Hunting new particles in rare beauty decays

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A backdoor to New Physics beyond LHC reach

What and why?

- Beauty quarks decay to down-type quarks only via quantum loops

⇒ Rare processes highly sensitive to new particles in loops

- BSM physics at ~100 TeV scales (far beyond direct LHC reach)

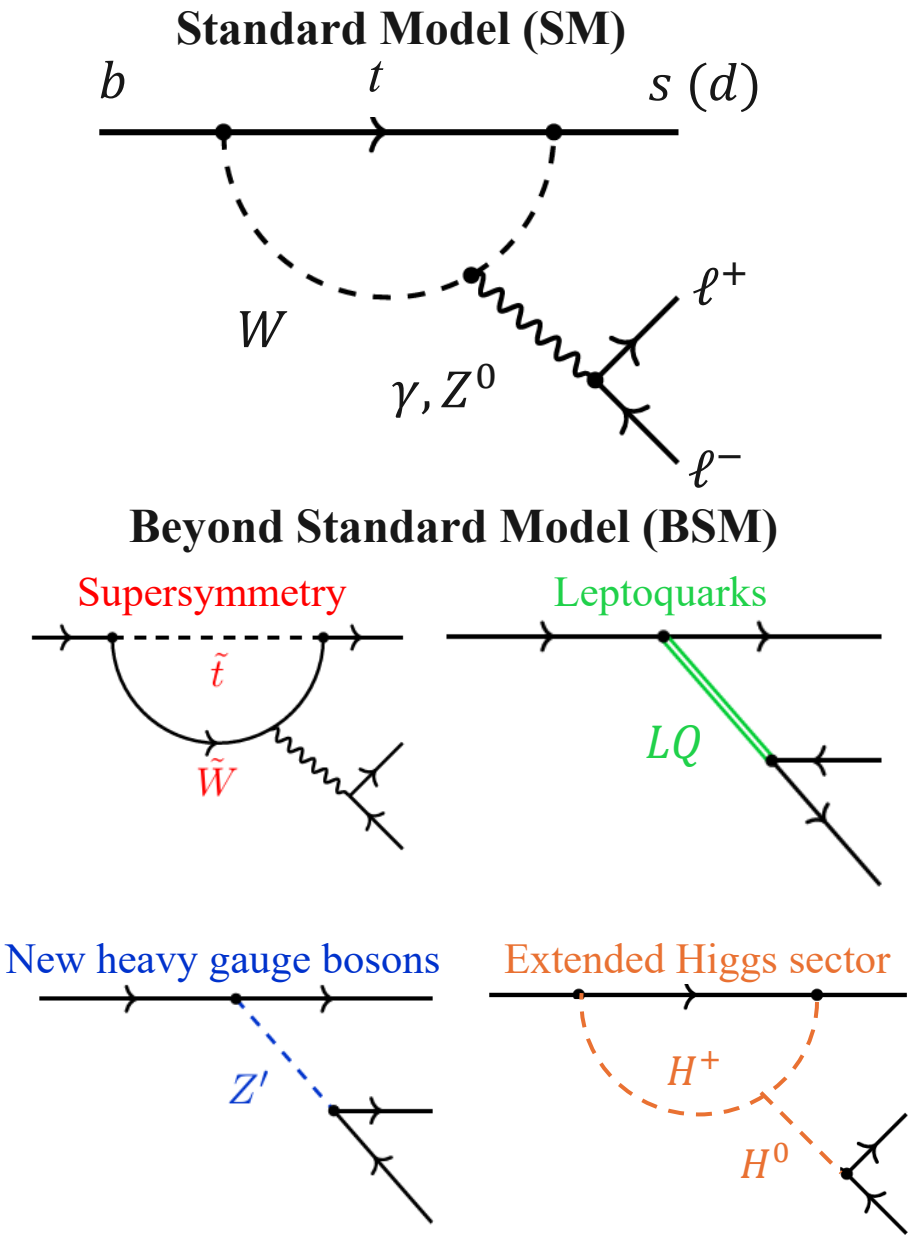
⇒ Possibly alters decay rates, angular and charge-parity asymmetries, or even produce decays entirely forbidden in the SM

How?

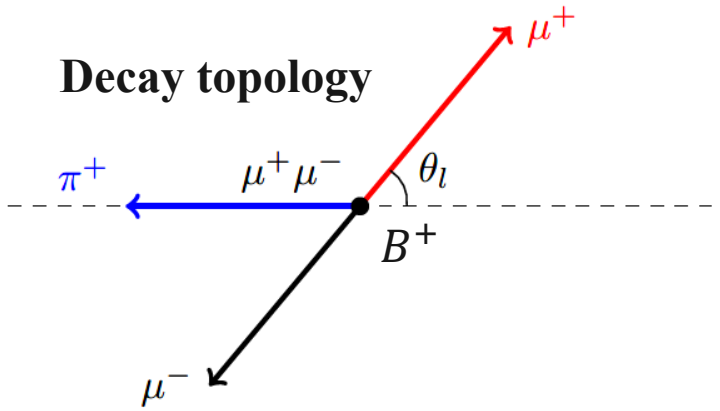
- Probe two complementary strategies:

⇒ **Rare decays** where new particles **interfere with SM**

⇒ **Forbidden decays** where any signals **unambiguously hint at BSM**



Hints of something new in $B^+ \to \pi^+\mu^+\mu^-$ decays



- Decay rarer than its better known $b \to s$ cousin (one in 10^8 decays)

⇒ Especially sensitive probe of BSM physics

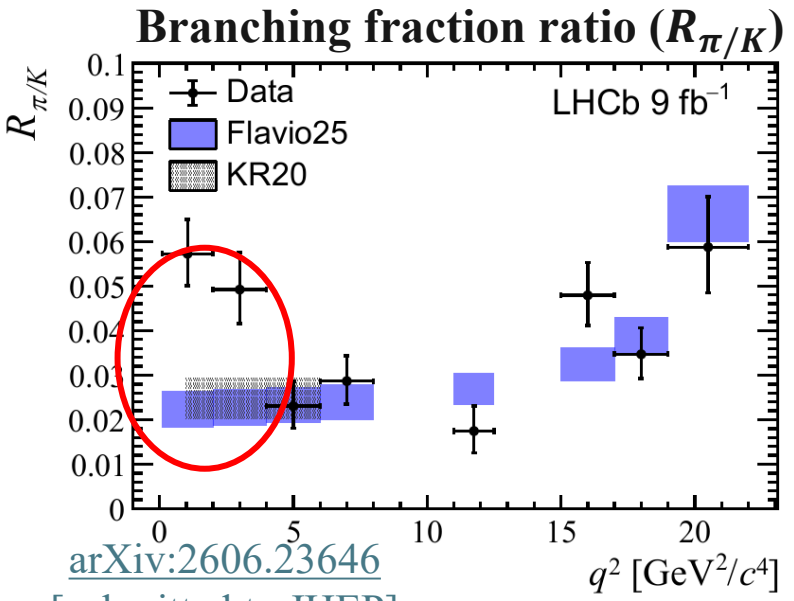
- Full Run 1+2 LHCb data revealed $2-3\sigma$ deviations from SM predictions at low dimuon masses

⇒ In both decay rate and angular distribution

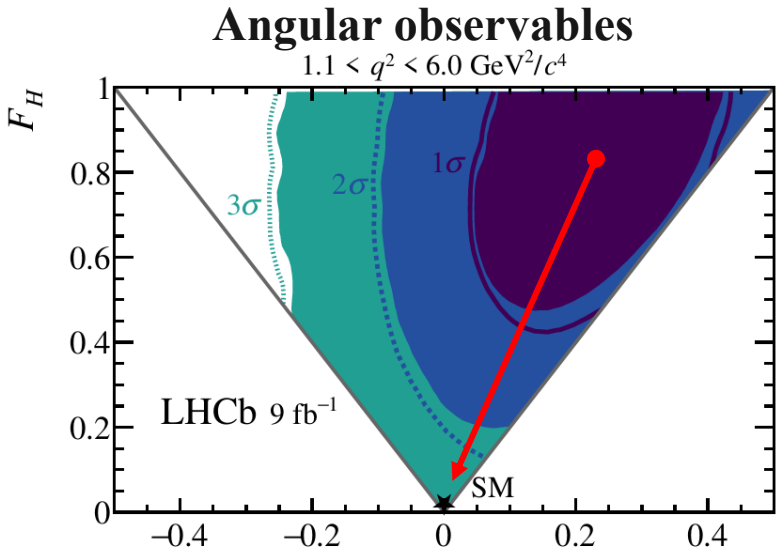
- Angular tensions hint at a new type of interaction

⇒ Intriguingly different from the type suggested by the $\boldsymbol{b \to s}$ **anomalies**

⇒ Points at a **potentially richer pattern of BSM physics**



arXiv:2606.23646
[submitted to JHEP]



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First search for Lepton Flavour Violation in baryons

- SM forbids electrons (e), muons (μ) and tau leptons (τ) from transforming into each other

⇒ Any new signal hints unambiguously at BSM physics with zero SM background

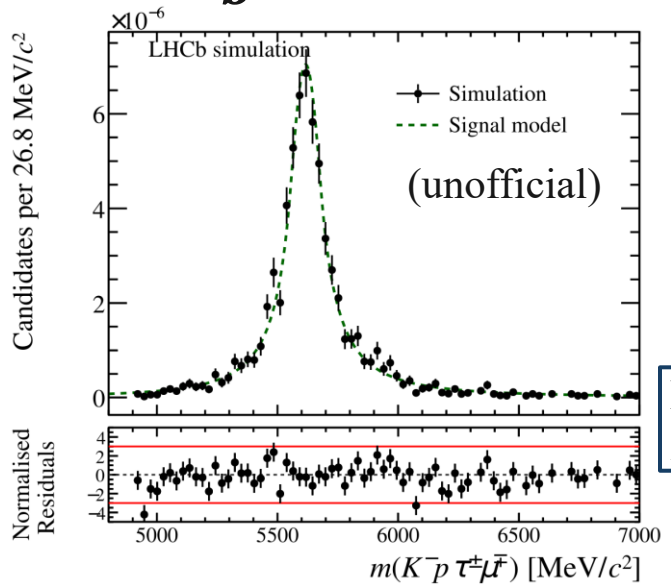
- Currently performing **first-ever search** for this in a baryon (3-quark bound state) decay ($\Lambda_b \to pK\,\tau\mu$)

⇒ Opening a new window through its **unique spin structure**

- Using only one year of Run 3 data already reaching sensitivity **comparable to world-best upper limits** on branching fraction

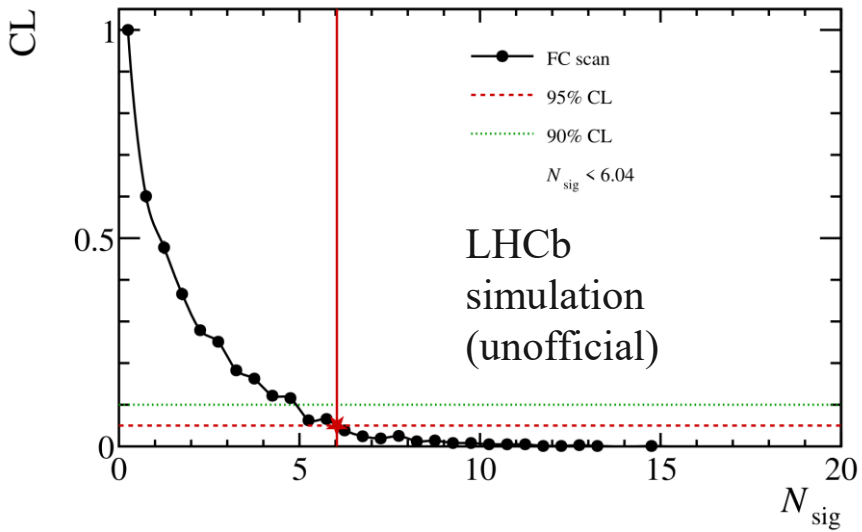
⇒ Extending to the full Run 2 (2015-2018) and Run 3 (2023-2026) datasets will push sensitivity well beyond

Λ_b mass distribution



MSc project of Akshat Dalmia

Feldman-Cousins scan



Getting the expectations right

- Deviations from Standard Model are found by comparing data with predictions from simulation

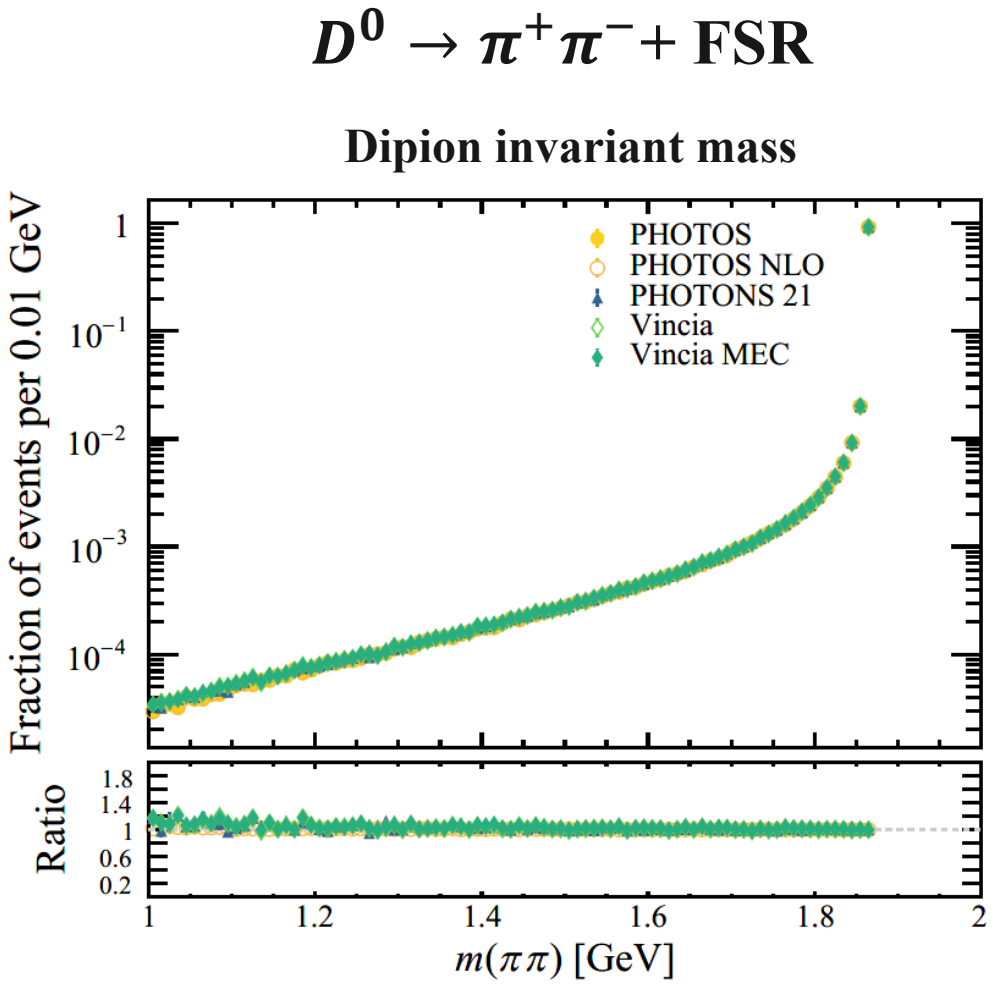
⇒ **EvtGen** is the world-standard simulation tool for hadron decays

- Led a **major modernisation**: enabled **multithreaded** computations, upgraded simulation of **final-state photon radiation (FSR)**, and extended support for new decay models (from LHCb and Belle II)

⇒ Enables precise systematic studies at lower computational cost

- Under development: reweighting framework to quantify the impact of different simulation configurations

⇒ Better control of systematic effects in multiple experiments



EvtGen and Vincia papers in preparation

Precision era just starting

- **$B^+ \to \pi^+\mu^+\mu^-$:** Interesting pattern of anomalies emerging at low q^2 for branching fraction and angular observables

$\Rightarrow$ Run 3 data will sharpen or dissolve the $2-3\sigma$ anomalies

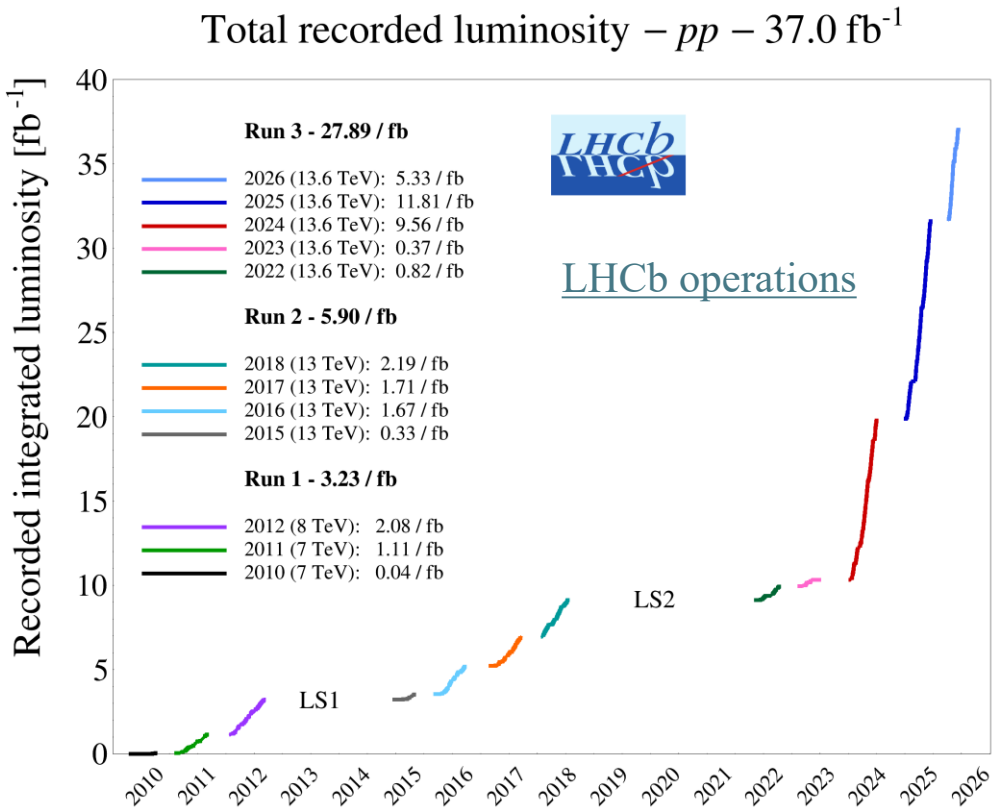
$\Rightarrow$ A definitive picture is within reach

- **Λ_b LFV search:** extending to the full Run 2 and 3 datasets

$\Rightarrow$ World-leading sensitivity in a completely new topology

- LHCb has now recorded a sample nearly 5 ×larger than before, with Run 4 and Upgrade II still ahead

$\Rightarrow$ The best measurements are yet to come!



$\Rightarrow$ Massive leap in precision ahead: Stay tuned!