Recent searches for new physics and rare decays at LHCb

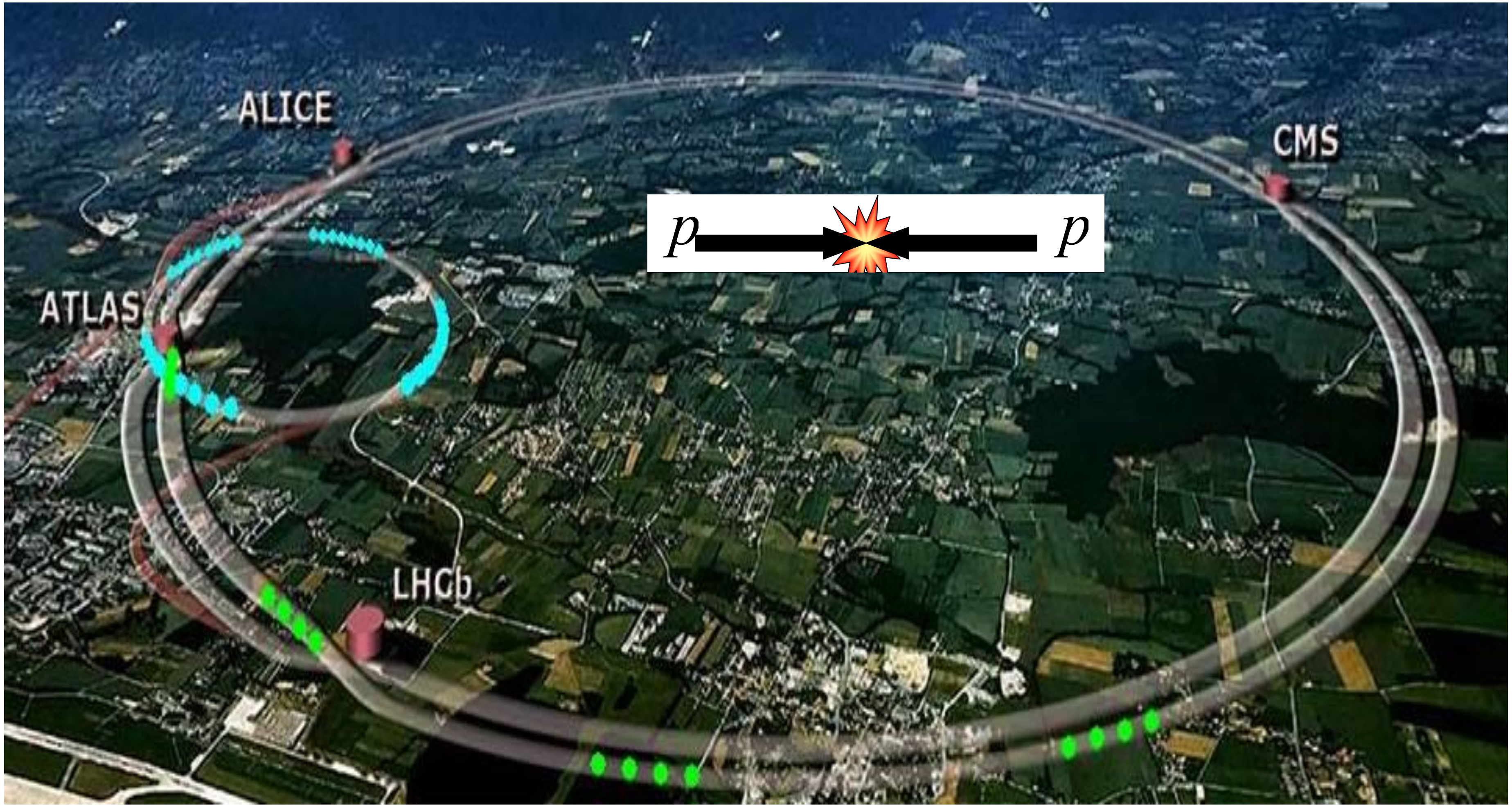
俞洁晟（湖南大学）

第十届中国LHC物理年会
山东大学*青岛
2024年11月15日

Outline

- Introduction
- Rare decays
  - FCNC
  - Other rare decays
- Prospects
- Summary

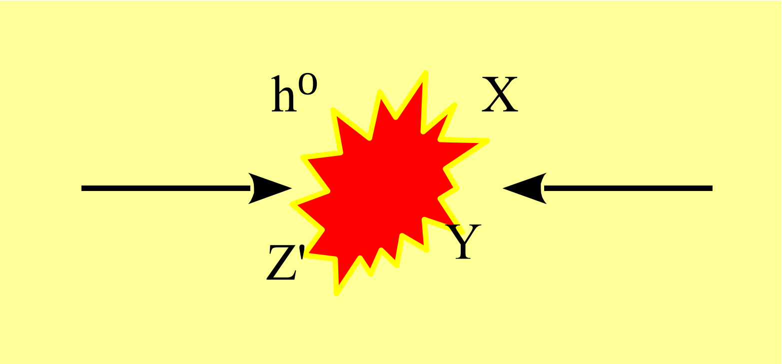
LHC is the forefront of high energy physics



Two ways to search for new physics in LHC

High energy frontier

- ATLAS and CMS
  Search new particles in collision directly



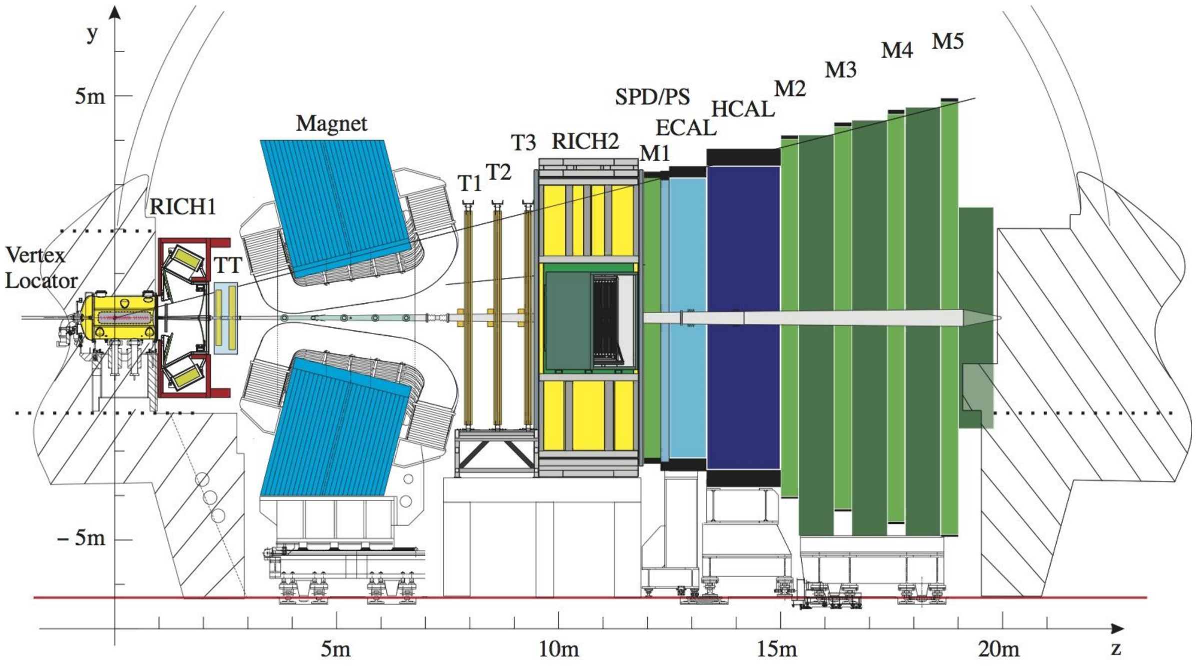
High precision frontier

- LHCb
  Precise measurement of FCNC processes to search for new particles.

  - Search for new physics far above the accelerator collision energy
  - Test new physics models, determining coupling constants and phases

LHCb experiment

LHCb collaboration： 25 counties, 107 institutes, 1770 members

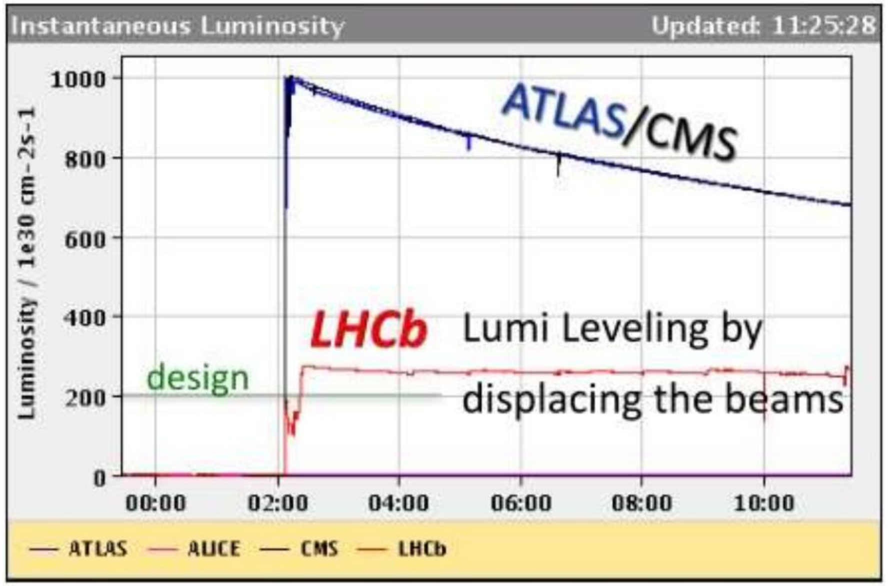


中国单位：
清华大学
华中师范大学
中国科学院大学
武汉大学
高能物理研究所
华南师范大学
北京大学
湖南大学
兰州大学

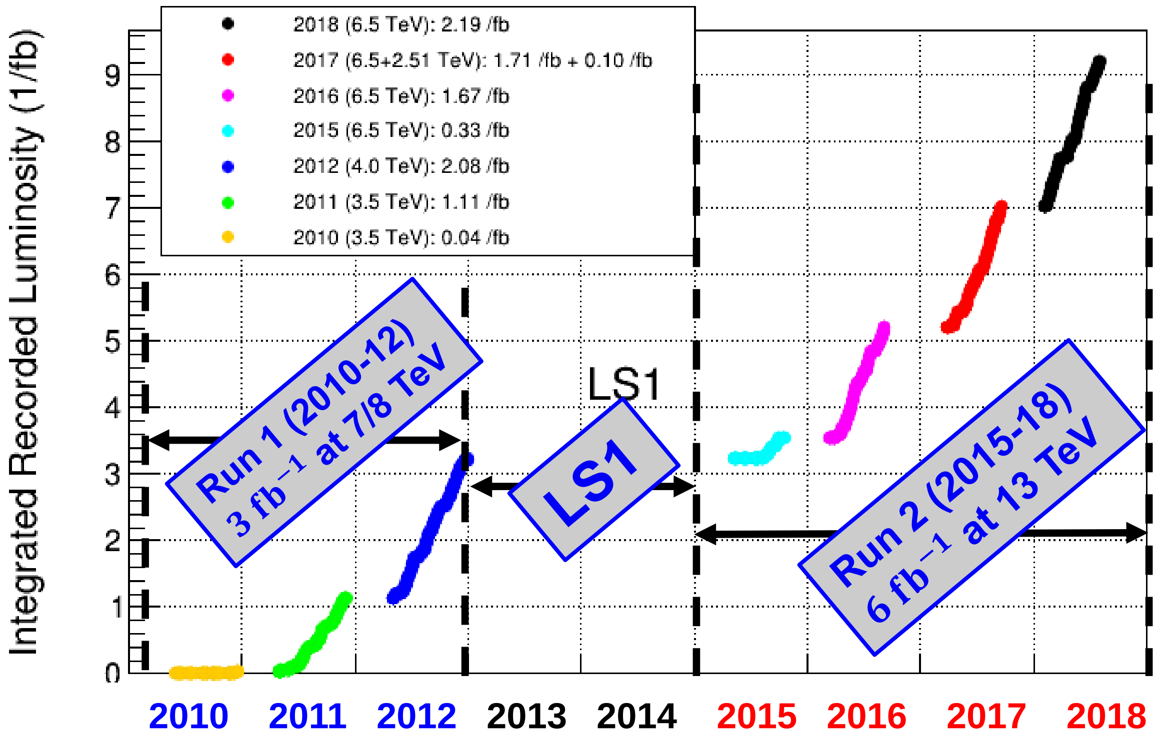
- Understand matter-antimatter imbalance (CP violation)
- Search for new physics (Rare decays)
- Explore and understand QCD (Hadron properties, exotic hadrons)

LHCb data samples

Luminosity levelling $L \sim 3 \times 10^{32}\ \mathrm{cm^{-2}s^{-1}}$



Run-I: 3 fb^{-1}, Run-II: 6 fb^{-1}



Large $b\bar{b}$ and $c\bar{c}$ production cross sections:

$\sigma(b\bar{b}X) \sim 0.5\% \times \sigma_{pp}^{\text{inelas}}$, $\sigma(c\bar{c}X) \sim 10\% \times \sigma_{pp}^{\text{inelas}}$

FCNC $b \to s\gamma(l^+l^-)$ decays

- Direct search of $B^0_{(s)} \to \gamma\mu^+\mu^-$[JHEP 07 (2024) 101]
- Direct search of $B^{*0}_{(s)} \to \mu^+\mu^-$ [arXiv:2409.17209v1]
- Amplitude analysis of $\Lambda_b^0 \to pK^-\gamma$ [JHEP 06 (2024) 098]
- Amplitude analysis of $B_s^0 \to K^+K^-\gamma$ [JHEP 08 (2024) 093]
- Photon polarization in $B_s^0 \to \phi e^+e^-$, low q2 [LHCb-PAPER-2024-030, prelim.]
- Angular analysis of $B^0 \to K^{*0}e^+e^-$, central q2 [LHCb-PAPER-2024-022, prelim.]
- Angular analysis of $\Lambda_b^0 \to pK^-\mu^+\mu^-$ [arXiv:2409.12629]
- z-Expansion fit with $B^0 \to K^{*0}\mu^+\mu^-$[PRD 109 (2024) 052009, PRL 132 (2024) 131801]
- Local & non-local amplitudes in $B^0 \to K^{*0}\mu^+\mu^-$[JHEP 09 (2024) 026]
- LFU in $B_s^0 \to \phi l^+l^-$ [arXiv:2410.13748]
- LFU in $B^+ \to K^+\pi^+\pi^-l^+l^-$[LHCb-PAPER-2024-046, prelim.]

$b \to s l^+ l^-$ decays

- $b \to s l^+ l^-$ **decays described by effective Hamiltonian**

$$H = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i C_i O_i + \frac{K}{\Lambda_{NP}^2} O_j^{(6)}$$

New physics can affect Wilson coefficients C_i or add new operators O_j

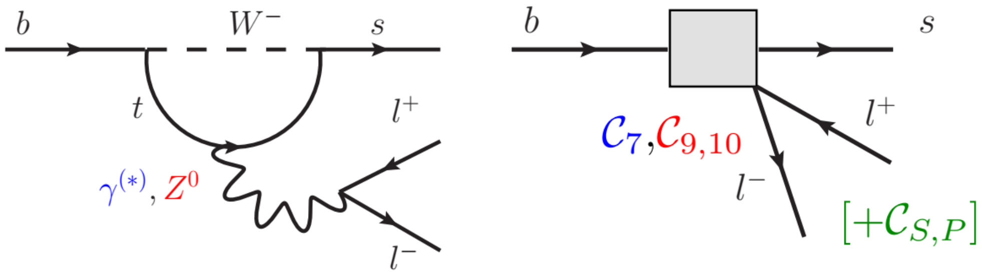
Wilson Coefficients: C_i

- → Perturbative, short distance physics
- → Describes heavy SM+NP effects

Operators: $\mathcal{O}_i$

- → Non-perturbative, long distance physics
- → Strong interactions, difficult to calculate

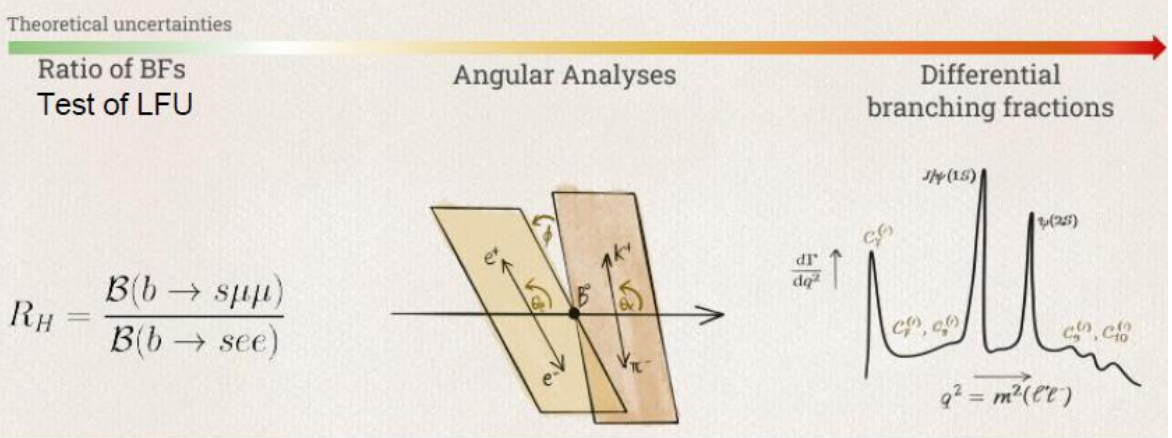
- **Sensitivity to Wilson coefficients**



- $B^0_{(s)} \to l^+ l^-$ $[\mathcal{C}_{10}, \mathcal{C}_S, \mathcal{C}_P]$
- $b \to s l^+ l^-$ $[\mathcal{C}_7, \mathcal{C}_9, \mathcal{C}_{10}]$

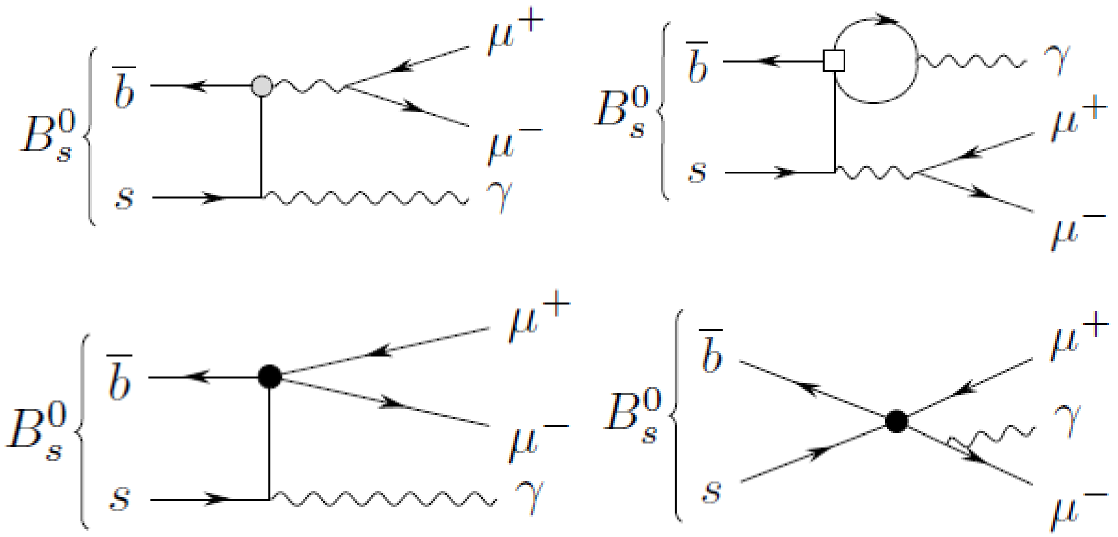
7: photon penguin; 9,10: EW penguin; S,P: (pseudo-) scalar penguin

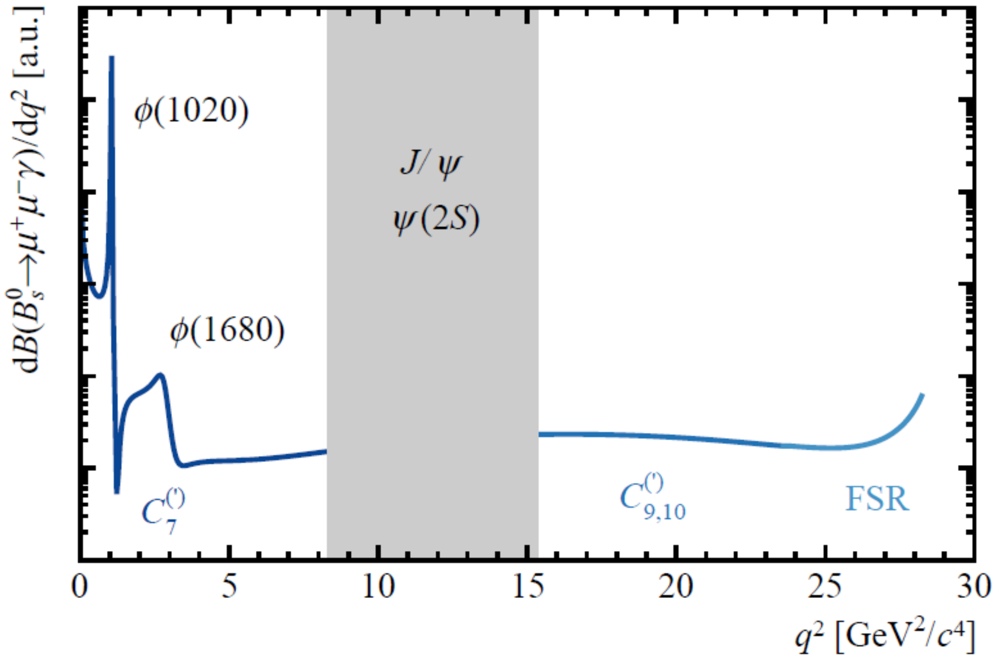
- **Theoretically clean probes of NP**
  - Pure leptonic decays
  - Ratio between $e/\mu/\tau$
  - Special angular observables
  - Differential BF



First direct search on $B^0_{(s)} \to \gamma\mu^+\mu^-$ with Run II data

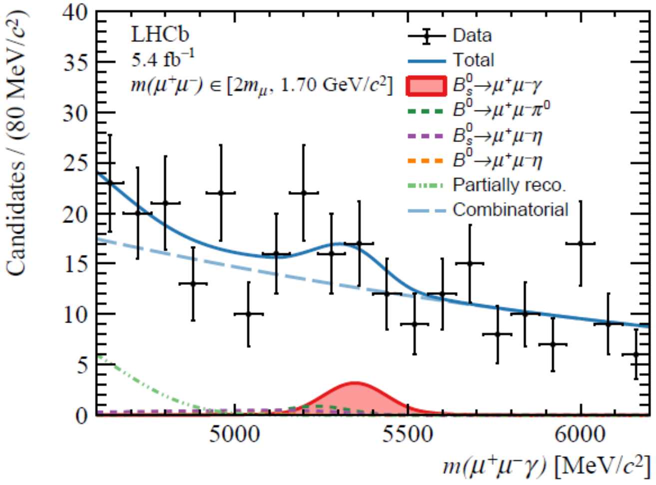
- Sensitive to the Wilson coefficients C7, C9, and C10
- SM predict: BF$\sim 10^{-10}$ to 10^{-9} JHEP 12 (2020) 148 JHEP 11 (2017) 184

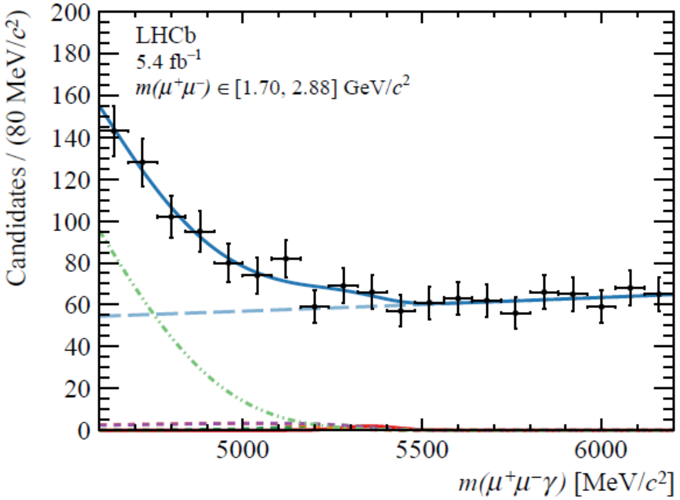


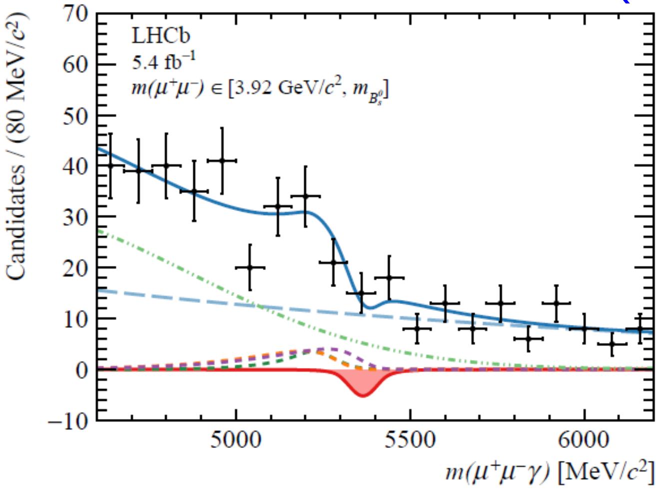


Search for $B^0_{(s)} \to \gamma\mu^+\mu^-$ with Run II data

JHEP 07 (2024) 101

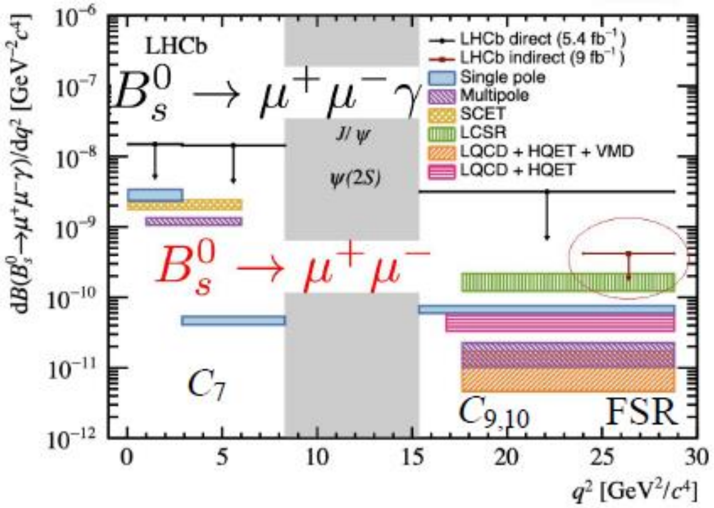






- First measurement, no significant signal and upper limits on the branching ratio

$$\mathcal{B}(B^0_s \to \mu^+\mu^-\gamma) < 4.2 \times 10^{-8},\ m(\mu^+\mu^-) \in [2m_\mu,\ 1.70]\ \text{GeV}/c^2,$$
$$\mathcal{B}(B^0_s \to \mu^+\mu^-\gamma) < 7.7 \times 10^{-8},\ m(\mu^+\mu^-) \in [1.70,\ 2.88]\ \text{GeV}/c^2,$$
$$\mathcal{B}(B^0_s \to \mu^+\mu^-\gamma) < 4.2 \times 10^{-8},\ m(\mu^+\mu^-) \in [3.92,\ m_{B^0_s}]\ \text{GeV}/c^2,$$



Search for $B_{(s)}^{*0} \to \mu^+\mu^-$ in $B_c^+ \to \pi^+\mu^+\mu^-$

- $B_{(s)}^{*0} \to \mu^+\mu^-$ are highly suppressed in SM due to EM, BF is $\sim 10^{-11}$

  Phys. Rev. Lett. 116 (2016) JHEP 11 (2015) 142

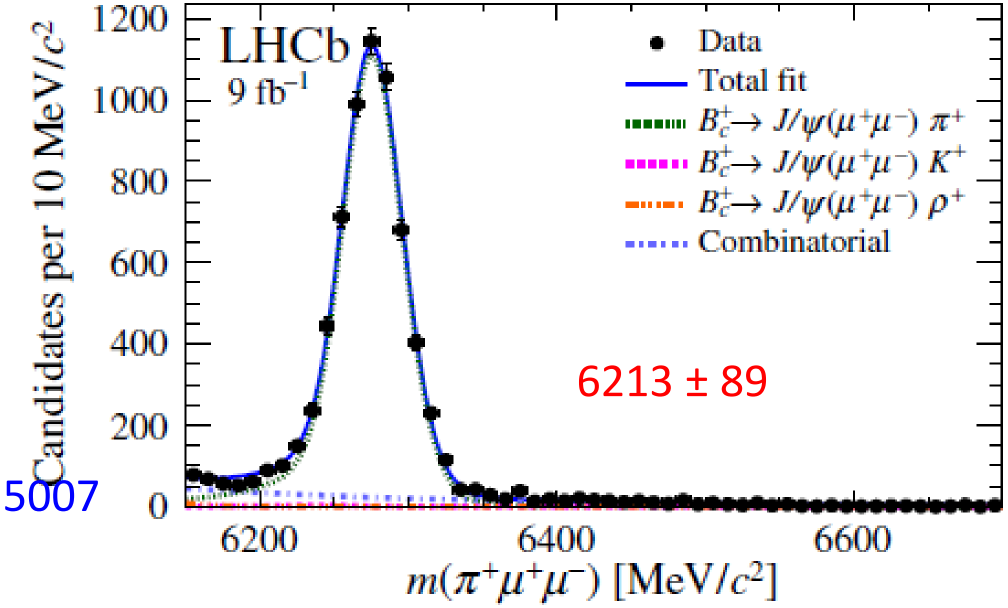
- Could be enhanced by New Physics

  Eur. Phys. J. C76 (2016) 583 J. Phys. G44 (2017) 035001

  Int. J. Mod. Phys. A32 (2017) 1750075 Phys. Rev. D97 (2018) 035007

- Prompt $B_{(s)}^{*0}$ have large background from pp interactions

- $B_c^+ \to J/\psi(\to \mu^+\mu^-)\pi^+$ as normalization channel

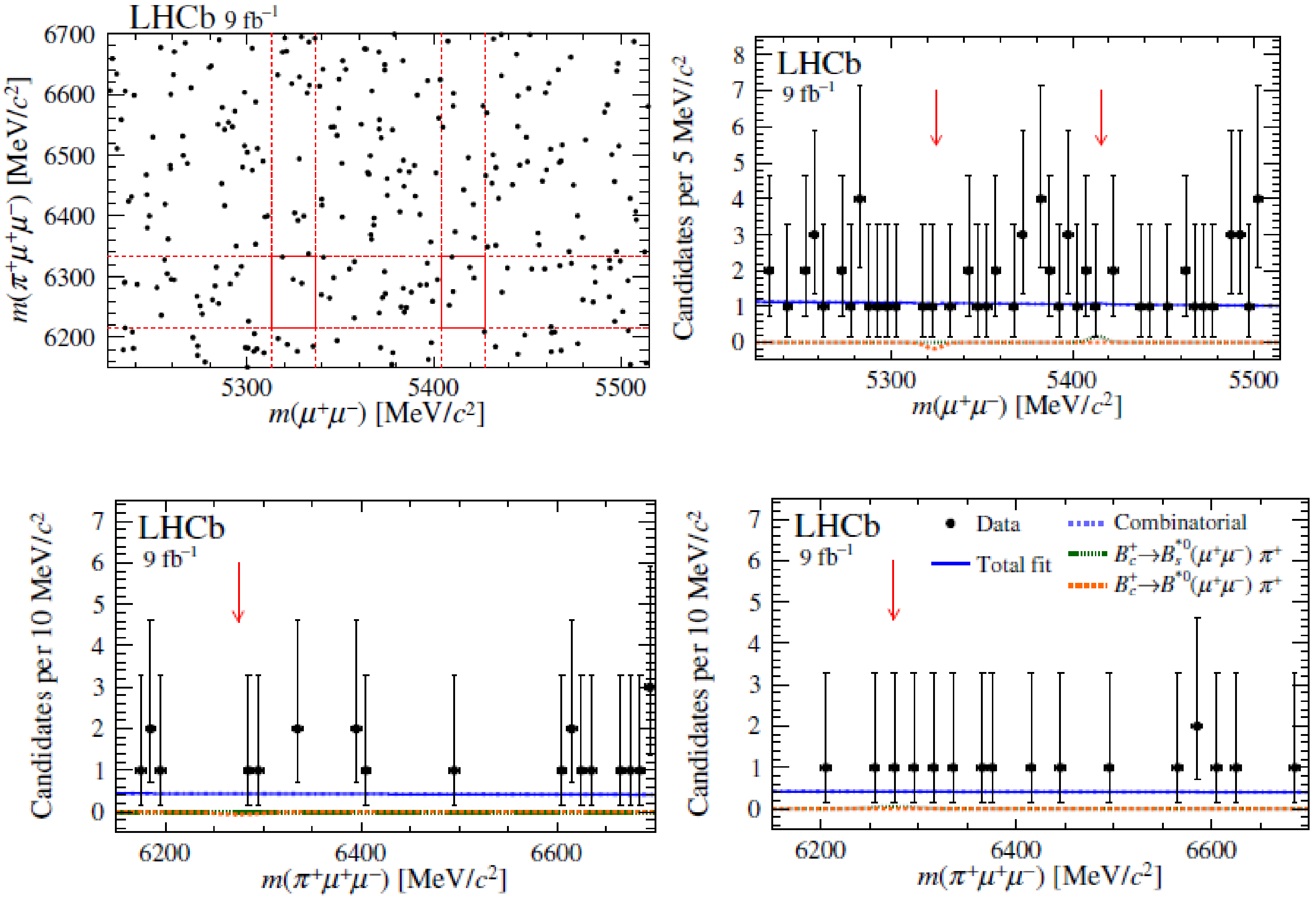


$$\mathcal{R}_{B_{(s)}^{*0}(\mu^+\mu^-)\pi^+/J/\psi\pi^+} \equiv \frac{\mathcal{B}(B_c^+ \to B_{(s)}^{*0}(\mu^+\mu^-)\pi^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)}$$
$$= \frac{N_{B_{(s)}^{*0}\pi^+}}{N_{J/\psi\pi^+}} \cdot \frac{\varepsilon_{J/\psi\pi^+}}{\varepsilon_{B_{(s)}^{*0}\pi^+}} \cdot \mathcal{B}(J/\psi \to \mu^+\mu^-)$$
$$= \alpha^{\mathrm{SES}}_{B_{(s)}^{*0}\pi^+} \cdot N_{B_{(s)}^{*0}\pi^+},$$

Search for $B_{(s)}^{*0} \to \mu^+\mu^-$ in $B_c^+ \to \pi^+\mu^+\mu^-$

- First measurement, no significant signal and upper limits on the branching ratio

$$\mathcal{R}_{B^{*0}(\mu^+\mu^-)\pi^+/J/\psi\pi^+} < 3.8 \times 10^{-5}\,,$$
$$\mathcal{R}_{B_s^{*0}(\mu^+\mu^-)\pi^+/J/\psi\pi^+} < 5.0 \times 10^{-5}\,,$$



Arxiv:2409.17209v1

Measurement of the $\Lambda_b^0 \to pK^-\mu^+\mu^-$ differential branching fraction

- Measured branching fractions and angular moments in bins of q^2 and m_{pK}
- $\Lambda_b \to pK^- J/\psi(\to \mu^+\mu^-)$ as normalization channel

$$\frac{d^2\mathcal{B}(\Lambda_b^0 \to pK^-\mu^+\mu^-)}{dq^2 dm_{pK}^2} = \frac{N_{\Lambda_b^0\to pK^-\mu^+\mu^-}}{N_{\Lambda_b^0\to J/\psi pK^-}} \frac{\mathcal{B}(\Lambda_b^0 \to J/\psi pK^-)\mathcal{B}(J/\psi \to \mu^+\mu^-)}{\Delta(q^2, m_{pK}^2)}$$

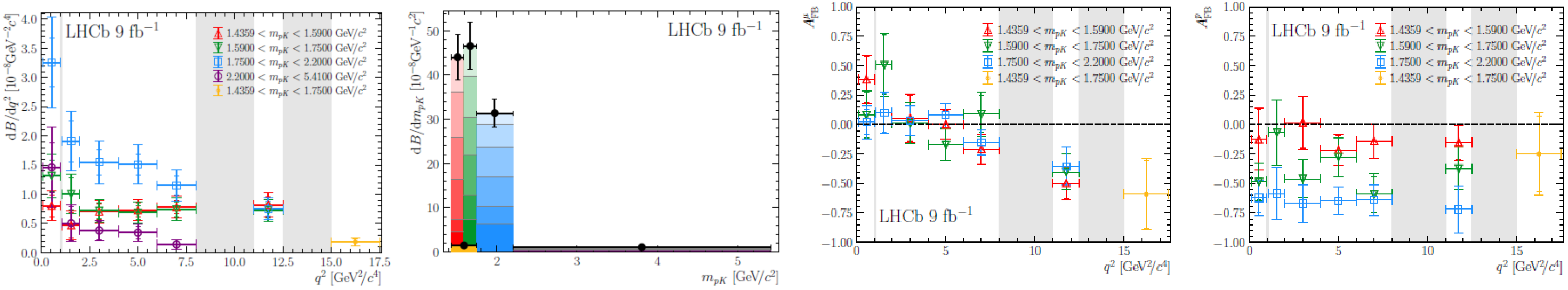
q^2 \ m_{pK}	[1.4359, 1.5900]	[1.59, 1.75]	[1.75, 2.20]	[2.20, 5.41]
[0.10, 0.98]	$5.22 \pm 1.21 \pm 0.43 \pm 0.98$	$8.22 \pm 1.69 \pm 0.38 \pm 1.54$	$7.24 \pm 0.92 \pm 0.52 \pm 1.36$	$0.46 \pm 0.13 \pm 0.14 \pm 0.09$
[1.1, 2.0]	$3.05 \pm 1.45 \pm 0.51 \pm 0.57$	$6.27 \pm 1.71 \pm 0.40 \pm 1.18$	$4.24 \pm 0.78 \pm 0.16 \pm 0.80$	$0.16 \pm 0.09 \pm 0.02 \pm 0.03$
[2.0, 4.0]	$4.56 \pm 0.90 \pm 0.26 \pm 0.86$	$4.50 \pm 0.86 \pm 0.21 \pm 0.84$	$3.44 \pm 0.47 \pm 0.08 \pm 0.64$	$0.12 \pm 0.05 \pm 0.02 \pm 0.02$
[4.0, 6.0]	$4.72 \pm 0.76 \pm 0.15 \pm 0.89$	$4.29 \pm 0.73 \pm 0.20 \pm 0.81$	$3.36 \pm 0.41 \pm 0.07 \pm 0.63$	$0.11 \pm 0.03 \pm 0.02 \pm 0.02$
[6.0, 8.0]	$5.08 \pm 0.76 \pm 0.12 \pm 0.95$	$4.65 \pm 0.79 \pm 0.34 \pm 0.87$	$2.56 \pm 0.36 \pm 0.05 \pm 0.48$	$0.04 \pm 0.02 \pm 0.01 \pm 0.01$
[11, 12.5]	$5.32 \pm 0.86 \pm 0.20 \pm 1.00$	$4.53 \pm 0.80 \pm 0.16 \pm 0.85$	$1.67 \pm 0.28 \pm 0.03 \pm 0.31$	—
[15.0, 17.5]	$0.59 \pm 0.19 \pm 0.07 \pm 0.11$		—	—

arXiv:2409.12629

- Decay rate described by 46 angular moments:

$$\frac{d\Gamma^5}{d\vec{\Phi}} = \frac{3}{8\pi} \sum_{i=0}^{46} K_i(q^2, m_{pK}^2) f(cos\theta_\mu, cos\theta_p, \phi)$$

Measurement of the $\Lambda_b^0 \to pK^-\mu^+\mu^-$ differential branching fraction

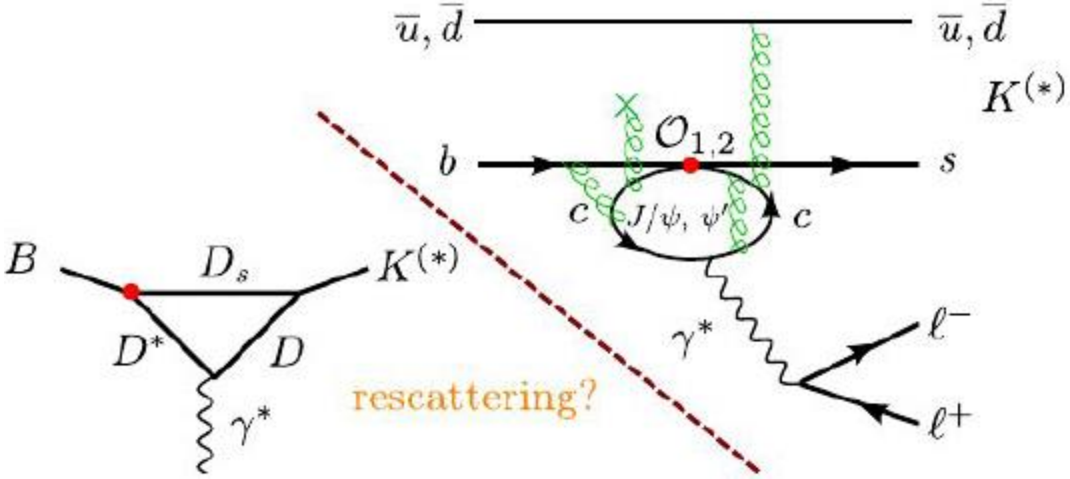


arXiv:2409.12629

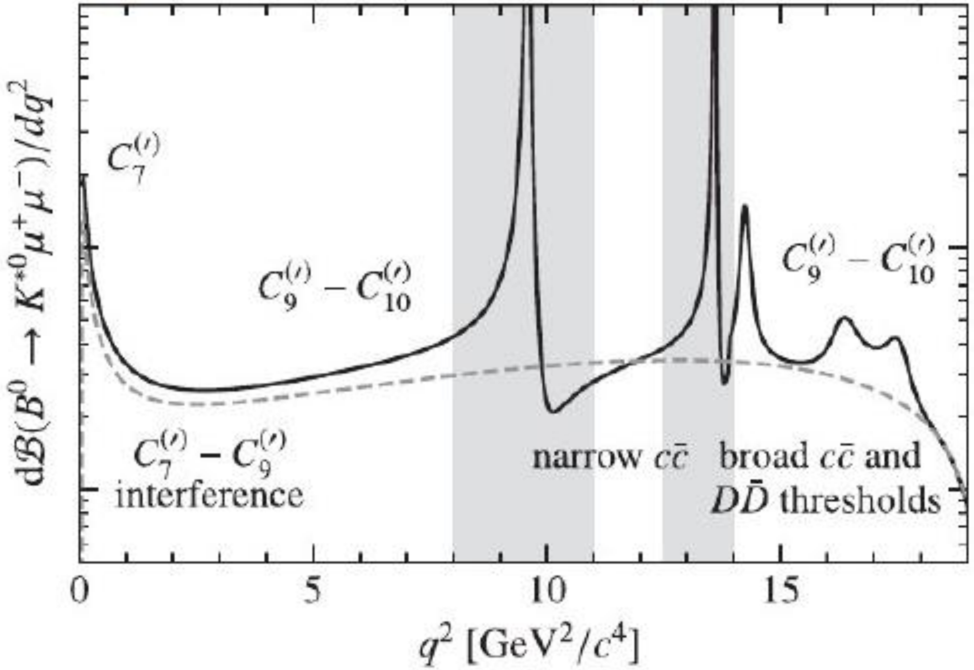
- Forward-background asymmetry (A_{FB}) of μ+ μ− sensitive to $C_{9,10}$
- Large A_{FB} observed in hadron is the effect of interference of resonances with different parity
- The pattern of measurements appears consistent with SM expectations

Data-driven approaches for $B^0 \to K^{*0}\mu^+\mu^-$

- Non-local (charm loop) hadronic contributions bring in large theoretical uncertainties, and can mimic BSM effects
- Data-driven approaches are needed
  - z-expansion
  - Dispersion

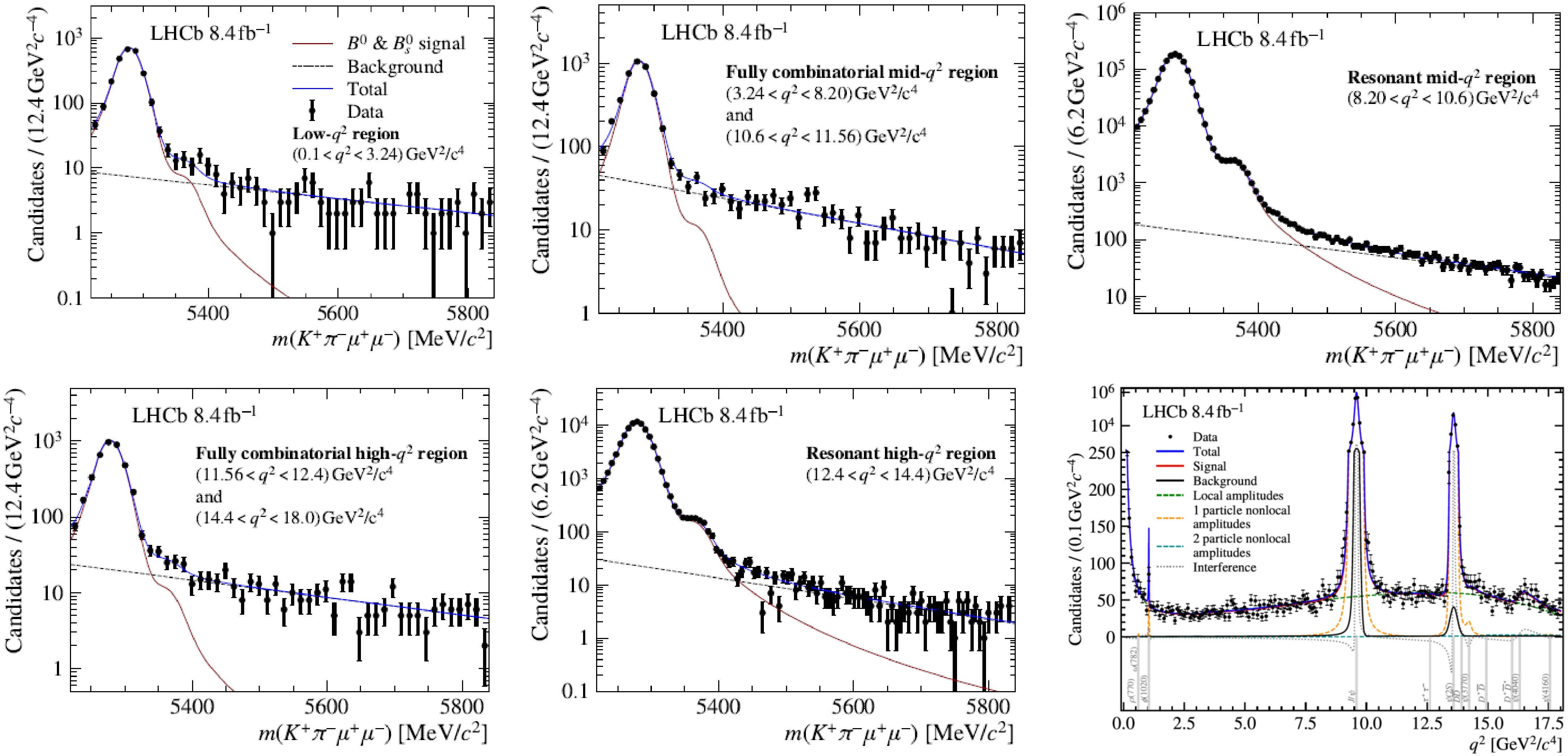


[PRL 132 (2024) 131801]



Data-driven approaches for $B^0 \to K^{*0}\mu^+\mu^-$

- First time employ a model of both one-particle and two-particle nonlocal amplitudes
- Without any veto regions in $\mu^+\mu^-$ mass JHEP 09 (2024) 026

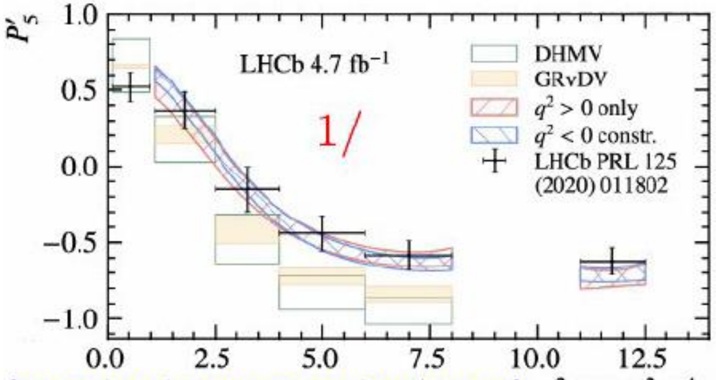


Data-driven approaches for $B^0 \to K^{*0}\mu^+\mu^-$

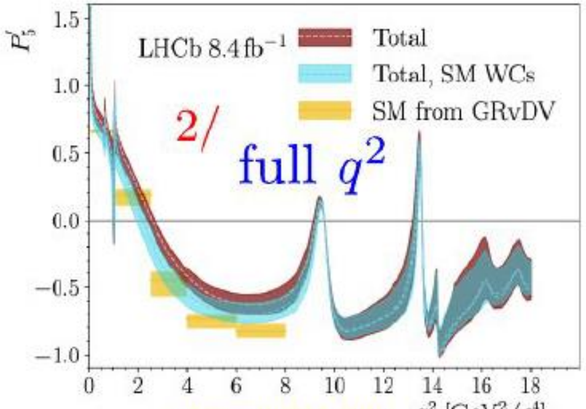
1/ Fit to long-distance $\mathcal{H}_\lambda(q^2)$ as model-independent z-expansion:

$$\mathcal{A}^{L,R}_{\lambda=0,\parallel,\perp} = \mathcal{N}_\lambda \left\{ \left[(C_9 \pm C_9') \mp (C_{10} \pm C_{10}') \right] \mathcal{F}_\lambda(q^2) + \frac{2 m_b M_B}{q^2} \left[(C_7 \pm C_7')_{\rm SM} \mathcal{F}^T_\lambda(q^2) - 16\pi^2 \frac{M_B}{m_b} \mathcal{H}_\lambda(q^2) \right] \right.$$

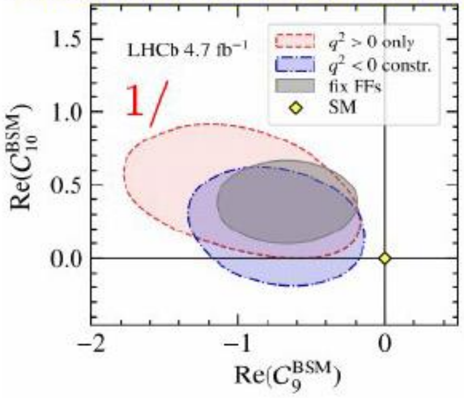
2/ $C^{(\rm eff)}_{9,\lambda} \to C_9 + Y_{q\bar{q},\lambda}(q^2)$. $Y_{q\bar{q}} \in$ sum $\{\rho,\ \omega,\ \phi,\ J/\psi,\ \ldots,\ D^{(*)}\overline{D}^{(*)}\}$



[PRL132(2024)131801, PRD109(2024)052009] q^2 [GeV$^2/c^4$]

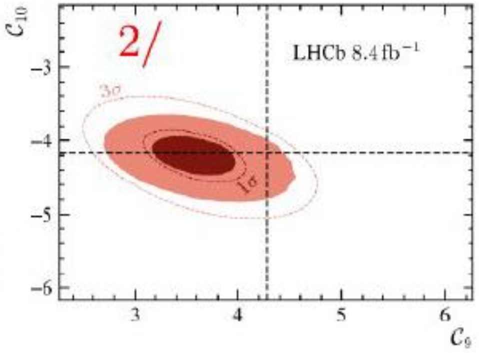


[JHEP09(2024)026] q^2 [GeV$^2/c^4$]



$\Delta C_9 < 0$ preferred but overall tension reduced

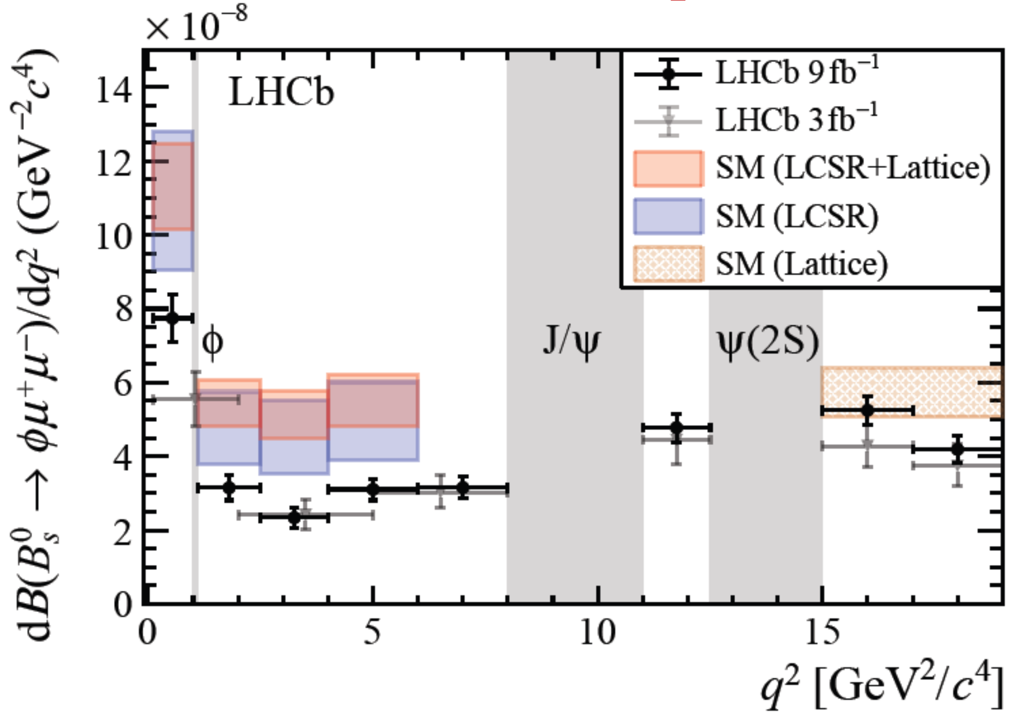
both exp. and theory improvements in future



LFU of $B^0_{(s)} \to \phi l^+ l^-$ (Run 1&2 data)

- In low-q^2: 1.1~6.0 GeV^2/c^4 3.6σ standard deviations with SM

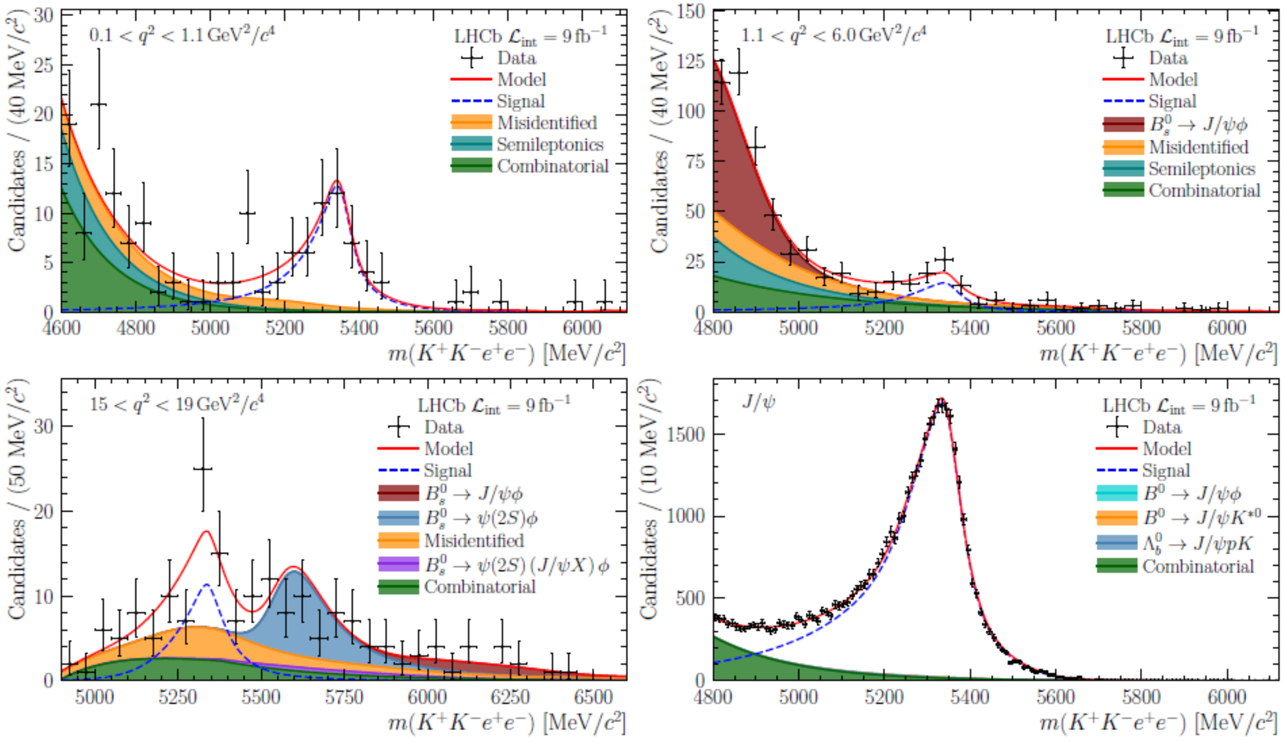
- LFU can provide powerful probes of the SM

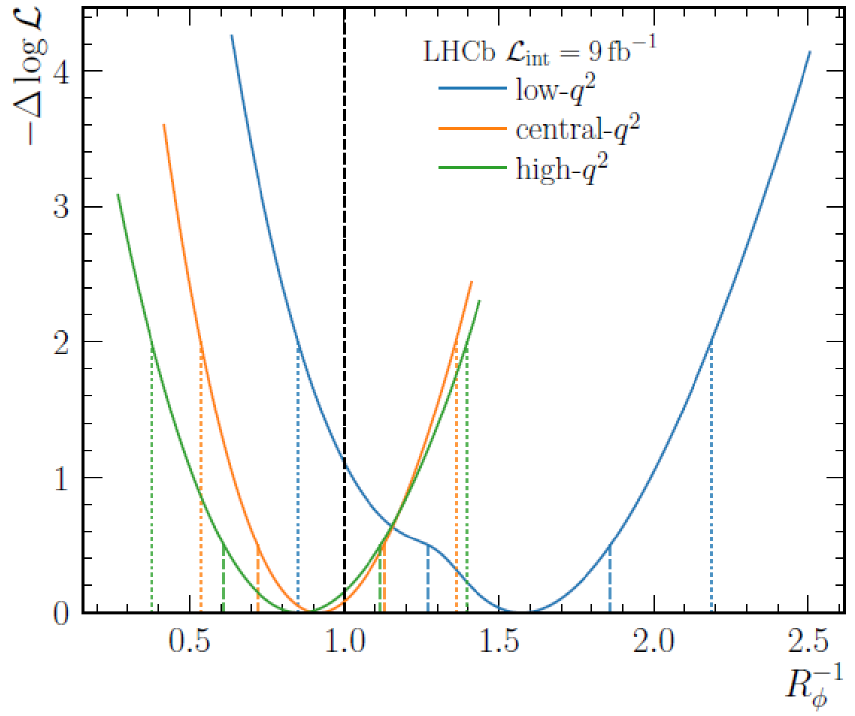


$$R_\phi = \left(\frac{\mathcal{B}(B^0_s \to \phi\mu^+\mu^-)}{\mathcal{B}(B^0_s \to J/\psi(\to \mu^+\mu^-)\phi)}\right) \Big/ \left(\frac{\mathcal{B}(B^0_s \to \phi e^+ e^-)}{\mathcal{B}(B^0_s \to J/\psi(\to e^+e^-)\phi)}\right),$$

Phys. Rev. Lett. 127 (2021) 151801

LFU of $B^0_{(s)} \to \phi l^+ l^-$ (Run 1&2 data)





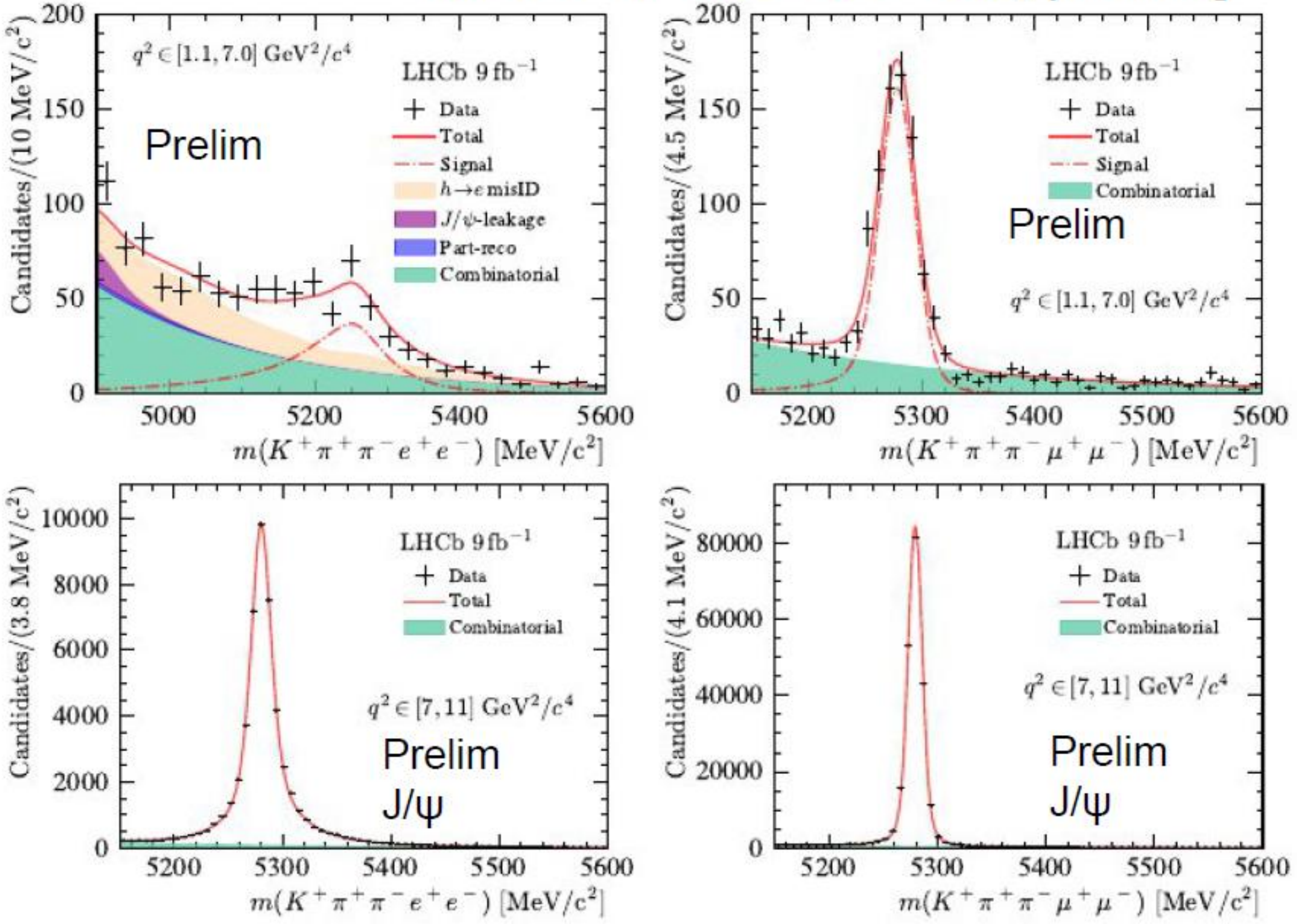
q^2 [GeV$^2/c^4$]	R_ϕ^{-1}	$d\mathcal{B}(B^0_s \to \phi e^+e^-)/dq^2$ [10^{-7} GeV$^{-2}c^4$]
$0.1 < q^2 < 1.1$	$1.57\,^{+0.28}_{-0.25} \pm 0.05$	$1.38\,^{+0.25}_{-0.22} \pm 0.04 \pm 0.19 \pm 0.06$
$1.1 < q^2 < 6.0$	$0.91\,^{+0.20}_{-0.19} \pm 0.05$	$0.26 \pm 0.06 \pm 0.01 \pm 0.01 \pm 0.01$
$15.0 < q^2 < 19.0$	$0.85\,^{+0.24}_{-0.23} \pm 0.10$	$0.39 \pm 0.11 \pm 0.04 \pm 0.02 \pm 0.02$

- First observation of the $B^0_{(s)} \to \phi e^+ e^-$
- Good agreement with the SM

arXiv:2410.13748v1

LFU of $B^+ \to K^+\pi^+\pi^-l^+l^-$(Run 1&2 data)

LHCb-PAPER-2024-046, prelim.]



$$R^{-1}_{K\pi\pi} = 1.31^{+0.18}_{-0.17}(\text{stat})^{+0.12}_{-0.09}(\text{syst})$$

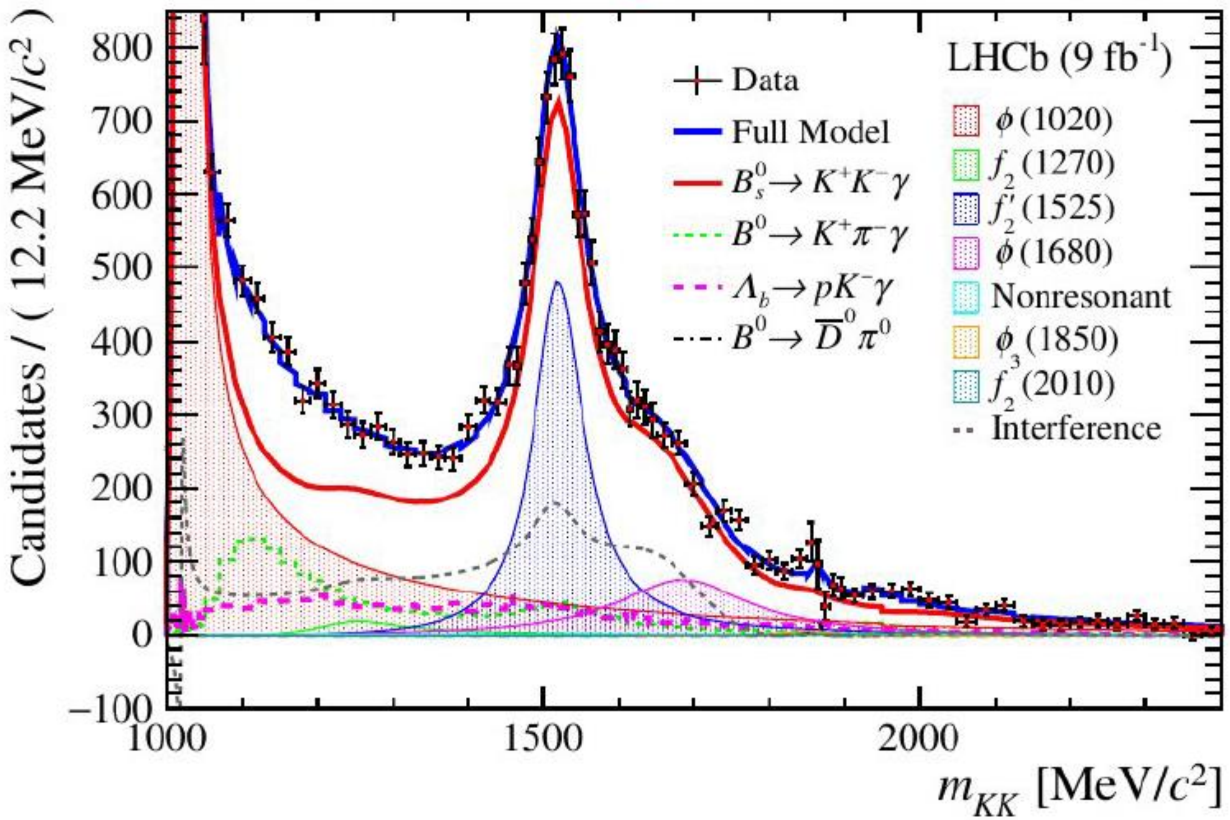
$q^2 \in [1.1, 7.0]$ GeV$^2/c^4$

$b \to s\gamma$

Amplitude analysis of $B_s^0 \to K^+K^-\gamma$

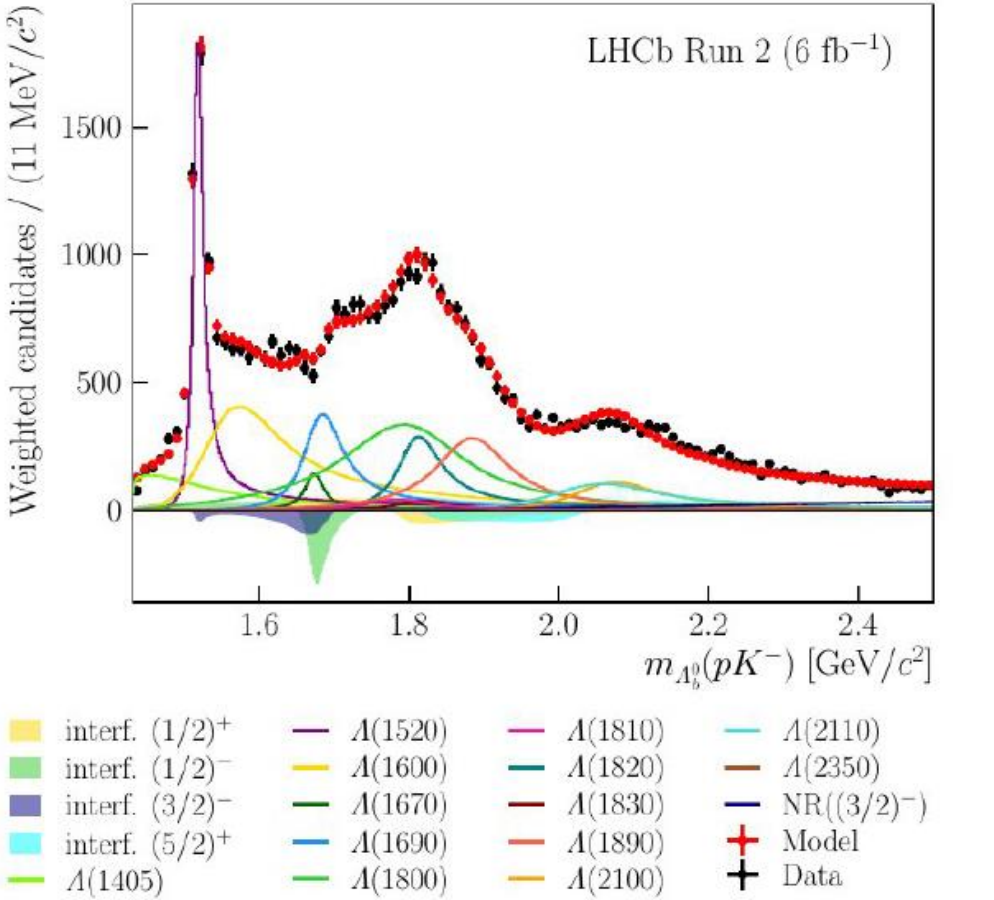
[JHEP 08 (2024) 093]

First observation of $B_s^0 \to f_2'(1525)\gamma$ decay



Amplitude analysis of $\Lambda_b^0 \to pK^-\gamma$

[JHEP 06 (2024) 098]



Other rare decays

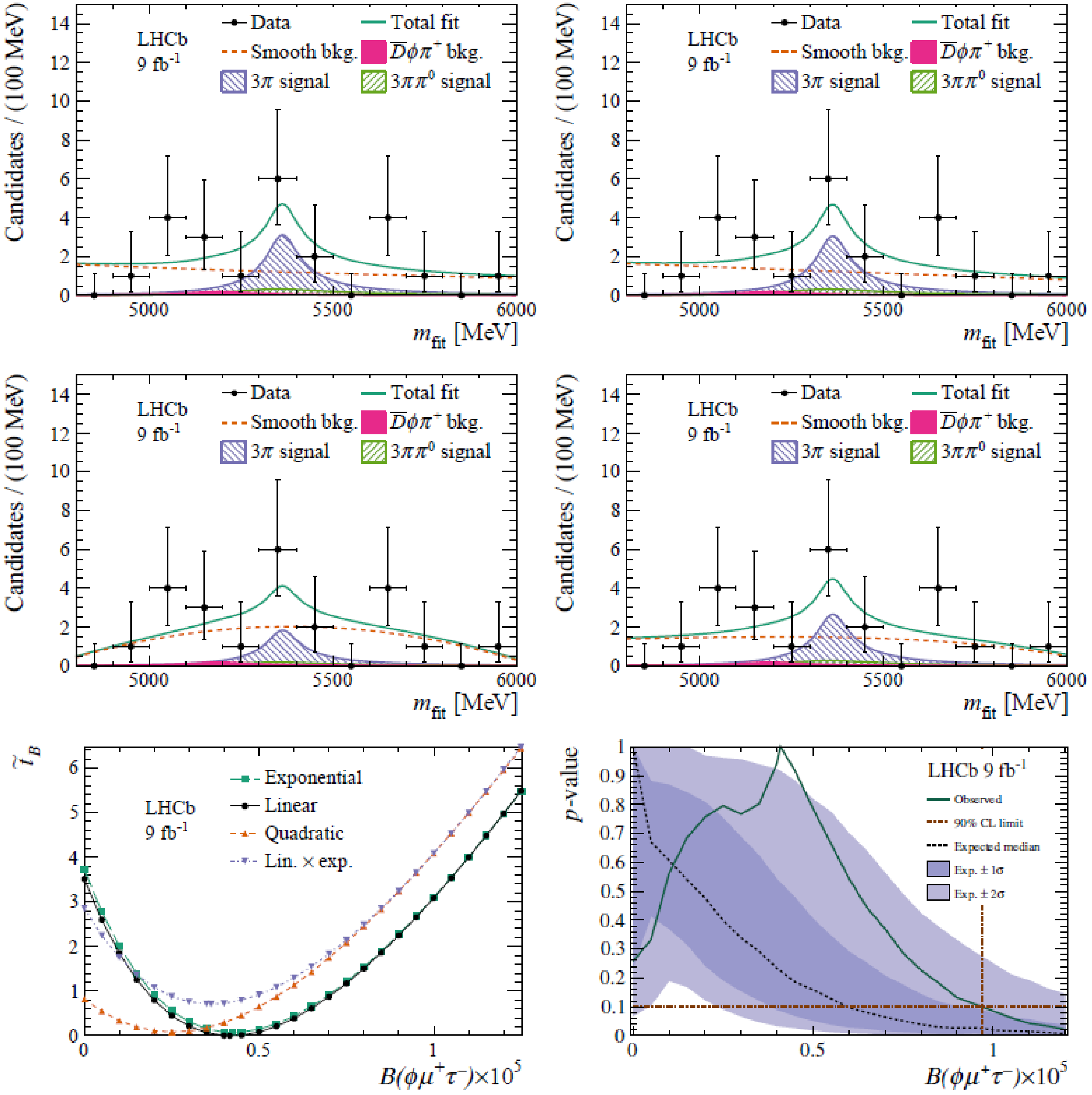
- $B \to D\mu^+\mu^-$ [JHEP 02 (2024) 032]
- $B_s^0 \to \phi\mu^\pm\tau^\mp$[arXiv:2405.13103]
- $D^0 \to hhe^+e^-$ [LHCb-PAPER-2024-047, prelim.]
- $\Lambda_c^+ \to p\mu^+\mu^-$ [PRD 110 (2024) 052007]
- $\Sigma^+ \to p\mu^+\mu^-$ [LHCb-CONF-2024-002]

Search for $B_s^0 \to \phi\mu^\pm\tau^\mp$ with Run 1&2 data

- Forbidden or strongly suppressed in the SM
- Sensitive to new heavy particles beyond the SM
- $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau$ or $\tau^- \to \pi^-\pi^+\pi^-\pi^0\nu_\tau$
- $B^0 \to \psi(2S)(\to \mu^+\mu^-)\phi$ as normalization channel
- No significant signals are observed

$$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.0 \times 10^{-5} \text{ at } 90\% \text{ CL},$$
$$\mathcal{B}(B_s^0 \to \phi\mu^+\tau^-) < 1.1 \times 10^{-5} \text{ at } 95\% \text{ CL}.$$

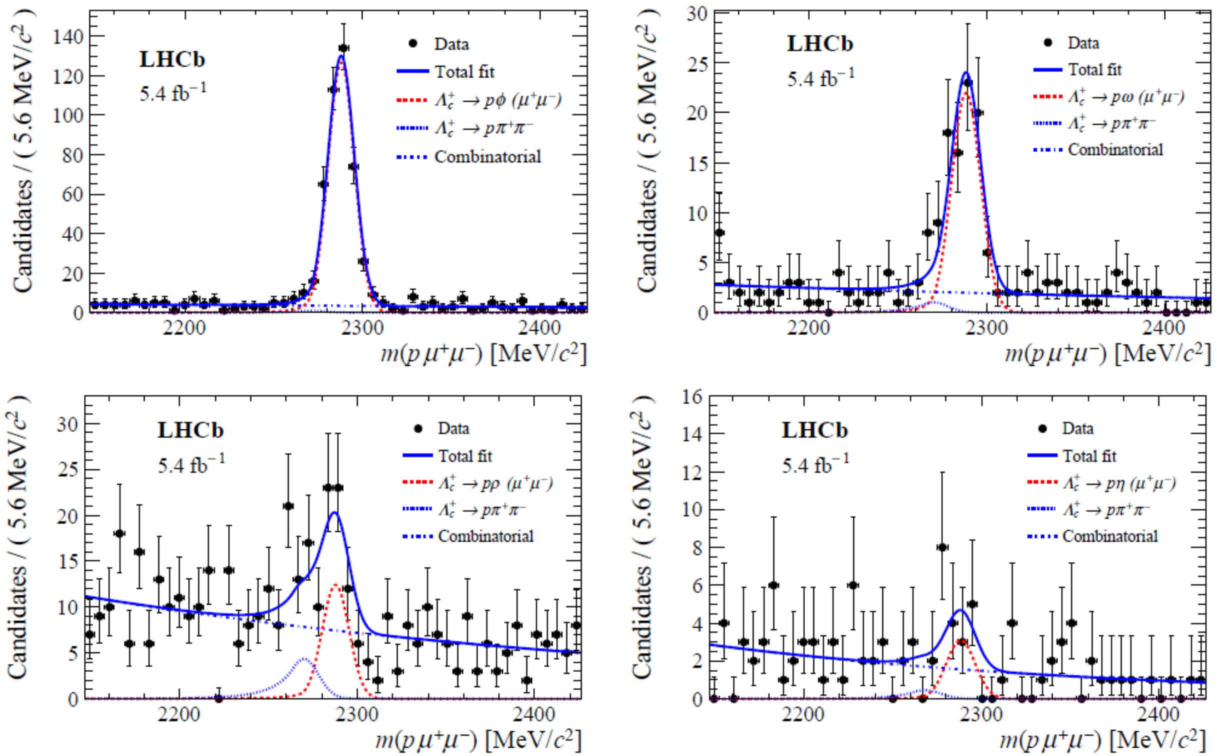
arXiv:2405.13103v1



Search for $\Lambda_c^+ \to p\mu^+\mu^-$ with Run 2 data

- $\boldsymbol{\Lambda_c^+ \to p\mu^+\mu^-}$ is heavily suppressed in SM
  - BF~10^{-8} with short-distance contributions
  - BF~10^{-6} with long-distance processes
- $\Lambda_c^+ \to p\phi(\to \mu^+\mu^-)$ as normalization channel

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) = \alpha \times N_{\rm sig}, \qquad \alpha = \frac{\epsilon_{\rm norm}}{\epsilon_{\rm sig} \times N_{\rm norm}} \times \mathcal{B}(\Lambda_c^+ \to p\phi) \times \mathcal{B}(\phi \to \mu^+\mu^-).$$

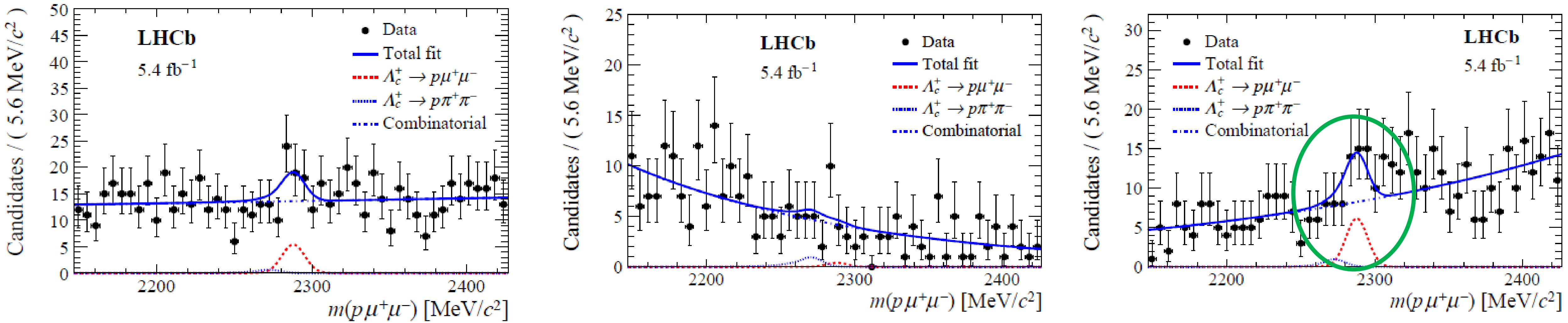


Region	$\Lambda_c^+ \to p\mu^+\mu^-$ yield	$\Lambda_c^+ \to p\pi^+\pi^-$ yield	Combinatorial yield	Significance $\Lambda_c^+ \to p\mu^+\mu^-$
signal	18 ± 10	3 ± 7	681 ± 28	2.0σ
low-m	1 ± 5	4 ± 4	241 ± 17	0.3σ
high-m	21 ± 8	4 ± 4	432 ± 22	2.8σ
η	12 ± 5	2.2 ± 1.6	84 ± 10	3.0σ
ρ	43 ± 10	20 ± 6	382 ± 22	5.6σ
ω	81 ± 10	4.8 ± 2.1	101 ± 11	$> 7\sigma$
ϕ	423 ± 22	3.8 ± 2.4	173 ± 15	$> 7\sigma$

$$\mathcal{B}(\Lambda_c^+ \to p\omega) = (9.82 \pm 1.23\ ({\rm stat.}) \pm 0.73\ ({\rm syst.}) \pm 2.79\ ({\rm ext.})) \times 10^{-4},$$
$$\mathcal{B}(\Lambda_c^+ \to p\rho) = (1.52 \pm 0.34\ ({\rm stat.}) \pm 0.14\ ({\rm syst.}) \pm 0.24\ ({\rm ext.})) \times 10^{-3},$$
$$\mathcal{B}(\Lambda_c^+ \to p\eta) = (1.67 \pm 0.69\ ({\rm stat.}) \pm 0.23\ ({\rm syst.}) \pm 0.34\ ({\rm ext.})) \times 10^{-3},$$

Phys. Rev. D 110 (2024) 052007

Search for $\Lambda_c^+ \to p\mu^+\mu^-$ with Run 2 data



- 2.8σ significance in high m region

$$\frac{\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-)}{\mathcal{B}(\Lambda_c^+ \to p\phi)\mathcal{B}(\phi \to \mu^+\mu^-)} < 0.029\ (0.034) \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}\ (low\text{-}m),$$

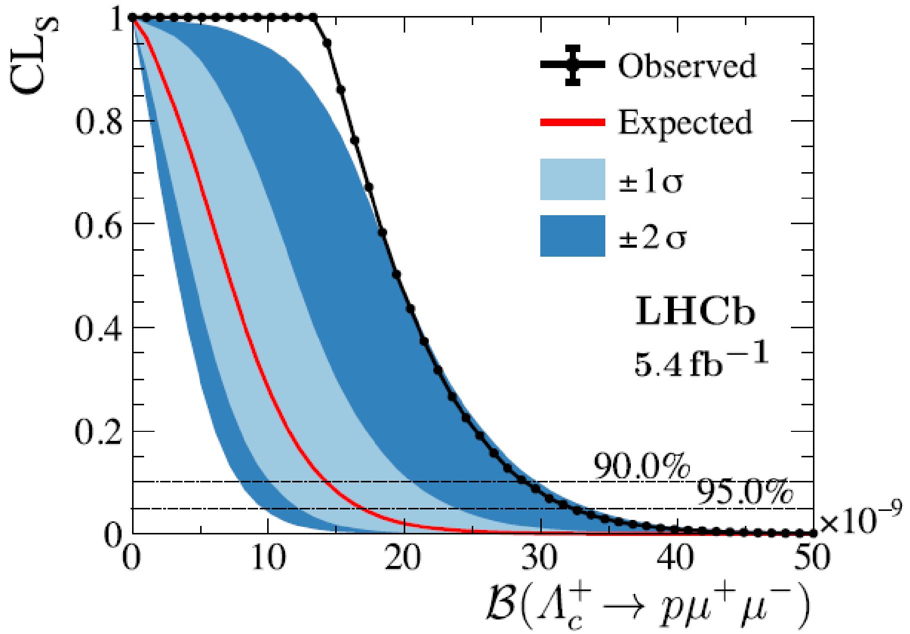
$$\frac{\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-)}{\mathcal{B}(\Lambda_c^+ \to p\phi)\mathcal{B}(\phi \to \mu^+\mu^-)} < 0.094\ (0.10) \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}\ (high\text{-}m),$$

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 0.93\ (1.1) \times 10^{-8} \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}\ (low\text{-}m),$$

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 3.0\ (3.3) \times 10^{-8} \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}\ (high\text{-}m).$$

$$\frac{\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-)}{\mathcal{B}(\Lambda_c^+ \to p\phi)\mathcal{B}(\phi \to \mu^+\mu^-)} < 0.23\ (0.25) \quad \text{at} \quad 90\%\ (95\%)\ \text{CL},$$

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 7.3\ (8.2) \times 10^{-8} \quad \text{at} \quad 90\%\ (95\%)\ \text{CL}.$$



Phys. Rev. D 110 (2024) 052007

Prospects

- Upgrade (2025: 14 fb^{-1} and Upgrade-II: 300 fb^{-1})

Observable	Current LHCb	LHCb 2025	Belle II	Upgrade II	ATLAS & CMS
EW Penguins					
R_K $(1 < q^2 < 6\,\mathrm{GeV}^2c^4)$	0.1 [274]	0.025	0.036	0.007	–
R_{K^*} $(1 < q^2 < 6\,\mathrm{GeV}^2c^4)$	0.1 [275]	0.031	0.032	0.008	–
R_ϕ, R_{pK}, R_π	–	0.08, 0.06, 0.18	–	0.02, 0.02, 0.05	–
CKM tests					
γ, with $B_s^0 \to D_s^+ K^-$	$(^{+17}_{-22})^\circ$ [136]	4°	–	1°	–
γ, all modes	$(^{+5.0}_{-5.8})^\circ$ [167]	1.5°	1.5°	0.35°	–
$\sin 2\beta$, with $B^0 \to J/\psi K_S^0$	0.04 [606]	0.011	0.005	0.003	–
ϕ_s, with $B_s^0 \to J/\psi\phi$	49 mrad [44]	14 mrad	–	4 mrad	22 mrad [607]
ϕ_s, with $B_s^0 \to D_s^+ D_s^-$	170 mrad [49]	35 mrad	–	9 mrad	–
$\phi_s^{s\bar{s}s}$, with $B_s^0 \to \phi\phi$	154 mrad [94]	39 mrad	–	11 mrad	Under study [608]
a_{sl}^s	33×10^{-4} [211]	10×10^{-4}	–	3×10^{-4}	–
$\lvert V_{ub}\rvert / \lvert V_{cb}\rvert$	6% [201]	3%	1%	1%	–
$B_s^0, B^0 \to \mu^+\mu^-$					
$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	90% [264]	34%	–	10%	21% [609]
$\tau_{B_s^0 \to \mu^+\mu^-}$	22% [264]	8%	–	2%	–
$S_{\mu\mu}$	–	–	–	0.2	–
$b \to c\ell^-\bar{\nu}_l$ **LUV studies**					
$R(D^*)$	0.026 [215, 217]	0.0072	0.005	0.002	–
$R(J/\psi)$	0.24 [220]	0.071	–	0.02	–
Charm					
$\Delta A_{CP}(KK - \pi\pi)$	8.5×10^{-4} [610]	1.7×10^{-4}	5.4×10^{-4}	3.0×10^{-5}	–
A_Γ $(\approx x \sin\phi)$	2.8×10^{-4} [240]	4.3×10^{-5}	3.5×10^{-4}	1.0×10^{-5}	–
$x \sin\phi$ from $D^0 \to K^+\pi^-$	13×10^{-4} [228]	3.2×10^{-4}	4.6×10^{-4}	8.0×10^{-5}	–
$x \sin\phi$ from multibody decays	–	$(K3\pi)$ 4.0×10^{-5}	$(K_S^0\pi\pi)$ 1.2×10^{-4}	$(K3\pi)$ 8.0×10^{-6}	–

CERN-LHCC-2018-027, 2021-012

Summary

- **There is no sign of beyond the SM source yet**
  - Many first searches, LFU tests, and angular analyses, esp. with electron channels
  - Data-driven approaches improve our understanding of non-local effects in $\boldsymbol{B^0 \to K^{*0}\mu^+\mu^-}$

- **Opportunities in future**
  - Higher precision in rare decay measurements: $B^0_{s/d} \to \mu^+\mu^-$, angular distributions and LFU tests in $b \to sl^+l^-$ decays, …
  - Wider scope for exploitation: LFU tests in $b \to dl^+l^-$ decays, CPV in baryon decays, CPV in rare decays,…

Thank you