Testing Lepton Flavour Universality in $b \to s\ell^+\ell^-$ decays at LHCb

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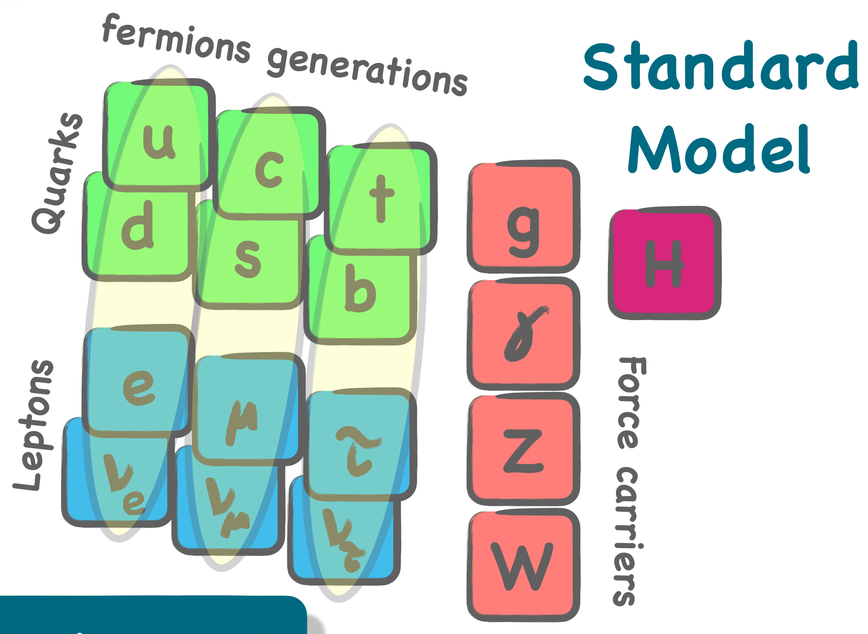
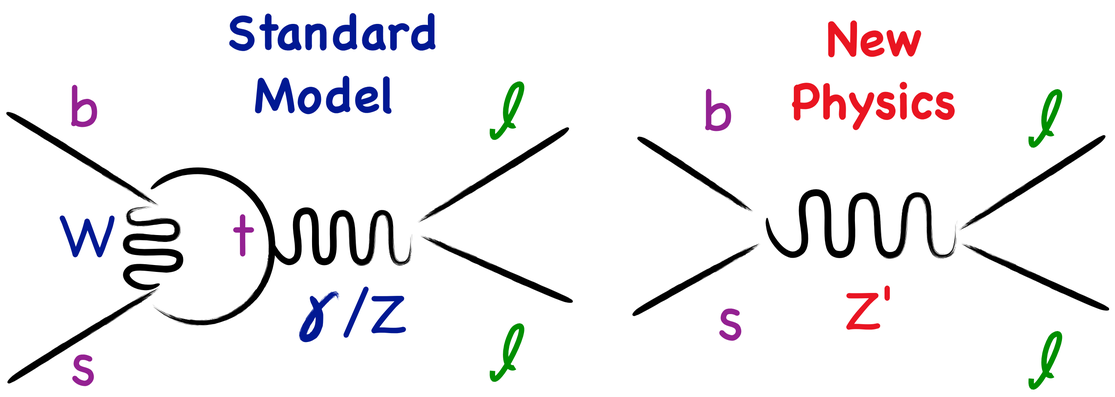
What is Lepton Flavour Universality (LFU)?

For the Standard Model of particle physics the 3 lepton generations are identical except for their masses

LFU is an "Accidental symmetry" of the Standard Model, well verified e.g. in $J/\psi \to \ell\ell$ (with a precision of ~0.5% on relative BR)





Why $b \to s\ell^+\ell^-$ decays ?

Flavour changing neutral current are ideal to study LFU:

- Very small SM amplitude (forbidden at tree level), sensitive to new physics contributions
- **New particles** can enter loops and/or create new diagrams

How to test LFU?

With ratios of branching fractions, as:

$$R_{X_s} = \frac{\mathcal{B}(B \to X_s \mu^+\mu^-)}{\mathcal{B}(B \to X_s e^+e^-)} \quad X_s = K, K^*, K\pi\pi \ldots$$

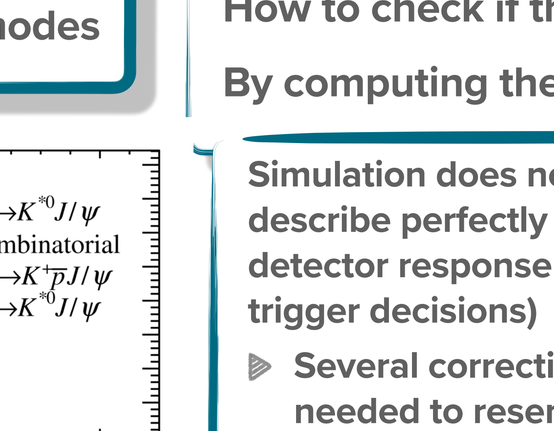
- Predicted to be exactly 1 in the SM (except for e/μ mass differences)
- Sensitive to differences between lepton species
- Small uncertainties from QCD theoretical corrections

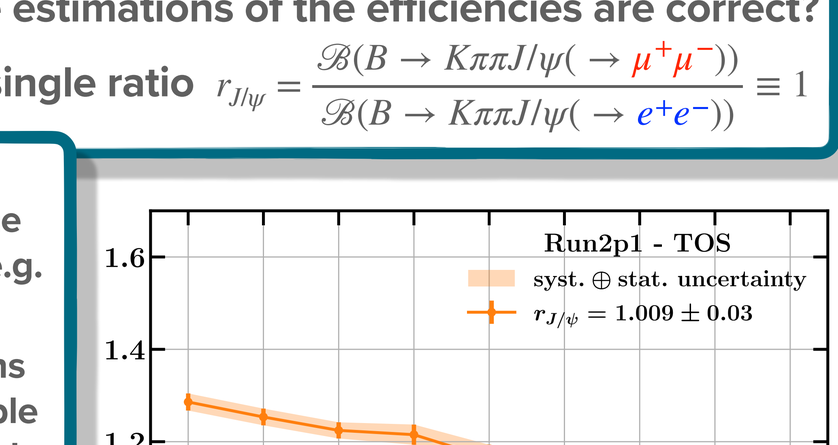
Already observed evidence of deviation!

- R_K found to be 3.1 σ away from the expected value of 1. arXiv:2103.11769

Why the LHCb detector ?

- Single arm forward spectrometer ($2 < \eta < 5$)
- Specialised in precision measurements of decays of particles containing b quarks
- Electrons reconstruction more challenging than muons
  - They can emit bremsstrahlung photons leading to a not trivial energy reconstruction





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A specific decay: $B^+ \to K^+\pi^+\pi^-\ell^+\ell^-$

- $R_{K\pi\pi}$ measured as a double ratio, using the resonant high-stat control channel $B \to K\pi\pi(J/\psi \to \ell\ell)$
  - $B \to K\pi\pi(J/\psi \to \ell\ell)$ does not happen via loop or boxes diagrams, thus not sensitive to new physics
  - $R_{K\pi\pi}$ value unaffected, but reduced uncertainties coming from differences in leptons reconstruction

$$R_{K\pi\pi} = \frac{N_{B\to K\pi\pi\mu^+\mu^-}}{N_{B\to K\pi\pi(J/\psi\to\mu^+\mu^-)}} \cdot \frac{N_{B\to K\pi\pi(J/\psi\to e^+e^-)}}{N_{B\to K\pi\pi e^+e^-}} \cdot \frac{\epsilon_{B\to K\pi\pi(J/\psi\to\mu^+\mu^-)}}{\epsilon_{B\to K\pi\pi\mu^+\mu^-}} \cdot \frac{\epsilon_{B\to K\pi\pi e^+e^-}}{\epsilon_{B\to K\pi\pi(J/\psi\to e^+e^-)}}$$

Yields from fits

Fit to the B meson mass shape in the four decay modes

JHEP 10 (2014) 064

JHEP 08 (2017) 055

Efficiencies from simulation

How to check if the estimations of the efficiencies are correct?

By computing the single ratio $r_{J/\psi} = \frac{\mathcal{B}(B \to K\pi\pi J/\psi(\to \mu^+\mu^-))}{\mathcal{B}(B \to K\pi\pi J/\psi(\to e^+e^-))} \equiv 1$

Simulation does not describe perfectly the detector response (e.g. trigger decisions)

- Several corrections needed to resemble as much as possible the data

Outlook

Available dataset allows to measure for the first time $\mathcal{B}(B \to K\pi\pi ee)$ and test LFU in the very rich $K\pi\pi$ system

- More detailed studies will be possible with the Future Run 3 dataset
- $R_{K\pi\pi}$ value still blinded, hope to have results soon!