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# Rare b-baryon decays

Lukas Calefice on behalf of the LHCb collaboration  
and MÉRIL Reboud

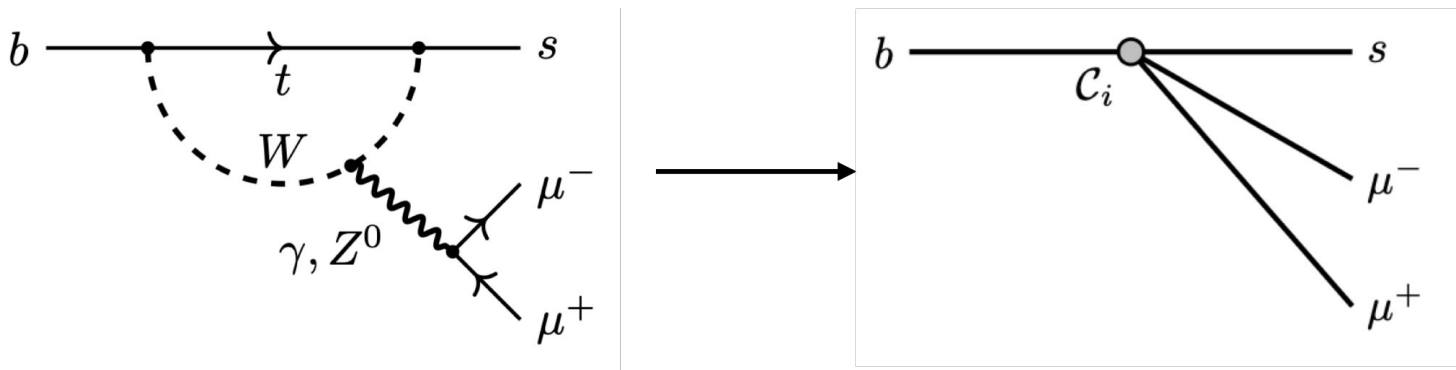
Beyond the Flavour Anomalies Workshop 2026,  
15.04.2026, Santiago de Compostela

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# Flavour Changing Neutral Currents (FCNCs)

- FCNCs like  $b \rightarrow s \ell \ell / s \gamma$  transitions are loop-suppressed in the SM
- Sensitive to NP that could enter at tree-level
- Indirect search for NP that can test mass scales up to 100TeV
- Effective Hamiltonian by integrating out heavy degrees of freedom



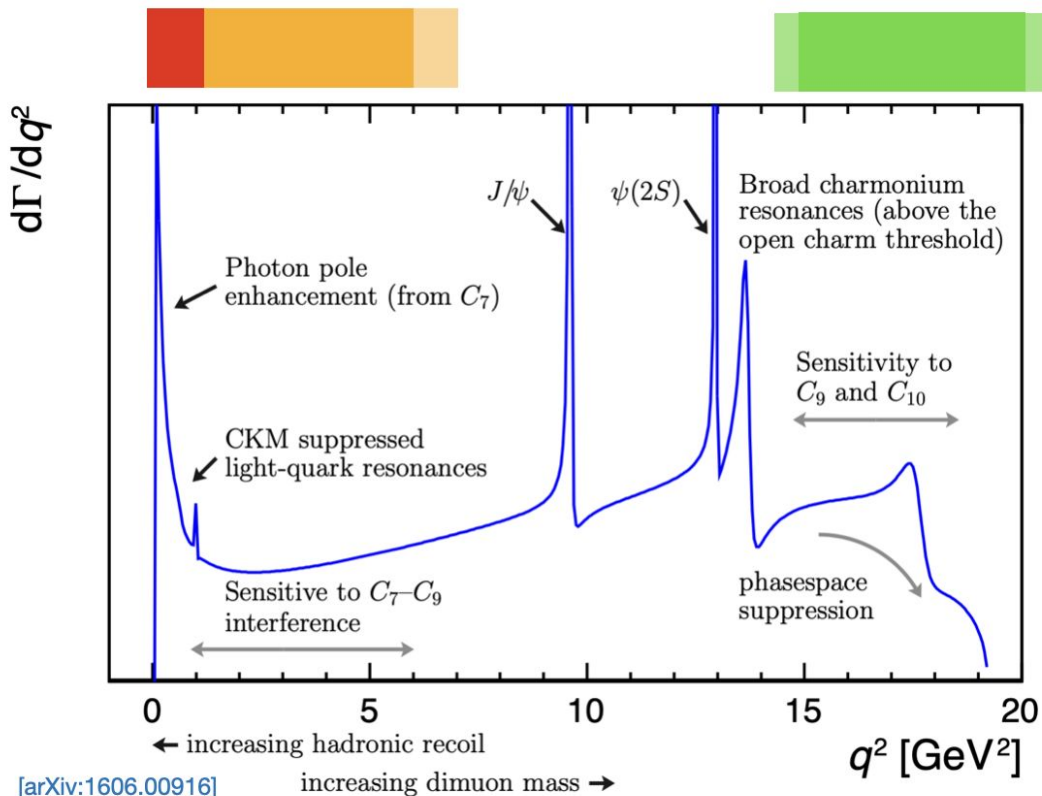
$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} \underbrace{(C_i O_i + \bar{C}_i \bar{O}_i)}_{\text{Wilson coefficients}} \underbrace{\quad}_{\text{Local operators}}$$

$$O_7^{(l)} \propto (\bar{s} \sigma_{\mu\nu} P_{R(L)} b) F^{\mu\nu}$$

$$O_9^{(l)} \propto (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{l} \gamma_\mu l)$$

$$O_{10}^{(l)} \propto (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{l} \gamma_\mu \gamma_5 l)$$

# $q^2$ - dependence



[arXiv:1606.00916]

$q^2 = m^2(\ell^+\ell^-)$ -regions allow to study different types of couplings of New Physics

■ Low- $q^2$  bin: [0.1, 1.1] GeV $^2$

Close to the photon pole, sensitive to dipole currents  $C_7$

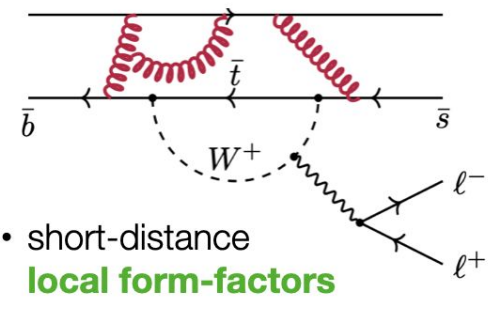
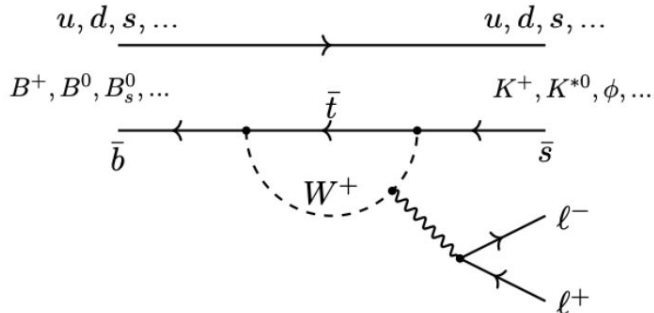
■ Central- $q^2$  bin: [1.1, 6] GeV $^2$

Sensitive to vector currents  $C_9$

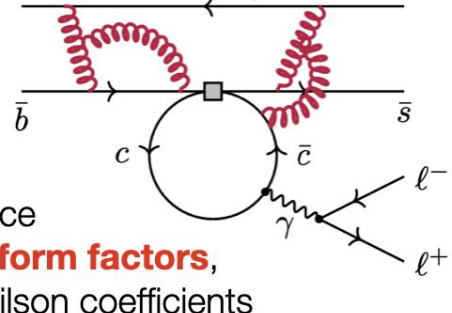
■ High- $q^2$  bin: [15, 19] GeV $^2$

Sensitive to vector and axial-vector currents  $C_9$  and  $C_{10}$

# Hadronic uncertainties in meson decays



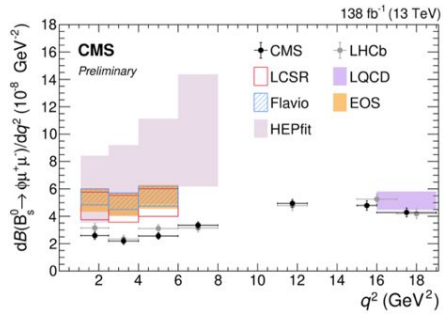
• short-distance **local form-factors**



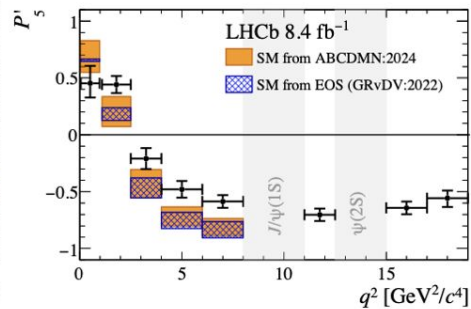
• long-distance **non-local form factors**, can shift Wilson coefficients

$$\mathcal{A}(B \rightarrow M \ell^+ \ell^-) = \frac{G_F \alpha V_{ts}^* V_{tb}}{\sqrt{2} \pi} [(C_9 \ell \gamma^\mu \ell + C_{10} \ell \gamma_5 \ell) \langle M | \bar{s} \gamma_\mu P_L b | \bar{B} \rangle - \frac{1}{q^2} \ell \gamma^\mu \ell (2im_b C_7 \langle M | \bar{s} \sigma_{\mu\nu} q^\nu P_R b | B \rangle + \mathcal{H}_\mu)]$$

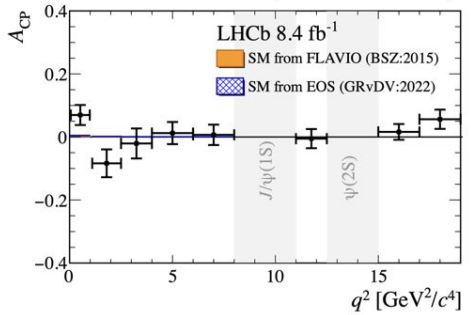
Differential decay rates



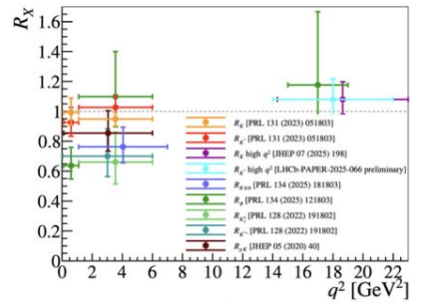
Angular Observables



CP asymmetries



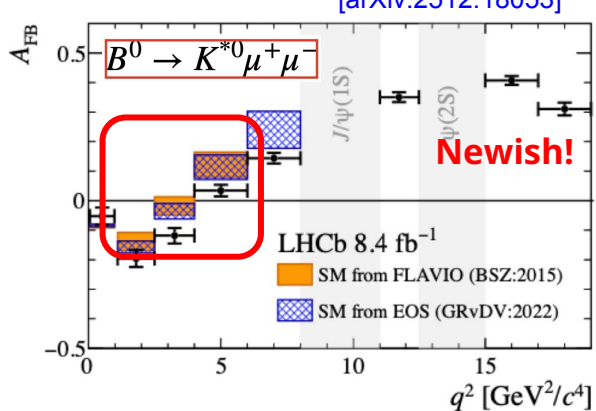
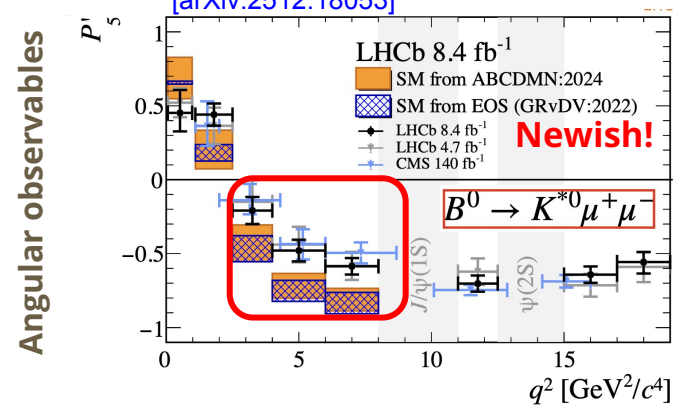
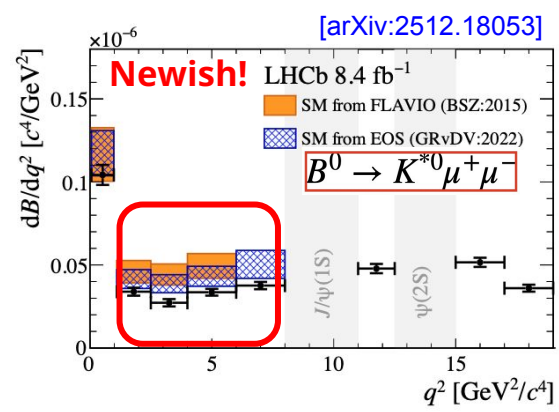
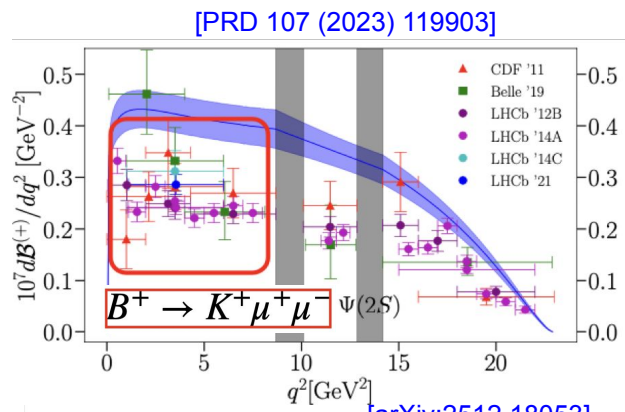
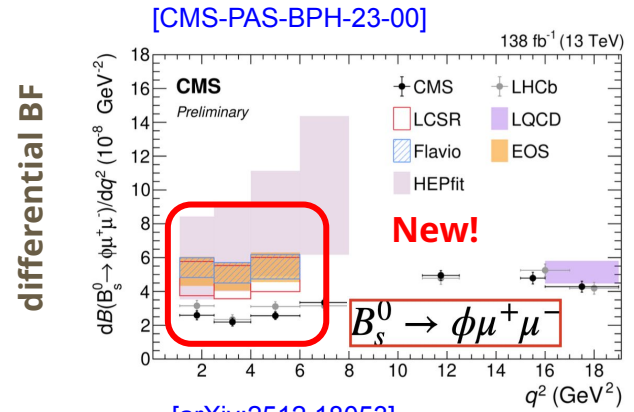
LFU tests



→ SM precision

# Local tensions with the SM

\*non-exhaustive selection of results



- Consistent offset across many channels in differential BF and angular observables
- Seen by multiple experiments (LHCb, CMS, Belle, ...)
- for  $B \rightarrow P \ell \ell$  and  $B \rightarrow V \ell \ell$  decays
- Same offset for  $\ell = \mu, e$  as confirmed by LFU tests

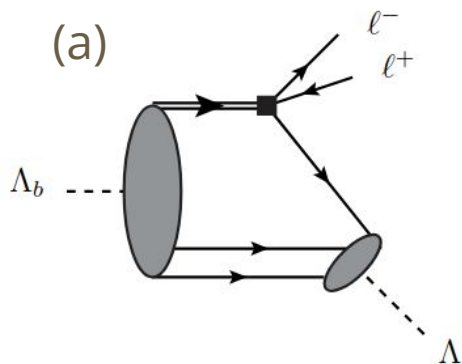
• tensions most simply dissolved with shift in Wilson coefficient C9

# Why looking at baryon FCNCs?

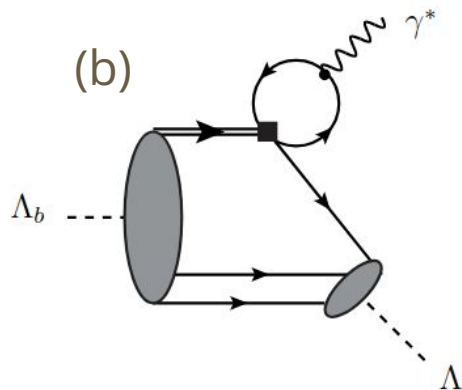
- Complementary sensitivity to NP contributions
- More angular observables, different spin structures
  - $1/2^+ \rightarrow 1/2^+$  (e.g.  $\Lambda_b \rightarrow \Lambda \mu \mu$ ,  $\Xi_b \rightarrow \Xi \mu \mu$ ),  $1/2^+ \rightarrow 3/2^-$  (e.g.  $\Lambda_b \rightarrow \Lambda(1520) \mu \mu$ ),  $1/2^+ \rightarrow 3/2^+$  (e.g.  $\Omega_b \rightarrow \Omega \mu \mu$ )
- Access to new observables  $\rightarrow$  polarisation
- Different hadronic environment  $\rightarrow$  cross-check/complement hadronic uncertainties from (non-)local form factors (e.g. via dispersive bounds)
- Experimentally different from mesonic decays (different backgrounds, event reconstruction)

# Theoretical challenges

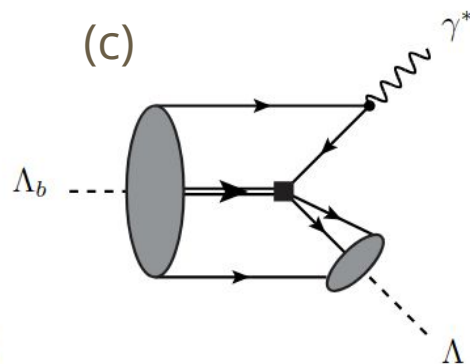
$$\mathcal{H}(b \rightarrow sll) = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} C_i(\mu) \mathcal{O}_i(\mu)$$



- $\mathcal{O}_9 \mathcal{O}_{10} \mathcal{O}_7$
- local form factors
- $\pm$  under control (see next slide)



- dominated by  $\mathcal{O}_1^c \mathcal{O}_2^c$
- non-local form factors
- same treatment as for meson decays would apply equally here [Gubernari, Reboud, van Dyk, Virto 2206.03797]



- non-factorizable contributions
- estimated  $\sim 1\%$  [Feldmann, Gubernari 2312.14146]

# Local form factors (10 for $1/2^+ \rightarrow 1/2^+$ , 14 for $1/2^+ \rightarrow 3/2^-$ )

Process	Collaboration	Ref.	$N_f$	publication status	continuum extrapolation	chiral extrapolation	finite volume	renormalization	heavy-quark treatment
$\Lambda_b \rightarrow \Lambda^*(1520) \ell^+ \ell^-$	Meinel 21B	[503]	2+1	A	○	○	■	○	✓
$\Lambda_b \rightarrow \Lambda^*(1520) \ell^+ \ell^-$	Meinel 20	[670]	2+1	A	○	○	■	○	✓
$\Lambda_b \rightarrow \Lambda \ell^+ \ell^-$	Detmold 16	[666]	2+1	A	○	○	■	○	✓

[FLAG 2411.04268]

- LCSR estimates are harder than for mesons [Wang et al. 0804.0648, 0907.4008, 1511.09036; Huang et al. 2412.06515; Mahmoudi, Mishra 2601.02302]
- Lattice calculation (high  $q^2$ ) [Meinel et al. 2009.09313, 1602.01399, 2107.13140]
- Other modes? Recently  $\Xi_b \rightarrow \Xi$  [Farrell, Meinel 2603.18438]
- Extrapolation to low- $q^2$  using analyticity and unitarity [Blake, Meinel, Rahimi, van Dyk 2205.06041; Amhis, Bordone, Reboud 2208.08937]

# Dispersive bound

↪ Relate hadronic and partonic calculation of the inclusive  $e^+e^- \rightarrow sb$  rate

- Partonic calculation (OPE or lattice) [Bharucha, Feldmann, Wick 1004.3249]

$$\Pi_{\Gamma}^{\mu\nu}(q) \equiv i \int d^4x e^{iq \cdot x} \langle 0 | \mathcal{T} \{ J_{\Gamma}^{\mu}(x) J_{\Gamma}^{\dagger, \nu}(0) \} | 0 \rangle \simeq \text{diagrams} + \dots$$

- Optical theorem

$$\text{Im} \Pi_{\Gamma}^X(q^2) = \frac{1}{2} \sum_{\Gamma} \int d\rho_{\Gamma} (2\pi)^4 \delta^4(q - p_{\Gamma}) P_{\Gamma}^{\mu\nu} \langle 0 | j_{\mu}^X | \Gamma \rangle \langle \Gamma | j_{\nu}^{\dagger X} | 0 \rangle$$

|form factor|<sup>2</sup> ←

- Dispersive bound

$$\chi_{\Gamma}^{(\lambda)} \Big|_{\text{OPE}} = \chi_{\Gamma}^{(\lambda)} \Big|_{\text{1pt}} + \chi_{\Gamma}^{(\lambda)} \Big|_{\bar{B}K} + \chi_{\Gamma}^{(\lambda)} \Big|_{\bar{B}K^*} + \chi_{\Gamma}^{(\lambda)} \Big|_{\bar{B}_s\phi} + \dots$$

known terms

sum of positive quantities

# Dispersively bounded form factor analyses

- Mesonic  $b \rightarrow s\ell\ell$  [Gubernari, MR, van Dyk, Virto 2305.06301]
  - global  $B \rightarrow K, B \rightarrow K^*, B_s \rightarrow \varphi$  analysis with EOS
  - mild impact from the bounds due to precise inputs
- $\Lambda_b \rightarrow \Lambda$  [Blake, Meinel *et al* 2205.06041]
  - Visible reduction of the uncertainties thanks to bound

w/o the bound:

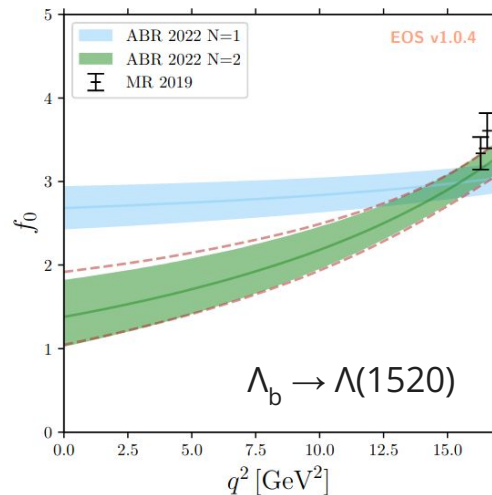
$$f_{\perp}^T(q^2 = 0)|_{[14]} = 0.166 \pm 0.072$$

w the bound:  $f_{\perp}^T(q^2 = 0)|_{N=2} = 0.190 \pm 0.043,$

$$f_{\perp}^T(q^2 = 0)|_{N=3} = 0.173 \pm 0.053,$$

$$f_{\perp}^T(q^2 = 0)|_{N=4} = 0.166 \pm 0.049.$$

- $\Lambda_b \rightarrow \Lambda(1520)$  [Amhis, Bordone, MR 2208.08937]
  - Analysis impossible without the bound!



# Finite width effects

- Most baryons are not narrow
- Generalize the matrix elements

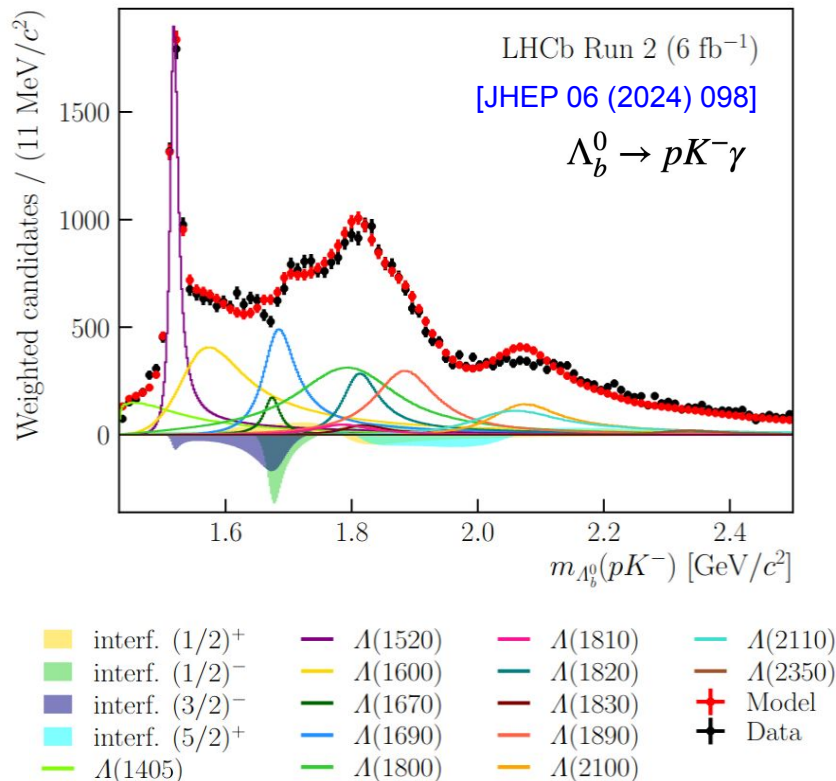
$$\langle p(k_1)K(k_2) | \mathcal{O}_i^\mu | \Lambda_b(q+k) \rangle = F_i(q^2, m_{pK}^2, \cos \theta_K) \mathcal{S}_\mu^i$$

- Partial-wave expansion

$$F_i(q^2, m_{pK}^2, \cos \theta_K) = \sum_{\ell=0}^{\infty} \sqrt{2\ell+1} F_i^{(\ell)}(q^2, m_{pK}^2) P_\ell(\cos \theta_K)$$

- Parametrization?

- Double z expansion?
- Omnès + z expansion [[Gustafson et al 2311.00864](#), [Herren et al 2502.20960](#)]
- K-Matrix?



# Experimental challenges

- Low production fractions
- Strange baryons decay via (chain of) weak decays → Displaced decay topologies

$$\begin{array}{ll} \Lambda_b^0 \quad \text{b u d} & f_{\Lambda_b^0} \sim 18 \% \\ \Xi_b^0 \quad \text{b s u} & f_{\Xi_b^0} \sim 1.5 - 2 \% \\ \Xi_b^- \quad \text{b s d} & f_{\Xi_b^-} \sim 1.5 \% \\ \Omega_b^- \quad \text{b s s} & f_{\Omega_b^-} \sim 0.3 - 0.5 \% \end{array}$$

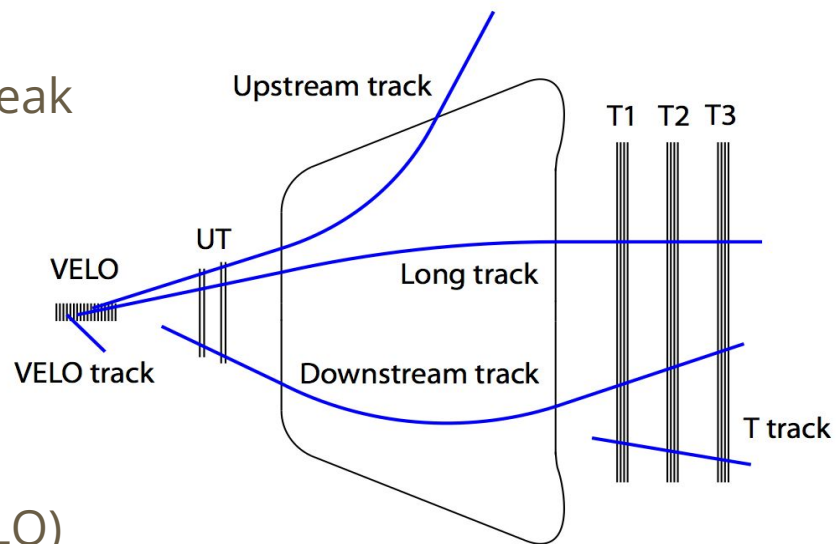
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particle	mean lifetime
$\Lambda_b^0$	$1.468 \times 10^{-12} \text{ s}$
$\Lambda^0$	$2.617 \times 10^{-10} \text{ s}$
$\Xi^-$	$1.639 \times 10^{-10} \text{ s}$
$\Omega^-$	$0.821 \times 10^{-10} \text{ s}$

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# Experimental challenges

- Low production fractions
- Strange baryons decay via (chain of) weak decays → Displaced decay topologies
- Final state tracks are reconstructed
  - with (long tracks (L))
  - without (downstream tracks (D))detector hits in the Vertex Locator (VELO)



$$\Lambda_b^0 \rightarrow \Lambda \mu^+ \mu^- \quad \text{LL: 40-45\%, DD: 55\%-60\%}$$

# LHCb results

Table 1: Rare  $b$ -baryon decay measurements by LHCb:  $b \rightarrow s\ell^+\ell^-$ ,  $b \rightarrow s\gamma$ ,  $b \rightarrow d\ell^+\ell^-$

Channel	Observables	Dataset	Publication
$\Lambda_b^0 \rightarrow \Lambda\mu^+\mu^-$	Angular moments	Run 1+15-16 (5 fb <sup>-1</sup> )	<a href="#">JHEP 09 (2018) 146</a>
	diff. BF+angular	Run 1 (3 fb <sup>-1</sup> )	<a href="#">JHEP 09 (2018) 145</a>
	diff. BF	2011 (1 fb <sup>-1</sup> )	<a href="#">PLB 725 (2013) 25</a>
$\Lambda_b^0 \rightarrow \Lambda(1520)\mu^+\mu^-$	diff. BF	Run 1+2 (9 fb <sup>-1</sup> )	<a href="#">PRL 131 (2023) 151801</a>
$\Lambda_b^0 \rightarrow pK\ell^+\ell^-$	Angular moments $\mu^+\mu^-$	Run 1+2 (9 fb <sup>-1</sup> )	<a href="#">JHEP 12 (2024) 147</a>
	Observation $\mu^+\mu^- + \text{CPV}$	Run 1 (3 fb <sup>-1</sup> )	<a href="#">JHEP 06 (2017) 108</a>
	Observation $e^+e^- + R_{pK}^{-1}$	Run 1 + 2016 (4.7 fb <sup>-1</sup> )	<a href="#">JHEP 05 (2020) 40</a>
$\Lambda_b^0 \rightarrow \Lambda\gamma$	Photon polarisation: $\alpha_\gamma$	Run 2 (6 fb <sup>-1</sup> )	<a href="#">PRD 105 (2022) L051104</a>
	Observation+BF	2016 (1.7 fb <sup>-1</sup> )	<a href="#">PRL 123 (2019) 031801</a>
$\Xi_b^- \rightarrow \Xi^-\gamma$	Search	2016-18 (5.4 fb <sup>-1</sup> )	<a href="#">JHEP 01 (2022) 069</a>
$\Lambda_b^0 \rightarrow pK\gamma$	Amplitude analysis	Run 1+2 (9 fb <sup>-1</sup> )	<a href="#">JHEP 06 (2024) 098</a>
$\Lambda_b^0 \rightarrow p\pi^-\mu^+\mu^-$	Observation+BF	Run 1 (3 fb <sup>-1</sup> )	<a href="#">JHEP 04 (2017) 029</a>

- No new rare baryon decay results recently, but full Run1+2 updates in preparation:
  - Angular  $\Lambda_b \rightarrow \Lambda(1520)\mu\mu$ , Search for  $\Xi_b \rightarrow \Xi\mu\mu$
  - $R_{pK}$ ,  $\Lambda_b \rightarrow \Lambda\mu\mu$  diff. BF,  $\Lambda_b \rightarrow p\pi\mu\mu$ ,  $\Lambda_b \rightarrow pK\tau\tau$

# Update of the $\Lambda_b \rightarrow \Lambda J/\psi$ BF

- $\Lambda_b \rightarrow \Lambda \mu \mu$  diff. BF used external value for  $B(\Lambda_b \rightarrow \Lambda J/\psi)$  from D0/CDF measurements

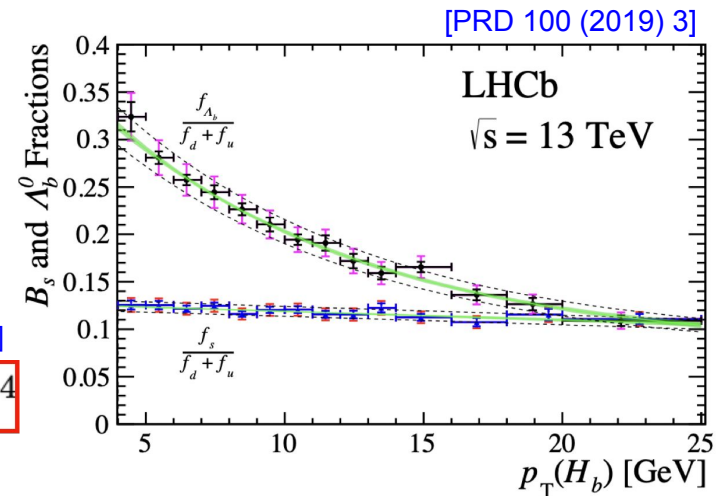
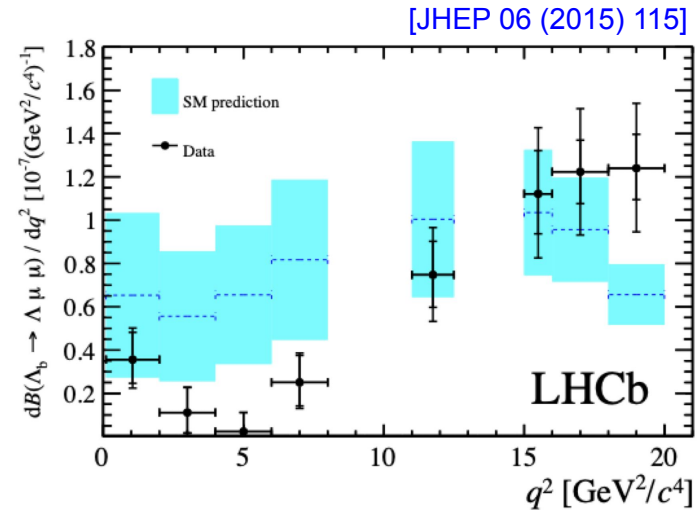
$$\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda) = (6.3 \pm 1.3) \times 10^{-4}$$

- The problem:
  - only measured  $f(\Lambda_b) \times B(\Lambda_b \rightarrow \Lambda J/\psi)$
  - assumptions about  $f(\Lambda_b)$  can change value of  $B(\Lambda_b \rightarrow \Lambda J/\psi)$  [PRD 85 (2012)] [PRD 100 (2019) 3]
- LHCb measurements of  $f(\Lambda_b)/(f_u + f_d)$  revealed strong  $p_T$  dependence

- Updated BF:

[JHEP 01 (2026) 159]

$$\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi \Lambda) = (3.34 \pm 0.02 \pm 0.10 \pm 0.08 \pm 0.28) \times 10^{-4}$$



# Update of the $\Lambda_b \rightarrow \Lambda J/\psi$ BF

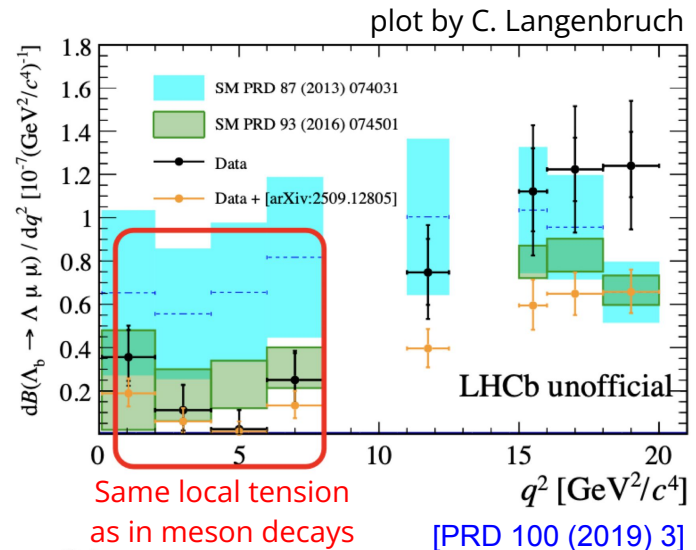
- $\Lambda_b \rightarrow \Lambda \mu \mu$  diff. BF used external value for  $B(\Lambda_b \rightarrow \Lambda J/\psi)$  from D0/CDF measurements

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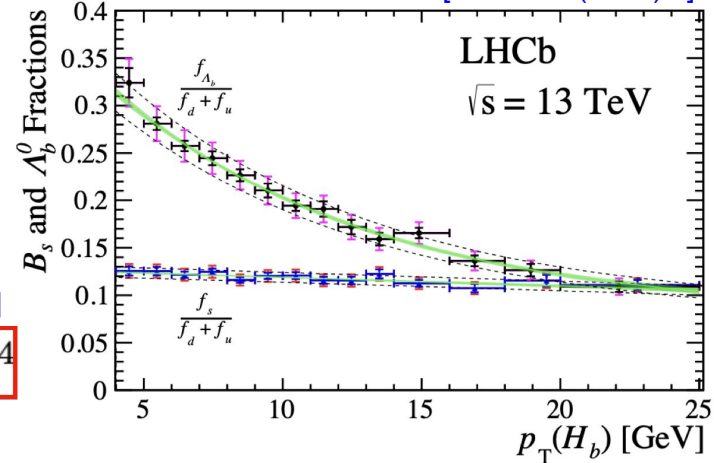
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Same local tension as in meson decays [PRD 100 (2019) 3]



# J/ψ and ψ(2S) modes

- BF for resonant charmonia modes helpful to constrain the charm loops
- $B(\Lambda_b \rightarrow \Lambda \psi(2S))/B(\Lambda_b \rightarrow \Lambda J/\psi)$  has been measured with Run1

[JHEP 03 (2019) 126]

$$\mathcal{B}(\Lambda_b^0 \rightarrow \psi(2S)\Lambda)/\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi\Lambda) = 0.513 \pm 0.023 (\text{stat}) \pm 0.016 (\text{syst}) \pm 0.011 (\mathcal{B})$$

- No direct measurements of  $B(\Xi_b^- \rightarrow \Xi^- J/\psi)$  or  $B(\Omega_b^- \rightarrow \Omega^- J/\psi)$  exist
  - D0/CDF measured  $B(\Xi_b^- \rightarrow \Xi^- J/\psi) \times f_{\Xi_b^-}$
  - $B(\Xi_b^- \rightarrow \Xi^- \psi(2S)) / B(\Xi_b^- \rightarrow \Xi^- J/\psi)$  has been measured by CMS

$$\frac{\mathcal{B}(\Xi_b^- \rightarrow \psi(2S)\Xi^-)}{\mathcal{B}(\Xi_b^- \rightarrow J/\psi\Xi^-)} = 0.84_{-0.19}^{+0.21} (\text{stat}) \pm 0.10 (\text{syst}) \pm 0.02 (\mathcal{B}) \quad [\text{PRD 110 (2024) 012002}]$$

- $\psi(2S)/J/\psi$  ratio expected to be very similar for  $\Lambda_b$  and  $\Xi_b$  from SU(3) symmetry
- To be updated soon by LHCb (preliminary result from J. Nicolini's thesis):

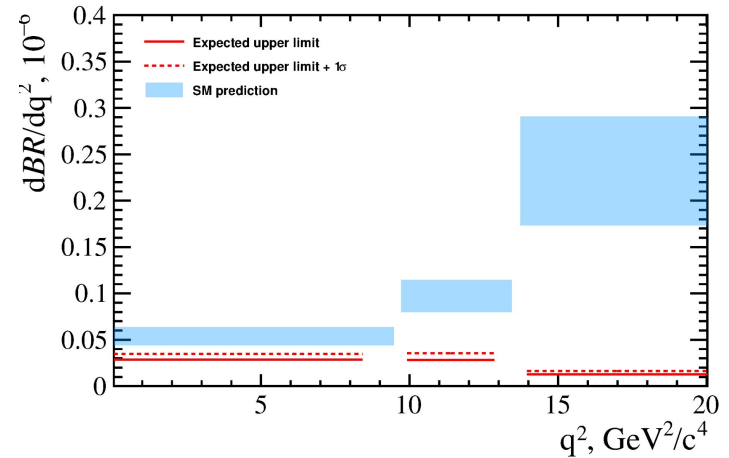
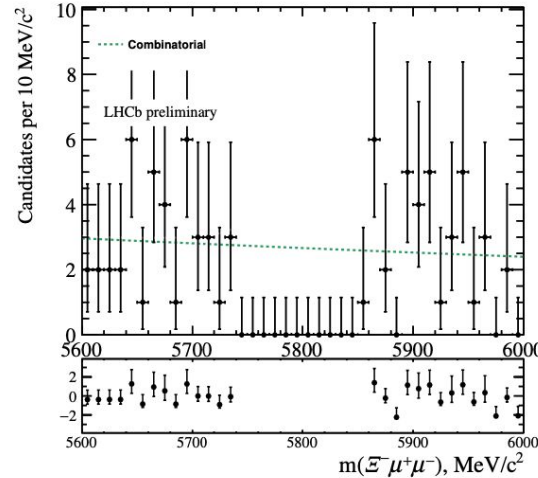
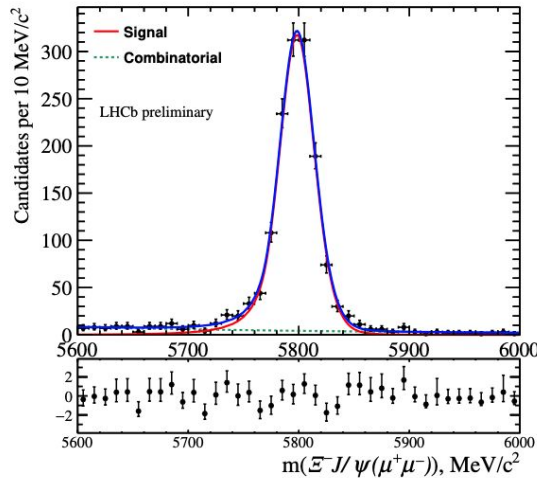
$$r_{BR}^\psi = 0.492 \pm 0.041 (\text{stat}) \pm 0.021 (\text{syst}) \quad [\text{CERN-THESIS-2024-178}]$$

- $\Omega_b^- \rightarrow \Omega^- \psi(2S)$  has not been observed yet
- Anything we should measure in the resonant modes?
- For  $\Lambda_b \rightarrow p K \mu \mu$ ,  $\Lambda_b \rightarrow p \pi \mu \mu$  both J/ψ and ψ(2S) measurements exist  
→ complicated to use due to pentaquark contributions in experimental data

# Run 1+Run 2 search for $\Xi_b \rightarrow \Xi \mu \mu$

- $\Xi$ 's are reconstructed in LLL, DDL and DDD track type categories
- Predictions so far from LCSR form factors or  $\Lambda_b \rightarrow \Lambda \mu \mu$  prediction+assume SU(3)
- Rare mode is blinded  $\rightarrow$  Observation expected in the high- $q^2$  bin

[CERN-THESIS-2024-178]



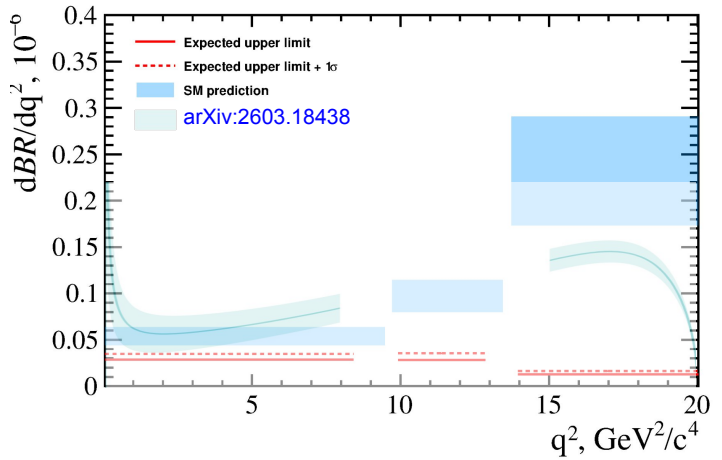
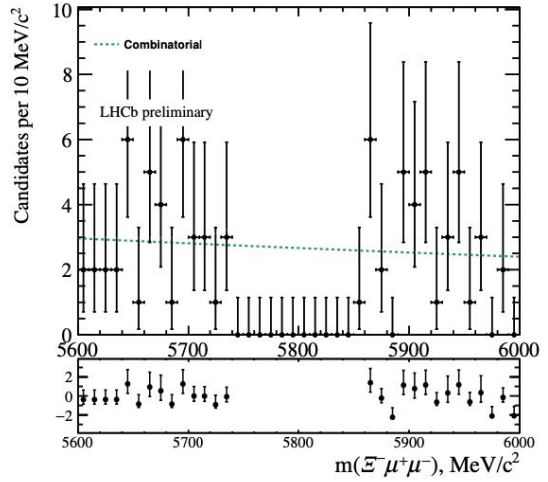
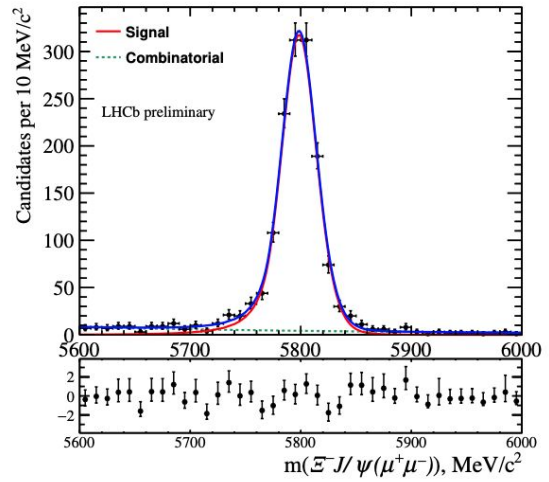
- Run1+2+3: expect  $N(\Xi_b \rightarrow \Xi \mu \mu) > 300$  events  
 $\rightarrow$  differential BF + ACP (+  $\Xi$  polarisation?)

$$\frac{1}{\Gamma} \frac{d\Gamma}{d \cos(\theta_p)} = \frac{1}{2} (1 + \alpha_{\Xi} P_{\Xi} \cos(\theta_p))$$

# Run 1+Run 2 search for $\Xi_b \rightarrow \Xi \mu \mu$

- $\Xi$ 's are reconstructed in LLL, DDL and DDD track type categories
- **New! Form Factor prediction from Lattice** [Farrell, Meinel [arXiv:2603.18438](https://arxiv.org/abs/2603.18438)]
- Rare mode is blinded  $\rightarrow$  Observation expected in the high- $q^2$  bin

[CERN-THESIS-2024-178]

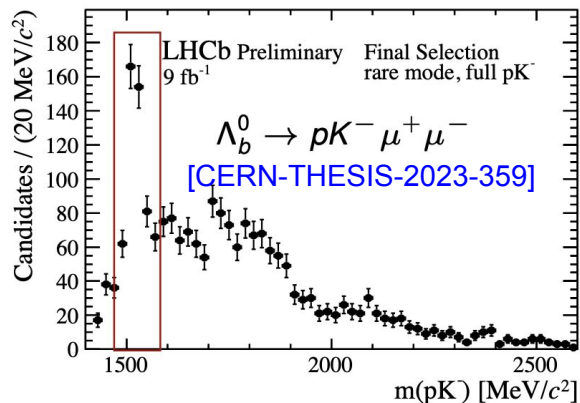
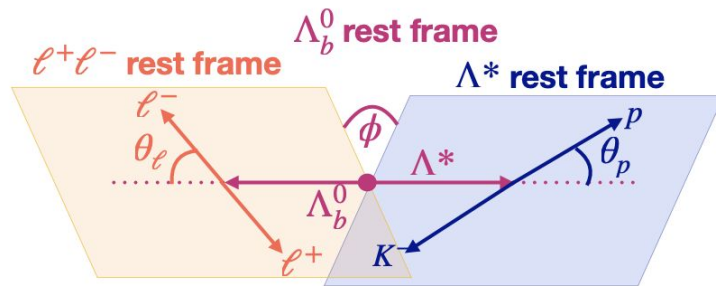


- Run1+2+3: expect  $N(\Xi_b \rightarrow \Xi \mu \mu) > 300$  events  $\rightarrow$  differential BF + ACP (+  $\Xi$  polarisation?)

$$\frac{1}{\Gamma} \frac{d\Gamma}{d \cos(\theta_p)} = \frac{1}{2} (1 + \alpha_{\Xi} P_{\Xi} \cos(\theta_p))$$

# Angular analysis of $\Lambda_b \rightarrow \Lambda$ and $\Lambda(1520)\mu\mu$

- Angular analysis of  $\Lambda_b \rightarrow \Lambda\ell\ell$ 
  - 34 angular observables [Kreps, Blake 1710.00746]
  - measured by LHCb at high  $q^2$  [JHEP 09 (2018) 146]
- Also for  $\Lambda_b \rightarrow pK\ell\ell$  [2409.12629]
- Ongoing analysis for  $\Lambda_b \rightarrow \Lambda(1520)$ :  
**Simplified angular pdf for  $\Lambda(1520)$  in HQ limit**  
[\[arXiv:1903.00448\]](#)  $\rightarrow$  measure AFB, S1cc in bins of  $q^2$

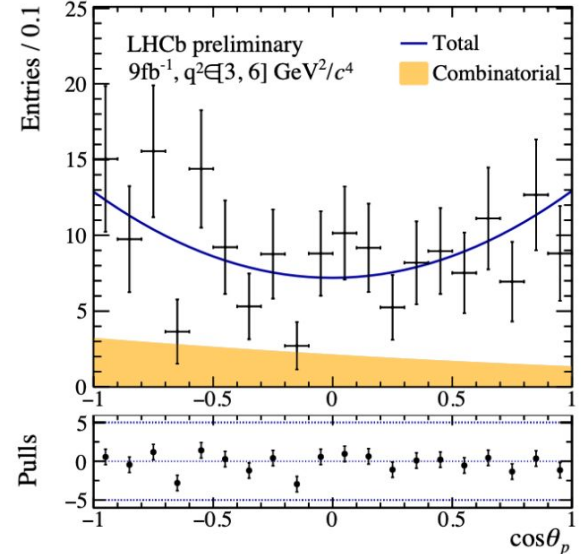
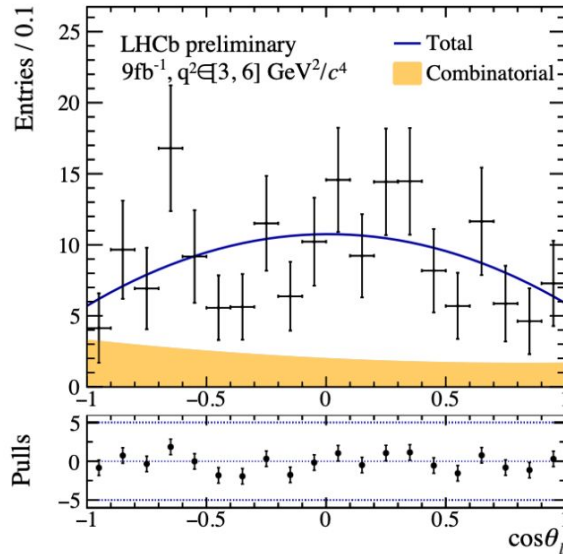
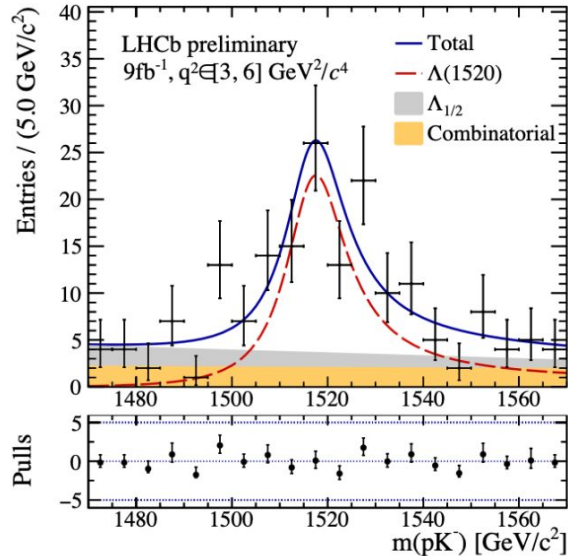


$$\begin{aligned}
 \text{PDF}_{\text{ang}}^{\text{Int},1/2} &= f_{3/2} \left( \left( 1 - \frac{1}{2} S_{1cc} \right) \left( 1 - \cos^2 \theta_\ell \right) + S_{1cc} \cos^2 \theta_\ell + \frac{4}{3} A_{FB,3/2}^\ell \cos \theta_\ell \right) \\
 &\quad \times \left( \frac{1}{4} + \frac{3}{4} \cos^2 \theta_p \right) \quad \text{summed } \Lambda^*(J=1/2) \text{ angular pdf} \\
 &\quad \times \left( \frac{3-i_2}{3} + i_1 \cos \theta_p + i_2 \cos^2 \theta_p \right) \quad \text{Interference} \\
 &\quad \text{[arXiv:1410.2115]}
 \end{aligned}$$

# Angular analysis of $\Lambda_b \rightarrow \Lambda(1520)\mu\mu$

- Angular acceptance modeled with method-of-moments [\[arXiv:1503.04100\]](https://arxiv.org/abs/1503.04100)
- Fits are robust, but coefficients still blinded

[CERN-THESIS-2023-359]



# b → dll

• **Further suppressed** than  $b \rightarrow s\ell^+\ell^-$  by  $|V_{td}|^2/|V_{ts}|^2 \approx 0.04$

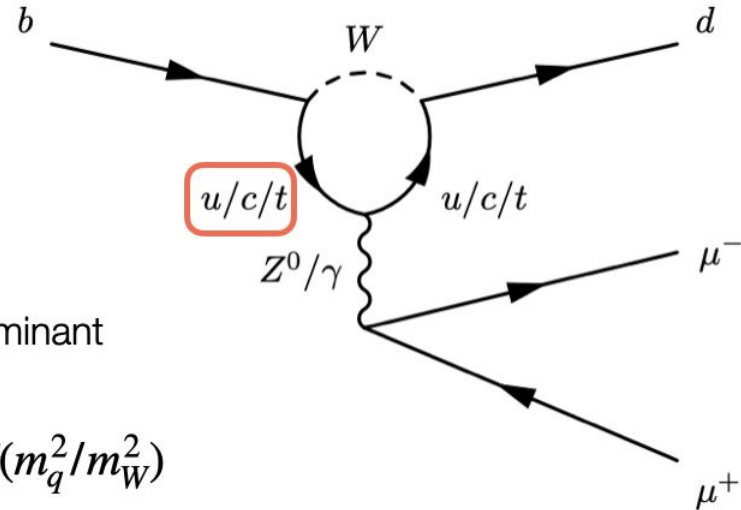
- Can be even more sensitive to NP
- Testing the coupling from third to first quark generations
- Compare to  $b \rightarrow s\ell^+\ell^-$  to measure  $|V_{td}|/|V_{ts}|$  and **test Minimal Flavour Violation models**

•  $u, c, t$  all run at the **same CKM order** ( $\lambda^3$ ) in the loop

- Different to  $b \rightarrow s\ell^+\ell^-$  where top-quark loop ( $\lambda^2$ ) is very dominant
- CP violation predicted to be large
- Impact on rate change is small → Inami-Lim functions  $F = F(m_q^2/m_W^2)$

$$A_{\text{CP}} = \frac{|A_f|^2 - |\bar{A}_f|^2}{|A_f|^2 + |\bar{A}_f|^2} \sim 2 \frac{|A_2|}{|A_1|} \sin(\Delta\phi)\sin(\Delta\delta)$$

$$\begin{aligned} A(b \rightarrow q\ell\ell) &= V_{tb}V_{tq}^*F_t + V_{cb}V_{cq}^*F_c + V_{ub}V_{uq}^*F_u \\ &= V_{ub}V_{td}^*(F_u - F_c) + V_{tb}V_{td}^*(F_t - F_c) \\ &\quad \sim 0.05 \qquad \qquad \qquad \sim 1 \end{aligned}$$



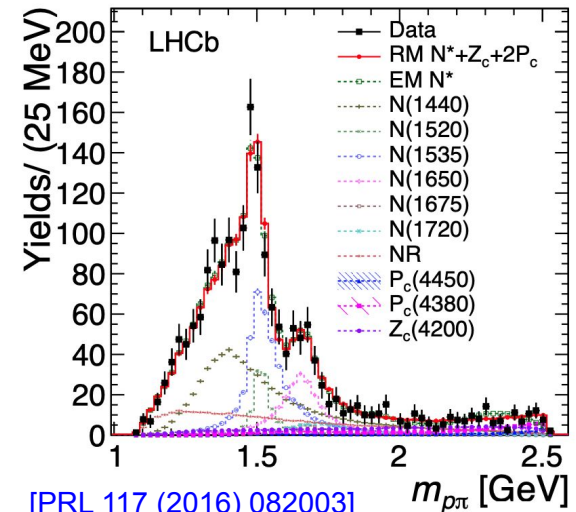
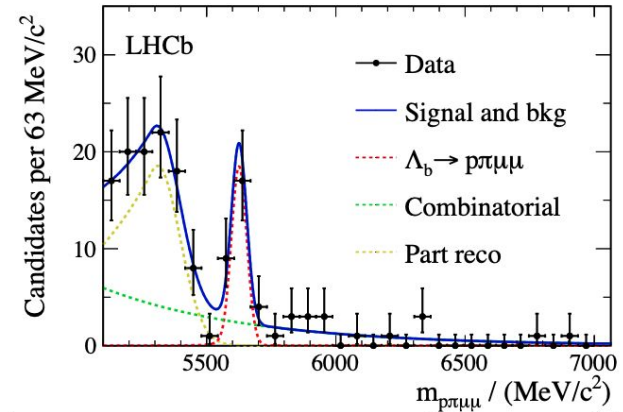
# $b \rightarrow dll: \Lambda_b \rightarrow p\pi\mu\mu$

- Decay has been observed by LHCb with Run 1 data [JHEP 04 (2017) 029]

$$\frac{\mathcal{B}(\Lambda_b^0 \rightarrow p\pi^- \mu^+ \mu^-)}{\mathcal{B}(\Lambda_b^0 \rightarrow J/\psi (\rightarrow \mu^+ \mu^-) p\pi^-)} = 0.044 \pm 0.012 \pm 0.007$$

- Update with Run1+Run2 ongoing
  - Estimated yield of  $\sim 100$  decays
  - Measure diff. BF in 3-4  $q_2$  bins
  - First measurement of ACP
- Can we do anything on the local form factors for this mode?
- e.g. for some  $N^*$  resonances?
  - States are not as narrow as for  $\Lambda(1520)$
  - $\Gamma(\Lambda(1520)) \sim 16\text{MeV}$ ,  $\Gamma(N(1520)) \sim 110\text{MeV}$
  - Overlapping states  $\rightarrow$  See amplitude analysis of  $\Lambda_b \rightarrow p\pi J/\psi$  [PRL 117 (2016) 082003]

[JHEP 04 (2017) 029]

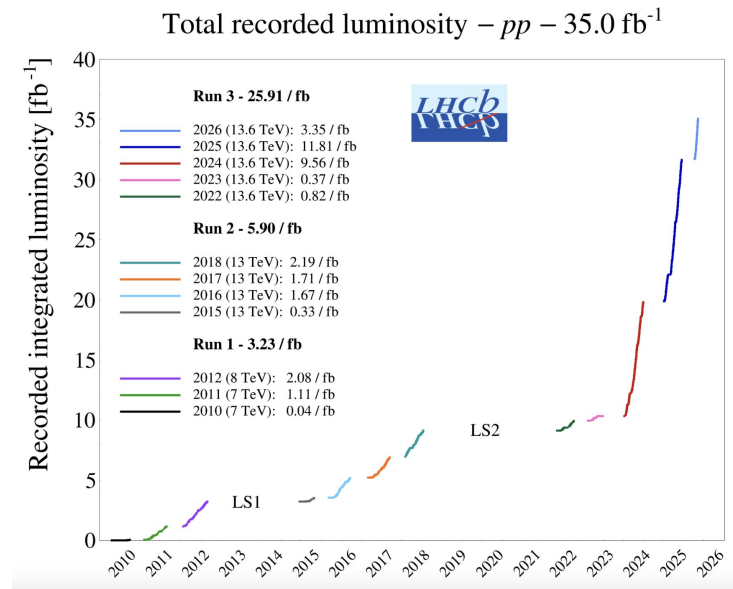


[PRL 117 (2016) 082003]

$m_{p\pi}$  [GeV]

# What can we do with Run 3 data?

- $\sim 25\text{fb}^{-1}$  already collected in Run 3, expect additional gains from hardware trigger removal + downstream tracking in HLT1  
[\[arXiv:2503.13092\]](#)
- New  $b \rightarrow s\ell\ell$  decays:
  - $\Omega_b \rightarrow \Omega\mu\mu$  (control mode studies have been done in [\[CERN-THESIS-2024-178\]](#), with Run1+2+3 expected sensitivity for an observation)
- Radiative decays: Repeat search for  $\Xi_b \rightarrow \Xi\gamma$ , ( $\Omega_b \rightarrow \Omega\gamma$ )
- Unexplored channels:
  - $\Xi_b \rightarrow \Lambda K\mu\mu$  (might even be easier than  $\Xi_b \rightarrow \Xi\mu\mu$ , less downstream tracks to reconstruct)
  - $\rightarrow \Xi_b \rightarrow \Xi(1820)\mu\mu$ ?  $\Xi(1820)$  is relatively narrow (24MeV) so Lattice FF calculation could be possible?
  - $\Xi_b \rightarrow pK\mu\mu$ ? (some initial work in [\[CERN-THESIS-2019-202\]](#))
  - $\Omega_b \rightarrow \Xi\mu\mu$  ( $b \rightarrow d\ell\ell$ , suggest by [\[arXiv:2209.04457\]](#))
  - Electron modes
- Other ideas are welcome!



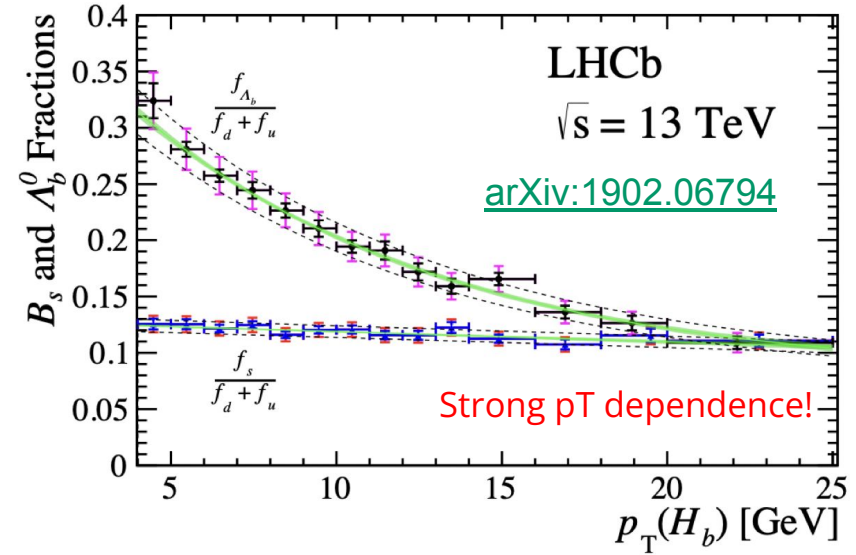
# Discussion & open question

1. How far do we want to go with the baryon decays?
  - a. Complicated measurements, complicated predictions
  - b. Is it just an exercise or do we expect to find anything new here?
2. Theory predictions for heavier baryon?
  - a. Is there any limit to LQCD predictions, apart from finite width effects?
  - b. Sum rules suffer from the lack of DA inputs, is this something we can improve?
  - c. Analytic parameterisations are limited by increasingly complicated analytic structure.

**Backup**

# Baryon production fractions

- $f_{\Lambda_b^0}/f_{\Lambda_b}$  [arXiv:1901.07075](https://arxiv.org/abs/1901.07075)
- $f_c/(f_u+f_d)$  [arXiv:1910.13404](https://arxiv.org/abs/1910.13404)
- $f_s/(f_u+f_d)$  &  $f_{\Lambda_b^0}/(f_u+f_d)$  [arXiv:1902.06794](https://arxiv.org/abs/1902.06794)



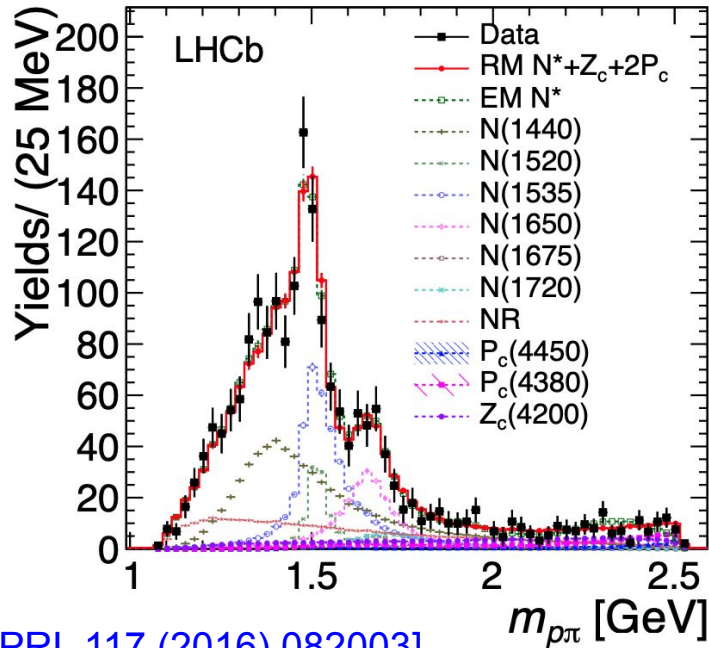
$$f_u + f_d + f_s + f_c + f_{\Lambda_b^0} + f_{\Xi_b^0} + f_{\Xi_b^-} + f_{\Omega_b^-} = 1$$

Fraction	$f_u$	$f_d$	$f_s$	$f_c$	$f_{\Lambda_b^0}$	$f_{\Xi_b^-}$	$f_{\Xi_b^0}$	$f_{\Omega_b^-}$
Value	0.35	0.35	0.085	0.002	0.18	0.015	0.020*	0.005*

\* values based on assumptions, not measurements

# $N^*$ states in the $p\pi$ system

[A. Alfonso's PhD thesis]



[PRL 117 (2016) 082003]

