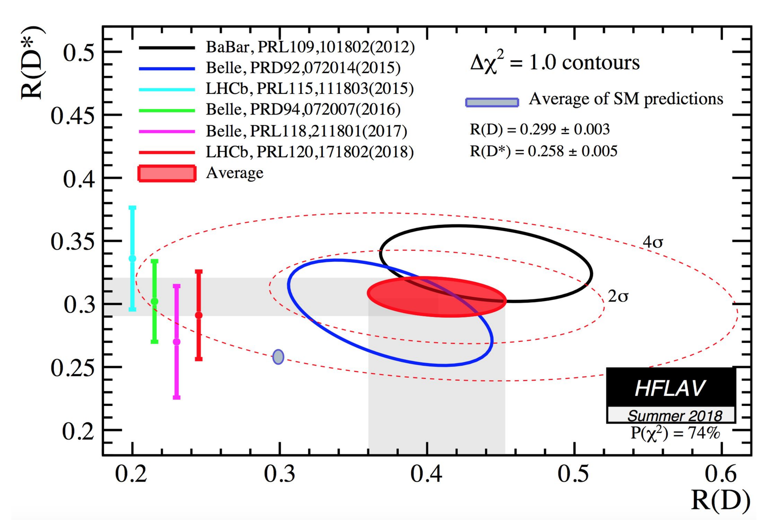
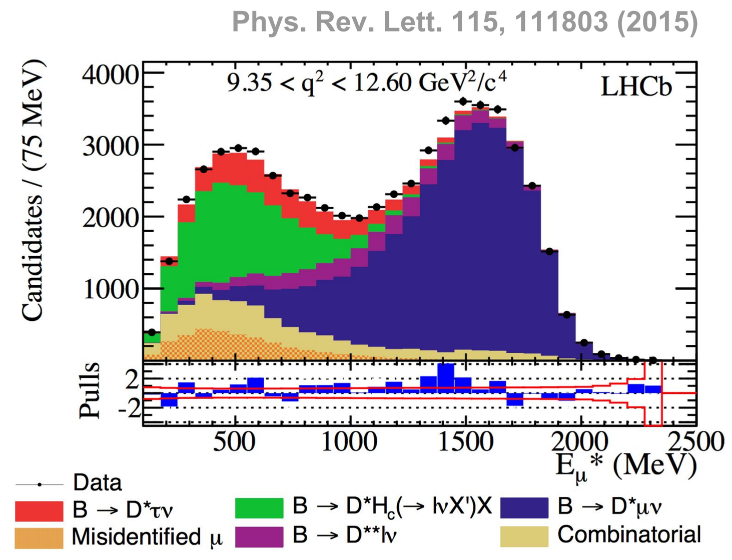


This kind of decays (dominated by **"tree" diagrams**) are favoured in the SM, having larger decay rates. A deviation in these ratios would require large contributions from new particles.

The measurements



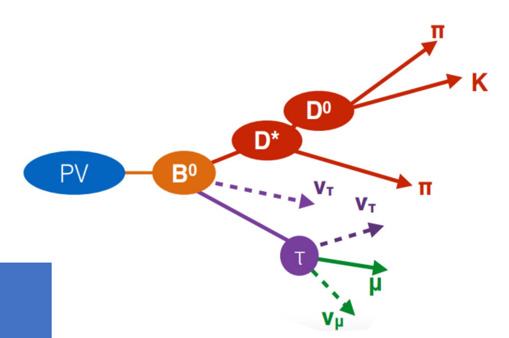
Phys. Rev. Lett. 115, 111803 (2015)

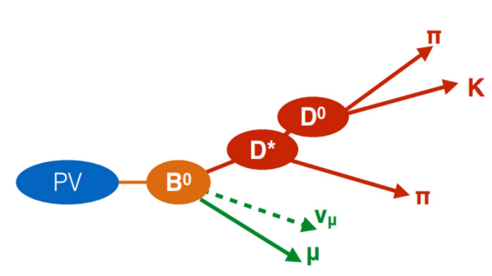


Current deviations: (HFLAV)
- 2.3σ in $R(D)$
- 3σ in $R(D^*)$
- 3.8σ combining $R(D)$ and $R(D^*)$

Experimental challenges

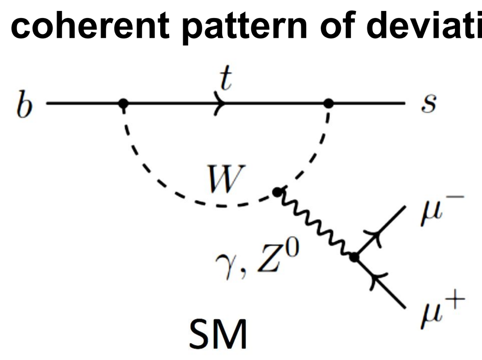
Undetected neutrinos



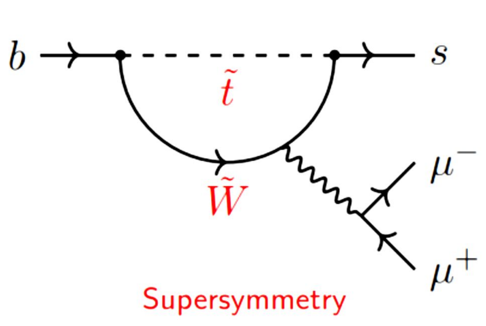


Hints of new particles?

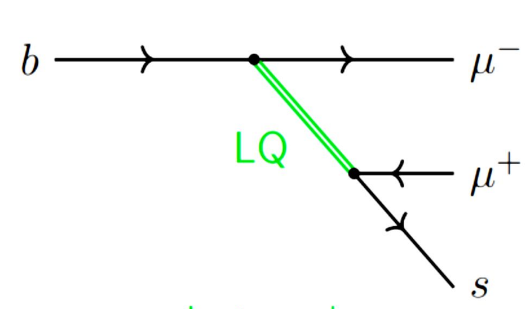
The anomalies seem to form a **coherent pattern of deviations** and several different **NP models** are being considered as possible explanations for them.



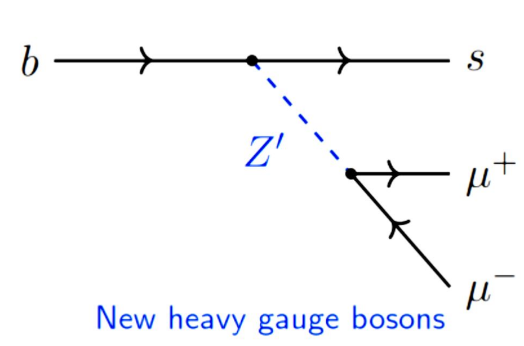
SM



Supersymmetry



Leptoquarks



New heavy gauge bosons

The **Flavour-Physics group at the UZH (Group Serra)** works in understanding the nature of these anomalies, looking at different decay modes and measuring these and other key observables through multi-dimensional analyses.

Are we close to finding new particles? Will this lead to understanding the origin of the flavour structure? An exciting time is ahead of us!

For more information:

Group Serra webpage: https://www.physik.uzh.ch/en/researcharea/lhcb/B-physics.html
Flavour anomalies: https://www.nature.com/articles/nature21721.pdf (*Nature* volume 546, pages 221–226), https://www.nature.com/articles/nature22346.pdf (*Nature* volume 546, pages 227–233)
The LHCb experiment: http://lhcb-public.web.cern.ch/lhcb-public/