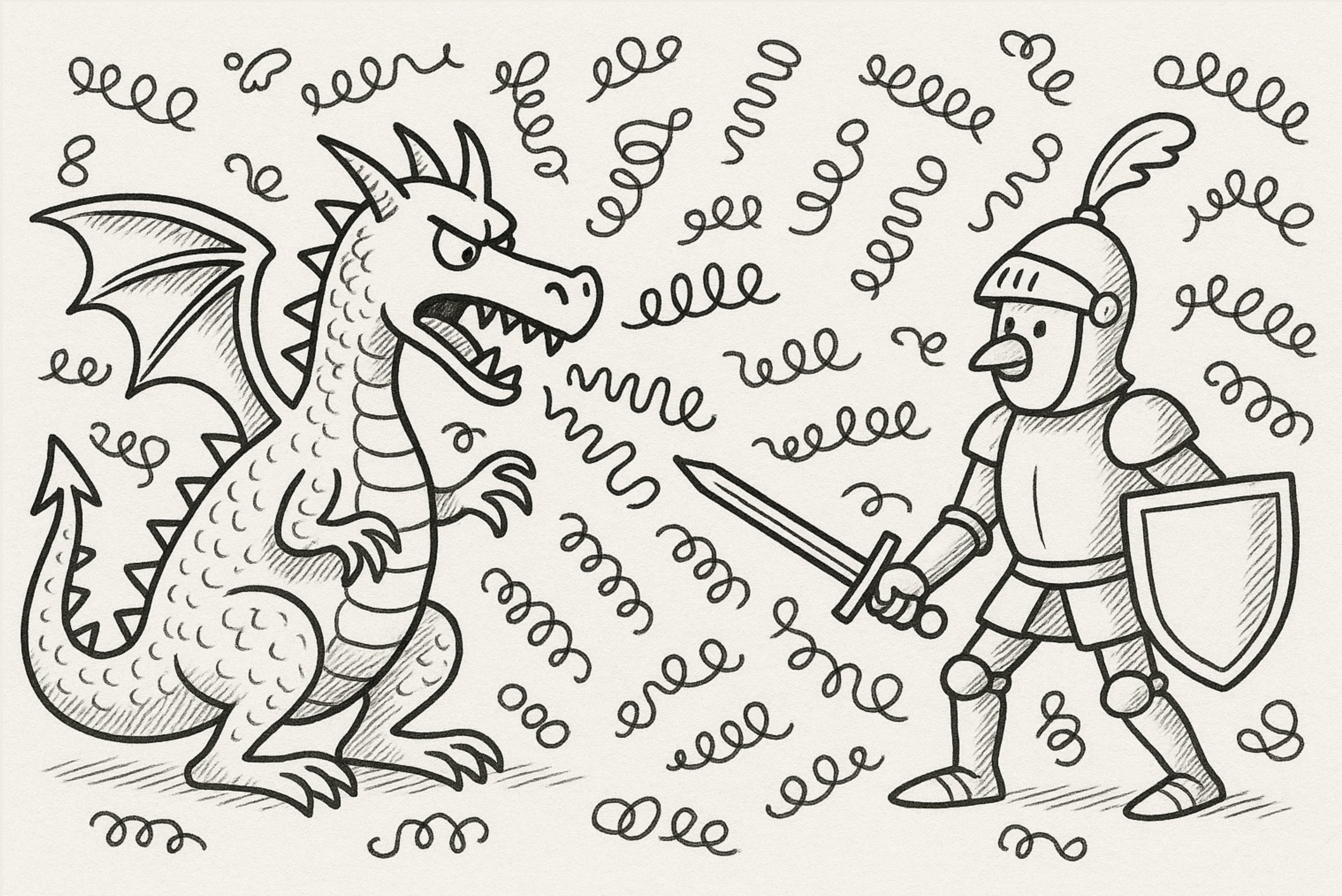


Generated with DALL-E

Taming hadronic uncertainties using rare (semi-)leptonic decays

Martino Borsato

Università degli Studi di Milano Bicocca

INFN Istituto Nazionale di Fisica Nucleare

23 October 2025 - Orsay

Website LHCb@Bicocca

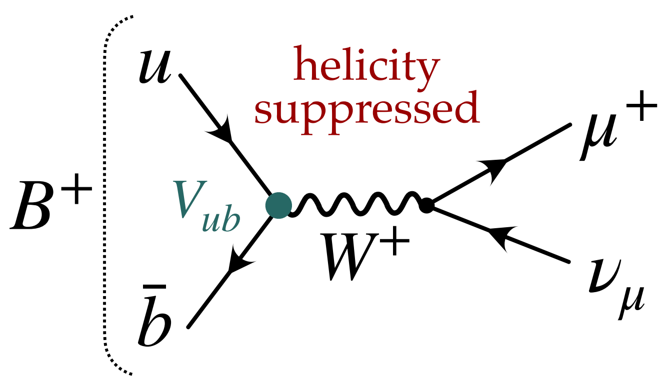
Topics covered today

An experimental perspective

- Radiative leptonic B decays
  - Searches for $B^+ \to \ell^+ \nu \gamma$ and $B^+ \to \ell^+ \nu \ell'^+ \ell'^-$
  - Searches for $B_s^0 \to \ell^+ \ell^- \gamma$ and $B_s \to \ell^+ \ell^- \ell'^+ \ell'^-$
- Semileptonic $b \to s \ell^+ \ell^-$ decays
  - Precision measurements of $B \to K^{(*)} \mu\mu$
  - Attempts to fit Wilson coeffs together with hadronic uncertainties and long-distance contributions

Radiative leptonic

$B^+ \to \ell\nu\gamma$: **why?**

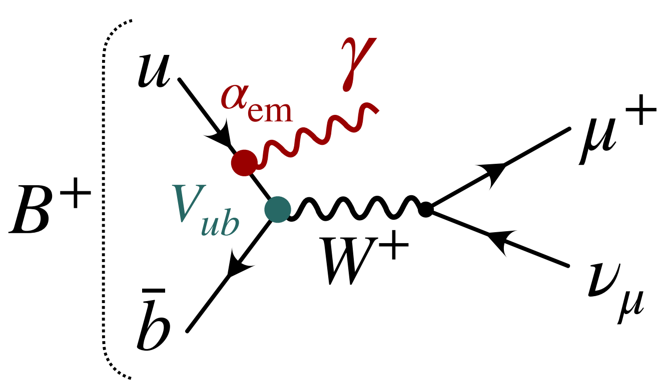


$B^+ \to \mu^+\nu_\mu$ decay

Suppressed by V_{ub} + helicity
Very precise prediction
Theory: $\mathrm{BR} = (3.8 \pm 0.4) \times 10^{-7}$
PDG: $\mathrm{BR} < 8.6 \times 10^{-7}$ at 90% CL

Test the SM

measure V_{ub},
search for H^+, LQ



$B^+ \to \mu^+\nu_\mu\gamma$ decay

Suppressed by V_{ub} + ~~helicity~~ + α_{em}
Depends on $B \to \gamma$ form factors
Theory: $\mathrm{BR} \simeq 2 \times 10^{-6}$
PDG: $\mathrm{BR} < 3.4 \times 10^{-6}$ at 90% CL

Study B^+ meson

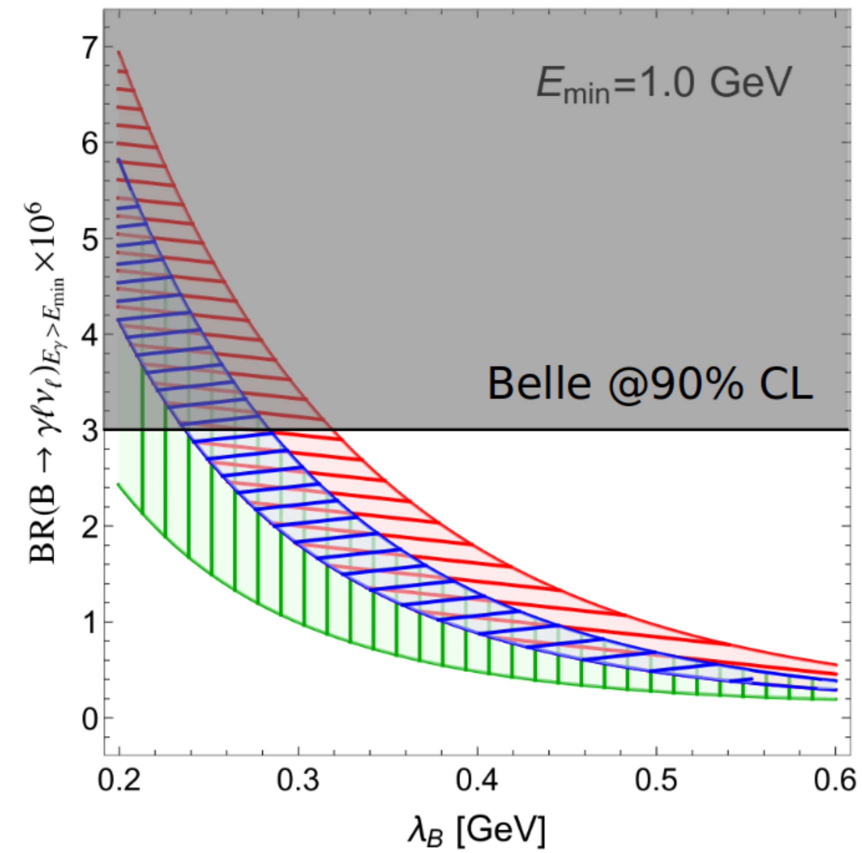
to improve predictions
for other channels

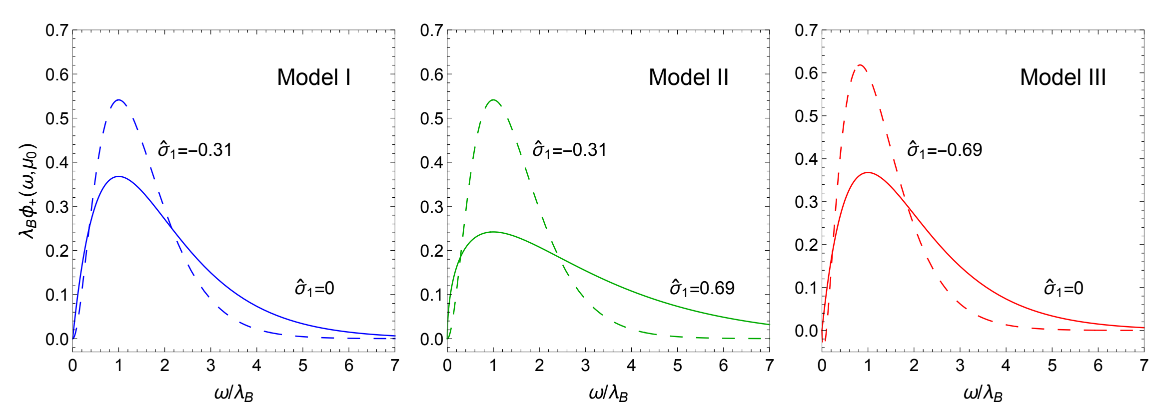
$B^+ \to \ell\nu\gamma$: **why?**

See Aoife's talk

- $B^+ \to \ell\nu\gamma$ considered **golden mode** to probe the B sub-structure
  - Improve understanding of B light-cone distribution amplitudes (LCDA)
  - At first order $\mathrm{Br}(B^+ \to \ell\nu\gamma)$ measures of the B LCDA parameter λ_B
  - Essential for calculations of non-leptonic B decays (QCD factorisation)

M.Beneke et al JHEP 07 (2018) 154





BR also depends on value of $\hat{\sigma}_1$

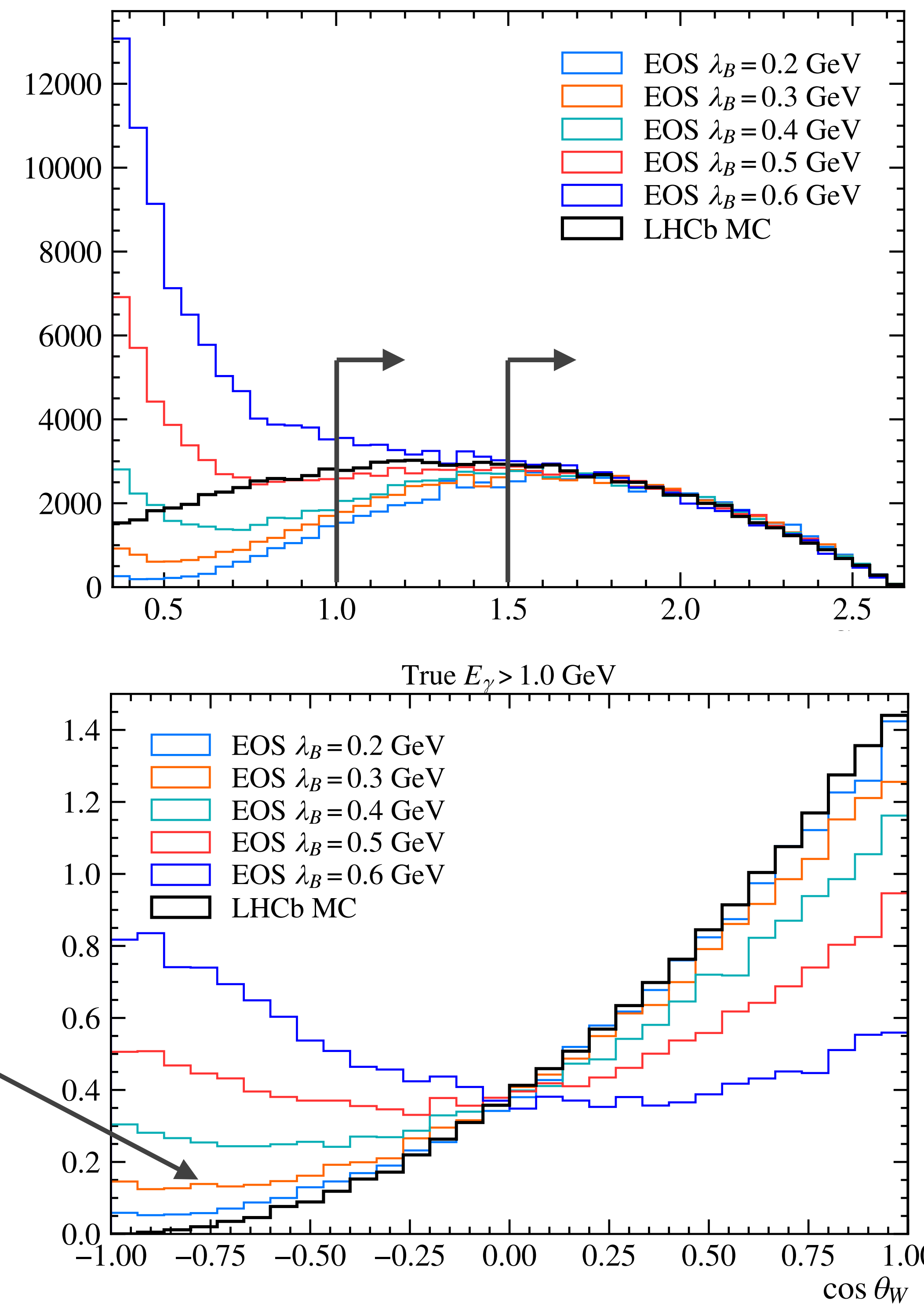
Non-exhaustive list of references:

- G.Grozin, M. Neubert, Phys. Rev. D55 (1997) 272-290
- M. Beneke, G. Buchalla, et al, Phys.Rev.Lett.83:1914-1917,1999
- M. Beneke, T. Feldmann, Nucl. Phys. B592 (2001) 3-34
- M. Beneke, J.Rohrwild, Eur.Phys.J.C 71 (2011) 1818
- T.Feldmann, P.Lüghausen, D.van Dyk, JHEP 10 (2022) 162
- Proof of concept Lattice calculation from P.Boer (talk at CKM)

Observables in $B^+ \to \ell^+ \nu \gamma$

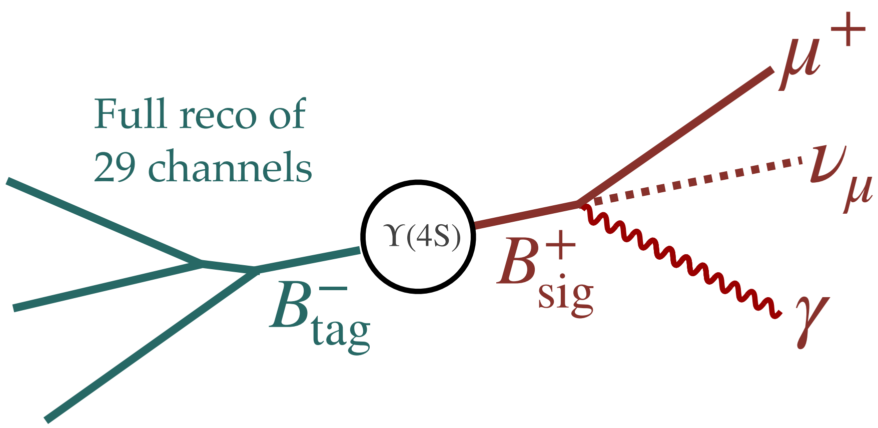
- Three-body decay described by E_γ and $\cos\theta_W$
- E_γ spectrum and $A_{\rm FB}$ depend on B^+ meson LCDA
- Analysis cut on min E_γ larger than 1.0 or 1.5 GeV
- Typically get low efficiency at $\cos\theta_W \simeq -1$ where all energy goes to ν rather than μ

MC generated with EOS



$B^+ \to \ell\nu\gamma$: **how?**

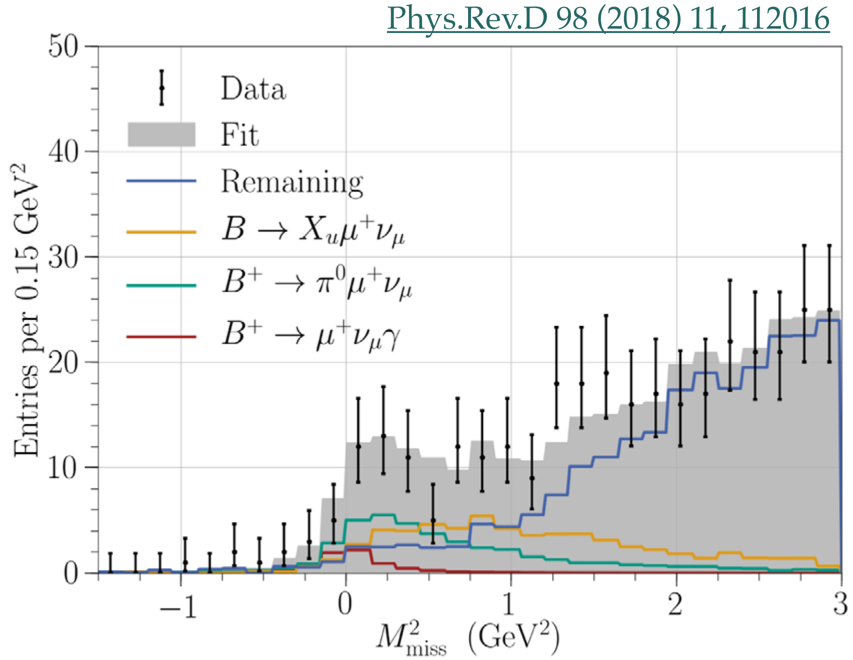
Method @Belle



- Full reco of $B_{\rm tag}$ $\varepsilon \simeq 0.8\,\%$

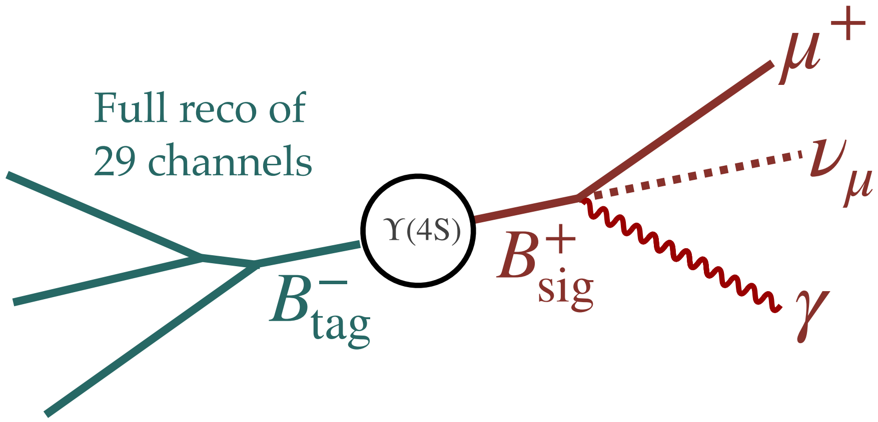
$$p_{B_{\rm sig}} = \left(\frac{\sqrt{s}}{2}, -\vec{p}_{B_{\rm tag}}\right) \qquad M^2_{\rm miss} = p_\nu^2 = \left(p_{B_{\rm sig}} - p_\ell - p_X\right)^2$$

Phys.Rev.D 98 (2018) 11, 112016



$B^+ \to \ell \nu \gamma$: **how?**

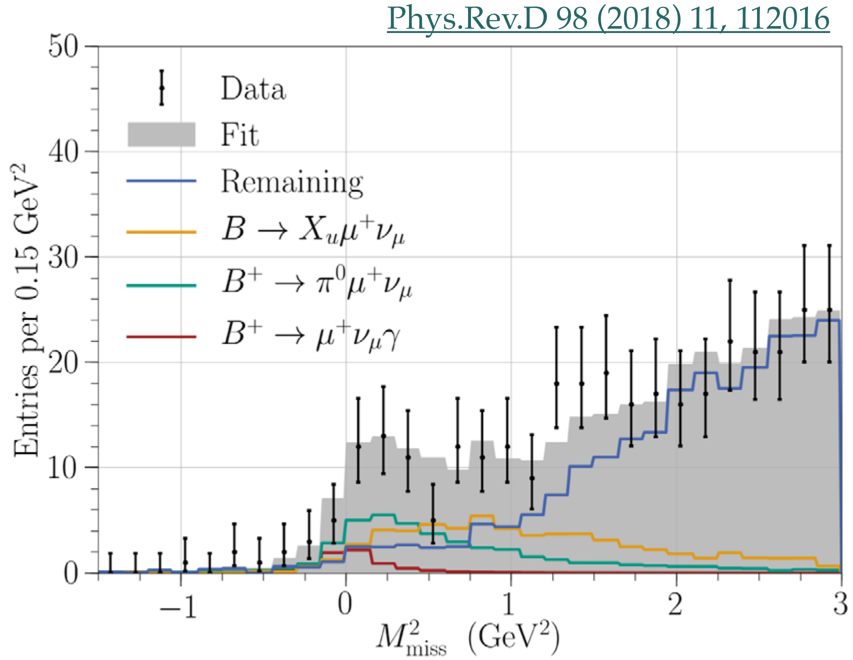
Method @Belle



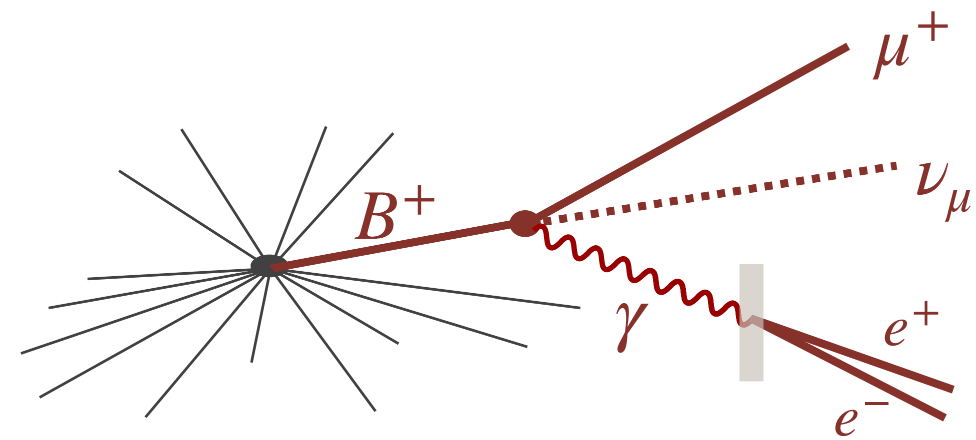
- Full reco of B_{tag} $\varepsilon \simeq 0.8\ \%$

$$p_{B_{\text{sig}}} = \left(\frac{\sqrt{s}}{2}, -\vec{p}_{B_{\text{tag}}} \right) \qquad M^2_{\text{miss}} = p^2_\nu = \left(p_{B_{\text{sig}}} - p_\ell - p_X \right)^2$$

Phys.Rev.D 98 (2018) 11, 112016

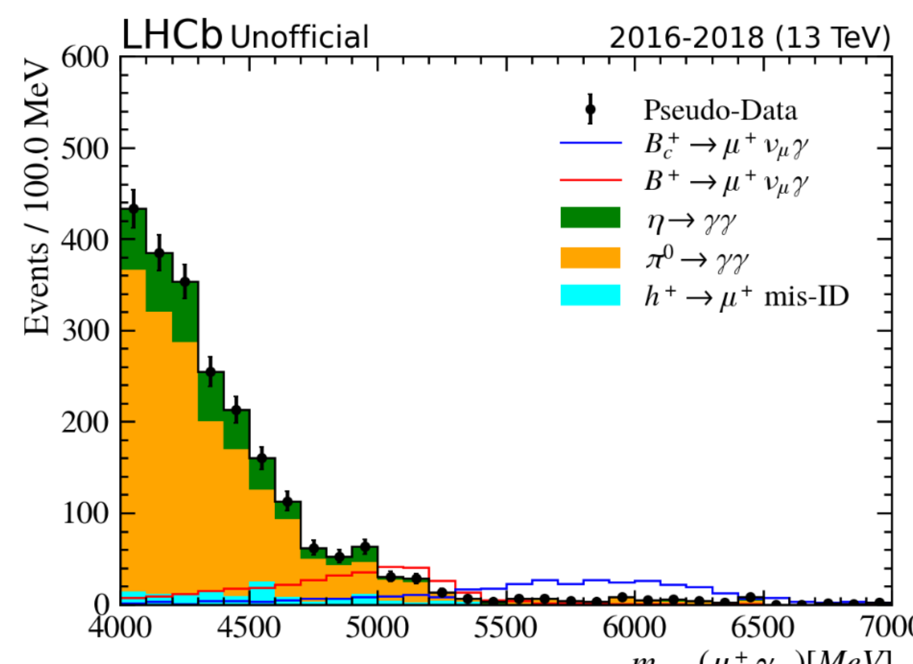


Method @LHCb

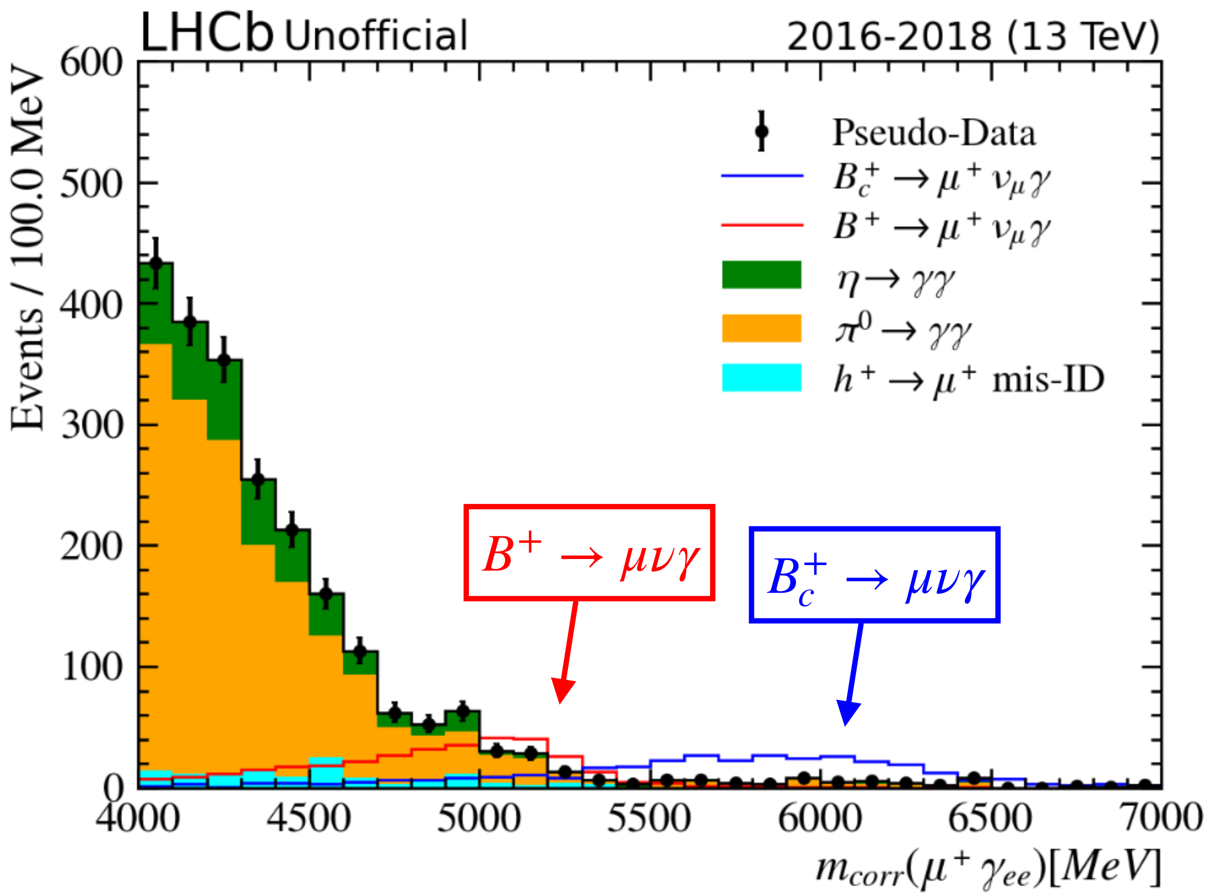


- γ conversion in material $\to$ get B^+ displaced vertex

$$m_{\text{corr}} = \sqrt{m^2_{\text{visible}} \, (\mu^+ \gamma_{ee}) + p^2_\perp} + p_\perp$$



Also $B_c^+ \to \mu\nu\gamma$ in LHCb



- Can also search for $B_c^+ \to \mu\nu\gamma$
  - Never been searched for!
  - Useful to study B_c^+ meson structure?
  - Expect similar rate as B^+ due to $\frac{f_c}{f_u} \simeq \frac{|V_{ub}|^2}{|V_{cb}|^2}$
  - Lower efficiency due to $\tau(B_c^+) \simeq 0.3 \times \tau(B^+)$
  - Much lower background under the peak

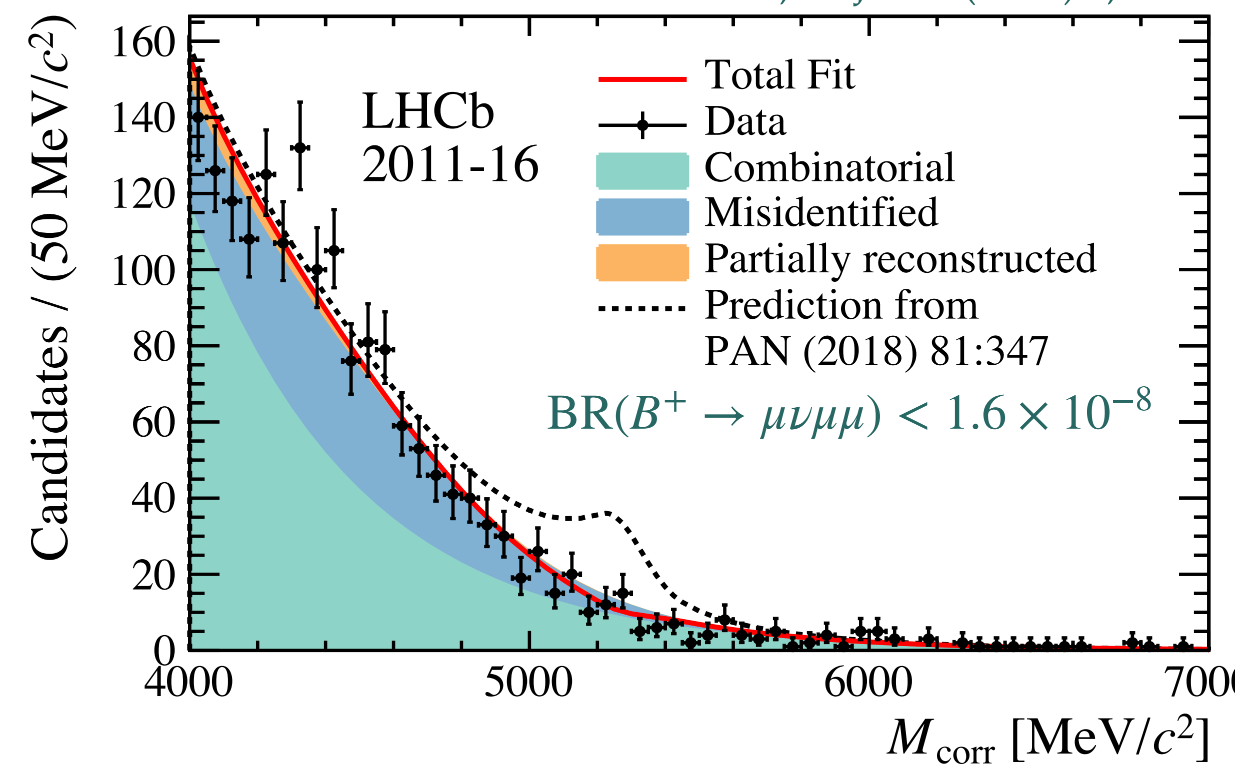
$B^+ \to \mu^+\nu\mu^+\mu^-$ at LHCb

- Much higher detection efficiency
- Search peak in corrected mass distribution
- Searched with 4.7/fb, now analyzing 9/fb
- $\mathrm{Br}^{\mathrm{exp}}(B^+ \to \mu\nu\mu\mu) < 1.6 \times 10^{-8}$
  LHCb, EPJC 79 (2019) 8, 675

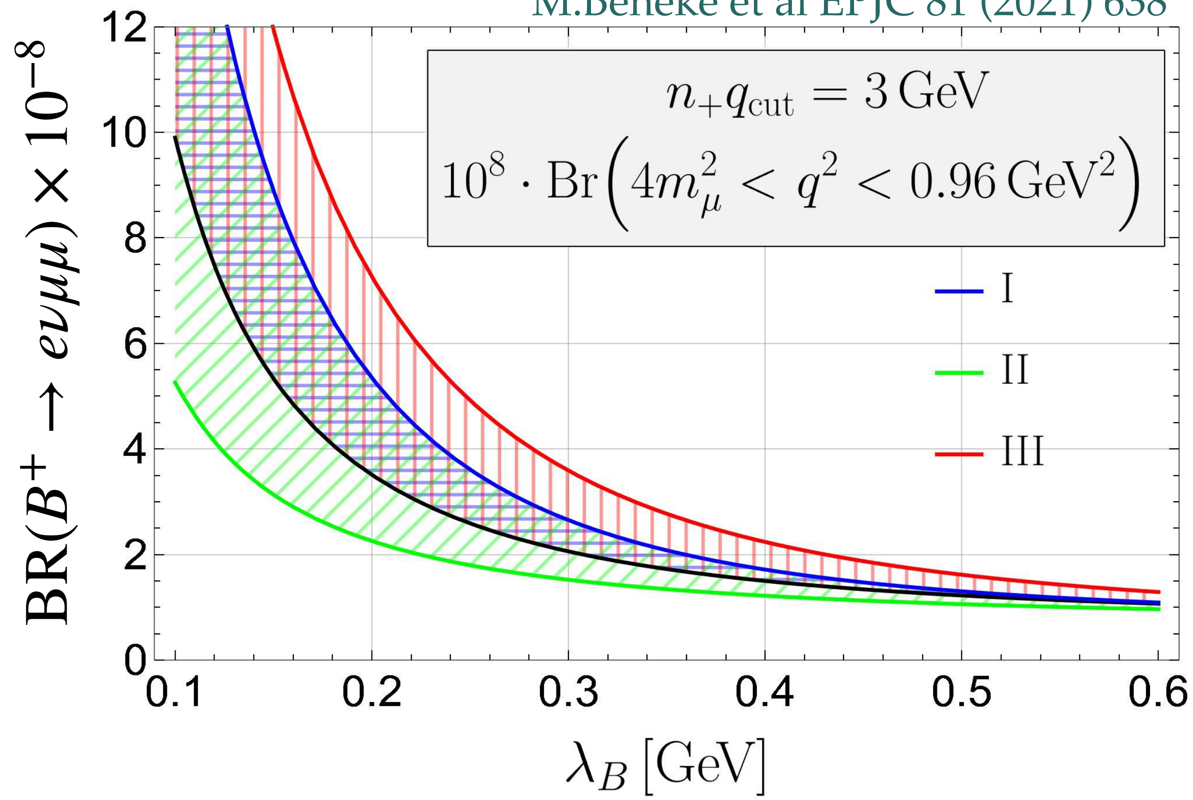
- Predictions less reliable than $B \to \ell\nu\gamma$ due to ρ/ω contributions
- $\mathrm{Br}^{\mathrm{th}}(B \to \mu\nu\mu\mu) = 1.54 \pm 1.77 \times 10^{-8}$ for $m_{\mu\mu} \in [4m_\mu^2, 0.96]$ and $n_+q_{\mathrm{low}} > 3$ GeV ($\lambda_B = 0.35 \pm 0.15$ MeV)
  M.Beneke et al EPJC 81 (2021) 638

See Aoife's talk

LHCb, EPJC 79 (2019) 8, 675

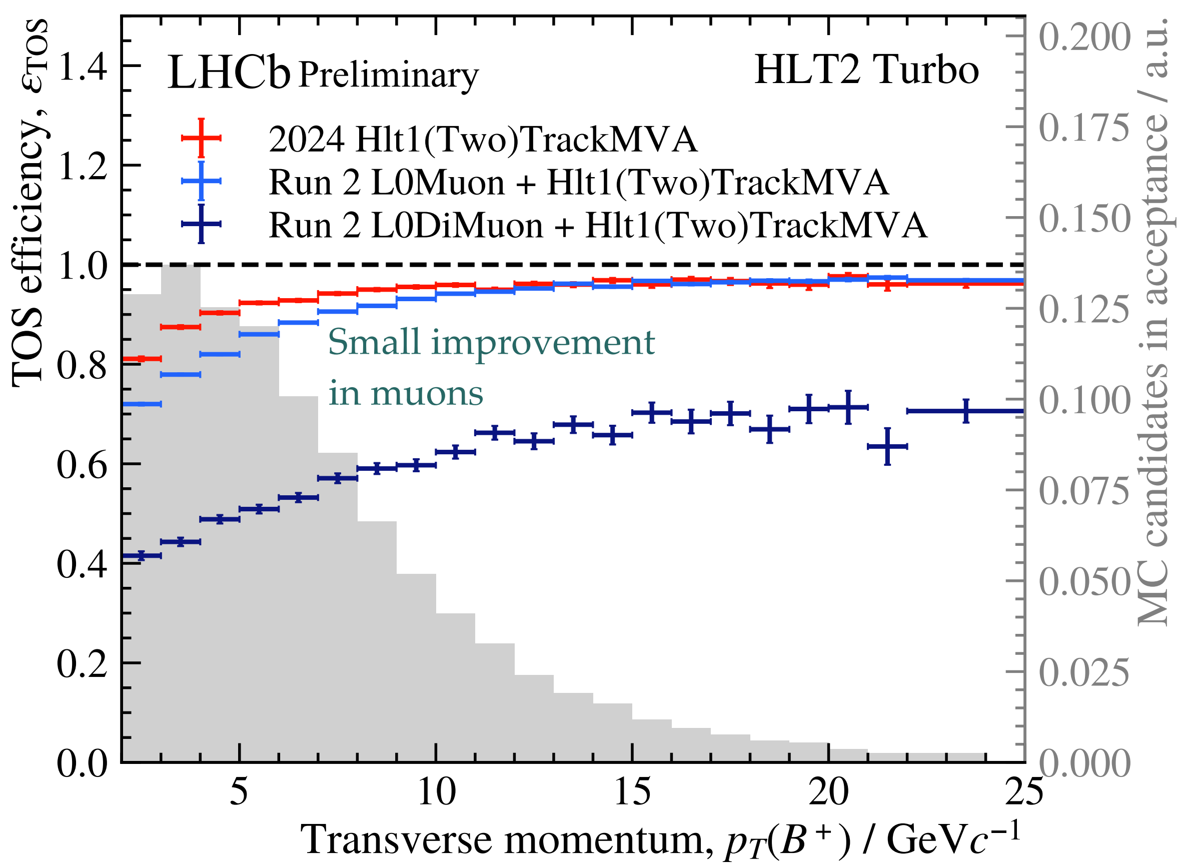


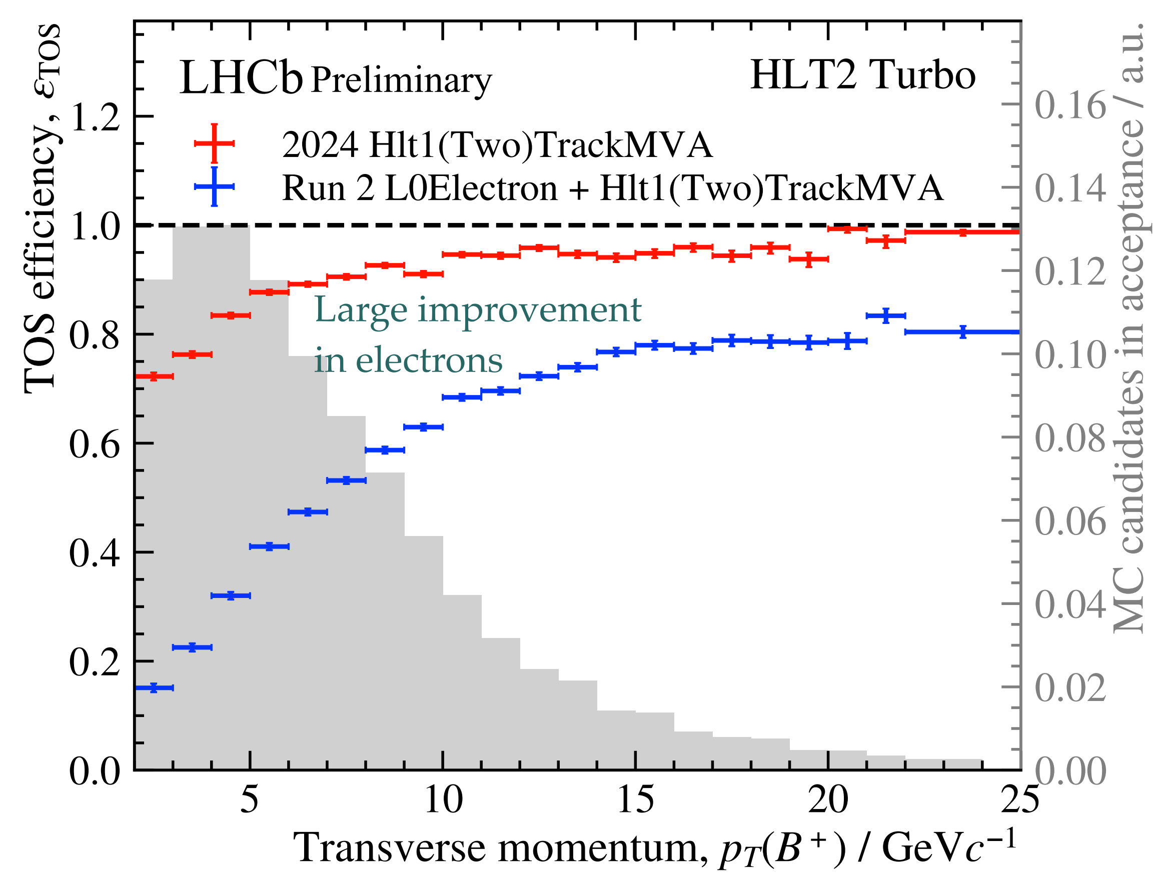
M.Beneke et al EPJC 81 (2021) 638



Prospects for electrons

- Belle(2) normally integrating channels with μ and e (cf $B \to \ell\nu\gamma$ search)
- LHCb focusing on μ, but can also search final states with electrons such as: $B \to e\nu\gamma$, $B \to e\nu\mu\mu$, $B \to \mu\nu ee$ (and $B \to e\nu ee$)
- Trigger efficiency with electrons significantly improved in Run 3 thanks to software-based trigger

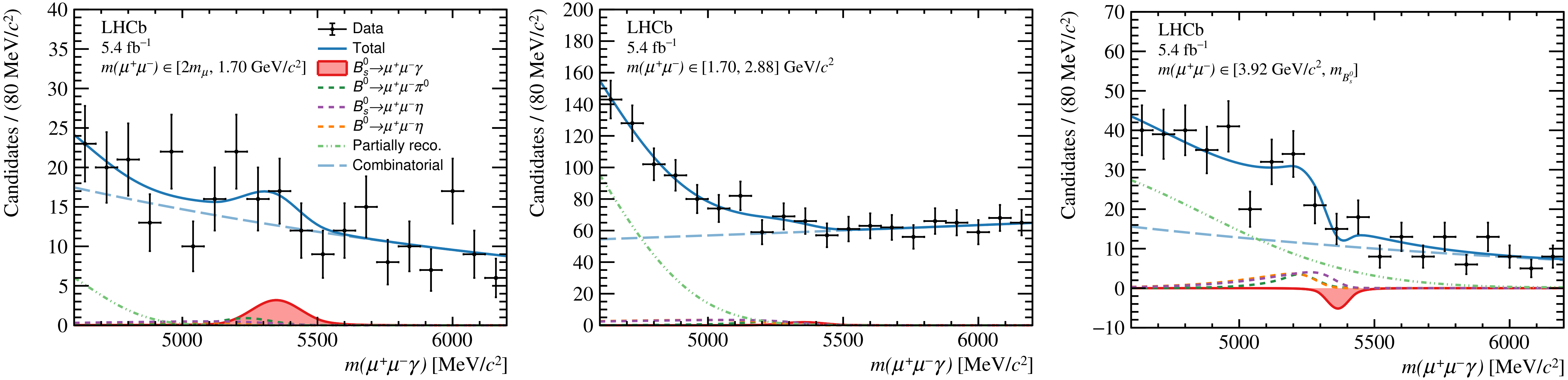




Search for $B_s^0 \to \mu^+\mu^-\gamma$

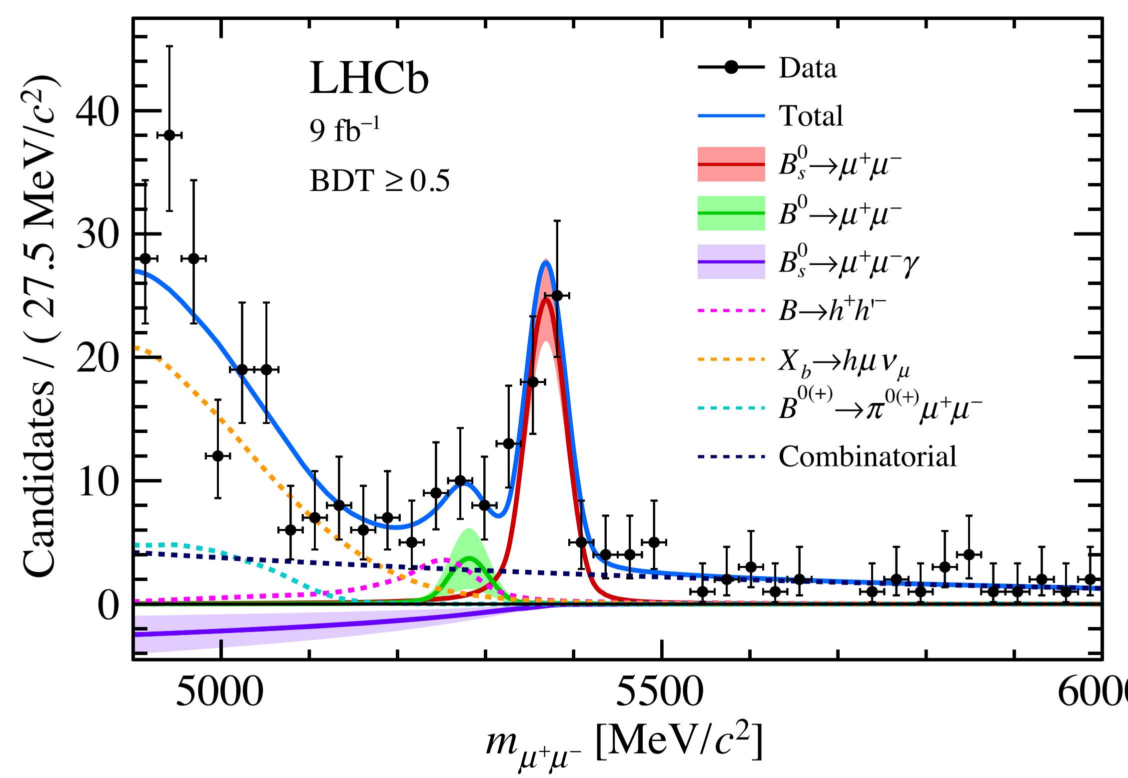
LHCb JHEP07(2024)101

Bin I | Bin II | Bin III



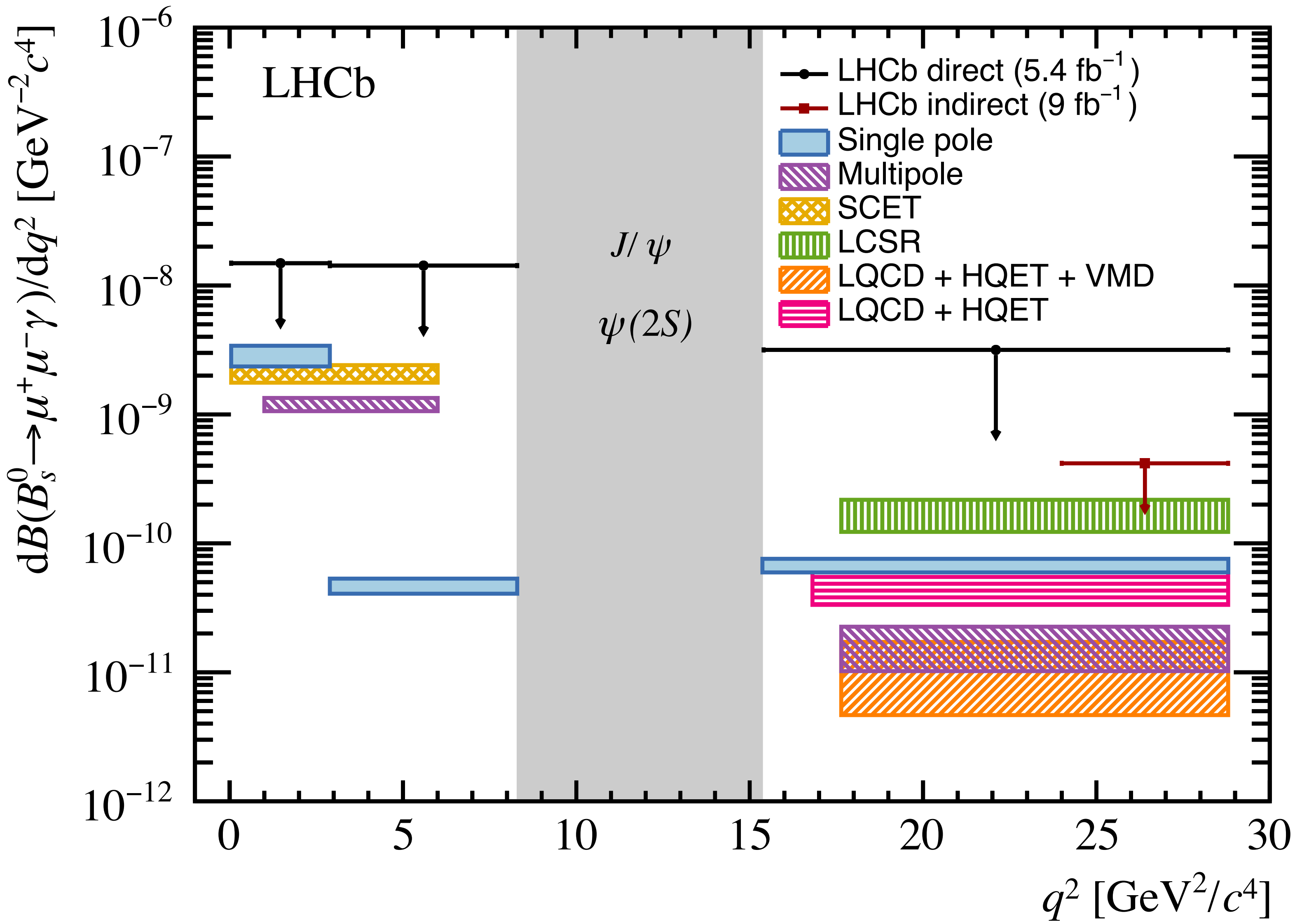
- FCNC radiative leptonic
  - Lifted helicity suppr, but pay α_{em}
  - Sensitive to C_9 and C_{10}
  - See talk by Diego
- Search for $B_s \to \mu\mu\gamma$
  - Searched in both $\mu\mu\gamma$ (full-reco) and $\mu\mu$ (part-reco)
- Full-reco search should be possible in Run3 using $e^+e^-\gamma$

PRL 128, (2022) 041801



Search for $B_s^0 \to \mu^+\mu^-\gamma$

LHCb JHEP07(2024)101

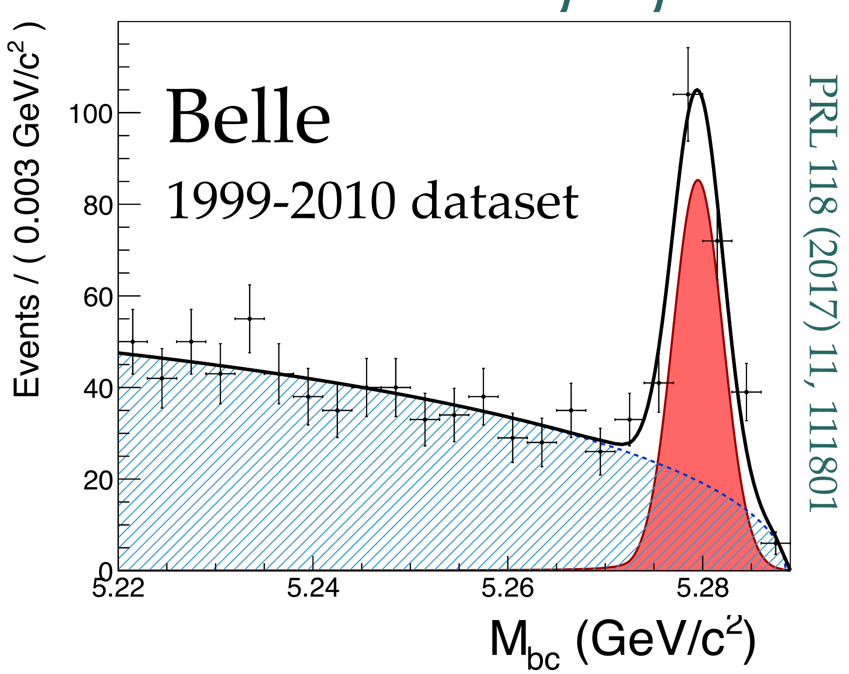


See Diego's talk for a theory perspective

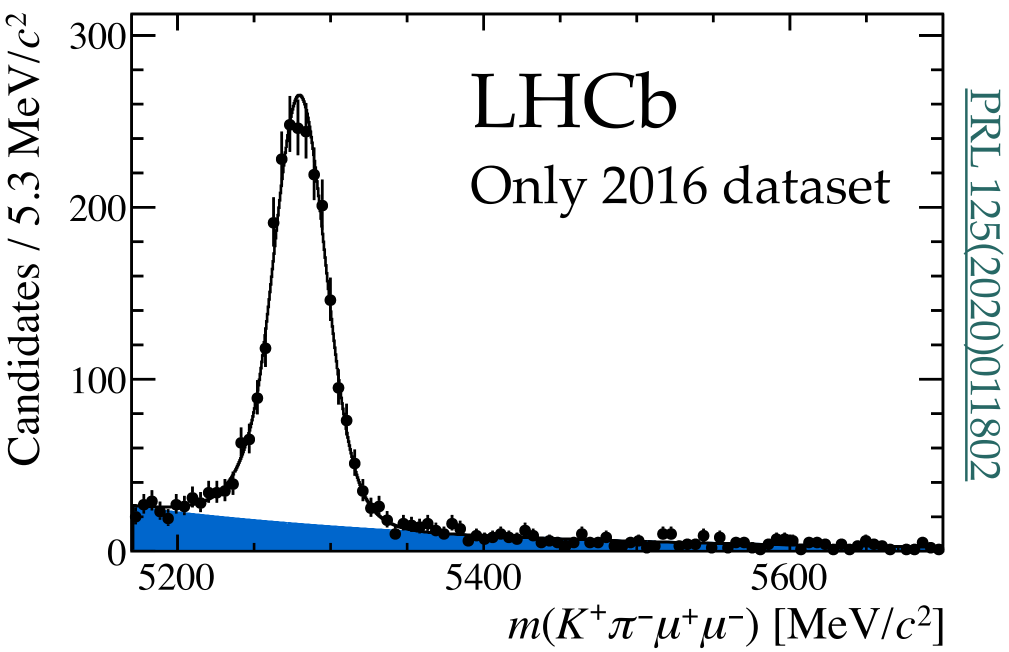
Semileptonic $b \to s\ell\ell$

LHCb's **strength**

$B^0 \to K^* \mu^+ \mu^-$



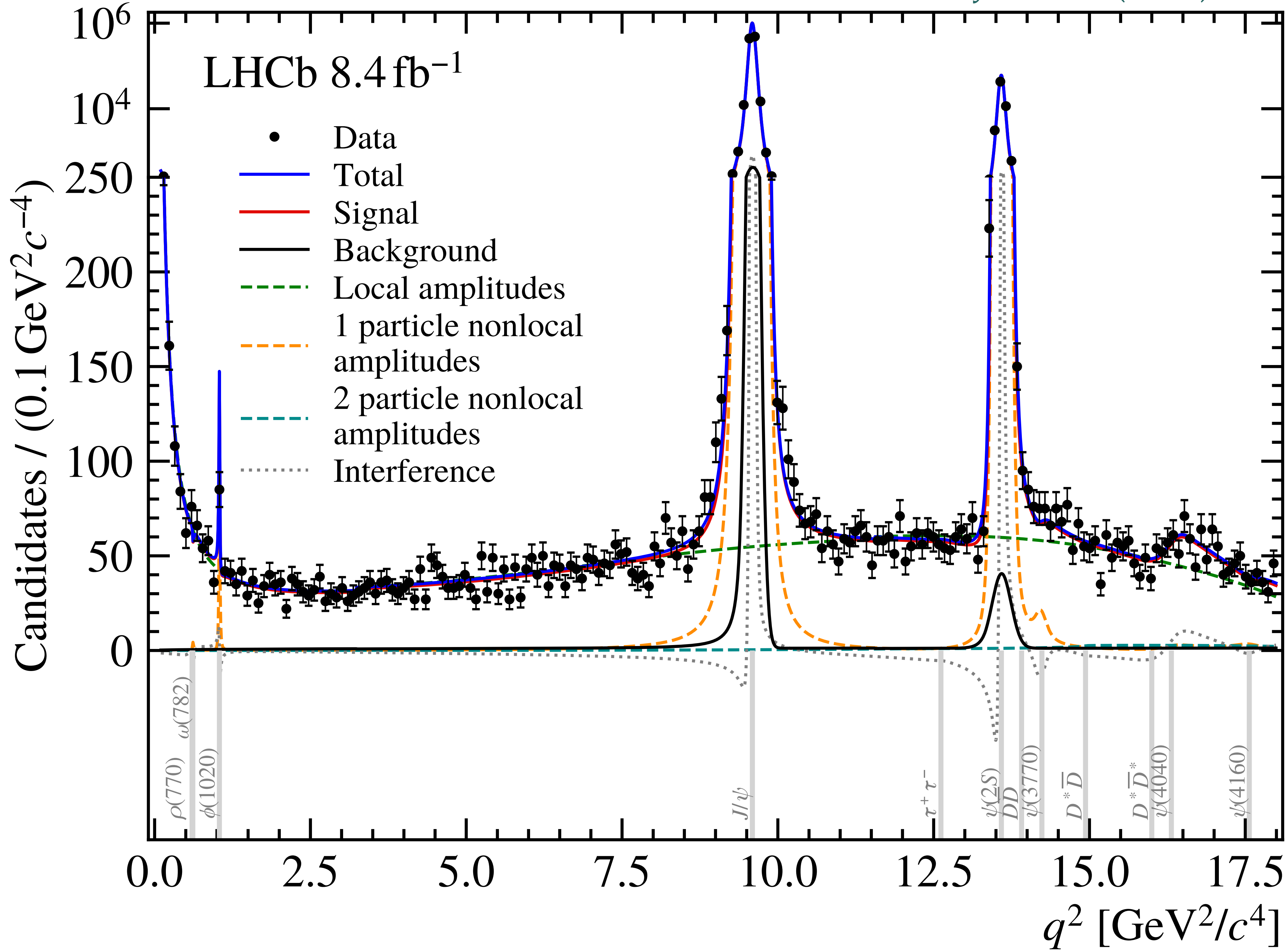
$B^0 \to K^* \mu^+ \mu^-$



But probably impossible
to do $B \to K\nu\bar{\nu}$ at LHCb
(see Belle2 talk by Meihong Liu)

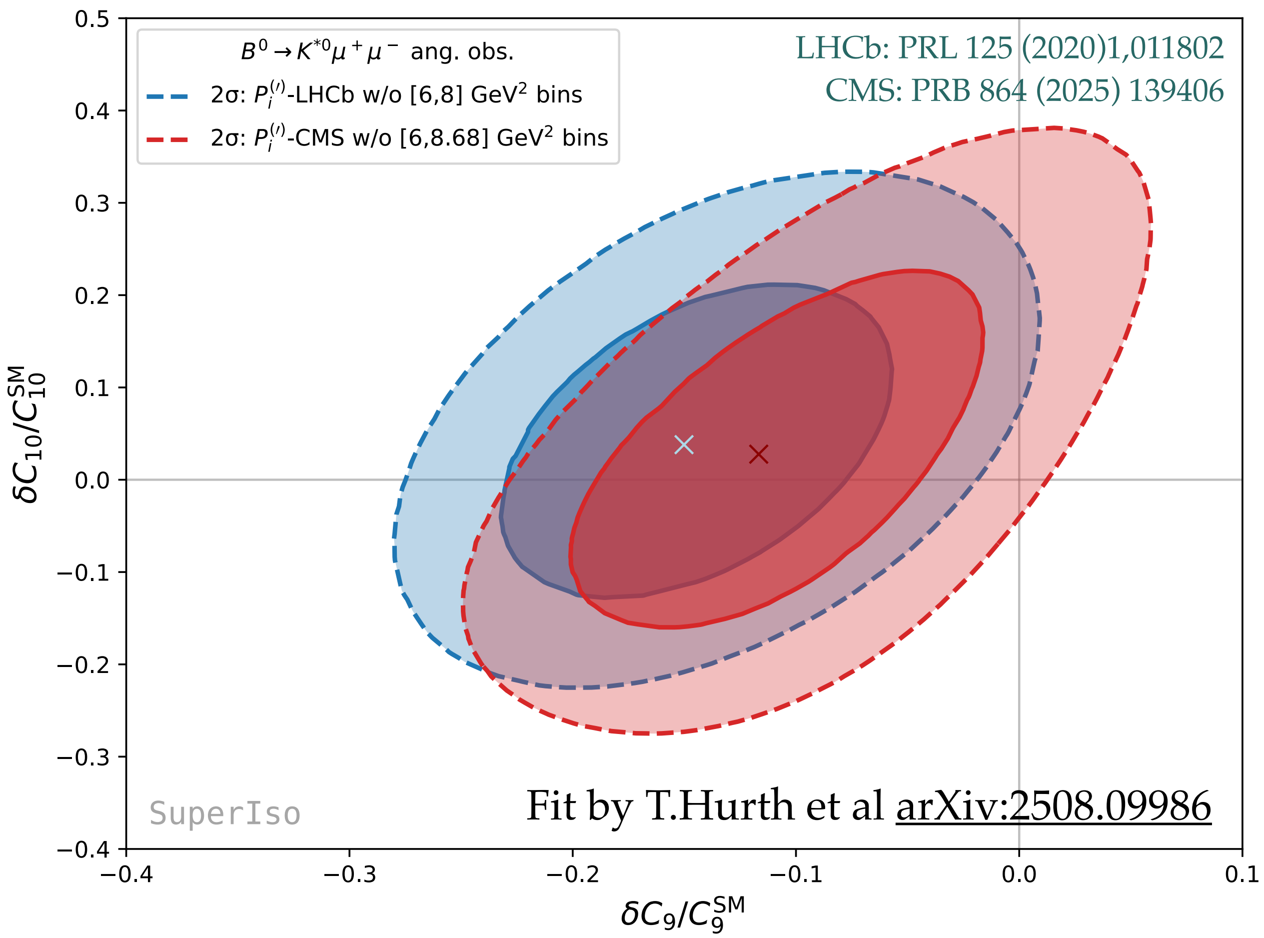
The $B^0 \to K^*\mu\mu$ dataset

JHEP 09 (2024) 026



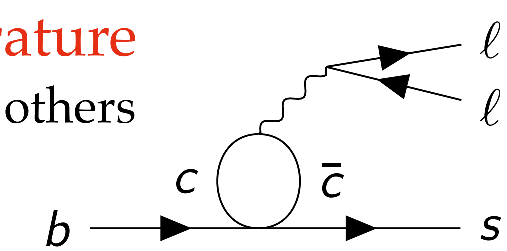
The $B^0 \to K^* \mu\mu$ dataset

Deviation in C_9 Wilson coeff confirmed by CMS



Long distance effects from $b \to sc\bar{c}$ under debate in the literature

[arXiv:2507.17824] and many others



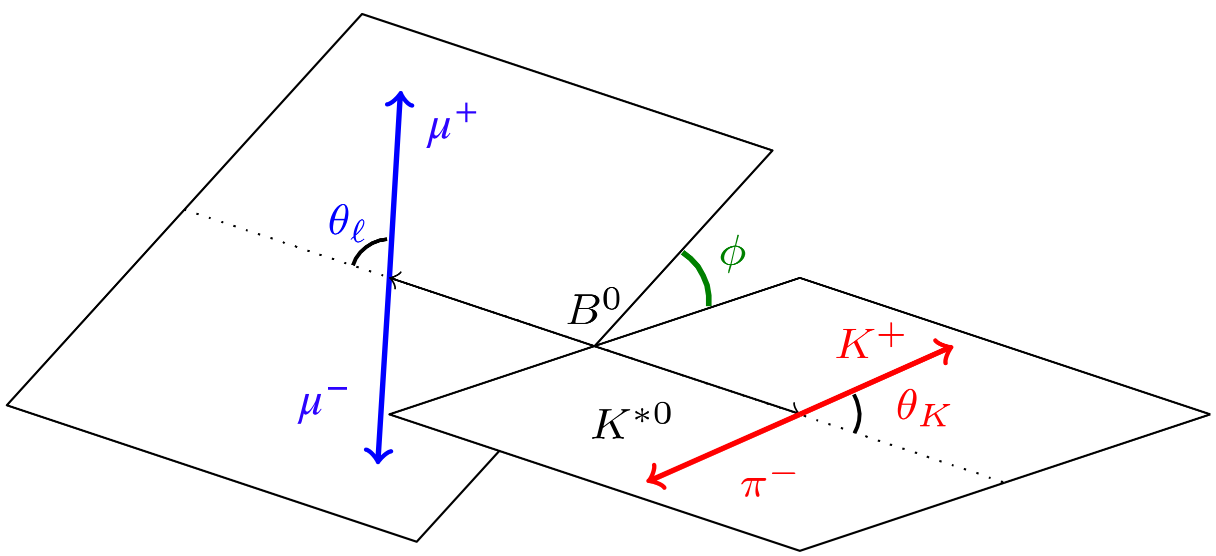
- LHCb has performed several angular analyses with different levels of model dependence
  - 4.7/fb Binned CP-averaged observables [PRL 125 (2020)1,011802]
  - 4.7/fb **Ampl.Ana** based on z-expansion [PRL 132 (2024) 131801]+ [PRD 109 (2024) 052009]
  - 8.4/fb **Ampl.Ana** with dispersion model [JHEP 09 (2024) 026]
- Anomaly in C_9 not covered by fit models allowing for long-distance effects

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

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)
  $\to$ doubled stat compared to previous analysis

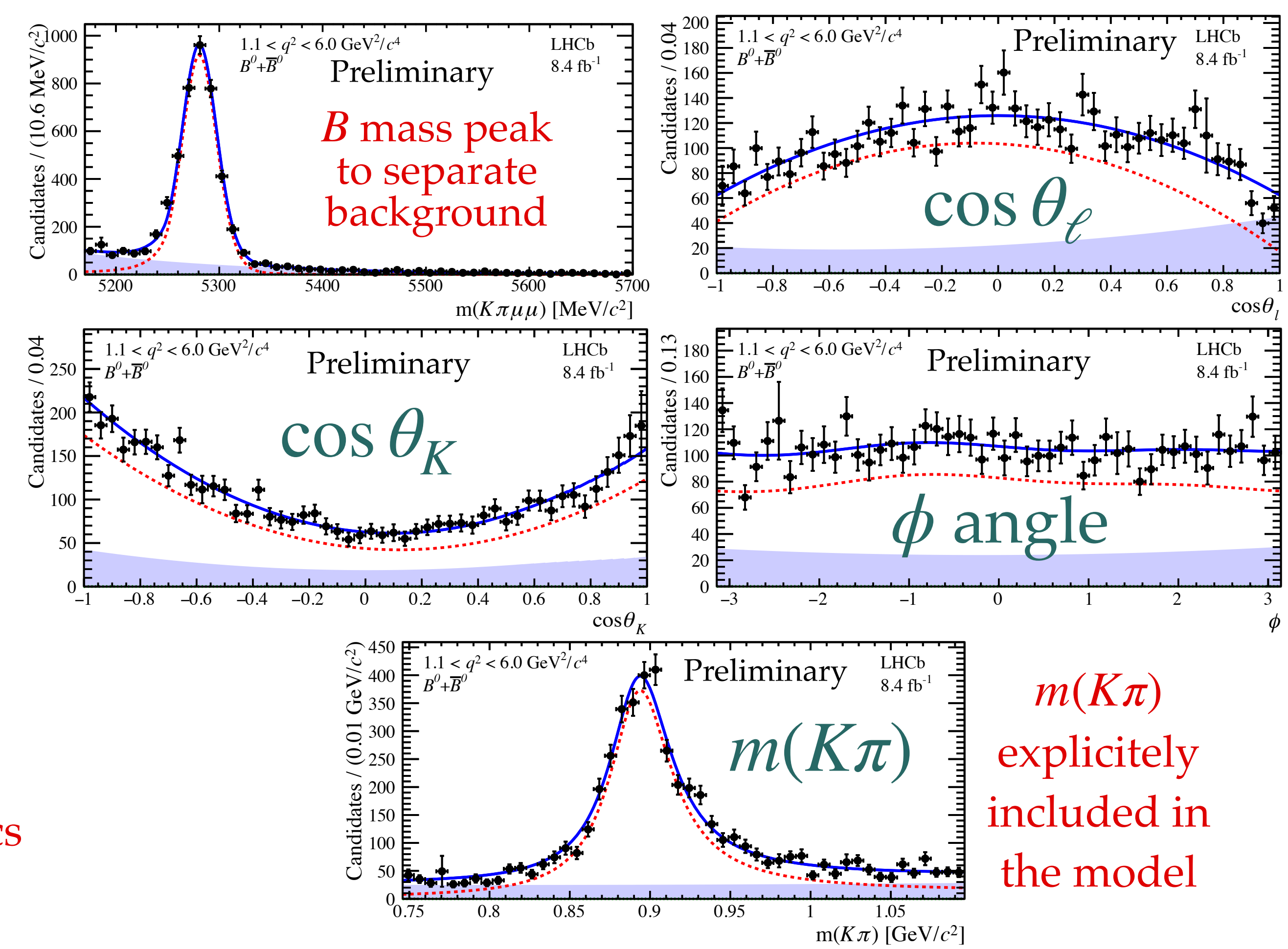
See CERN talks by L.Carus and M.Smith



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

Ang. observables — Spherical harmonics

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

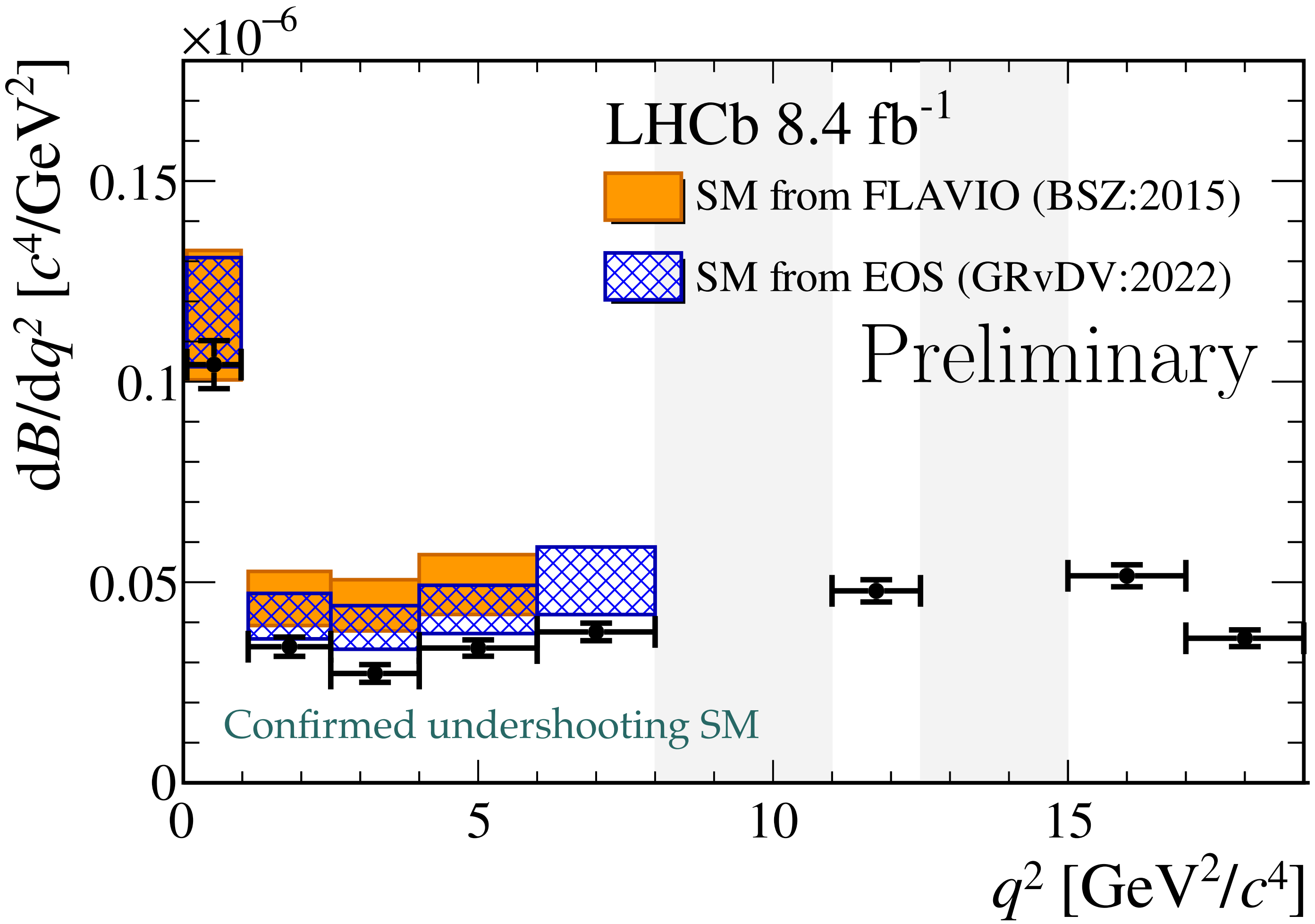


$m(K\pi)$ explicitely included in the model

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

NEW

LHCb-PAPER-2025-041 (in preparation)



- $\mathrm{dBr}/\mathrm{d}q^2$ 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]

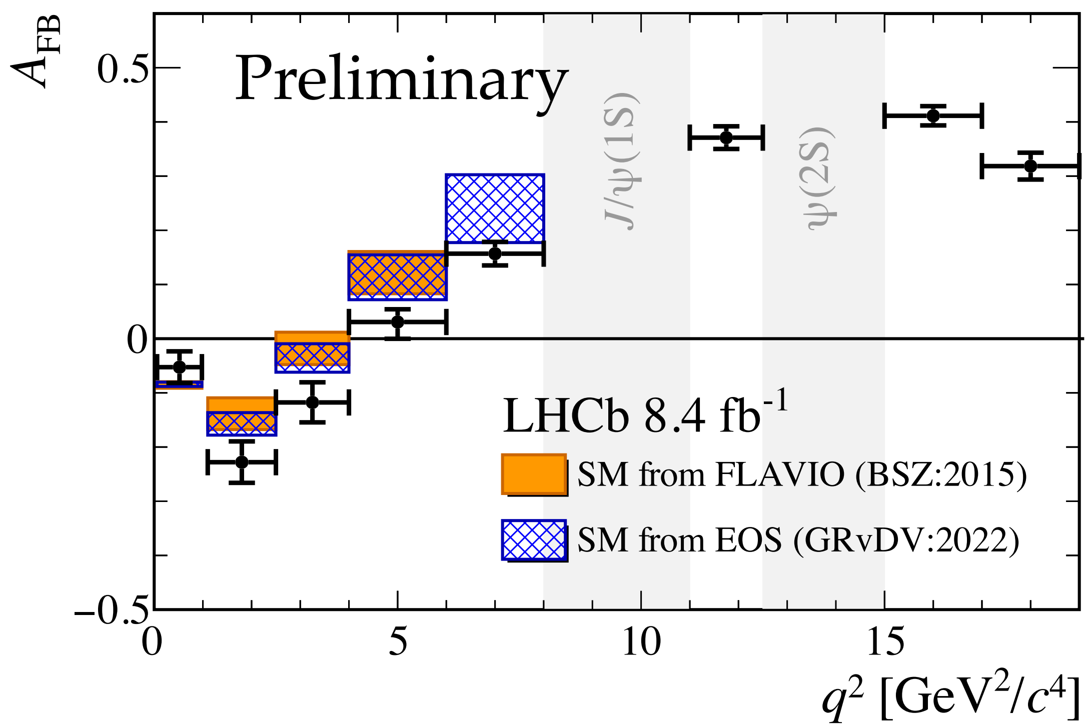
Check CERN seminar for all preliminary results (plots, tables)

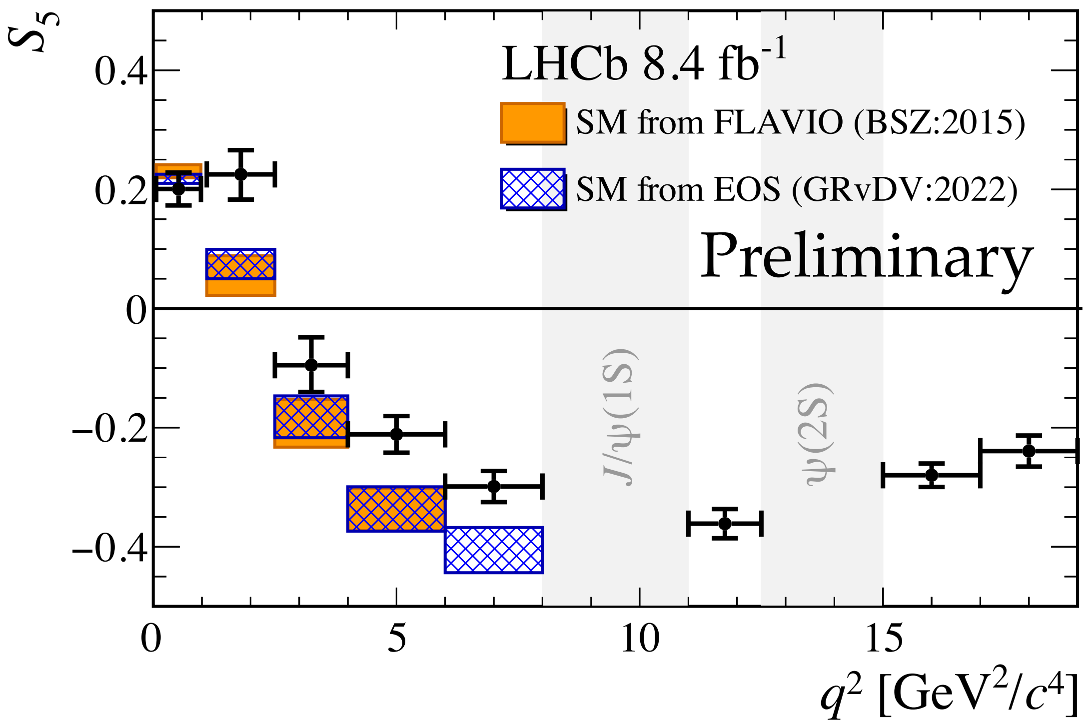
$B^0 \to K^*\mu\mu$ angular analysis

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)

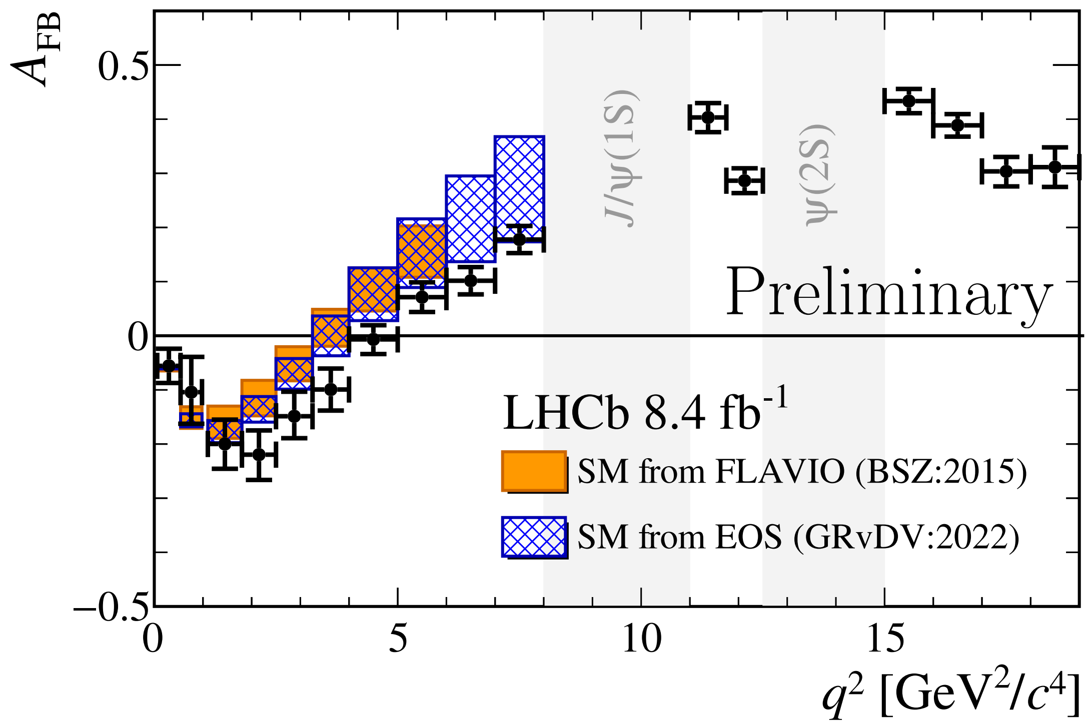
BSZ:
[arXiv:1810.08132]
[JHEP 08 (2016) 098]
GRvDV:
[EPJC 82 (2022) 569]
[JHEP 09 (2022) 133]

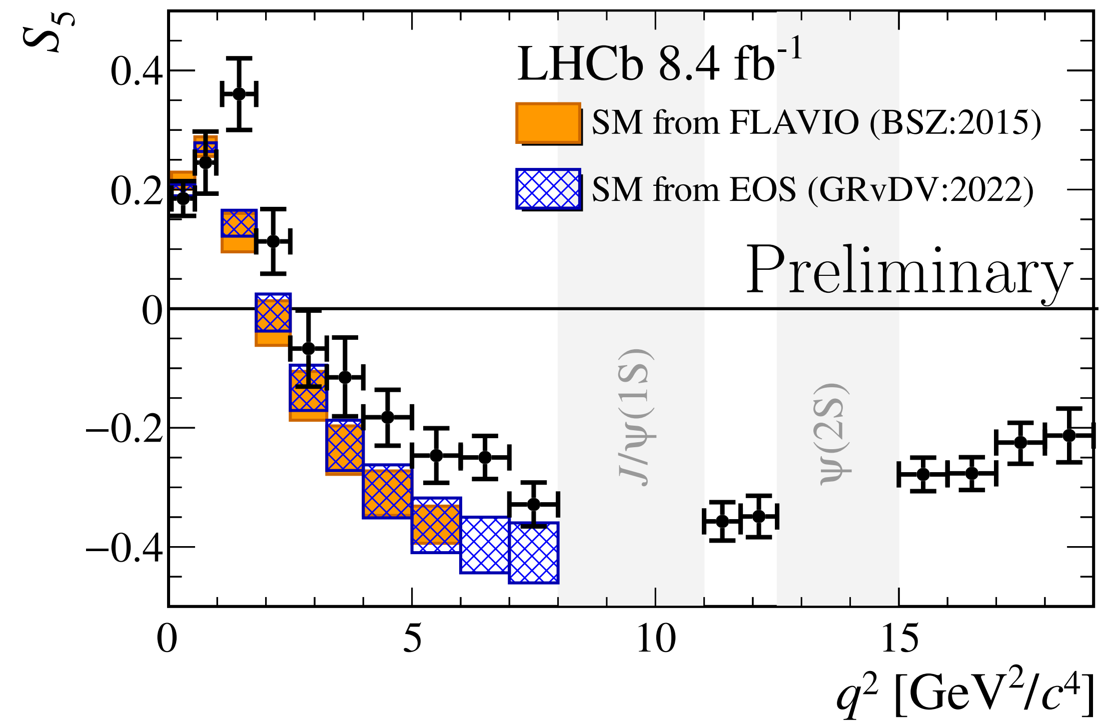
$B^0 \to K^*\mu\mu$ angular analysis

NEW

LHCb-PAPER-2025-041 (in preparation)

Halved q^2 bins to have better resolution on observables q^2 dependence





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

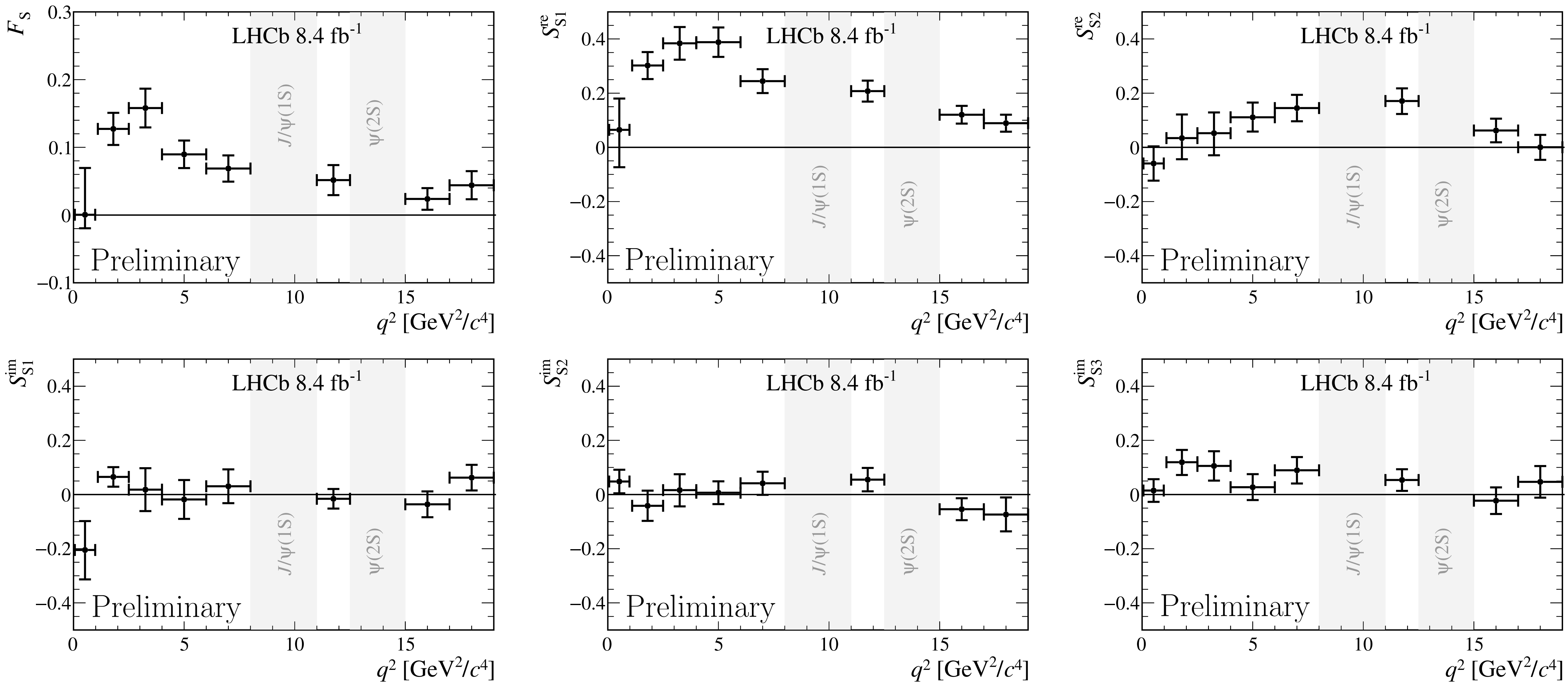
Check CERN seminar for all preliminary results (plots, tables)

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

NEW

LHCb-PAPER-2025-041 (in preparation)

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

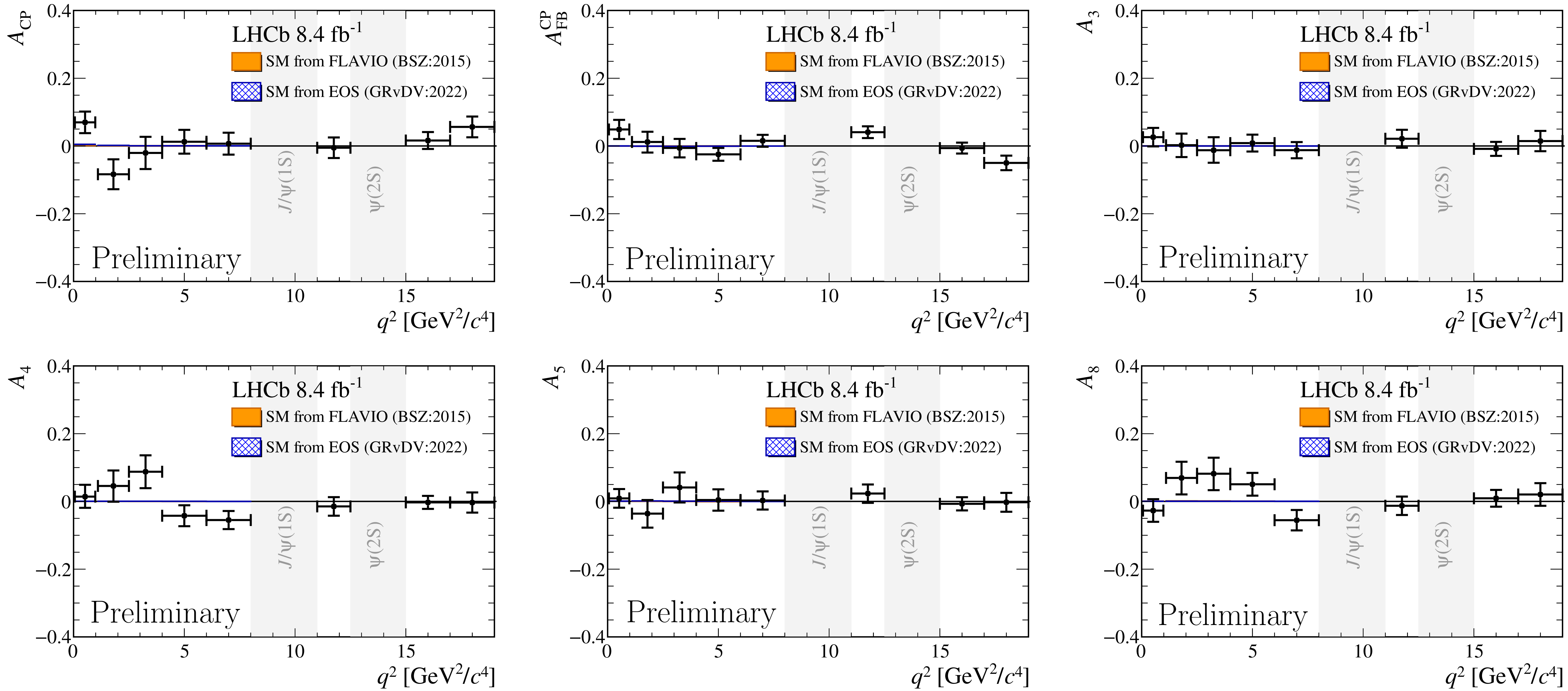


Check CERN seminar for all preliminary results (plots, tables)

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

LHCb-PAPER-2025-041 (in preparation)

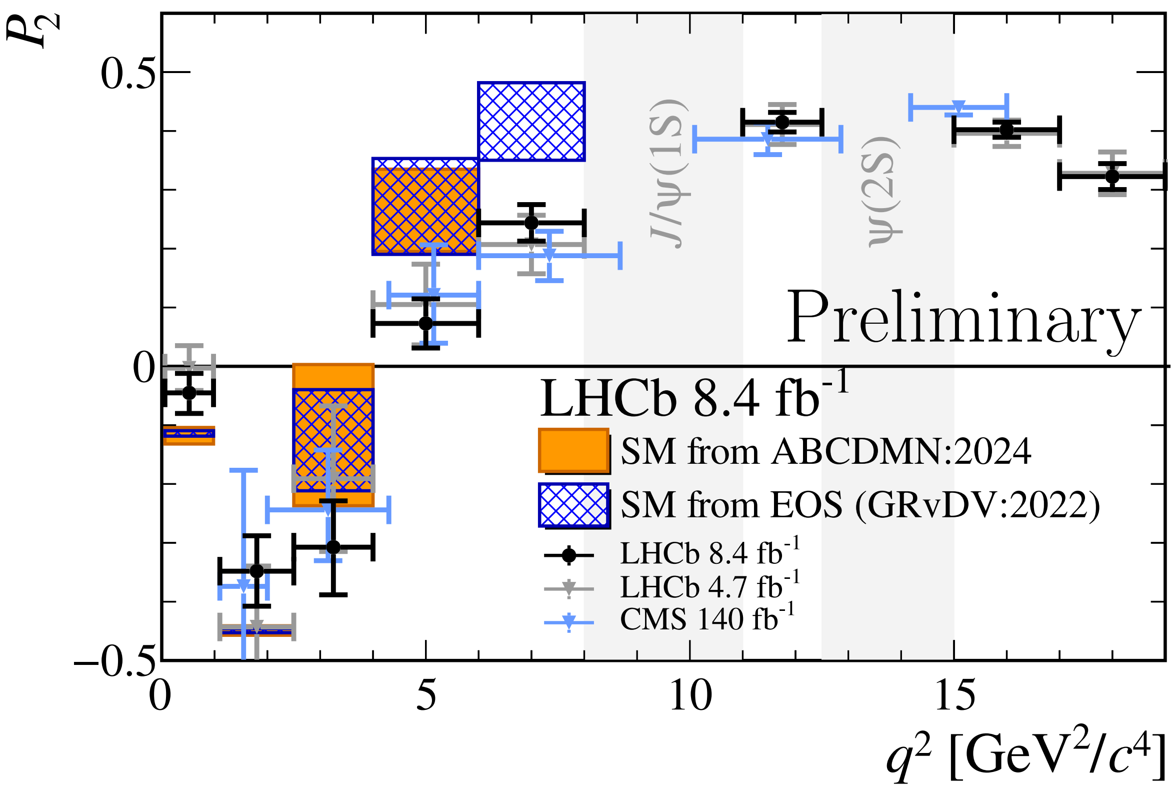
- CP asymmetric angular observables measured: no significant CP asymmetry observed

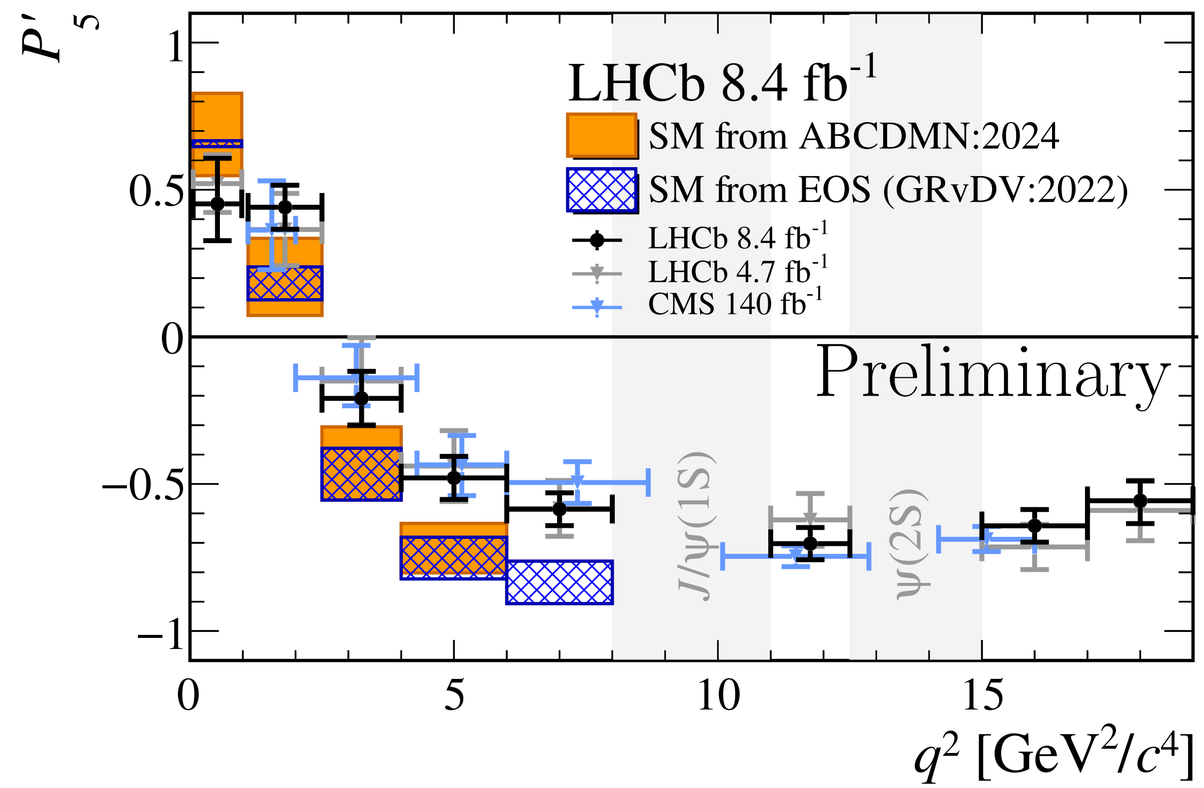


Check CERN seminar for all preliminary results (plots, tables)

Comparison to previous results

LHCb-PAPER-2025-041 (in preparation)



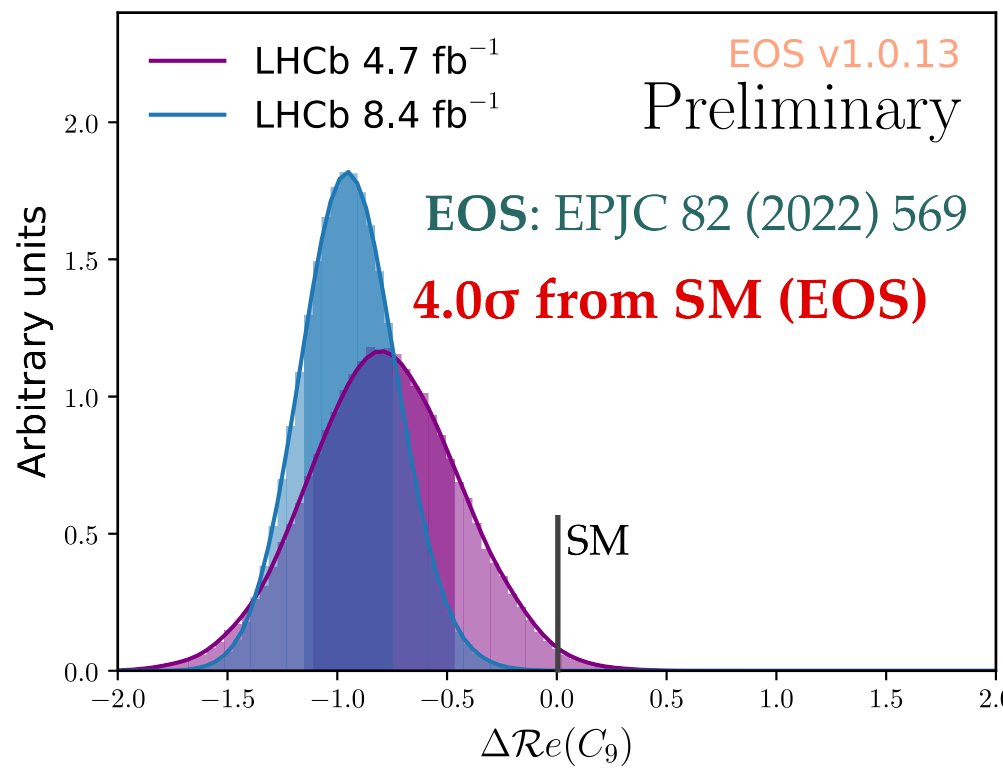


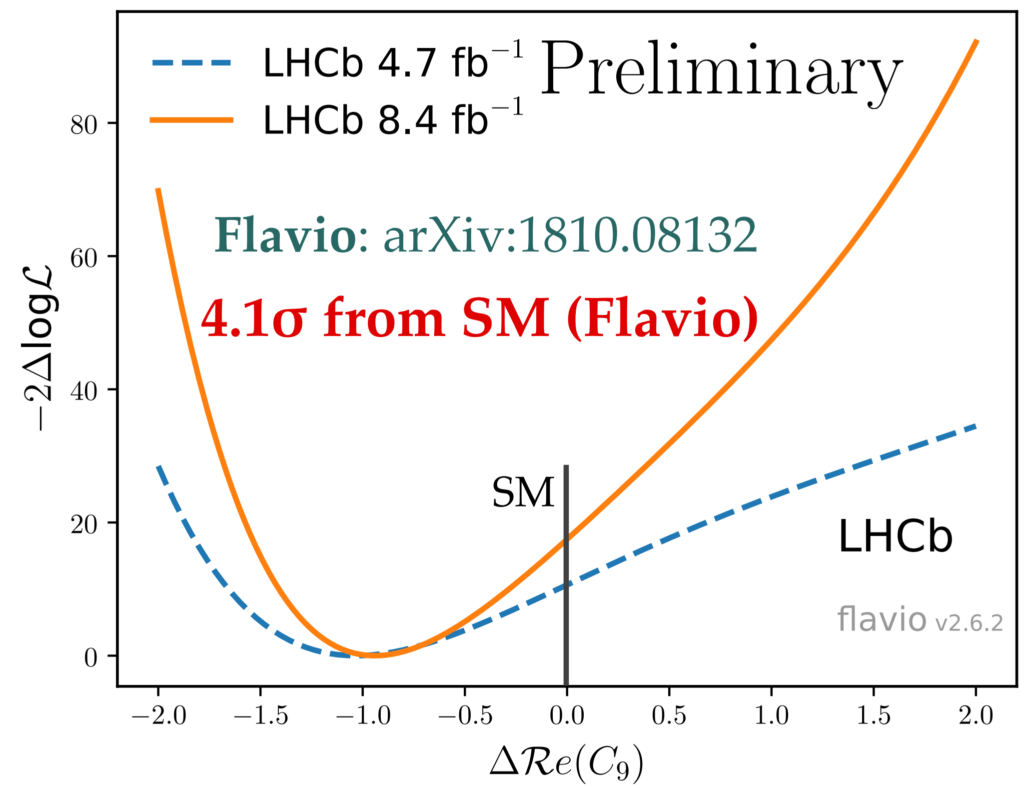
- New result consistent with previous LHCb measurement (superseded)
- Also consistent and more precise than latest CMS measurement (140 fb^{-1})

Wilson coefficients fits

LHCb-PAPER-2025-041 (in preparation)

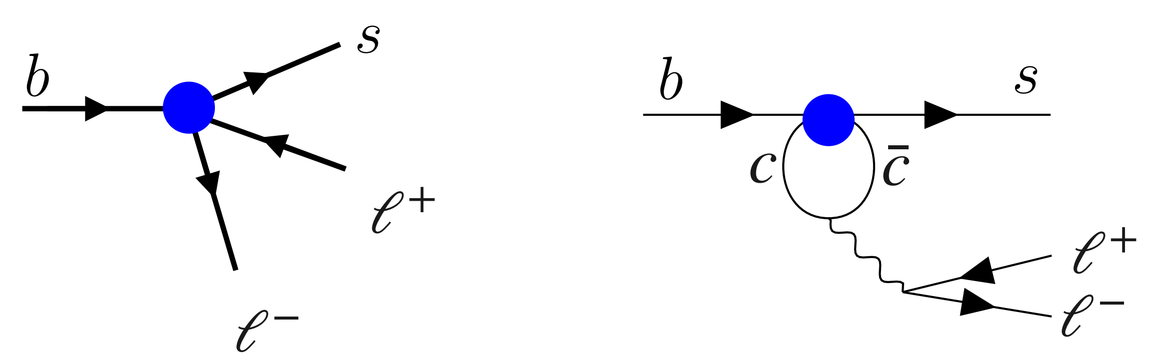
- Can fit C_9 Wilson coefficient to angular observables and Br
  - Precise results depend on fit setup and treatment of non-local effects $\rightarrow$ take it with a grain of salt
  - Many predictions available, just two sets compared here
- **Anomaly wrt SM persists and gets more significant**





All observables and corr matrices will be provided in HepData
Is this information in q^2 bins enough for theorists to play with?

Comparison to unbinned LHCb analyses



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

- 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)
- Model with disp.relation (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)

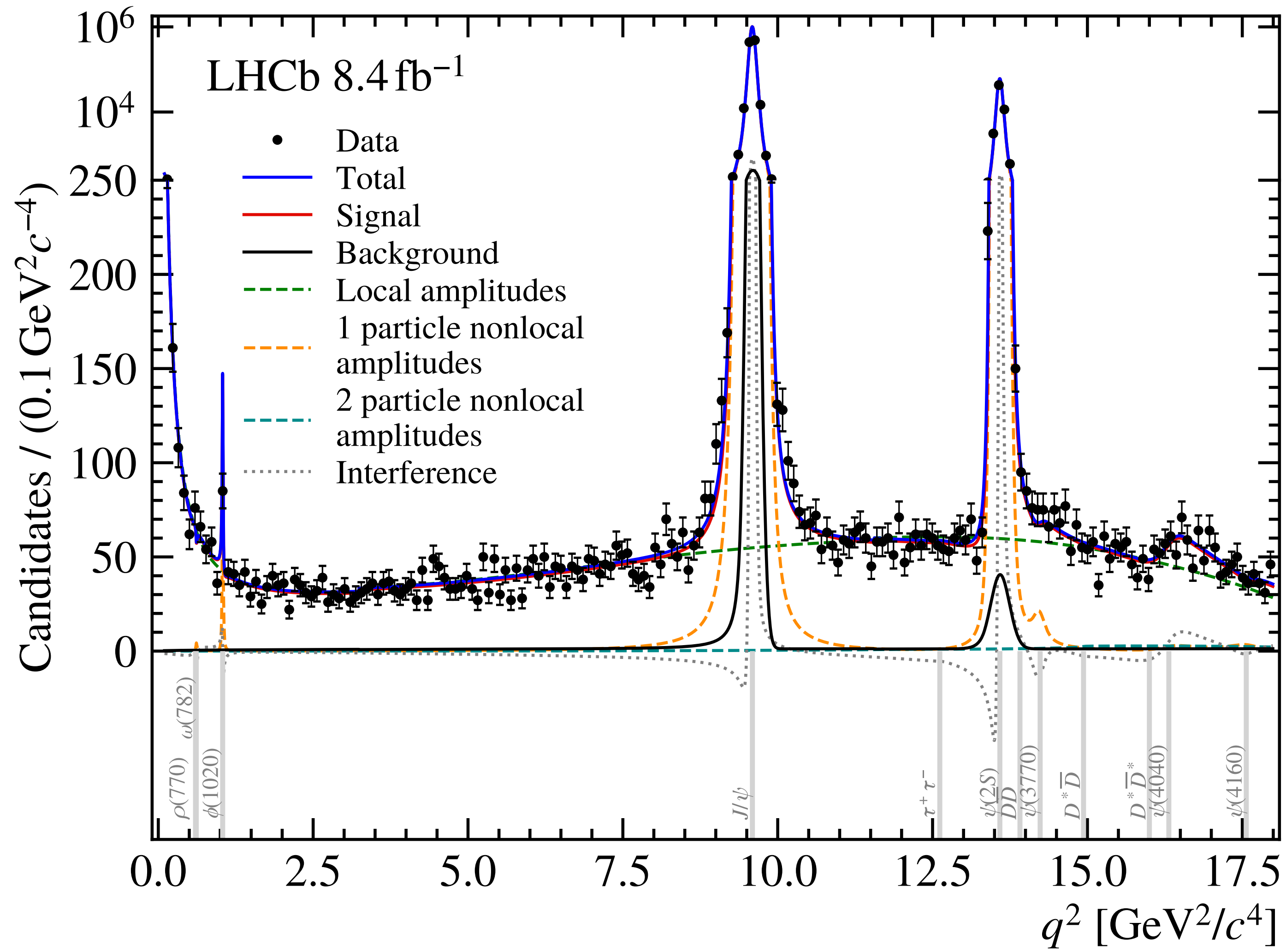
(ii) [PRL 132 (2024) 131801]+ [PRD 109 (2024) 052009]

(iii) [JHEP 09 (2024) 026]

$B^0 \to K^*\mu\mu$ analysis with disp. relation model

LHCb, JHEP 09 (2024) 026

- Unbinned amplitude analysis of entire q^2 spectrum
- Local form factors constrained from combination of LCSR and LQCD
  Gubernari et al, JHEP 09(2022)133
- Dispersion relation model for long-distance contributions to C_9^{eff}



Non-local contributions

$$C_9^{\text{eff},\lambda}(q^2) = C_9^\mu + Y_{c\bar{c}}^{(0),\lambda} + Y_{q\bar{q}}^{1P,\lambda}(q^2) + Y_{c\bar{c}}^{2P,\lambda}(q^2) + Y_{\tau\bar{\tau}}(q^2)$$

Determined at negative q^2
Asatrian et al JHEP 04(2020)012

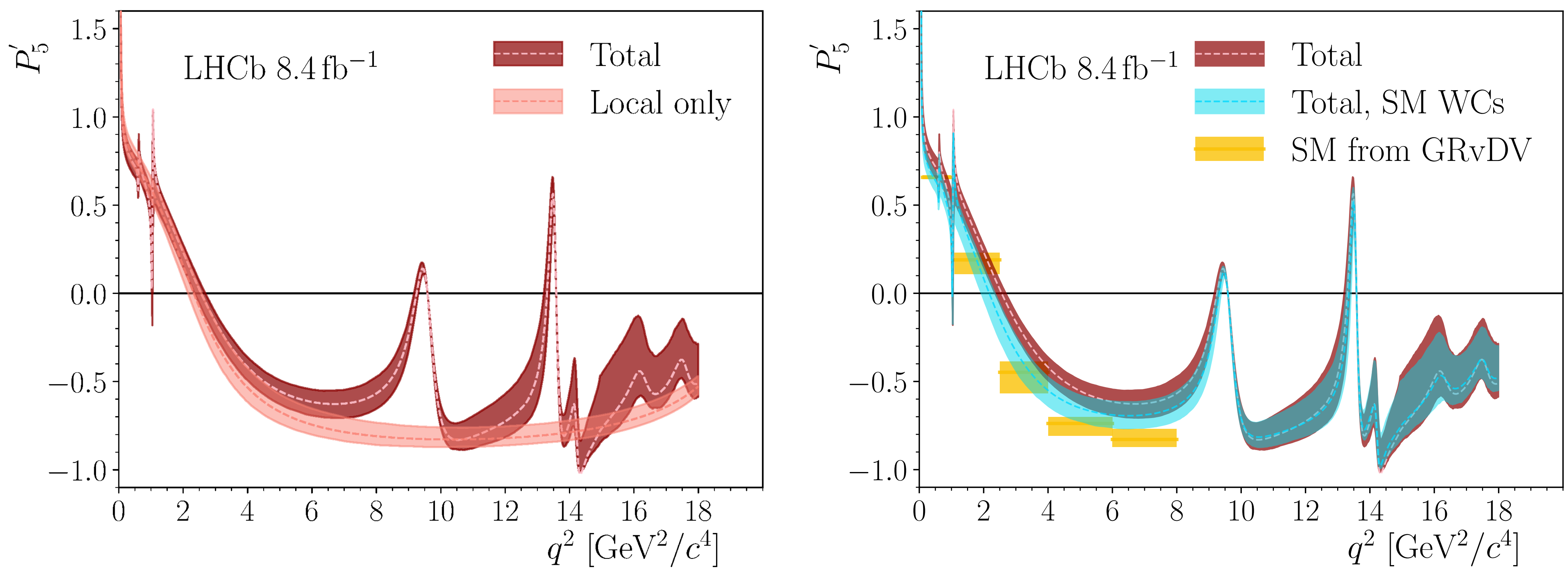
Includes: $\omega(782)$, $\rho(770)$, $\phi(1020)$, J/ψ, $\psi(2S)$, $\psi(3770)$, $\psi(4040)$, $\psi(4160)$

Includes: $D\bar{D}$, $D^*\bar{D}$, $D^*\overline{D^*}$

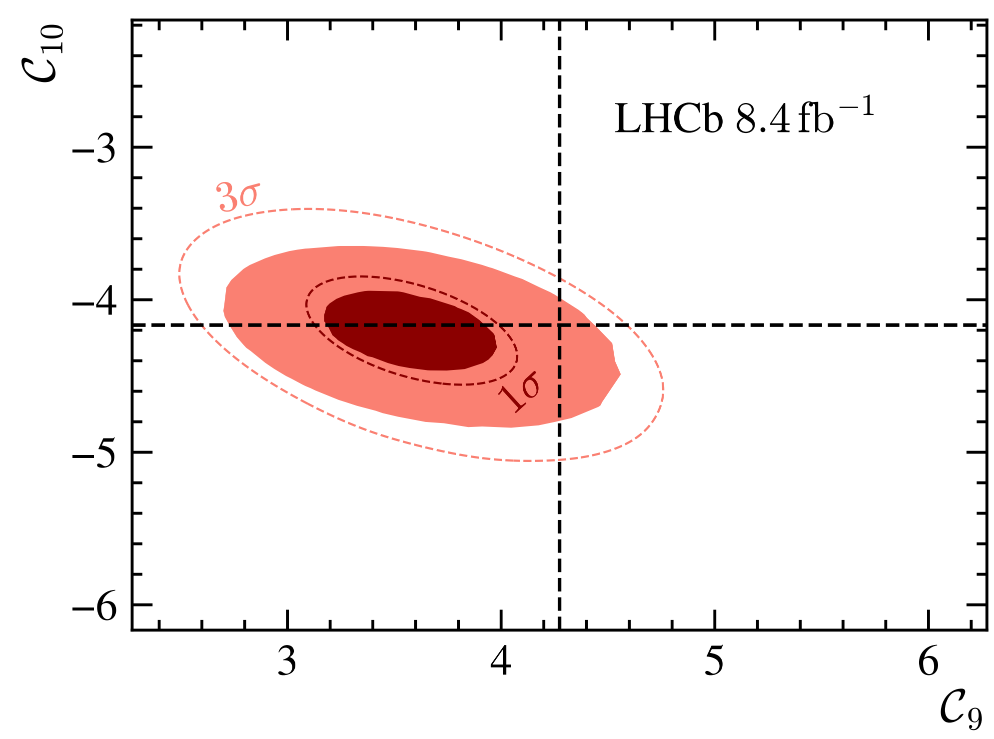
$b \to s\tau\tau$ non-local
C.Cornella et al EPJC 80(2020)12,1095

$B^0 \to K^*\mu\mu$ analysis with disp. relation model

JHEP 09 (2024) 026



- Fit determines 150 parameters including short distance WC non-local contributions and local form factors
- Non-local contributions have significant impact on observables
- Effect not fully degenerate with NP contribution to local C_9, but anomaly reduced to 2.1σ

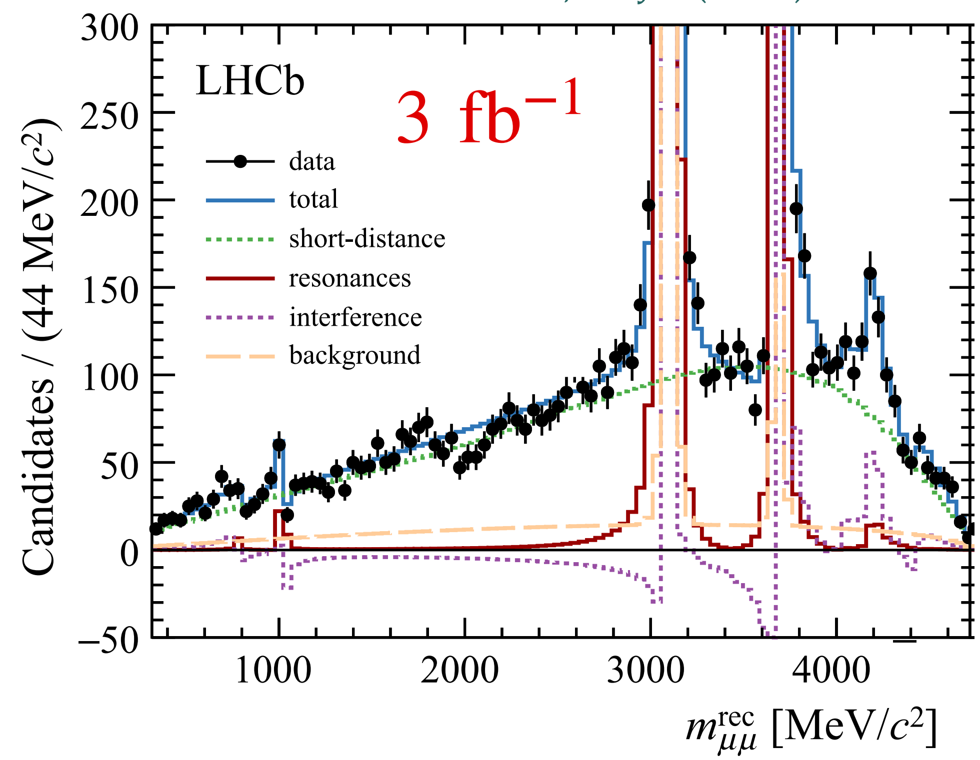


Future prospects

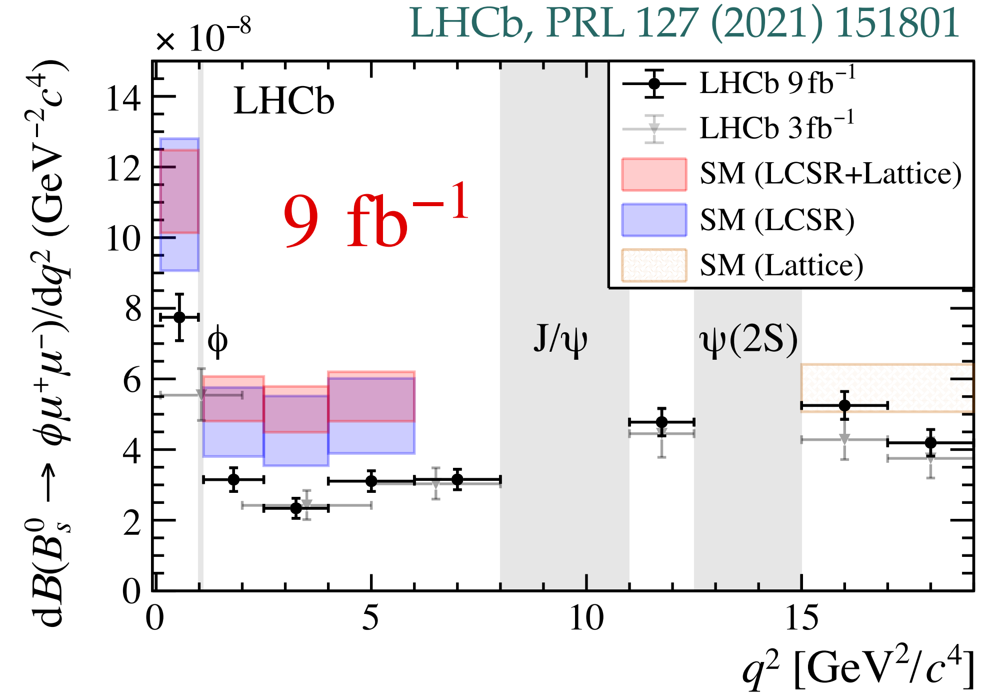
See talks from Simon and Arianna
for the theory perspective

- The data from LHCb (and CMS) can give more inputs
- Huge $B^+ \to K^+\mu\mu$ dataset allows sophisticated analysis of q^2 spectrum
- Extend $B^0 \to K^*\mu\mu$ disp.relation method to CPV observables
- Sophisticated analyses of the complementery $B_s \to \phi\mu\mu$ channel
- Dataset on tape for LHCb and CMS is much larger than what is published

LHCb, EPJC (2017) 77 :161

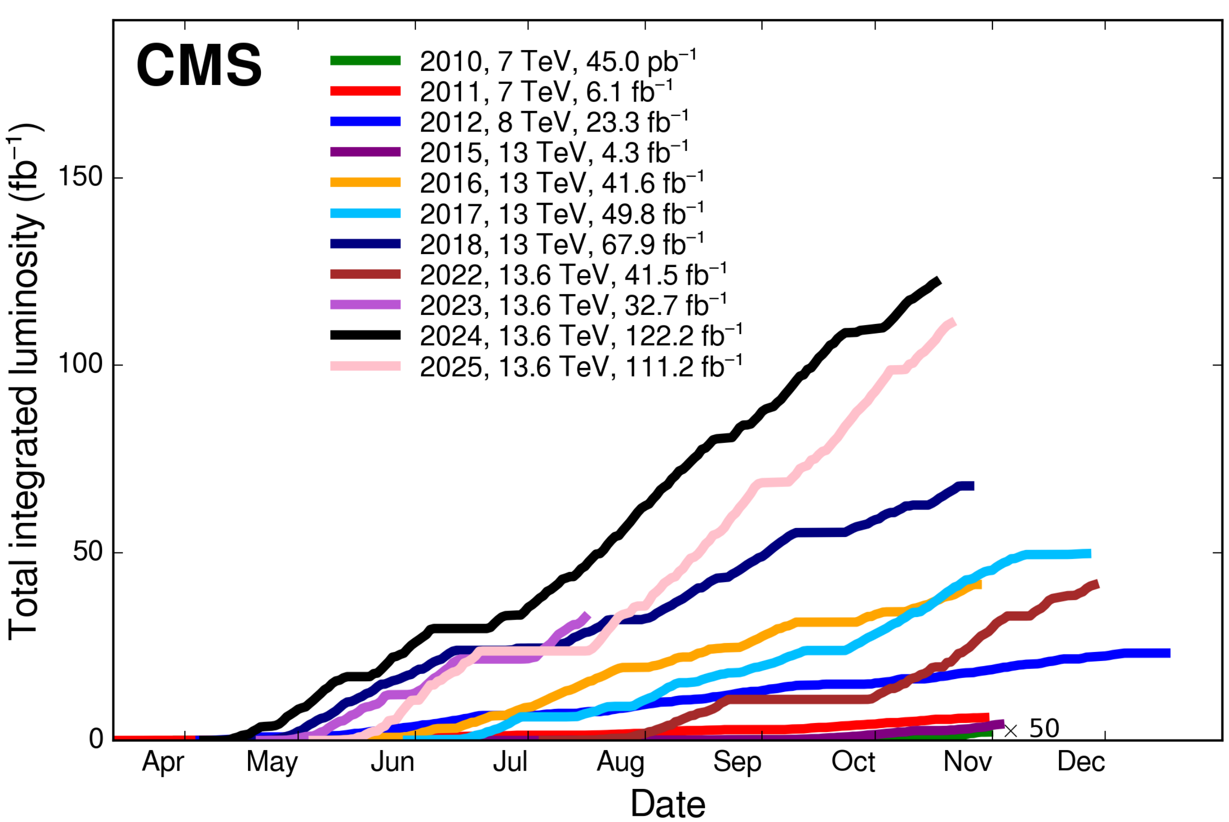


LHCb, PRL 127 (2021) 151801

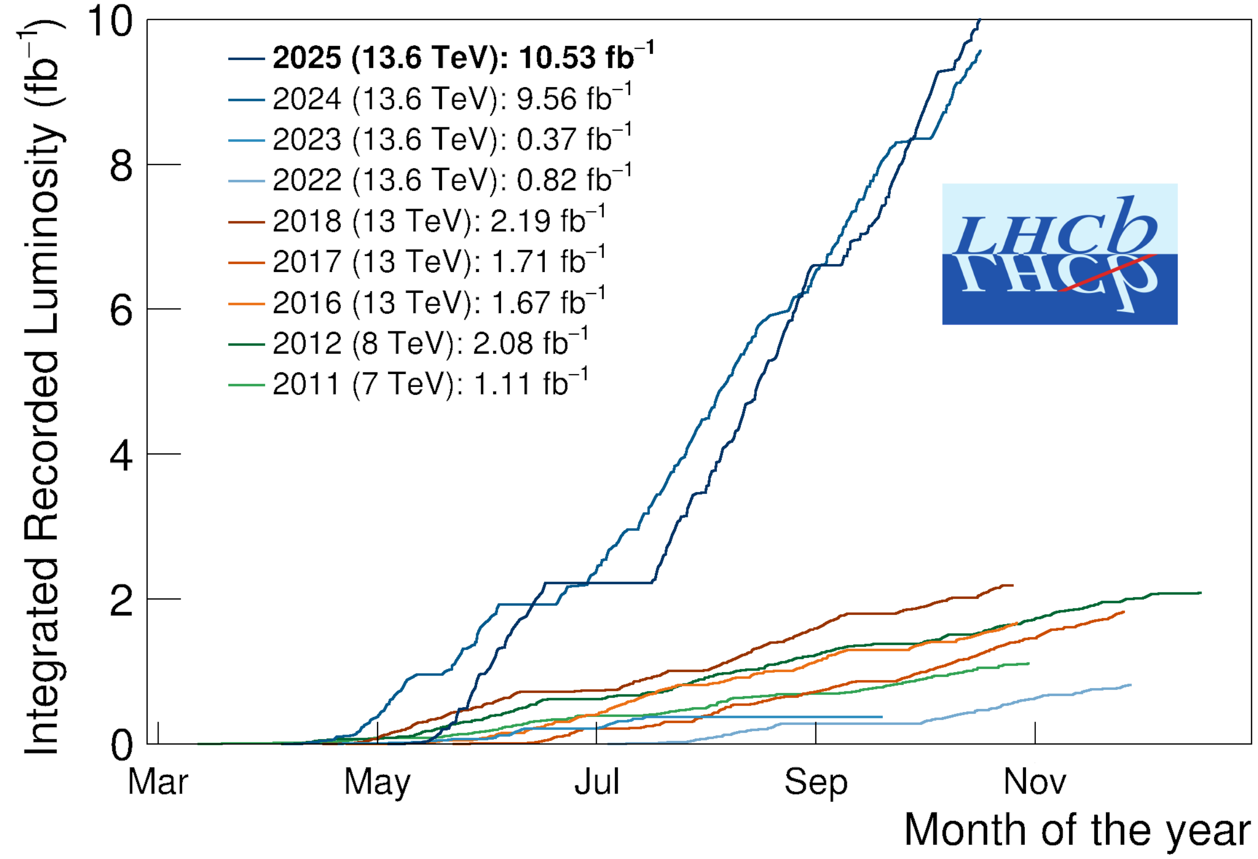


Growing datasets

Latest K*$\mu\mu$ published with Run 2 (140/fb)



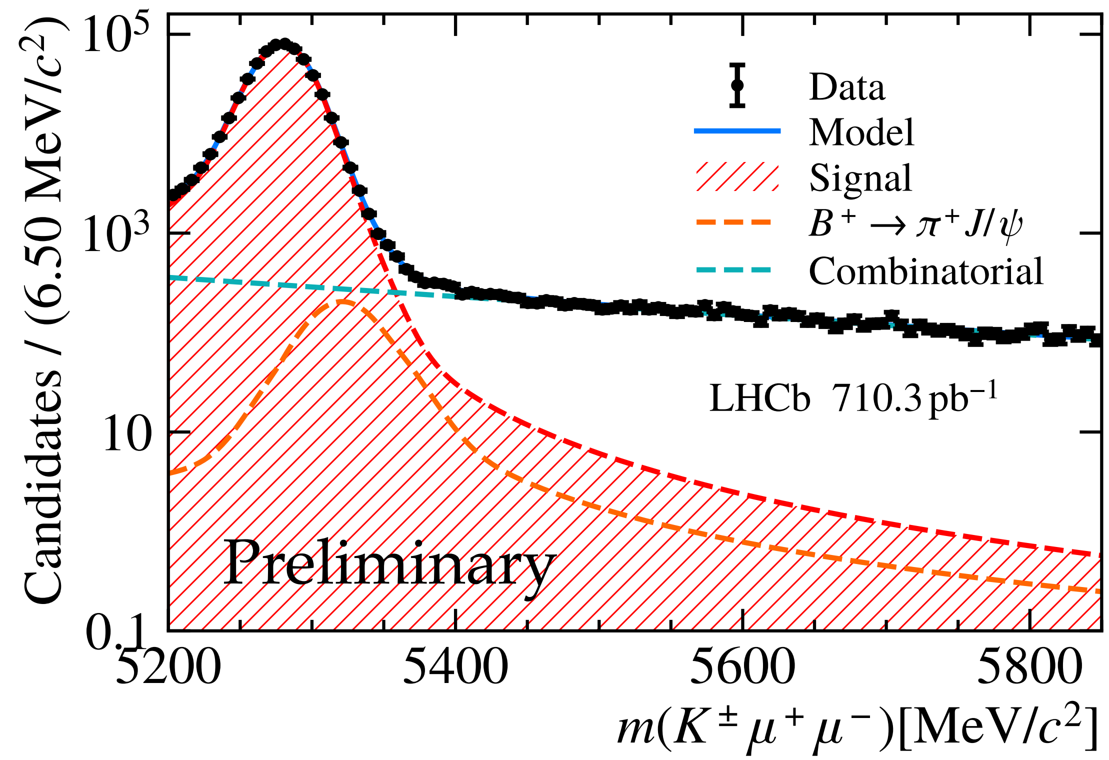
Latest K*$\mu\mu$ published with Run 1+2 (9/fb)



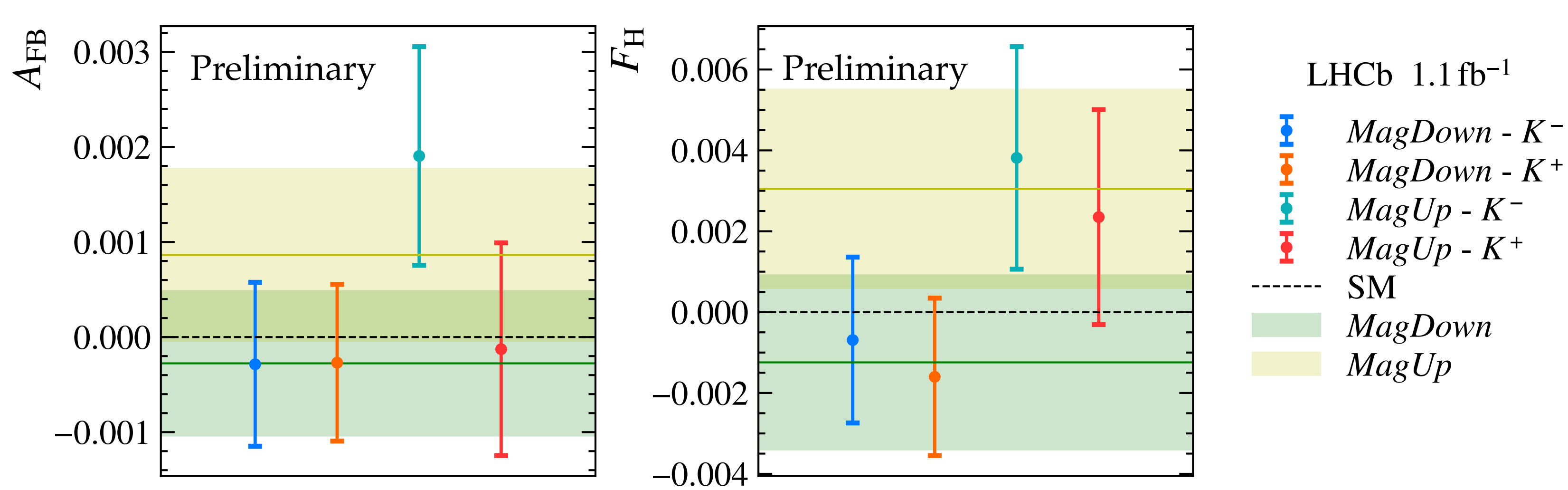
$B^+ \to K^+ J/\psi$ to validate Run3 data

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



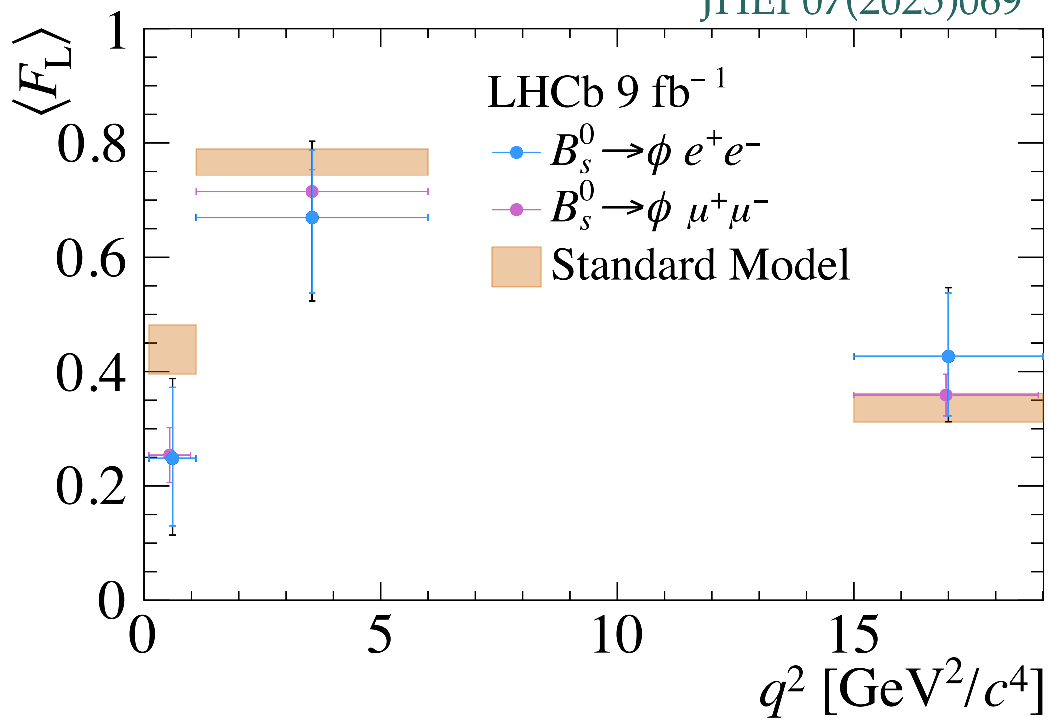
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_\ell} = \frac{3}{4}\left(1-F_{\rm H}\right)\left(1-\cos^2\theta_\ell\right) + \frac{1}{2}F_{\rm H} + A_{\rm FB}\cos\theta_\ell$$



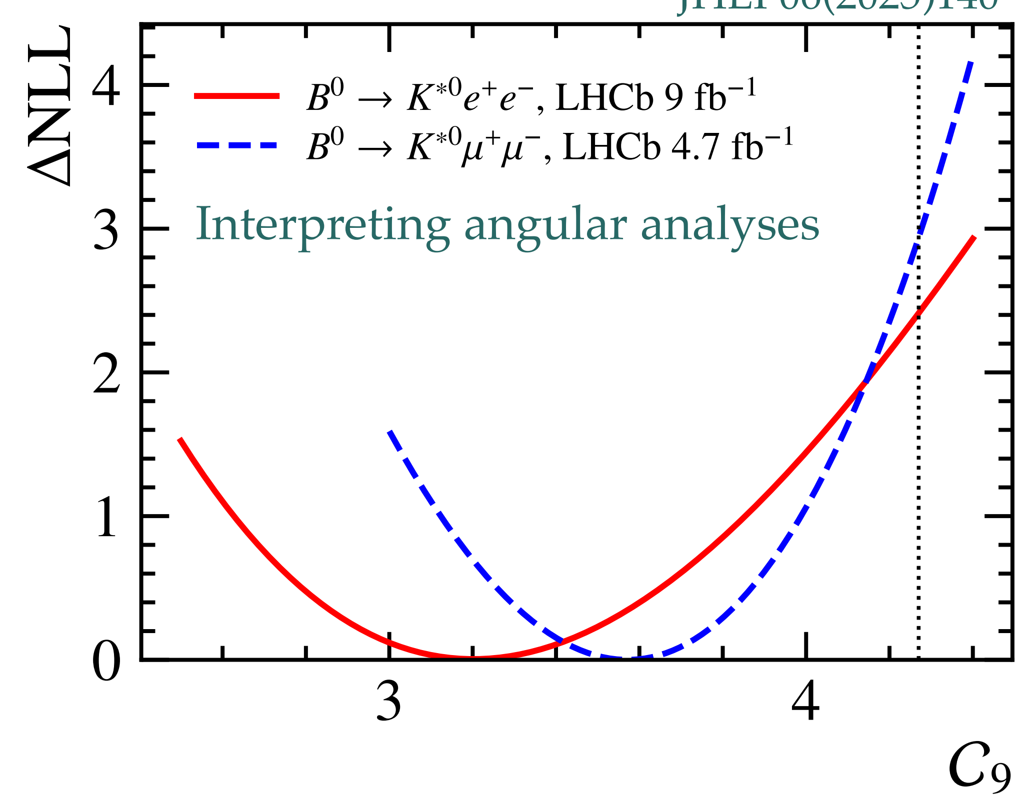
Angular analyses in $b \to s e^+ e^-$

- Angular analyses of $b \to see$ channels now allowing LFU tests also in the angles
- $B^0 \to K^* ee$ angular analysis JHEP06(2025)140
  - Higher statistics, Analysis in central q^2 bin
- $B_s \to \phi ee$ angular analysis JHEP07(2025)069
  - Lower stat but cleaner, Analysis in 3 q^2 bins

JHEP07(2025)069



JHEP06(2025)140

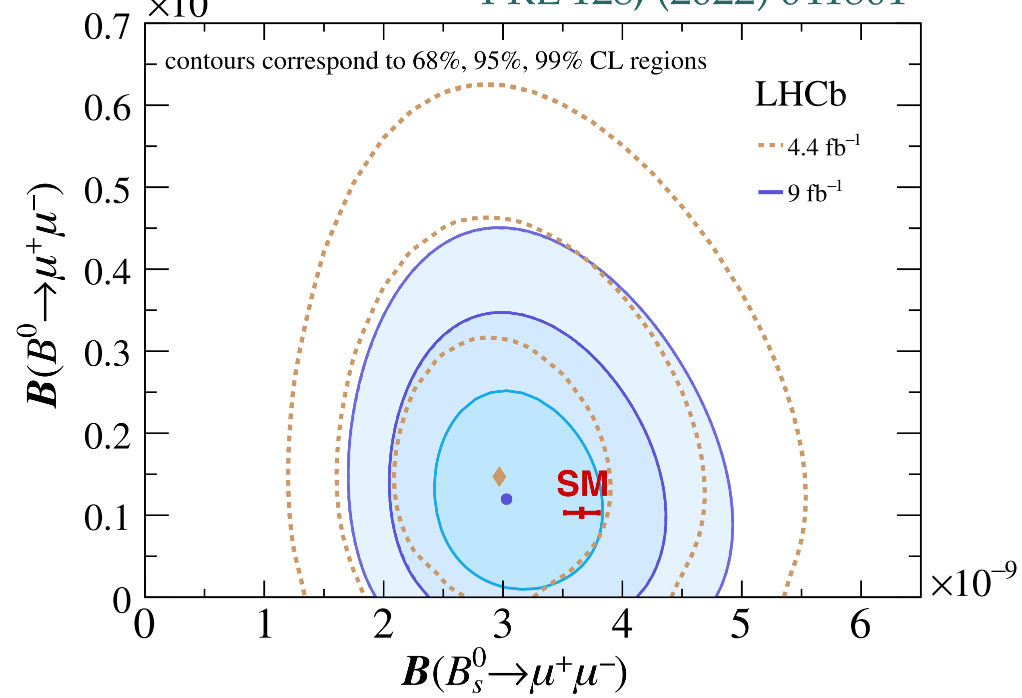


Electrons confirm shift in C_9 observed in muons (LFU)

Semileptonic $b \to d\ell\ell$

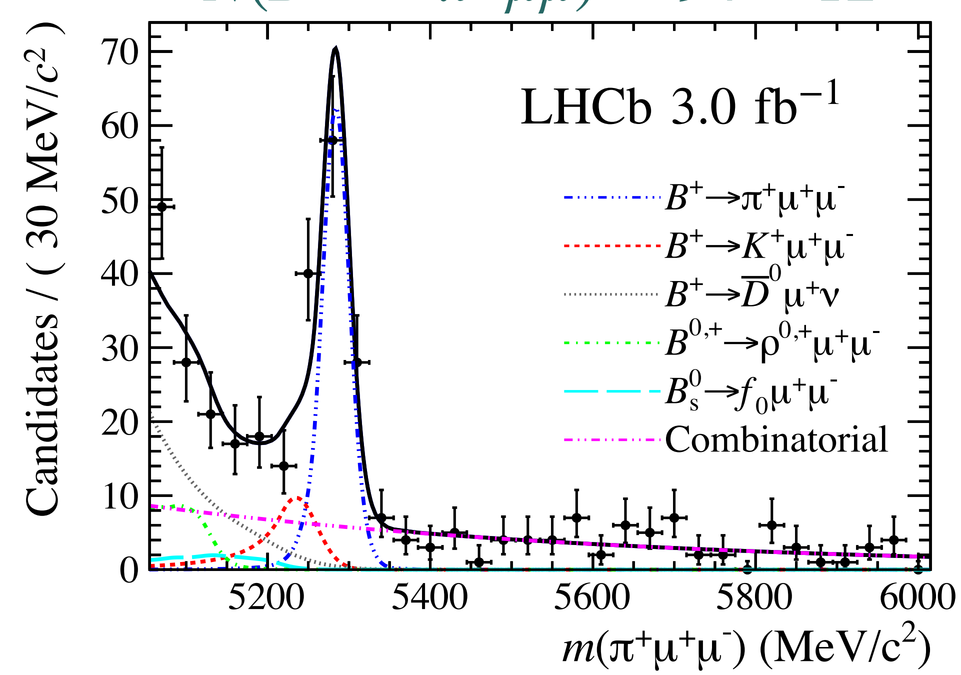
- A further $|V_{td}/V_{ts}|^2 = \simeq 0.05$ suppresion of decay rates w.r.t. $b \to s$
  - Starting to explore the $b \to d$ frontier
- Leptonic $B_d \to \mu\mu$ is almost at reach of experimental sensitivity
- $B^+ \to \pi^+\mu\mu$ measured with Run 1 dataset at 13% stat precision

PRL 128, (2022) 041801



- Many ongoing $b \to d\ell\ell$ analyses. We are about to enter the precision regime (time-dep, angular, …)
  → **Stay tuned for upcoming results**
- Can we learn something about long-distance contributions by comparing $b \to d\ell\ell$ and $b \to s\ell\ell$?

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

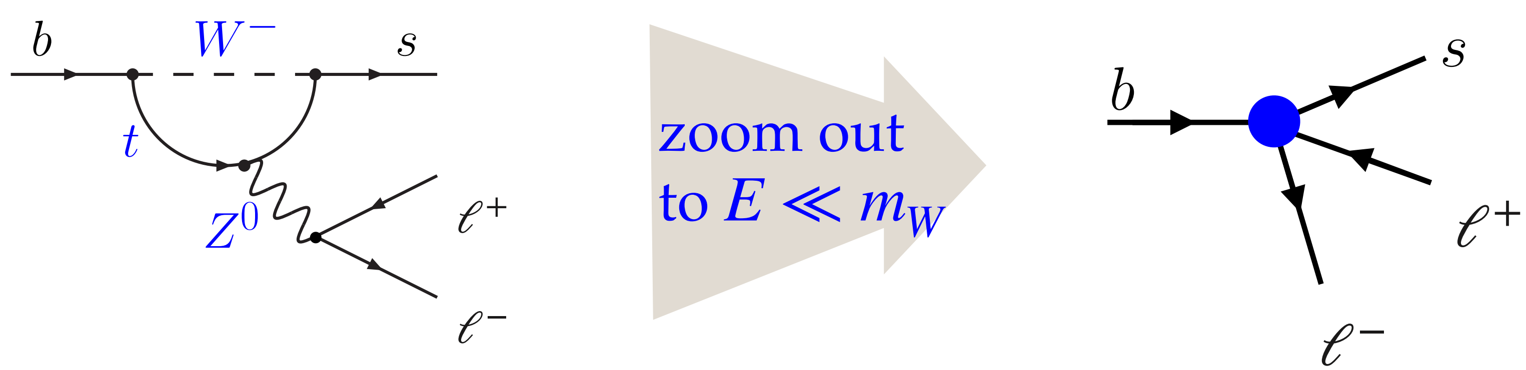


Conclusions

- Experimental progress on radiative leptonic decays
  - Upper limits close to SM predictions for $B \to \ell\nu\gamma$, $B \to \ell\nu\ell'\ell'$ and $B_s \to \mu\mu\gamma$
  - LHCb can contribute to $B \to \ell\nu\gamma$ (although it's very hard)
  - Good prospects for Belle2 and LHCb-Upgrade to observe these decays for the first time
- Status of $b \to s\mu\mu$ analyses
  - Huge datasets from LHCb and CMS
  - Sophisticated model (in)dependent analyses
  - Can we tame the long-distance contributions using data?

BACKUP

Effective theory interpretation



EFT below EW scale:

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

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

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

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

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

$O_P^{(\prime)} = (\bar{s}\gamma_\mu P_{\text{R(L)}}b)(\bar{\ell}\gamma_5\ell)$ **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 $C^e \neq C^\mu \neq C^\tau$

See previous talk by Paula Alvarez Cartelle

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

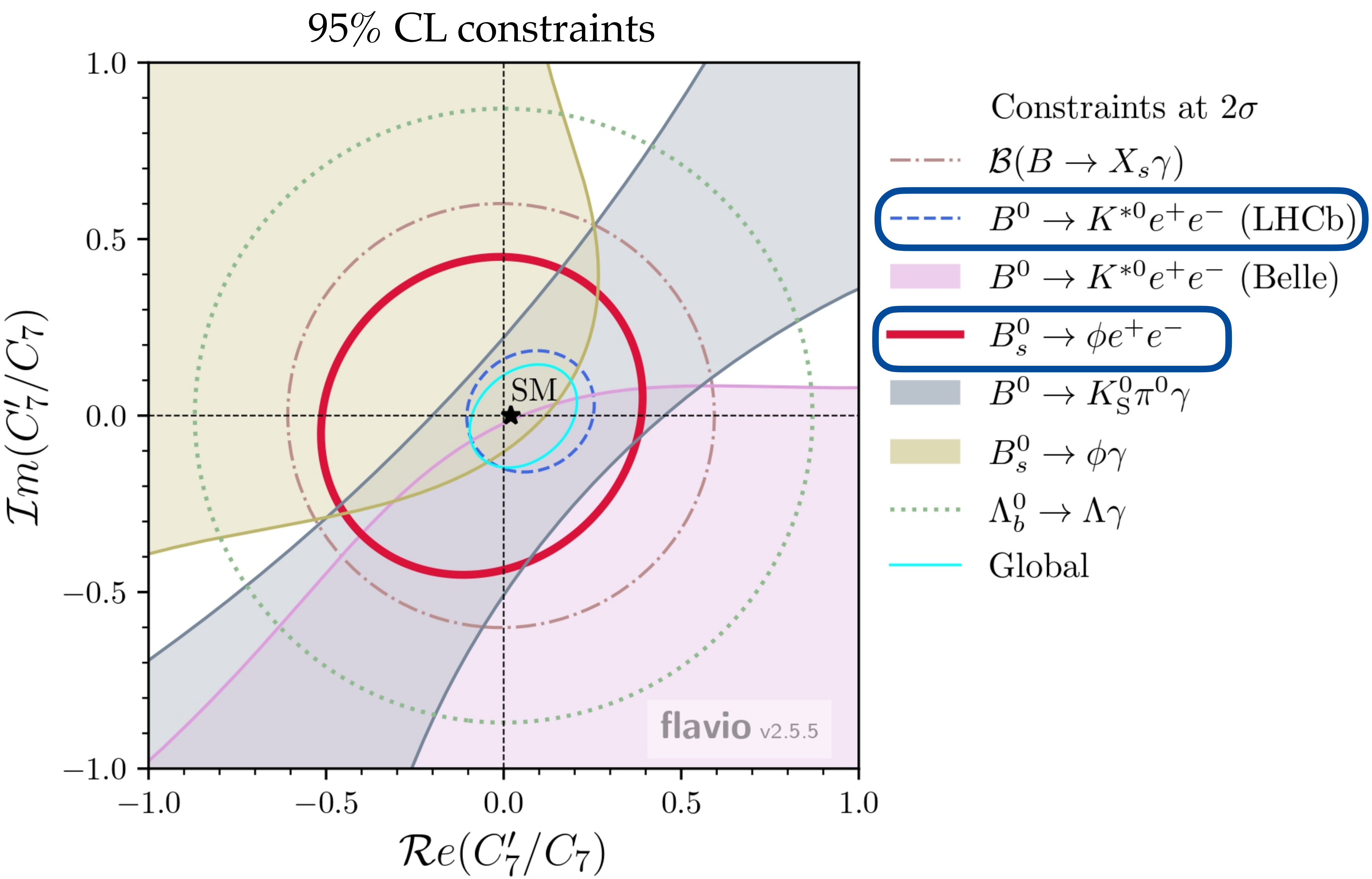
- Mixing-induced CPV in $B \to K_S\pi^0\gamma$ at B-factories [2]
- $\Delta\Gamma_s$ induced rate asymmetry in $B_s \to \phi\gamma$ at LHCb [3]
- Angular analysis of $\Lambda_b \to \Lambda\gamma$ at LHCb [4]
- Transverse asymmetries in $B \to Ve^+e^-$ at LHCb [5]

-> 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 $B^0 \to K^* e^+ e^-$

LHCb JHEP 03 (2025) 047



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

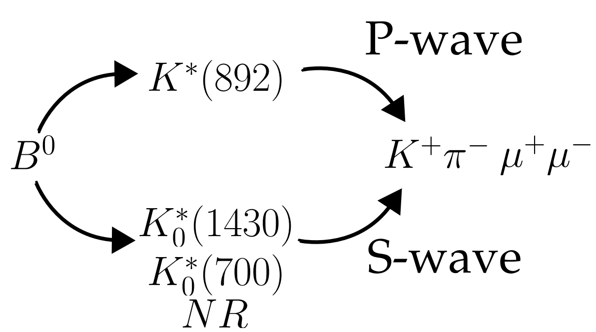
LHCb-PAPER-2025-041 (in preparation)

Angular observables
S_i : CP average
A_i : CP asymmetries

$$\frac{d^4\Gamma}{dq^2\, d\vec{\Omega}\, dm_{K\pi}} \frac{1}{\Gamma + \bar{\Gamma}} = \left(1 - \hat{\Gamma}_S\right) \frac{9}{64\pi} \sum_i \left(S_i - A_i\right) f_i(\vec{\Omega}) \left| \mathscr{BW}_P\left(m_{K\pi}\right) \right|^2 + \frac{1}{8\pi} \sum_{1ac,2ac} \left(\tilde{S}_i - \tilde{A}_i\right) f_i(\vec{\Omega}) \left| \mathscr{BW}_S\left(m_{K\pi}\right) \right|^2 + \frac{1}{8\pi} \sum_{1bc,\ S1-S5} \mathscr{Re}/\mathscr{Im}\left[\left(\tilde{S}_i - \tilde{A}_i\right) f_i(\vec{\Omega}) \mathscr{BW}_S\left(m_{K\pi}\right) \mathscr{BW}_P\left(m_{K\pi}\right)^*\right]$$

$m(K\pi)$ explicitely included

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



- $\mathscr{BW}_P$ is rel. Breit Wigner with Blatt-Weisskopf ang.mom. factors
- $\mathscr{BW}_S$ is LASS function with most parameters thaken from $B^0 \to K\pi J/\psi$ (apart from range parameter $r = 1.7\ \text{GeV}^{-1}$)

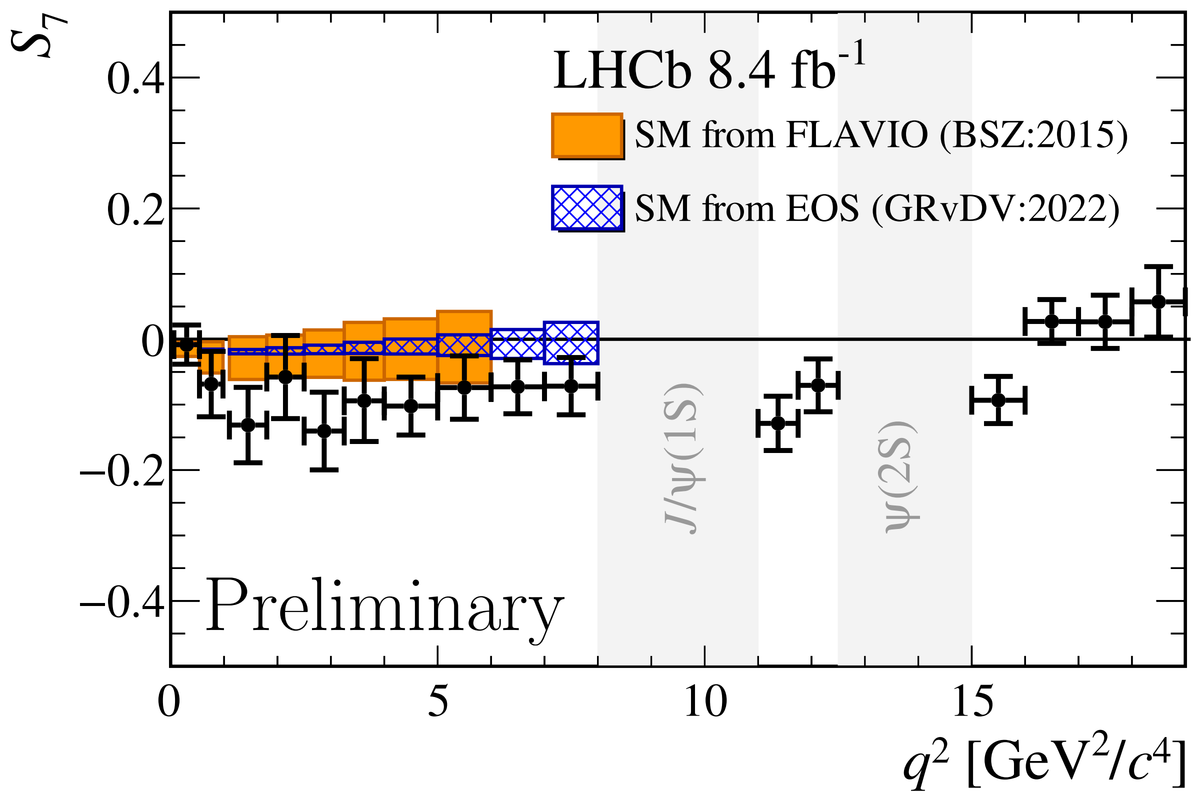
Check CERN seminar for more details

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

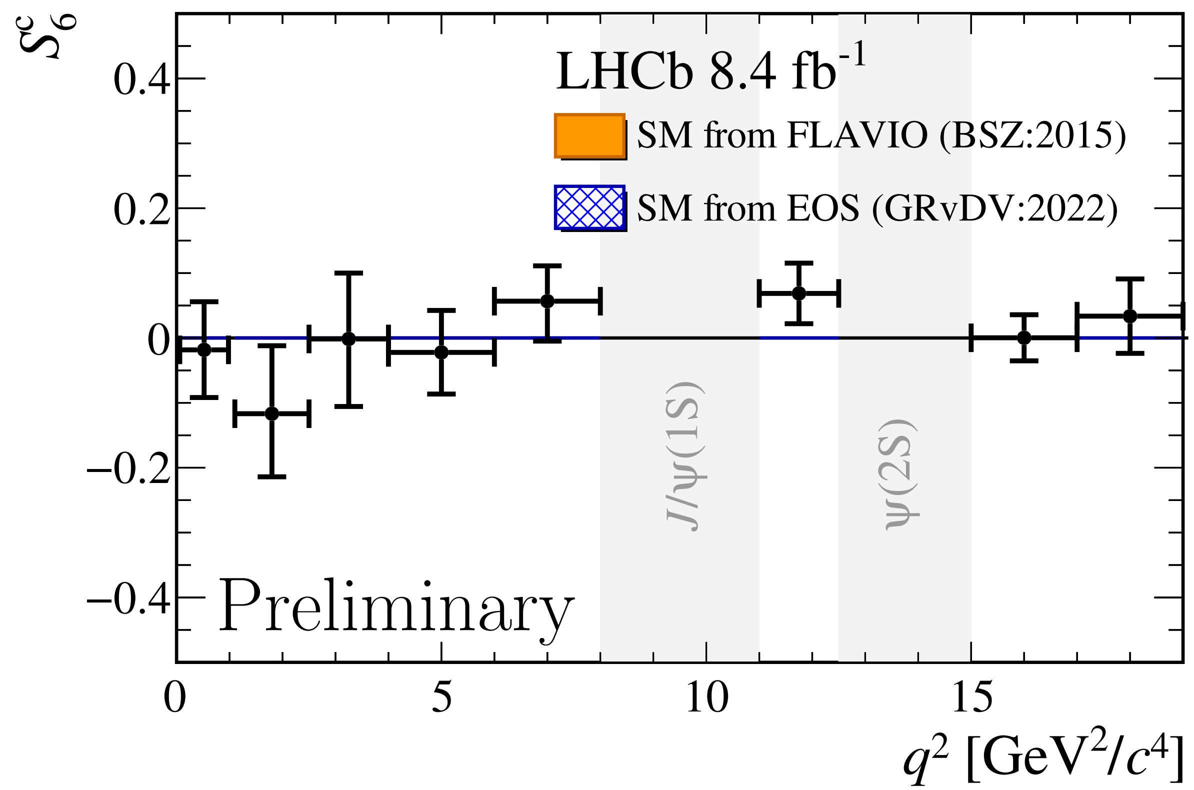
NEW

LHCb-PAPER-2025-041 (in preparation)

S_7 is sensitive to strong phases



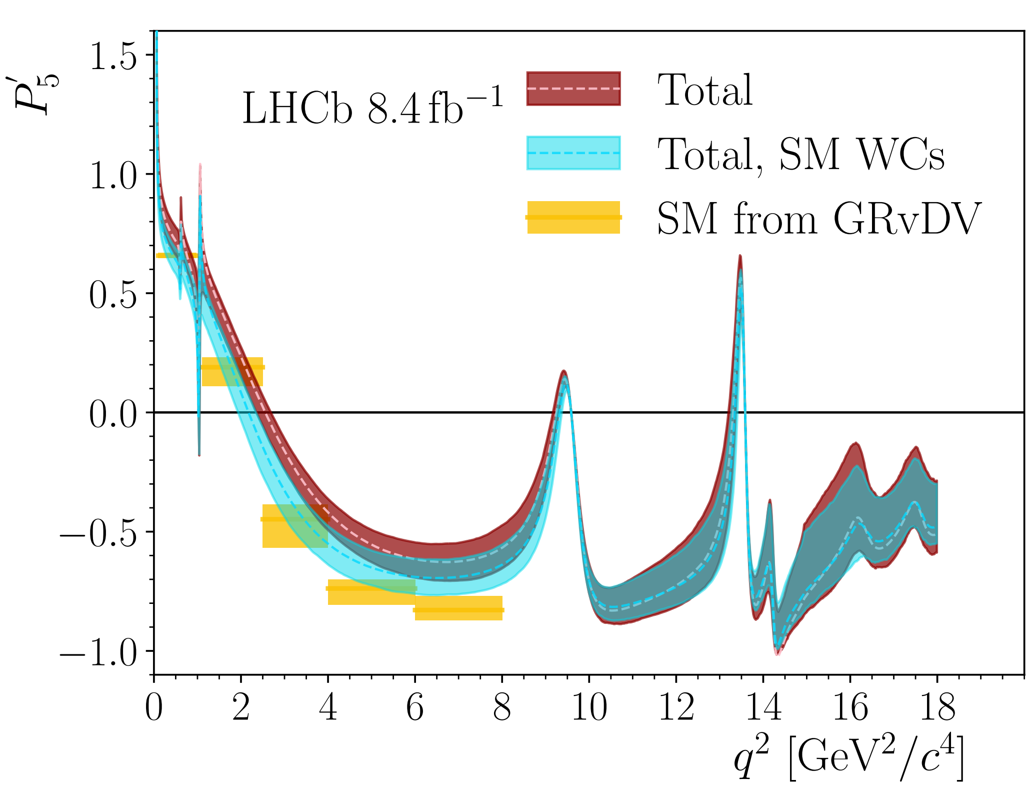
S_6^c is sensitive to NP tensor or scalar

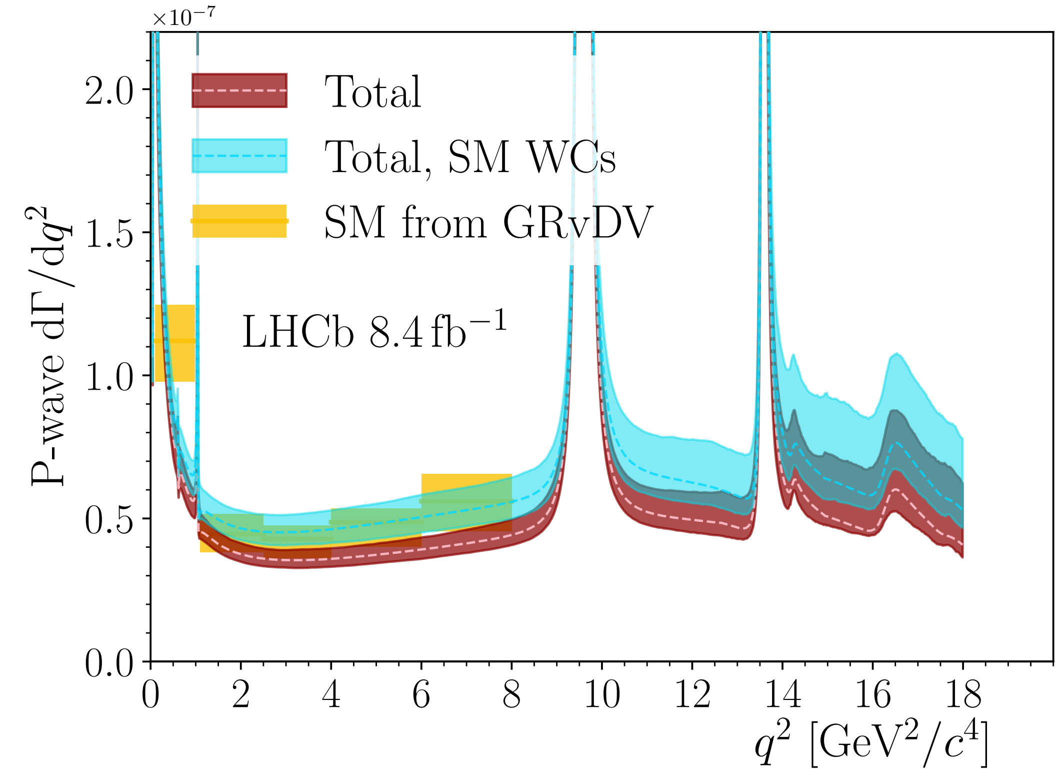


Check CERN seminar
for all preliminary
results (plots, tables)

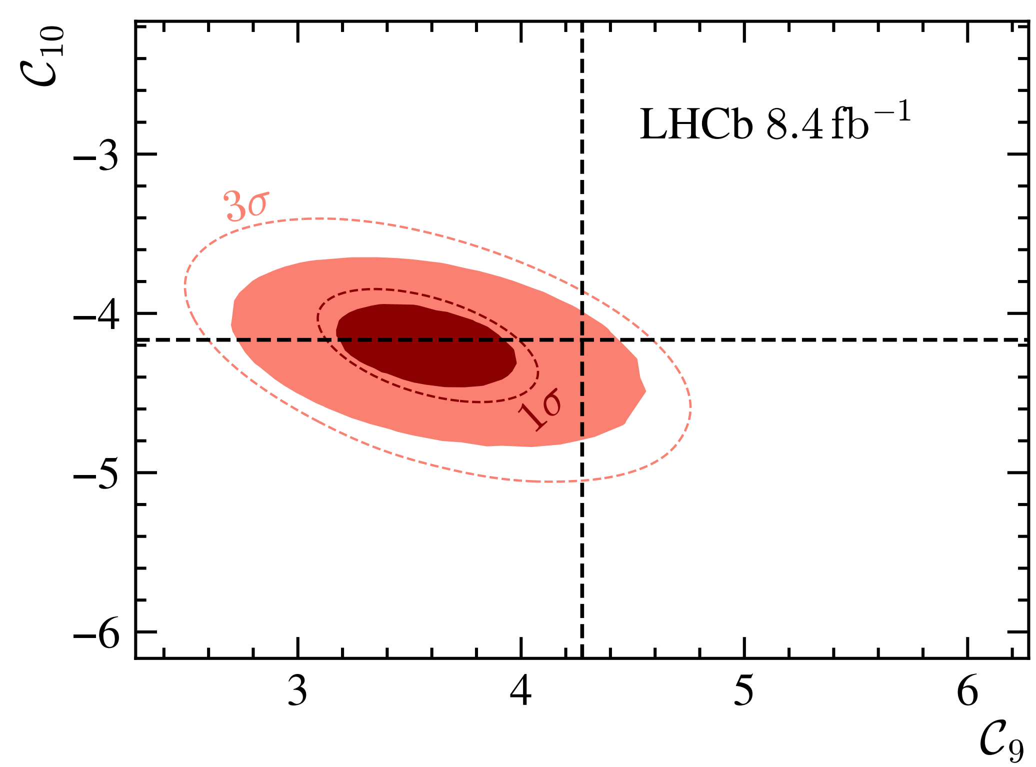
Amplitude analysis of $B^0 \to K^*\mu\mu$

JHEP 09 (2024) 026

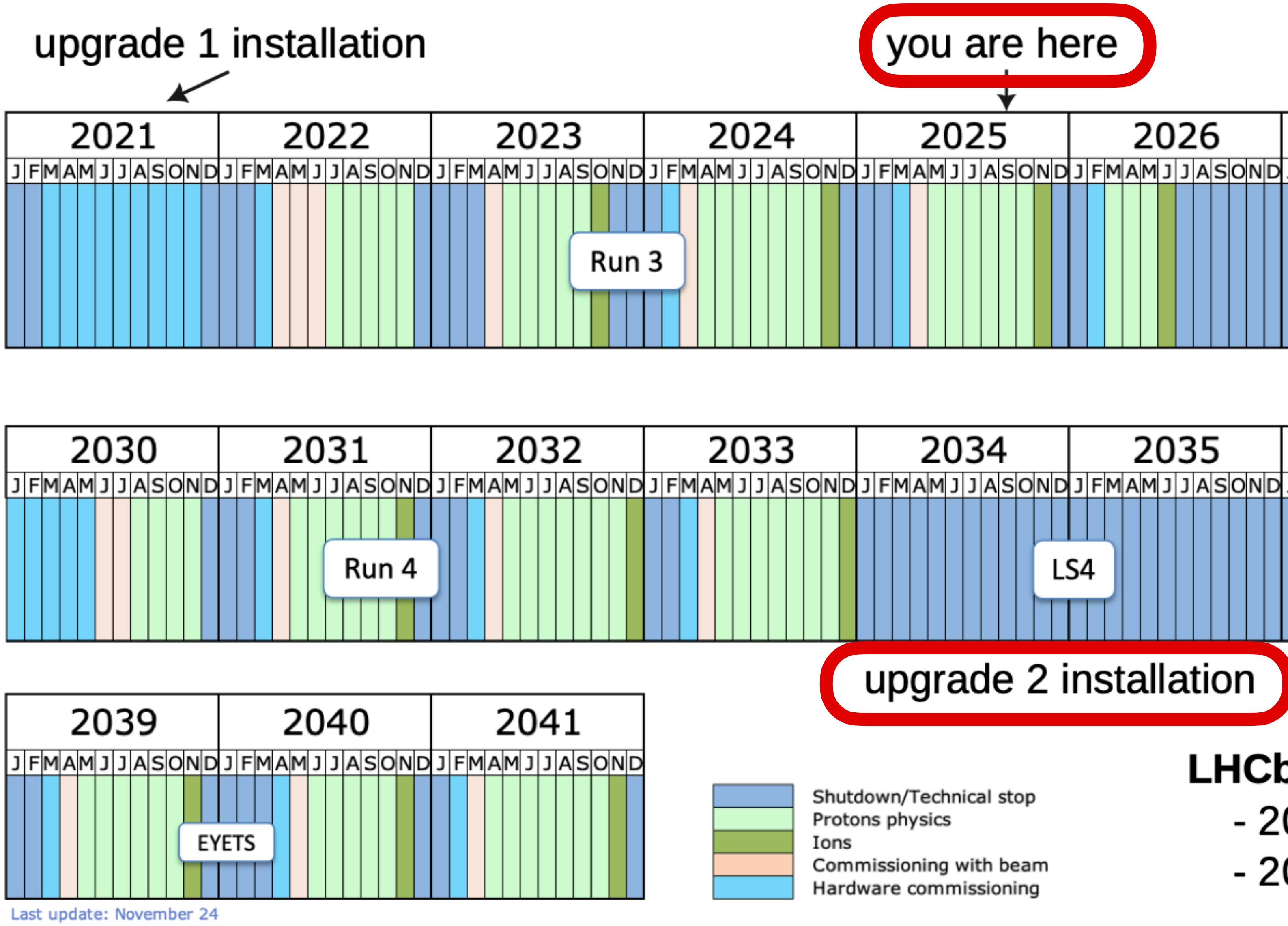




Wilson Coefficient results	
$\mathcal{C}_9$	$3.56 \pm 0.28 \pm 0.18$
$\mathcal{C}_{10}$	$-4.02 \pm 0.18 \pm 0.16$
$\mathcal{C}_9'$	$0.28 \pm 0.41 \pm 0.12$
$\mathcal{C}_{10}'$	$-0.09 \pm 0.21 \pm 0.06$
$\mathcal{C}_{9\tau}$	$(-1.0 \pm 2.6 \pm 1.0) \times 10^2$



Future runs and Upgrade II



LHCb v1:
- 2010-2012 - Run 1, 7/8 TeV
- 2015-2018 - Run 2, 13 TeV

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)