# Using LHCb to Search for Violations of Fundamental Symmetries of the Standard Model

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The LHCb experiment (Large Hadron Collider Beauty) is one of several particle detectors situated on the LHC, a world renown particle collider in Geneva Switzerland. This detector aims at understanding the nature of the birth of the universe. To accomplish this goal, LHCb has been specialized to study b-quarks and the physics behind them. Examples of this include measuring CP-violation in b-hadrons (heavy particles that contain a bottom quark), as well as examining the postulates of lepton flavor universality. These measurements primarily search for deviations from predictions based on our Standard Model of Physics, which could lead to the discovery of new physics and learning the secrets of our Universe.

## Charge-Parity Violation (CPv)

We exist. This is a problem.

Humans, like the universe, are mostly made of matter; but as we understand the Standard Model, there should not be such an impressive imbalance of matter and antimatter as what we observe in the world today.

The study of CPv is integral to understanding this conundrum, with the LHCB playing a leading role, in the observation of high-energy decays.

### LHCb and the Standard Model, with a dash of CPv

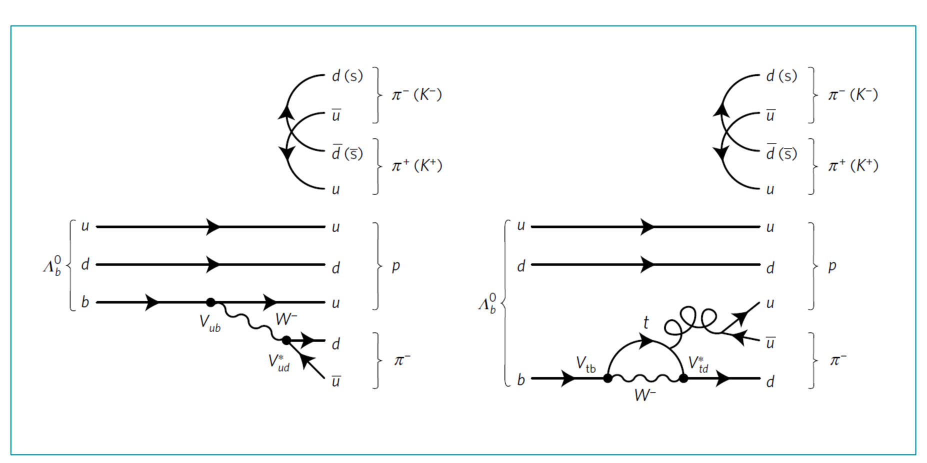


Figure (1) – Lambda Baryon decays

- In 2017, the LHCb found evidence (above 3.3 σ) of CPv in the Lambda-Bottom Baryons; a first for spinning particles.

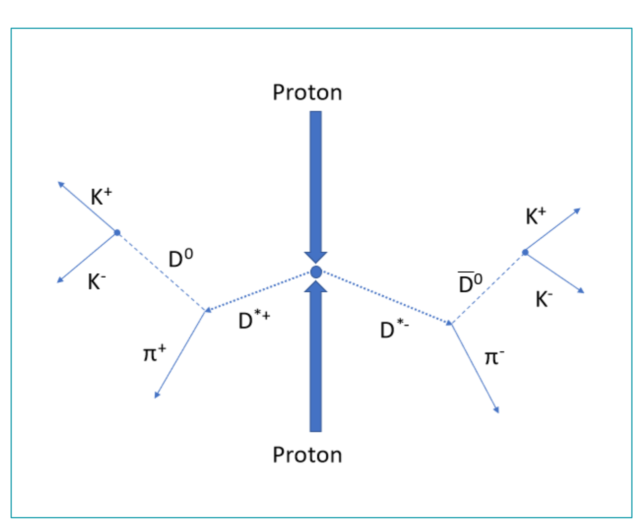



Figure (2) – D(0) meson decays

- …But the big news involve **D0 mesons**; on March 21st the collaboration reported strong evidence (5.3 σ!) of CPv in charmed particles, a previously unobserved phenomena.

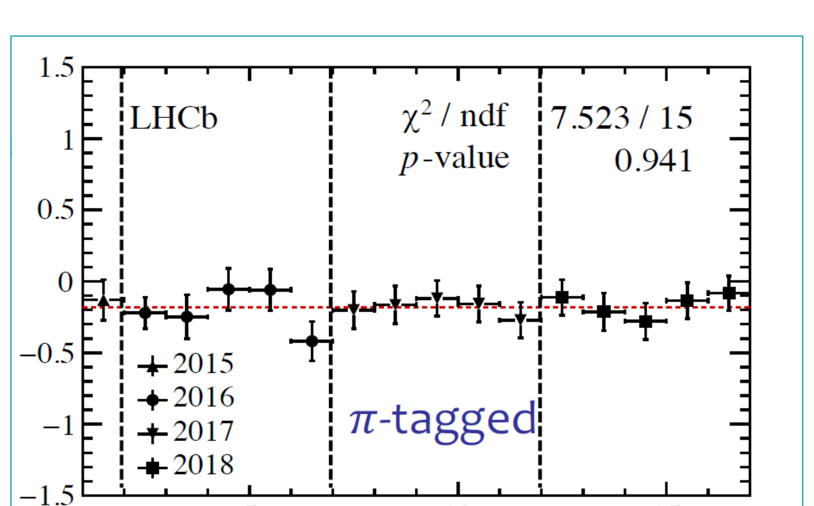



Figure (3) – A(CP) of D meson results

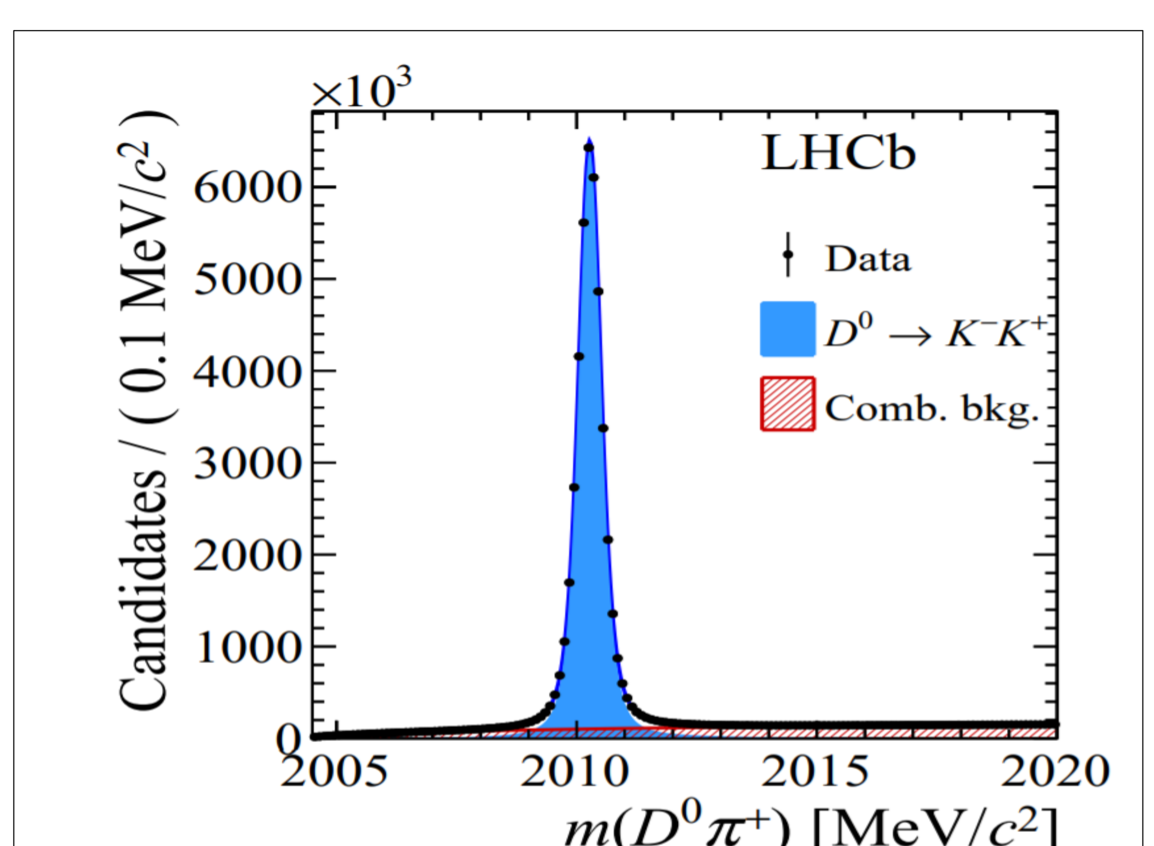
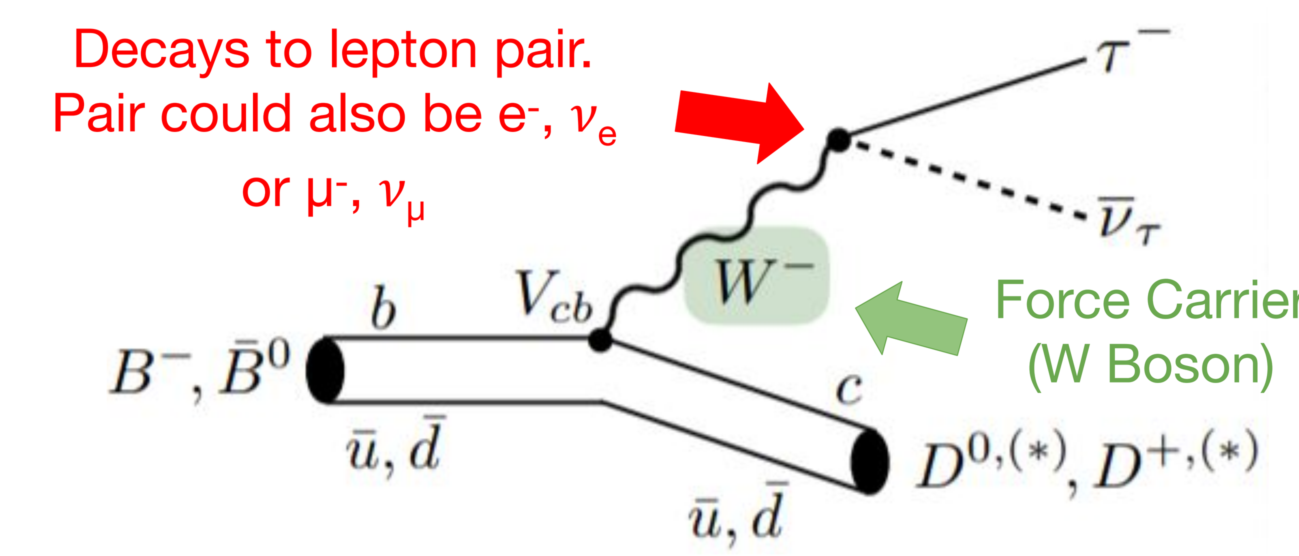



Figure (4) – Invariant mass of D(0), tagged with pion plus

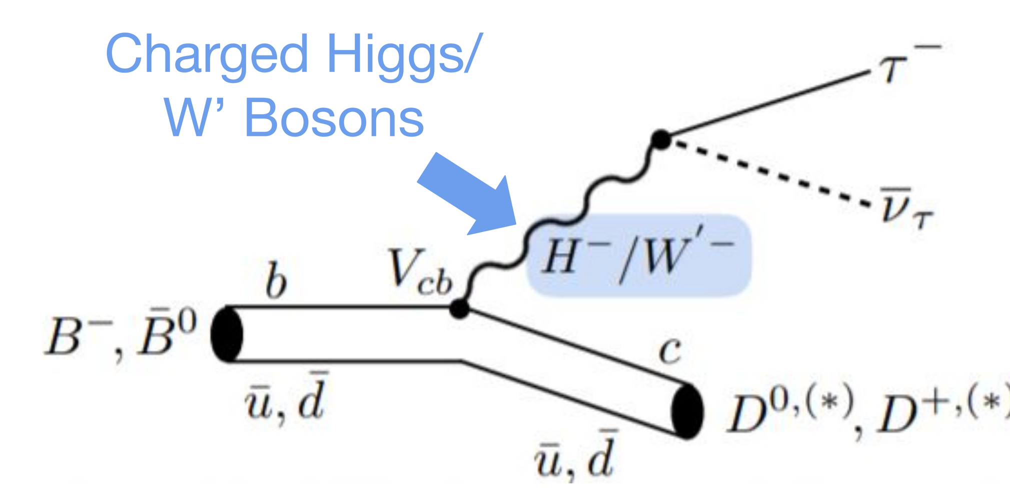
Citations: (1) Aaij, R. *et al.* (LHCb collaboration) *Nat. Phys.* **13**, 391–396 (2017), (2) Observation of CP violation in charm decays LHCb Collaboration (Roel Aaij (NIKHEF, Amsterdam) et al.). Mar 20, 2019. 18 pp

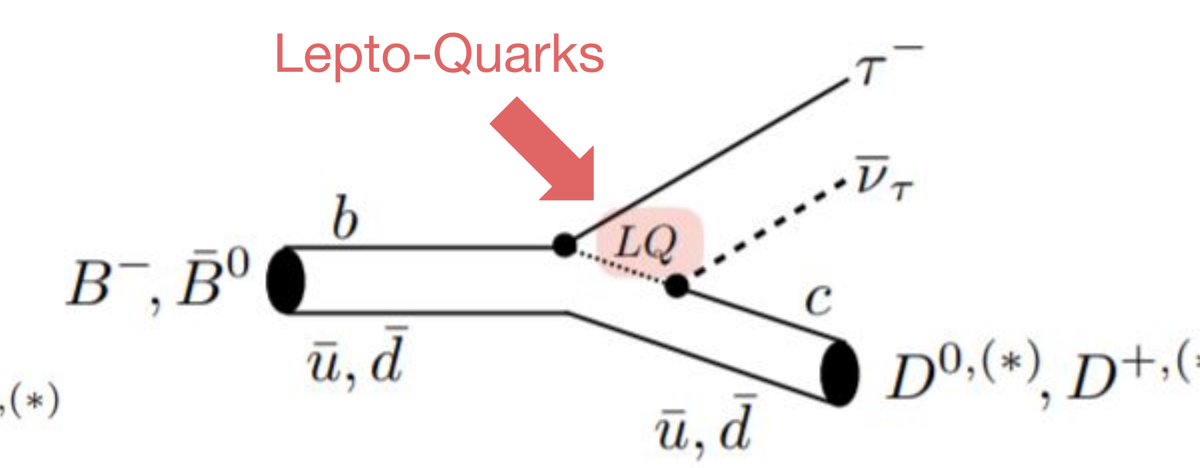
## Lepton Flavor Universality (LFU) Violation

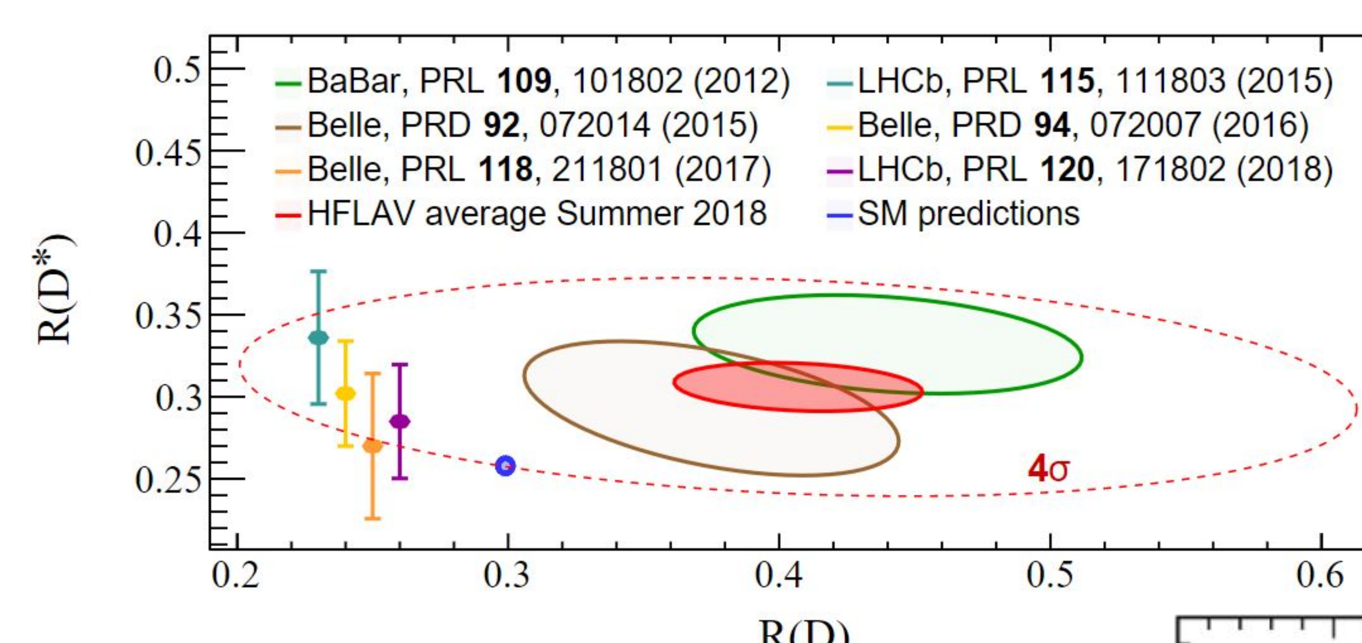
- Standard Model (SM) predicts that force carriers for particle decays interact with the same strength for **ALL** leptons ($e^-$, $\mu^-$, $\tau^-$)




New exotic particles could violate lepton flavor universality!



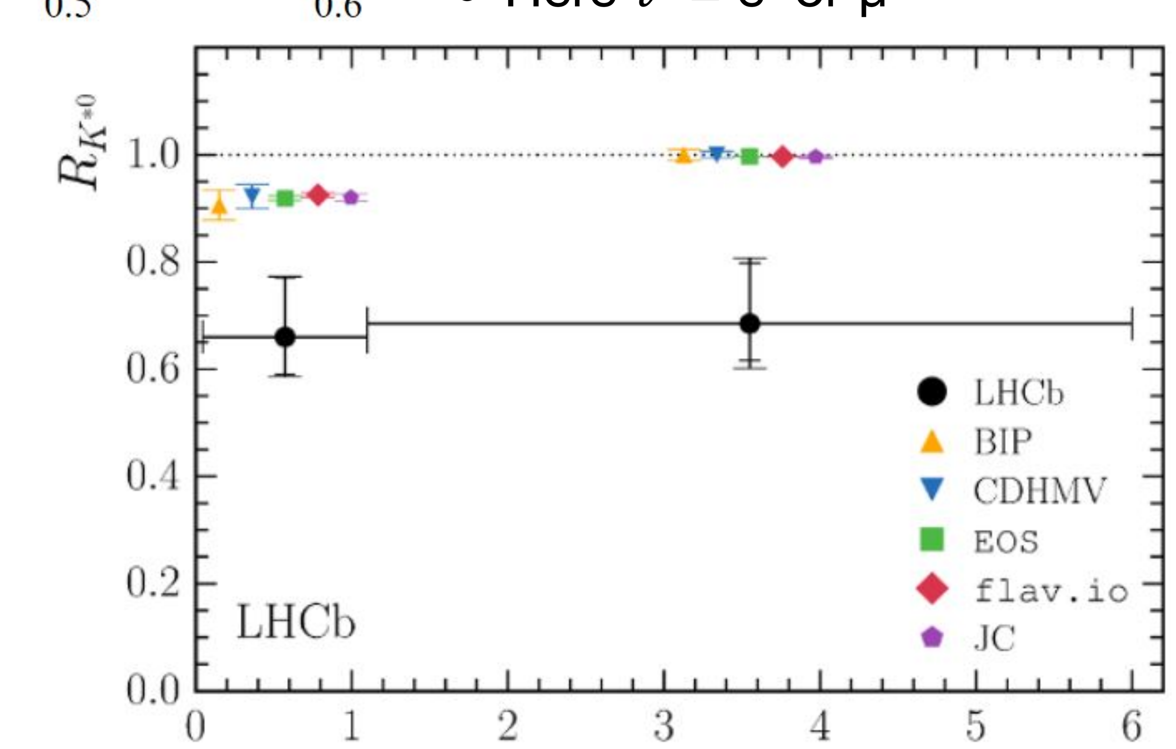

- Previous experiments have shown a possible anomaly in B-meson decays to **heavy leptons** ($\tau^-$) and **light leptons** ($e^-$, $\mu^-$)

$$R(D^{(*)}) = \frac{\mathcal{B}(\overline{B} \to D^{(*)}\tau^-\overline{\nu}_\tau)}{\mathcal{B}(\overline{B} \to D^{(*)}\ell^-\overline{\nu}_\ell)}$$

- Here $\ell^-$ = $e^-$ or $\mu^-$

- LHCb measurements show a similar anomaly for B-meson decays involving **only light leptons** ($e^-$, $\mu^-$)

$$R_{K^{*0}} = \frac{\mathscr{B}\left(B^0 \to K^{*0}\mu^+\mu^-\right)}{\mathscr{B}\left(B^0 \to K^{*0}e^+e^-\right)}$$




LHCb collaboration, Test of lepton universality with $B^0 \to K^{*0}\ell^+\ell^-$ decays, JHEP 08 (2017) 055 [arXiv: 1705.05802]

- More LHCb data needs to be taken to make further conclusions about this anomaly!