

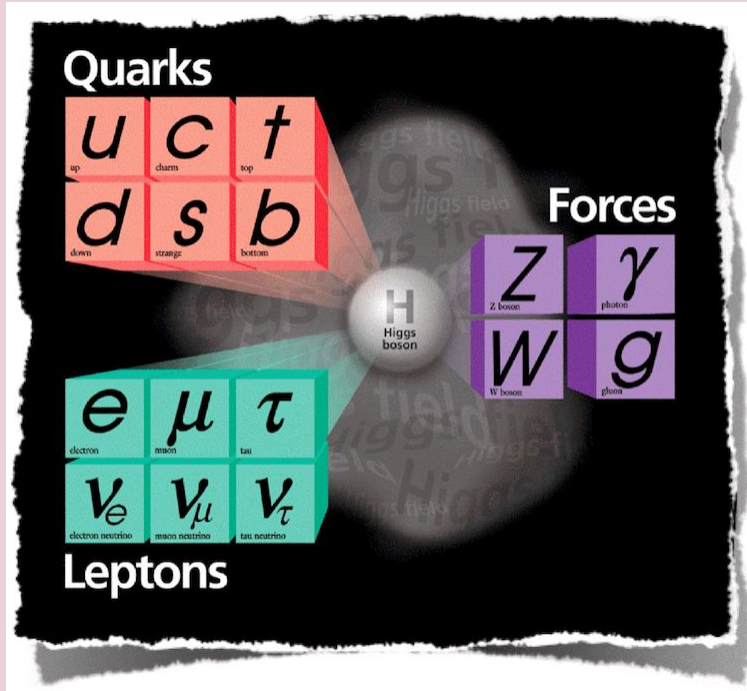
LHCb highlights: a magical saga

Miriam Lucio Martínez,
on behalf of the bfys group



The Standard Model (SM) of Particle Physics

A **successful** theory that describes the interactions among particles ...



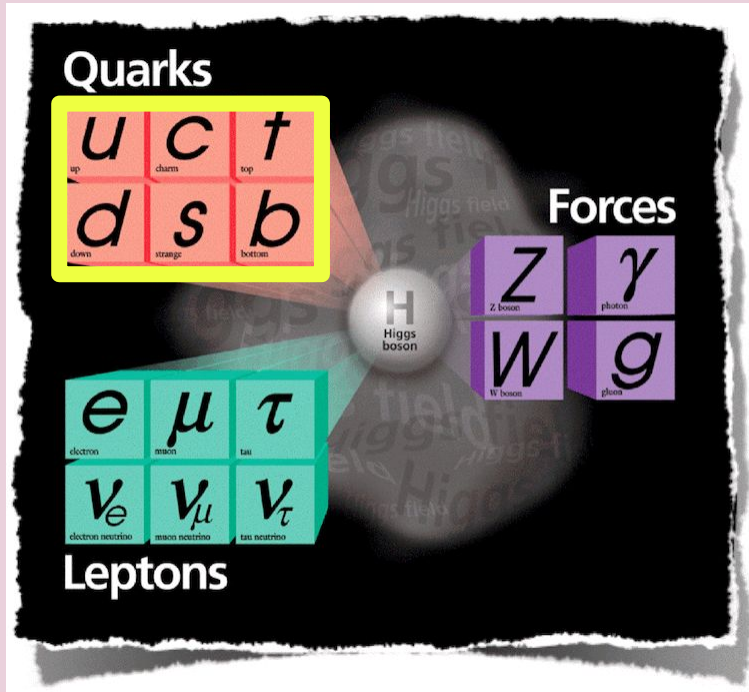
... **but** fails to explain several phenomena observed in the Universe:

- Observed matter-antimatter asymmetry
- Origin of Dark Matter & Dark Energy
- etc

⇒ need of **Physics Beyond the Standard Model** (BSM) !!

Why flavour?

There are **6** (known) **flavours** of quarks, grouped into **3 generations**.



In Flavour Physics, we study them and their couplings, to:

- make **precision tests** of the SM
- look for **indirect evidences** of BSM, inaccessible via direct searches

*Looking at the **heart** of the problem*

How we do what we do: Nikhef & LHCb

*A.k.a our **hands-on***

1. Study mechanisms of CP violation (matter-antimatter)

$$\mathbf{B}_s^0 \rightarrow \mathbf{J}/\Psi \mathbf{K}^+ \mathbf{K}^-, \mathbf{B}_s^0 \rightarrow \mathbf{D}_s \mathbf{K}, \mathbf{B}^0 \rightarrow \Psi (\rightarrow \mathbf{l}^+ \mathbf{l}^-) \mathbf{K}_S^0 (\rightarrow \pi^+ \pi^-), \Lambda_b^0 \rightarrow \mathbf{J}/\Psi \Lambda, \dots$$

2. Test the limits of the *standard model of particle physics* in “rare” events

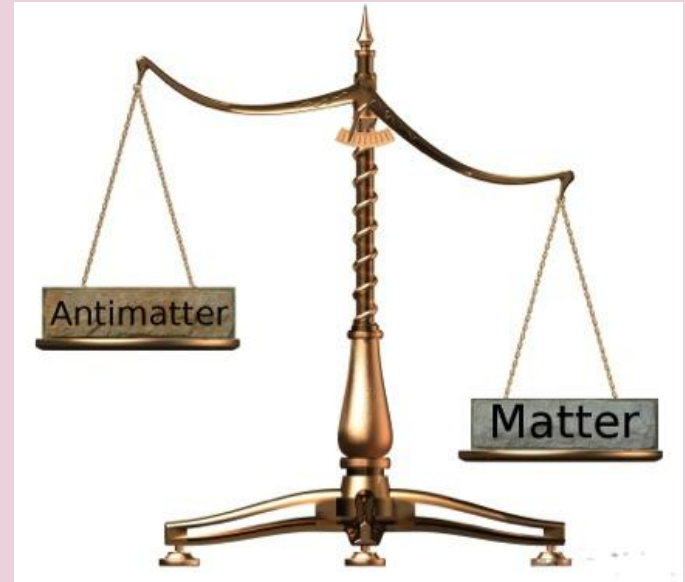
$$\mathbf{B}^0 \rightarrow \mathbf{K}^* \mathbf{e}^+ \mathbf{e}^-, \mathbf{R}(\Lambda), \mathbf{B}_{(s)}^0 \rightarrow \mathbf{e}^+ \mathbf{e}^-, \mathbf{B}_{(s)}^0 \rightarrow \mu^+ \mu^-, \dots$$

+ Semileptonic measurements, Exotic measurements, Spectroscopy

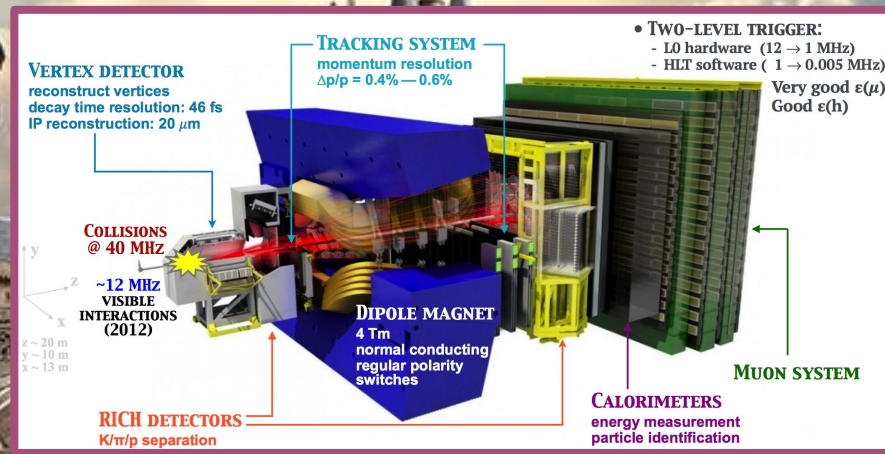
LHCb and the Chamber of matter-antimatter

- CP Violation needed to explain **matter-antimatter asymmetry**
- SM predicts an amount much smaller than the one observed in the Universe

→ measure @ LHCb and compare with these predictions



LHCb: the detector that (long-)lived



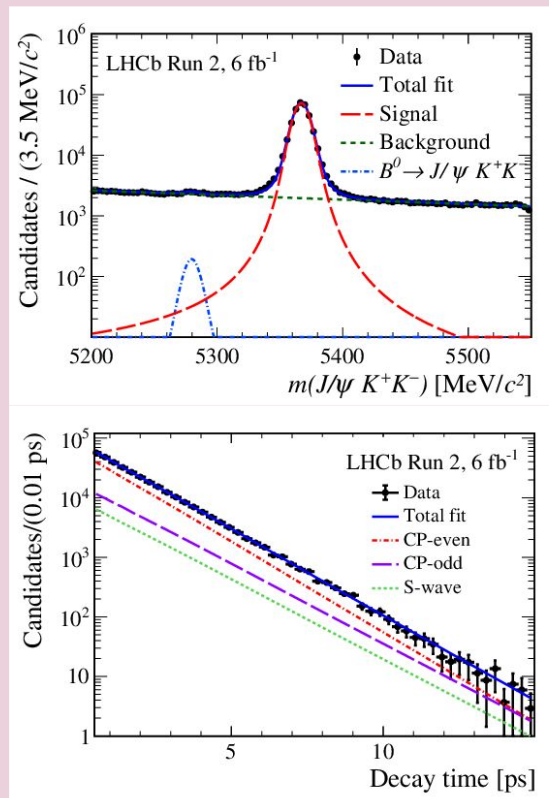
LHCb and the Chamber of matter-antimatter

- Consistent with SM predictions, still room for BSM physics!

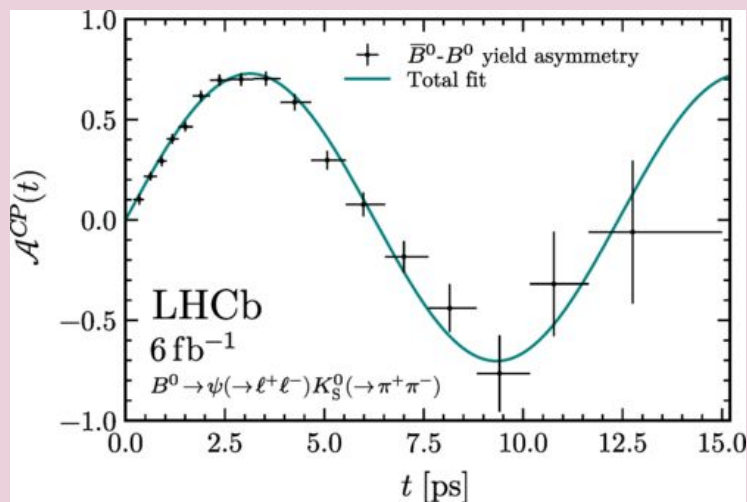


Time resolution basilisk

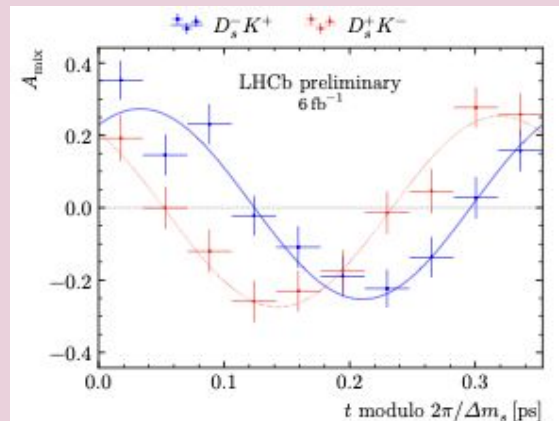
[\[PRL 132 \(2024\) 051802\]](#)



LHCb and the Chamber of matter-antimatter



[[PRL 132 \(2024\) 021801](#)]



[[LHCb-CONF-2023-004](#)]



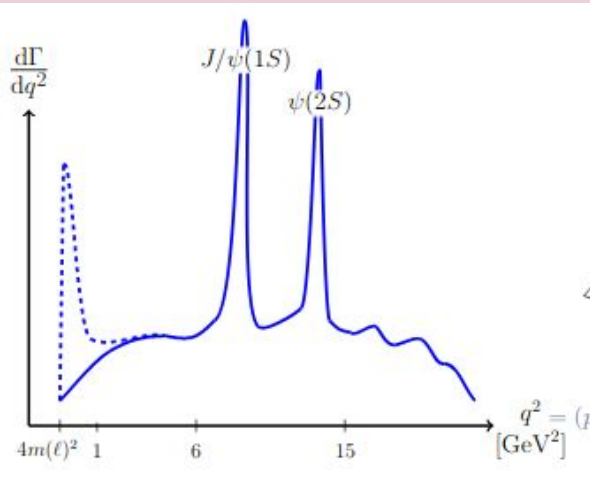
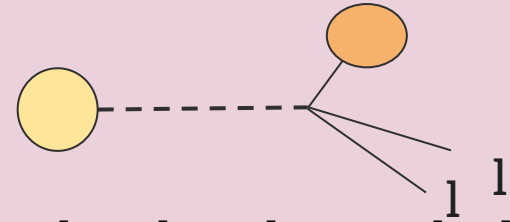
FANTASTIC
BEASTS

AND WHERE
TO FIND THEM

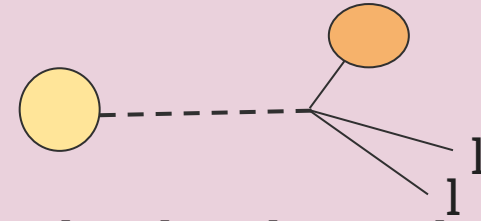
Fantastic beasts

$b \rightarrow sl^+l^-$ decays: strongly suppressed in SM \rightarrow good probe where to look for BSM contributions

[Branching fractions]



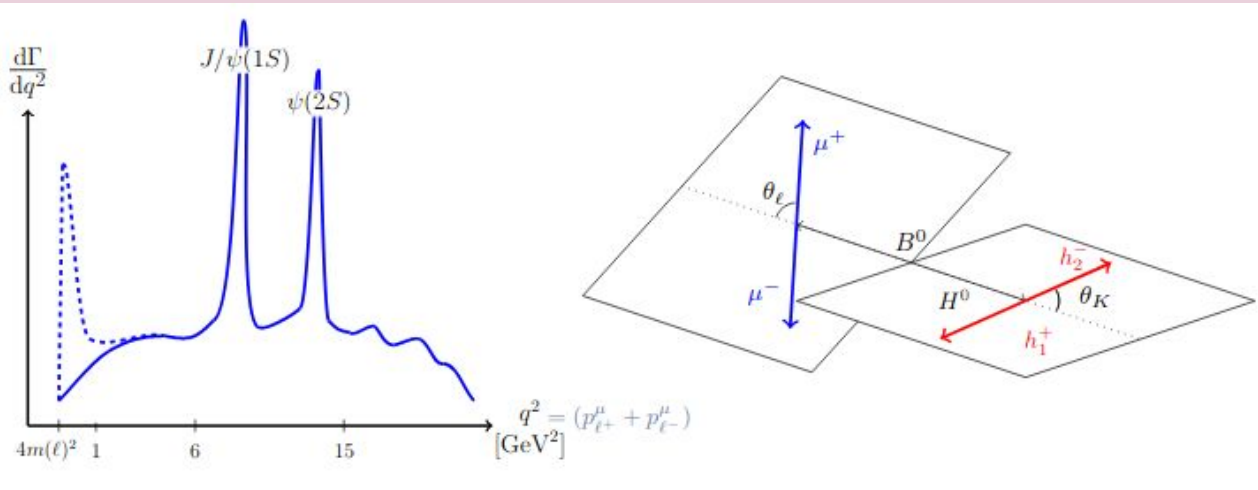
Fantastic beasts



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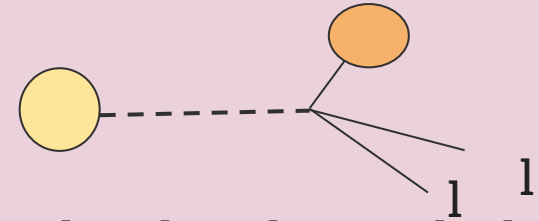
[Branching fractions]

[Angular distributions]

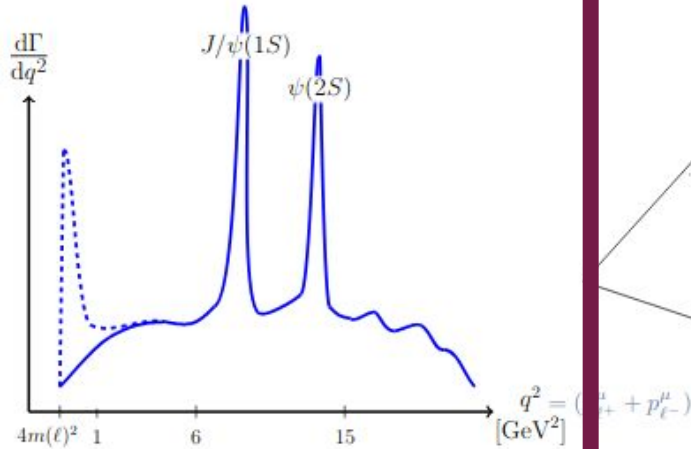


Fantastic beasts

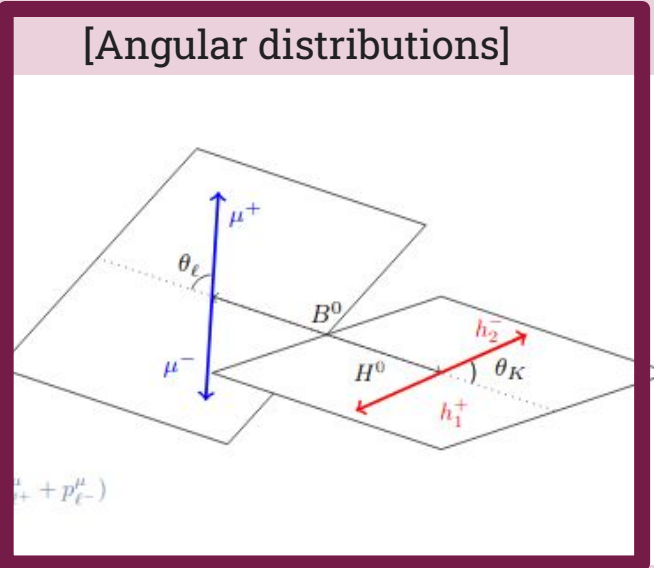
$b \rightarrow sl^+l^-$ decays: strongly suppressed in SM \rightarrow good probe where to look for BSM contributions



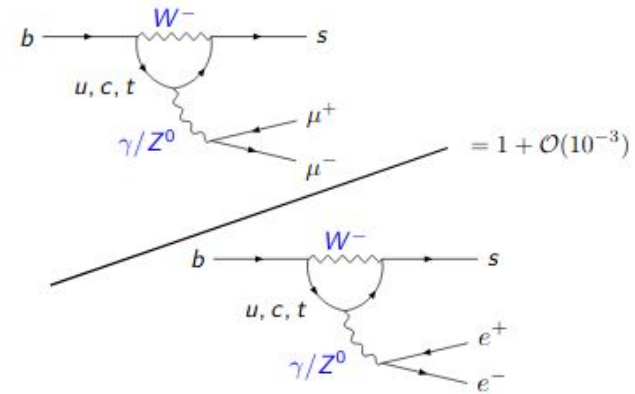
[Branching fractions]



[Angular distributions]



[Lepton Flavour Universality]



High theoretical uncertainties

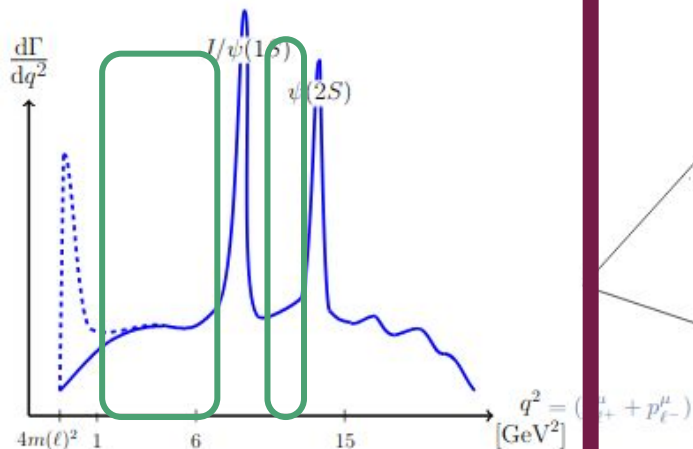


Low theoretical uncertainties

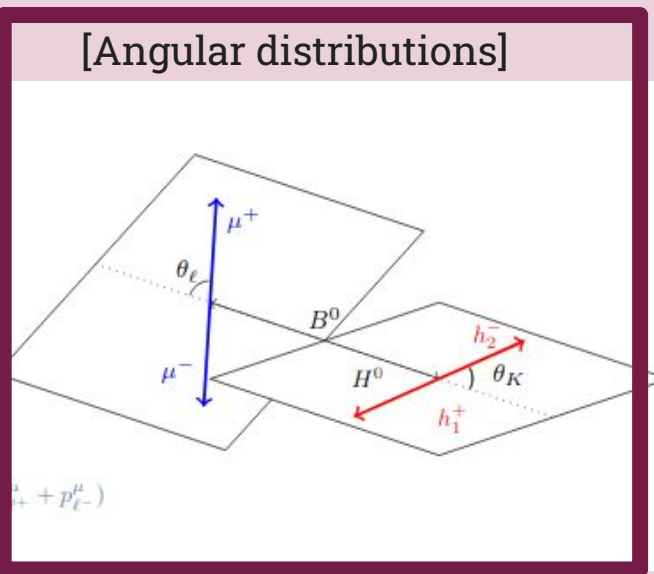
Fantastic beasts

$b \rightarrow sl^+l^-$ decays: strongly suppressed in SM \rightarrow good probe where to look for BSM contributions

[Branching fractions]



[Angular distributions]



[Lepton Flavour Universality]

$$R_X \equiv \frac{\mathcal{B}(B \rightarrow X\mu^+\mu^-)}{\mathcal{B}(B \rightarrow Xe^+e^-)} \simeq 1$$

High theoretical uncertainties



Low theoretical uncertainties

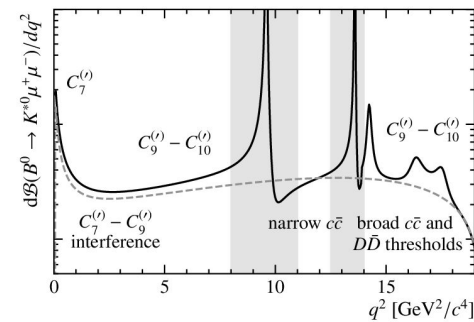
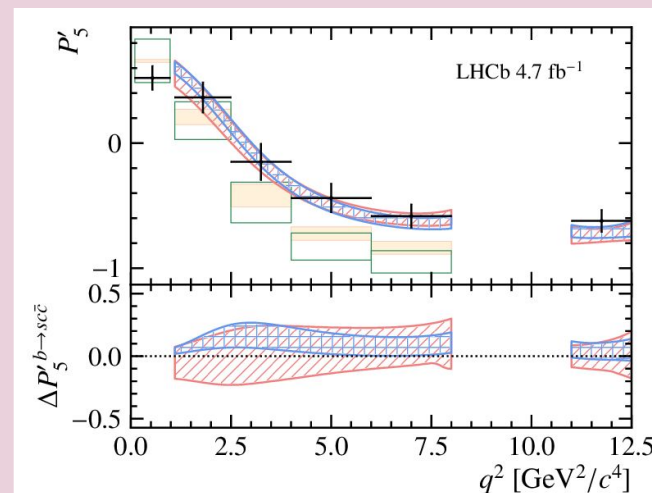
LHCb and the half-leptonic Prince

$B^0 \rightarrow K^* \mu^+ \mu^-$ [[PRL \(2020\) 1, 011802](#)]

Complementary study: $B^0 \rightarrow K^* e^+ e^-$

(more details: [Alice Jamboree 2023](#))

[[PRL 132 \(2024\) 13, 131801](#)]



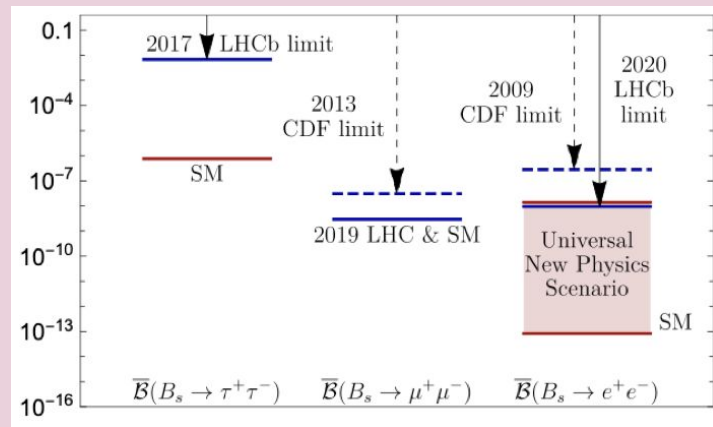
LHCb and the Order of the Electrons

- **Very rare decay, highly sensitive to BSM effects** [[JHEP 05 \(2017\) 156](#)]

$$\mathcal{B}_{SM}(B_s^0(s\bar{b}) \rightarrow e^+e^-) = (8.60 \pm 0.10) \times 10^{-14}$$

$$\mathcal{B}_{SM}(B^0(d\bar{b}) \rightarrow e^+e^-) = (2.39 \pm 0.14) \times 10^{-15}$$

- **Decay rate of $B_s^0 \rightarrow e^+e^-$: a factor $O(10^4)$ more suppressed in the SM than its sibling, $B_s^0 \rightarrow \mu^+\mu^-$**
 - results compatible with SM [[PRD 105 \(2022\) 1, 012010](#)]



Work ongoing with the **full** LHCb dataset!

LHCb and the Goblet of quarks

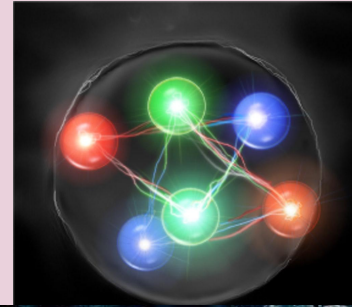
Sexaquarks: types of hexaquarks

→ bound state *uuddss*

- Stable?!
- Feebly interacting
- Compact (0.2 fm)

→ **Dark Matter** candidates

Ξ_b^0 (baryon) → K^+ antiproton



Conclusions

- Very exciting times for LHCb!
- *At the **head** of the search*
- Strong contributions from Nikhef team to important physics results
- Work ongoing, looking forward to new updates and Run 3(*) measurements

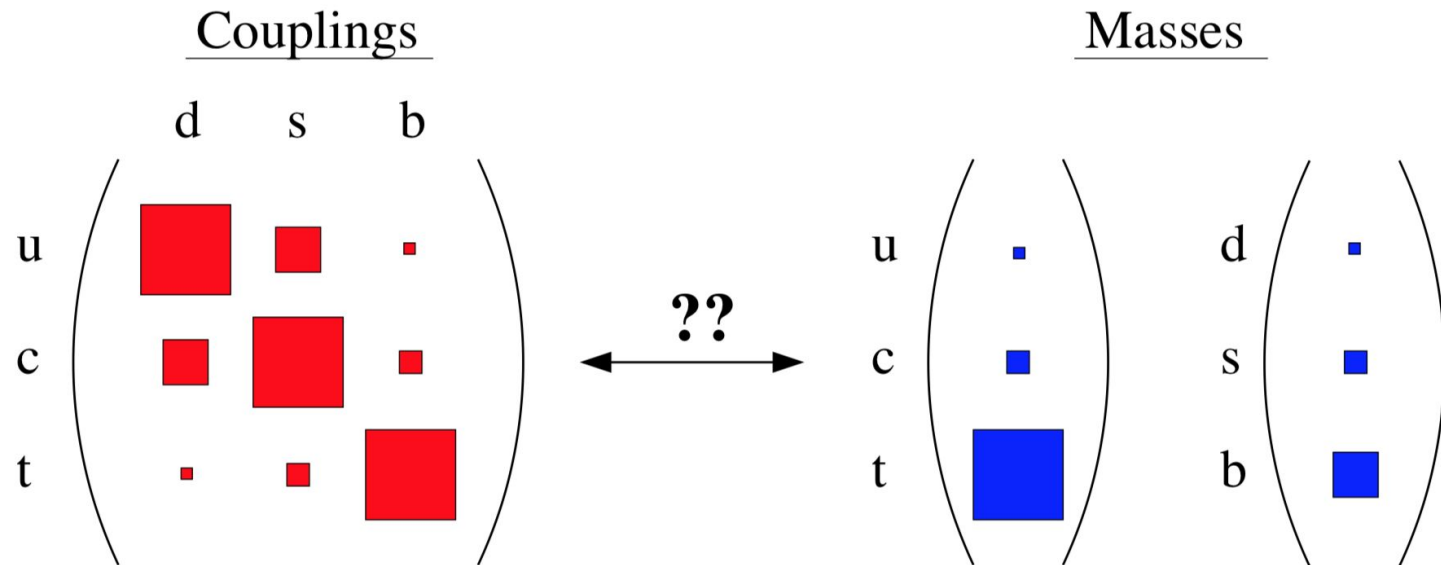
(*) check out Andrii's talk for more information



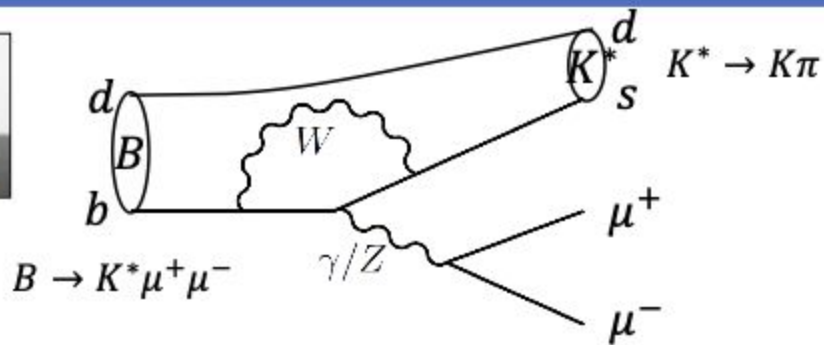
Thanks for your attention!

LHCb and the Sorcerer's Flavour Puzzle

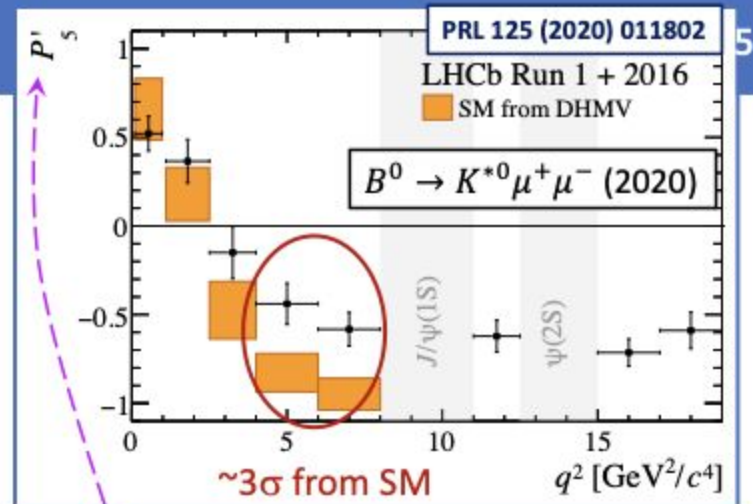
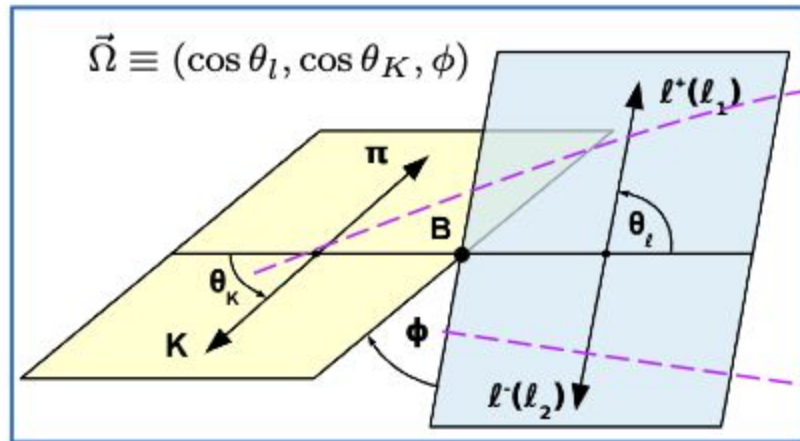
Yukawa Couplings



b) ii. Angular observable P'_5



- LHCb: Study angular distribution of the produced particles



P'_5 : count blue minus red:

