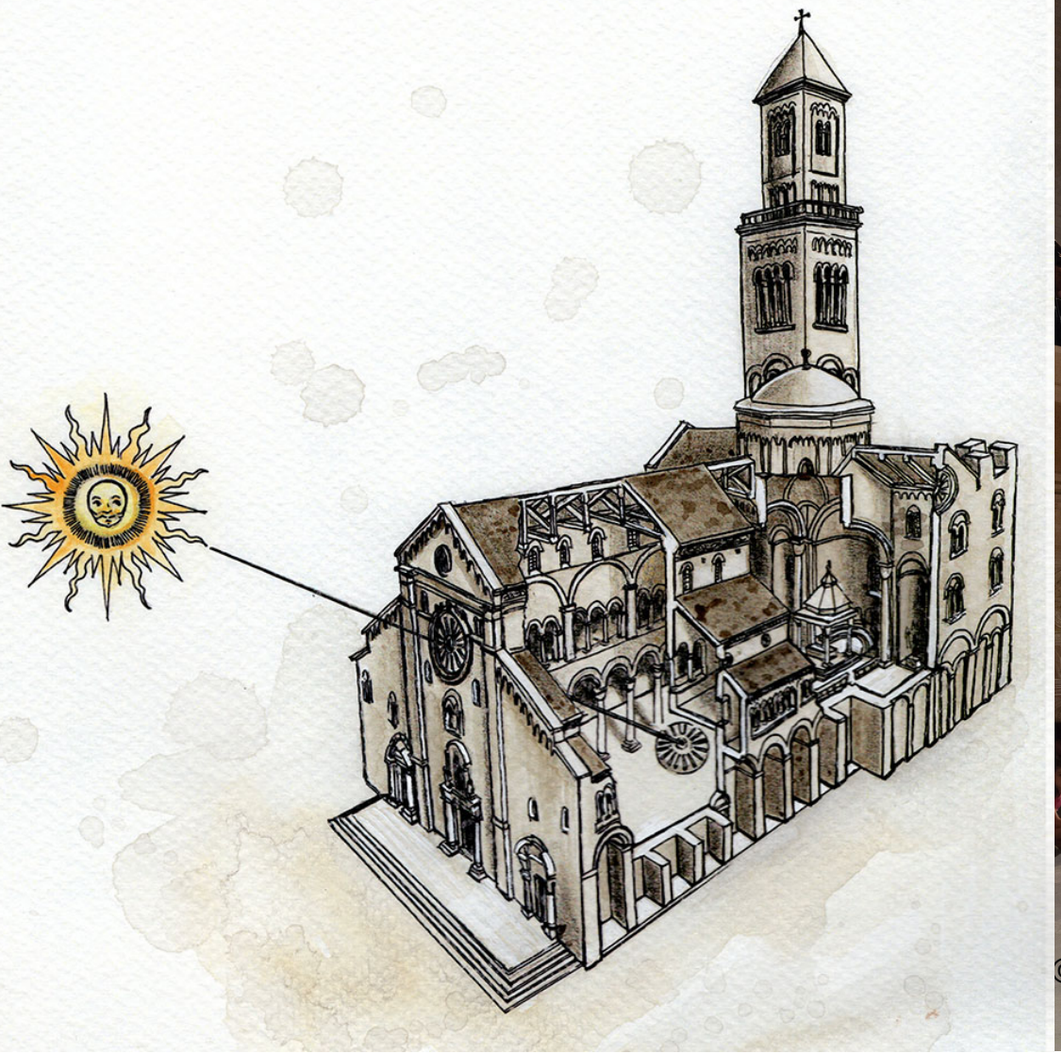
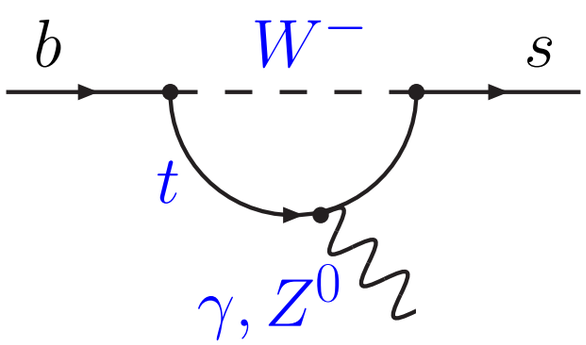


Rare *B* decays at LHCb



13 Nov 2025 - WIFAI - Bari

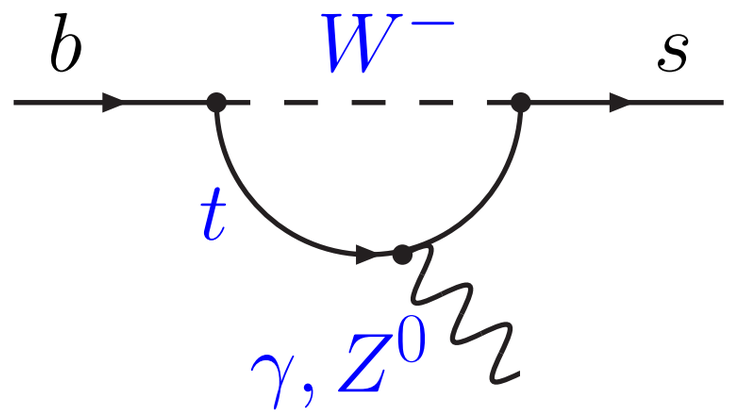
Martino Borsato

University and INFN of Milano-Bicocca

Website LHCb@Bicocca

Electroweak FCNC in $b \to s$

- Electroweak $b \to s$ transitions
  - Suppressed by loop and $V_{\rm CKM}$ → decay rates of order 10^{-6} or less
  - Tiny BSM contributions can enter at the same order as SM amplitude
  - Sensitive up to few(several) TeV depending on BSM flavour structure

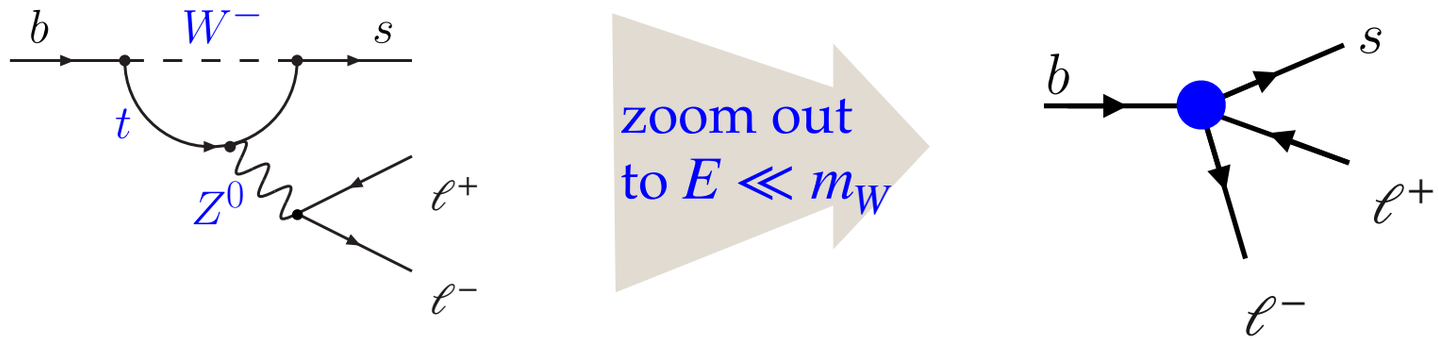


$b \to s\gamma,\ b \to s\ell^+\ell^-,\ B_s \to \ell^+\ell^-$

- Excellent experimental probe
  - $m_b \gg \Lambda_{\rm QCD} \Rightarrow$ perturbative calculations
  - B is narrow and long-lived ($\tau_B \simeq 1.5$ ps)
  - No neutrinos involved!
  - Several complementary observables
  - Several complementary decay channels

→ Branching ratios, angular analyses, SM symmetry tests

Effective theory interpretation



EFT below EW scale:

$$\mathscr{H}_{\text{eff}} = \frac{1}{(34\ \text{TeV})^2} \sum_i C_i O_i$$

$$O_7^{(\prime)} = \frac{m_b}{e}(\bar{s}\sigma_{\mu\nu}P_{\text{R(L)}}b)F^{\mu\nu} \qquad \textbf{dipole } (b \to s\gamma)$$

$$O_9^{(\prime)} = (\bar{s}\gamma_\mu P_{\text{L(R)}}b)(\bar{\ell}\gamma^\mu \ell) \qquad \textbf{vector}$$

$$O_{10}^{(\prime)} = (\bar{s}\gamma_\mu P_{\text{L(R)}}b)(\bar{\ell}\gamma^\mu\gamma_5 \ell) \qquad \textbf{axial-vector}$$

$$O_S^{(\prime)} = (\bar{s}\gamma_\mu P_{\text{R(L)}}b)(\bar{\ell}\ell) \qquad \textbf{scalar}$$

$$O_P^{(\prime)} = (\bar{s}\gamma_\mu P_{\text{R(L)}}b)(\bar{\ell}\gamma_5 \ell) \qquad \textbf{pseudo-scalar}$$

Experimental probes

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

- Wilson coefficients are complex valued
- SM quark current mostly left-handed, but need to constrain BSM right-handed Wilson coefficients C'
- SM is LFU but one should consider the lepton-flavour dimension $C^e \neq C^\mu \neq C^\tau$

(Today I won't cover LFV $b \to s\ell\ell'$)

DIEV ET MON DROIT

It appeareth by the discourse of Fr
a Sumner of this yeare 1584 that th
vnto the west part of America and the
which hath bene ordinarily sett out a
and a round we must measure the streight
about 1200 leagues spite of the latitud
And that the distance betweene cape M
cape California which many maps d
make to be 1200 or 1500 leagues is fa

GRONLAND

ENGLAND

FRANCE

SPAIN

AFRICA

Mare

ARABIA

INDIA

CHINA

CAPRICORNI

THE SOUTH

SEA

BRASILIA

PERV

CHILI

GVINEA

I doe hold here good to make a briefe hydrographicall description of so much of the world as hath hetherto discovered, and to expresse large knowledge with the same in this first version and
all places begin for severall times the same position and distance that they stand in the globe, being there
in plaine sea charts and mappes which they vse in, of short which by the ordinarie fa-
shion can not well be performed. The way to make the position or scituation from one place to
other betweene, doth shew differeth nothing from that which is vsed in the ordinarie sea char-
ts. But to all the scituations of both places have the same latitude set how many degrees of
the meridian they be short latitude are contained betweene the two places, for to shew how
leagues to the discourse. If they differ in latitude set how many degrees of the meridian
lieth about the middle of that scituation are contained betweene them, and so many seuen
leagues as the discourse.

Radiative $b \to s\gamma$

Radiative $b \to s\gamma$

Left handed $C_7 = C_7^{\rm SM} + C_7^{\rm NP}$

- $\mathcal{B}(B \to X_s\gamma) \propto C_7^2 + C_7'^2$
  - 5% precise prediction [1]
  - 5% precise from B-factories (Very hard at LHCb) [2]
- $\mathrm{Im}(C_7)$ measured with $A_{\rm CP}$
  - $B \to K_S\pi^0\gamma$ at B-factories [2]
  - Tagged time-dep. analysis of $B_s \to \phi\gamma$ at LHCb [3]

Right handed $C_7' \simeq C_7'^{\rm NP}$

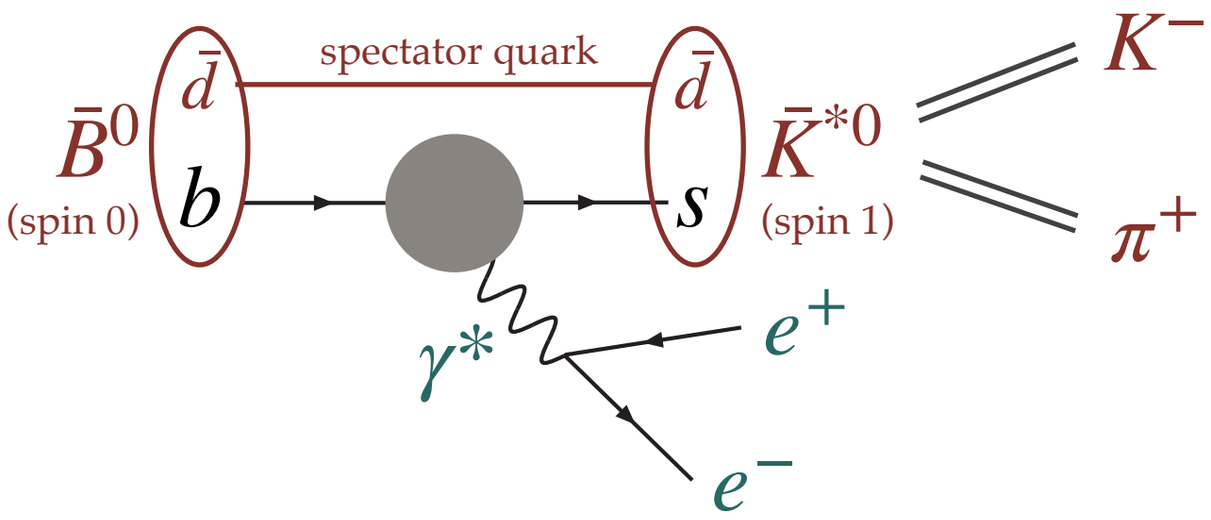
- Mixing-induced CPV in $B \to K_S\pi^0\gamma$ at B-factories [2]
- $\Delta\Gamma_s$ induced rate asymmetry in $B_s \to \phi\gamma$ at LHCb [3]
- Angular analysis of $\Lambda_b \to \Lambda\gamma$ at LHCb [4]
- Transverse asymmetries in $B \to Ve^+e^-$ at LHCb [5]

-> the most sensitive

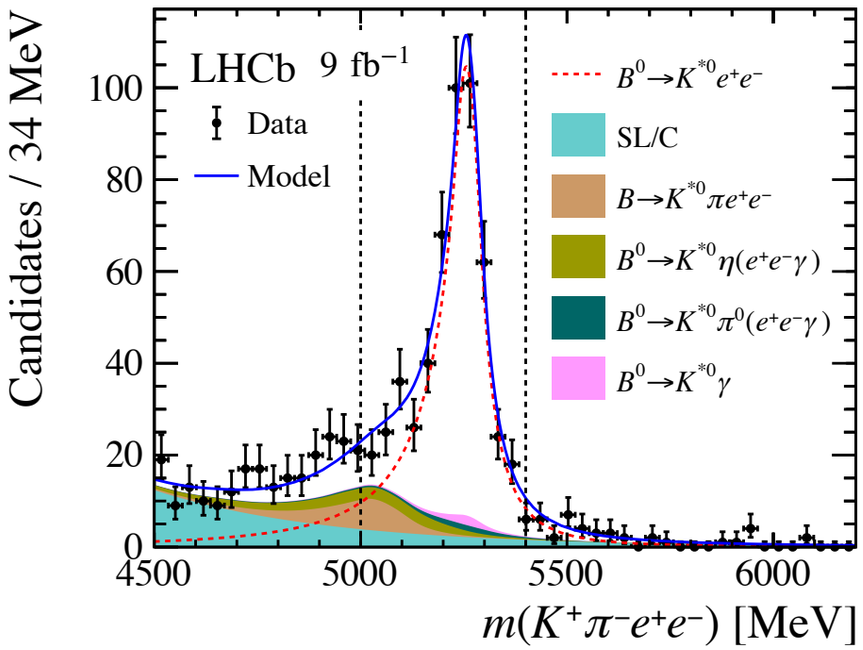
[1] M. Misiak et al JHEP 06(2020)175
[2] HFLAV average of BaBar and Belle
[3] LHCb PRL 123 (2019) 081802
[4] LHCb PRD 105 (2022) L051104
[5] LHCb JHEP 12 (2020) 081 and JHEP 03 (2025) 047

$b \to s\gamma$ in $B \to Ve^+e^-$

- ✓ Use $\gamma^* \to e^+e^-$ to measure photon polarisation!
- ✓ Get nice $h^-h^+e^-e^+$ final state
- ◉ Rate lower by $\alpha_{\text{e.m.}}$

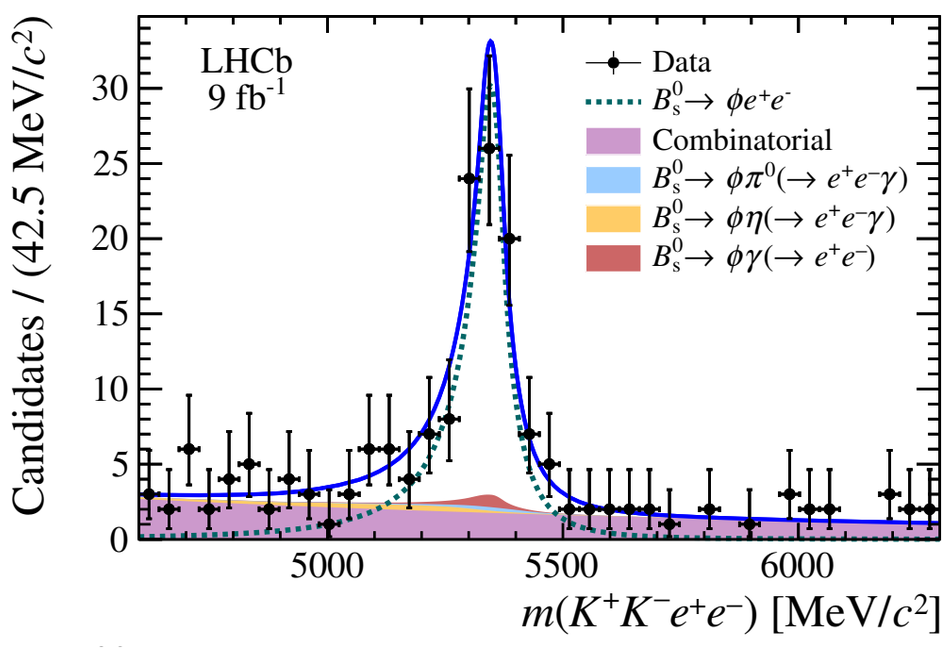


✓ About 500 $B^0 \to K^*ee$



LHCb JHEP 12 (2020) 081

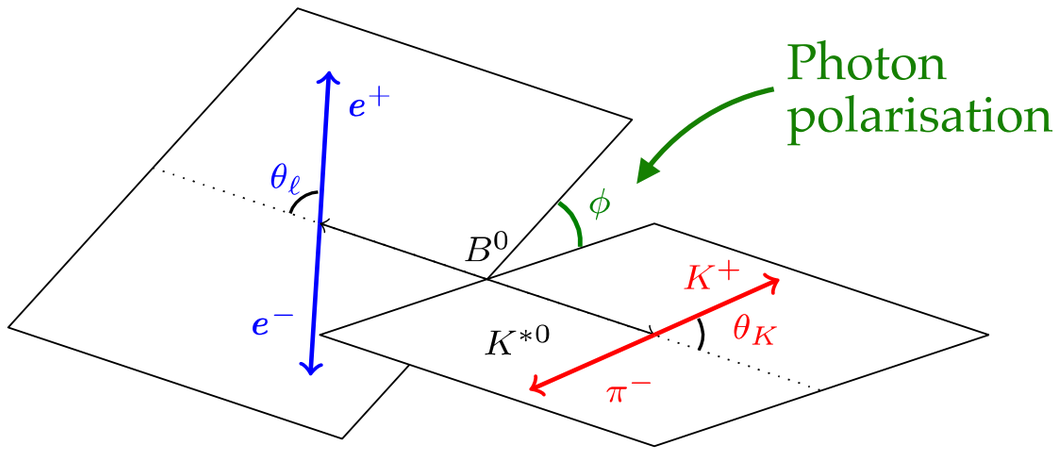
✓ About 100 $B_s^0 \to \phi ee$

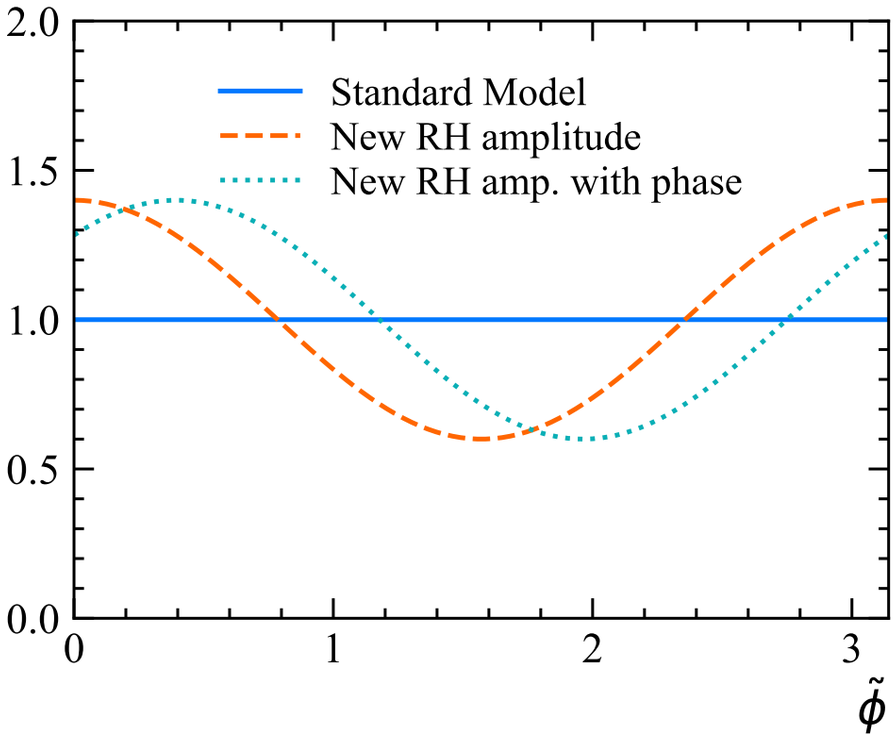


LHCb JHEP 03 (2025) 047

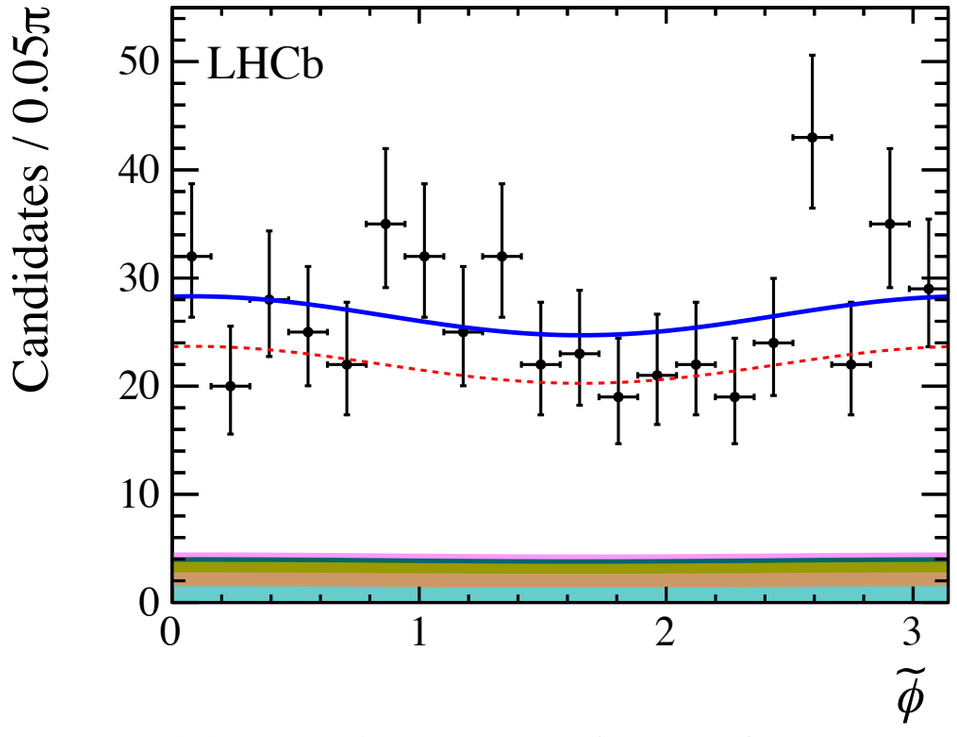
$b \to s\gamma$ in $B \to Ve^+e^-$

- $B^0 \to h^+h^-e^+e^-$ described by 3 angles
- Photon polarisation measured with ϕ
  - $\cos 2\phi$ or $\sin 2\phi$ modulation would signal right-handed contribution





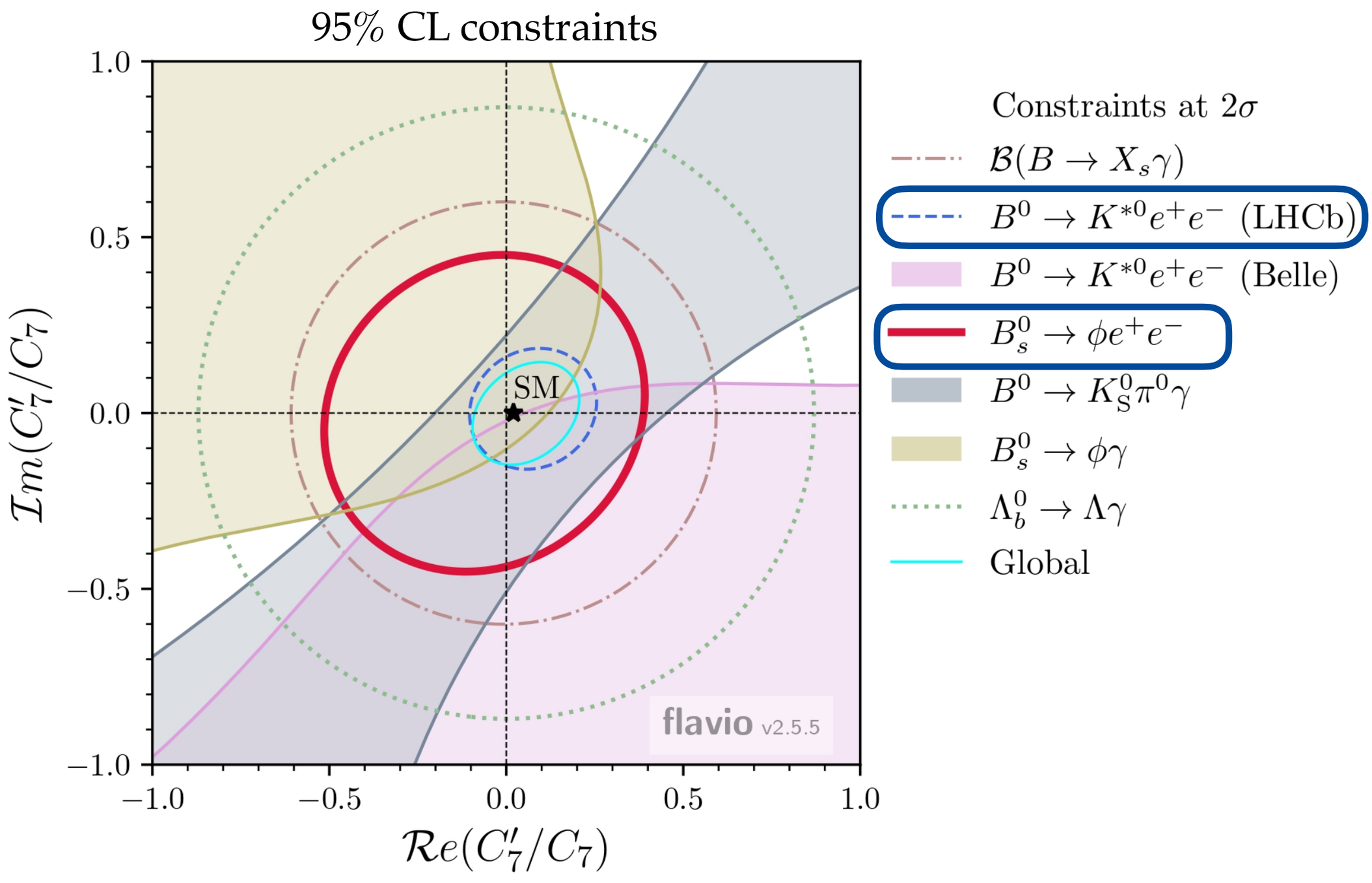
LHCb JHEP 12 (2020) 081



No significant modulation observed

$b \to s\gamma$ in $B^0 \to K^* e^+ e^-$

LHCb JHEP 03 (2025) 047

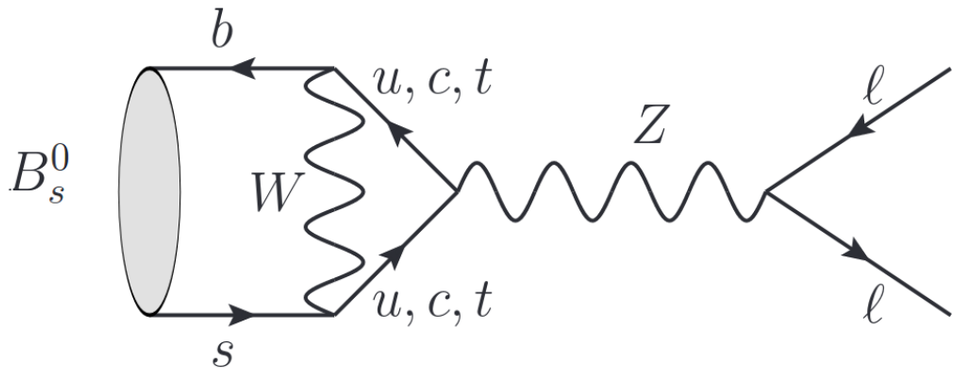


Leptonic $B_s \to \ell\ell$

Leptonic $B_s \to \mu^+\mu^-$

- A golden flavour physics channel
  - Very rare 10^{-9} BR (helicity suppression)
  - Precise 4% BR prediction (fully leptonic)

Beneke et al. JHEP 10 (2019) 232
Kozachuk et al., PRD 97 (2018) 053007



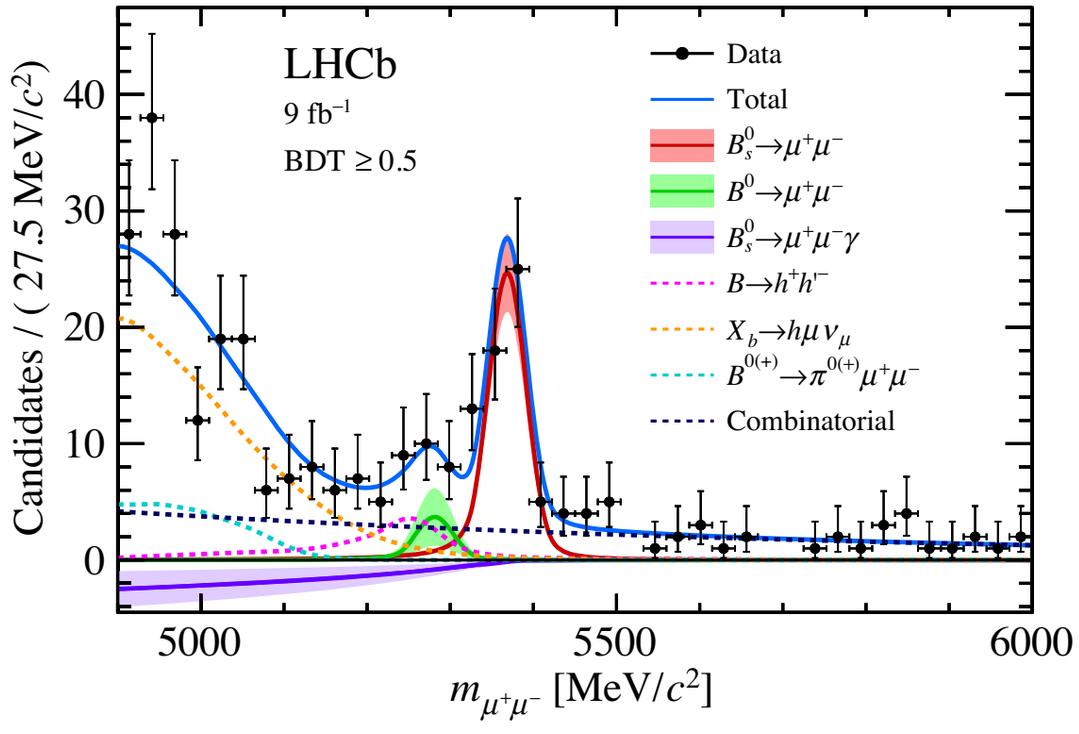
+ box diagram involving neutrinos

- Searched since the 80's and firstly observed in 2014 by LHCb+CMS (Nature 522 (2015) 68)

- Current experimental world average of $\mathrm{Br}(B_s \to \mu\mu)$ has **precision of about 9%**

- Measurements **compatible with SM** → strong constraints on C_{10}, C_S and C_P

PRL 128, (2022) 041801



LHCb: PRL 128, (2022) 041801
CMS: *PLB* 842 (2023) 137955
ATLAS: *JHEP* 04 (2019) 098

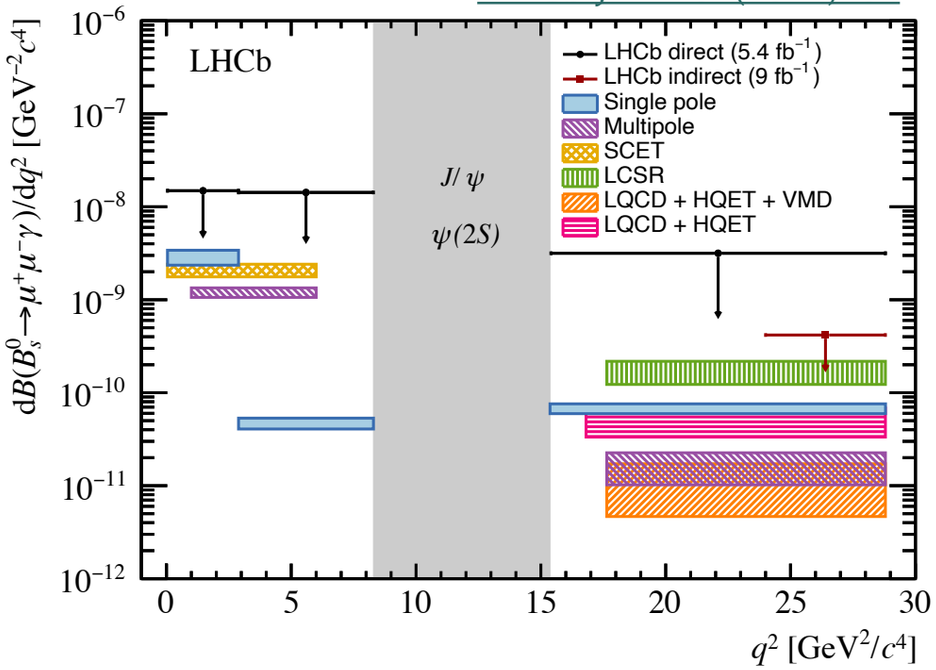
Other leptonic decays

- Search for $B_s \to \mu\mu\gamma$ (LHCb JHEP07(2024)101)
  - Lifted helicity suppr, but pay α_{em}
  - Sensitive to both C_9 and C_{10} but challenging theory predictions
  - Searched as par-reco contribution to $B_s \to \mu\mu$ analysis (covering high dimuon mass)

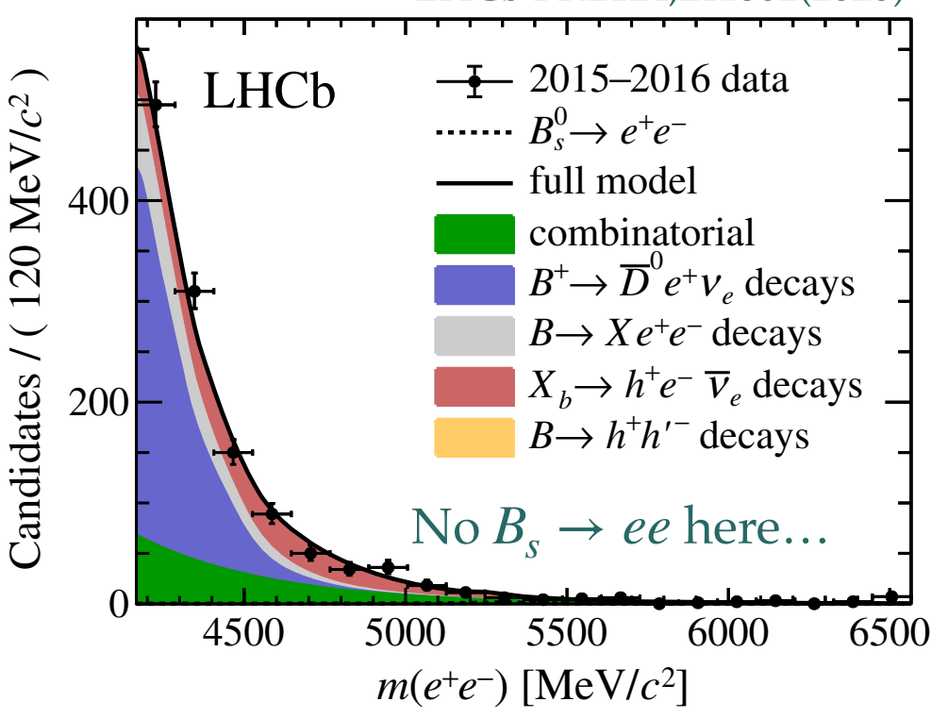
- Search for $B_s \to ee$ (LHCb PRL124,211802(2020))
  - Further suppressed by $(m_e/m_\mu)^2$
  - Signal at current sensitivity would be a clear sign of NP
  - $\text{Br}(B_s^0 \to e^+e^-) < 11.2 \times 10^{-9}$ at 95% CL

- Search for $B_s \to \tau\tau$ (LHCb PRL118(2017)251802)
  - Lifted helicity suppression
  - Difficult signature with at least two neutrinos and no B vertex
  - $\text{Br}(B_s^0 \to \tau^+\tau^-) < 6.8 \times 10^{-3}$ at 95% CL

LHCb JHEP07(2024)101

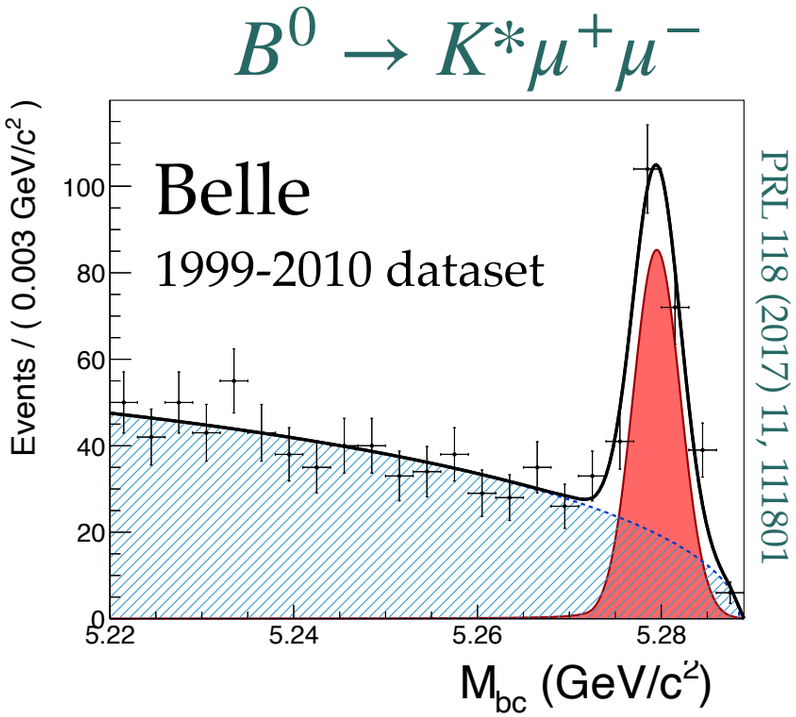


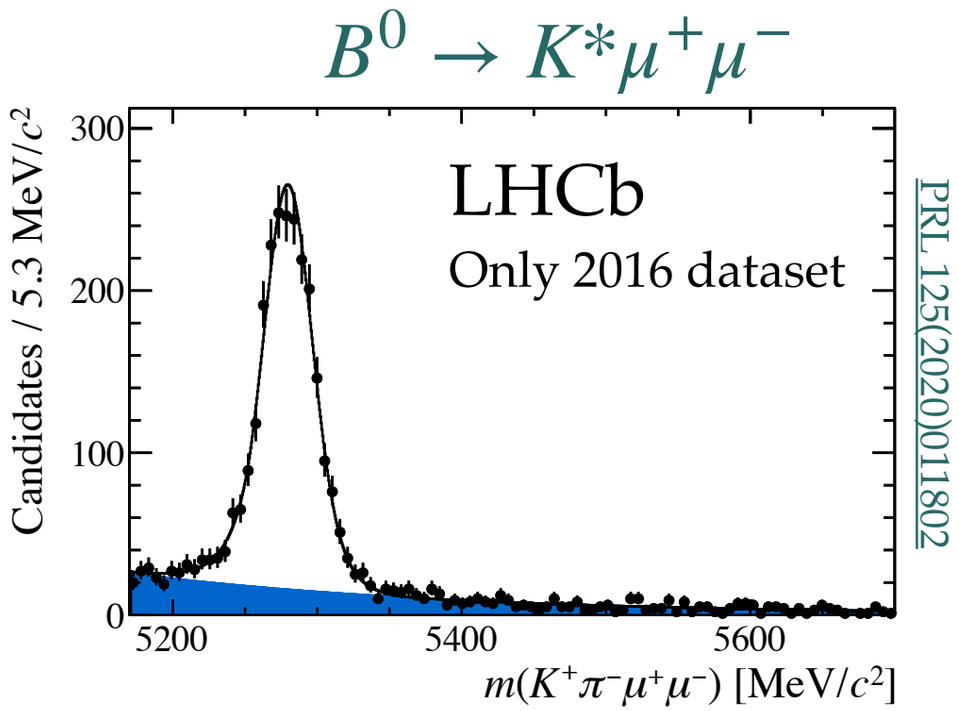
LHCb PRL124,211802(2020)



Semileptonic $b \to s\ell\ell$

LHCb's strength

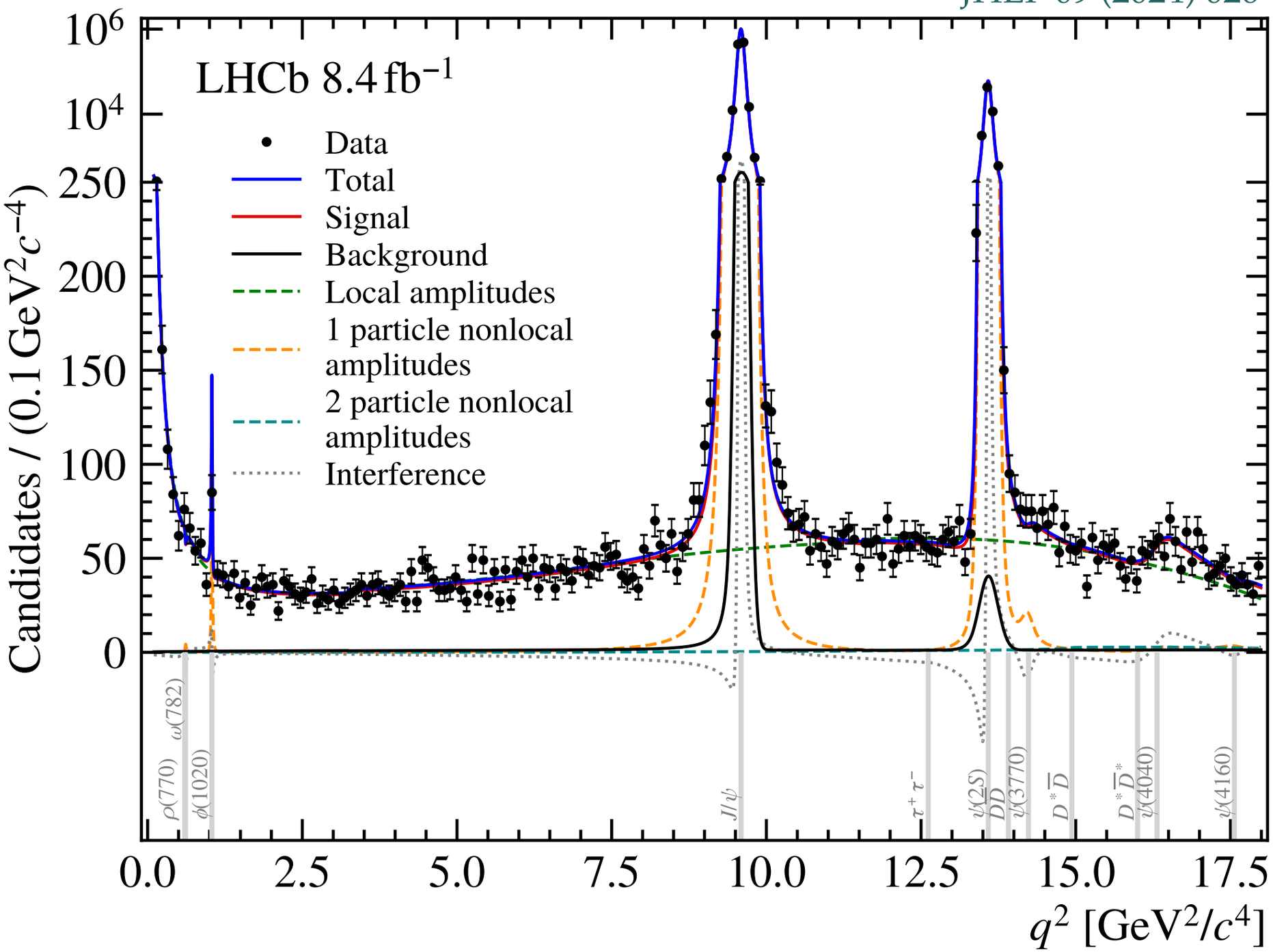




But ~impossible at LHCb
to do $B \to K\nu\bar{\nu}$ and others

The $B^0 \to K^*\mu\mu$ dataset

JHEP 09 (2024) 026



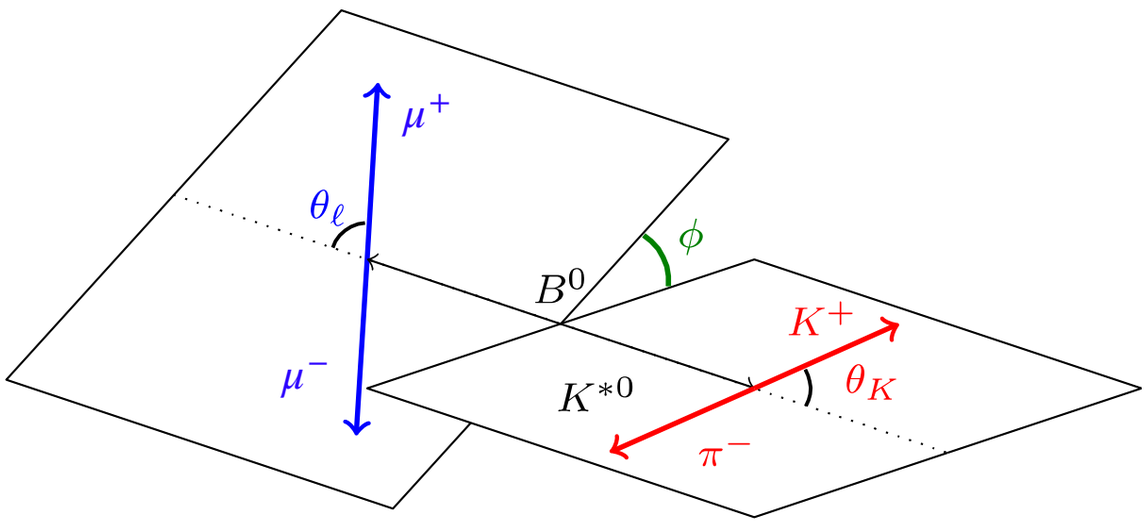
$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)

- New comprehensive analysis measuring model-indep angular observables in q^2 bins
- Using full Run 1+2 dataset (8.4/fb)
  → doubled stat compared to previous analysis

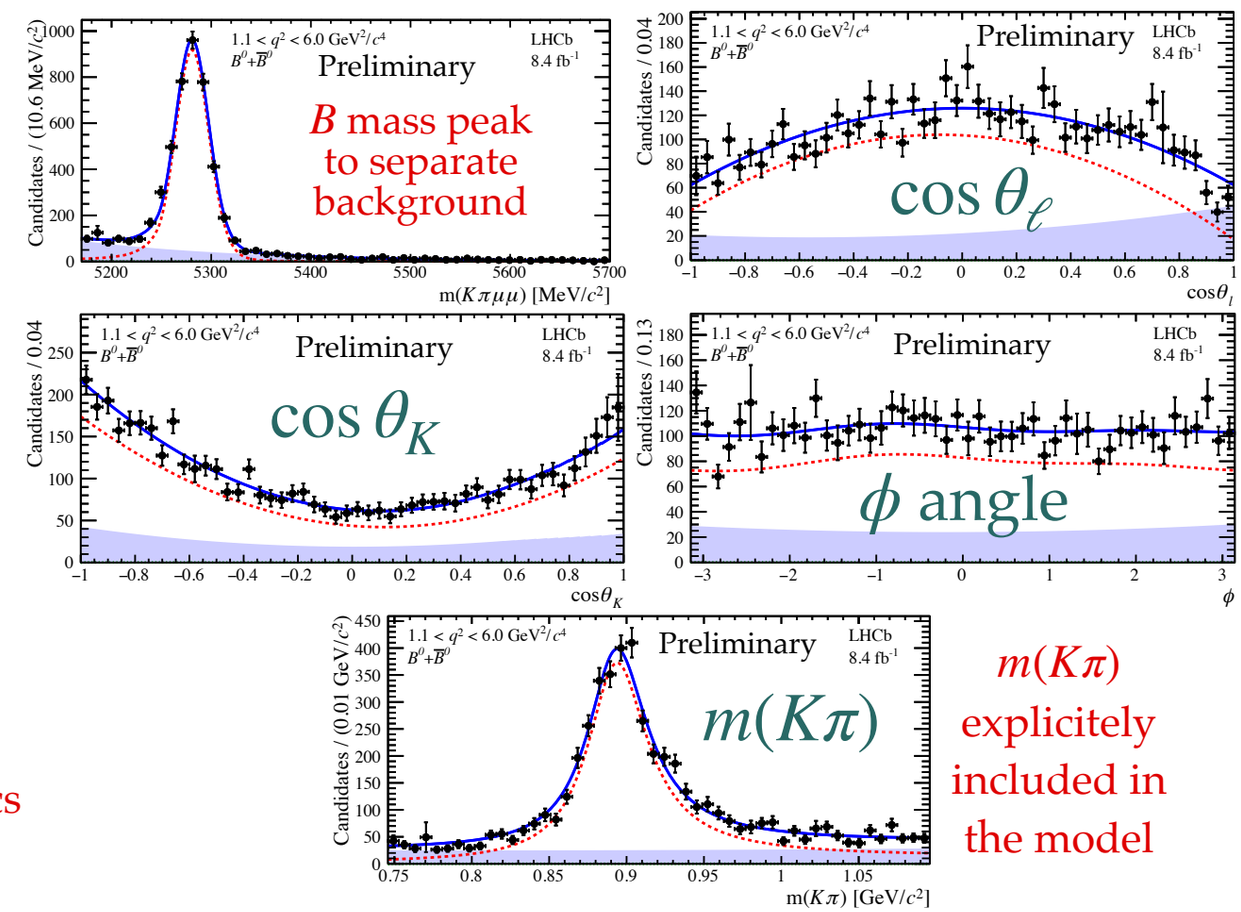
See CERN talks by L.Carus and M.Smith



$$\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\vec{\Omega}\,\mathrm{d}m_{K\pi}}\frac{1}{\Gamma+\bar{\Gamma}} \propto \sum_i S_i(q^2) f_i(\vec{\Omega}) \left|\mathrm{BW}(m_{K\pi})\right|^2$$

Ang. observables — Spherical harmonics

5D fit in large q^2 bin 1-6 GeV^2

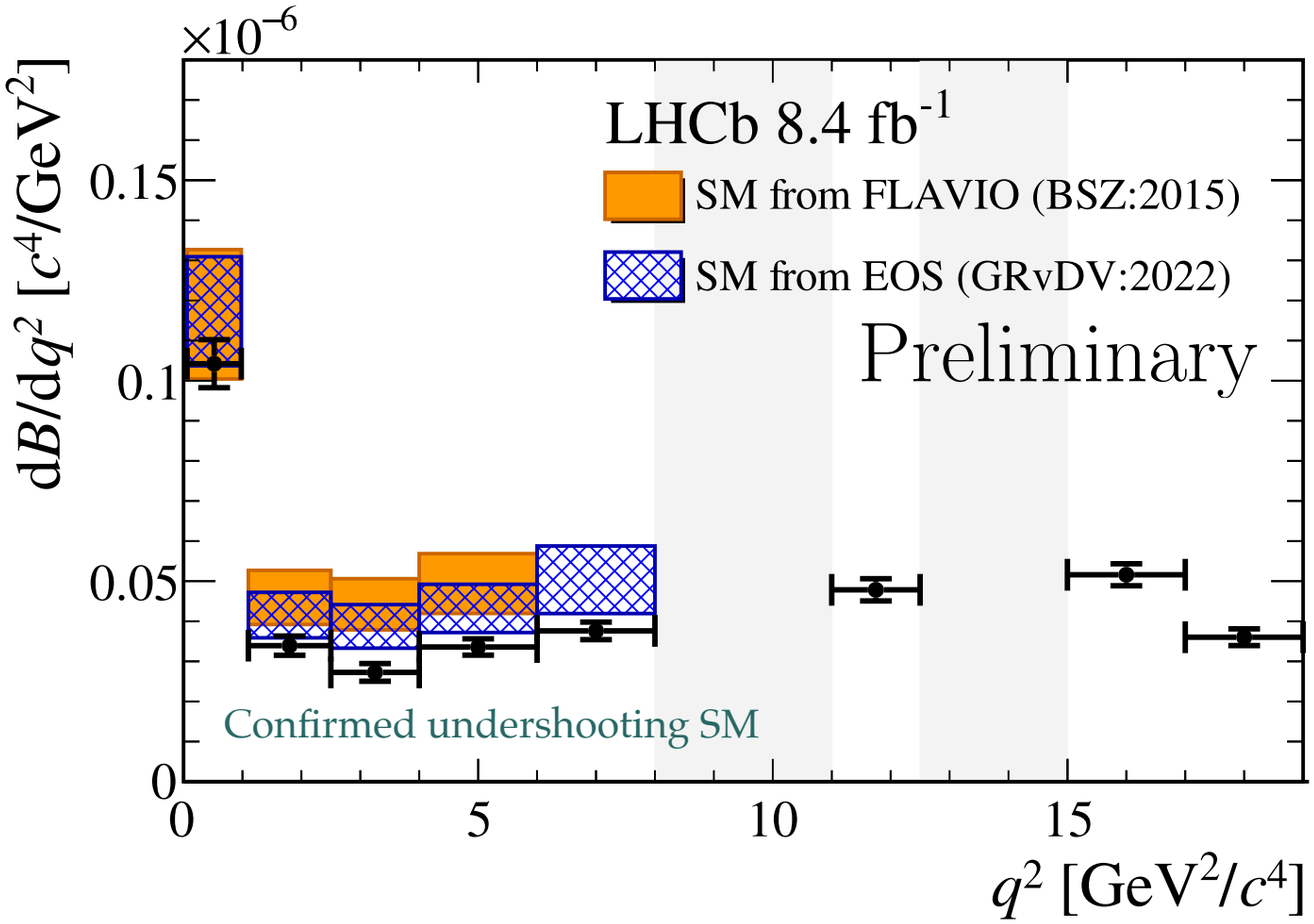


$m(K\pi)$ explicitely included in the model

$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)



- dBr/dq^2 determined simultaneously with the angular shape
- Allows result to be independent on the angular distribution
- Also provides full correlation matrix for global fits of Wilson coeffs

BSZ:
[arXiv:1810.08132]
[JHEP 08 (2016) 098]
GRvDV:
[EPJC 82 (2022) 569]
[JHEP 09 (2022) 133]

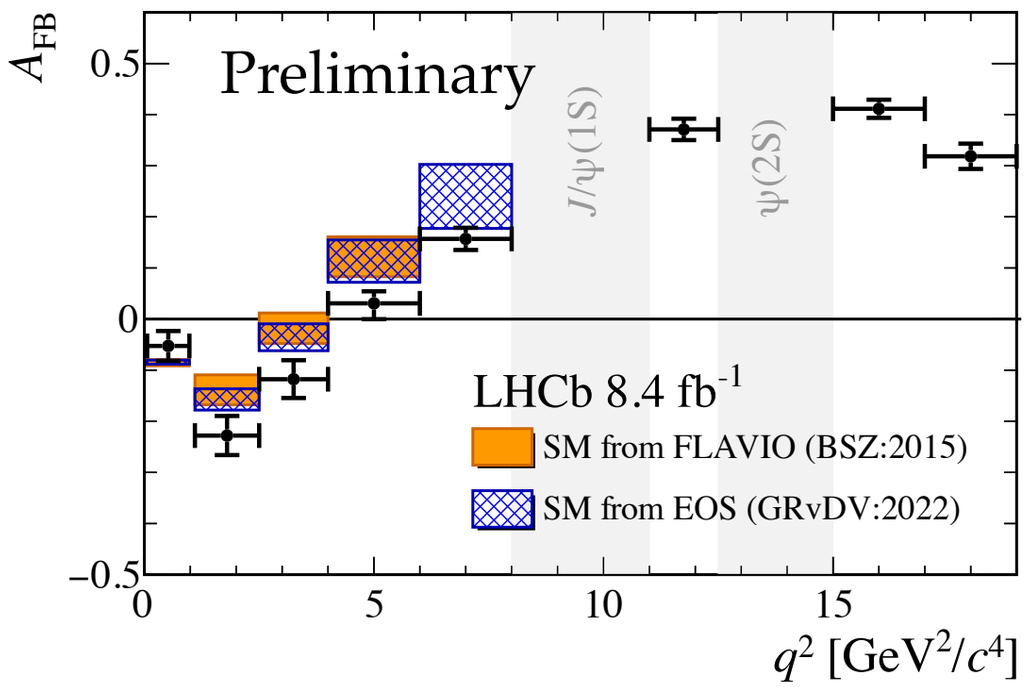
Check CERN seminar for all preliminary results (plots, tables)

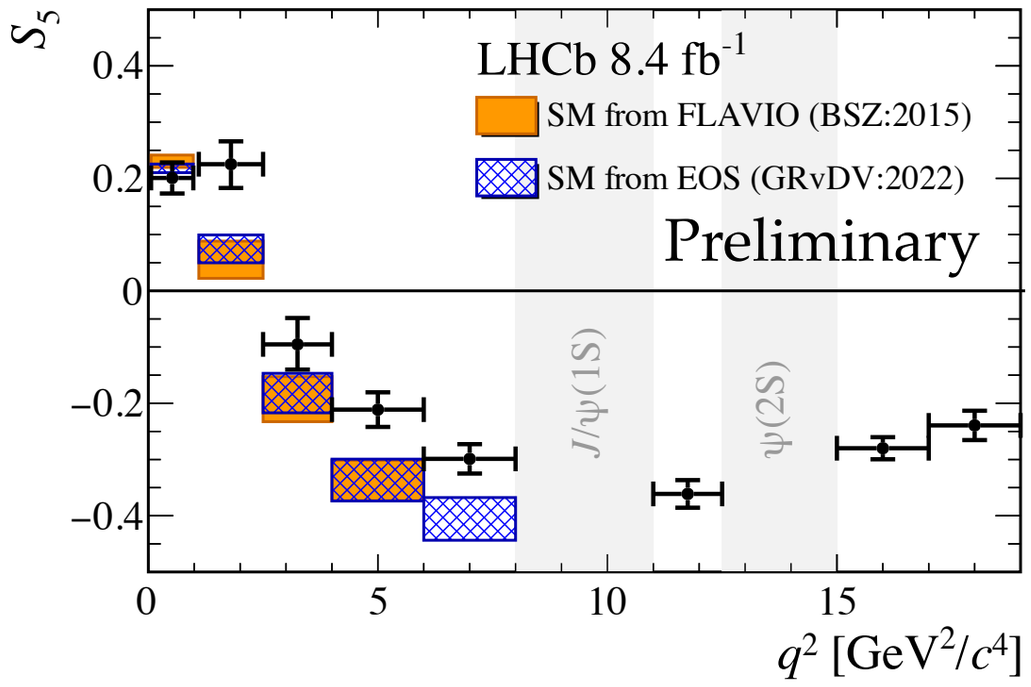
$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)

Here a couple of examples of the fitted angular observables





- Several fit configurations to extract max information with best sensitivity (e.g. assuming or not $m_\mu = 0$, allowing or not A_{CP})
- Also fitting optimised observables (e.g. P_5')
- Shown here: fit with "partially massive model" ($S_1^s = 3S_2^s$ but $S_2^c \neq -S_1^c$) and no CP assymmetries

Check CERN seminar for all preliminary results (plots, tables)

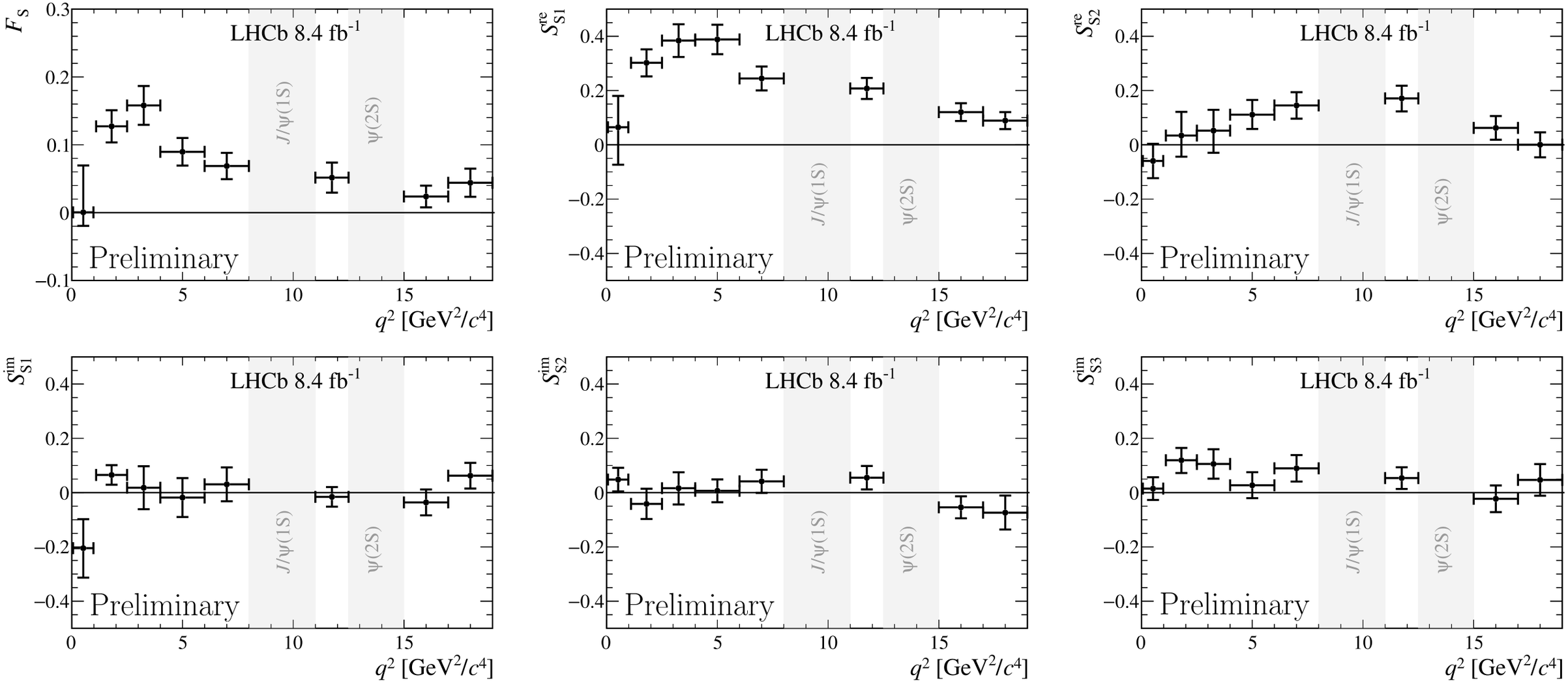
BSZ:
[arXiv:1810.08132]
[JHEP 08 (2016) 098]
GRvDV:
[EPJC 82 (2022) 569]
[JHEP 09 (2022) 133]

$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)

- Fitting also S-wave component and S/P interference observables for the first time



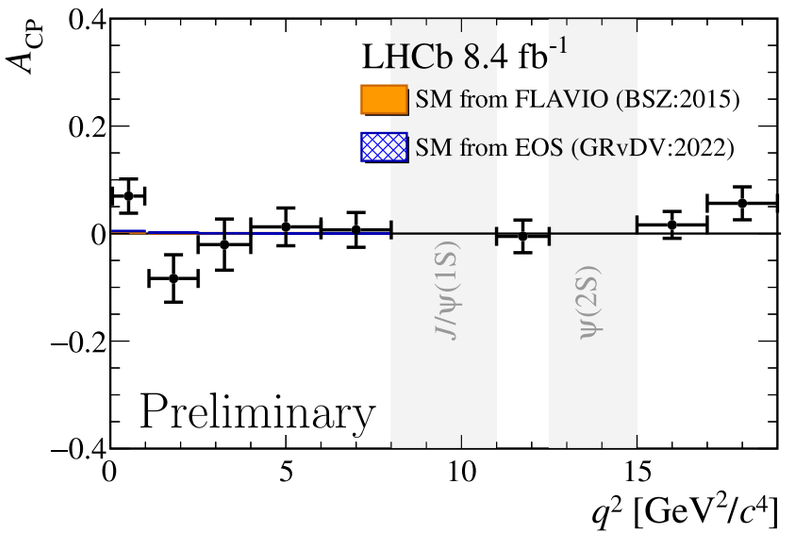
Check CERN seminar for all preliminary results (plots, tables)

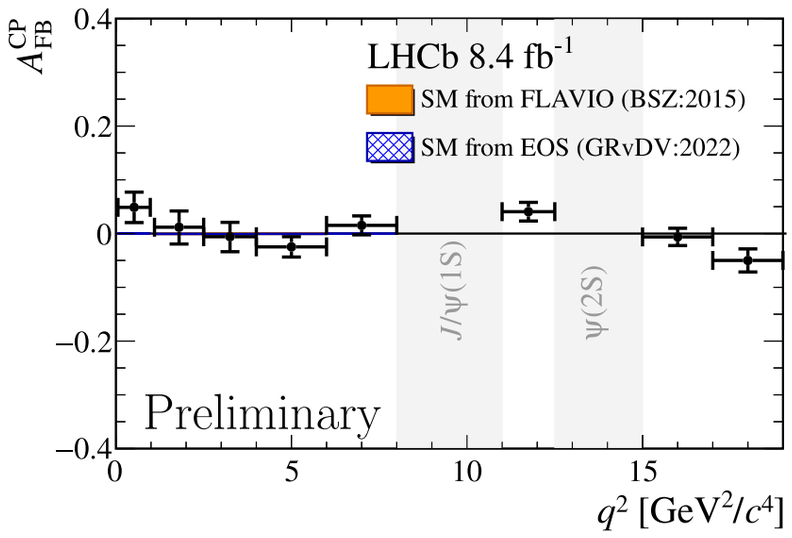
$B^0 \to K^*\mu\mu$ angular analysis

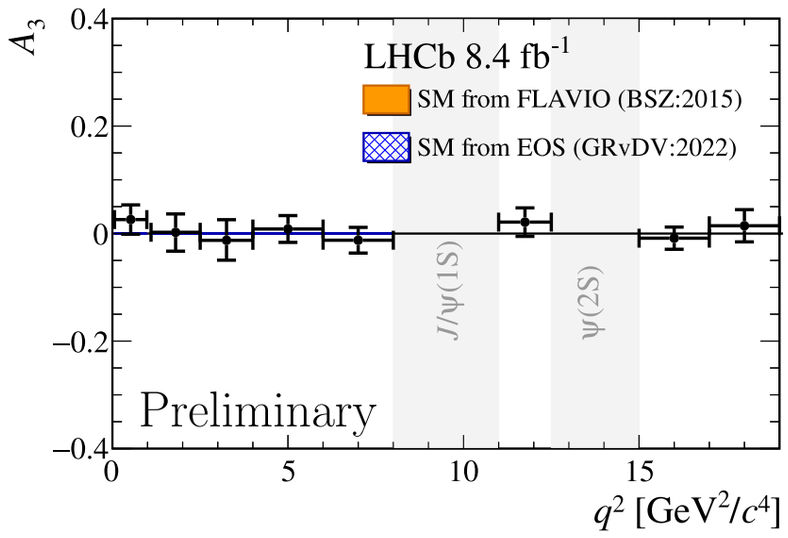
NEW

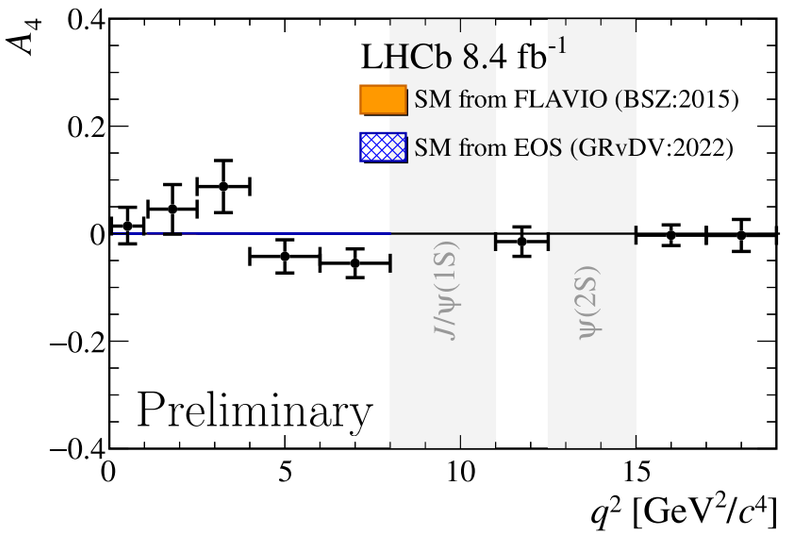
LHCb-PAPER-2025-041 (in preparation)

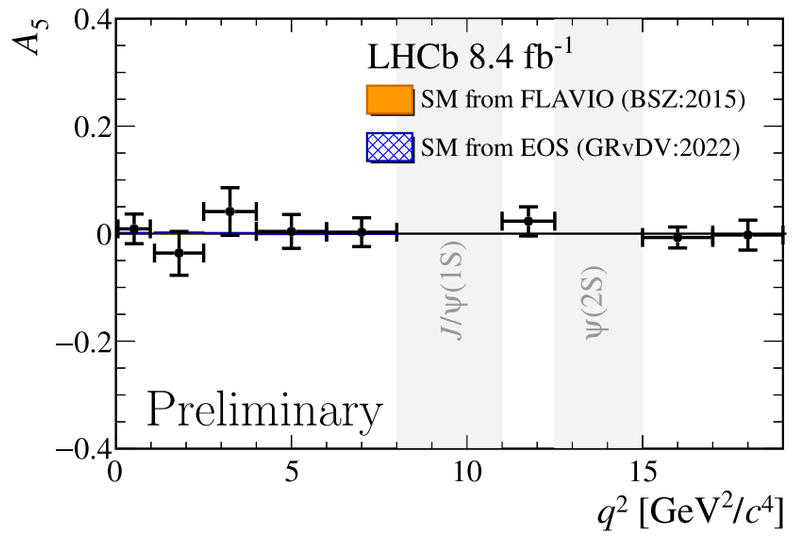
- CP asymmetric angular observables measured:
  no significant CP asymmetry observed

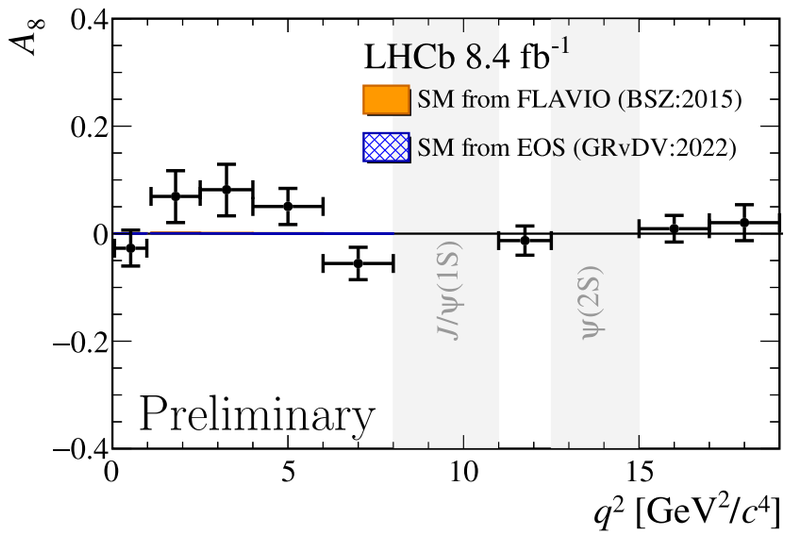










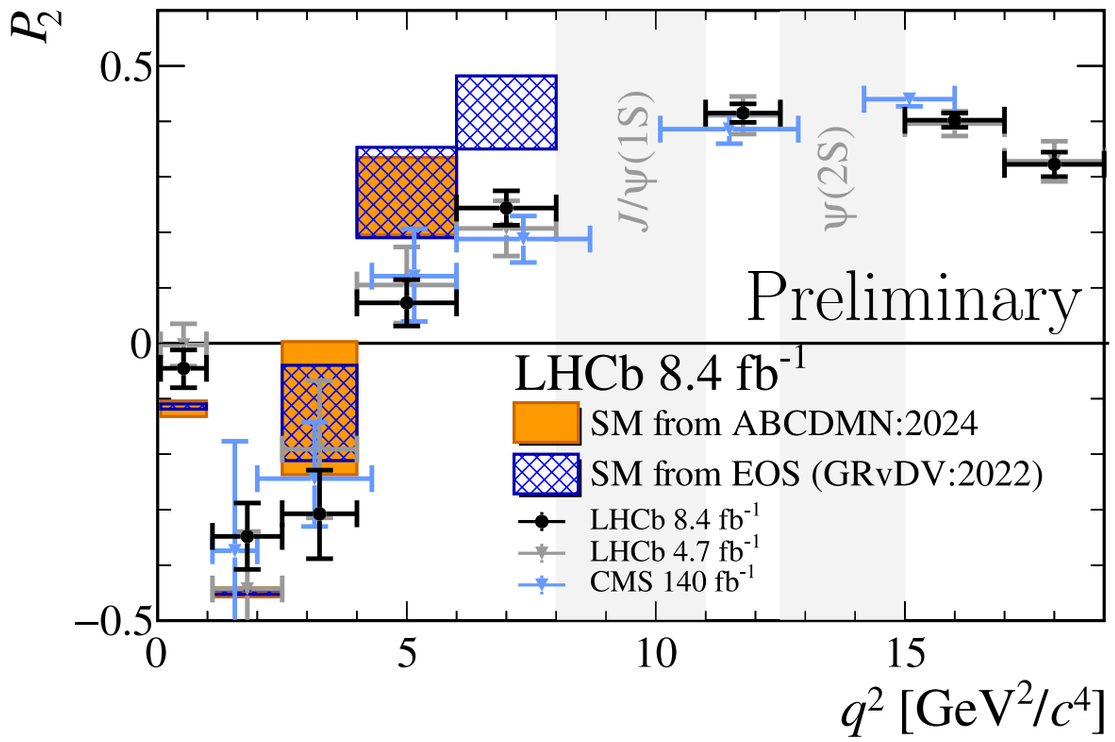


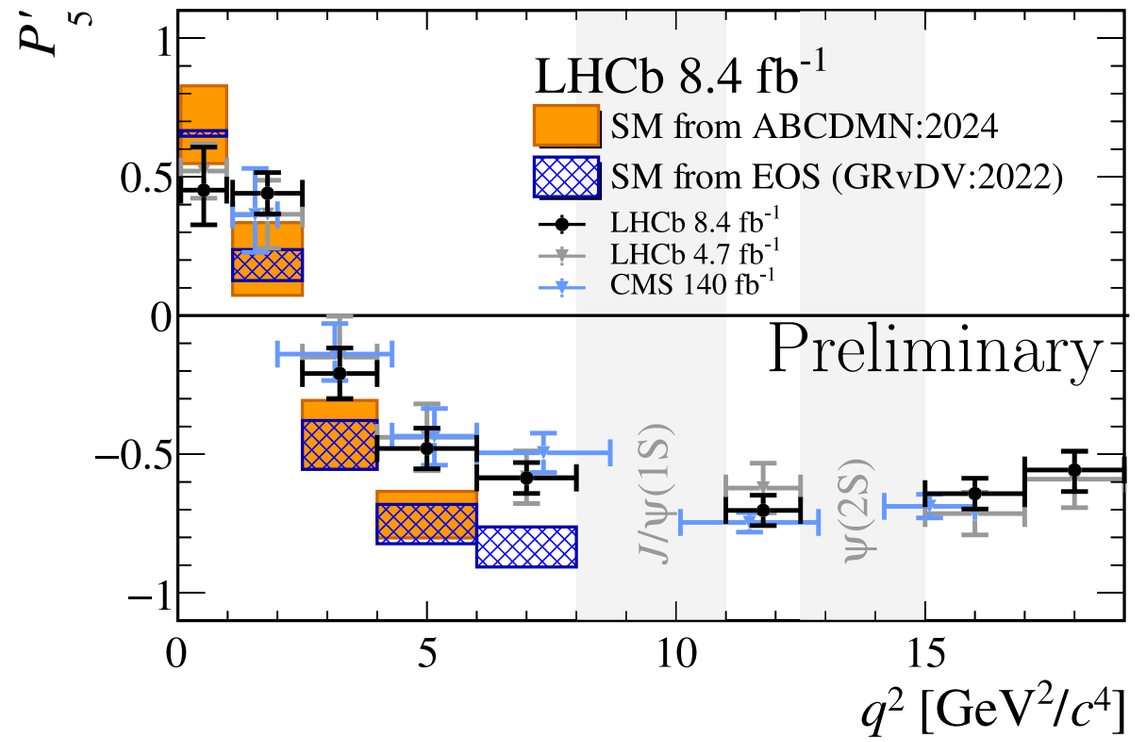
Check CERN seminar for all
preliminary results (plots, tables)

Comparison to previous results

NEW

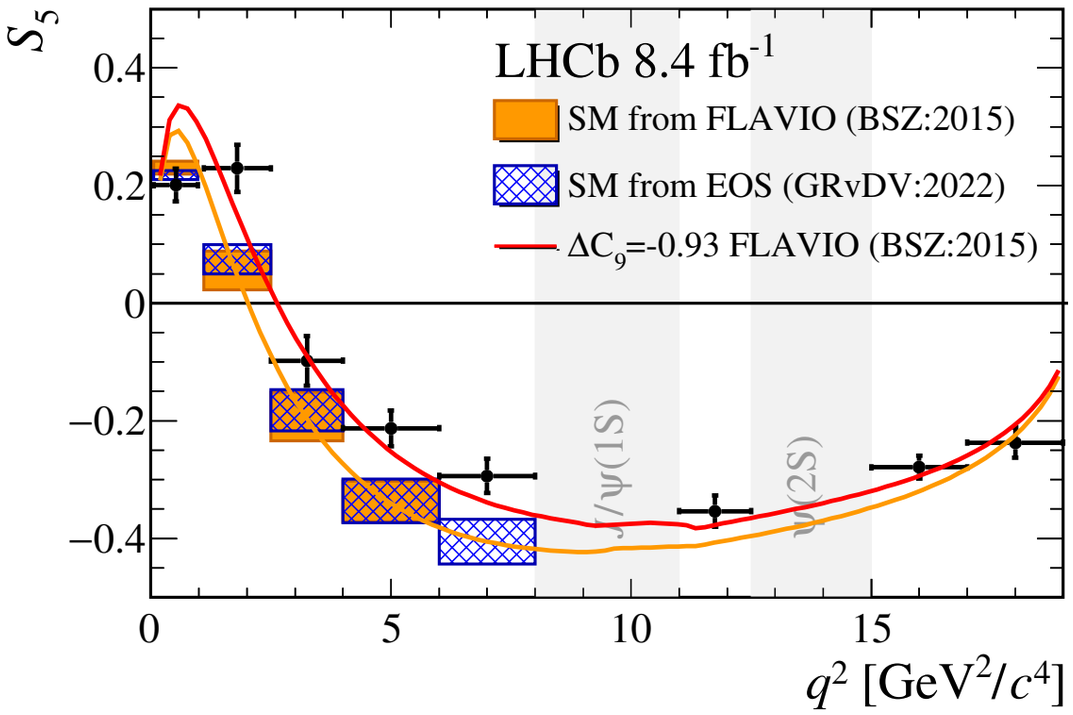
LHCb-PAPER-2025-041 (in preparation)

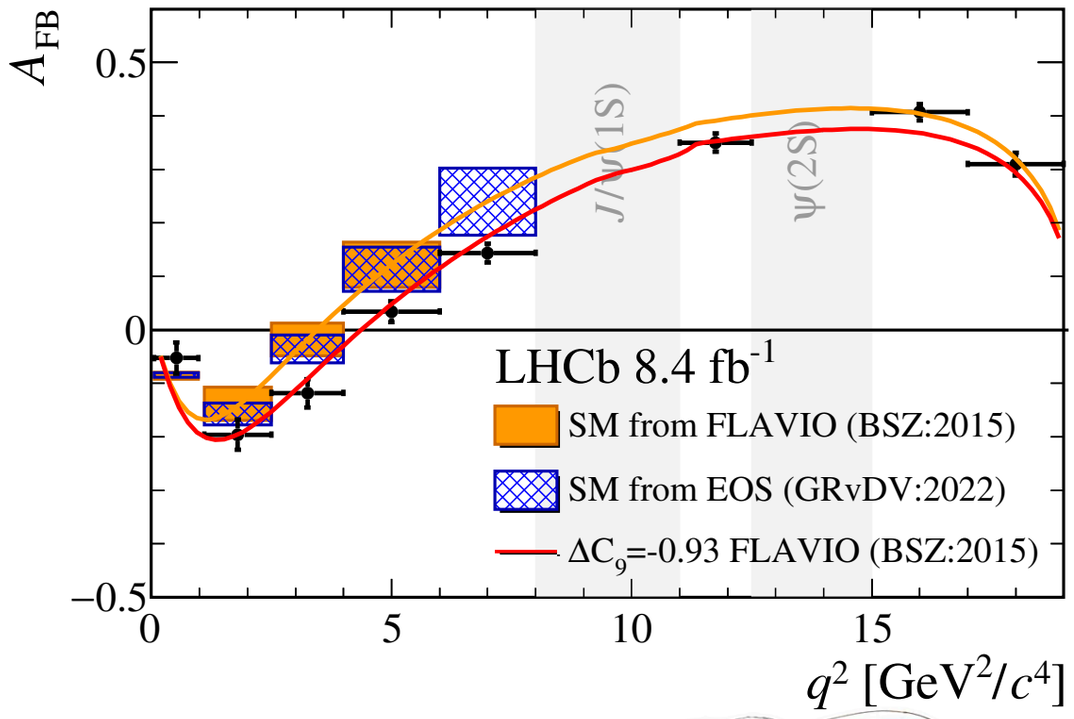




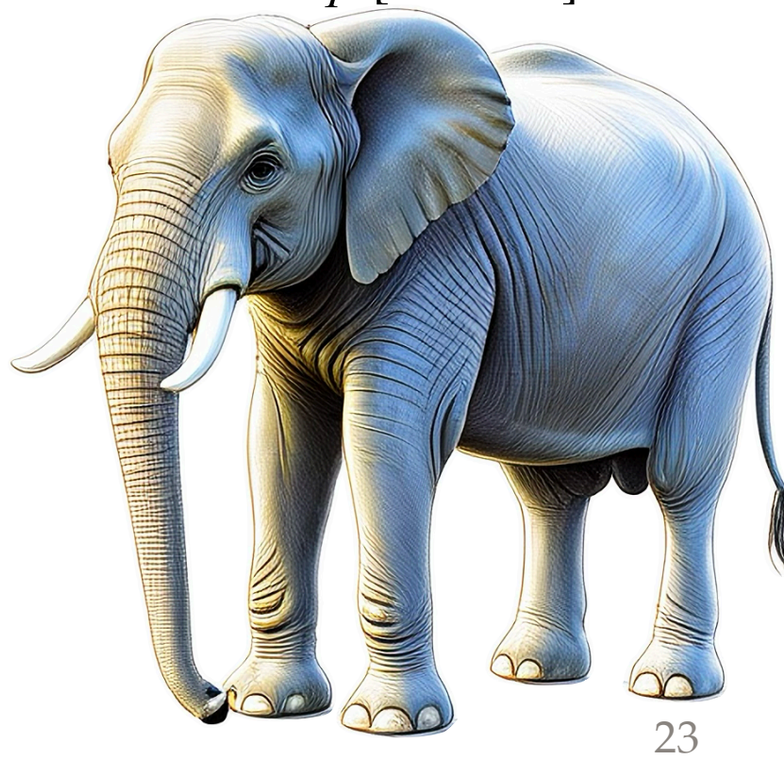
- New result consistent with previous LHCb measurement (superseded)
- Also consistent and more precise than latest CMS measurement (140 fb^{-1})

The anomaly



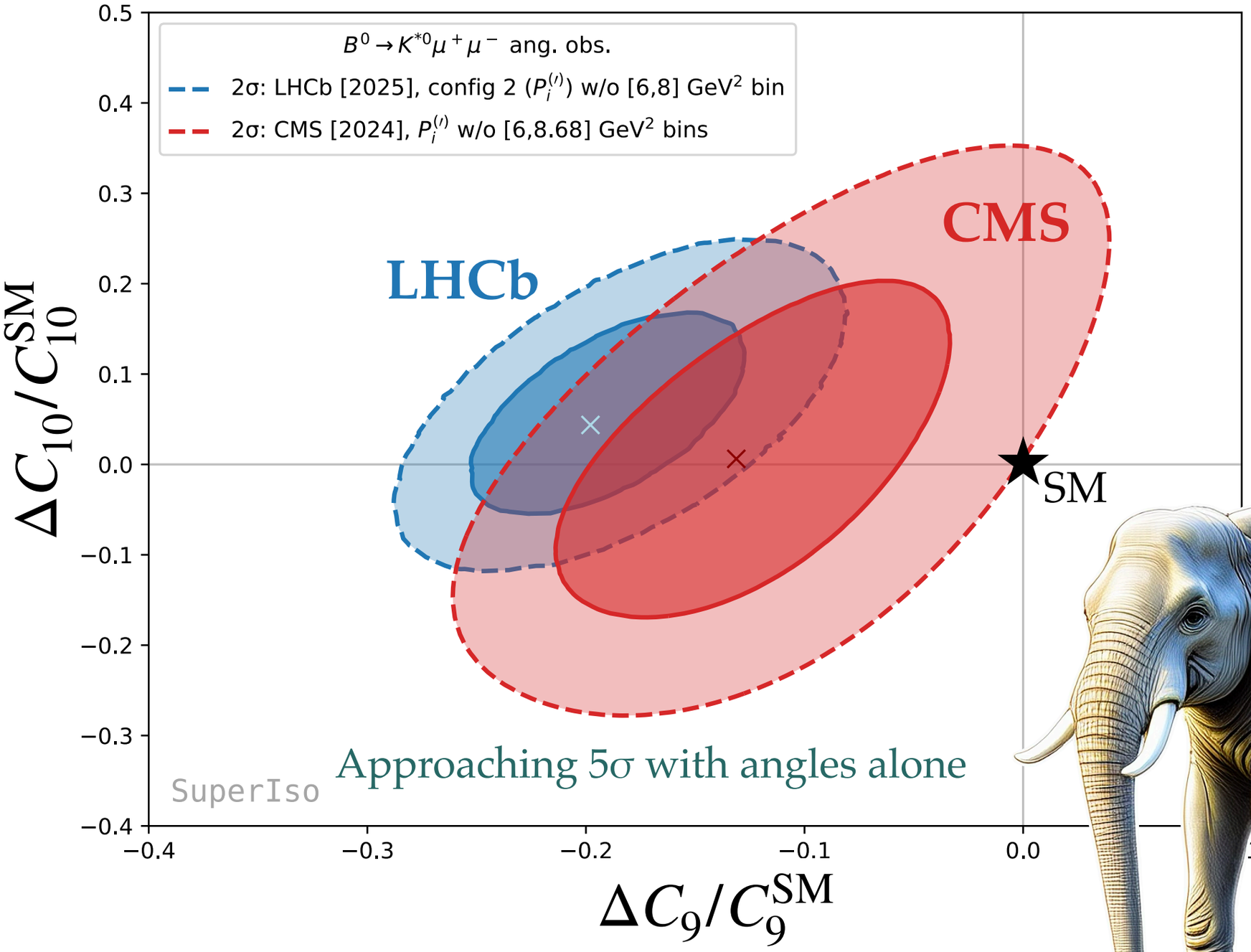


- Improved description of data when shifting C_9 Wilson coefficient!

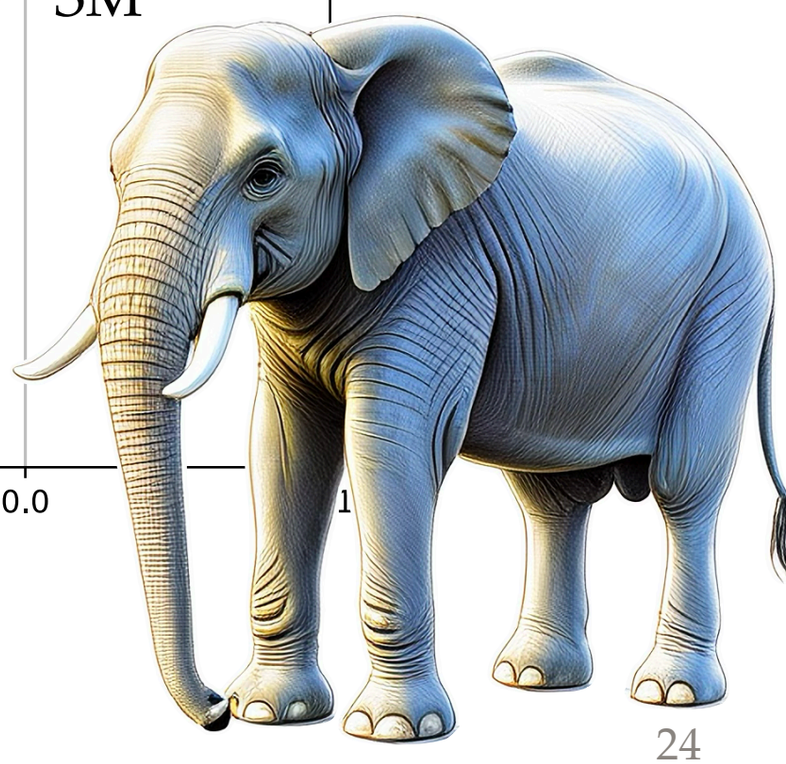


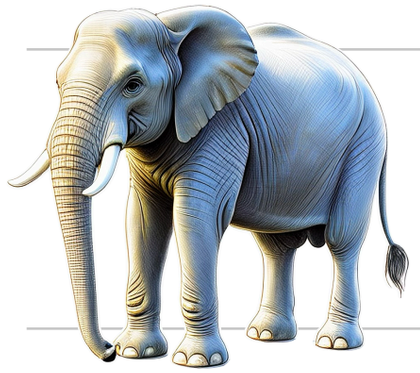
The anomaly

Based on Hurth 2025, updated in Nazila's talk



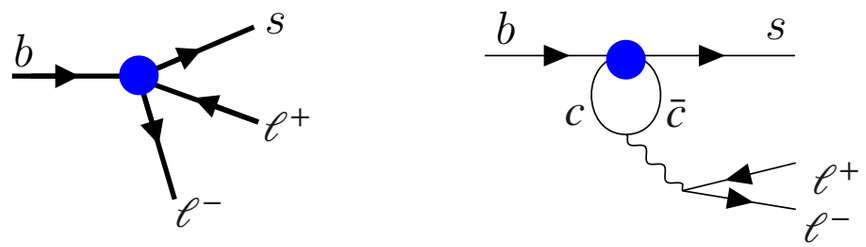
Approaching 5σ with angles alone





Long distance contributions

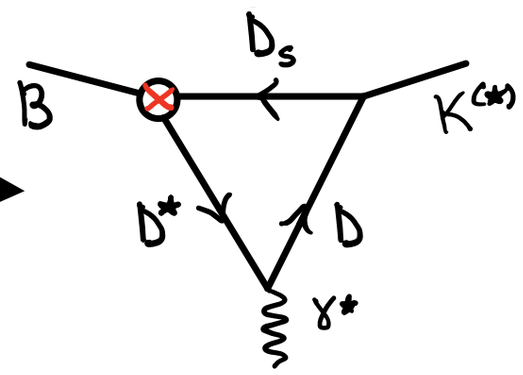
- Long distance contributions can mimic shift in C_9 and are not completely under control theoretically



$$C_{9,\lambda}^{\text{eff}}(q^2) = C_9^{\text{SM}} + \Delta C_9 + H_\lambda(q^2)$$

short distance | long distance

- Steady progress in theory:
  - Recent reviews: Mahmoudi 2024, Gubernari 2024
  - Long-distance triangle rescattering diagrams Ciuchini 2022, Mutke 2024, Gopal 2024, Isidori 2025
  - First framework for Lattice calculation Gagliardi 2025



- Model-dependent fits of $\Delta C_9 + H_\lambda(q^2)$ to data JHEP 09 (2024) 026
  - Amplitude analysis in full q^2 (including $c\bar{c}$ resonances)
  - Hard to disentangle ΔC_9 and $H_\lambda(q^2)$, but the $H_\lambda(q^2)$ model used does not completely account for the observed anomaly

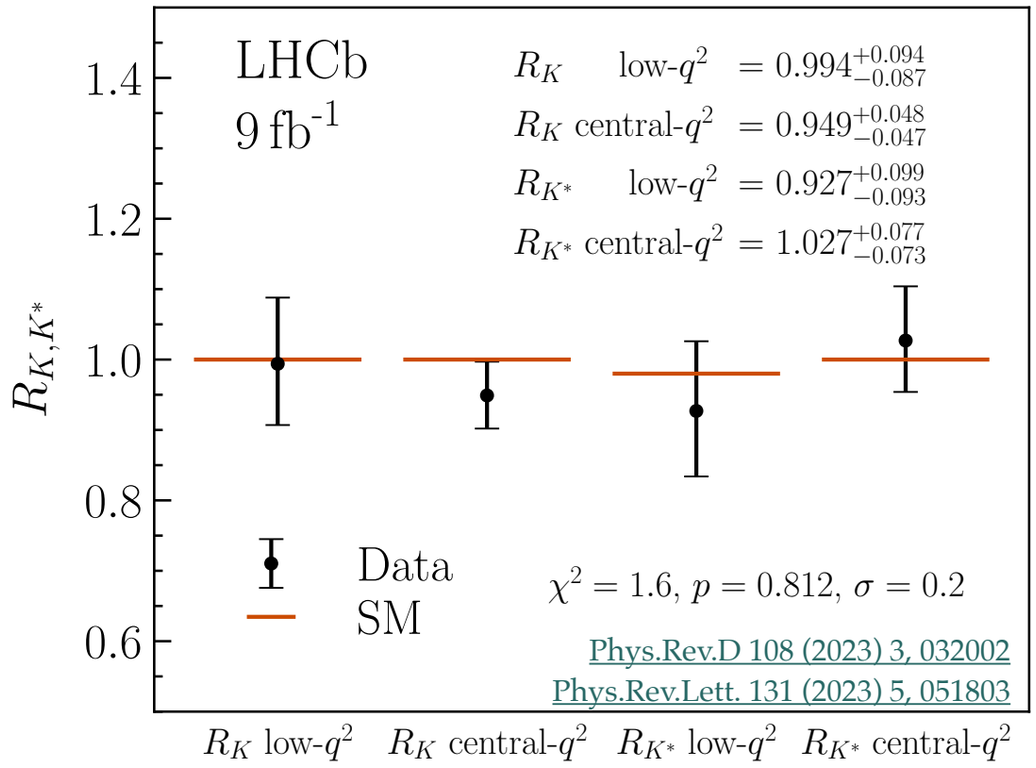
The lepton flavour dimension

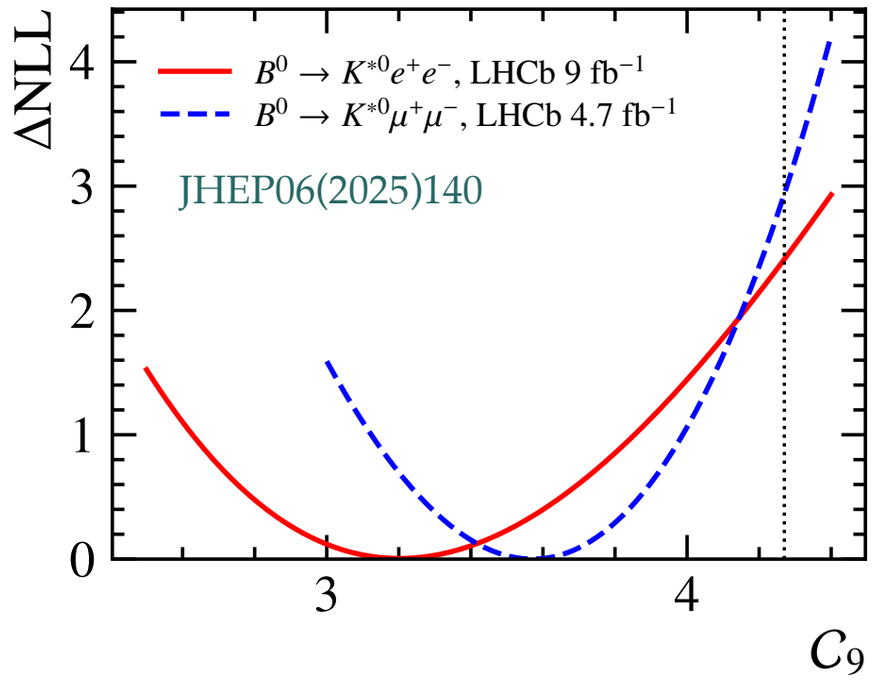
The lepton flavour dimension

- Using $b \to s\ell\ell$ to test lepton flavour universality up to high energy scales
- Hadronic uncertainties do not affect LFU tests (modulo lepton mass)
- **Tested extensively in $bs\mu\mu$ vs $bsee$**
- Ratios of branching fractions (e.g. R_K) with several channels and q^2 bins
  - Latest is R_K at high q^2 JHEP07(2025)198
- **Now tested also with angular analyses** of $B^0 \to K^*ee$ and $B_s \to \phi ee$ JHEP06(2025)140, JHEP07(2025)069

NEW

LFU hold to better than 5% in $bs\mu\mu$ vs $bsee$



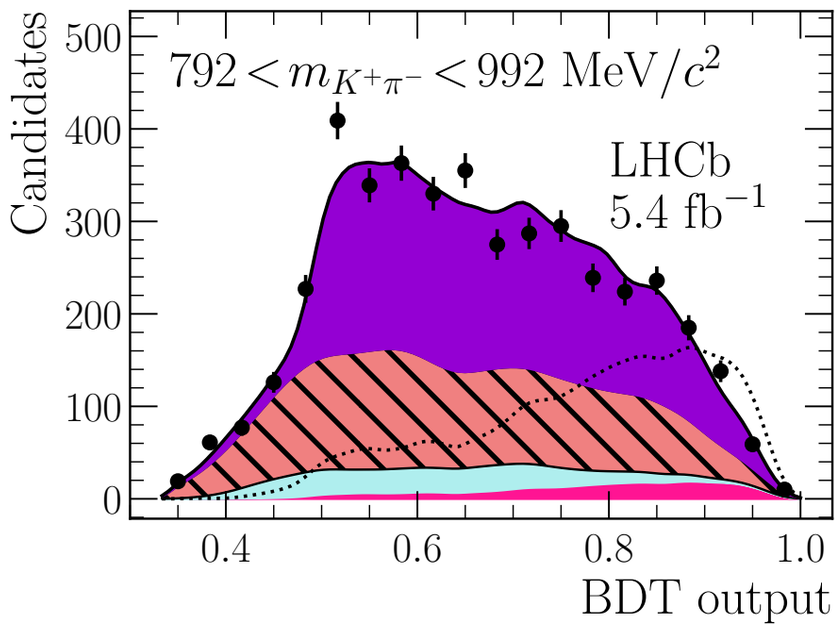


Searches for $b \to s\tau\tau$

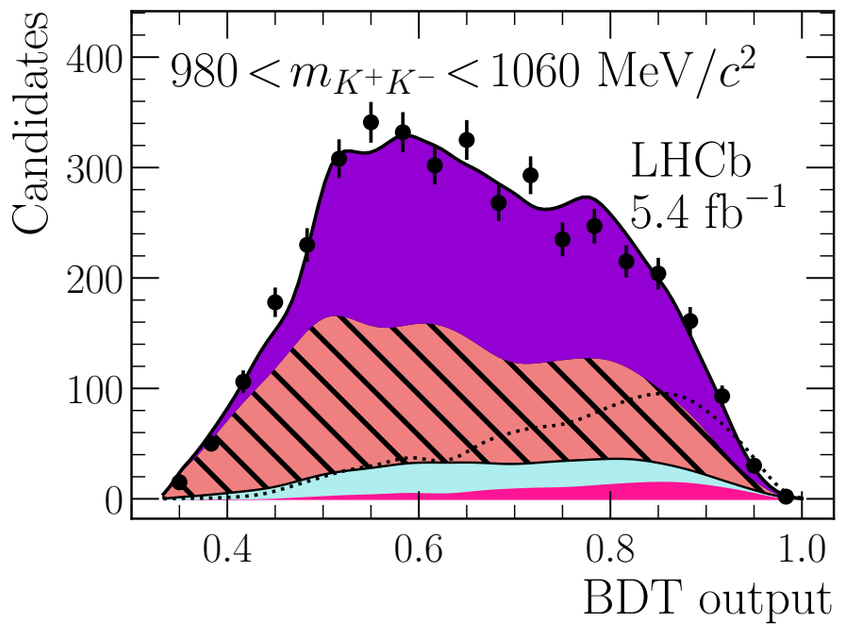
LHCb, arXiv:2510.13716

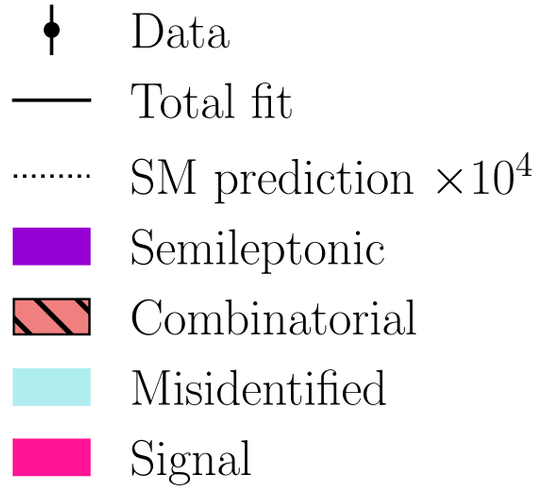
- $b \to s\tau\tau$ decays poorly studied because of experimental difficulties
- Models addressing $b \to s\ell\ell$ and $b \to c\ell\nu$ anomalies often predict huge $b \to s\tau\tau$ enhancements
- New search at LHCb base on muonic $\tau\tau \to \mu\mu + 4\nu$ final state
  - Based on topology, kinematics and fit to ML classifier output
  - One order of magnitude better sensitivity than previous searches!

$\mathrm{Br}(B^0 \to K^*\tau\tau) < 2.5 \times 10^{-4}$ at 90% CL



$\mathrm{Br}(B_s^0 \to \phi\tau\tau) < 4.1 \times 10^{-4}$ at 90% CL



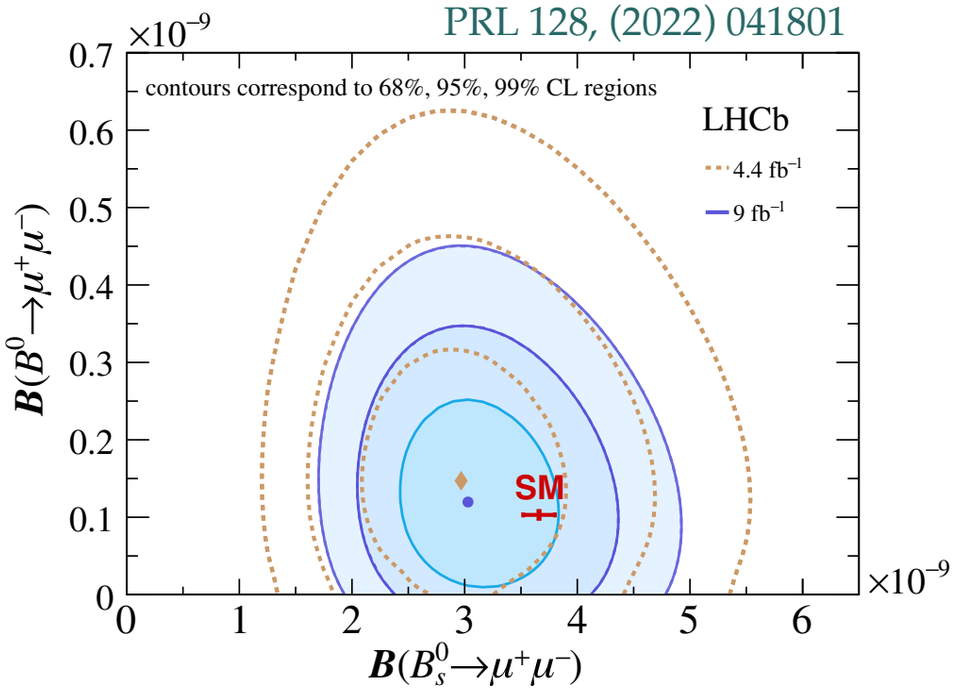


Electroweak FCNC in $b \to d$

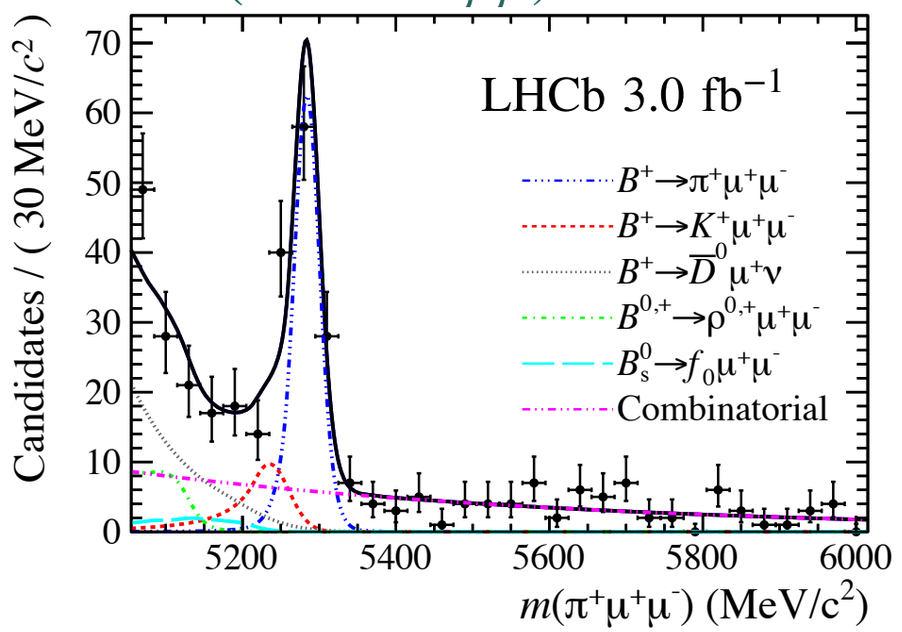
$b \to d$ FCNC decays

- A further $|V_{td}/V_{ts}|^2 = \simeq 0.05$ suppresion of decay rates w.r.t. $b \to s$
  - Starting to explore the $b \to d$ frontier
- Leptonic $B_d \to \mu\mu$ is almost at reach of experimental sensitivity
- $B^+ \to \pi^+\mu\mu$ measured with Run 1 dataset at 13% stat precision
- Many ongoing $b \to d\ell\ell$ analyses. We are about to enter the precision regime (time-dep, angular, …)
  → **Stay tuned for upcoming results**

PRL 128, (2022) 041801



$N(B^+ \to \pi^+\mu\mu) = 94 \pm 12$



Radiative $b \to d\gamma$

NEW

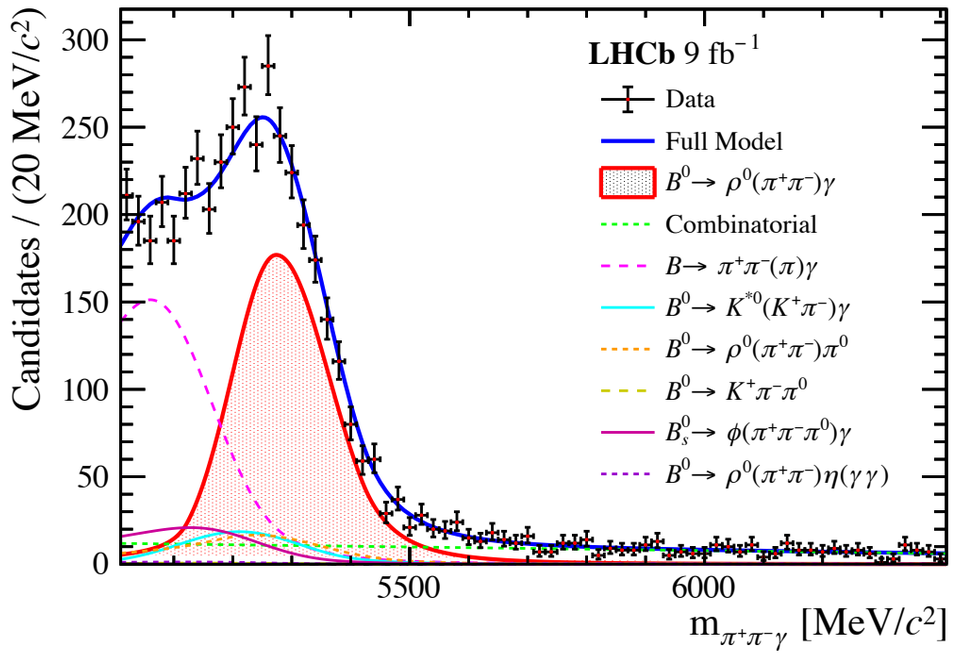
- **New**: Precise measurement of $B^0 \to \rho\gamma$
  $\mathrm{Br}(B^0 \to \rho\gamma) = (7.9 \pm 0.3 \pm 0.2 \pm 0.2) \times 10^{-7}$
  LHCb, arXiv:2507.14401

- **Preliminary**: 3.5σ Evidence for $B_s^0 \to K^*\gamma$
  LHCb-PAPER-2025-056 in preparation
  - Enhanced resolution from photon conversions to disentangle from $B^0 \to K^*\gamma$

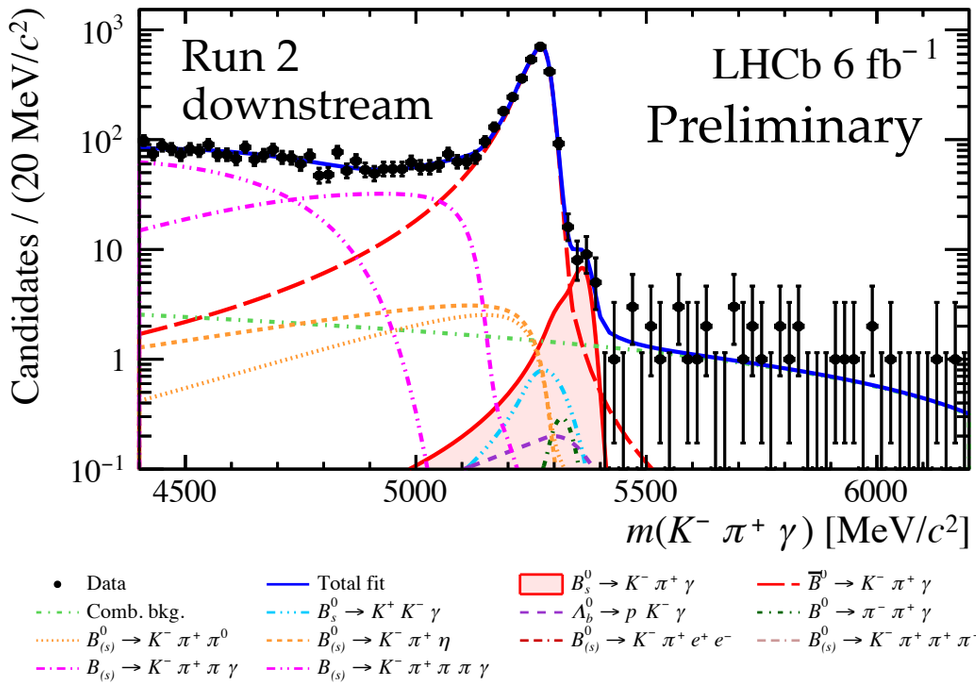
$$\frac{\mathcal{B}(B_s^0 \to K^-\pi^+\gamma)}{\mathcal{B}(\bar{B}^0 \to K^-\pi^+\gamma)} = (3.7 \pm 1.2 \pm 0.4) \times 10^{-2} \quad \text{(stat., sys.)}$$
$$\text{for} \quad 796 < m(K^-\pi^+) < 996\ \text{MeV}/c^2$$

  - In excellent agreement with SM prediction
    $\dfrac{\mathrm{Br}(B_s^0 \to K^*\gamma)}{\mathrm{Br}(B^0 \to K^*\gamma)} = (3.9 \pm 0.7) \times 10^{-2}$
    (Ball 2007 with updated inputs)
  - More precise prediction technically possible thanks to excellent cancellation of hadronic uncertainties

$N(B^0 \to \rho^0\gamma) = 1917 \pm 71$



$N(B_s^0 \to \phi\gamma) = 32 \pm 11$



Conclusions

- The LHCb experiment marked **a new era for rare B decays**
  - Very large yields allowing more and more sophisticated analyses
  - Probing large number of WCs to ever high precision,
    most are far from being limited by theory or syst uncertainties
  - Persistent anomaly in C_9 under scrutiny: long distance? 

- Many new results from 2025 presented today:
  - Comprehensive model-independent analysis of $B \to K^*\mu\mu$
  - First evidence for $B_s^0 \to K^*\gamma$ and precise measurement of $B^0 \to \rho^0\gamma$
  - Tests of lepton universality in $b \to s\ell\ell$ angular analyses
  - World-best upper limits on Br of $B^0 \to K^*\tau\tau$ and $B_s \to \phi\tau\tau$

"Extraordinary claims require extraordinary evidence"
Carl Sagan

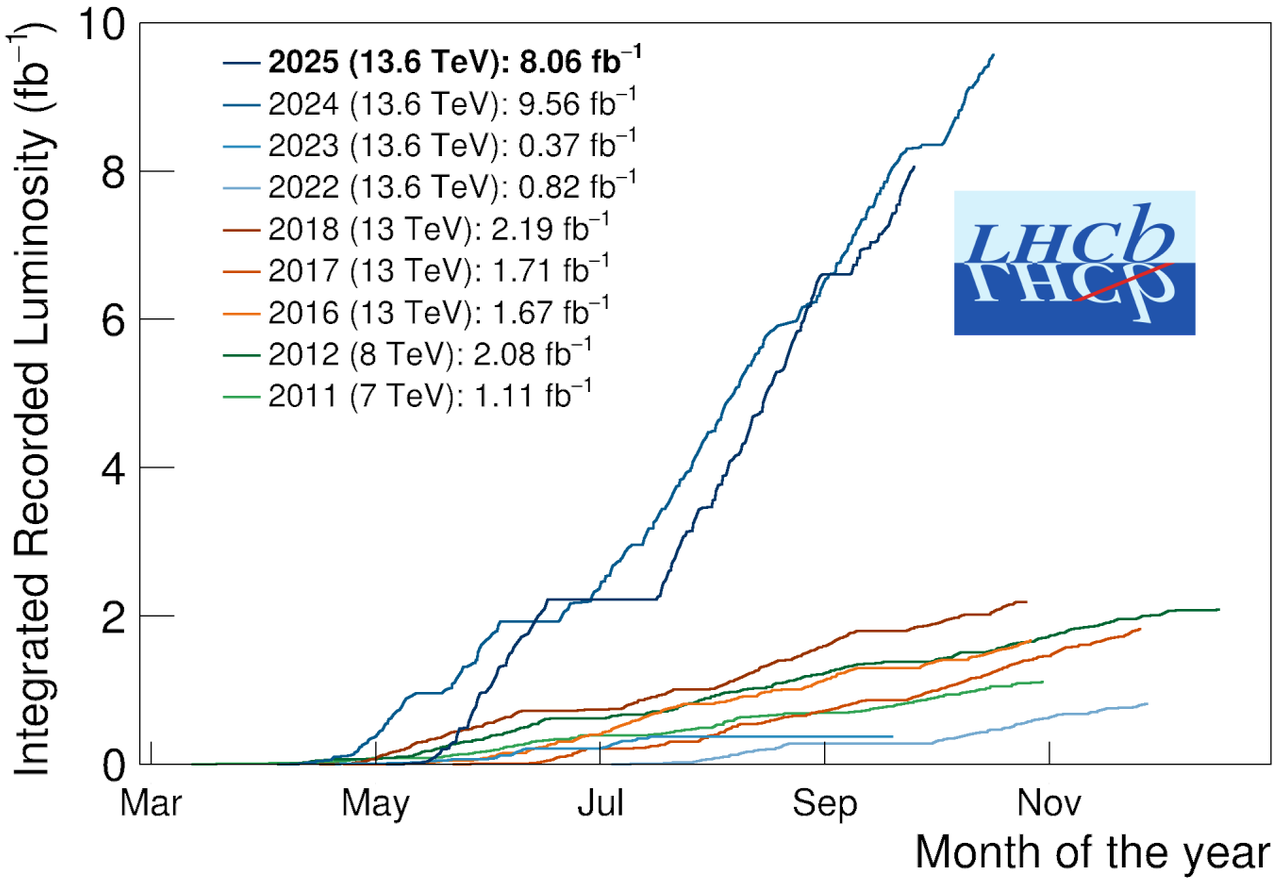
"Discovery commences with the awareness of anomaly"
Thomas Kuhn

BACKUP

Current LHCb detector

- Upgraded to run at 5 × luminosity
  - Removed hardware trigger: reading out full detector in real time (30 MHz)
  - Real time analysis allows more precise and efficient triggering
- **Upgrade II** aims to collect 300/fb by end of HL-LHC, installation by 2036

https://lbgroups.cern.ch/online/OperationsPlots/index.htm

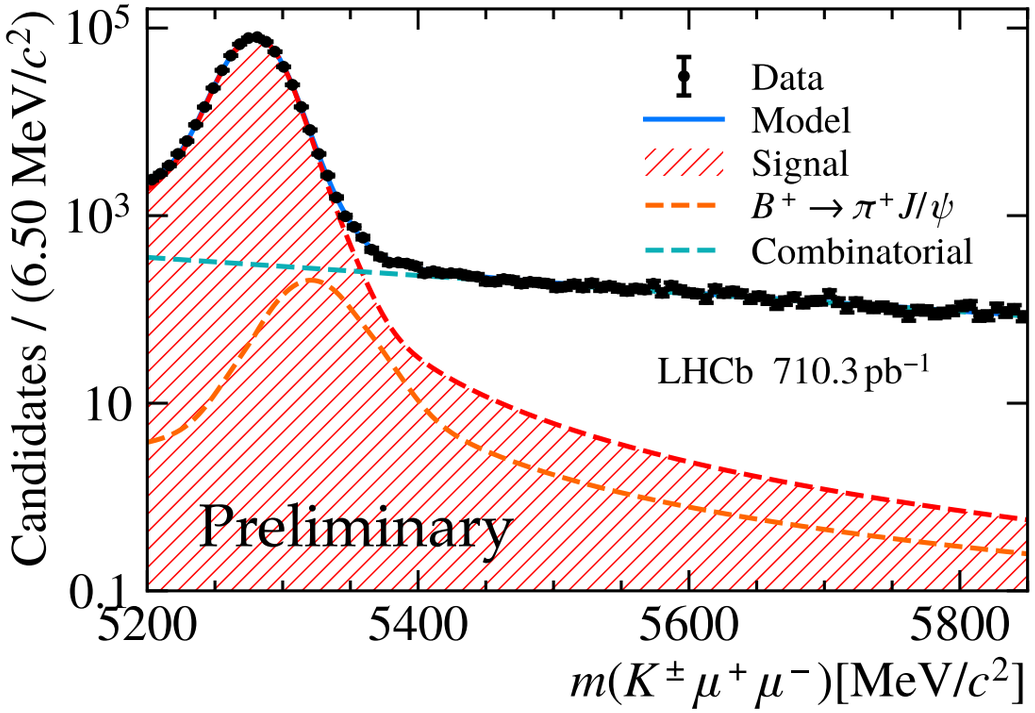


$B^+ \to K^+ J/\psi$ to validate Run3 data

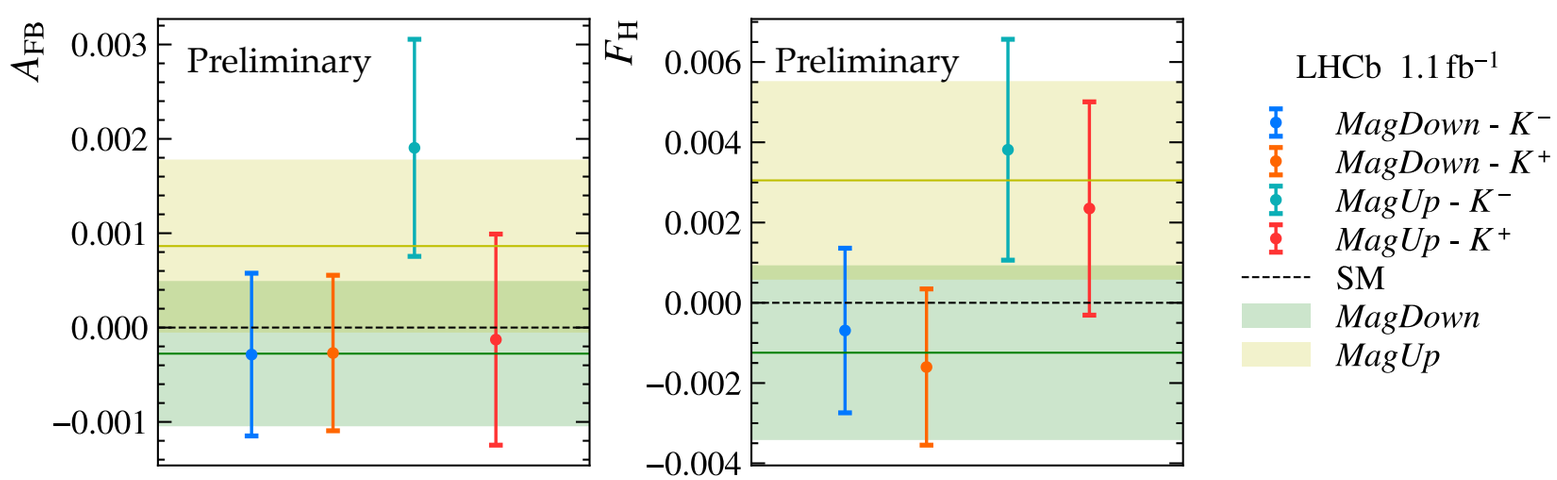
NEW

LHCb-PAPER-2025-040, in preparation

- SM candle with no new physics expected and large stat
- Measured $A_{\rm FB}$ and F_H differentially across kinematic using data from 2024 run with pileup μ=5.3
- Validated $b \to s\mu\mu$ analyses with Run3
- Systematics 5-10 times smaller than stat

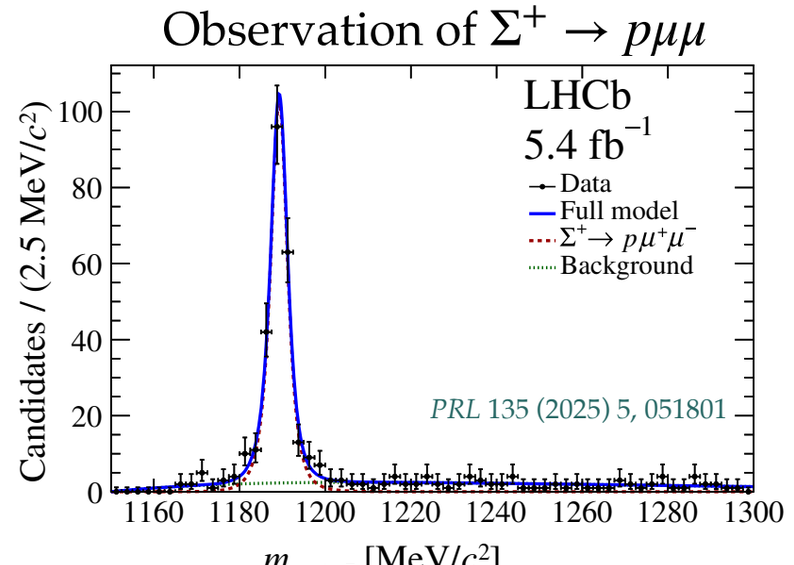


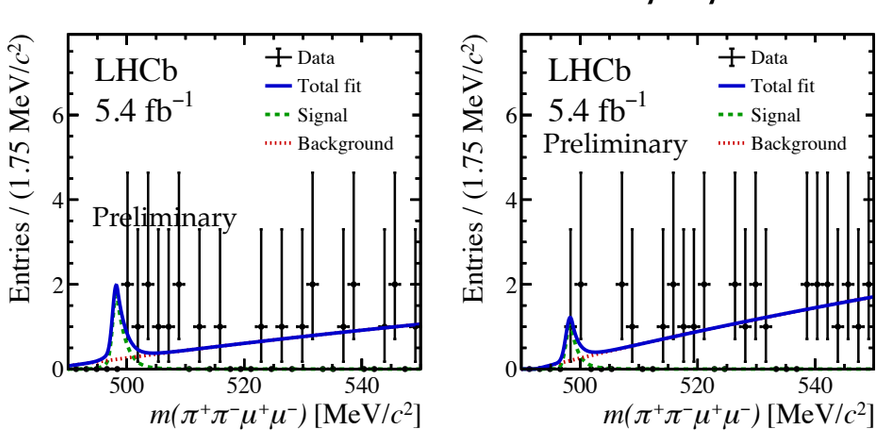
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_\ell} = \frac{3}{4}\left(1 - F_{\rm H}\right)\left(1 - \cos^2\theta_\ell\right) + \frac{1}{2}F_{\rm H} + A_{\rm FB}\cos\theta_\ell$$



Rare Kaon decays at LHCb

- At LHC pp collisions the kaon cross section is ~ 2400 times larger than that of the *b*-quark
- LHCb trigger not designed for kaons, but huge improvements with Run2 and Run3
- LHCb now at the forefront of rare kaon:
  - (i) $Br(K_S \to \mu\mu) < 2.2 \times 10^{-10}$ at 90% CL
  - (ii) $Br(K_S \to \mu\mu\mu\mu) < 5.1 \times 10^{-12}$ at 90% CL
  - (iii) **New! Observation** of $\Sigma^+ \to p\mu\mu$ with $Br = (1.08 \pm 0.17) \times 10^{-8}$
  - (iv) **Very new!** $Br(K_S \to \pi\pi\mu\mu) < 1.4 \times 10^{-9}$ at 90% CL
  - (v) Also anomalous decays of η and η' to $\mu\mu$ and $\pi\pi\mu\mu$





(i) PRL 125 (2020) 231801
(ii) PRD108 (2023) L031102
(iii)PRL 135 (2025) 5, 051801
(iv)LHCb-PAPER-2025-045 in preparation
(v) LHCb-CONF-2025-002

Example of global fit

- $\mathrm{BR}(B \to X_s\gamma)$
- $\mathrm{BR}(B \to K^*\gamma)$
- $\Delta_0(B \to K^*\gamma)$
- $\mathrm{BR}^{\mathrm{low}}(B \to X_s\mu^+\mu^-)$
- $\mathrm{BR}^{\mathrm{high}}(B \to X_s\mu^+\mu^-)$
- $\mathrm{BR}^{\mathrm{low}}(B \to X_s e^+e^-)$
- $\mathrm{BR}^{\mathrm{high}}(B \to X_s e^+e^-)$
- $\mathrm{BR}(B_s \to \mu^+\mu^-)$
- $\mathrm{BR}(B_s \to e^+e^-)$
- R_K in the low q^2 bin
- R_{K^*} in 2 low q^2 bins
- R_ϕ in low and high q^2 bins
- $\mathrm{BR}(B \to K^0\mu^+\mu^-)$
- $B \to K^+\mu^+\mu^-$: BR, F_H
- $B \to K^*e^+e^-$: BR, F_L, $P_{1,2,3}$, $P'_{4,5,6,8}$, in [1.1, 6] bin (LHCb) and $A_T^{(2)}$ in [0.008, 1.12] bin (Belle)
- $B \to K^{*0}\mu^+\mu^-$: BR, F_L, $P_{1,2,3}$, $P'_{4,5,6,8}$, S_1^c, S_2^s, S_6^c in low q^2 and high q^2 bins
- $B^+ \to K^{*+}\mu^+\mu^-$: BR, F_L, A_{FB}, S_3, S_4, S_5, S_7, S_8, S_9 in low q^2 and high q^2 bins
- $B_s \to \phi\mu^+\mu^-$: BR, F_L, S_3, S_4, S_7, $A_T^{(2)}$ in low q^2 and high q^2 bins
- $\Lambda_b \to \Lambda\mu^+\mu^-$: BR, A_{FB}^ℓ, A_{FB}^h, $A_{FB}^{\ell h}$, F_L in high q^2 bins
- $B_s \to \phi e^+e^-$ in low q^2 and high q^2 bin

Fit to 263 exp observables using SuperIso code

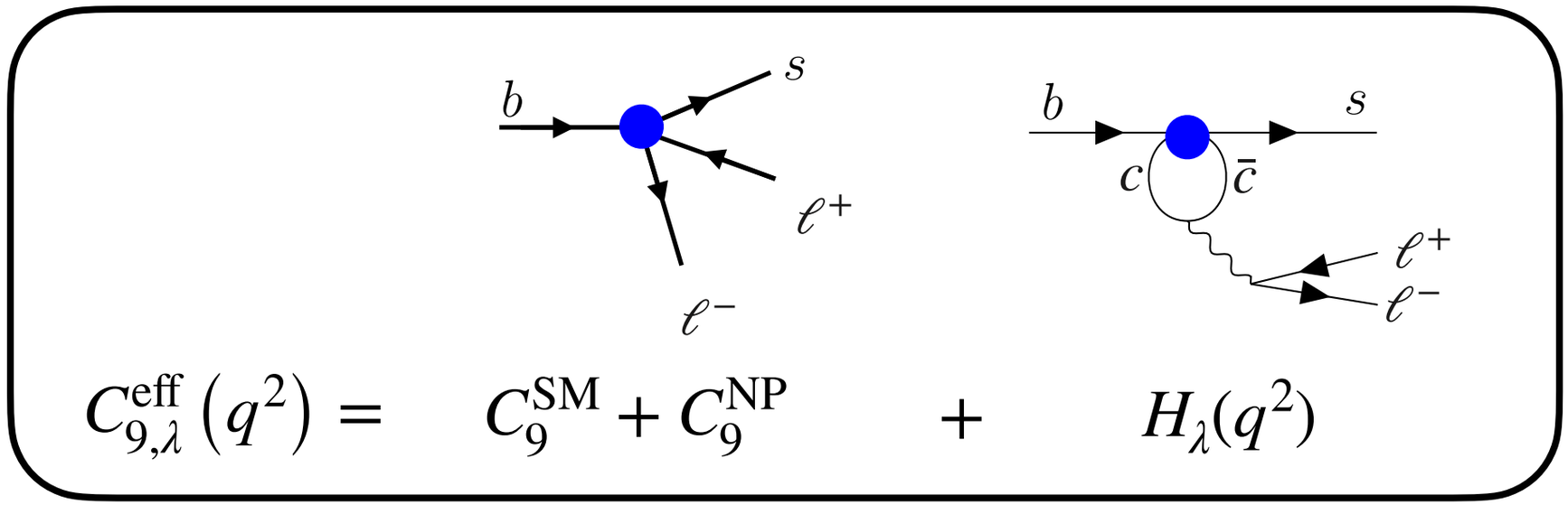
Based on Hurth 2025, updated in Nazila's talk

All observables except [6-8] GeV^2 bins with $\chi^2_{\mathrm{SM}} = 321.6$

$(\chi^2_{\mathrm{min}} = 282.1;\ \mathrm{Pull}_{\mathrm{SM}} = 3.9\sigma)$

δC_7		δC_8	
0.06 ± 0.02		-0.74 ± 0.24	
$\delta C'_7$		$\delta C'_8$	
0.00 ± 0.01		0.50 ± 0.50	
δC_9	$\delta C'_9$	δC_{10}	$\delta C'_{10}$
-0.87 ± 0.16	-0.22 ± 0.21	0.08 ± 0.19	-0.01 ± 0.15
C_{Q_1}	C'_{Q_1}	C_{Q_2}	C'_{Q_2}
-0.32 ± 0.13	-0.19 ± 0.12	0.03 ± 0.07	-0.03 ± 0.02

Comparison to unbinned LHCb analyses



- Flavio fit to binned analysis (8.4/fb): $\Delta C_9 = -0.94^{+0.21}_{-0.17}$ (i)
- Model with z-expansion (4.7/fb): $\Delta C_9 = -0.93^{+0.53}_{-0.57}$ (ii)
- Local/non-local amplitudes (8.4/fb): $\Delta C_9 = -0.71 \pm 0.33$ (iii)

- Differences in ΔC_9 value and significance expected
- Non-local contributions effect very degenerate with ΔC_9

(i) LHCb-PAPER-2025-041 (in preparation)
(ii) [PRL 132 (2024) 131801]+ [PRD 109 (2024) 052009]
(iii) [JHEP 09 (2024) 026]

WC dependence of $Br(B_s \to \ell\ell)$

$$\bar{\mathcal{B}}r(B_s \to \ell^+\ell^-)_{\rm SM} = \frac{1}{1-y_s}\frac{G_F^2\alpha^2}{16\pi^3}\tau_{B_s}|V_{ts}V_{tb}^*|^2 f_{B_s}^2 M_{B_s} m_\ell^2 \sqrt{1-4\frac{m_\ell^2}{M_{B_s}^2}}|C_{10}^{\rm SM}|^2$$

$$P_{\ell\ell} \equiv \frac{C_{10}^{\ell\ell} - C_{10'}^{\ell\ell}}{C_{10}^{\rm SM}} + \frac{M_{B_s}^2}{2m_\ell}\left(\frac{m_b}{m_b+m_s}\right)\left[\frac{C_P^{\ell\ell} - C_{P'}^{\ell\ell}}{C_{10}^{\rm SM}}\right],$$

$$S_{\ell\ell} \equiv \sqrt{1-4\frac{m_\ell^2}{M_{B_s}^2}}\frac{M_{B_s}^2}{2m_\ell}\left(\frac{m_b}{m_b+m_s}\right)\left[\frac{C_S^{\ell\ell} - C_{S'}^{\ell\ell}}{C_{10}^{\rm SM}}\right].$$

$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)

Angular observables

S_i : CP average

A_i : CP asymmetries

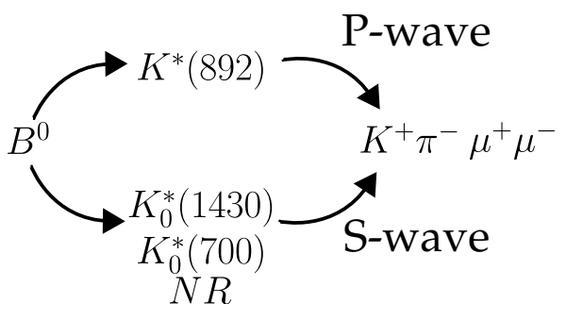
$$\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\vec{\Omega}\,\mathrm{d}m_{K\pi}}\frac{1}{\Gamma+\bar{\Gamma}} = \left(1-\hat{\Gamma}_S\right)\frac{9}{64\pi}\sum_i \left(S_i - A_i\right) f_i(\vec{\Omega}) \left|\mathscr{BW}_P\left(m_{K\pi}\right)\right|^2$$

$$+\frac{1}{8\pi}\sum_{1ac,2ac}\left(\tilde{S}_i - \tilde{A}_i\right) f_i(\vec{\Omega}) \left|\mathscr{BW}_S\left(m_{K\pi}\right)\right|^2$$

$$+\frac{1}{8\pi}\sum_{1bc,\ \mathrm{S1-S5}} \mathscr{R}e/\mathscr{I}m\left[\left(\tilde{S}_i - \tilde{A}_i\right) f_i(\vec{\Omega}) \mathscr{BW}_S\left(m_{K\pi}\right) \mathscr{BW}_P\left(m_{K\pi}\right)^*\right]$$

$m(K\pi)$ explicitely included

Measured also all S-wave and P-/S-wave interference observables



- Large number of parameters: 25 S_i if allowing for massive leptons and scalar+tensor amplitudes
- **Several fit configurations** to extract max information with best sensitivity (e.g. assuming or not massless leptons, allowing or not CP asymmetries)

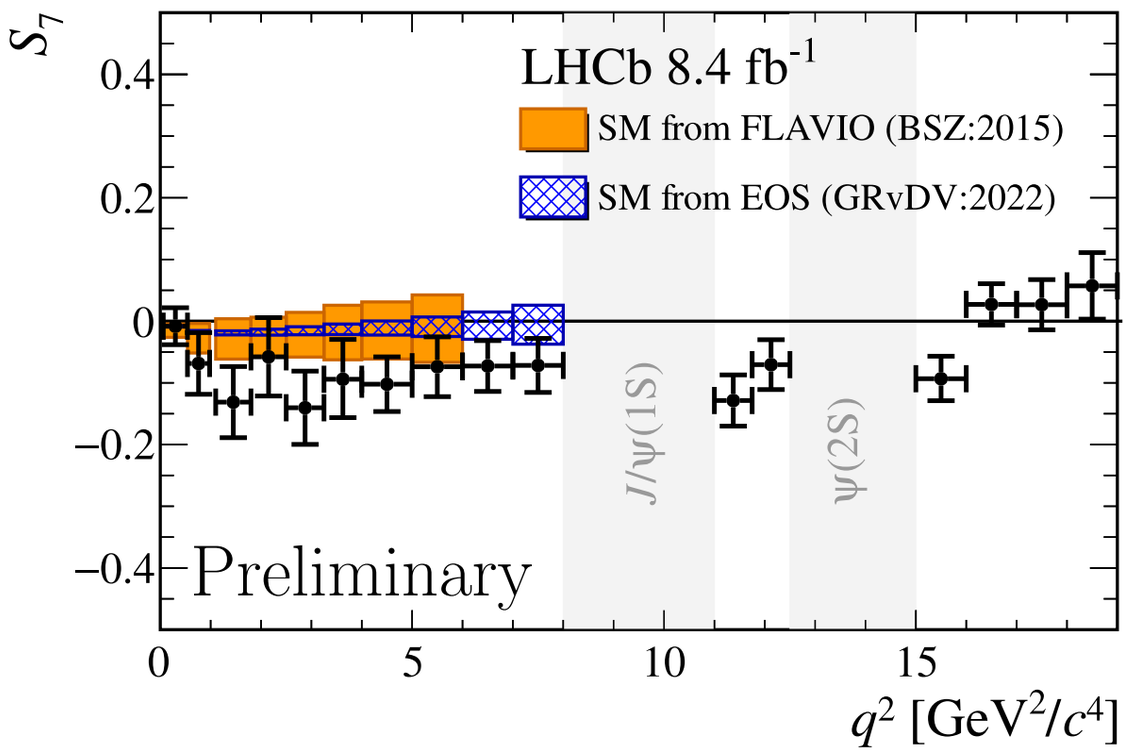
Check CERN seminar for more details

$B^0 \to K^*\mu\mu$ angular analysis

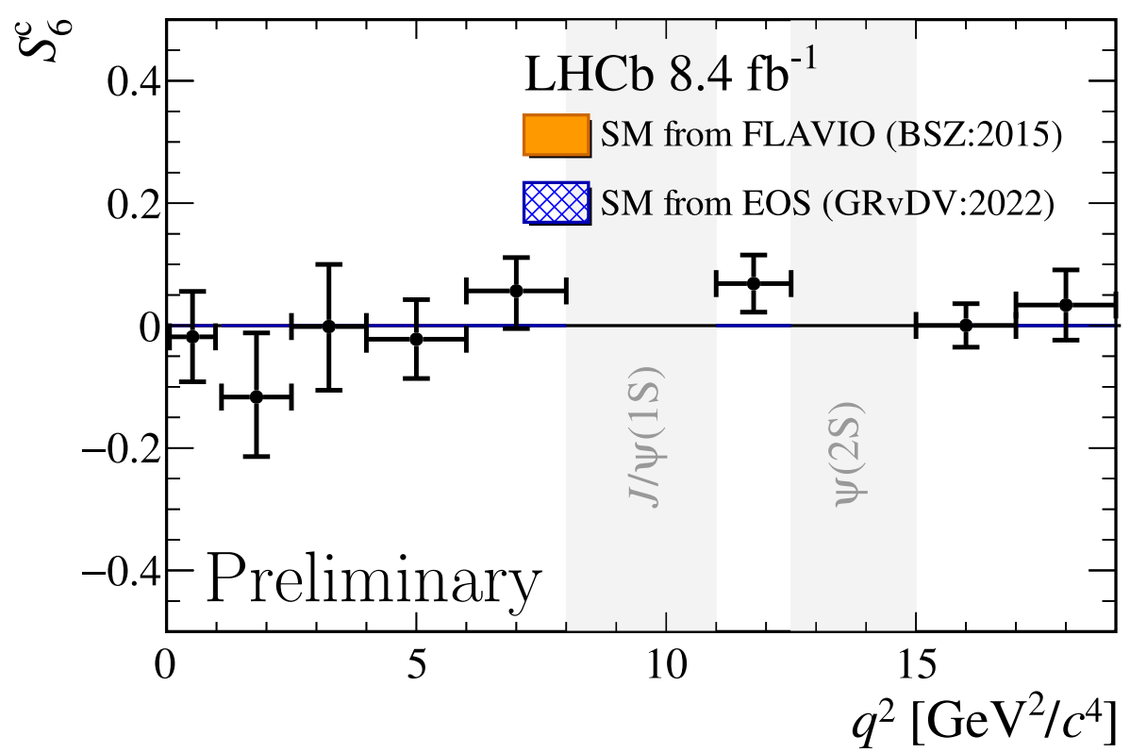
NEW

LHCb-PAPER-2025-041 (in preparation)

S_7 is sensitive to strong phases



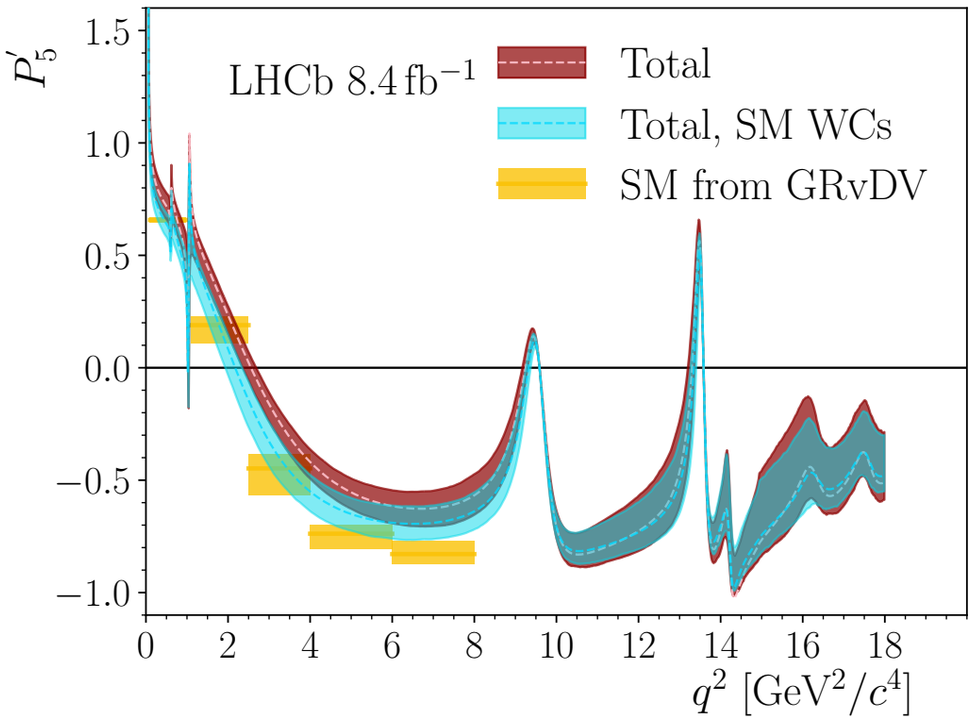
S_6^c is sensitive to NP tensor or scalar

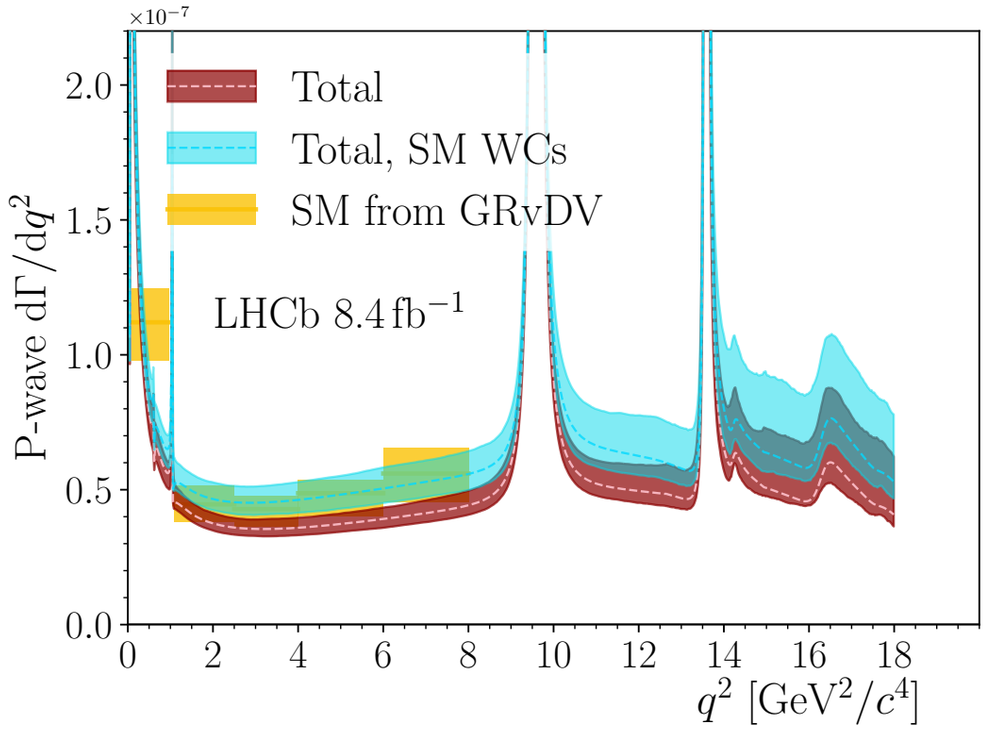


Check CERN seminar for all preliminary results (plots, tables)

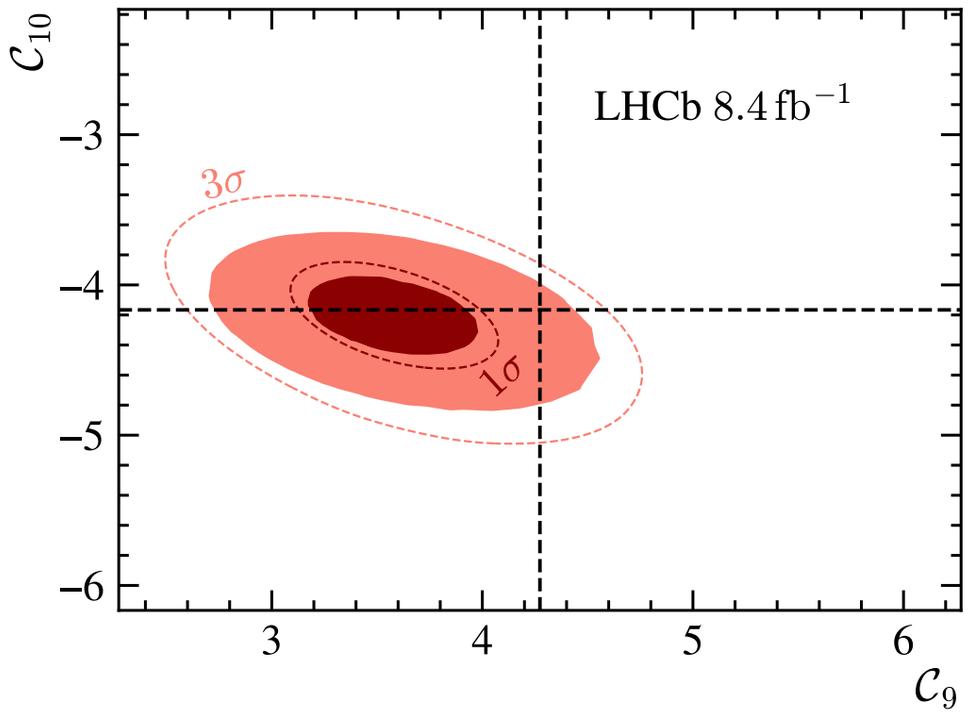
Amplitude analysis of $B^0 \to K^*\mu\mu$

JHEP 09 (2024) 026

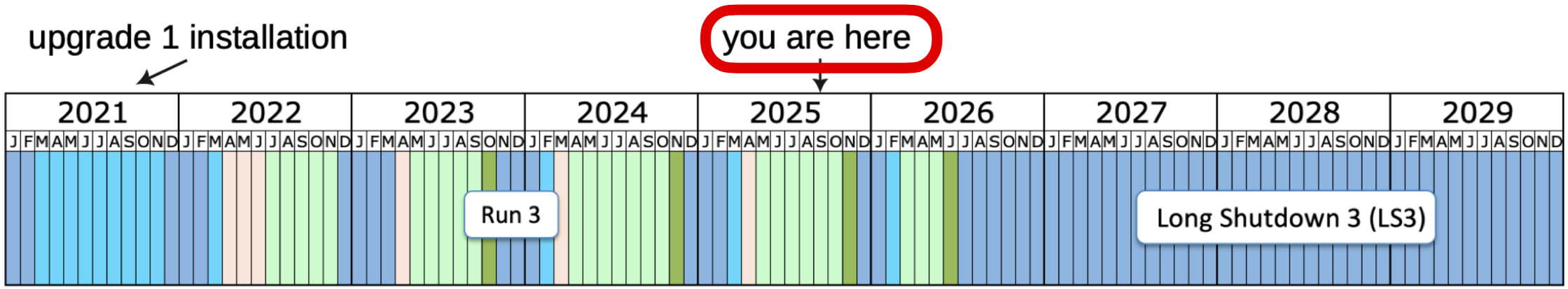


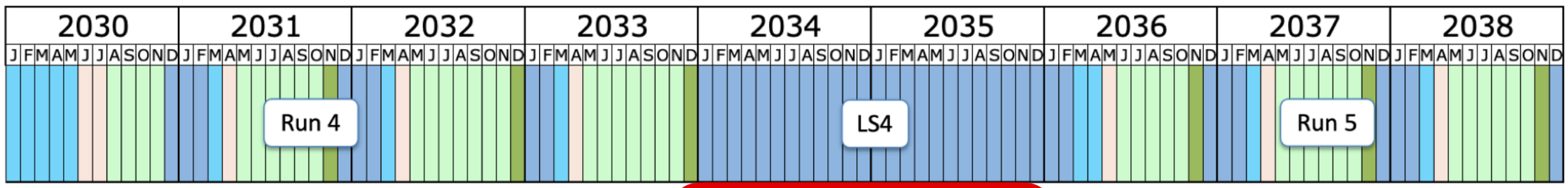


Wilson Coefficient results	
$\mathcal{C}_9$	$3.56 \pm 0.28 \pm 0.18$
$\mathcal{C}_{10}$	$-4.02 \pm 0.18 \pm 0.16$
$\mathcal{C}'_9$	$0.28 \pm 0.41 \pm 0.12$
$\mathcal{C}'_{10}$	$-0.09 \pm 0.21 \pm 0.06$
$\mathcal{C}_{9\tau}$	$(-1.0 \pm 2.6 \pm 1.0) \times 10^2$

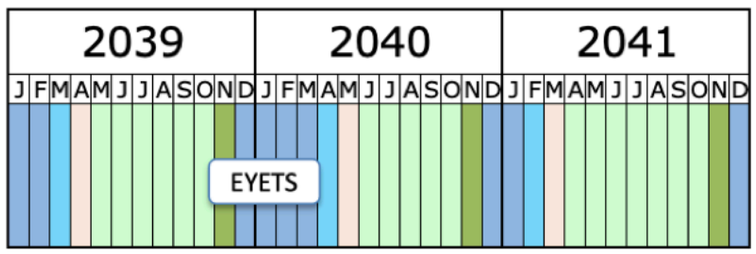


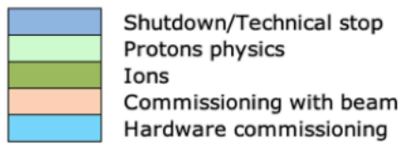
Future runs and Upgrade II





upgrade 2 installation





LHCb v1:

- 2010-2012 - Run 1, 7/8 TeV
- 2015-2018 - Run 2, 13 TeV

Int.J.Mod.Phys. A 30, 1530022 (2015)

The LHCb experiment in Run 1-2

LHCb detector design

- Huge $\sigma(pp \to b\bar{b}X)$ at the LHC
  $\to 10^{12}$ b-hadrons in LHCb acceptance in Run 1+2

- Hardware trigger on object with p_T exceeding 2-3 GeV
- Displaced vertex identification in software trigger stage
- Dipole magnet with precise tracking detectors $\sigma_p/p \sim 0.5\,\%$
- Particle ID with calorimeters, muon system and Cherenkov detectors (RICH)