Study of Rare Decays at LHCb

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On behalf of LHCb collaboration

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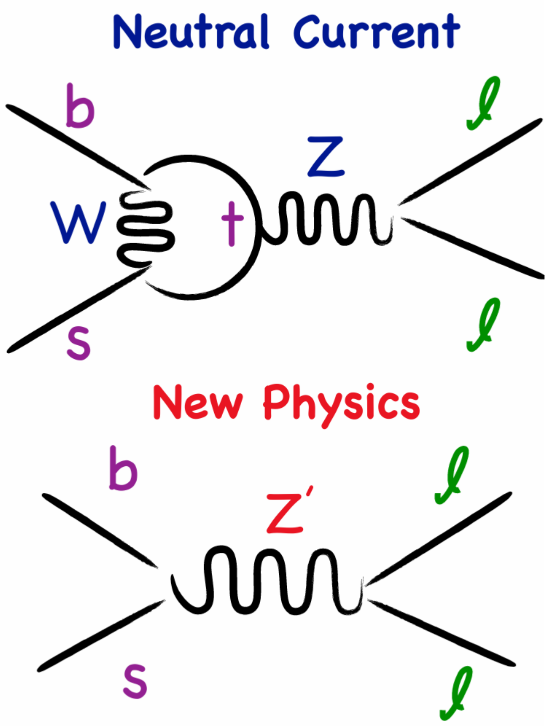
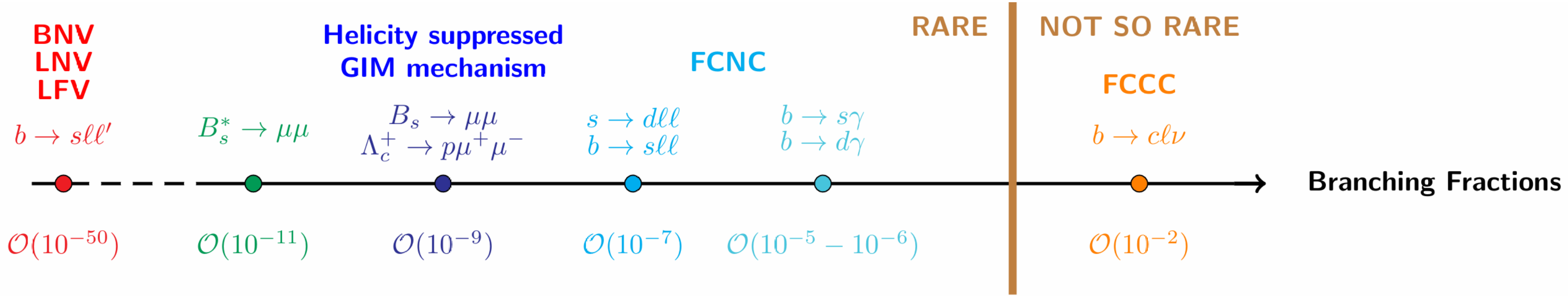
1 (Semi)Leptonic Flavour-changing Neutral Current B decays

Study of $b \to s\ell\ell$ transitions at LHCb

- New Physics (NP) beyond SM ⇒ indirect searches: test SM predictions to look for deviations from new virtual particles
- SM contribution is suppressed in rare decays ⇒ sensitive to explore NP
- How would NP manifest?
  - Modification of the **Branching Fraction**
  - Modification of the **Angular Distributions**
  - Violation of **Lepton Flavour Universality**
  - New sources of **CP Violation**
  - Modification of **Photon Polarization**





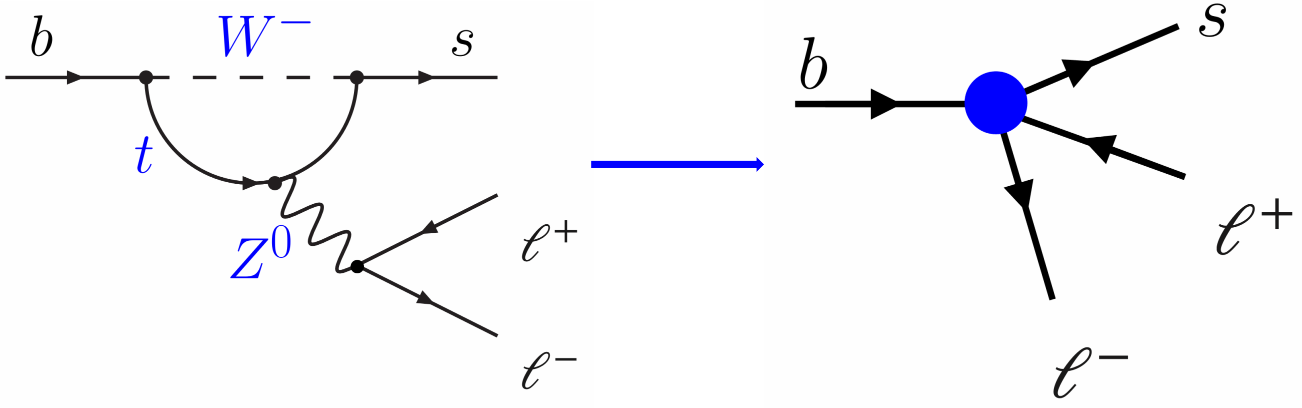
$b \to s\ell\ell$ decays in theory

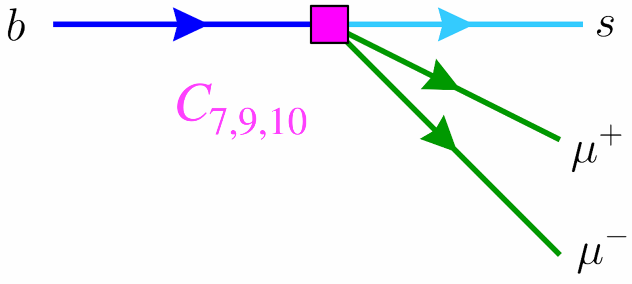
- Electroweak penguin (EWP) decays in effective theory interpretation
- ✓ Wilson coefficients are complex values (CPV)
- ✓ SM is LFU but could be violated in NP:

$$C^e \neq C^\mu \neq C^\tau$$

$O_7^{(\prime)} = \frac{m_b}{e}(\bar{s}\sigma_{\mu\nu}P_{\mathrm{R(L)}}b)F^{\mu\nu}$	**dipole ($b \to s\gamma$)**
$O_9^{(\prime)} = (\bar{s}\gamma_\mu P_{\mathrm{L(R)}}b)(\bar{\ell}\gamma^\mu\ell)$	**vector**
$O_{10}^{(\prime)} = (\bar{s}\gamma_\mu P_{\mathrm{L(R)}}b)(\bar{\ell}\gamma^\mu\gamma_5\ell)$	**axial-vector**
$O_S^{(\prime)} = (\bar{s}\gamma_\mu P_{\mathrm{R(L)}}b)(\bar{\ell}\ell)$	**scalar**
$O_P^{(\prime)} = (\bar{s}\gamma_\mu P_{\mathrm{R(L)}}b)(\bar{\ell}\gamma_5\ell)$	**pseudo-scalar**

	$C_7^{(\prime)}$	$C_9^{(\prime)}$	$C_{10}^{(\prime)}$	$C_{S,P}^{(\prime)}$
Radiative $b \to s\gamma$	✓			
Leptonic $B_s \to \ell^+\ell^-$			✓	✓
Semileptonic $b \to s\ell^+\ell^-$	✓	✓	✓	✓

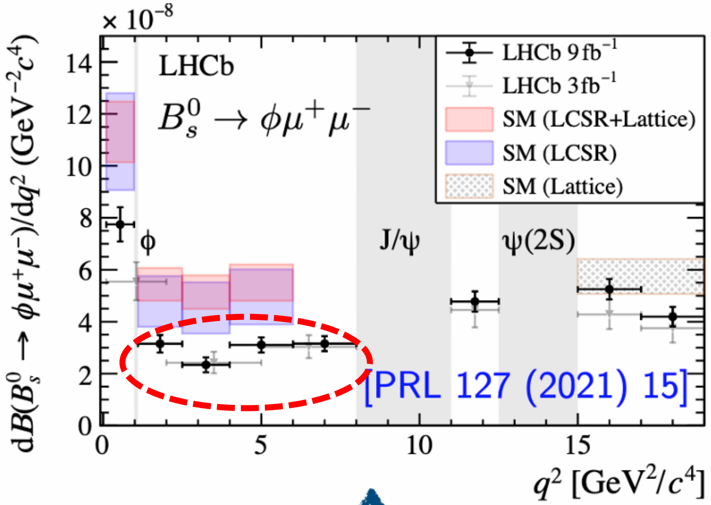




$$H_{eff} \propto \sum_i \mathcal{O}_i C_i$$

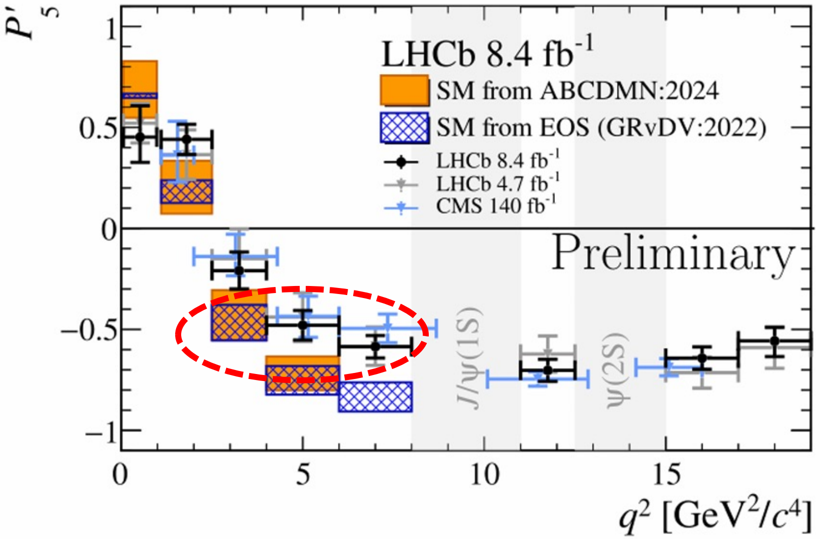
Local-operator

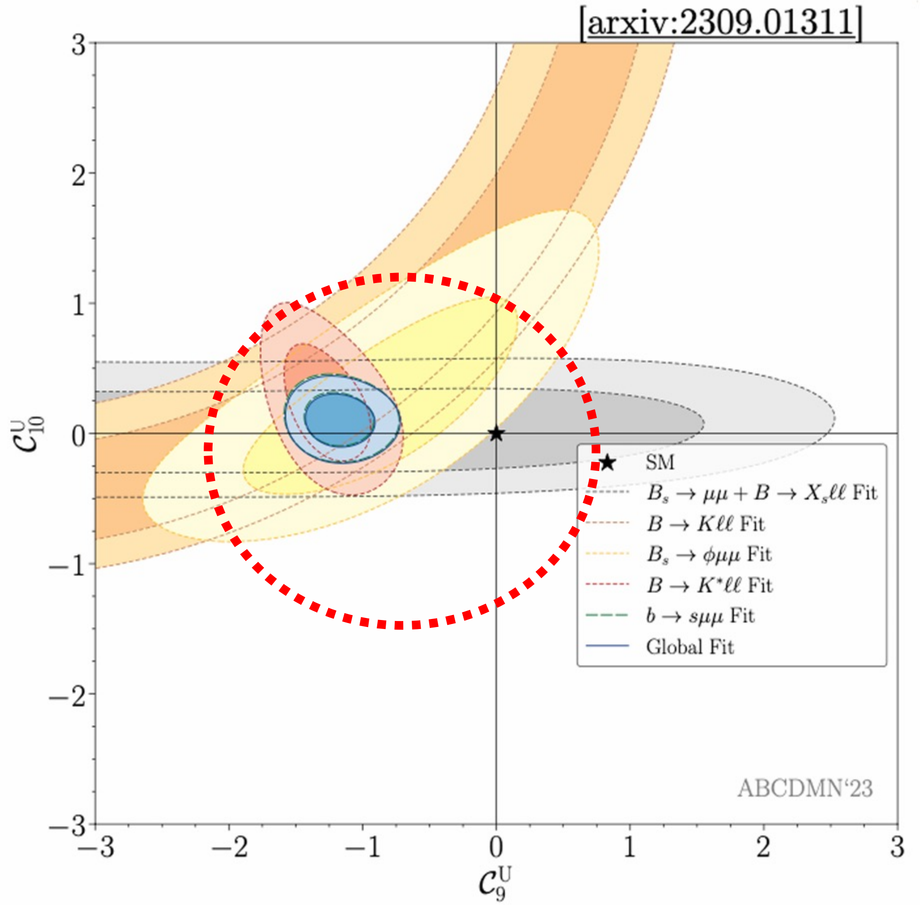
$b \to s\ell\ell$ anomalies



Branching ratios

Angular observables

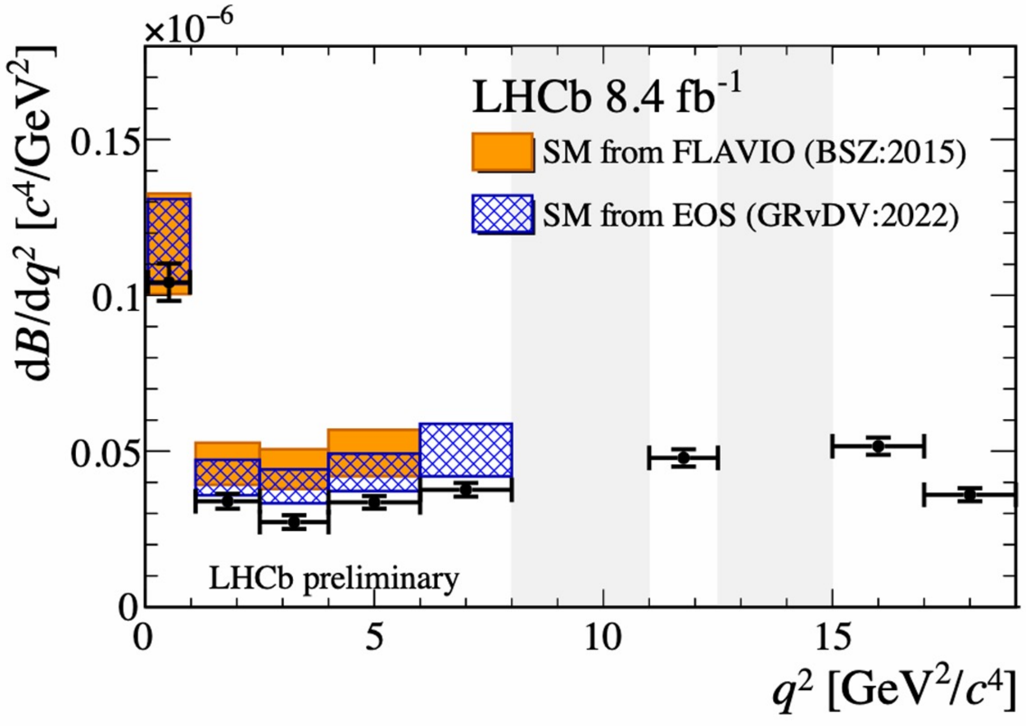


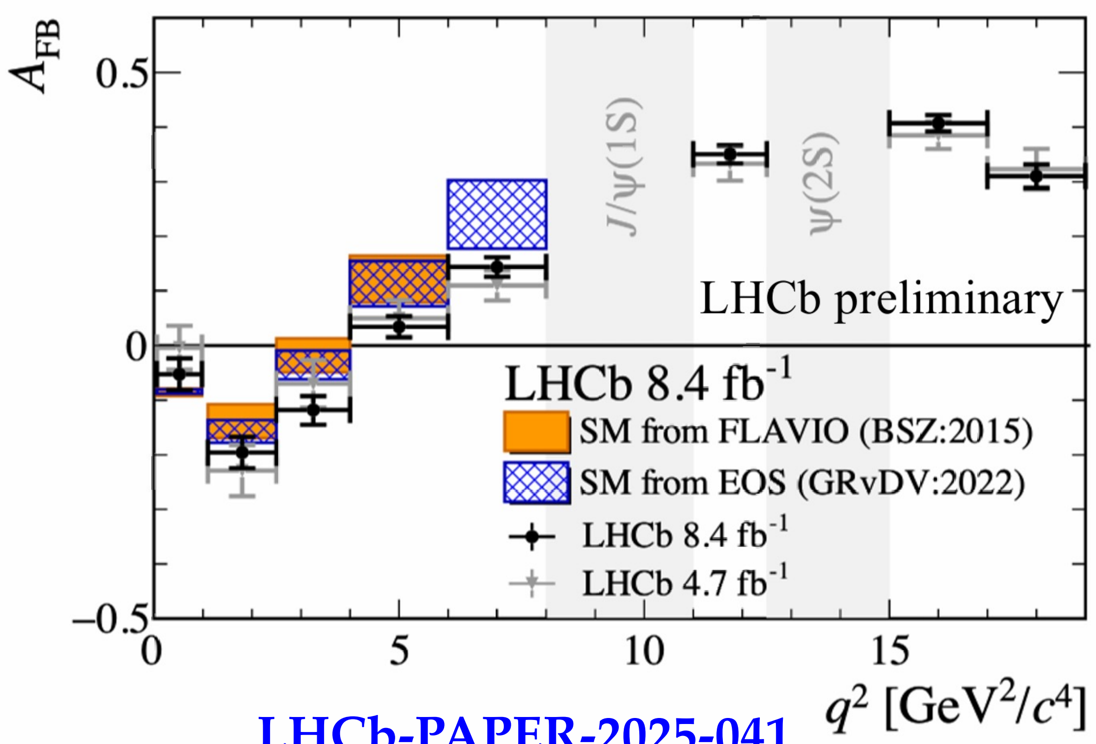


Global fits to all these observables point to a non-SM vector coupling (C_9)

Latest news for $B^0 \to K^{*0}\mu^+\mu^-$

✓ A comprehensive analysis is re-performed to the LHCb Run1 +Run2 $B^0 \to K^{*0}\mu^+\mu^-$ **dataset**





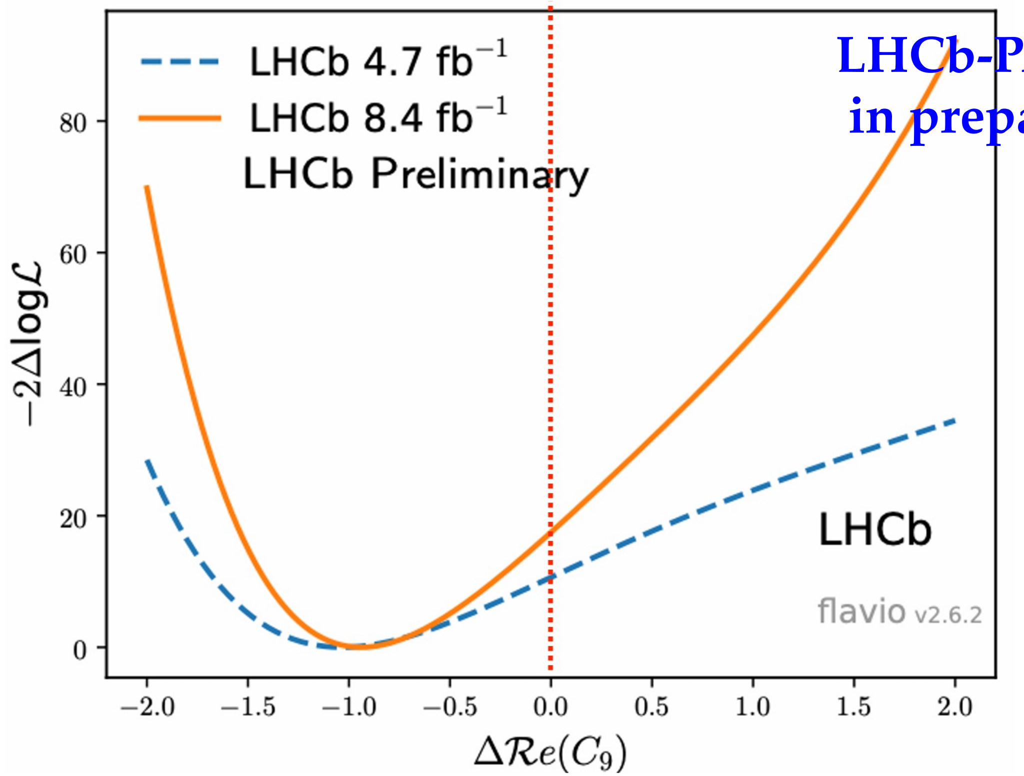
LHCb-PAPER-2025-041, in preparation

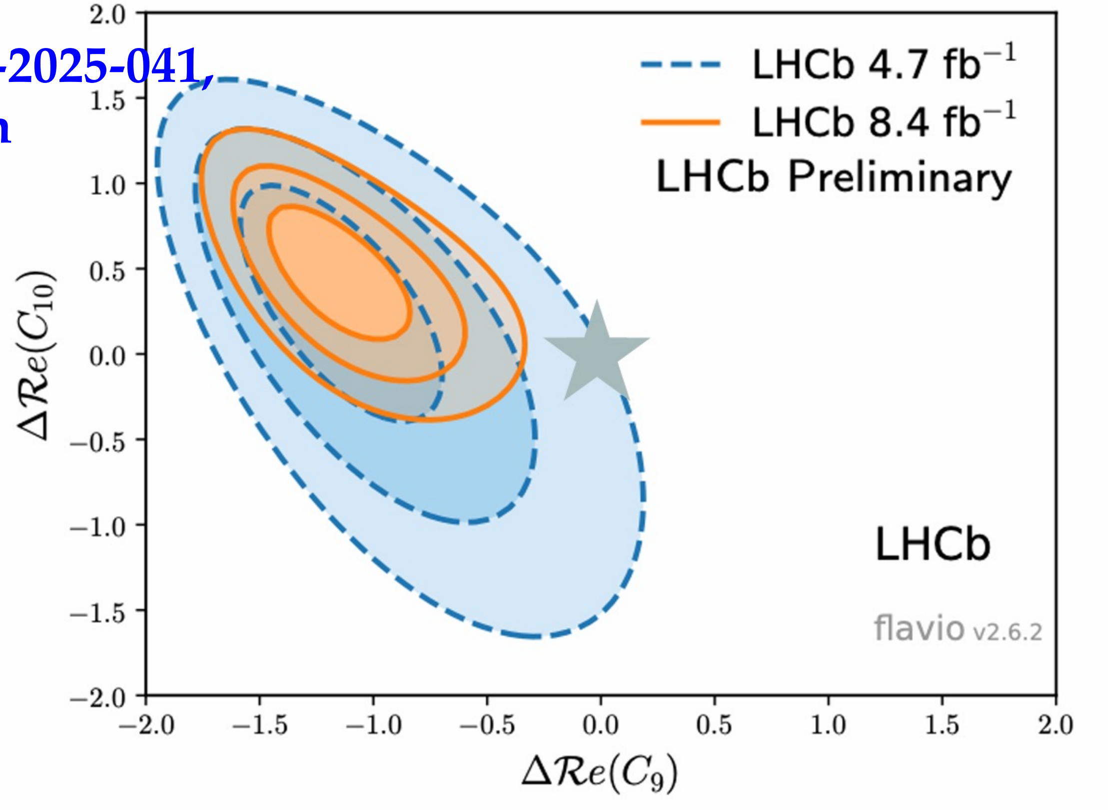
✓ The anomaly remains with the increasing sensitivity.

✓ Tensions of 2.5 (2.2) σ and 1.9 (1.7) σ in 2.5-4 and 4-6 GeV^2

Latest news for $B^0 \to K^{*0}\mu^+\mu^-$

LHCb-PAPER-2025-041, in preparation





As expected, deviation most pronounced in C_9

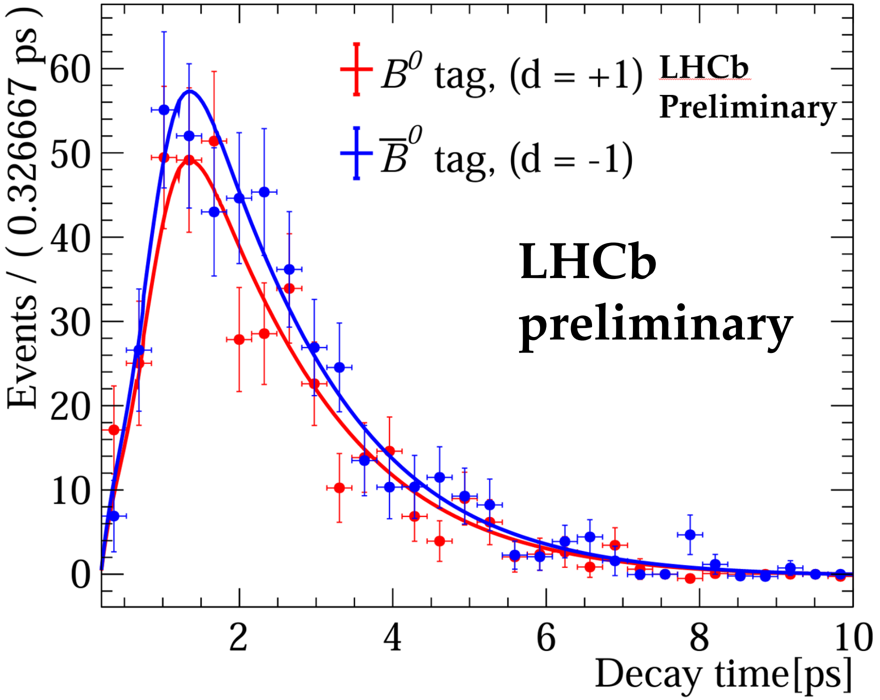
$$\Delta\mathrm{Re}(C_9) = -0.93^{+0.18}_{-0.16}$$

Significance: 4.1σ

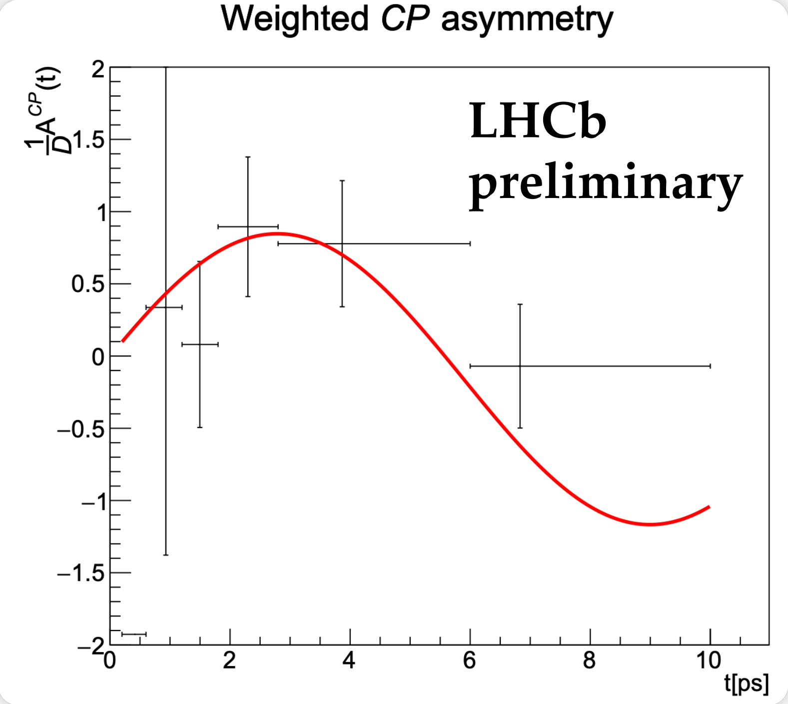
Time-dependent CP violation: a new avenue

河南师大、华中师大

✓ Searching for NP using time dependent CP violation in $\boldsymbol{b \to s l^+ l^-}$ **decays**



LHCb-PAPER-2024-008，Coming soon!



Background-subtracted decay time distribution
n of $B^0 \to K_S^0 \mu^+ \mu^-$ candidates

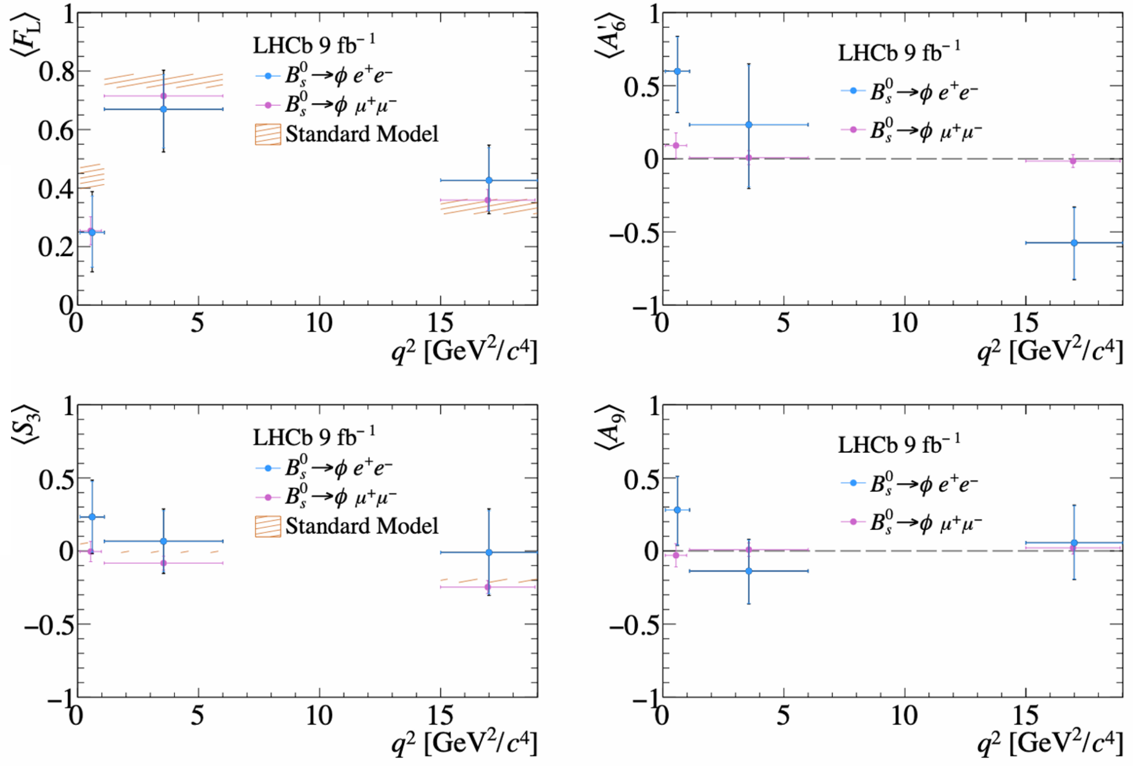
$$\mathcal{A}^{CP}(t) = \frac{\Gamma(\bar{B}^0(t) \to K_S^0\mu^+\mu^-) - \Gamma(B^0(t) \to K_S^0\mu^+\mu^-)}{\Gamma(\bar{B}^0(t) \to K_S^0\mu^+\mu^-) + \Gamma(B^0(t) \to K_S^0\mu^+\mu^-)}$$

Angular analysis of $B_s^0 \to \phi e^+ e^-$ decay

- Angular analysis of similar decay mode in the low, central and high q^2 regions, to extract angular coefficients.
- Results compatible with SM predictions and previous measurements on $B_s^0 \to \phi\mu^+\mu^-$ [JHEP 11 (2021) 43]

Observable	$0.1 < q^2 < 1.1\,\mathrm{GeV}^2/c^4$	$1.1 < q^2 < 6.0\,\mathrm{GeV}^2/c^4$	$15.0 < q^2 < 19.0\,\mathrm{GeV}^2/c^4$
$\langle F_L \rangle$	$0.25\,^{+0.12}_{-0.12} \pm 0.06$	$0.67\,^{+0.12}_{-0.13} \pm 0.06$	$0.43\,^{+0.11}_{-0.10} \pm 0.05$
$\langle A_6' \rangle$	$0.60\,^{+0.23}_{-0.28} \pm 0.05$	$0.24\,^{+0.40}_{-0.42} \pm 0.09$	$-0.57\,^{+0.24}_{-0.25} \pm 0.05$
$\langle S_3 \rangle$	$0.23\,^{+0.24}_{-0.24} \pm 0.07$	$0.07\,^{+0.21}_{-0.21} \pm 0.07$	$-0.01\,^{+0.29}_{-0.28} \pm 0.08$
$\langle A_9 \rangle$	$0.28\,^{+0.23}_{-0.24} \pm 0.04$	$-0.14\,^{+0.23}_{-0.24} \pm 0.04$	$0.06\,^{+0.25}_{-0.25} \pm 0.05$

Statistic limited, require more data for further improvement!



[JHEP03(2025)047]

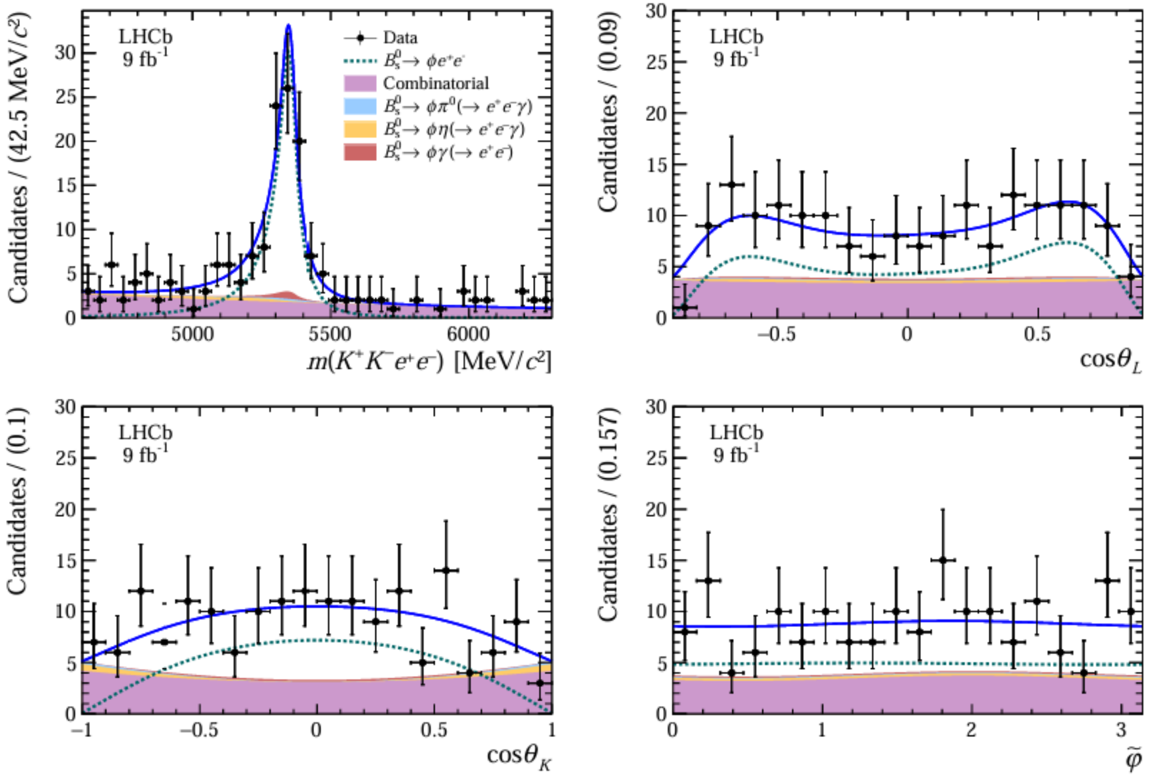
Photon polarisation constraints from $B_s^0 \to \phi e^+ e^-$

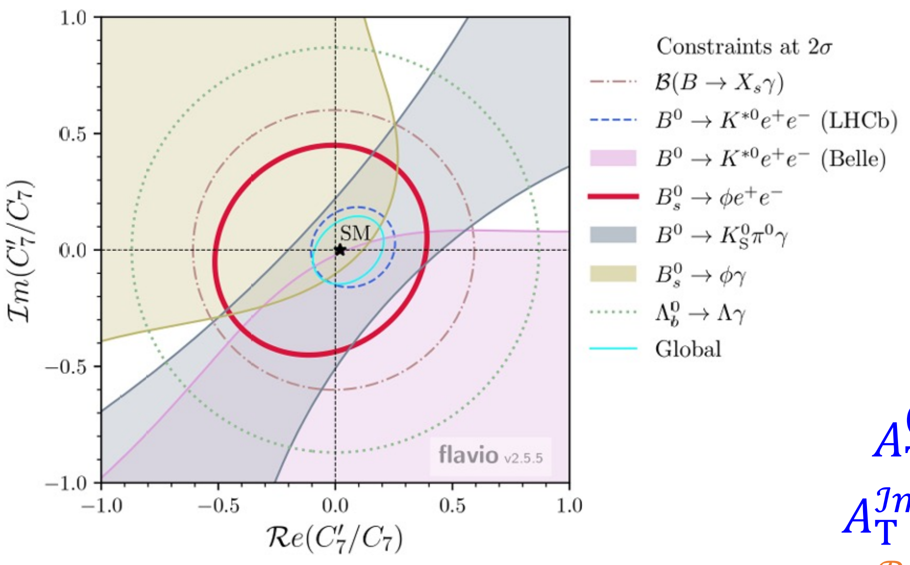
- Perform angular analysis at very low q^2 region , angular observables are sensitive to C_7 and C_7'

*First observation of $B_s^0 \to \phi e^+ e^-$ decay

- Consistent with the SM predictions

$q^2 \in [0.0009, 0.2615]\ \mathrm{GeV}^2/c^4$





[JHEP03(2025)047]

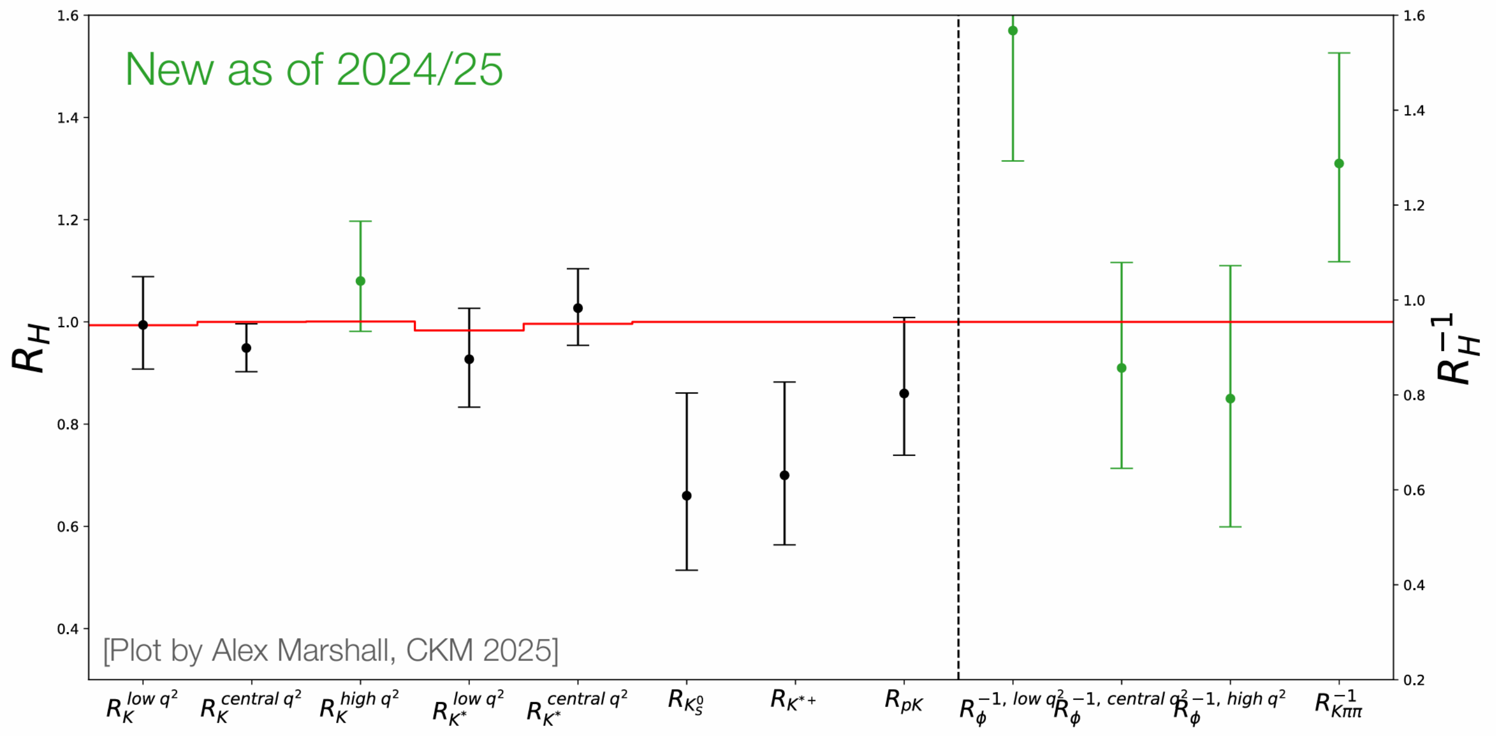
$$A_{\mathrm{T}}^{(2)} = -0.045 \pm 0.235 \pm 0.014,$$
$$A_{\mathrm{T}}^{\mathcal{I}mCP} = 0.002 \pm 0.247 \pm 0.016,$$
$$A_{\mathrm{T}}^{\mathcal{R}eCP} = 0.116 \pm 0.155 \pm 0.006,$$
$$F_{\mathrm{L}} = (0.4 \pm 5.6 \pm 1.2)\%,$$

Sensitive to photon polarisation

Fwd-bkd asymmetry

Longitudinal polarisation

Measurements of Lepton Flavour Universality $b \to s l^+ l^-$ decays

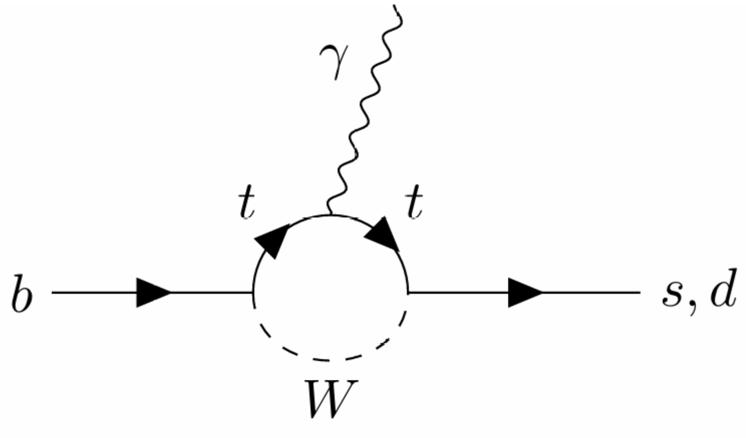


[Talk on CKM2025]

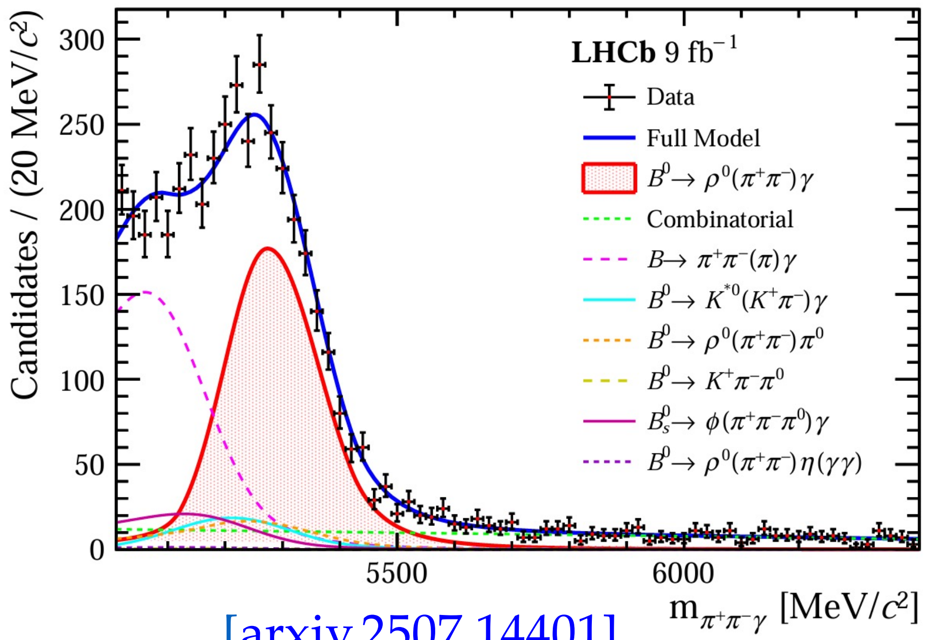
- ✓ Most of the LFU ratios are consistent with the SM prediction
- ✓ The anomalies in angular distribution &BF disappeared:
  - ▶️ Use CP violation as complementary probe
  - ▶️ Probe the flavour structure of NP using $b \to d$ transition or $\tau\tau$ final states

Probing NP in $b \to d\gamma$

- ✓ $b \to d\gamma$ decay is further suppressed by $|V_{td}/V_{ts}|$, probe the NP in photon polarization.
- ✓ Recent combination in this decay gives: $B(B^0 \to \rho^0\gamma) = (8.2 \pm 1.3)\times 10^{-7}$
- ✓ The analysis uses 9 fb^{-1} of full Run1 + Run2 data set, and observed ~ 2k signal yields



$m(\pi^+\pi^-) \in (630,920)\mathrm{MeV/c^2}$



[arxiv.2507.14401]

$$Br(B^0 \to \rho^0\gamma) = (7.9 \pm 0.3 \pm 0.2 \pm 0.2)\times 10^{-7}$$

- ✓ Consistent with the current world average and the most precise to date
- ✓ Measurement of time-dependent CP violation to probe NP using $B^0 \to \rho^0\,\gamma$ polarization ongoing

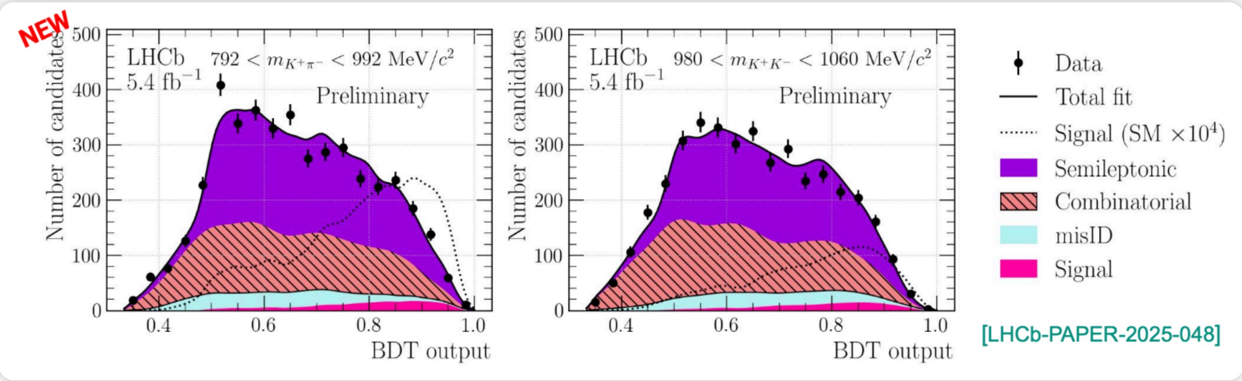
Searching for b → $s\tau\tau$ decays

- New LHCb search for $B^0 \to K^+\pi^-\tau^+\tau^-$ and $B_s^0 \to K^+K^-\tau^+\tau^-$

  -using muonic taus

- BSM effects could be constrained by the BF:

No signal is observed!



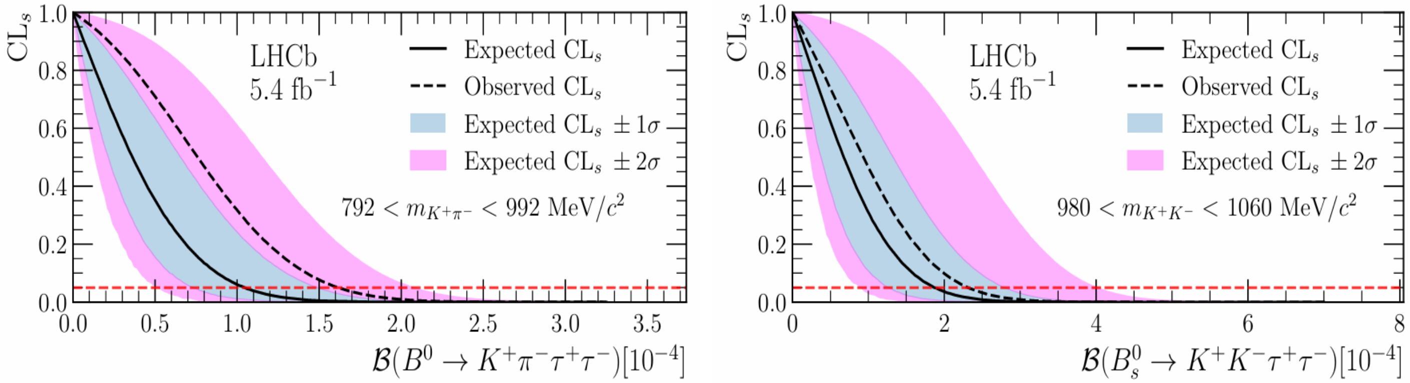
$$C_9^{\tau\tau} = C_9^{SM} - \Delta$$

If $\Delta \gg C_{9,10}^{SM}$,

$$C_{10}^{\tau\tau} = C_{10}^{SM} - \Delta$$

$$B(B^0 \to K^{*0}\tau\tau) = (10.1 \pm 0.8)\times 10^{-9}\,)\times\Delta^2$$

$$B(B_s^0 \to \phi\tau\tau) = (9.1 \pm 0.5)\times 10^{-9}\,)\times\Delta^2$$



Could perfectly explain the $R(D^*)$ anomalies

[See backup slides]

[arxiv.2510.13716]

$$\mathcal{B}(B^0 \to K^{*0}\tau^+\tau^-) < 2.8\times 10^{-4}\ (2.5\times 10^{-4})\ \text{at 95\% (90\%) CL},$$
$$\mathcal{B}(B_s^0 \to \phi\tau^+\tau^-) < 4.7\times 10^{-4}\ (4.1\times 10^{-4})\ \text{at 95\% (90\%) CL}.$$

World's best precision!

2

Hadronic FCNC decays

CP asymmetries in $B^+ \to K_S^0 h^+$ decays

华中师大

- ✓ The CP asymmetries of $B^+ \to K_S^0 h^+$ decays are measured using full Run2 data, which yields

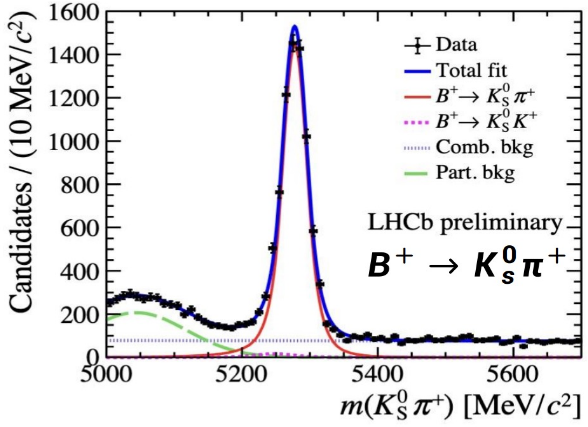
$$\mathcal{A}^{CP}(B^+ \to K_S^0 \pi^+) = -0.028 \pm 0.009(\text{stat}) \pm 0.009(\text{syst})$$

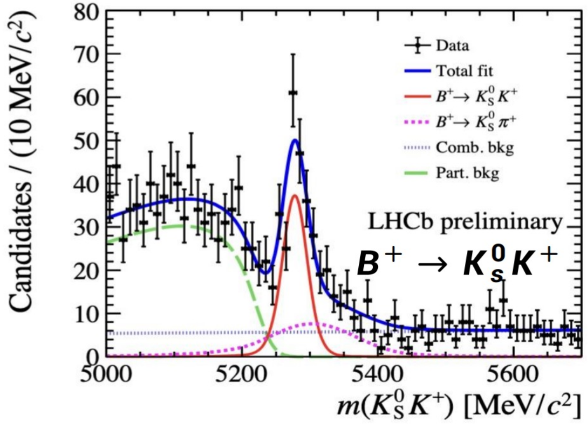
$$\mathcal{A}^{CP}(B^+ \to K_S^0 K^+) = 0.118 \pm 0.062(\text{stat}) \pm 0.031(\text{syst})$$

$$\mathcal{R} = \frac{\mathcal{B}(B^+ \to K_S^0 K^+)}{\mathcal{B}(B^+ \to K_S^0 \pi^+)} = 0.055 \pm 0.004(\text{stat}) \pm 0.002(\text{syst})$$

World' best precise measurement

[JHEP 01 (2018) 074]





- ✓ Could be used to probe NP in $b \to s$ decays as well as testing the isospin symmetry relation

$$A_{CP}(K^+\pi^-) + A_{CP}(K^0\pi^+)\frac{B(K^0\pi^+)}{B(K^+\pi^-)}\frac{\tau_0}{\tau_+}$$
$$= A_{CP}(K^+\pi^0)\frac{2B(K^+\pi^0)}{B(K^+\pi^-)}\frac{\tau_0}{\tau_+} + A_{CP}(K^0\pi^0)\frac{2B(K^0\pi^0)}{B(K^+\pi^-)}$$

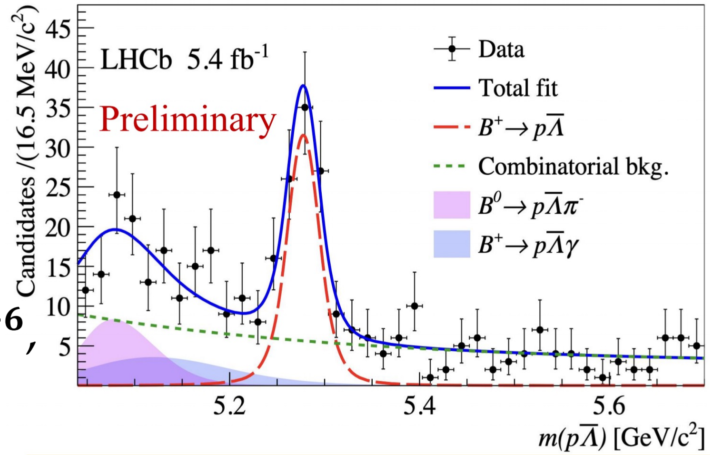
Mode	BR[10^{-6}]	A_{CP}
$B^+ \to K^+\pi^0$	12.94 ± 0.52	0.040 ± 0.021
$B_d^0 \to K^+\pi^-$	19.57 ± 0.53	-0.082 ± 0.006

First observation of baryonic decay $B^+ \to p\Lambda$ 华中师大、湖南大学

- The decay $\boldsymbol{B^+ \to p\Lambda}$ is first time observed using LHCb Run2 data
- Branching fraction： $\mathcal{B}(\boldsymbol{B^+ \to p\bar{\Lambda}^0}) = (1.24 \pm 0.17(stat) \pm 0.05(syst) \pm 0.03(norm))\times 10^{-7}$

  –Consistent with theoretical prediction
- Lower than the corresponding 3-body decay: $\mathcal{B}(\boldsymbol{B^+ \to p\bar{\Lambda}^0\pi^0}) = (\boldsymbol{3.0^{+0.7}_{-0.6}})\times\boldsymbol{10^{-6}}$, $\mathcal{B}(\boldsymbol{B^0 \to p\bar{\Lambda}^0\pi^-}) = (\boldsymbol{3.16 \pm 0.24})\times\boldsymbol{10^{-6}}$ (Threshold Enhancement?)

First observation!



Total Yields: $N(B^+ \to p\bar{\Lambda}) = 88 \pm 12$

- The decay parameter of the $\boldsymbol{B^+ \to p\bar{\Lambda}^0}$ process is also measured:

$$\frac{d\Gamma}{d\cos\theta_p} \propto 1 - \alpha_\Lambda\, \alpha_B \cos\theta_p,\ \text{here}\ \alpha_\Lambda^{avg} = 0.755 \pm 0.003$$

$$\alpha_B = 0.87^{+0.26}_{-0.29}(stat.) \pm 0.09(syst.)$$

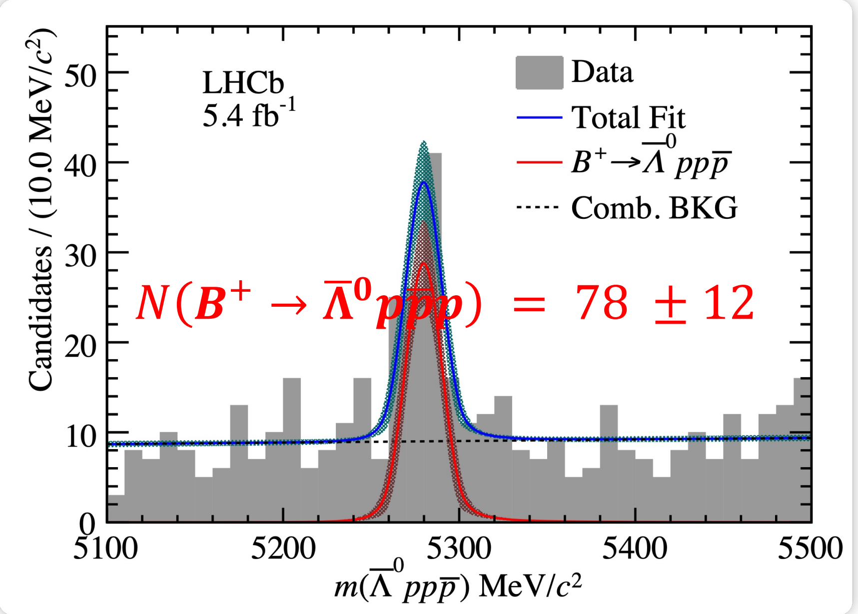
✓ indicating the presence of comparable S-wave and P-wave decay amplitudes.

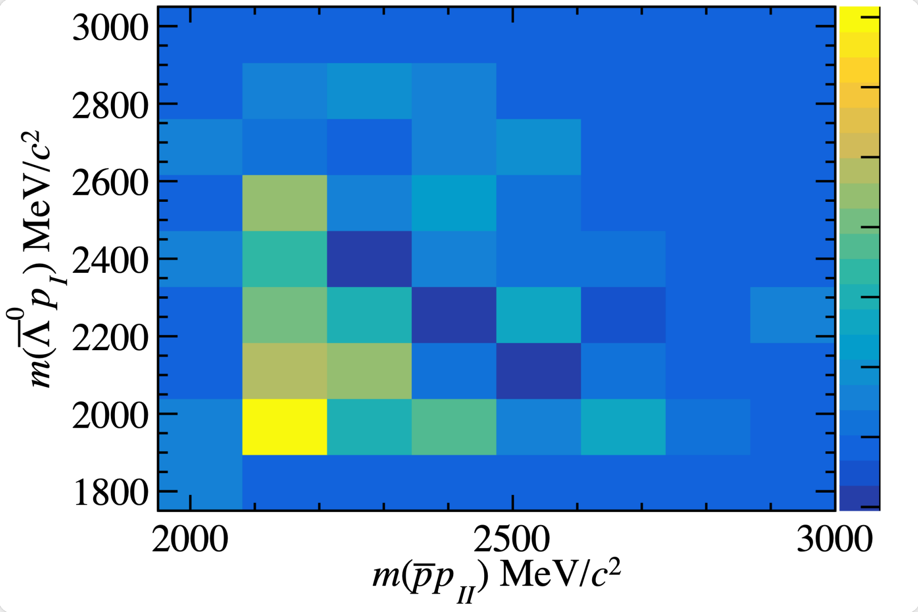
First observation of $B^+ \to \bar{\Lambda}^0 p\bar{p}p$ decay 武汉大学

- Observation of B^+ purely four body-baryonic decay:

$$\mathcal{B}(\boldsymbol{B^+ \to \bar{\Lambda}^0 p\bar{p}p}) = (1.80 \pm 0.30_{stat} \pm 0.05_{syst} \pm 0.25_{ext})\times 10^{-7}$$

- 2σ lower than theoretical prediction
- A double threshold enhancement is observed.
- The CP asymmetry is determined to be $A_{CP} = (5.4 \pm 15.6 \pm 2.4)\%$





[arxiv.2508.16259](https://arxiv.org/abs/2508.16259)

3 Very Rare Decays

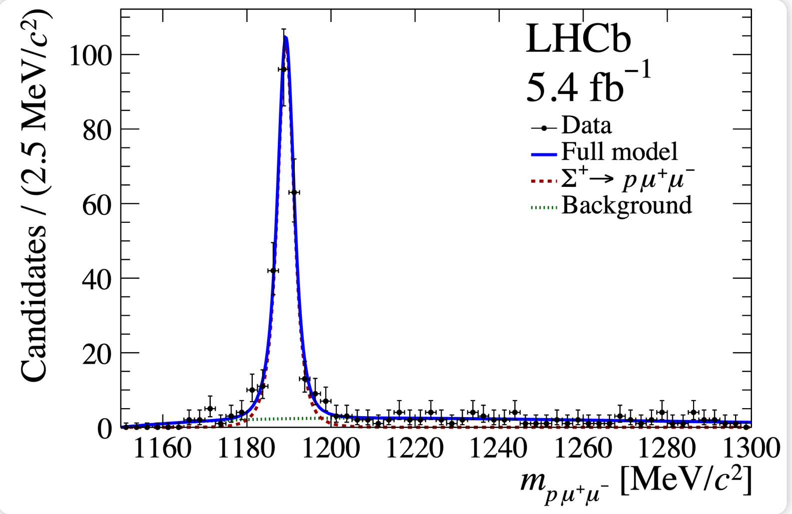
Observation of $\Sigma^+ \to p\mu^+\mu^-$ decays

✓ Observe $\boldsymbol{\Sigma^+ \to p\mu^+\mu^-}$ decay using LHCb Run 2 data

$$\boxed{\mathcal{B}(\Sigma^+ \to p\mu^+\mu^-) = (1.08 \pm 0.17) \times 10^{-8},}$$

Rarest baryon decay ever observed!

$N(\boldsymbol{\Sigma^+ \to p\mu^+\mu^-}) = 78 \pm 12$

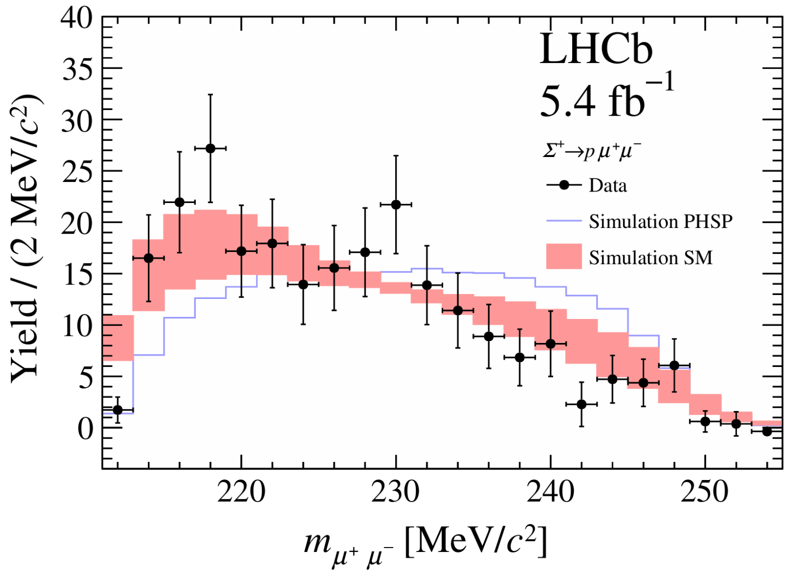


[arxiv.2504.06096]

✓ Study resonances in the dimuon invariant mass distribution to probe P^0 particle predicted by HyperCP.[PRD(43)2005 073]

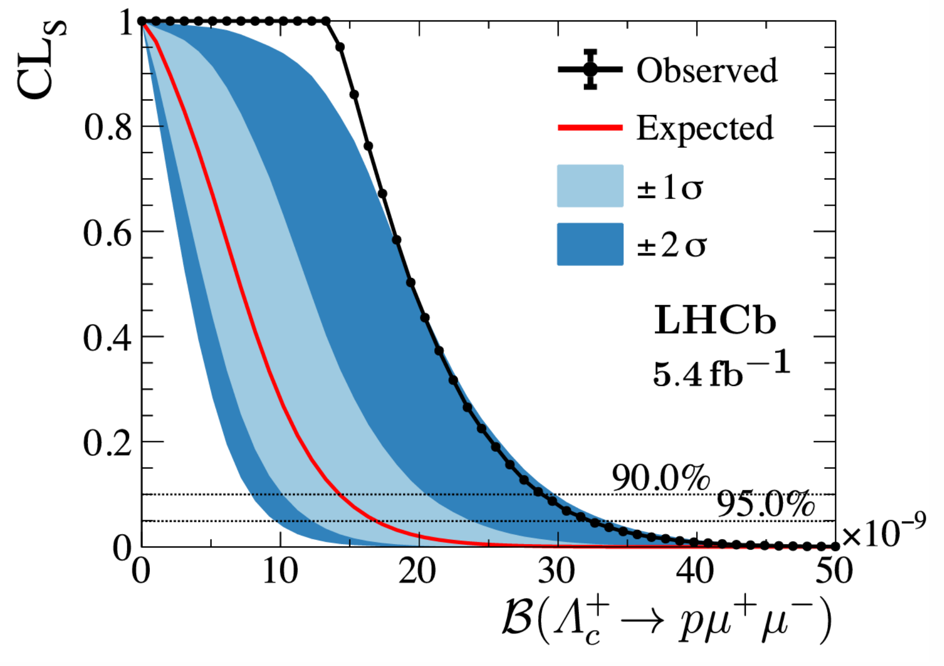
✓ Distribution compatible with SM prediction

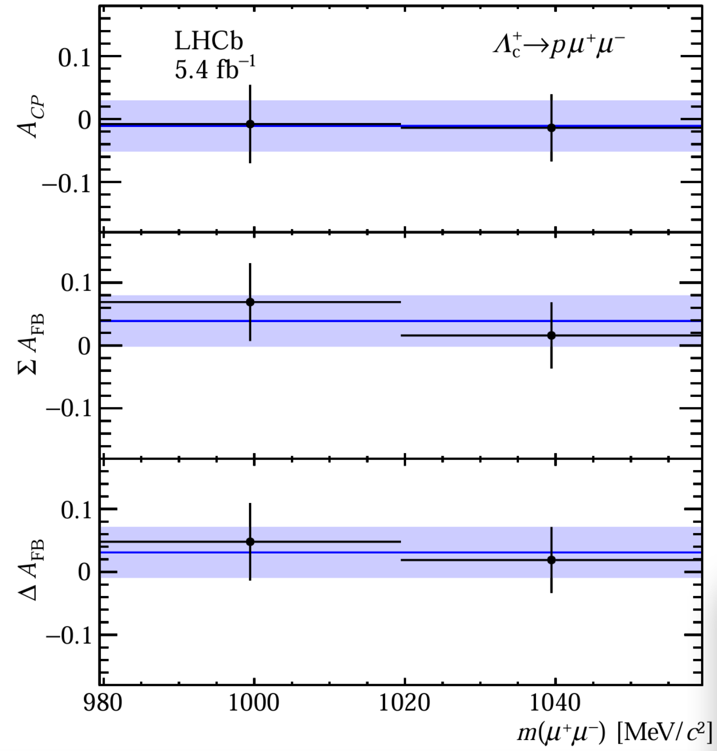
⟶ HyperCP anomaly excluded



CP asymmetries in $\Lambda_c^+ \to p\mu^+\mu^-$ decays

The FCNC decay $\Lambda_c^+ \to p\mu^+\mu^-$ is not observed yet. The CP asymmetry is measured in $\boldsymbol{\mu^+\mu^-}$ resonances.





- ✓ First study of angular and CP asymmetries
- ✓ Consistent with SM prediction 0.

[arxiv.2407.11474](https://arxiv.org/abs/2407.11474)

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 2.9\ (3.2) \times 10^{-8} \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}.$$

$$\begin{aligned} A_{CP} &= (-1.1 \pm 4.0 \pm 0.5)\%, \\ \Sigma A_{\mathrm{FB}} &= (\ \ \ 3.9 \pm 4.0 \pm 0.6)\%, \\ \Delta A_{\mathrm{FB}} &= (\ \ \ 3.1 \pm 4.0 \pm 0.4)\%, \end{aligned}$$

Search for LFV decays $b \to sll'$

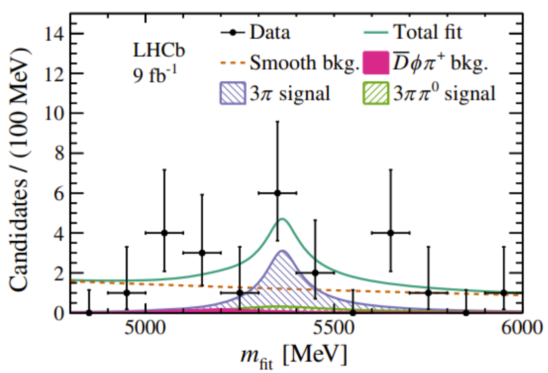
Any observation of a charged LFV decay would provide clear evidence for physics beyond the SM

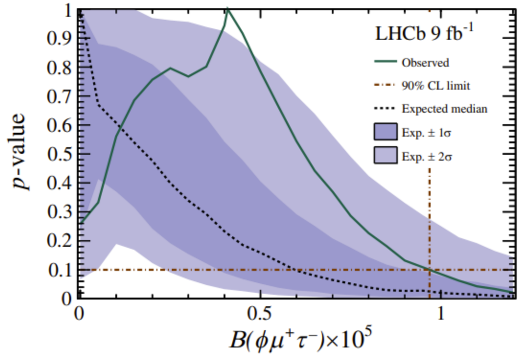
[Phys. Rev. D110 (2024) 7]

- Search for rare decay $B_s^0 \to \phi\mu\tau$
  - The first limit on this LFV decay

$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.0\times10^{-5}$ at 90%CL,

$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.1\times10^{-5}$ at 95%CL.

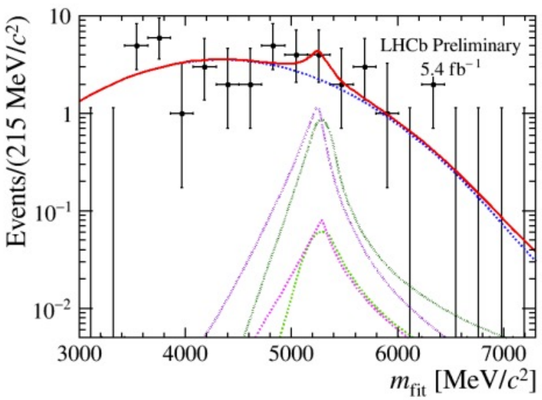


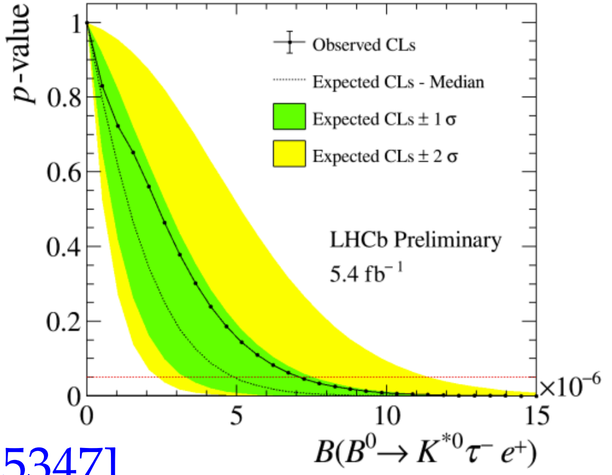


- Search for rare decay $B^0 \to K^{*0}\tau^\pm e^\mp$
  - Mass re-fitted including missing neutrino momentum and kinematic constraints

Model	Upper limit $[10^{-6}]$	
	$B^0 \to K^{*0}\tau^- e^+$	$B^0 \to K^{*0}\tau^+ e^-$
Phase-space	5.9 (7.1)	4.9 (5.9)
Left-handed	6.3 (7.7)	5.4 (6.4)
Scalar	6.6 (8.0)	5.7 (6.8)

the most stringent upper limits placed on $b \to s\tau e$ transitions





[arxiv.2506.15347]

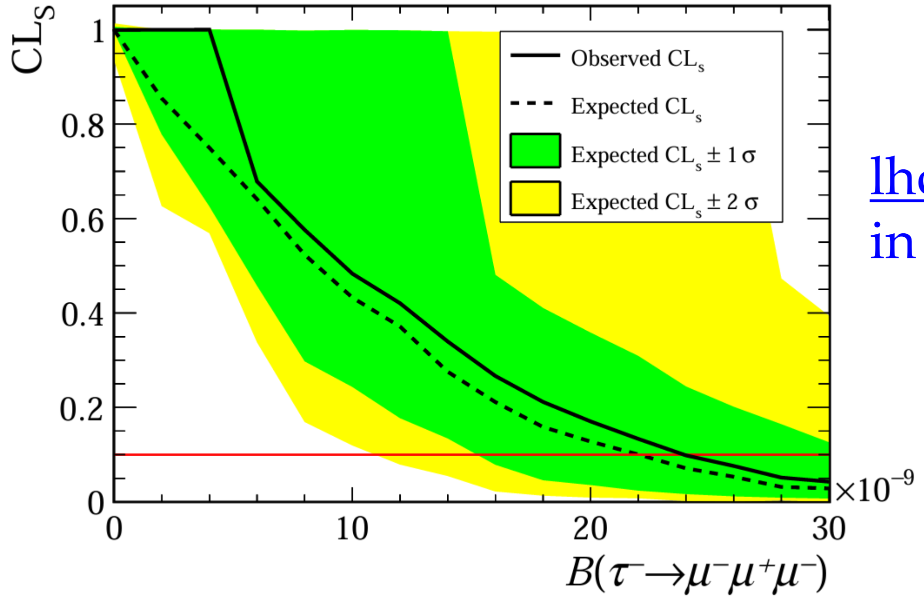
Search for LFV decays $\tau \to \mu\mu\mu$

- LFV decay strongly suppressed in SM + ν oscillations: $\mathcal{B}(\tau\to\mu\mu\mu) \sim 10^{-55}$ [Eur. Phys. J. C (2020) 80:506],

→ Observation of this decay will be a clear sign of new physics

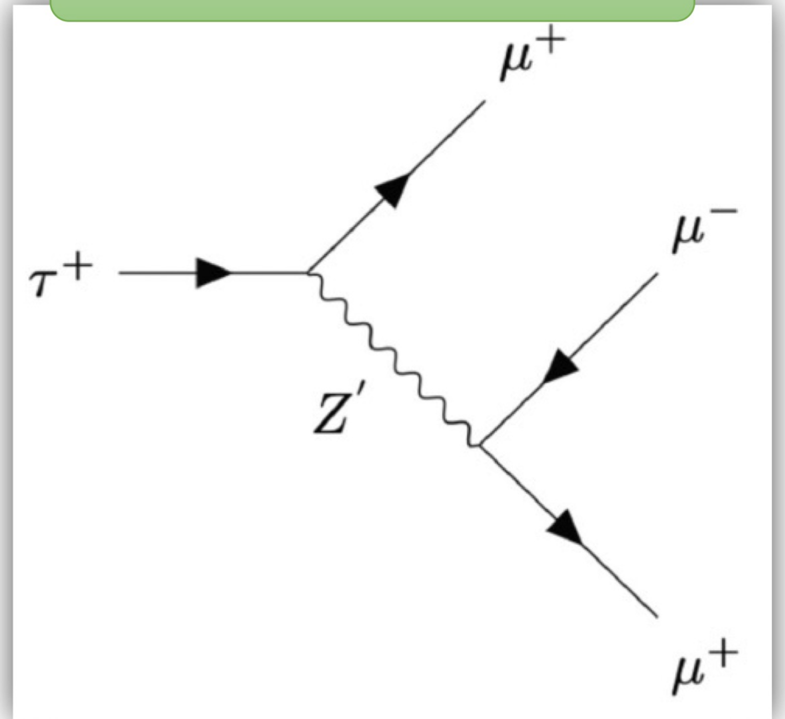
- Set upper limit on the BF
  - constrain theories of physics beyond the SM
  - including Z or leptoquarks, heavy neutrinos…

[PRD 92, 054013, PRD 94, 115021], predicting $\mathcal{B}(\tau\to\mu\mu\mu) \sim \mathcal{O}(10^{-10} - 10^{-7})$



lhcb-paper-2025-052, in preparation

NP model with Z' boson

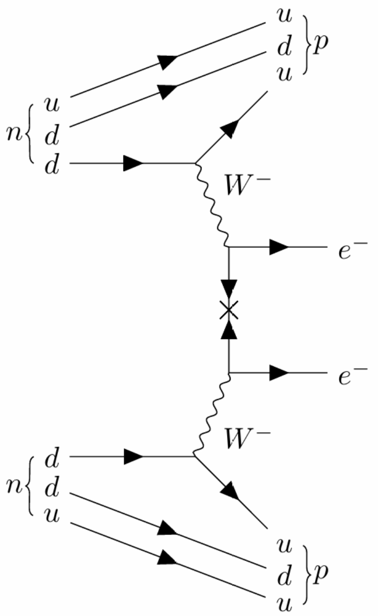


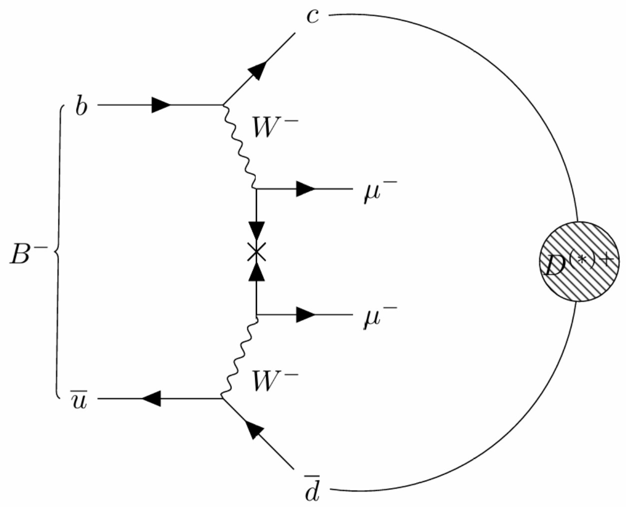
$B(\tau \to \mu\mu\mu) < 2.4(2.8)\times10^{-8}$ @ 90%(95%) CL

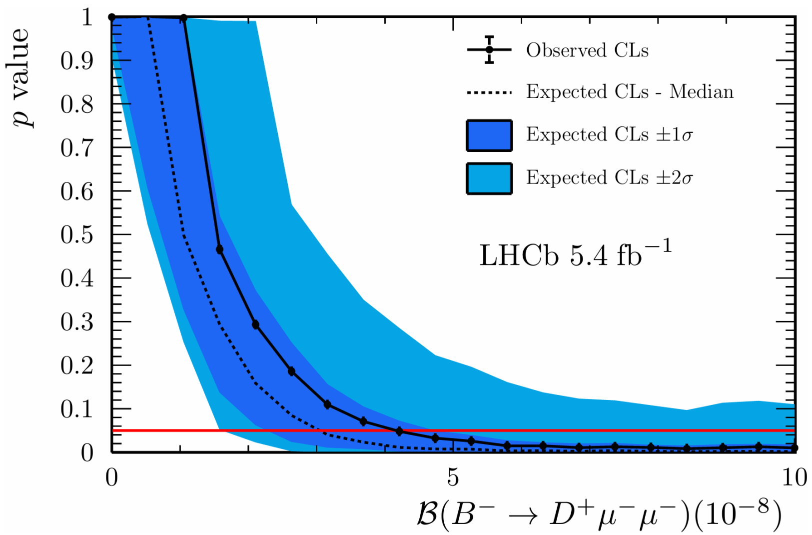
Search for B meson 0νββ decay

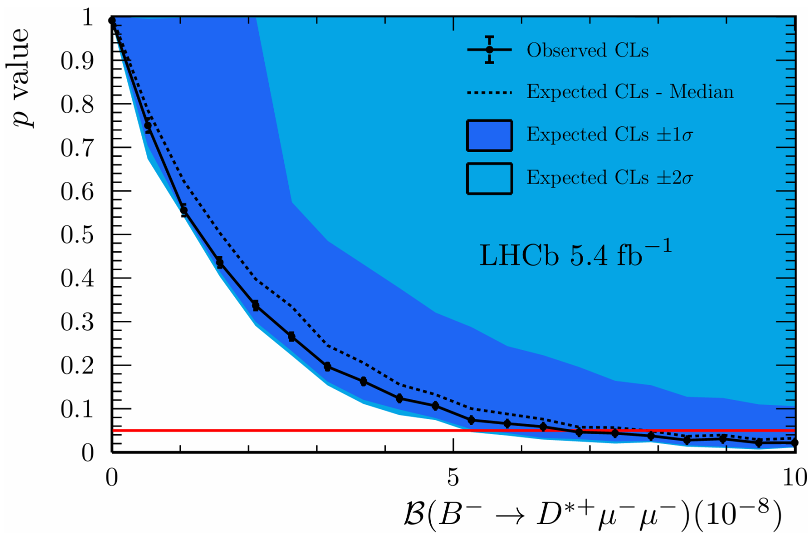
- Majorana nature of neutrinos can be tested with neutrinoless double β decay (0νββ)
  - B mesons can decay in the 0νββ mode
  - Upper limit is set using full Run2 data

$$\mathcal{B}(B^- \to D^+\mu^-\mu^-) < 3.3\ (4.2) \times 10^{-8} \text{ at } 90\%\ (95\%)\ \text{CL},$$
$$\mathcal{B}(B^- \to D^{*+}\mu^-\mu^-) < 4.8\ (6.7) \times 10^{-8} \text{ at } 90\%\ (95\%)\ \text{CL}.$$









4 Prospects & Conclusions

Prospects of LHCb physics

- The $b \to s(d)\ell\ell$ and $b \to s(d)\gamma$ decay will reach much better precision using the accumulated data after upgrade

Observable	Current LHCb (9 fb^{-1})	Upgrade I (23 fb^{-1})	Upgrade I (50 fb^{-1})	Upgrade II (300 fb^{-1})
$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	69%	41%	27%	11%
$S_{\mu\mu}(B_s^0 \to \mu^+\mu^-)$	—	—	—	0.2
$A_T^{(2)}(B^0 \to K^{*0}e^+e^-)$	0.10	0.060	0.043	0.016
$A_T^{\mathrm{Im}}(B^0 \to K^{*0}e^+e^-)$	0.10	0.060	0.043	0.016
$\mathcal{A}_{\phi\gamma}^{\Delta T}(B_s^0 \to \phi\gamma)$	$^{+0.44}_{-0.41}$	0.124	0.083	0.033
$S_{\phi\gamma}(B_s^0 \to \phi\gamma)$	0.32	0.093	0.062	0.025
$\alpha_\gamma(\Lambda_b^0 \to \Lambda\gamma)$	$^{+0.17}_{-0.29}$	0.148	0.097	0.038

CERN-LHCC-2021-012

Conclusions

- ✓ Persistent anomaly in $\boldsymbol{b \to s l^+ l^-}$ decays under scrutiny
- ✓ Wider scope for exploitation in LHCb: LFU ratio, polarization, CP violation...
- ✓ A large set of data samples will be collected in the coming years

Stay tuned for the new results!

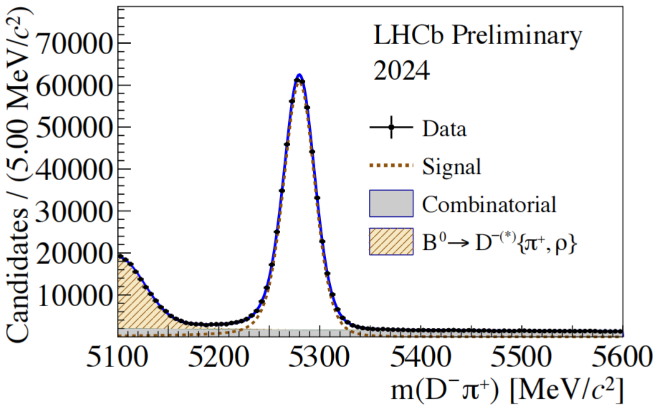
Thank you for listening!

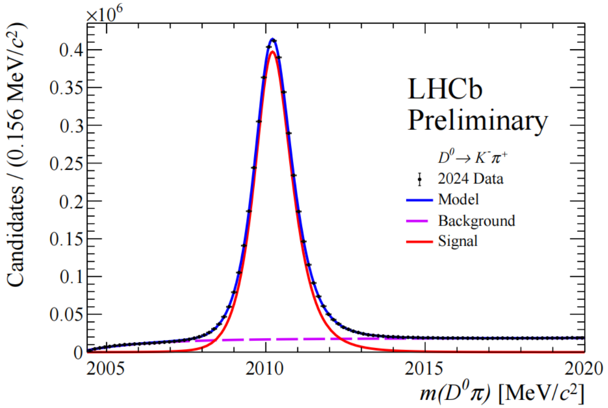
Backup slides

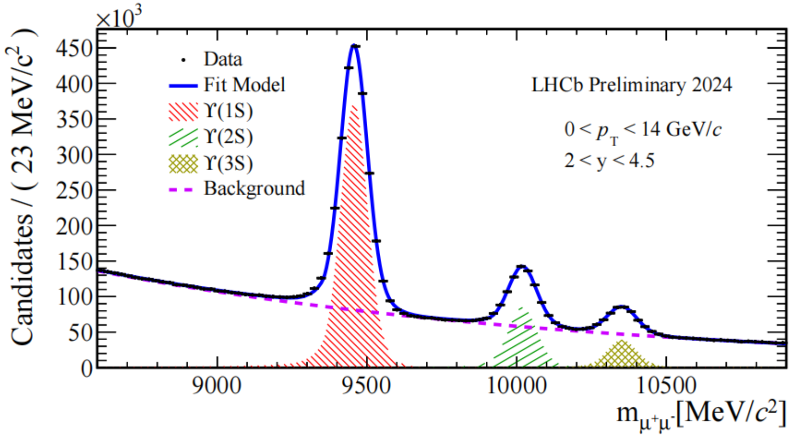
What could be expected after upgrades?

- More data than the expectation luminosity of Run 1 & 2 in 2024!

The gain maybe ~2× due to removal of hardware trigger

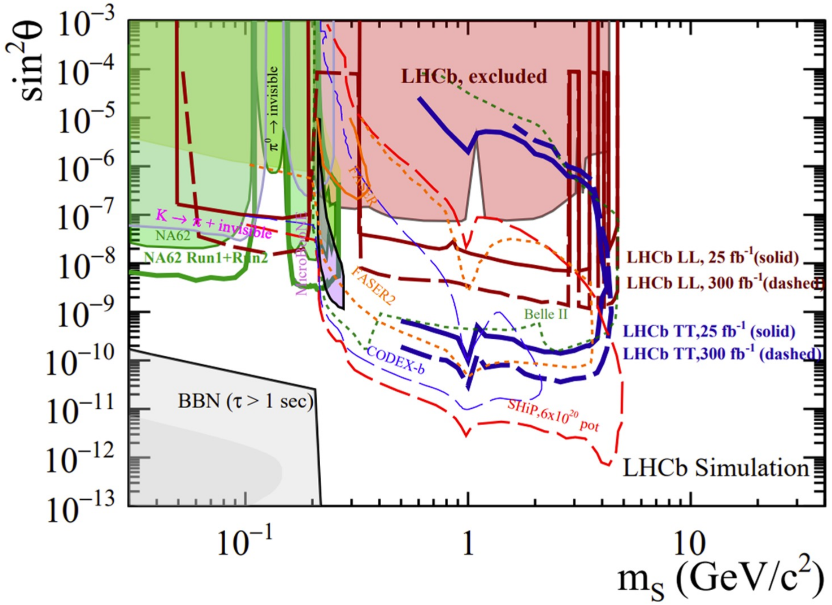






Topic	Comment
Spectroscopy	Enormous yields in gold-plated final states
	e.g. 4M $\Lambda_b^0 \to J\psi pK^-$ decays ('pentaquark' mode)
Higgs	Measure Higgs-charm Yukawa within factor 2 to 3 of SM value
$\sin^2\theta_W$	Uncertainty $< 10^{-4}$, better than LEP/SLD
Proton structure	Precision probes at extremely low and high Bjorken-x values,
	with $Q^2 > 10^5$ GeV^2
Hidden sector	Sensitivity to most of relevant parameter space for dark-photon models

e.g. Replacing TT → SCIFI allow to probe the invisible using SCIFI-only tracking



Search for NP in charged current decays

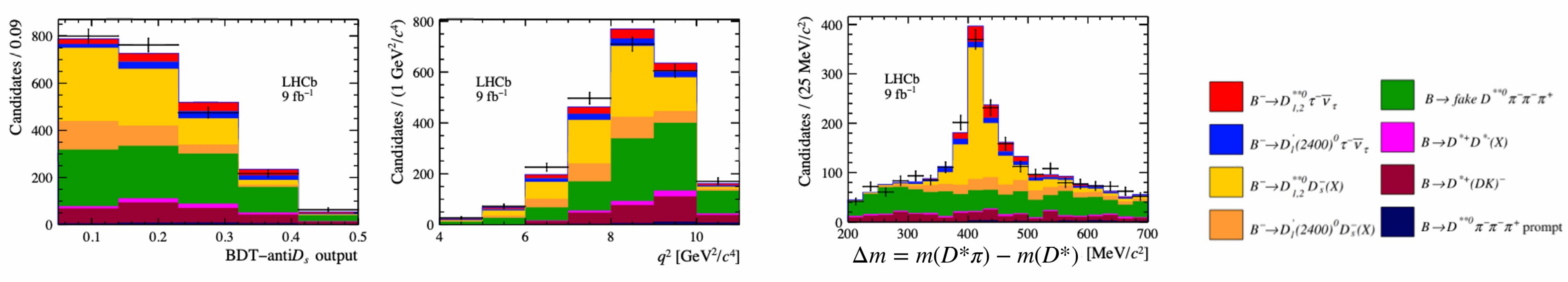
- First evidence of B+→D**0 τ+ ν (3.5 σ)
- Normalising to B+→D**0 Ds, the branching ratio is measured to be

$$\mathcal{B}(B^- \to D_{1,2}^{**0}\tau^-\nu_\tau) \times \mathcal{B}(D_{1,2}^{**0} \to D^{*+}\pi^-) = (0.051 \pm 0.013\ (\text{stat}) \pm 0.006\ (\text{syst}) \pm 0.009\ (\text{ext}))\ \%$$

- LFU ratio

$$R(D_{1,2}^{**0}) = \frac{\mathcal{B}(B^- \to D_{1,2}^{**0}\tau^-\nu_\tau)}{\mathcal{B}(B^- \to D_{1,2}^{**0}\mu^-\nu_\mu)} = 0.13 \pm 0.03\ (\text{stat}) \pm 0.01\ (\text{syst}) \pm 0.02\ (\text{ext})$$

compatible with SM prediction of $R(D^{**}_{1,2}) = 0.09 \pm 0.02$ [PRD 97 (2018) 075011]



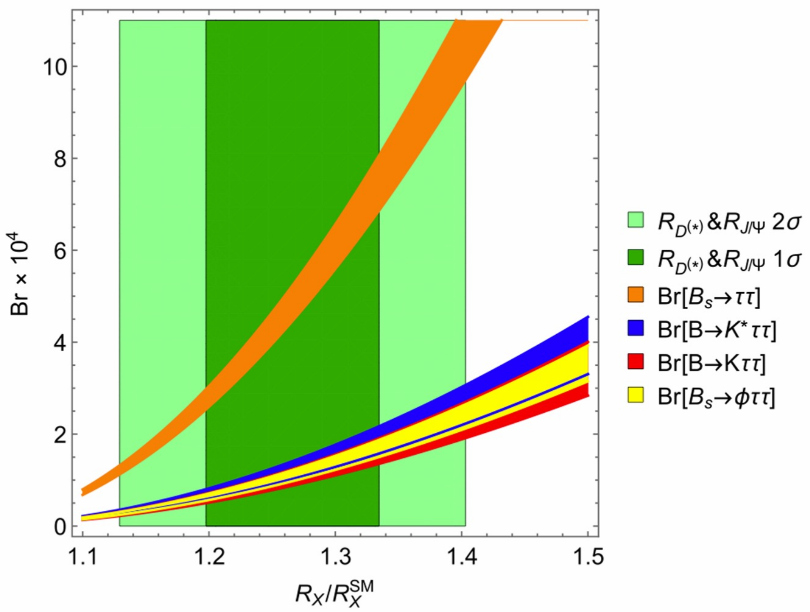
Connection between b→cℓν and b→s ℓ+ℓ− ?

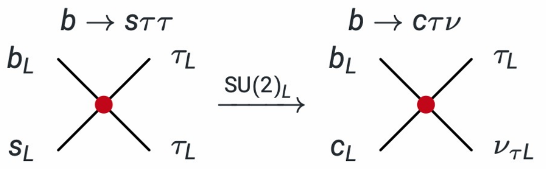
- Attempts to explain LFU violating effects in R(D)-R(D*) tend to **enhance $b \to s\tau\tau$ couplings** by 10^3-10^4 compared to the SM value

- As a bonus, one obtains higher order corrections to $b \to s\ell\ell$, causing a LFU shift in C_9

		SM prediction
$B_s \to \tau\tau$		$(7.73 \pm 0.49) \times 10^{-7}$
$B \to K\tau\tau$	$[15, 22]\mathrm{GeV}^2/c^2$	$(1.20 \pm 0.12) \times 10^{-7}$
$B \to K^*\tau\tau$	$[15, 19]\mathrm{GeV}^2/c^2$	$(0.98 \pm 0.10) \times 10^{-7}$
$B_s \to \phi\tau\tau$	$[15, 18.8]\mathrm{GeV}^2/c^2$	$(0.86 \pm 0.06) \times 10^{-7}$

Capdevila et al, PRL120 (2018) 181802

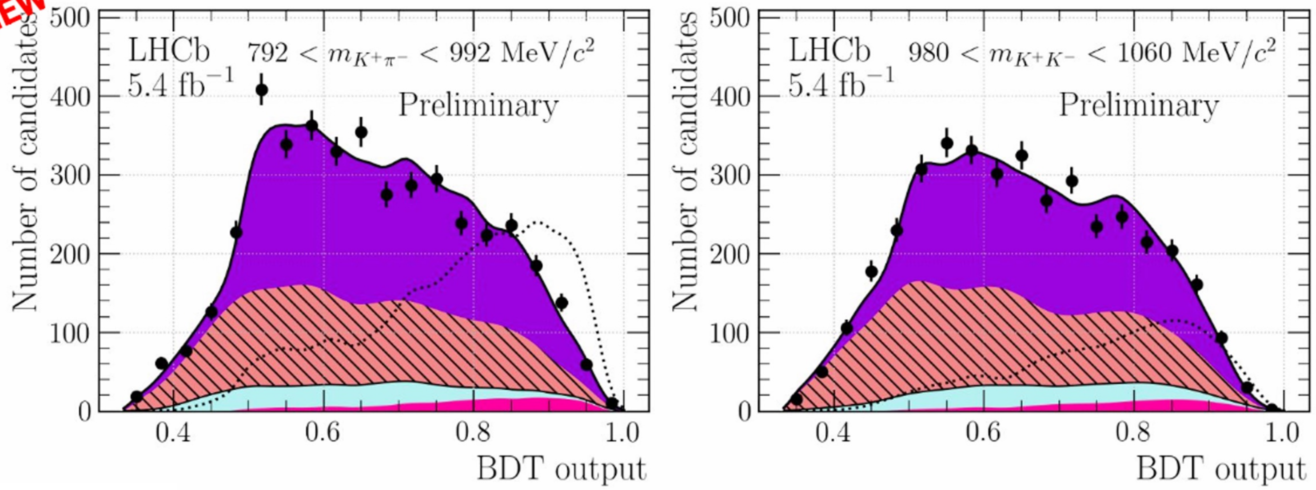


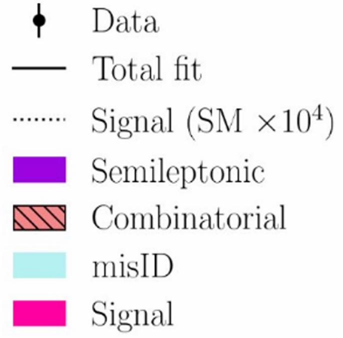


Search for b→s $\tau^+ \tau^-$ decays

- New LHCb search for $B^0 \to K^+\pi^-\tau^+\tau^-$ and $B_s^0 \to K^+K^-\tau^+\tau^-$
  - Using muonic taus

NEW





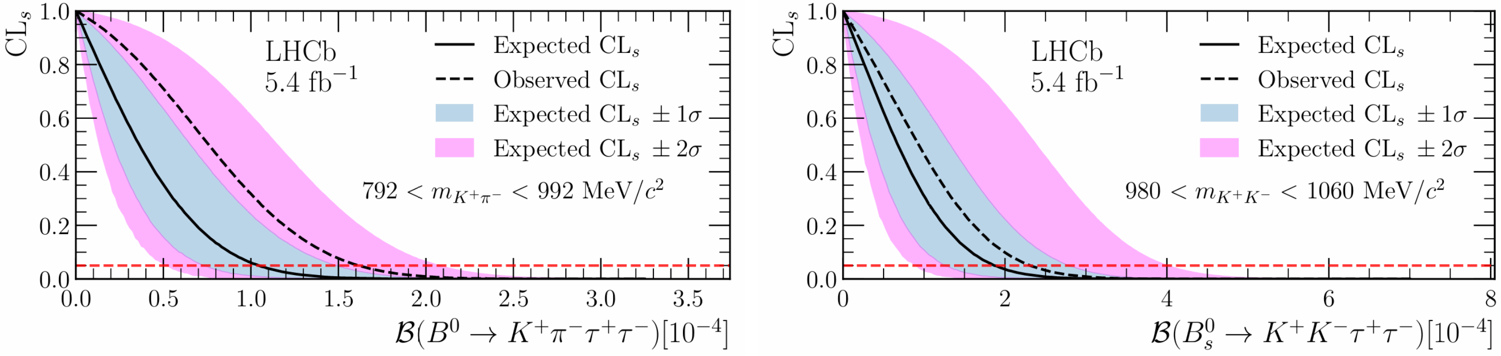
[LHCb-PAPER-2025-048]

- No signal is observed, UL is set as

$$\mathcal{B}(B^0 \to K^{*0}\tau^+\tau^-) < 2.8 \times 10^{-4}\ (2.5 \times 10^{-4}) \text{ at } 95\%\ (90\%) \text{ CL},$$
$$\mathcal{B}(B_s^0 \to \phi\tau^+\tau^-) < 4.7 \times 10^{-4}\ (4.1 \times 10^{-4}) \text{ at } 95\%\ (90\%) \text{ CL}.$$

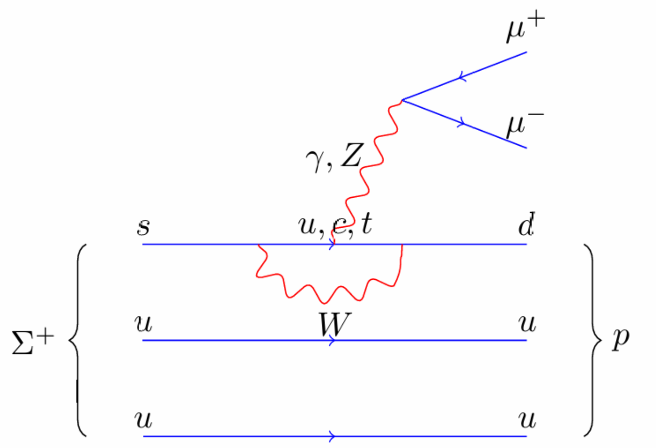
- Improves by approx a factor ✖10 the recent best limit from Belle

[arxiv: 2504.10042]

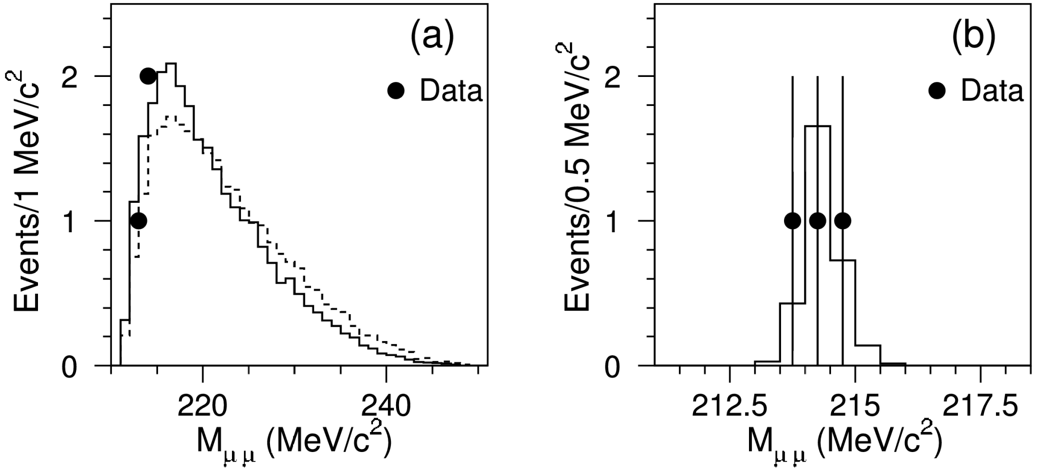


Observation of $\Sigma^+ \to p\mu^+\mu^-$ decays

- $\Sigma^+ \to p\mu^+\mu^-$ is a very rare decay mediated by $s \to d$ transition
  –Short-distance contribution(penguin/box diagrams) $B{\sim}\mathcal{O}(10^{-12})$
  –Long-distance contributions (from the decay $\Sigma^+ \to p\gamma^*$)
  $$1.28\times10^{-8} < B(\Sigma^+ \to p\mu^+\mu^-) < 7.8\times10^{-8}$$
  [PRD72(2005) 074003]
  [JHEP1810(2018)040]
  [PRD111(2025)013003]



- First evidence for $\Sigma^+ \to p\mu^+\mu^-$ decay was found by HyperCP (2005)
  –3 events found in absence of background
  –Measured branching fraction. [PRL94(2005)021801]
  $B(\Sigma^+ \to p\mu^+\mu^-) = 8.6^{+6.6}_{-5.4} \pm 5.5\times10^{-8}$



- Evidence of $\Sigma^+ \to pX^0(\to \mu^+\mu^-)$ is also found with
  $m(X^0) = 214.3 \pm 0.5\text{MeV}/c^2$

Search for $\Lambda_c^+ \to p\mu^+\mu^-$ decays

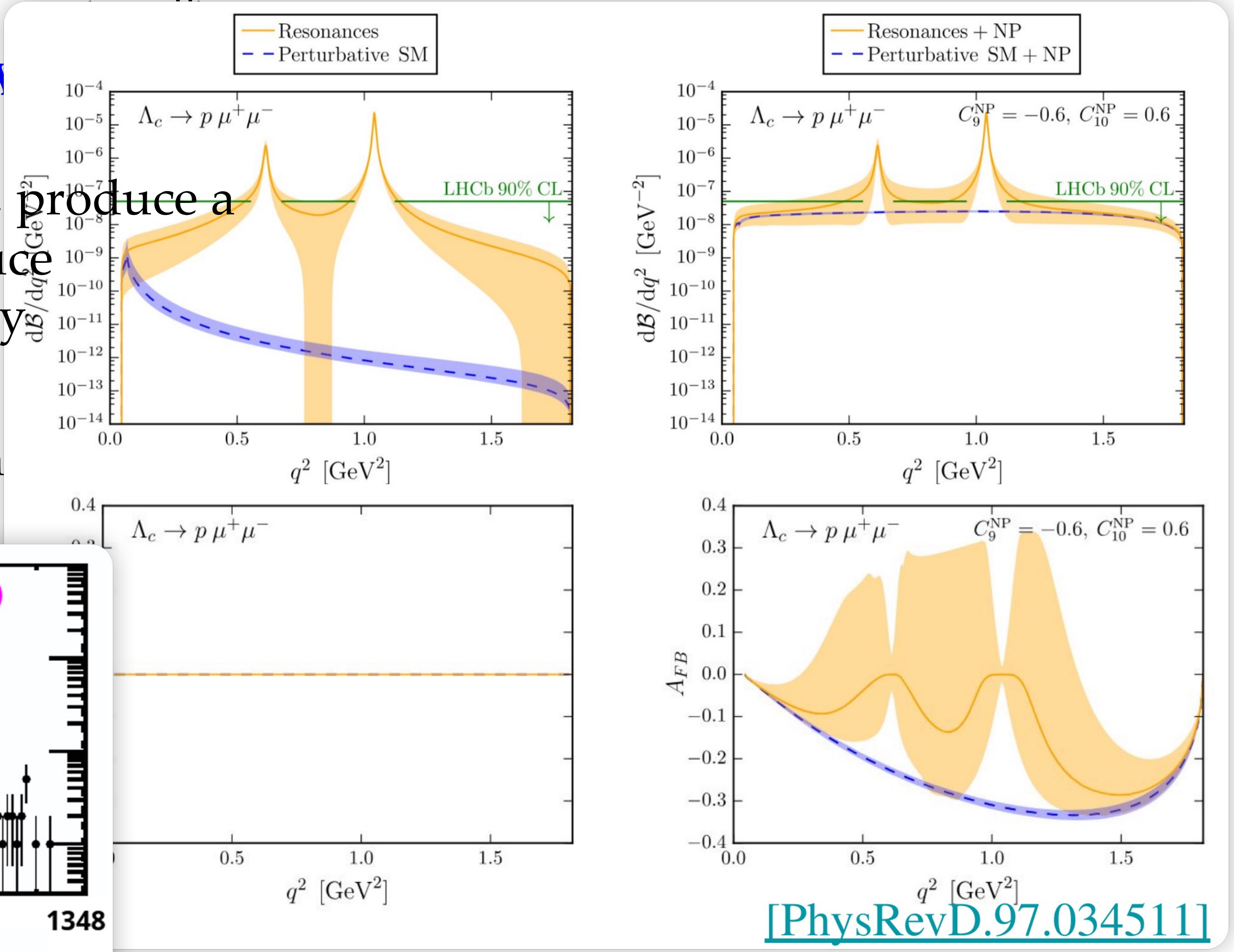
- $\Lambda_c^+ \to p\mu^+\mu^-$ is a very rare FCNC + GIM mechanism

–Short-distance contribution(penguin/box diagrams) B

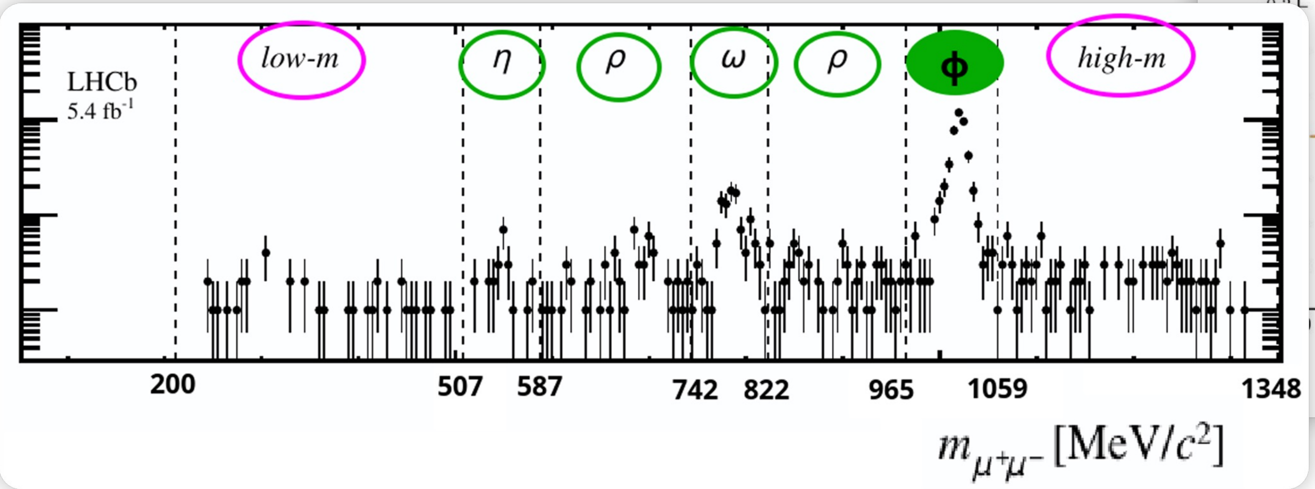
–Long-distance contributions $B \sim \mathcal{O}(10^{-8})$ from $\Lambda_c^+ \to p$

- BSM contributions could enhance the expected BR, produce a non-zero forward-backward asymmetry or introduce additional sources of charge-parity (CP) asymmetry

- Measure the BF of $\Lambda_c^+ \to p\mu^+\mu^-$ decay in 6 regions: **resonant**$(\eta, \rho, \omega, \phi)$ and non-resonant(low-mass and h



[PhysRevD.97.034511]



arxiv.2407.11474