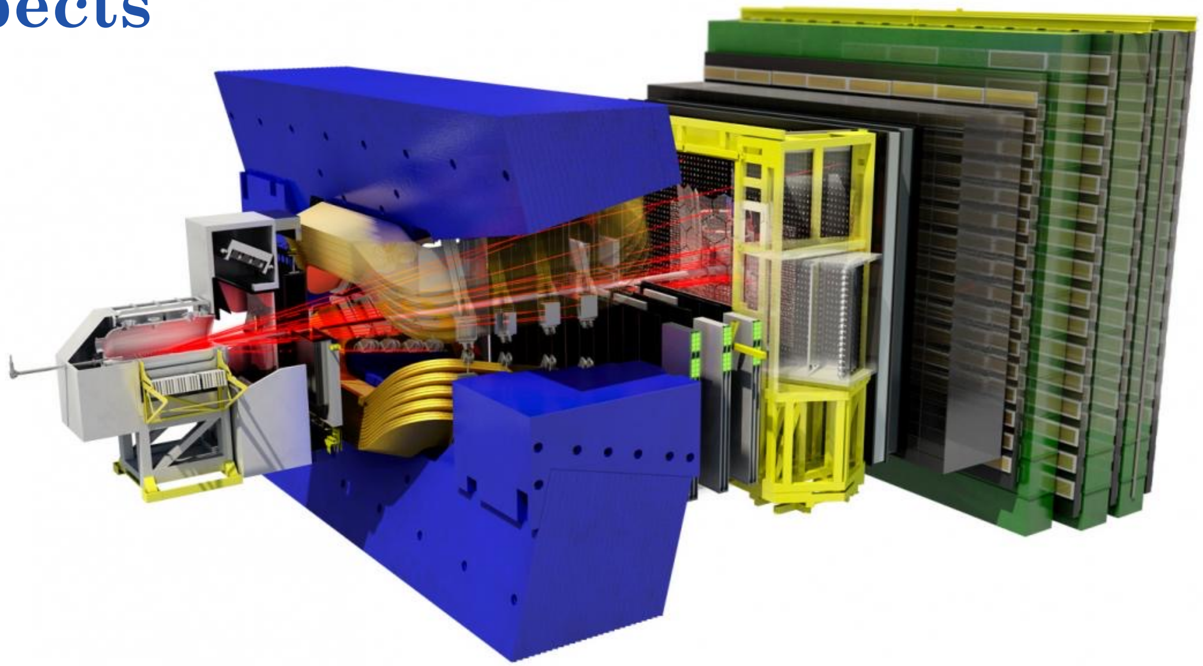
The LHCb experiment

Selected highlights & future prospects



Harry Cliff

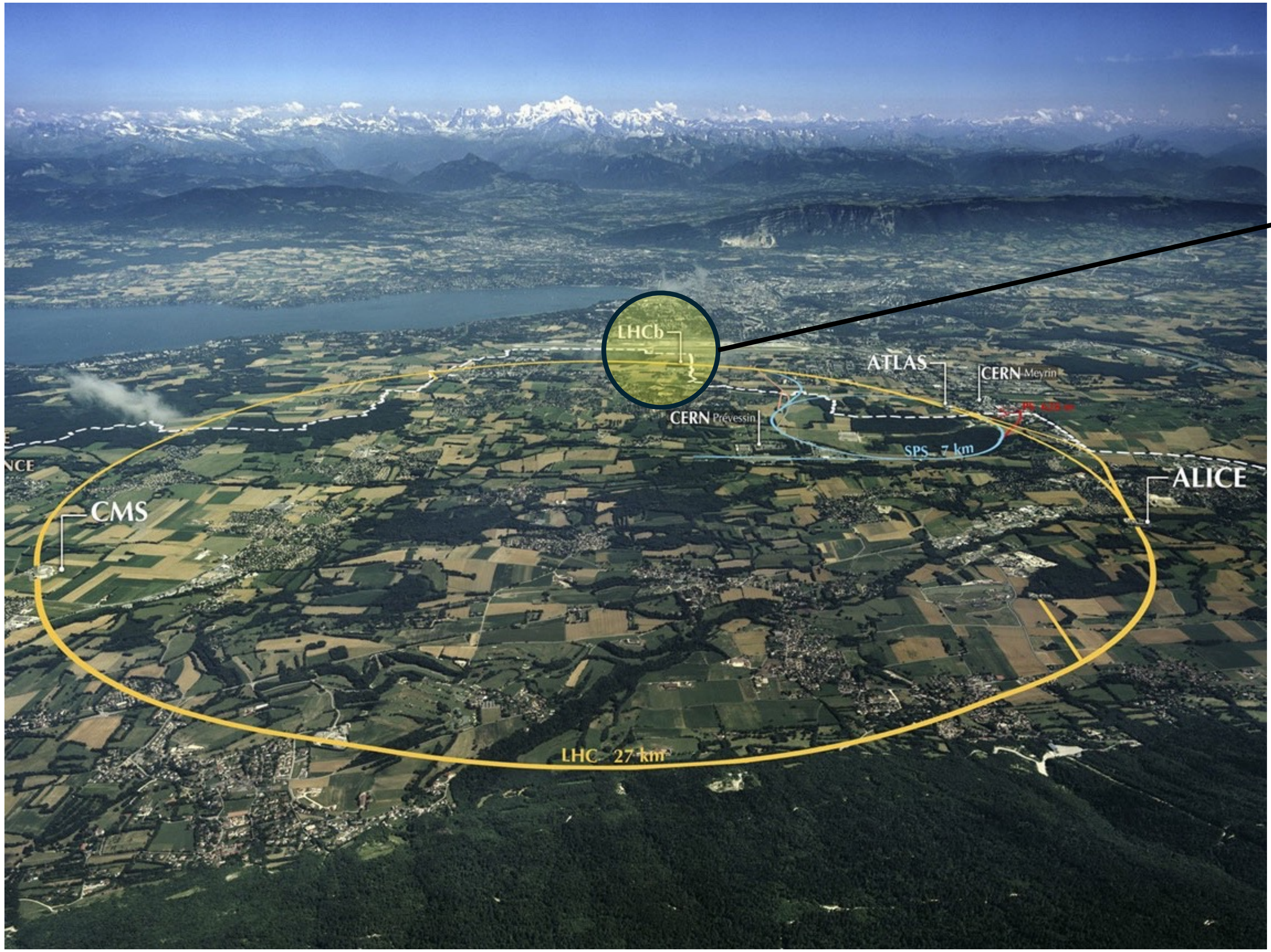
Ernest Rutherford Fellow and Public Physicist
Cavendish Laboratory, University of Cambridge

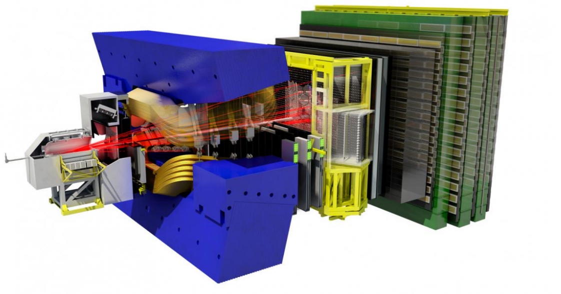
IOP APP and HEPP Conference, 9 April 2026

UKRI Science and Technology Facilities Council

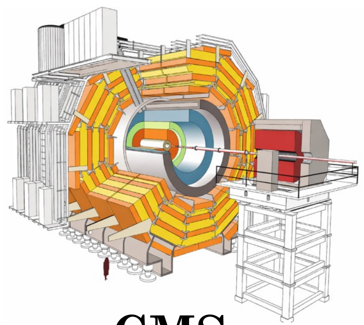
UNIVERSITY OF CAMBRIDGE

The LHCb Experiment

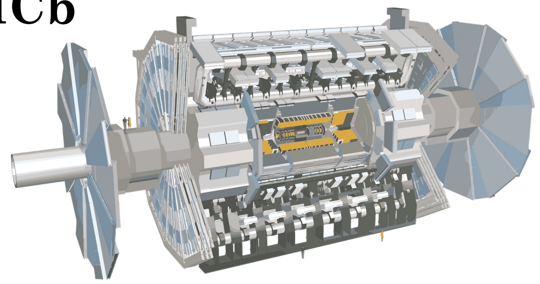




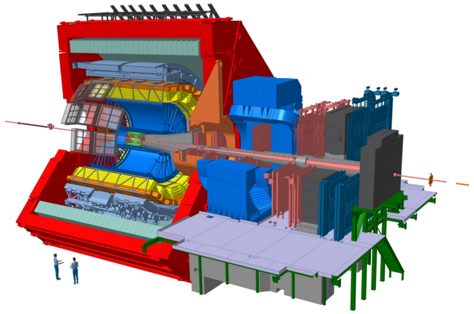
LHCb



CMS

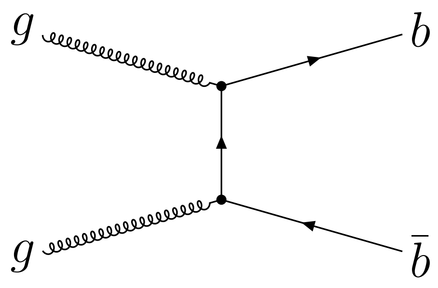


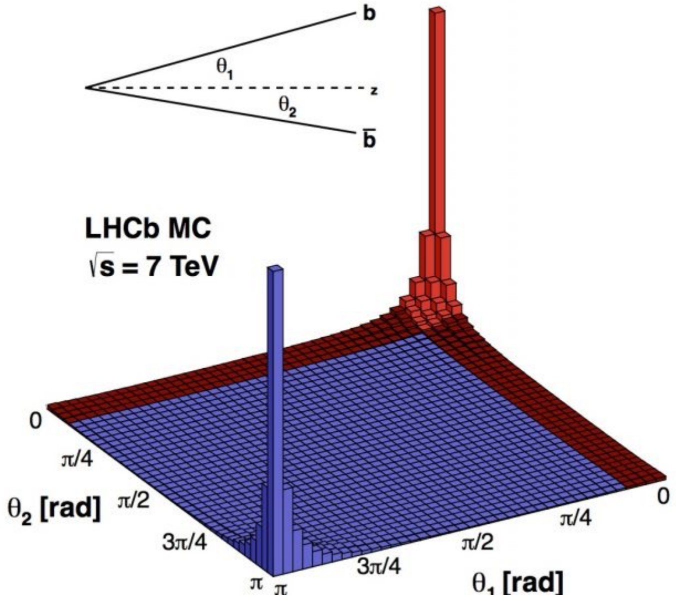
ATLAS

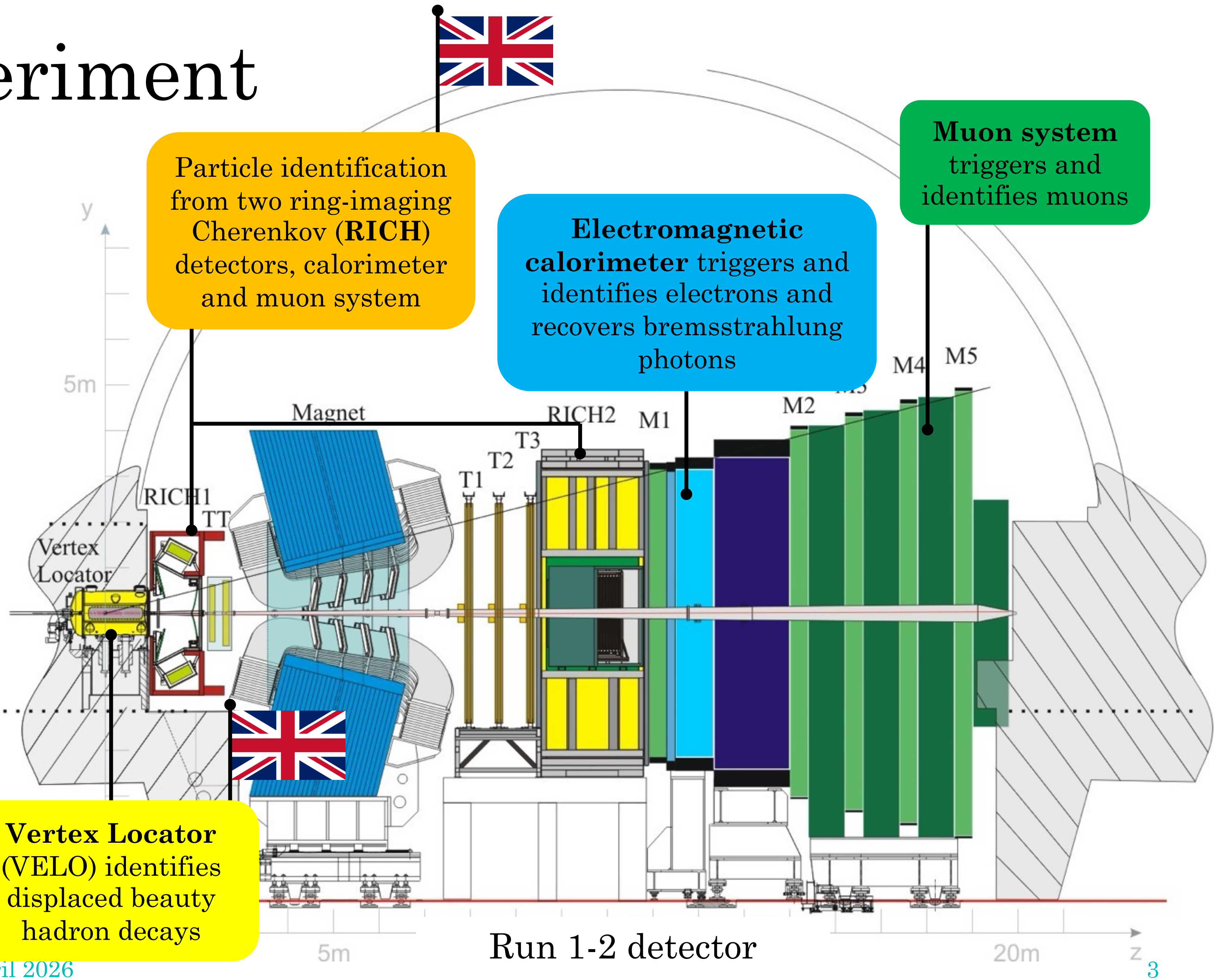


ALICE

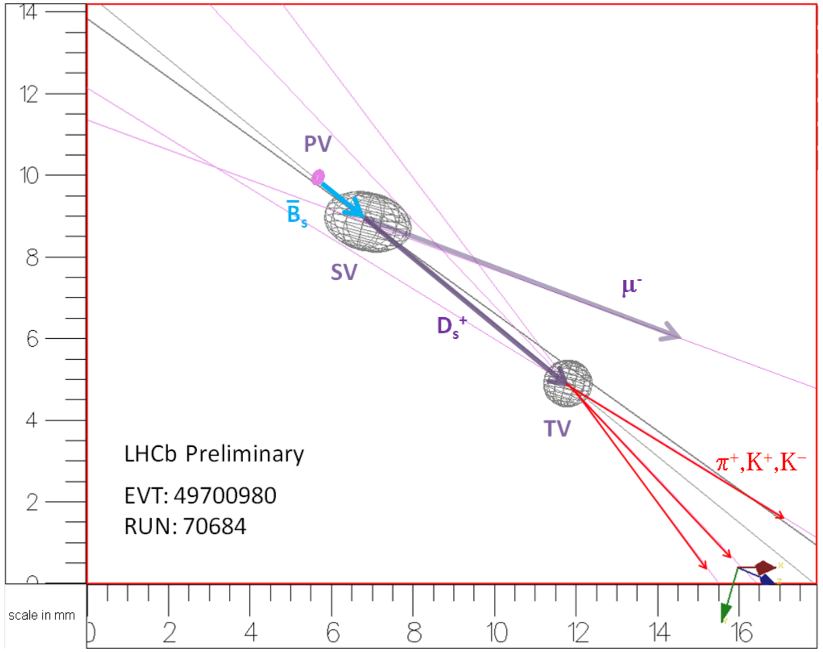
The LHCb Experiment







The LHCb Experiment

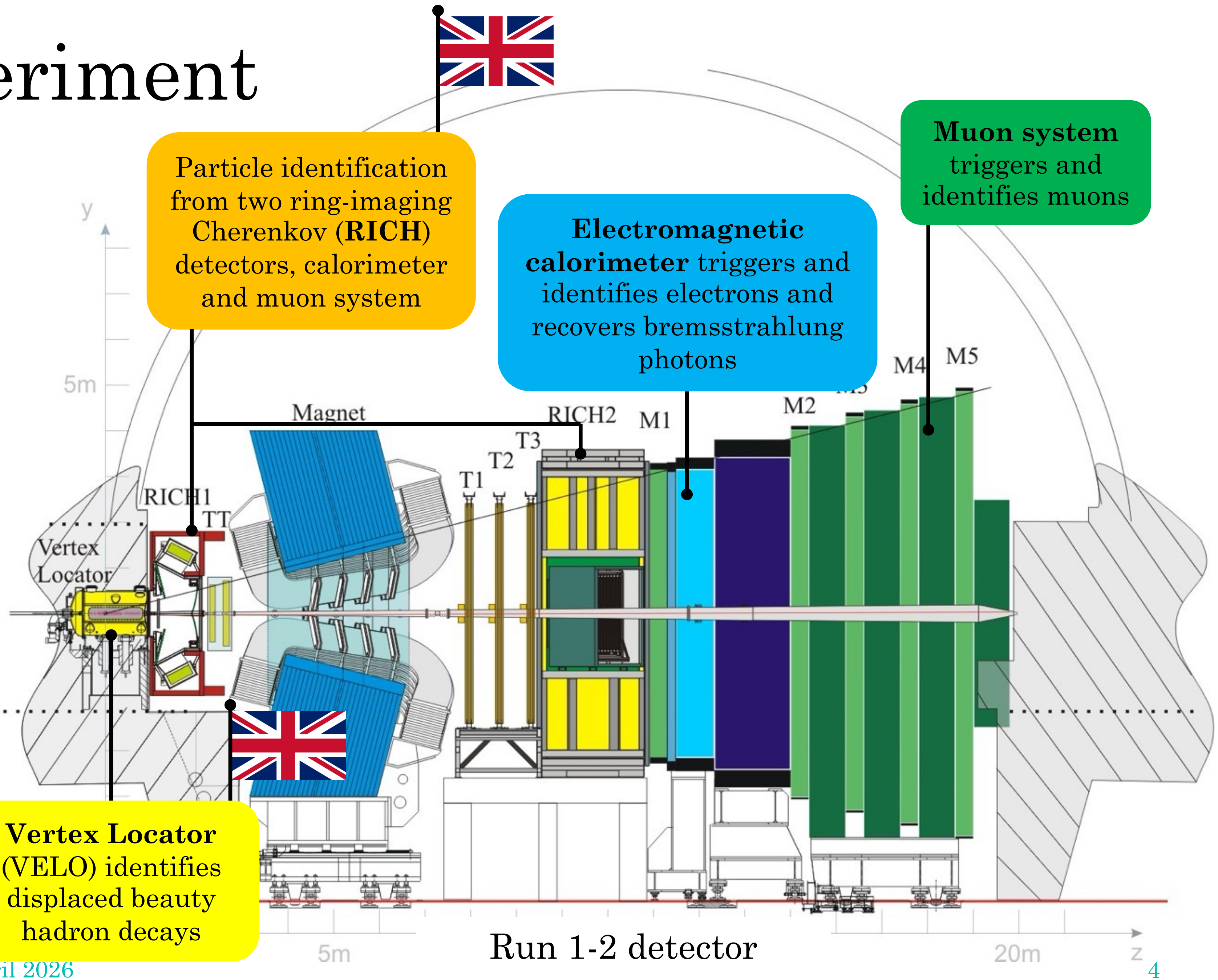


Particle identification from two ring-imaging Cherenkov (**RICH**) detectors, calorimeter and muon system

Electromagnetic calorimeter triggers and identifies electrons and recovers bremsstrahlung photons

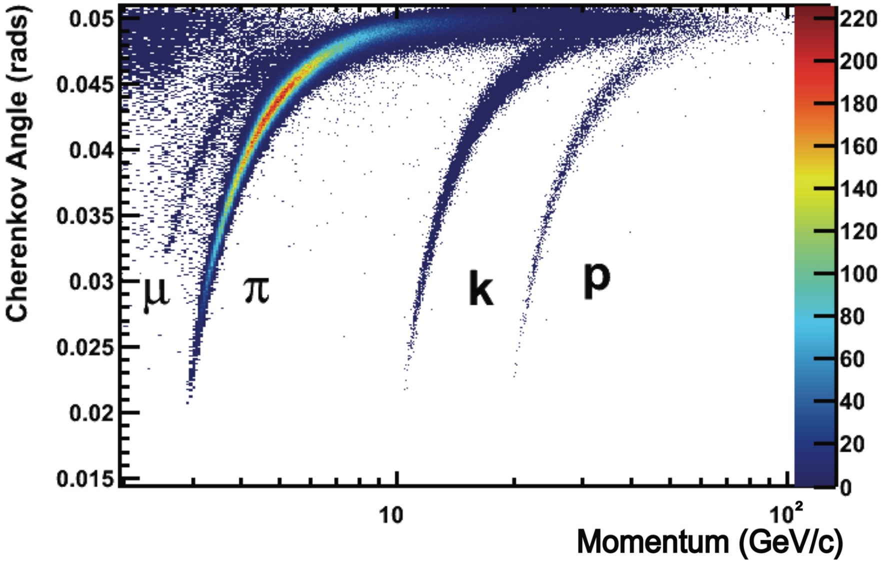
Muon system triggers and identifies muons

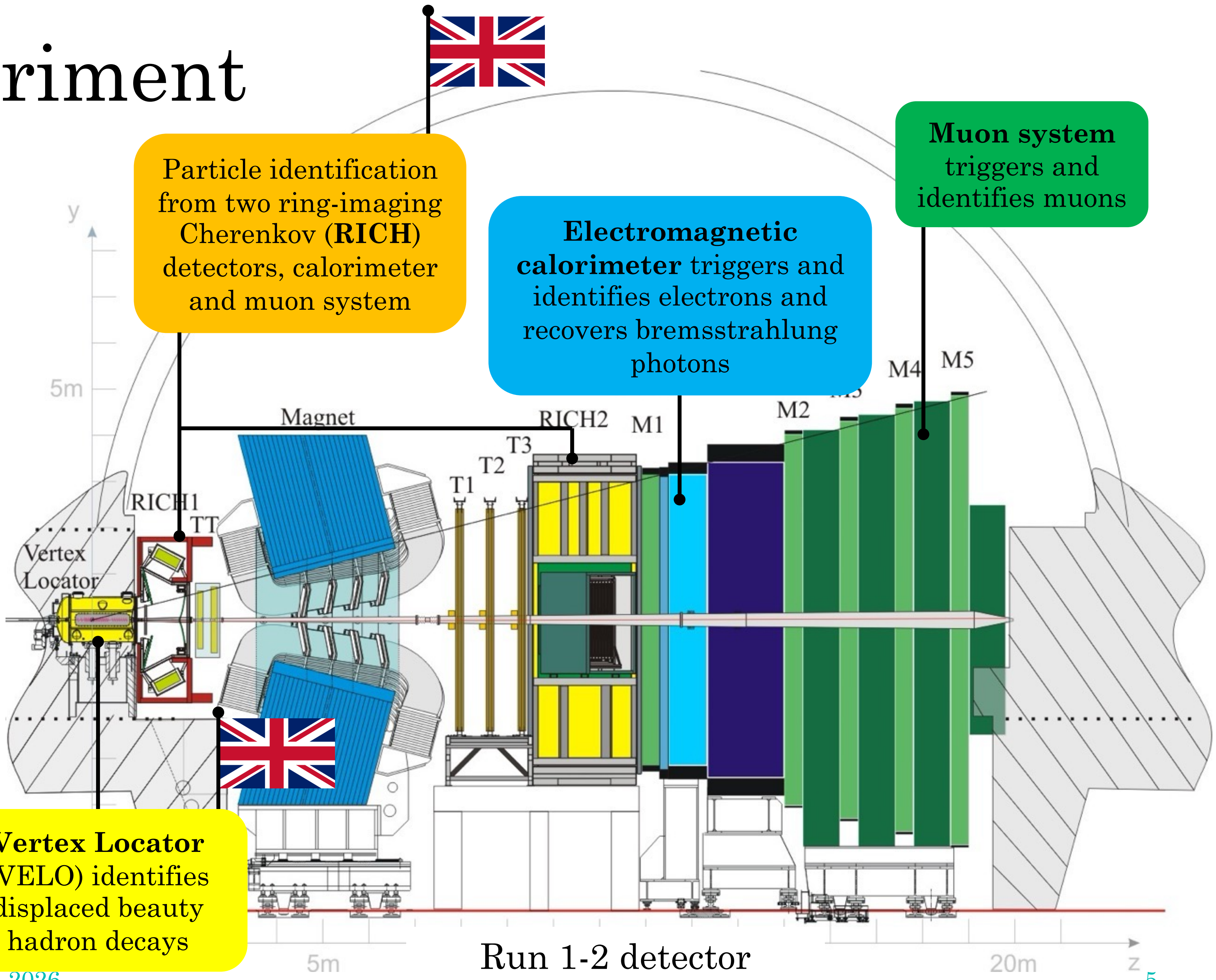
Vertex Locator (VELO) identifies displaced beauty hadron decays



Run 1-2 detector

The LHCb Experiment

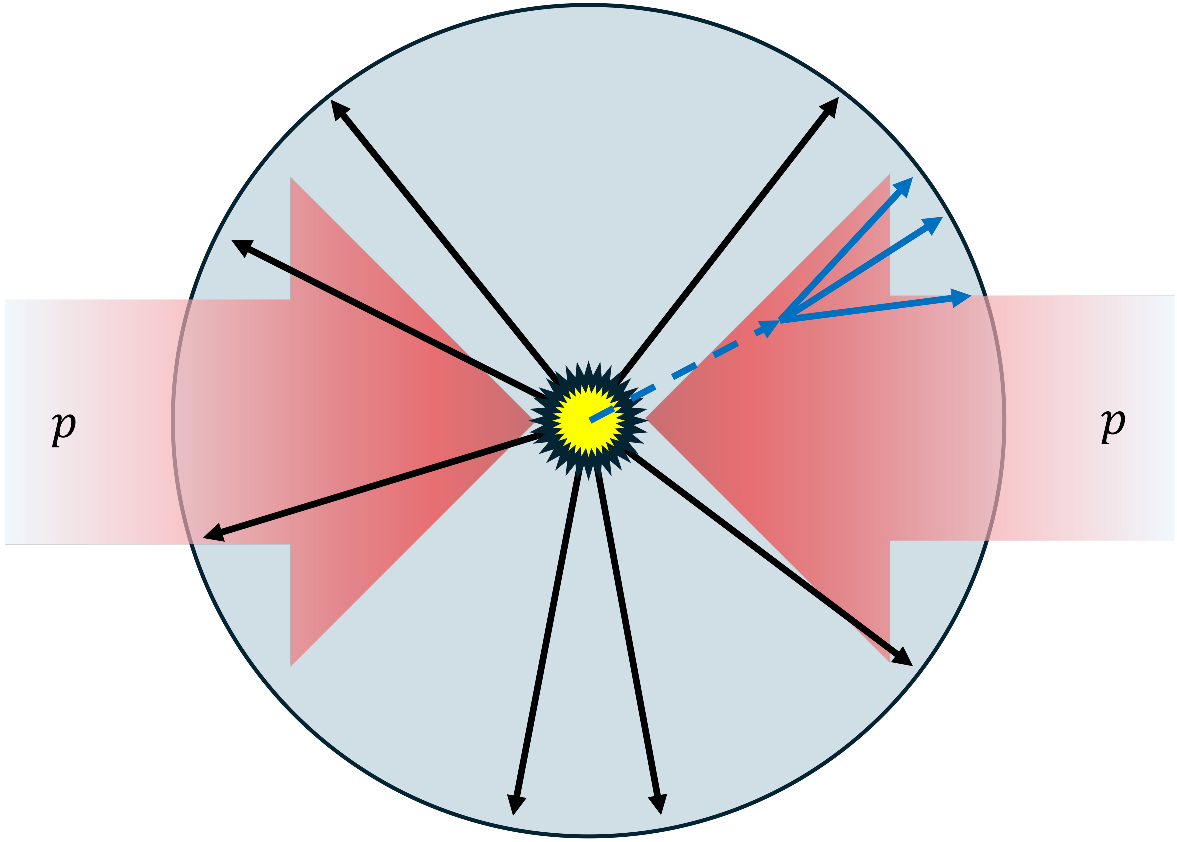




Run 1-2 detector

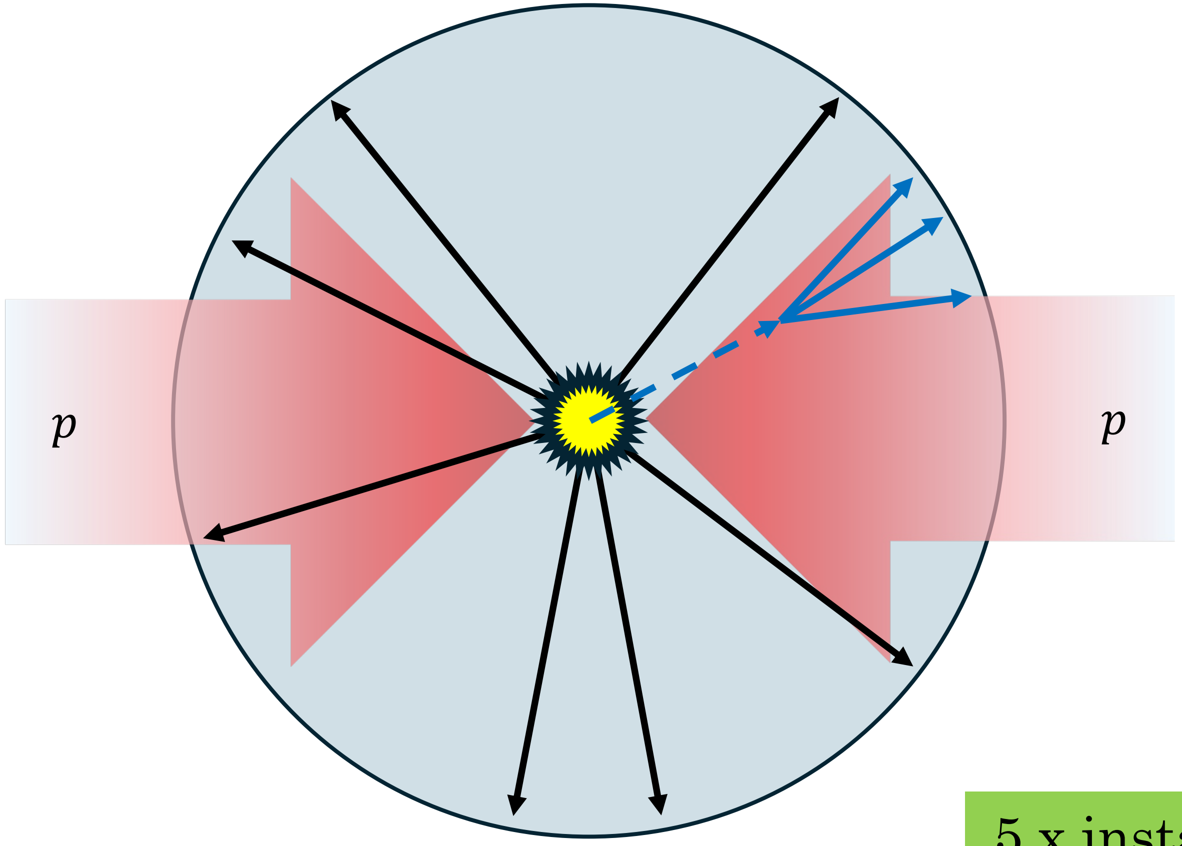
LHCb Upgrade I

LHCb classic

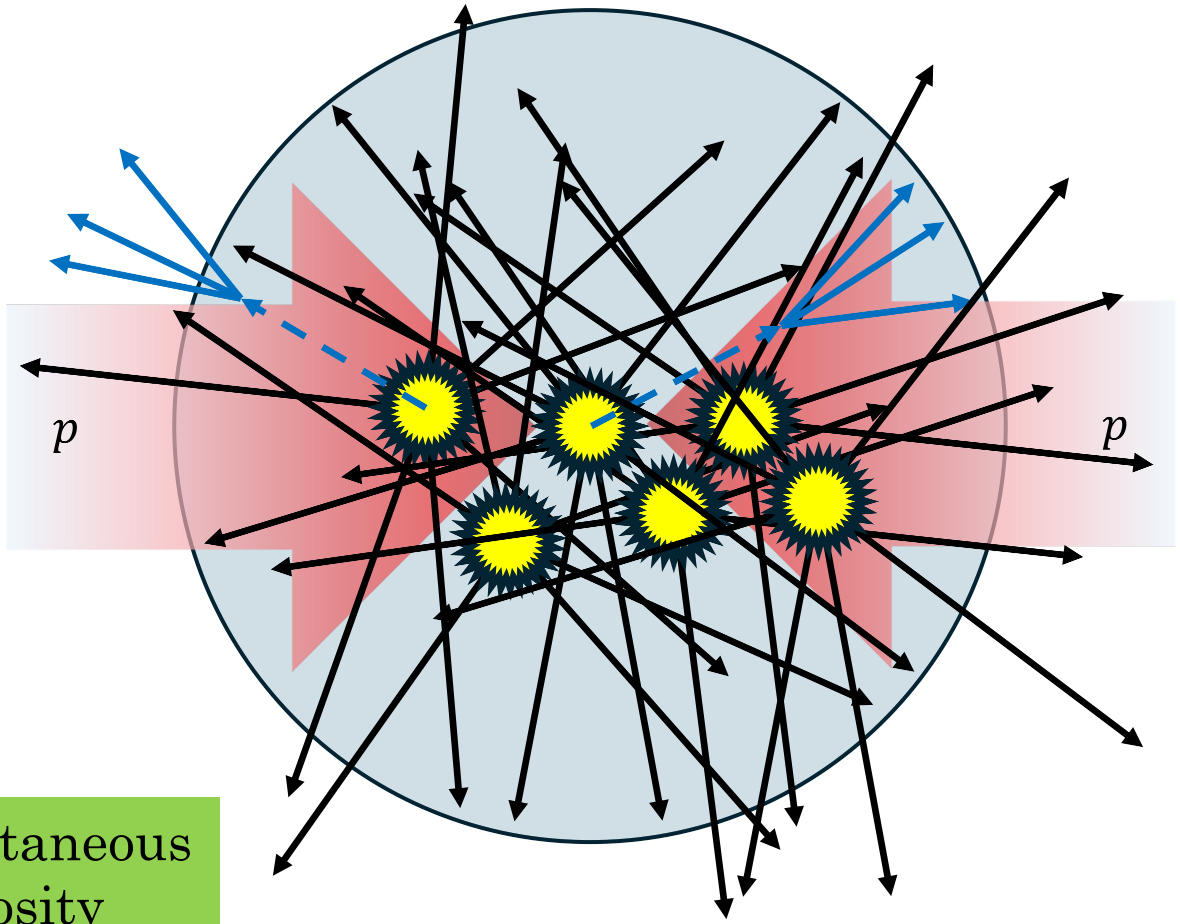


LHCb Upgrade I

LHCb classic

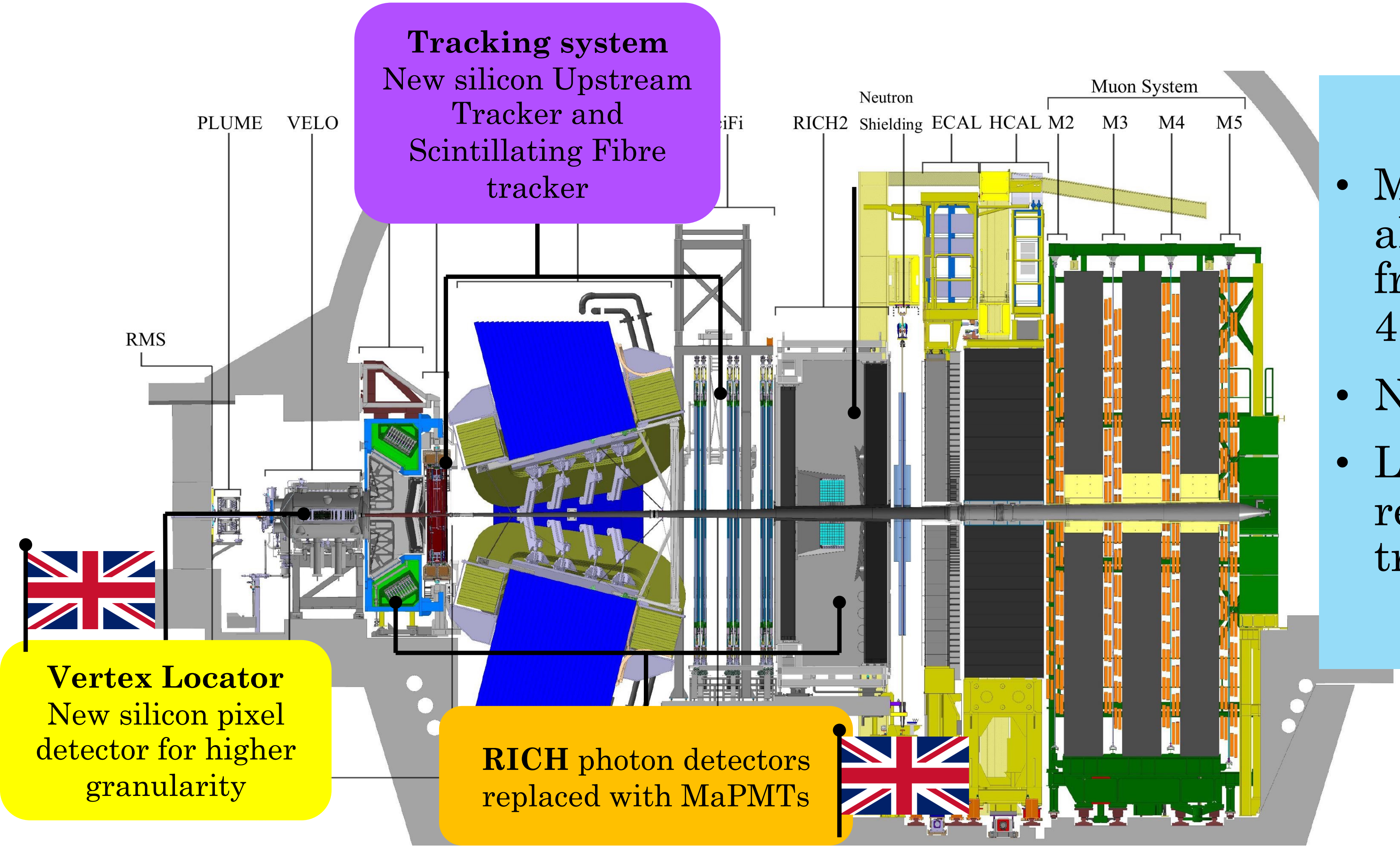


LHCb Upgrade I



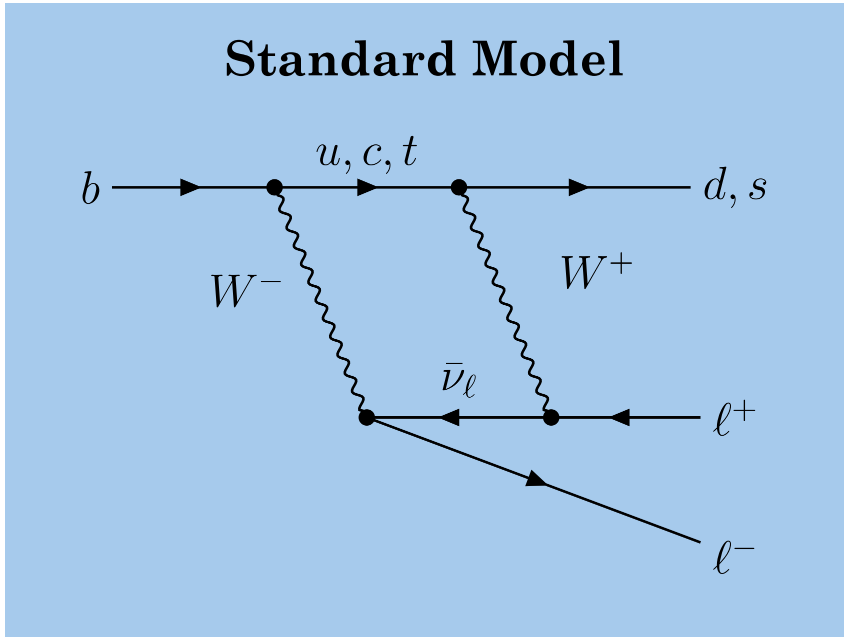
5 x instantaneous luminosity

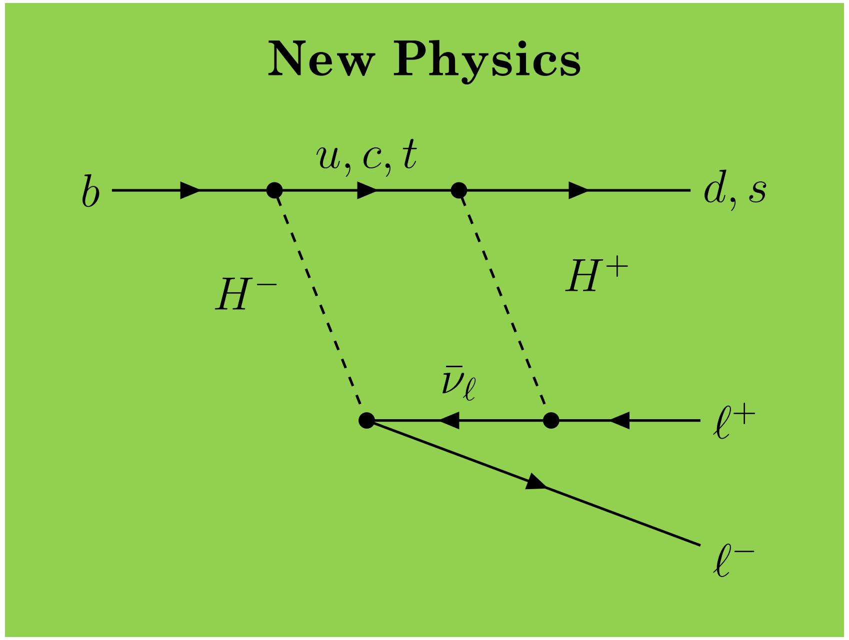
LHCb Upgrade I



- Major upgrade to readout of all subdetectors to move from 1MHz readout to 40MHz
- New data centre and DAQ
- Level-0 hardware trigger replaced with all-software trigger

Flavour as a probe of new physics

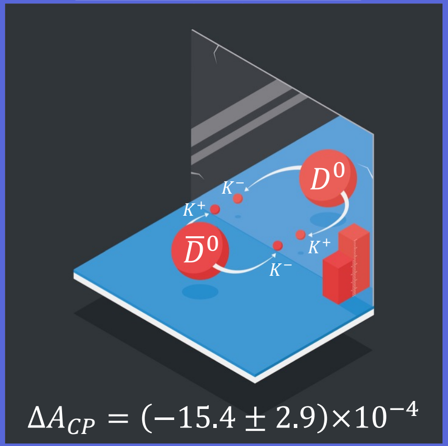




- studying heavy flavour decays gives sensitivity to BSM quantum fields in the loops
- sensitive to energy scales above direct reach of LHC (e.g. up to 100 TeV in FCNC b decays)

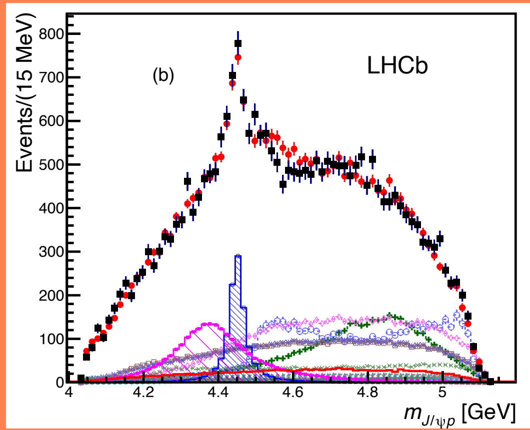
Some of LHCb’s greatest hits (so far)

Phys. Rev. Lett. 122, 211803



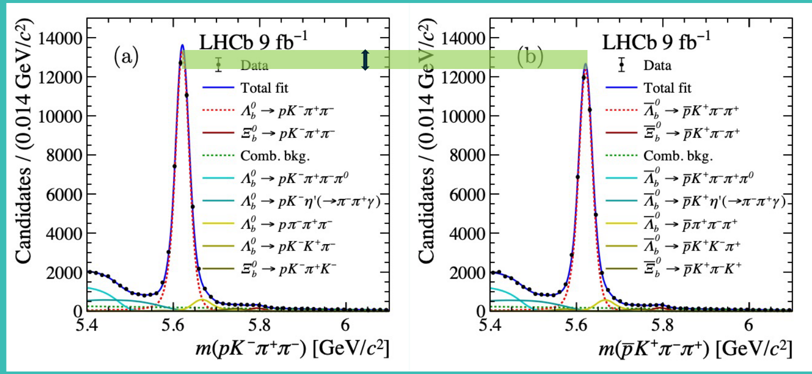
Discovery of CP violation in charm

Phys. Rev. Lett. 115, 072001 (2015)



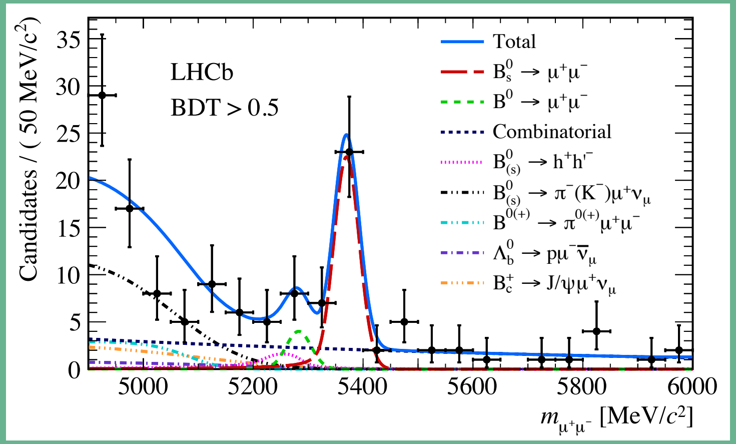
Discovery of pentaquarks

Nature 643 (2025) 1223



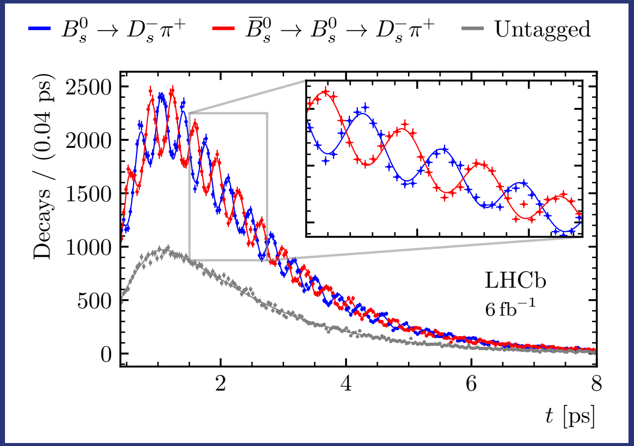
Discovery of CP violation in baryons

Phys. Rev. Lett. 118, 191801 (2017)



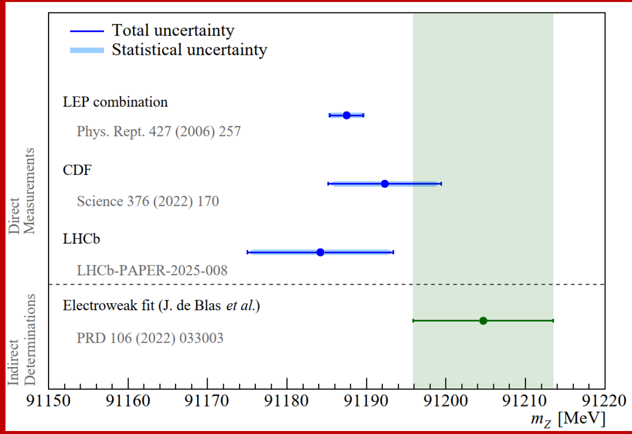
First single-experiment observation of $B_s^0 \to \mu^+\mu^-$

Nature Phys. 18 (2022) 1



B meson oscillations

Phys. Rev. Lett. 135 (2025) 161802



Electroweak physics in the forward region

Part I
CP violation

CP violation and CKM matrix unitarity

CKM matrix describes relationship between quark flavour and mass eigenstates:

$$V_{C\mathrm{KM}} = \begin{pmatrix} V_{u\mathrm{d}} & V_{us} & V_{u\mathrm{b}} \\ V_{\mathrm{cd}} & V_{\mathrm{cs}} & V_{\mathrm{cb}} \\ V_{\mathrm{td}} & V_{\mathrm{ts}} & V_{\mathrm{tb}} \end{pmatrix}$$

CP violation and CKM matrix unitarity

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$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Unitary in SM: $V_{CKM}^{\dagger} V_{CKM} = \mathbf{1}$ giving 9 equations including

$$\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} + 1 + \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = 0$$

A triangle in complex plane.

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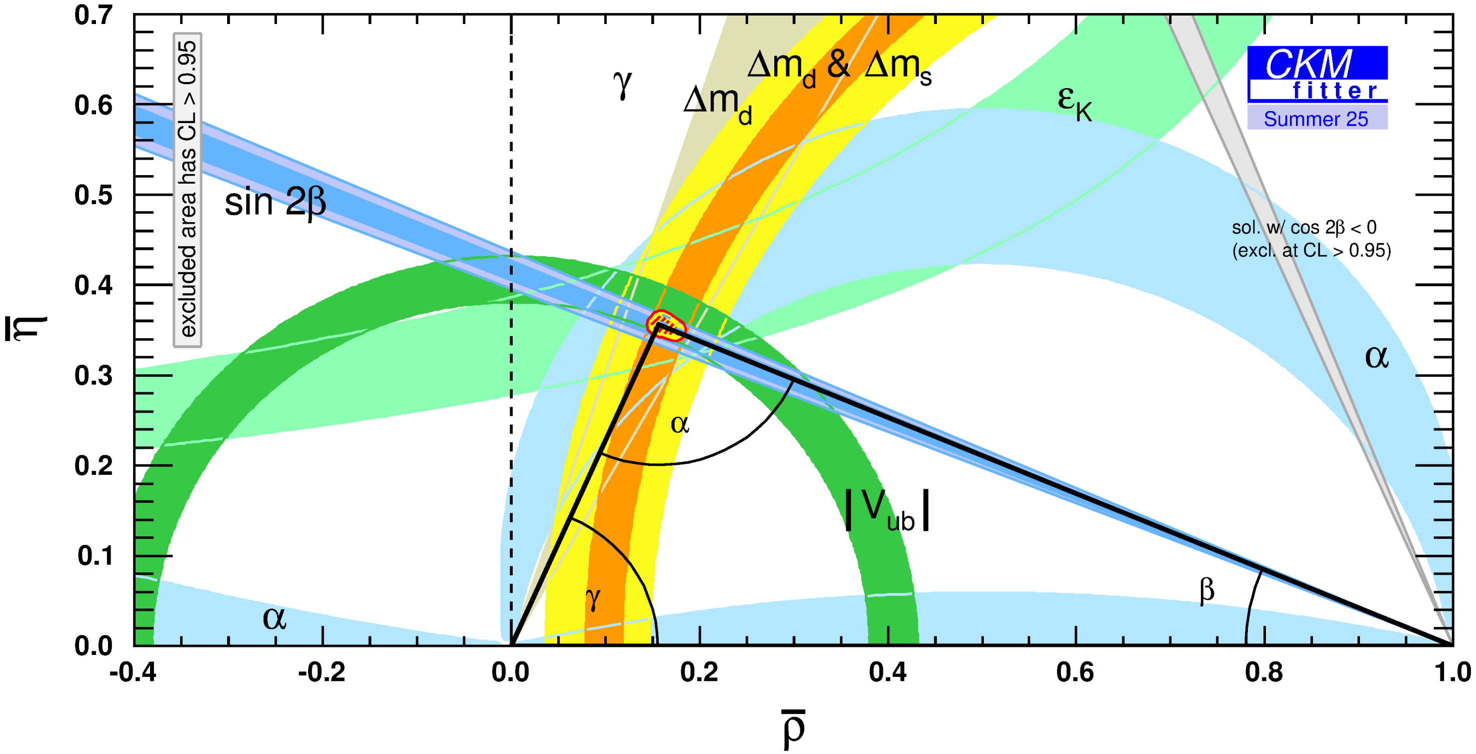
A triangle in complex plane.



$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right)$

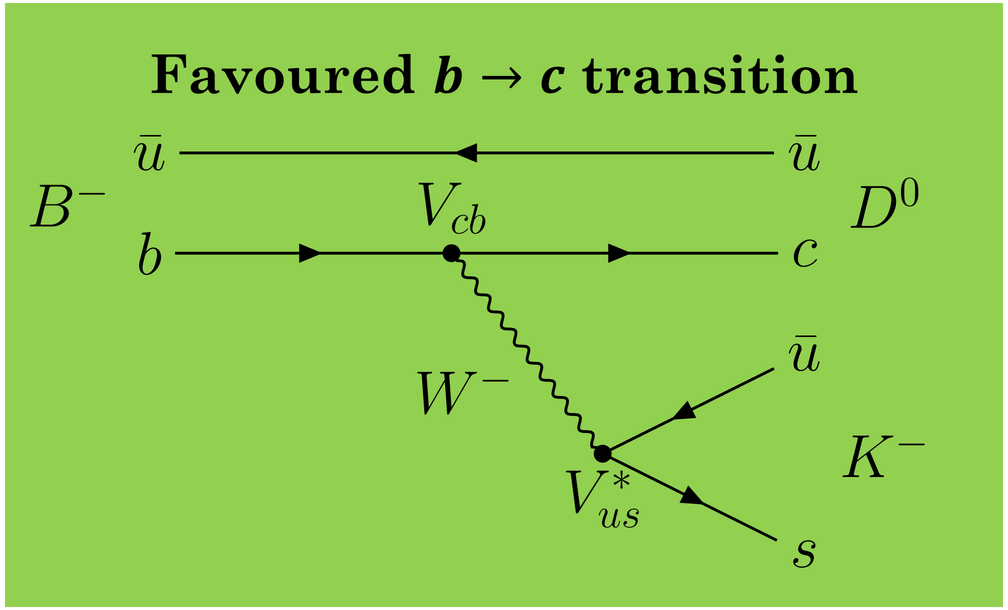
$\beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$

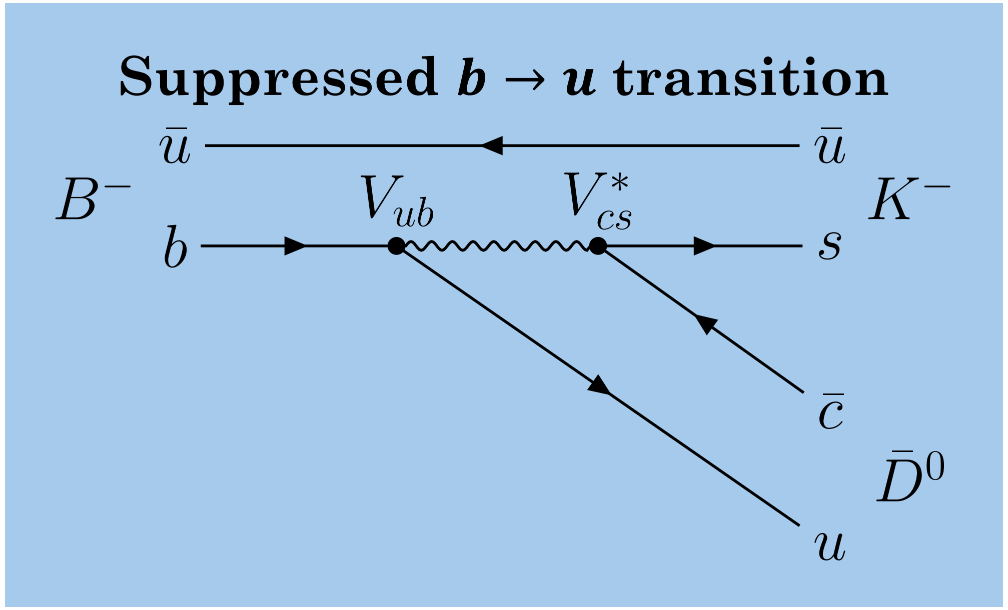
$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$

Quantum trigonometry: measuring γ

$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

The angle γ measured using interference between tree-level b-decays:



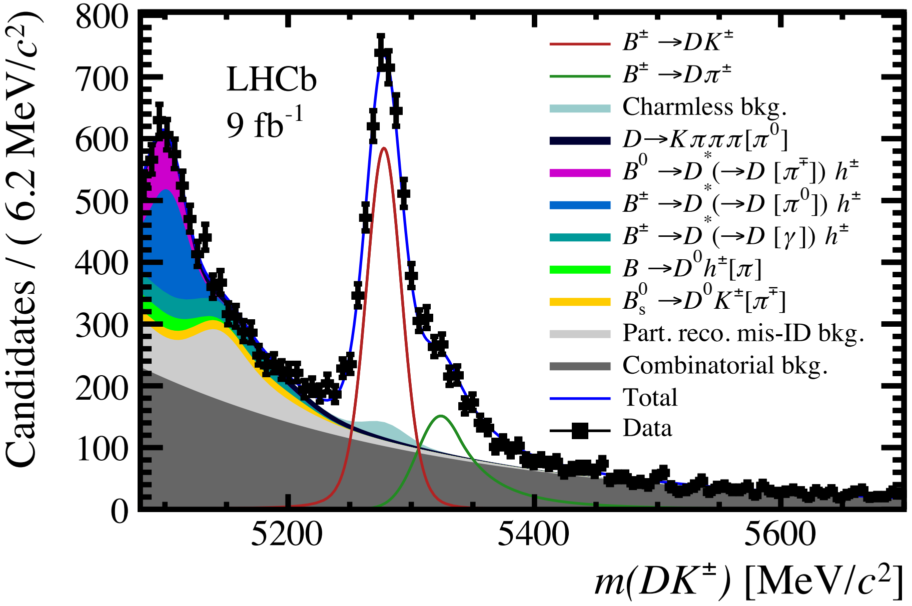


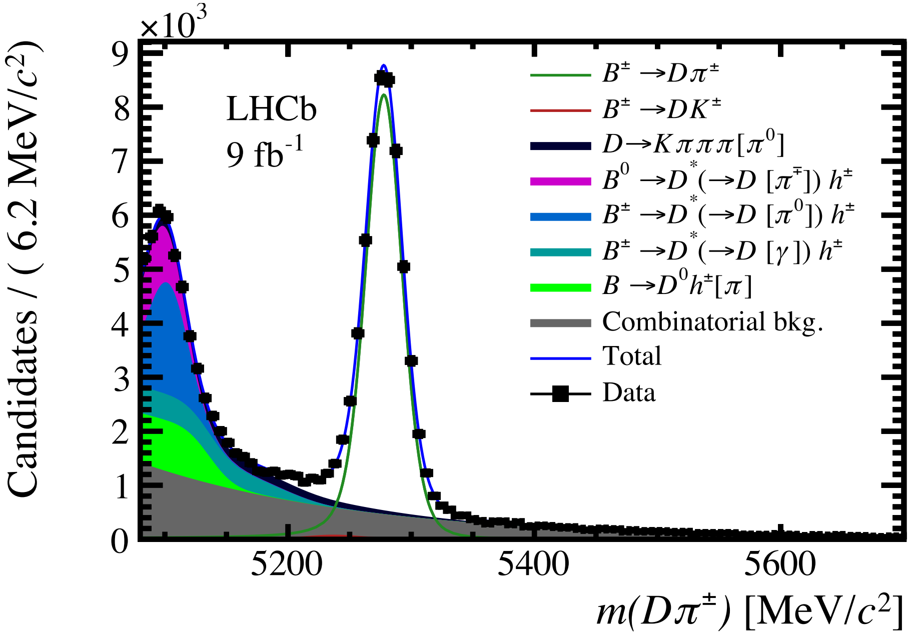
- Best sensitivity achieved by combining multiple measurements of different decay modes (ADS/GLW/GGSZ)
- Difference between direct and indirect measurements of γ gives sensitivity to NP.

Latest LHCb γ combination

[LHCb-CONF-2025-003]

Includes three new LHCb measurements including from $B^{\pm} \to [K^{+}K^{-}\pi^{+}\pi^{-}]_{D}h^{\pm}$ and $B^{\pm} \to [\pi^{+}\pi^{-}\pi^{+}\pi^{-}]_{D}h^{\pm}$ $(h = K, \pi)$ and new measurements of D decay properties.



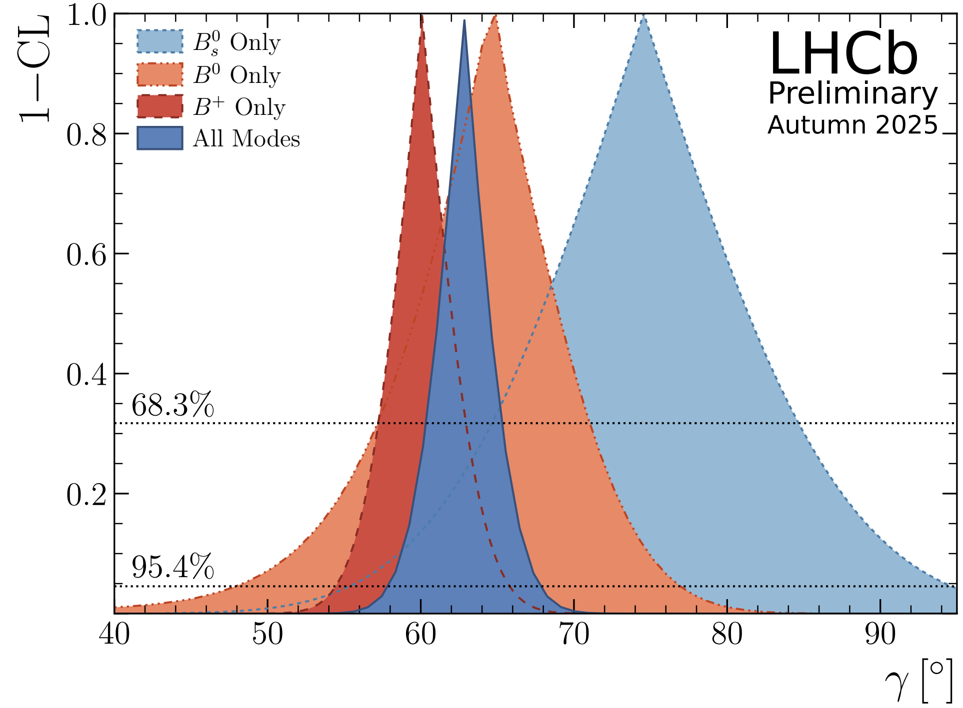


J. High Energ. Phys. 2026, 62 (2026)

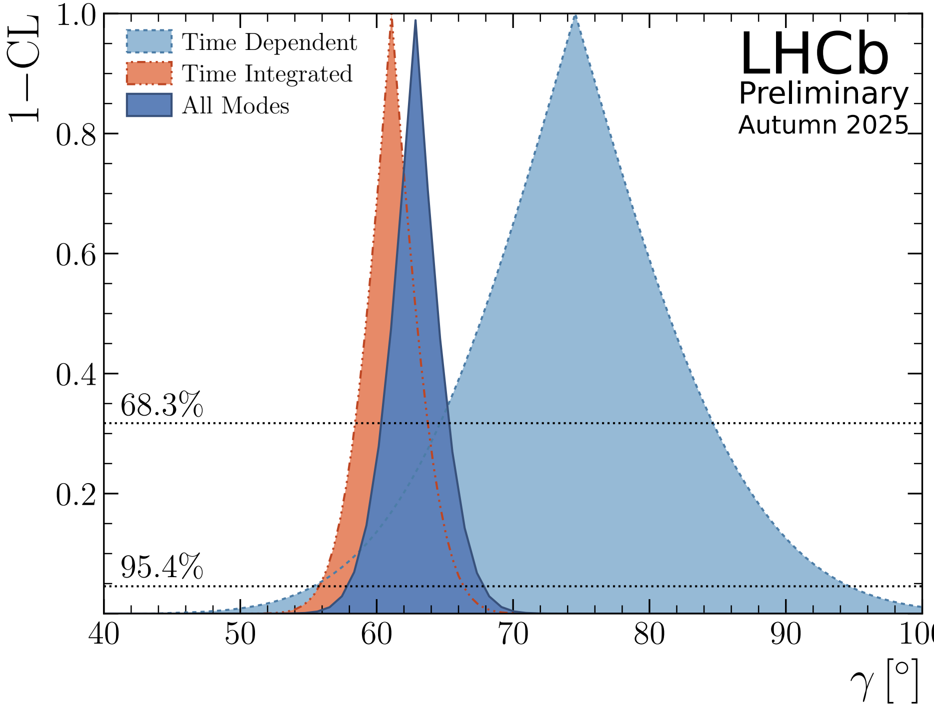
Latest LHCb γ combination

[LHCb-CONF-2025-003]

By B-meson species



Time dependent vs time integrated



Direct (this result)

$$\gamma = (62.8 \pm 2.6)^\circ$$

Indirect (CKM fitter)

$$\gamma = (66.3^{+0.7}_{-1.9})^\circ$$

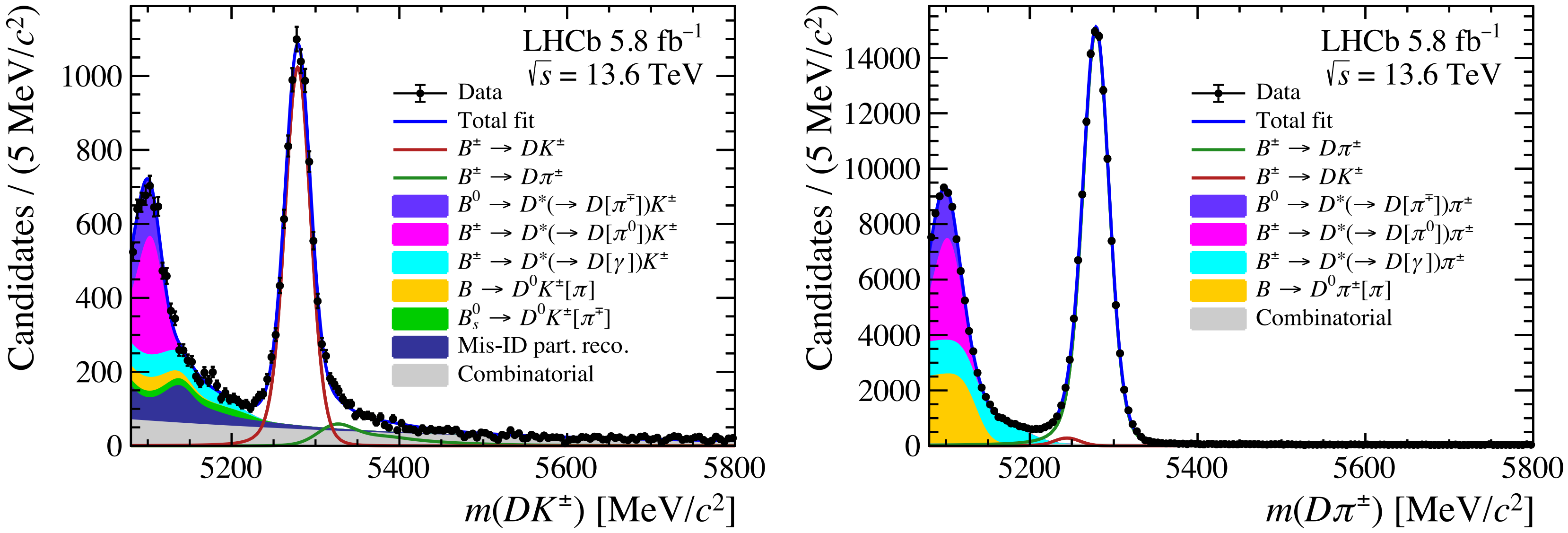
Phys. Rev. D91 (2015) 073007

First measurement of γ with Run 3 data

Run 3

Measured with $B^{\pm} \rightarrow DK^{\pm}$ and $B^{\pm} \rightarrow D\pi^{\pm}$ with $D \rightarrow K_S^0\pi^+\pi^-$ or $D \rightarrow K_S^0K^+K^-$

- 5.4 fb^{-1} of 2024 data – higher yields with less integrated luminosity!



$\gamma = (68.1 \pm 6.7)^{\circ}$

Larger uncertainty than previous measurements with fewer events due to:

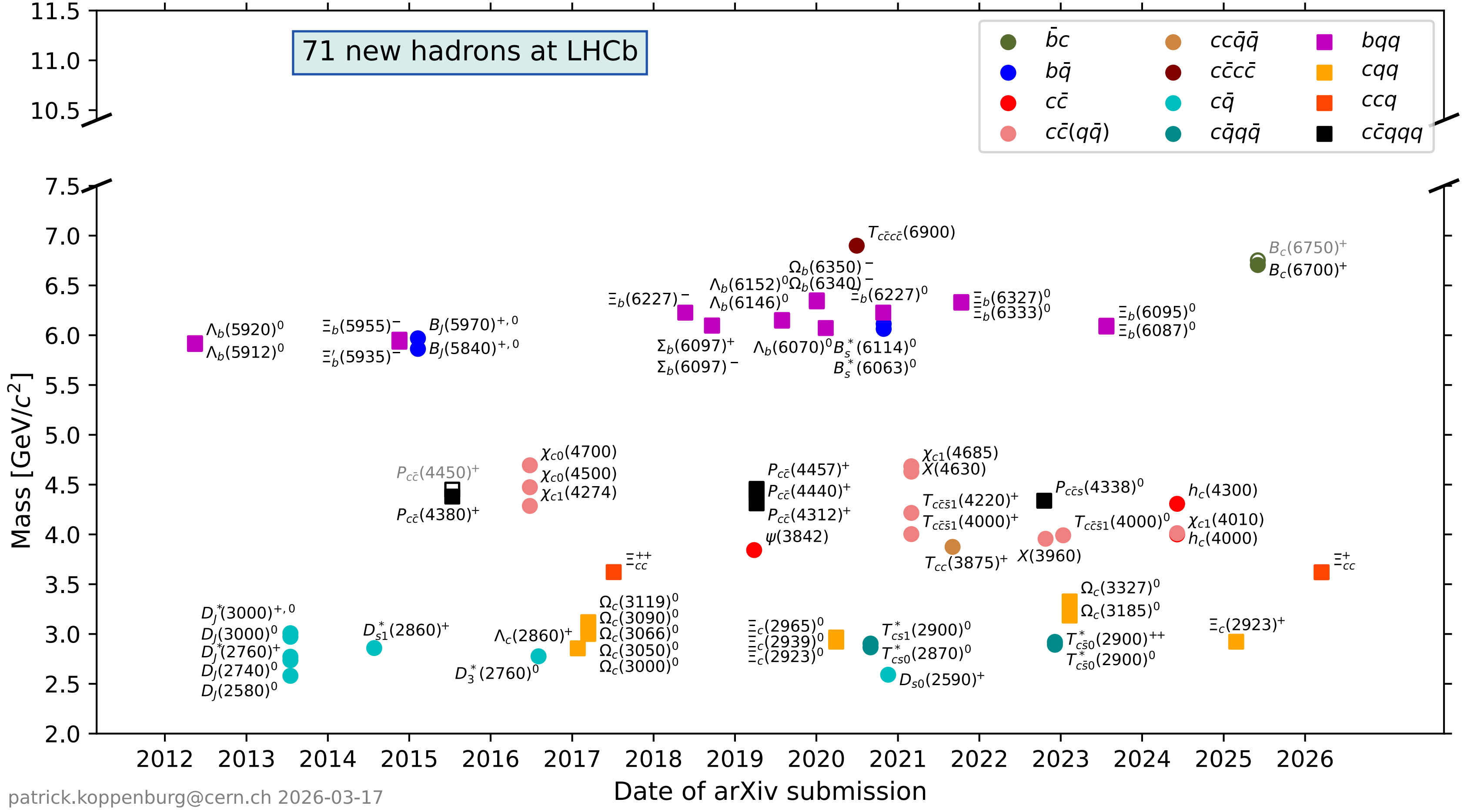
1) New input values for D-decay parameters from BESIII
2) Location of fit minimum

[LHCb-PAPER-2026-010 – paper in preparation]

Part II
Exotic hadrons

New hadrons at LHC

Of the 80 new hadrons discovered at the LHC, 71 observed by LHCb



Search for the doubly-charmed baryon, $\Xi_{cc}^{+}(ccd)$

Isospin partner $\Xi_{cc}^{++}(ccu)$, which was previously observed by LHCb:

$$m(\Xi_{cc}^{++}) = 3621.55 \pm 0.23 \pm 0.30 \text{ MeV/c}^2$$

[JHEP 02 (2020) 049]

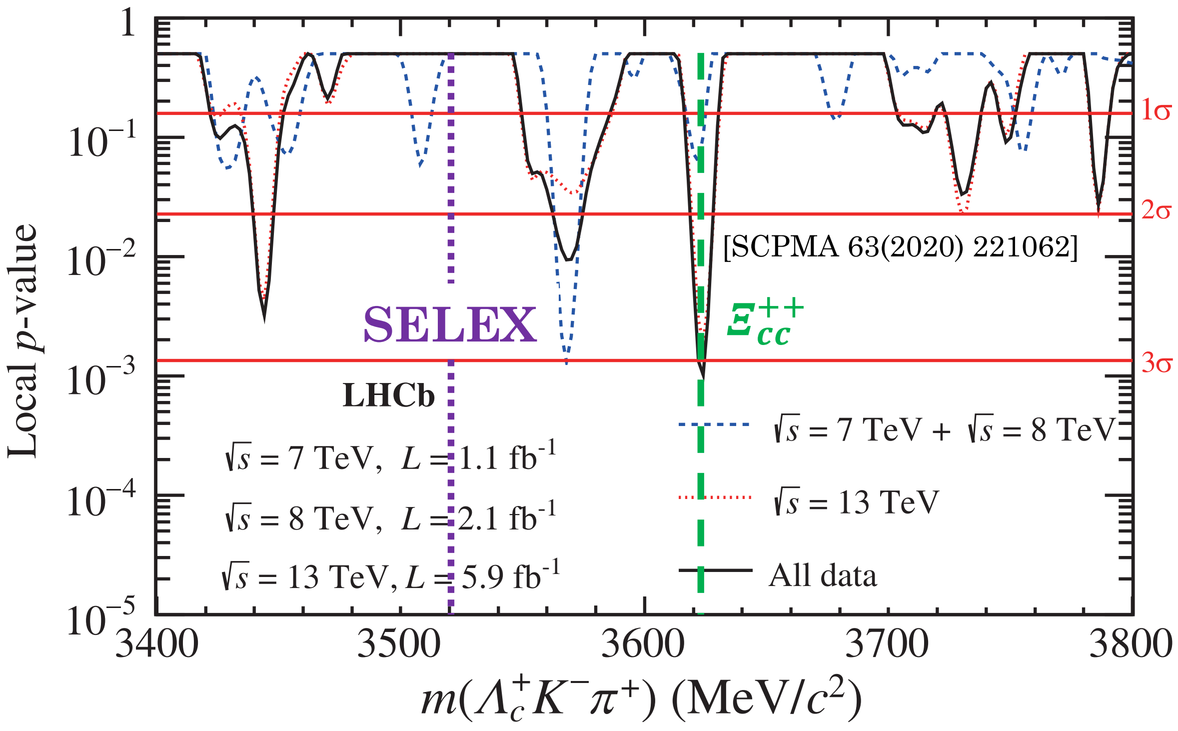
SELEX experiment claimed observation of Ξ_{cc}^{+} in 2002 with

$$m(\Xi_{cc}^{+}) = m(\Xi_{cc}^{++}) - 100 \text{ MeV/c}^2$$

[PhysRevLett.89.112001]

but not confirmed by other experiments.

With 9 fb^{-1} Run 1+2 data, LHCb saw 3σ excess.

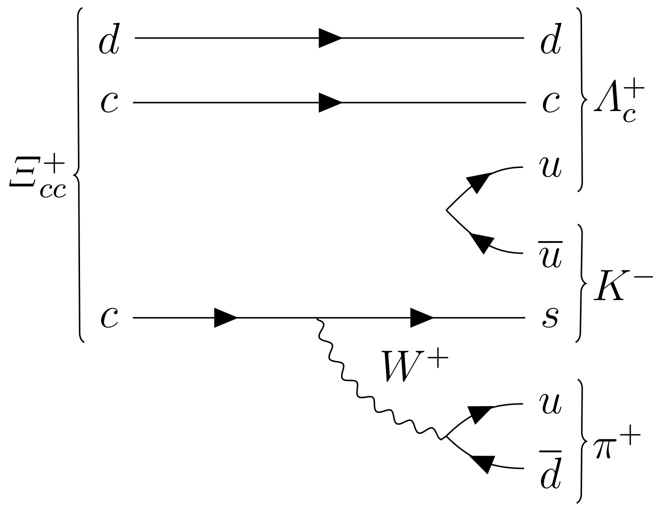


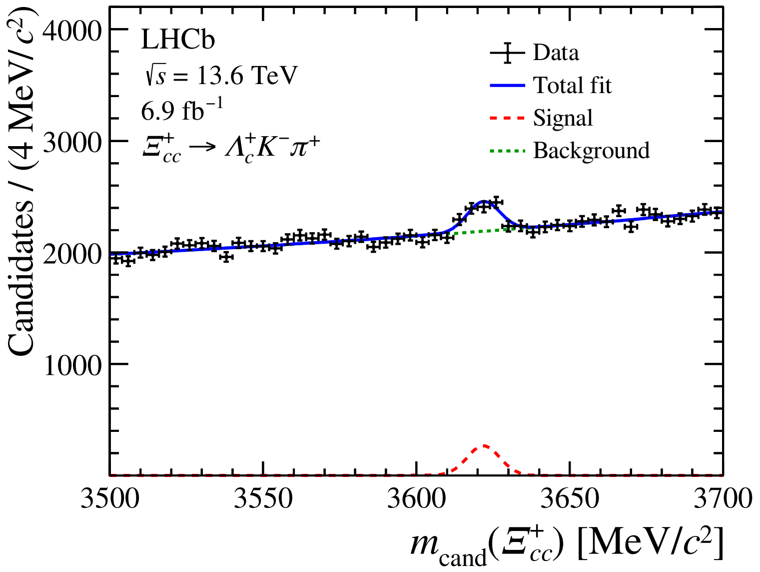
Observation of the doubly-charmed Ξ_{cc}^{+}

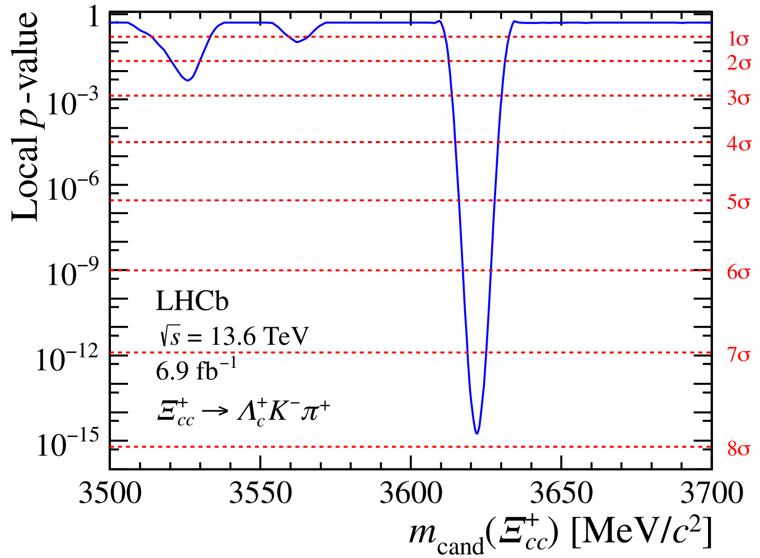
Run 3

New search performed with 6.9 fb^{-1} of 2024 data.

Significance >7σ







$$m(\Xi_{cc}^{+}) - m(\Xi_{cc}^{++}) = (-1.77 \pm 0.84 \pm 0.15^{+1.90}_{-1.30})\ \mathrm{MeV}/c^2$$

2.5 × higher yield per fb^{-1} due to removal of hardware trigger and improved VELO and RICH performance.

The Guardian

UK

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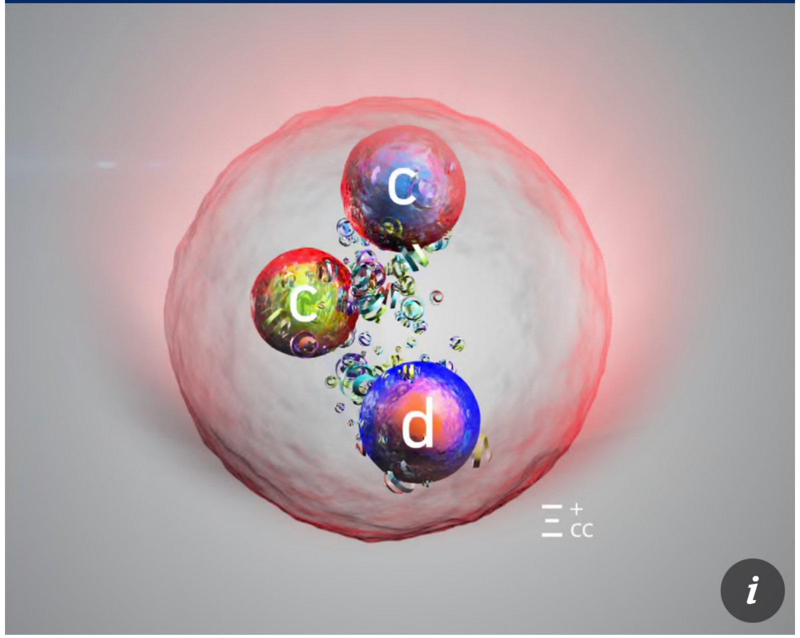
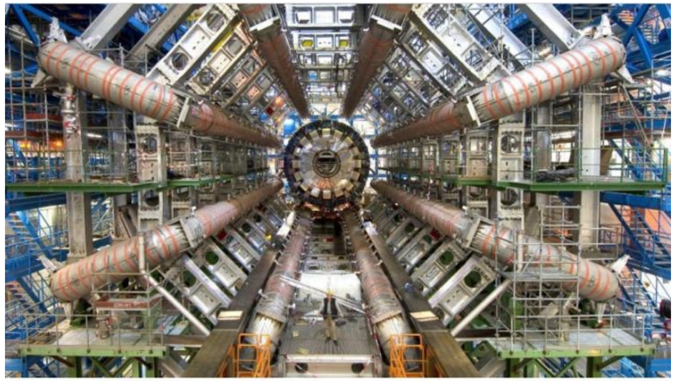


Particle physics

Scientists discover heavier version of proton with upgraded detector

THE TIMES
THE SUNDAY TIMES



The Xi-cc-plus was found using the Large Hadron Collider at Cern near Geneva, which has recently been upgraded
PA

‘Doubly charmed’ subatomic particle discovered at Cern

The finding of a previously unknown heavy type of proton could unlock the mystery of how all atomic nuclei are bound together

Kaya Burgess, Science Correspondent
Tuesday March 17 2026, 3.51pm, The Times

A entirely new subatomic particle has been discovered by a team including British researchers at Cern, the nuclear research laboratory, that could help scientists understand the force that binds

Part III
Rare decays

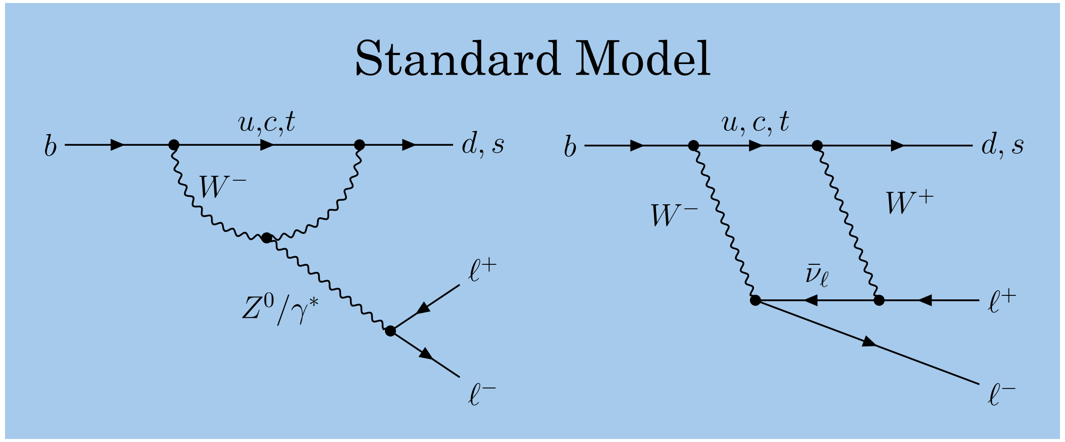
Probing new physics with rare beauty decays

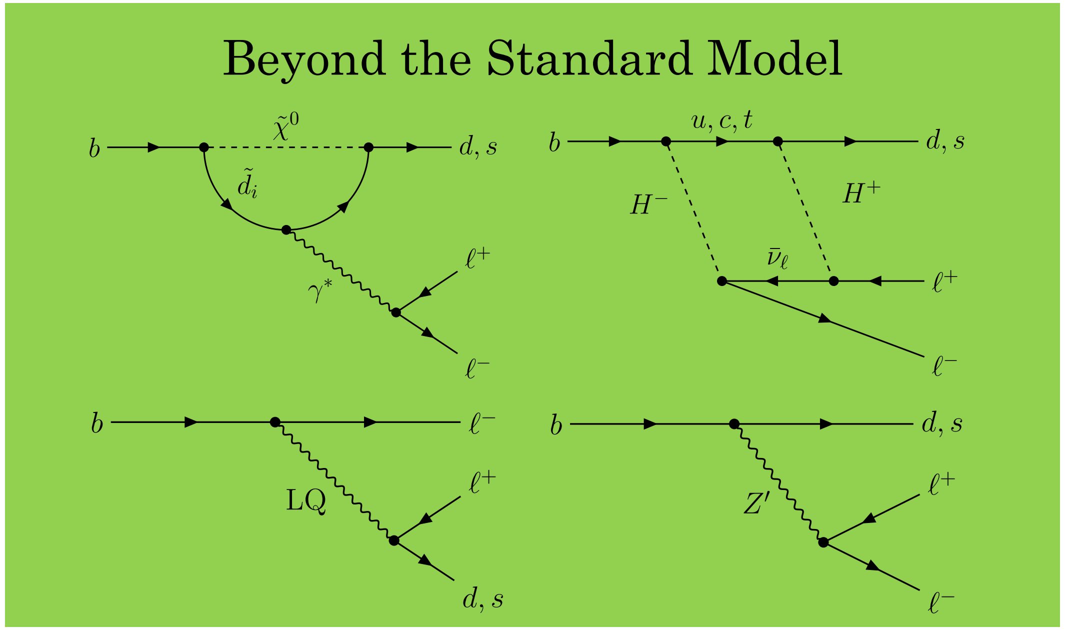
Flavour changing neutral currents (FCNC)

- Forbidden at tree level in SM
- Highly supressed with branching fractions below 10^{-6} → **rare**
- Wide range of different fundamental processes including $b \to s\ell^+\ell^-$, $b\bar{s} \to \ell^+\ell^-$, $b \to d\ell^+\ell^-$ and $b \to s\gamma$

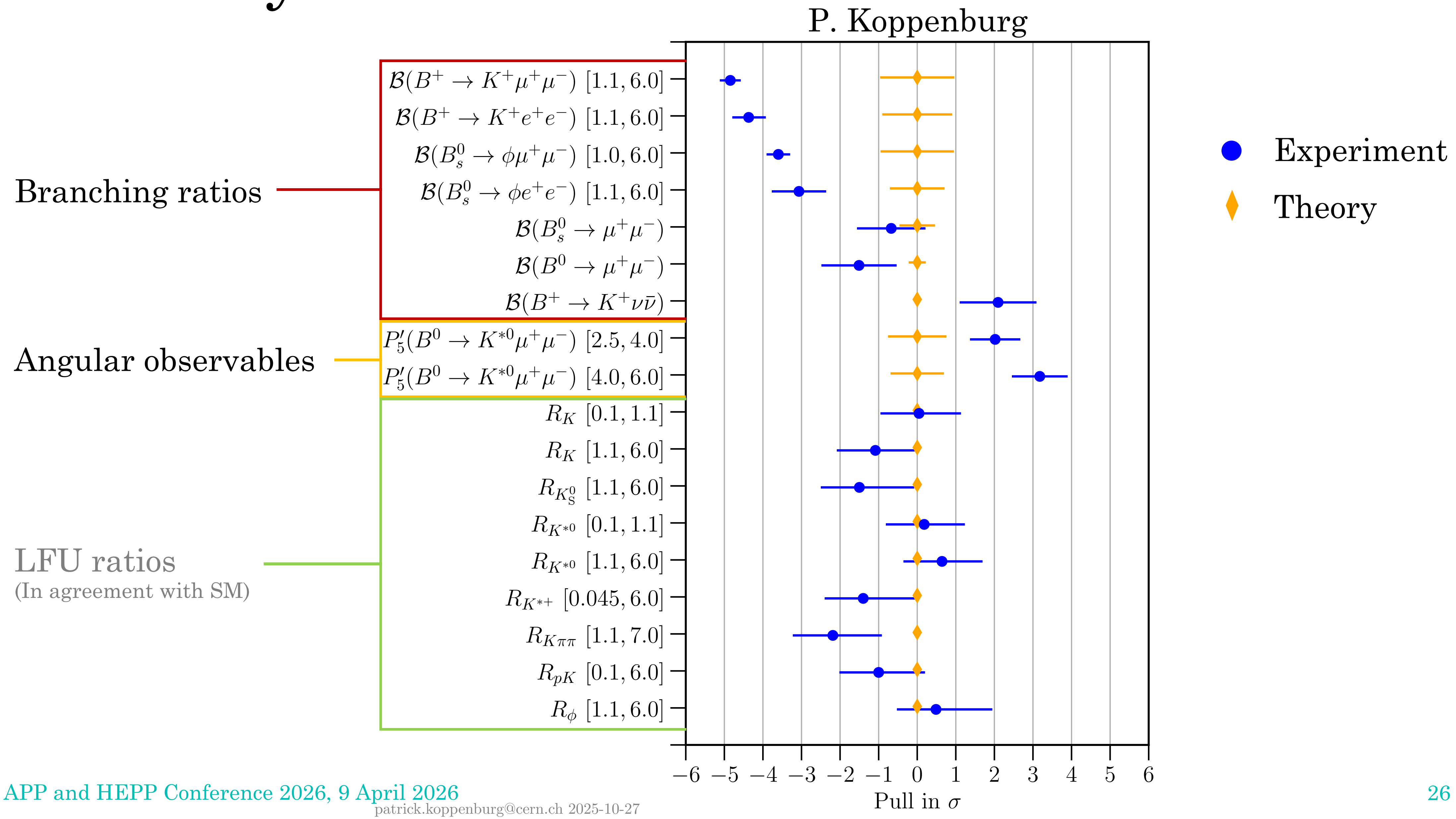
Highly sensitive to new particles

- Sensitive to broad spectrum of BSM contributions interfering with SM amplitudes
- Probes energy scales up to 100 TeV





Rare b-decay anomalies



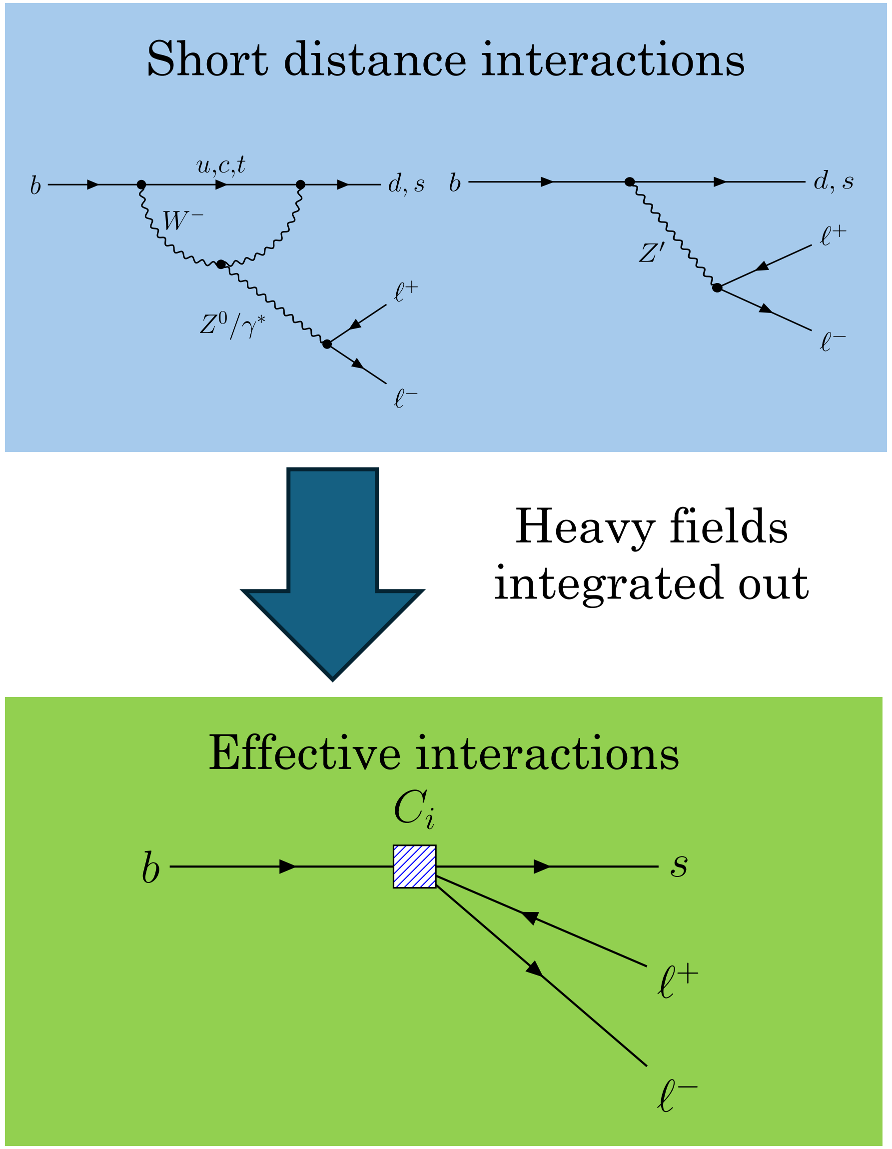
Theoretical interpretation

FCNC transitions described using **effective field theory**

- Zoom out to b-quark scale ~4.8 GeV
- Integrate out short-distance interactions – encoded in **Wilson coefficients C_i** multiplying **local operators $\mathcal{O}_i$**

Effective Hamiltonian:

$$H_{eff} \; - \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^{*} \sum_{i} C_i \mathcal{O}_i$$



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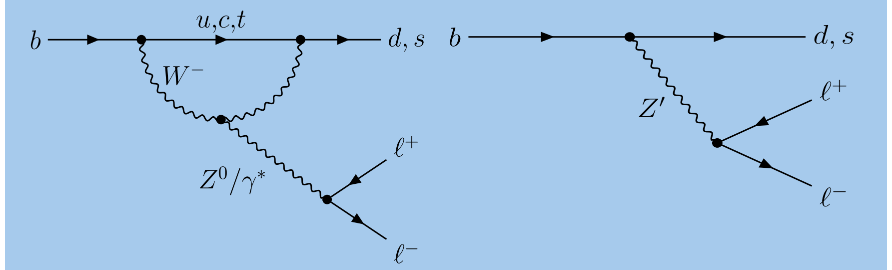
Effective Hamiltonian:

$$H_{eff} - \frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_i C_i \mathcal{O}_i$$

New physics would appear as shifts in Wilson coefficients

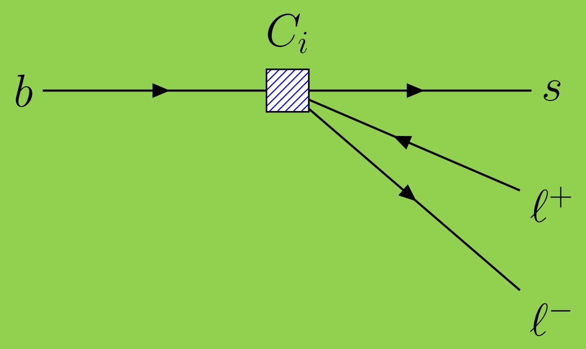
$$C_i \rightarrow C_i + \Delta C_i^{NP}$$

Short distance interactions



Heavy fields integrated out

Effective interactions



Global fits

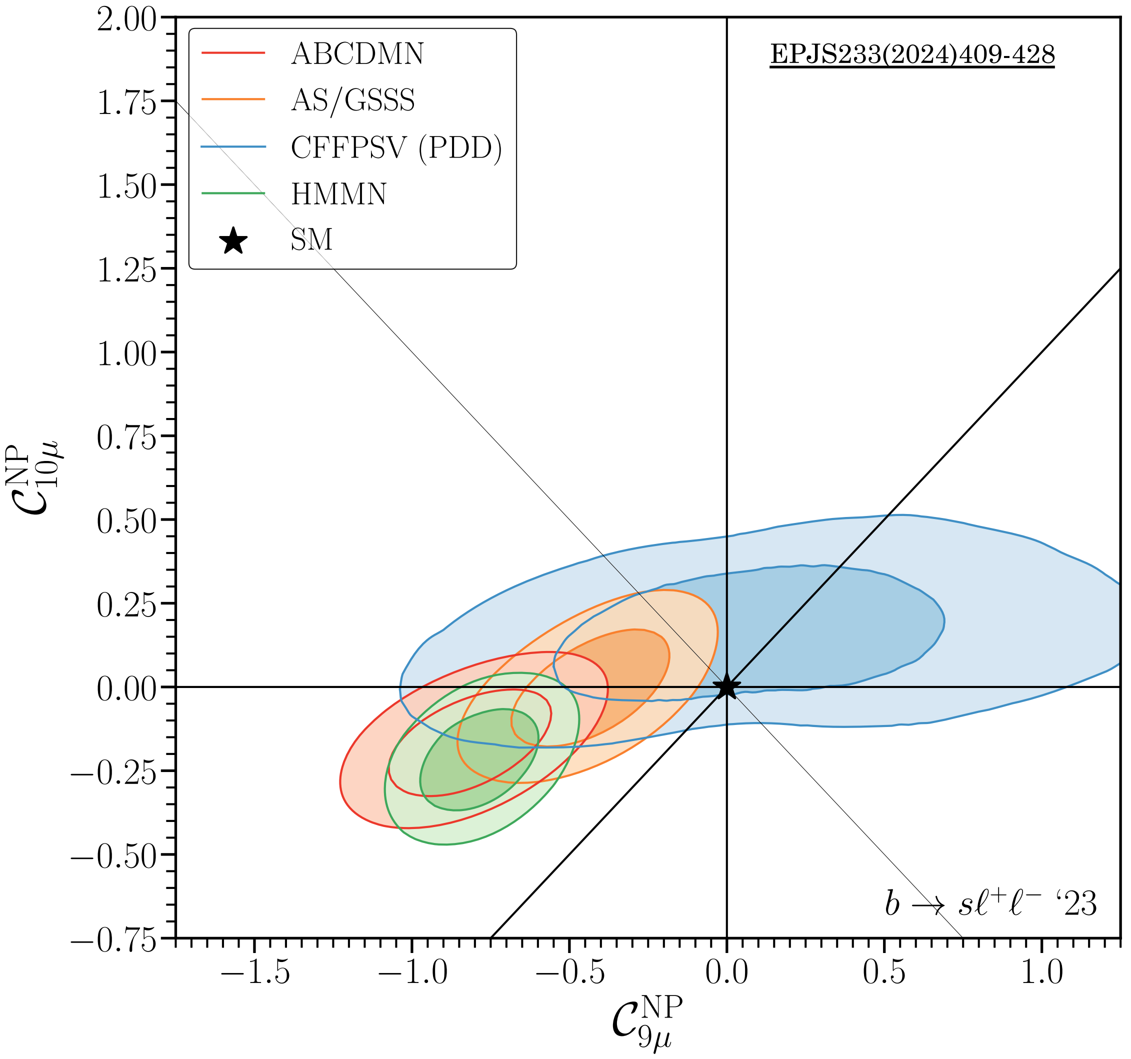
Fits to a range of FCNC observables performed to determine shifts in Wilson coefficients, especially:

C_9 – electroweak vector penguin

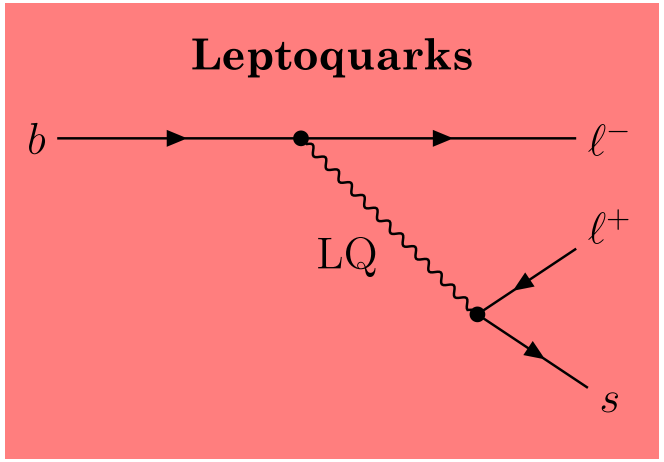
C_{10} – electroweak axial-vector penguin

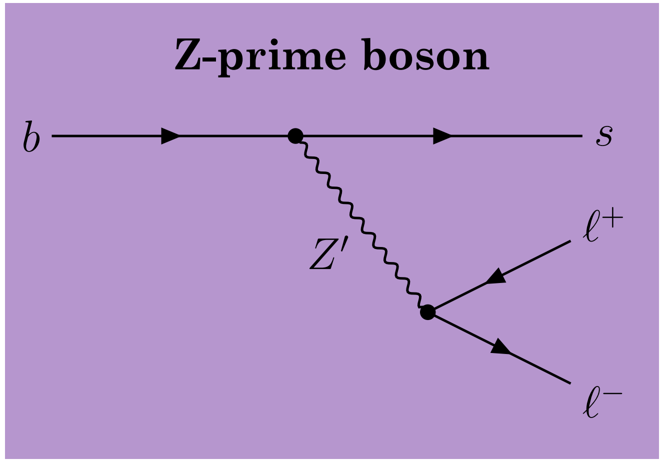
A flavour universal shift in C_9 can explain the observed tensions.

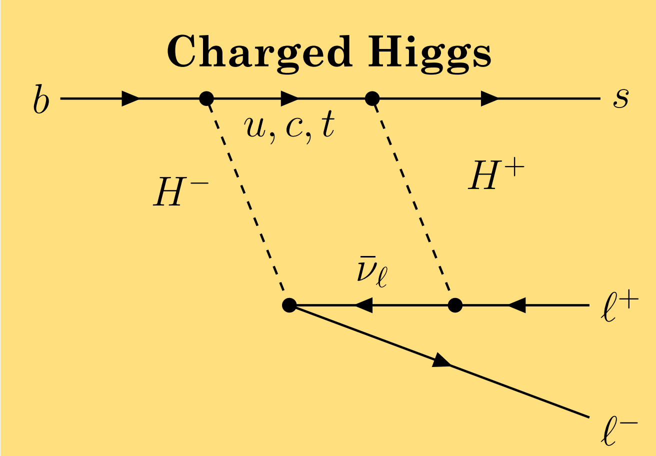
Combining multiple measurements tension with SM reaches 5.8σ–6.3σ



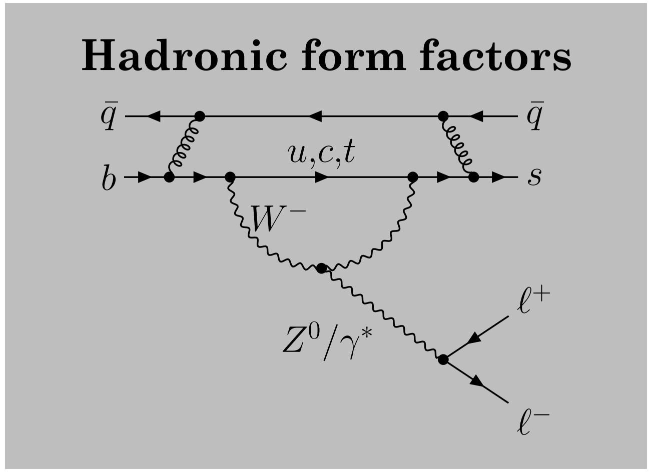
New physics...?

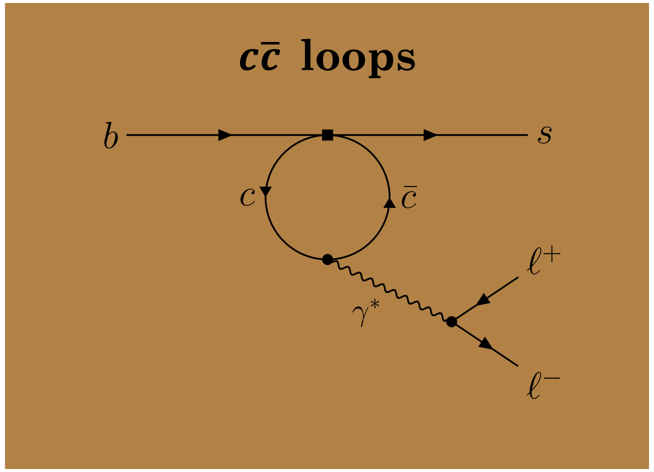




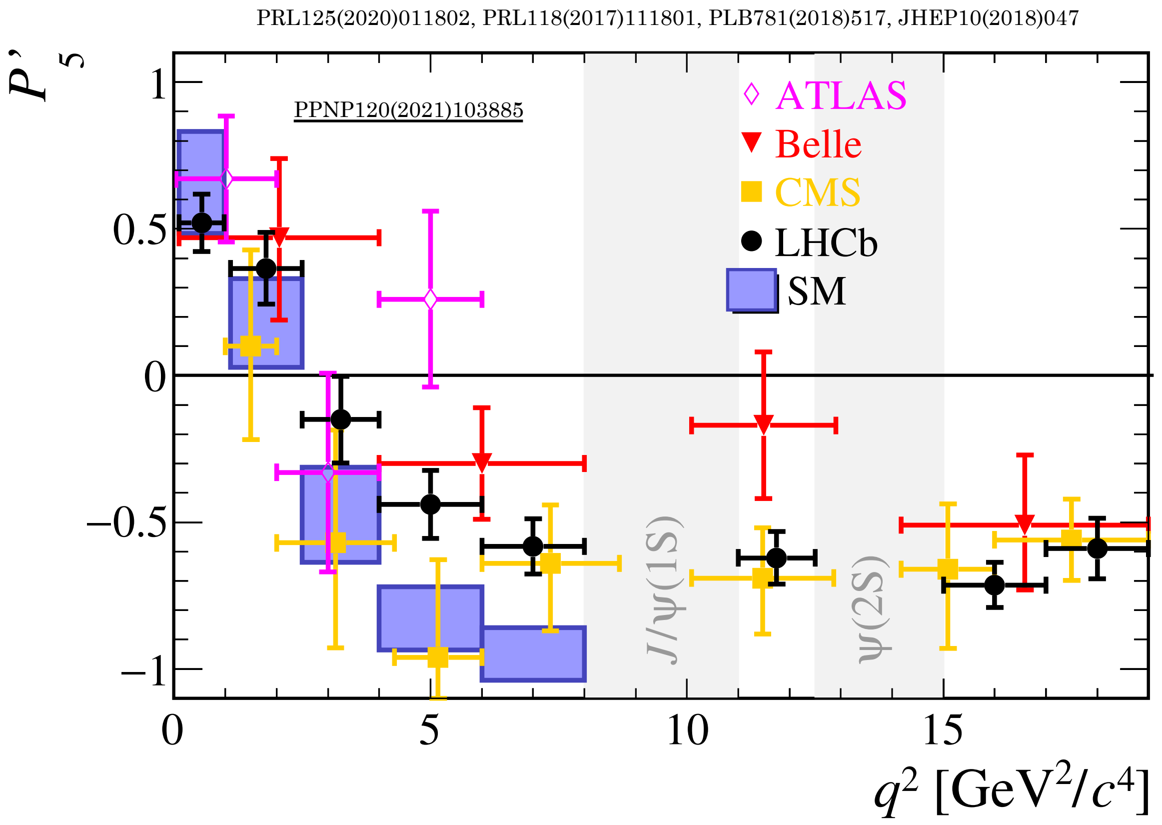


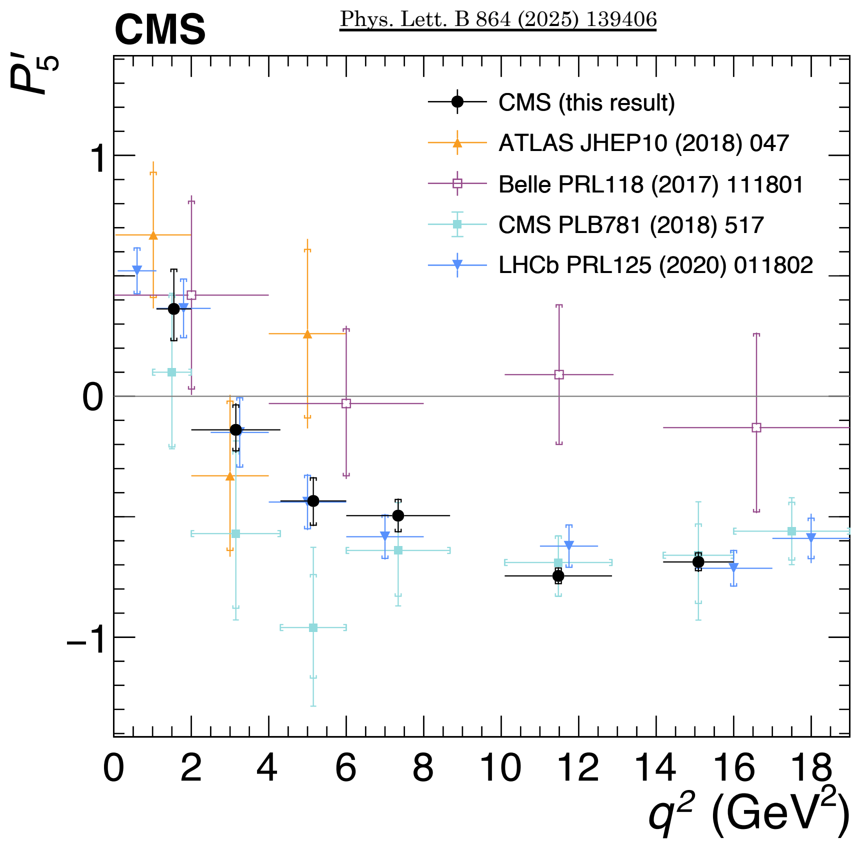
...or quarks and gluons?



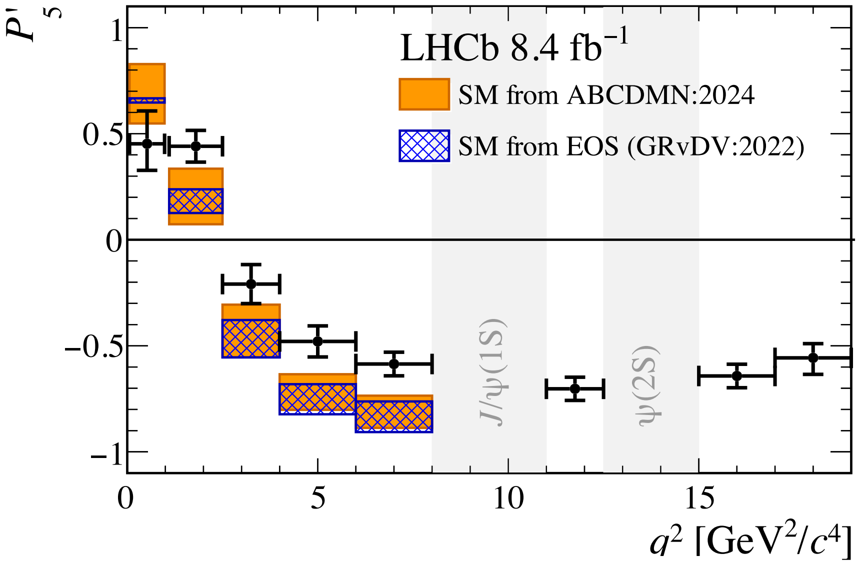


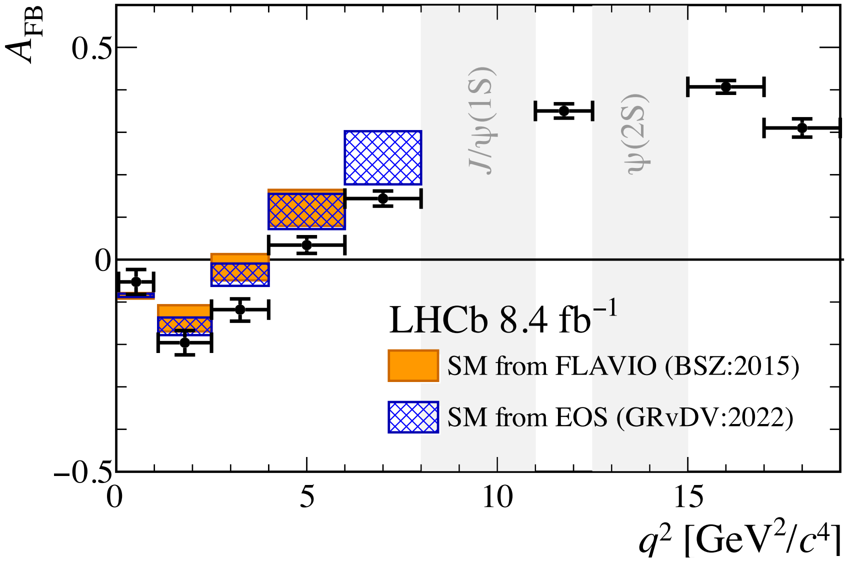
Angular analyses of $b \to s\ell^+\ell^-$





Angular analyses of $b \to s\ell^+\ell^-$





LHCB-PAPER-2025-041

Persistent tensions with SM in angular coefficients:

P'_5: (2.1–2.7)σ

A_{FB}: (1.7–2.5)σ

depending on q^2 region and SM predictions used

Global tension

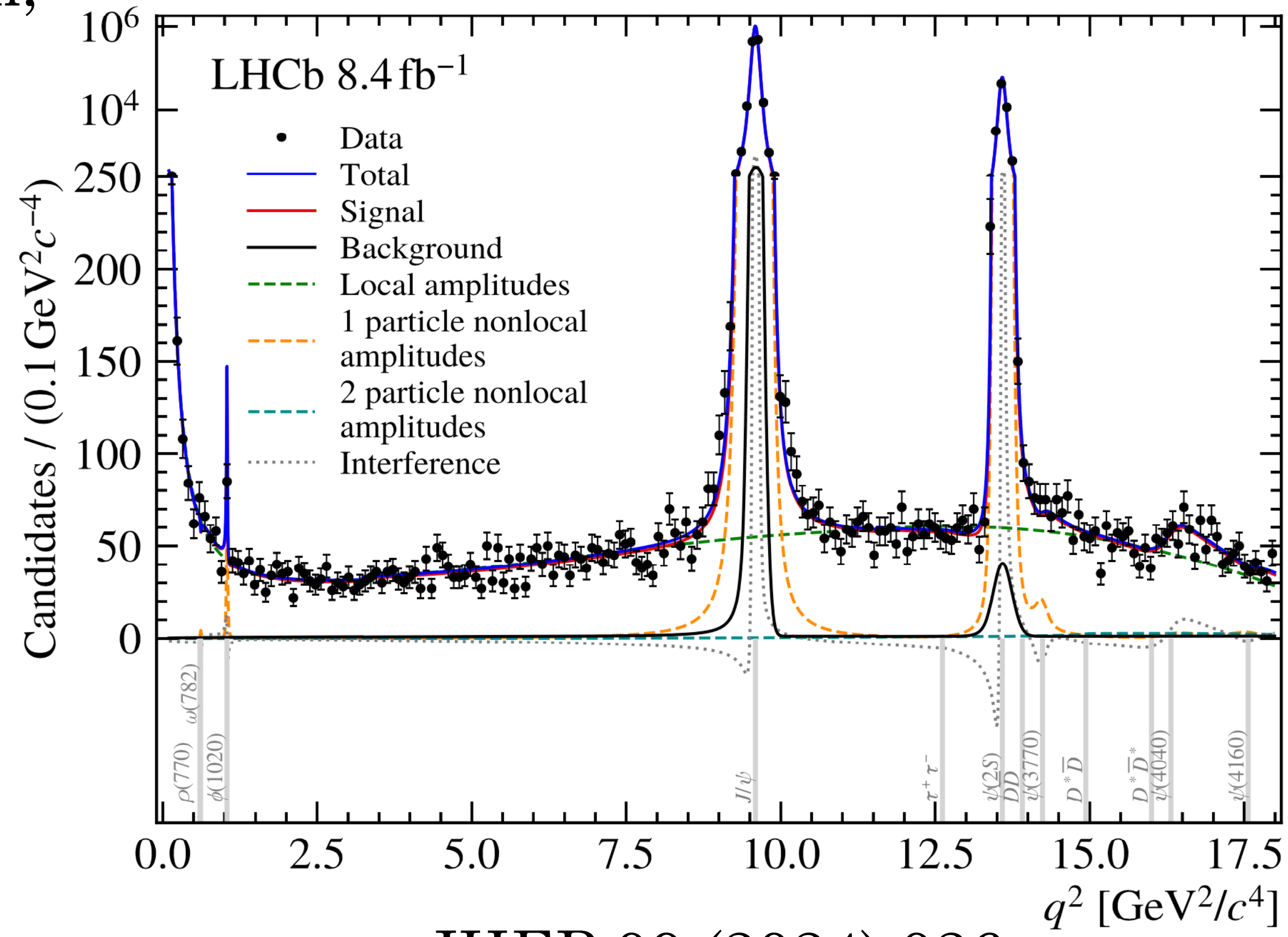
(3.6–3.8)σ

floating Re(C9).

Non-local effects from $B^0 \to K^{*0}\mu^+\mu^-$ data

Fit to entire q² and angular spectrum, including local and non-local effects and interference:

- ✓ $c\bar{c}$ loops
- ✓ light hadronic resonances
- ✓ $D^{(*)}\overline{D}^{(*)}$ loops
- ✓ $\tau^+\tau^-$ loops



JHEP 09 (2024) 026

Non-local effects from $B^0 \to K^{*0}\mu^+\mu^-$ data

Fit to entire q^2 and angular spectrum, including local and non-local effects and interference:

✓ $c\bar{c}$ loops

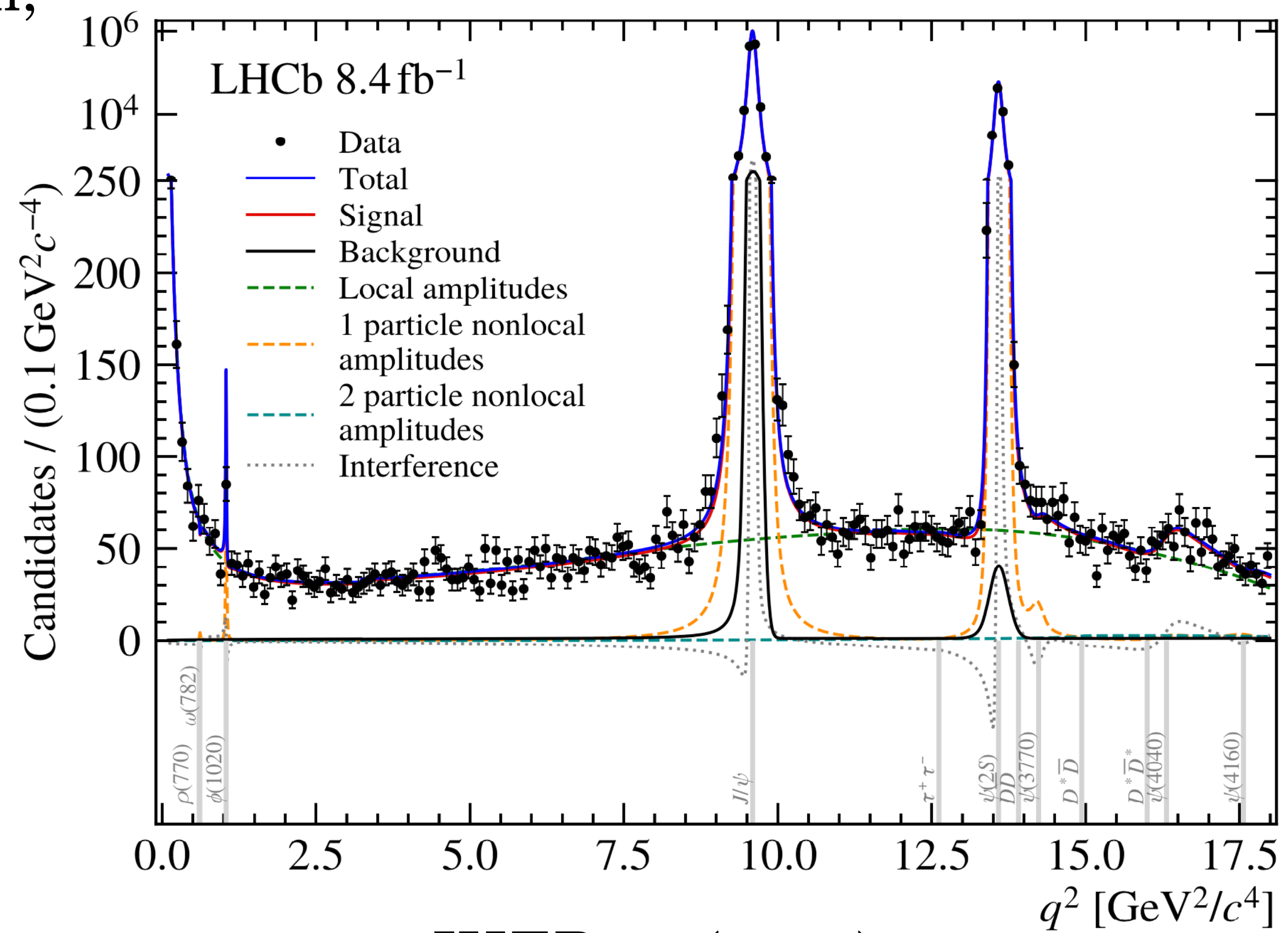
✓ light hadronic resonances

✓ $D^{(*)}\overline{D}^{(*)}$ loops

✓ $\tau^+\tau^-$ loops

Tension persists in fit for Wilson coefficients at 2.1σ in C_9.

Non-local effects cannot account entirely for tension with SM.



JHEP 09 (2024) 026

Non-local effects from $B^+ \to K^+\mu^+\mu^-$ data

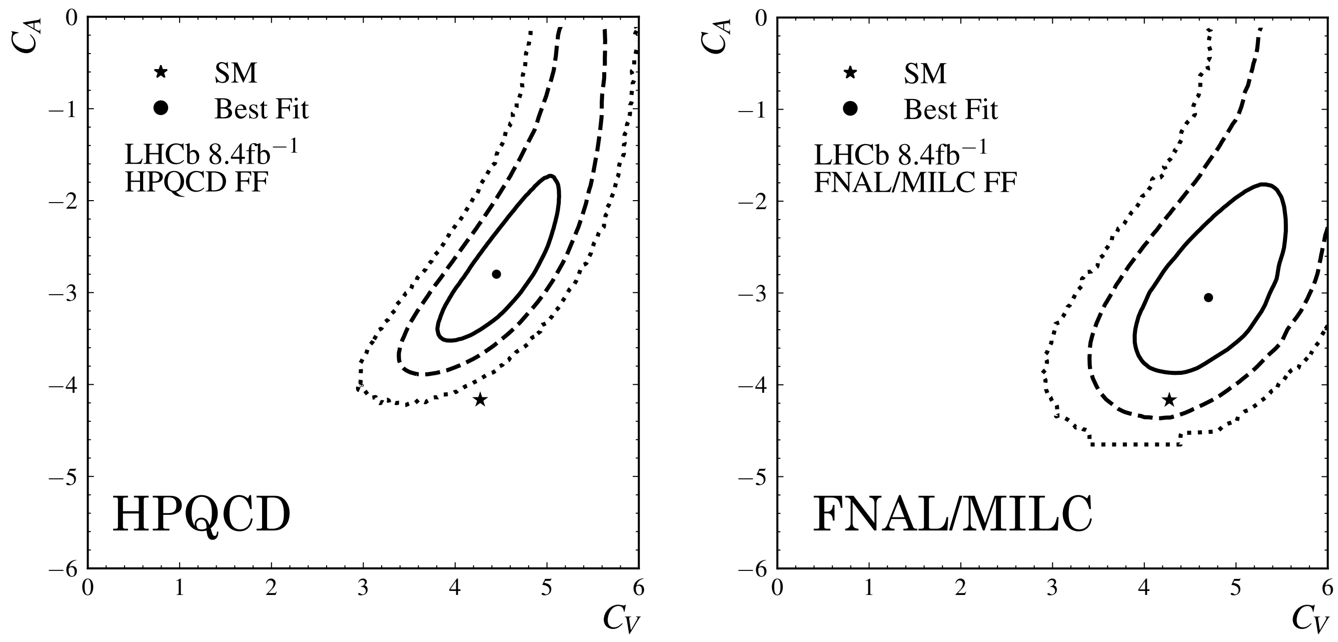
Fit to the dimuon mass spectrum, floating one- and two-particle non-local contributions.

Hadronic form factors from theory.

HOT OFF THE PRESS!

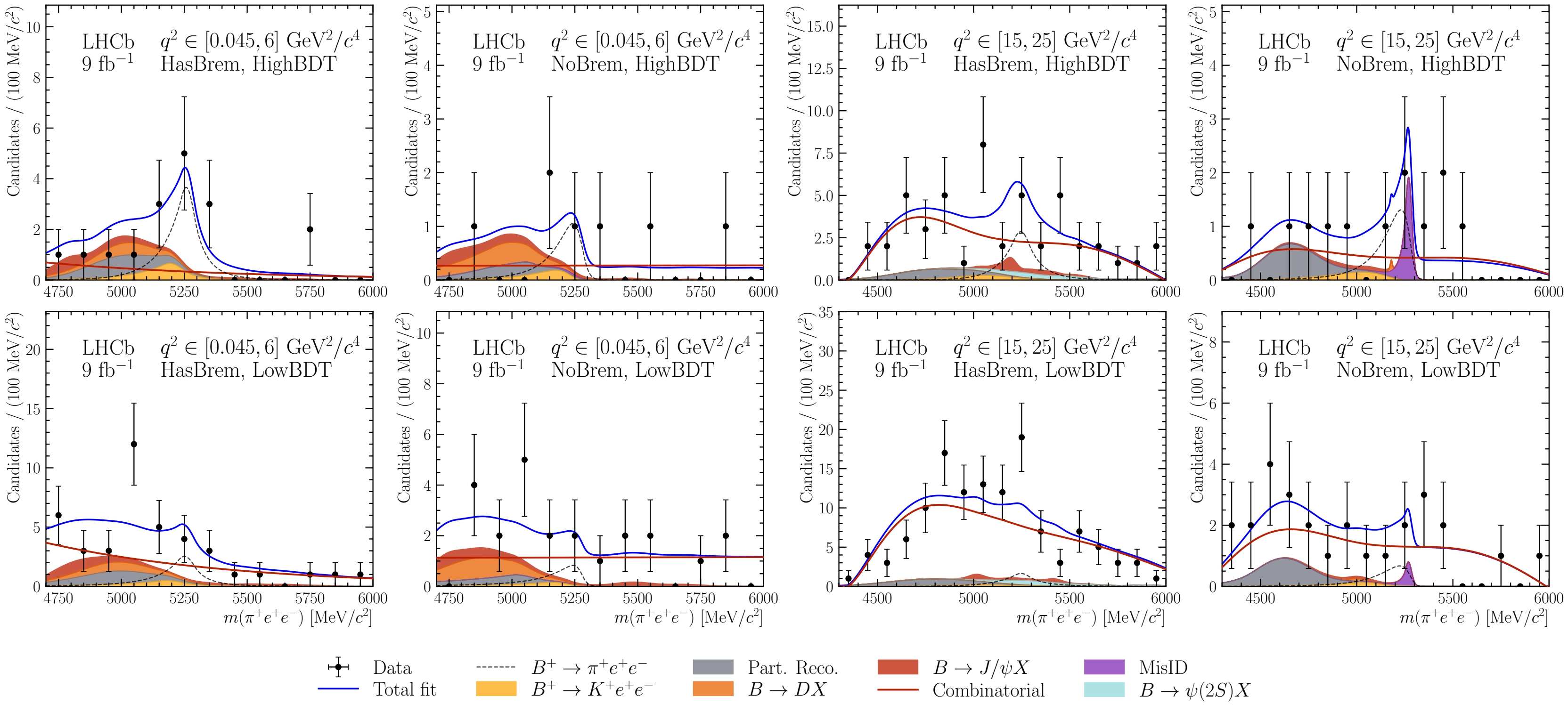
Tension depends on theory input:

- **HPQCD: 4σ**
- **FNAL/MILC: 1.6σ**



LHCb-PAPER-2025-055

Search for $B^+ \to \pi^+ e^+ e^-$



EVEN HOTTER OFF THE PRESS!

First evidence for a $b \to de^+e^-$ decay at 3.2σ

$$\mathcal{B}(B^+ \to \pi^+e^+e^-) = (2.4^{+0.9}_{-0.8}{}^{+0.4}_{-0.2})\times 10^{-8}$$

Consistent with SM and Lepton-Flavour Universality.

Part IV
Charmless B decays

$B^0_{(s)} \to K^{*0}\overline{K}^{*0}$ decays

$B^0 \to K^{*0}\overline{K}^{*0}$ and $B^0_s \to K^{*0}\overline{K}^{*0}$ decays proceed via $b \to ds\bar{s}$ and $b \to sd\bar{d}$ gluonic loop transitions.

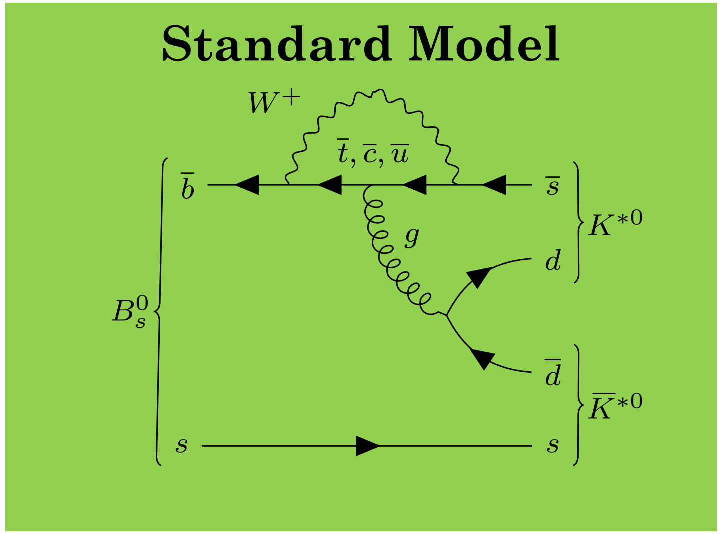
Highly suppressed → sensitive to NP. The quantity:

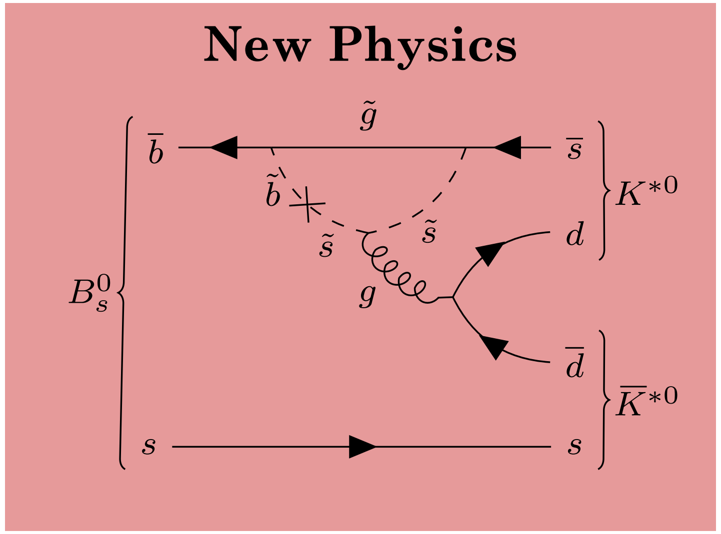
$$L_{K^{*0}\overline{K}^{*0}} = \mathcal{G}\,\frac{\mathcal{B}(B^0_s \to K^{*0}\overline{K}^{*0})}{\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0})}\,\frac{f^s_L}{f^d_L}$$

Is of interest - hadronic uncertainties largely cancel. Previous measurements by LHCb show tension with theory:

LHCb: $L_{K^{*0}\overline{K}^{*0}} = 4.43 \pm 0.92$ JHEP 04 (2021) 066

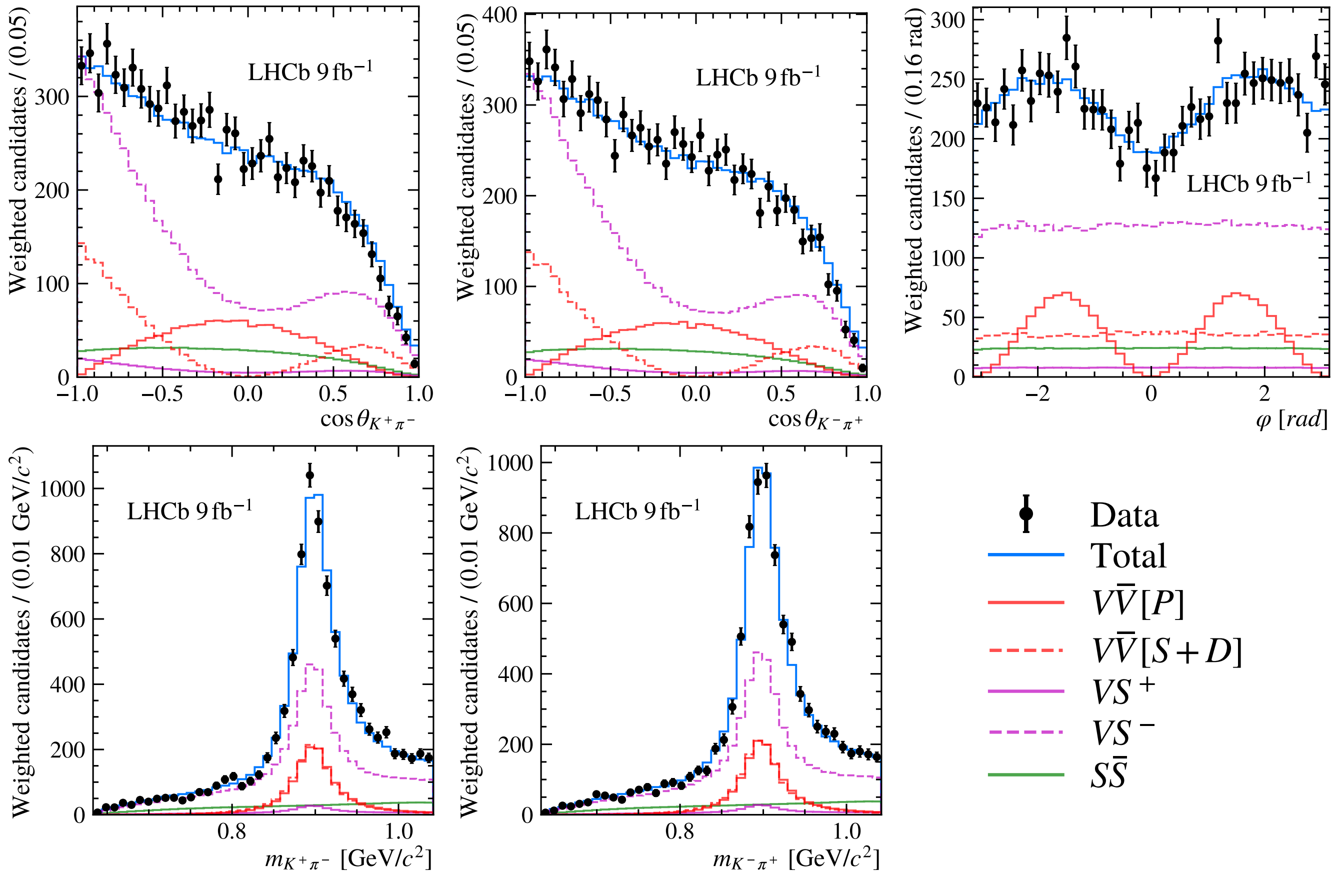
Theory: $L_{K^{*0}\overline{K}^{*0}} = 18.34^{+7.47}_{-5.83}$ or $26.08^{+5.70}_{-4.72}$ JHEP 09 (2025) 188





New measurements of $B^0_{(s)} \to K^{*0}\overline{K}^{*0}$ decays

New time and flavour-integrated amplitude analysis to determine longitudinal polarisation fractions and branching fractions, using 9 fb^{-1} Run 1+2 data.



This result:

$$L_{K^{*0}\overline{K}^{*0}} = 4.92 \pm 0.55\,(\text{stat}) \pm 0.47\,(\text{syst}) \pm 0.02\,(\text{ext}) \pm 0.10\,(f_s/f_d)$$

Tension confirmed at 4.4σ

LHCb-PAPER-2025-046

LHCb Upgrade II

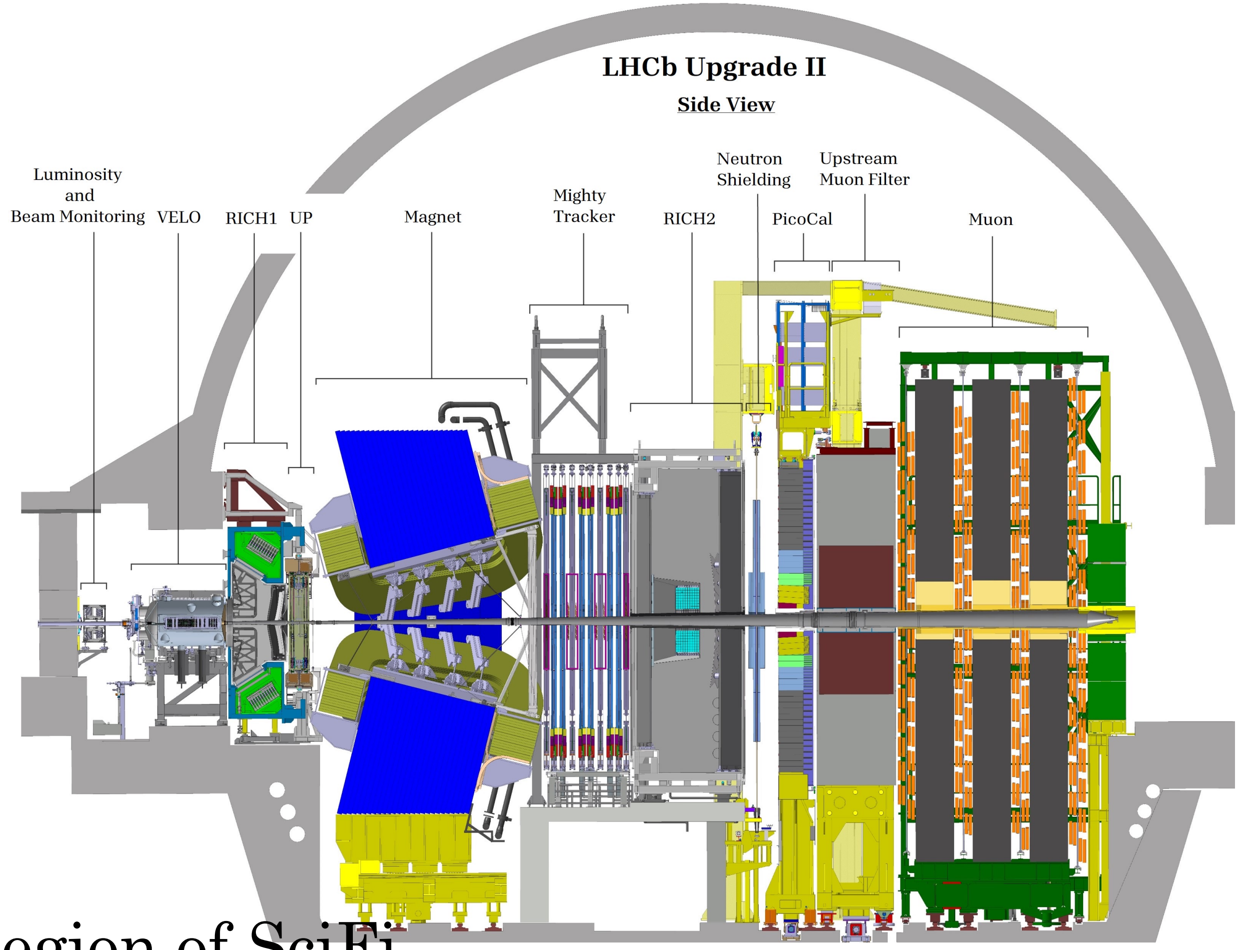
LHCb Upgrade II

For more see talk by Silvia tomorrow.

Detector for the HL-LHC era

Most physics statistically rather than systematically or theoretically limited→ motivates high luminosity experiment.

Aim to record 300fb^{-1} by end of HL-LHC.



Global changes:

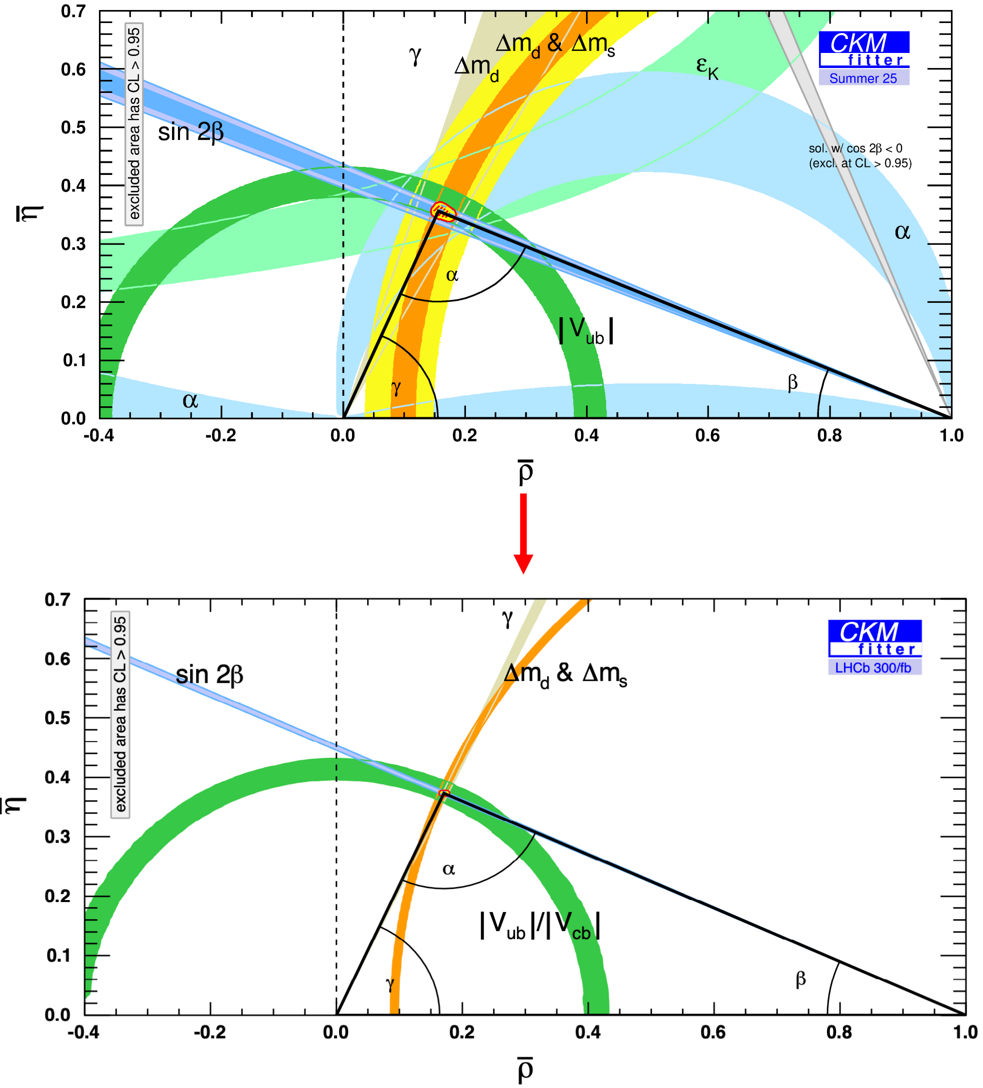
- Fast timing to reduce backgrounds
- Radiation hardness
- New silicon tracker to replace central region of SciFi
- Removal of HCAL,

LHCb Upgrade II

Targeting huge improvements in precision on key flavour observables

Observable	Current LHCb (up to $9\,\text{fb}^{-1}$)		Upgrade I ($23\,\text{fb}^{-1}$)	Upgrade I ($50\,\text{fb}^{-1}$)	Upgrade II ($300\,\text{fb}^{-1}$)
CKM tests					
γ ($B \to DK$, *etc.*)	2.8°	[20, 21]	1.3°	0.8°	0.3°
ϕ_s ($B_s^0 \to J/\psi\phi$)	20 mrad	[24]	12 mrad	8 mrad	3 mrad
$\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ ($\Lambda_b^0 \to p\mu^-\overline{\nu}_\mu$, *etc.*)	6%	[56, 57]	3%	2%	1%
Charm					
ΔA_{CP} ($D^0 \to K^+K^-, \pi^+\pi^-$)	29×10^{-5}	[27]	13×10^{-5}	8×10^{-5}	3.3×10^{-5}
A_Γ ($D^0 \to K^+K^-, \pi^+\pi^-$)	11×10^{-5}	[31]	5×10^{-5}	3.2×10^{-5}	1.2×10^{-5}
Δx ($D^0 \to K_S^0\pi^+\pi^-$)	18×10^{-5}	[58]	6.3×10^{-5}	4.1×10^{-5}	1.6×10^{-5}
Rare decays					
$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	69%	[32, 33]	41%	27%	11%
$S_{\mu\mu}$ ($B_s^0 \to \mu^+\mu^-$)	—		—	—	0.2
$A_{\mathrm{T}}^{(2)}$ ($B^0 \to K^{*0}e^+e^-$)	0.10	[59]	0.060	0.043	0.016
$S_{\phi\gamma}(B_s^0 \to \phi\gamma)$	0.32	[60]	0.093	0.062	0.025
$\alpha_\gamma(\Lambda_b^0 \to \Lambda\gamma)$	$^{+0.17}_{-0.29}$	[61]	0.148	0.097	0.038

LHCb-TDR-026



LHCb Upgrade II

Targeting huge improvements in precision on key flavour observables

Experiment Assumed data sample	ATLAS $3000\,\text{fb}^{-1}$	CMS $3000\,\text{fb}^{-1}$	LHCb $300\,\text{fb}^{-1}$	Belle II $50\,\text{ab}^{-1}$
CKM angles				
β	—	—	0.08°	0.3°
α	—	—	—	0.6°
γ	—	—	0.3°	1.0°
ϕ_s [mrad]	$(4 - 9)$	3	3	—
***CP* violation in loop-dominated decays**				
$S(B^0 \to \eta' K^0_\text{S})$	—	—	—	0.015
$\phi_s(B^0_s \to \phi\phi)$ [mrad]	—	—	9	—
$\phi_s(B^0_s \to K^{*0}\overline{K}^{*0})$ [mrad]	—	—	8	—
***CP* violation in $B^0_{(s)}$–$\overline{B}^0_{(s)}$ mixing**				
a^s_sl	—	—	3	—
a^d_sl	—	—	2	6.2
***CP* violation in the charm sector**				
ΔA_{CP} $[10^{-5}]$	—	—	3.3	60
$A_{CP}(D^{+,0} \to \pi^{+,0}\pi^0)$ $[10^{-5}]$	—	—	100, —	130, 70
$A_\Gamma(KK, \pi\pi)$ $[10^{-5}]$	—	—	1.2	—
$\Delta x(D^0 \to K^0_\text{S}\pi^+\pi^-)$ $[10^{-5}]$	—	—	1.6	40
Semileptonic *B* decays				
$\lvert V_{ub}\rvert$	—	—	1%	1.2%
$\lvert V_{cb}\rvert$	—	—	—	1.0%
$R(D)$, $R(D^*)$	—	—	3.3%, 3.0%	1.4%, 1.0%

Experiment Assumed data sample	ATLAS $3000\,\text{fb}^{-1}$	CMS $3000\,\text{fb}^{-1}$	LHCb $300\,\text{fb}^{-1}$	Belle II $50\,\text{ab}^{-1}$
Leptonic *B* decays				
$\mathcal{B}(B^0_s \to \mu^+\mu^-)$ $[10^{-9}]$	$(0.33 - 0.40)$	0.22	0.16	—
$\mathcal{B}(B^0 \to \mu^+\mu^-)$ $[10^{-10}]$	$(0.32 - 0.48)$	0.12	0.12	—
$\tau_\text{eff}(B^0_s \to \mu^+\mu^-)$ [ps]	$^{+(0.07-0.11)}_{-(0.05-0.08)}$	0.05	0.05	—
$S(B^0_s \to \mu^+\mu^-)$	—	—	0.2	—
$\mathcal{B}(B^+ \to \tau^+\nu_\tau)$	—	—	—	6%
$\mathcal{B}(B^+ \to \mu^+\nu_\mu)$	—	—	—	5%
Flavour-changing neutral current $b \to s\ell\ell$ decays				
$P'_5(B^0 \to K^{*0}\mu^+\mu^-)$ $[10^{-3}]$ †	$(47 - 82)$	23	12	—
$\mathcal{B}(B^{+,0} \to K^{+,*0}\nu\overline{\nu})$	—	—	—	8%, 23%
$\mathcal{B}(B^{+,0} \to K^{+,*0}\tau^+\tau^-)$ $[10^{-4}]$	—	—	—	< 0.9, < 1.5
Flavour-changing neutral current $b \to s\gamma$ decays				
$\mathcal{B}(B \to X_s\gamma; E_\gamma > 1.6\,\text{GeV})$	—	—	—	$(4.7 - 8.8)\%$
$S(B^0 \to K^0_\text{S}\pi^0\gamma)$	—	—	—	0.04
$S(B^0_s \to \phi\gamma)$	—	—	0.025	—
$A^{(2)}_\text{T}(B^0 \to K^{*0}e^+e^-; \text{very low } q^2)$	—	—	0.016	0.08
$\alpha_\gamma(\Lambda^0_b \to \Lambda^0\gamma)$	—	—	0.038	—
Lepton flavour violation in τ decays				
$\mathcal{B}(\tau^+ \to \mu^+\gamma)$ $[10^{-8}]$	—	—	—	< 0.7
$\mathcal{B}(\tau^+ \to \mu^+\mu^+\mu^-)$ $[10^{-8}]$	$< (0.13 - 0.64)$	< 0.39	< 0.26	$< (0.02 - 0.17)$

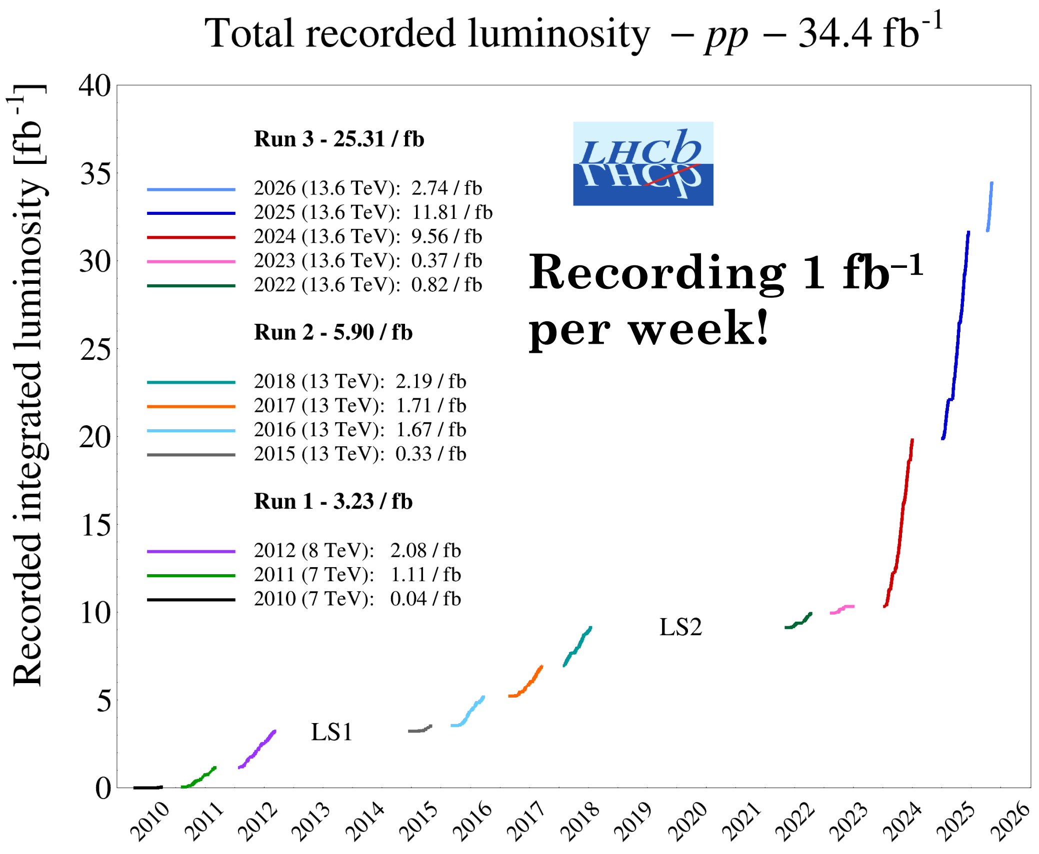
arXiv:2503.24346

Conclusions

Exciting and unique physics programme underway at LHCb:

- World-leading measurements of CP violation
- Discoveries of new exotic hadronic states
- Intriguing anomalies in suppressed beauty decays
- And much more besides that I couldn't cover: charm, electroweak, exotica, mixing

Only scratched the surface so far – collected just 10% of our target data set.



Stay tuned for many more Run 3 results in the near future

Backup

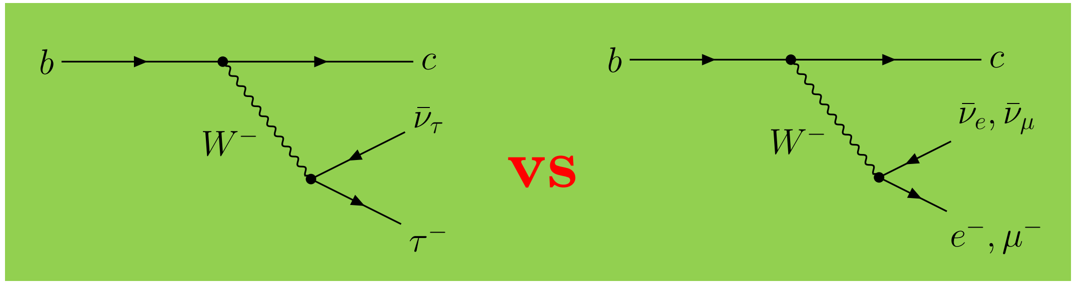
Lepton universality in charged-current decays

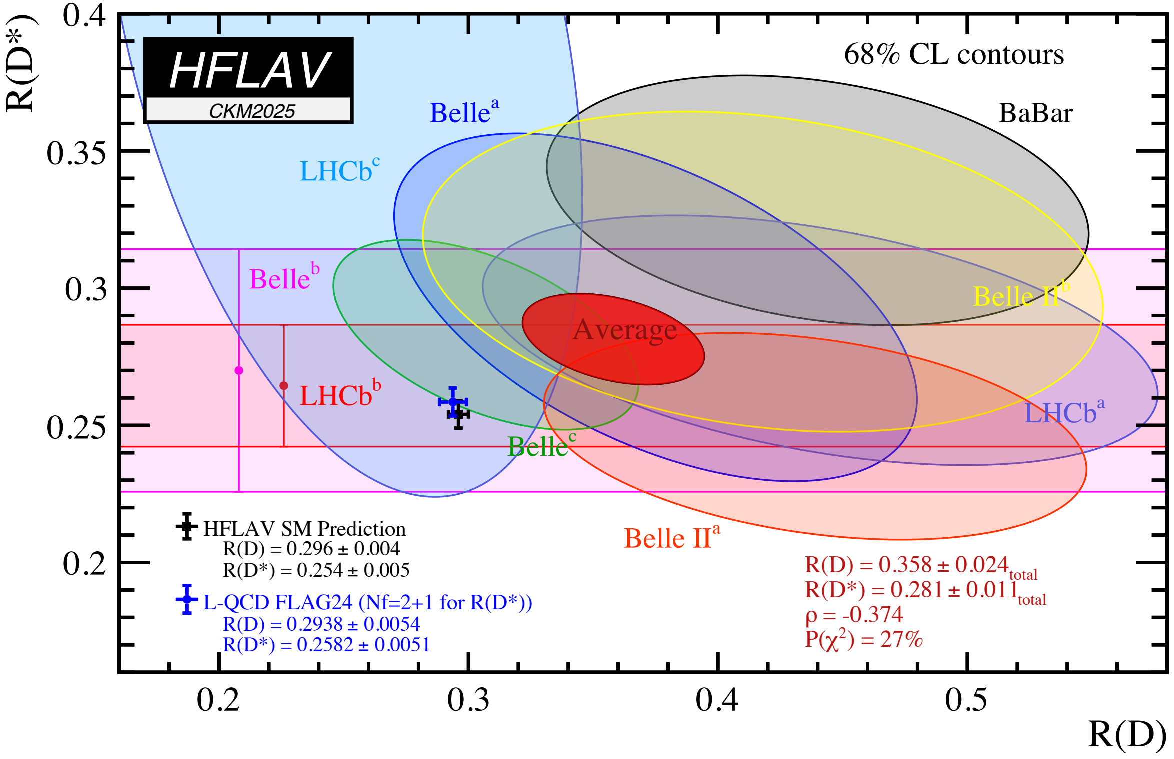
Tests of lepton universality in charged-current B decays

$$R(D) = \frac{\mathcal{B}(B \to D\,\tau\,\nu_\tau)}{\mathcal{B}(B \to D\,\ell\,\nu_\ell)}$$

$$R(D^*) = \frac{\mathcal{B}(B \to D^*\,\tau\,\nu_\tau)}{\mathcal{B}(B \to D^*\,\ell\,\nu_\ell)}$$

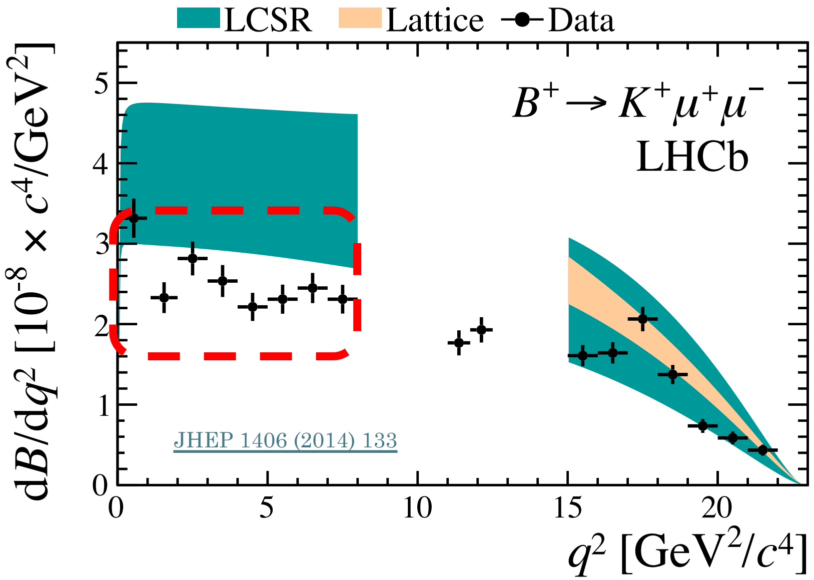
Combined tension with the arithmetic average of SM predictions at 3.8σ.

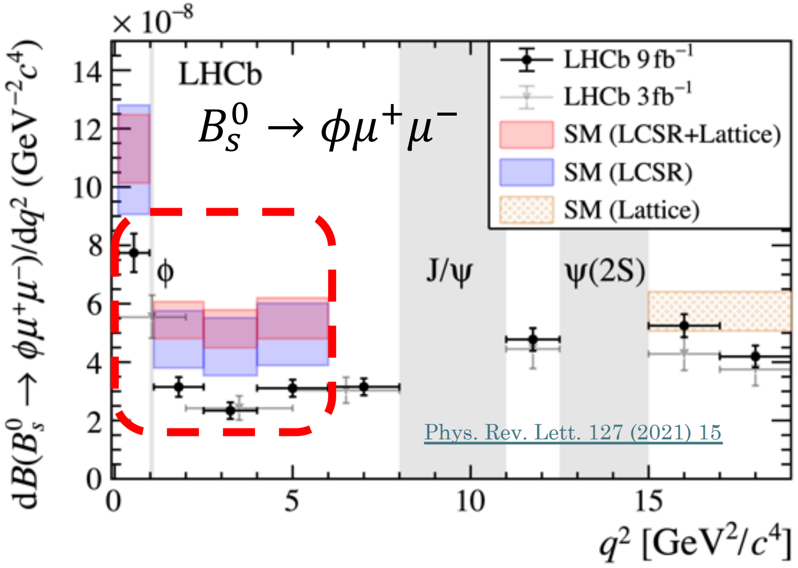


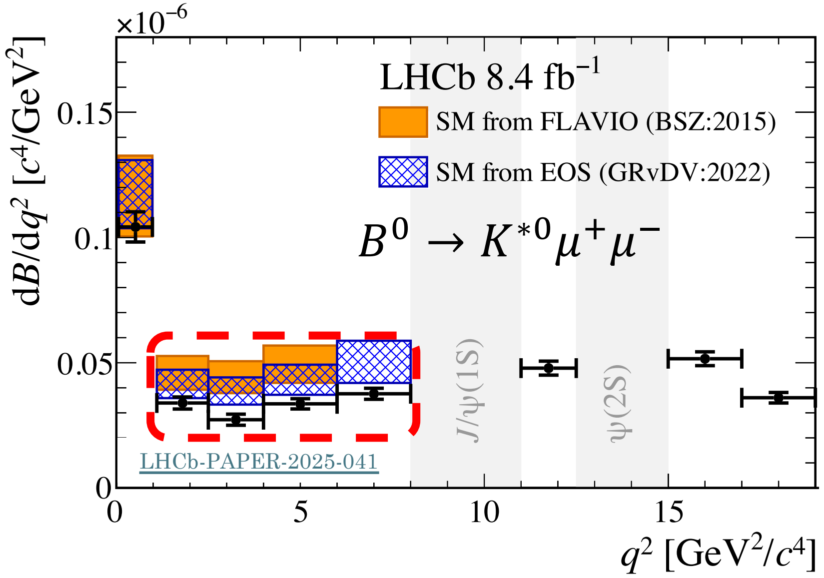


Branching ratios

Tensions with the SM in differential branching ratios of several $b \to s\mu^+\mu^-$ processes





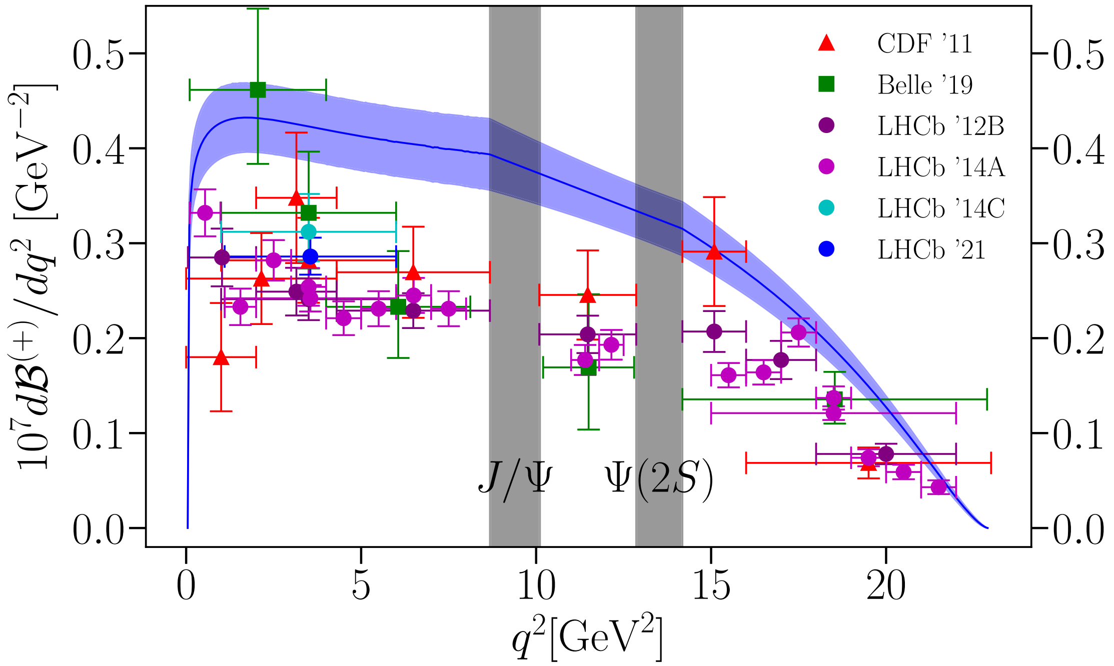


- Multiple measurements are below SM predictions at low dilepton mass squared (q^2)
- SM predictions suffer from (shrinking) **hadronic uncertainties**

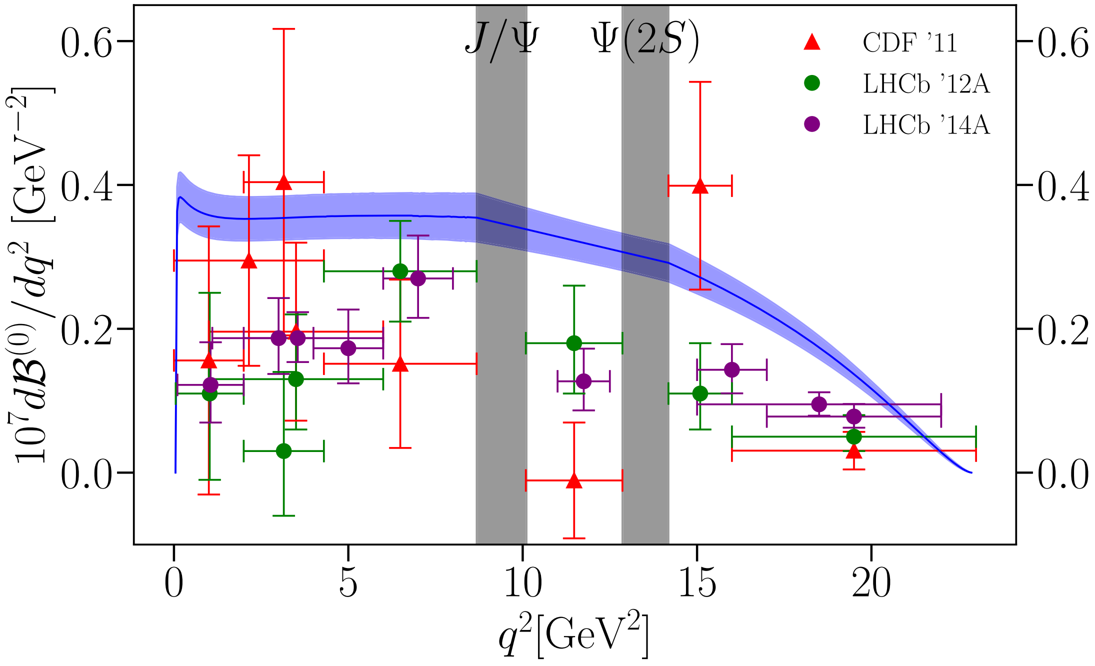
Branching ratios

HPQCD: Phys. Rev. D **107**, 014511

Improved SM predictions for $B^{(+,0)} \to K^{(+,0)}\mu^+\mu^-$ using using form factors from lattice QCD

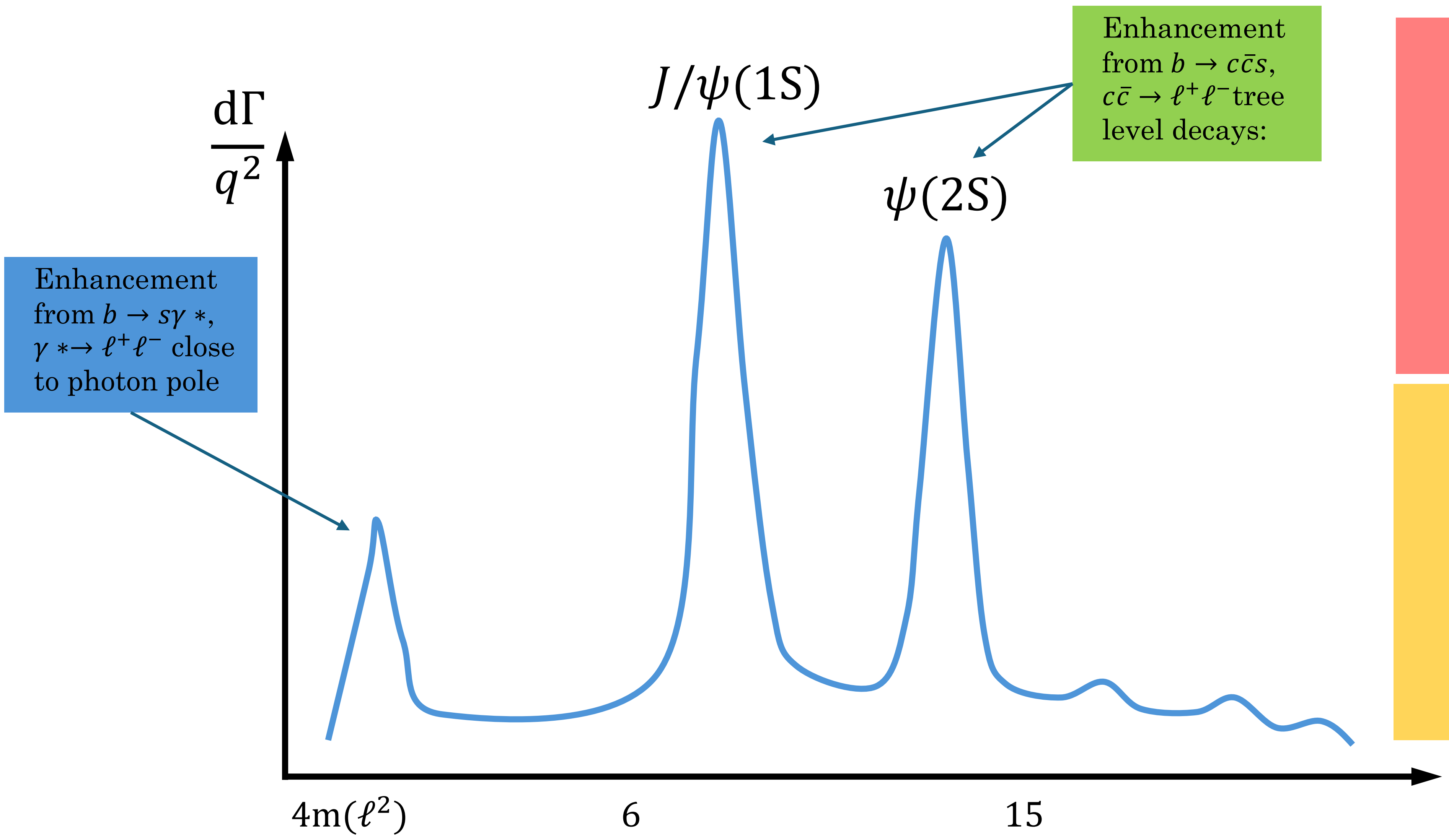


Tension at 4.7σ for $B^+ \to K^+\mu^+\mu^-$



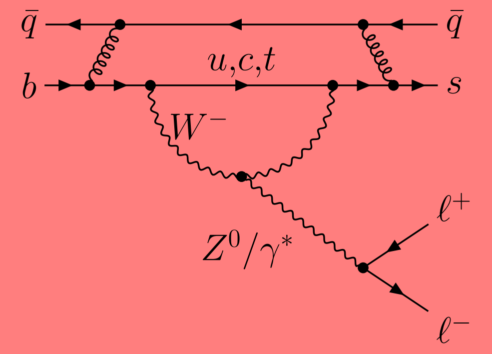
Tension at 3.6σ for $B^0 \to K^0\mu^+\mu^-$

Anatomy of $b \to s\ell^+\ell^-$ decays

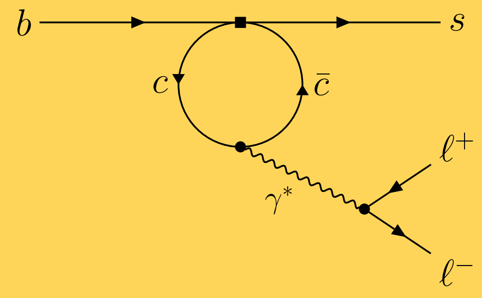


Theoretical predictions affective by hadronic uncertainties from

Hadronic form factors



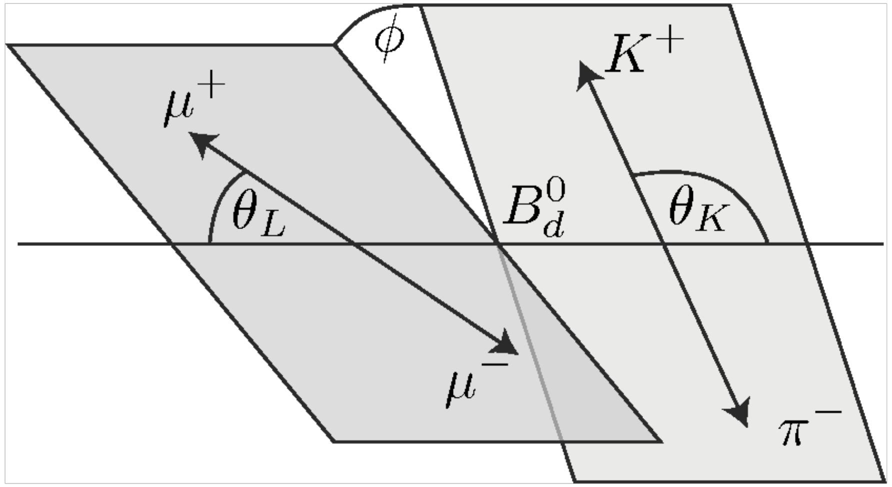
$c\bar{c}$ loops



Angular analyses of $b \to s\ell^+\ell^-$

Angular analyses of $b \to s\ell^+\ell^-$ decays provide NP sensitivity via angular coefficients

The **differential decay rate** is described in terms of the decay angles and **angular coefficients**

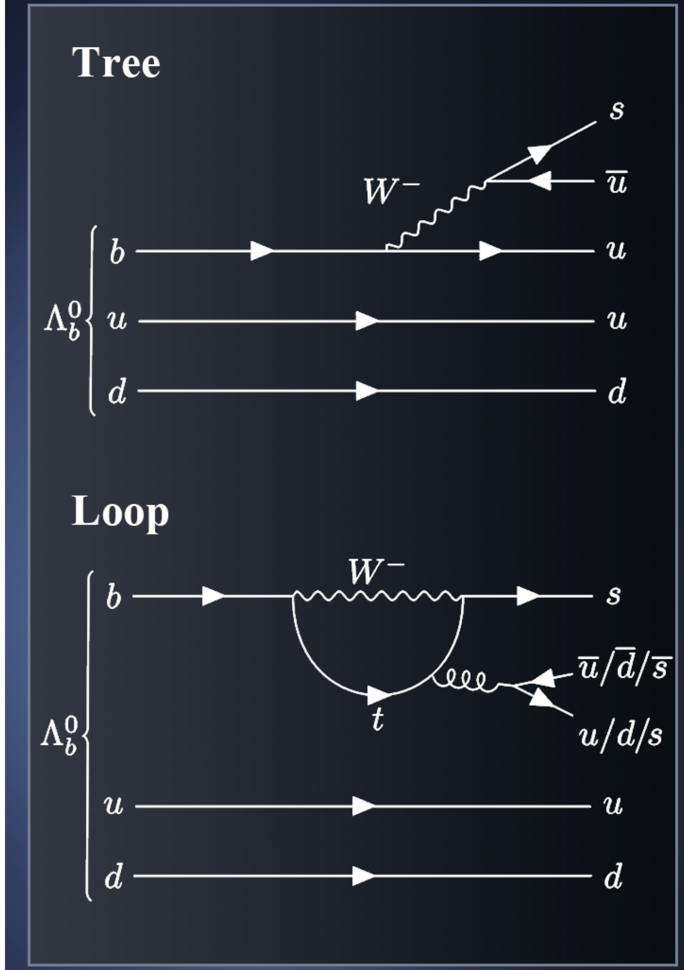


Ratios of angular coefficients are often constructed to reduce hadronic uncertainties. e.g.

$$P_5' = \frac{S_5}{\sqrt{F_L(1-F_L)}}$$

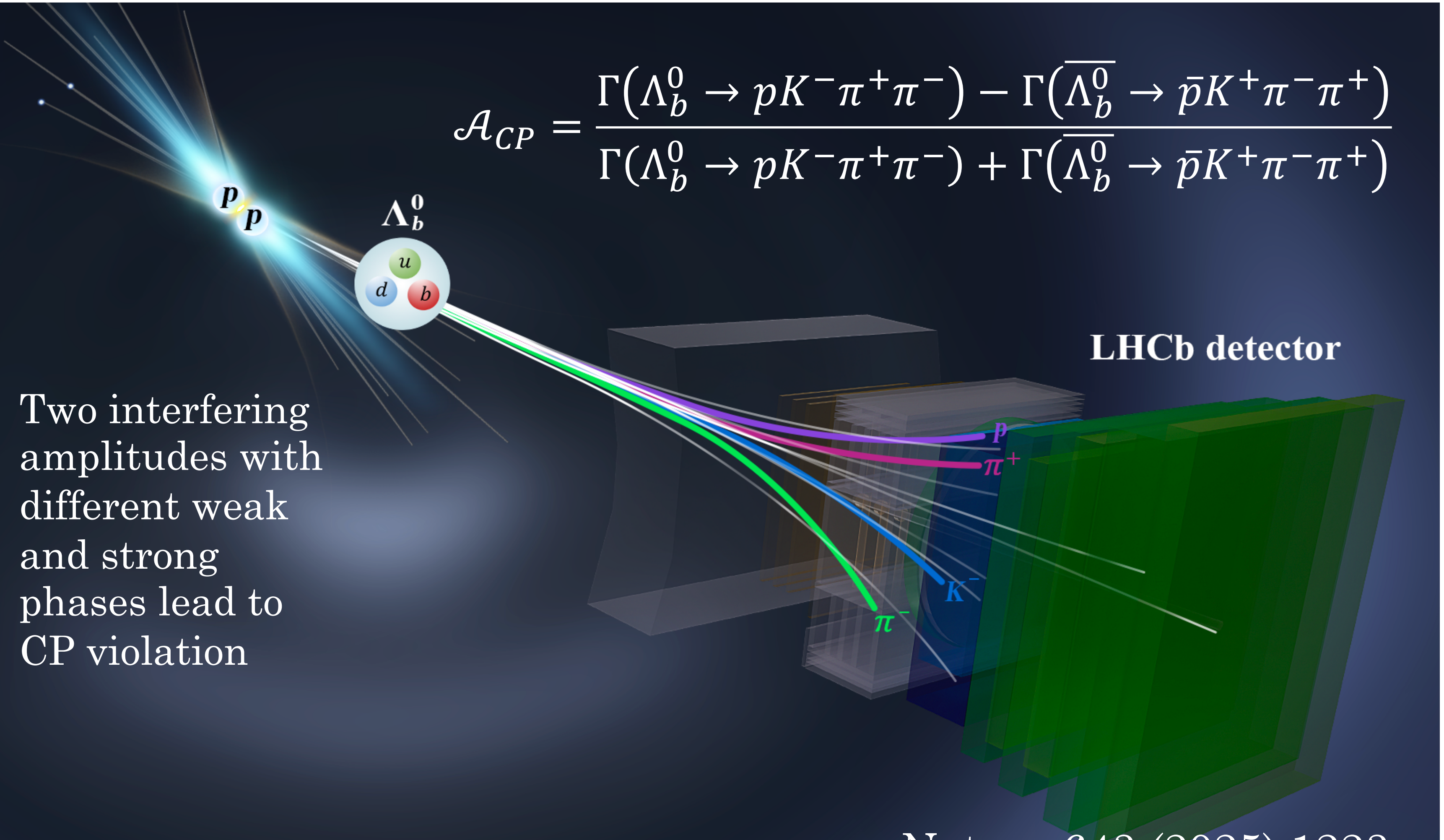
$$\frac{1}{d(\Gamma+\bar{\Gamma})/dq^2}\frac{d^4(\Gamma+\bar{\Gamma})}{dq^2\,d\vec{\Omega}}\bigg|_P = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K + F_{\mathrm{L}}\cos^2\theta_K + \frac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K\cos 2\theta_l$$
$$-F_{\mathrm{L}}\cos^2\theta_K\cos 2\theta_l + S_3\sin^2\theta_K\sin^2\theta_l\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_l\cos\phi + S_5\sin 2\theta_K\sin\theta_l\cos\phi$$
$$+\frac{4}{3}A_{\mathrm{FB}}\sin^2\theta_K\cos\theta_l + S_7\sin 2\theta_K\sin\theta_l\sin\phi + S_8\sin 2\theta_K\sin 2\theta_l\sin\phi + S_9\sin^2\theta_K\sin^2\theta_l\sin 2\phi\Big]$$

First observation of CP violation in baryons!



$$\mathcal{A}_{CP} = \frac{\Gamma(\Lambda_b^0 \to pK^-\pi^+\pi^-) - \Gamma(\overline{\Lambda_b^0} \to \bar{p}K^+\pi^-\pi^+)}{\Gamma(\Lambda_b^0 \to pK^-\pi^+\pi^-) + \Gamma(\overline{\Lambda_b^0} \to \bar{p}K^+\pi^-\pi^+)}$$

Two interfering amplitudes with different weak and strong phases lead to CP violation

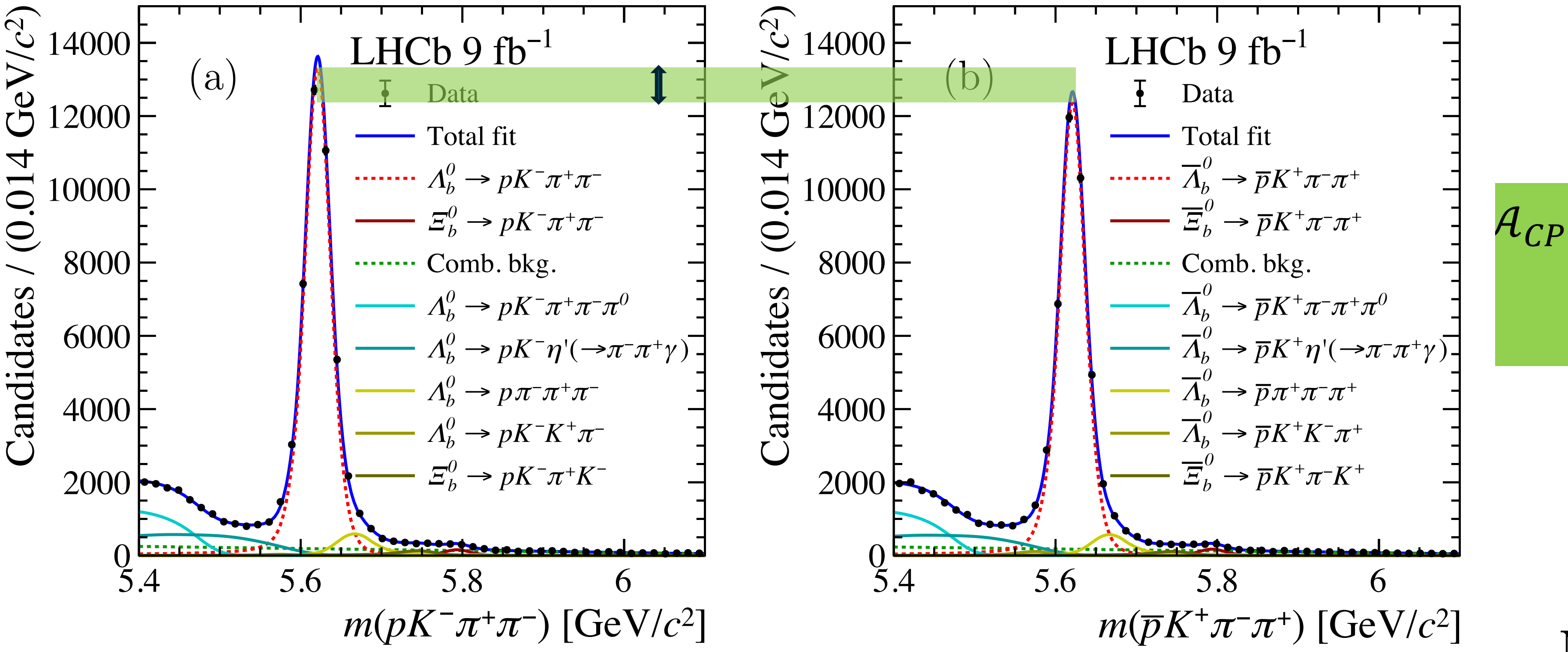


Nature 643 (2025) 1223

First observation of CP violation in baryons

Performed using Run 1 and Run 2 dataset: 9 fb^{-1}

Production and detection asymmetries controlled using $\Lambda_b^0 \to \Lambda_c^+(pK^-\pi^+)\pi^-$ decays.



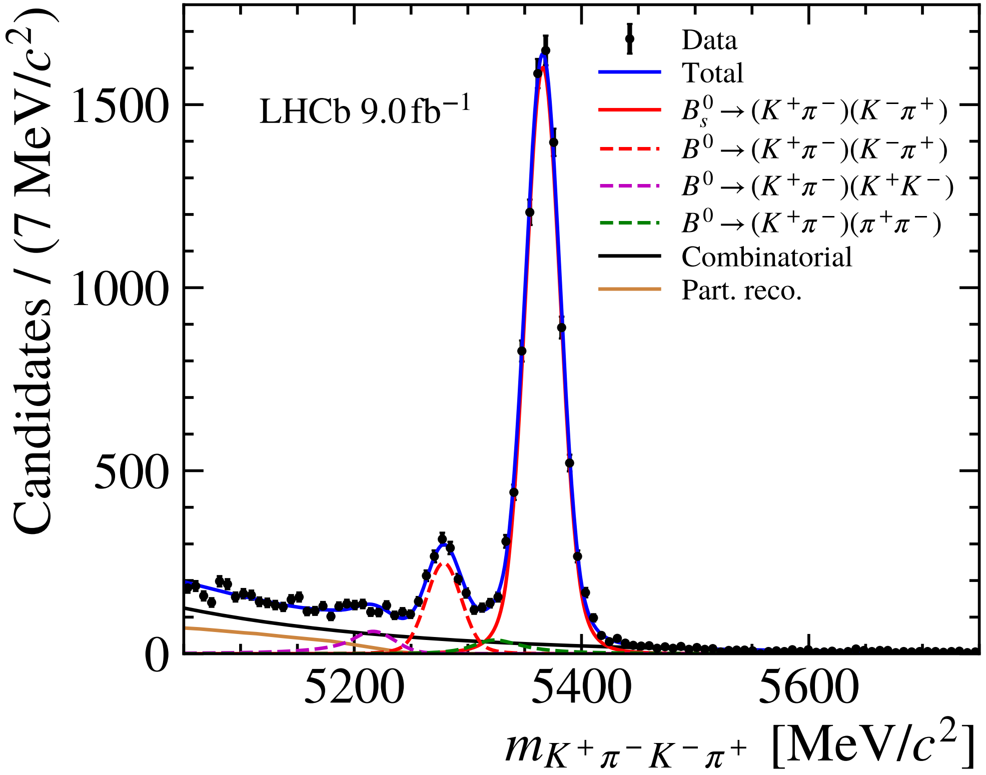
$\mathcal{A}_{CP} = (2.45 \pm 0.46 \pm 0.10)\%$

CPV at 5.2σ

Nature 643 (2025) 1223

New measurements of $B^0_{(s)} \to K^{*0}\overline{K}^{*0}$ decays

New time and flavour-integrated amplitude analysis to determine longitudinal polarisation fractions and branching fractions, using 9 fb^{-1} Run 1+2 data.



$$\mathcal{B}\left(B_s^0 \to K^{*0}\,\overline{K^{*0}}\right) = (0.932 \pm 0.025 \pm 0.018 \pm 0.036)\times 10^{-5}$$

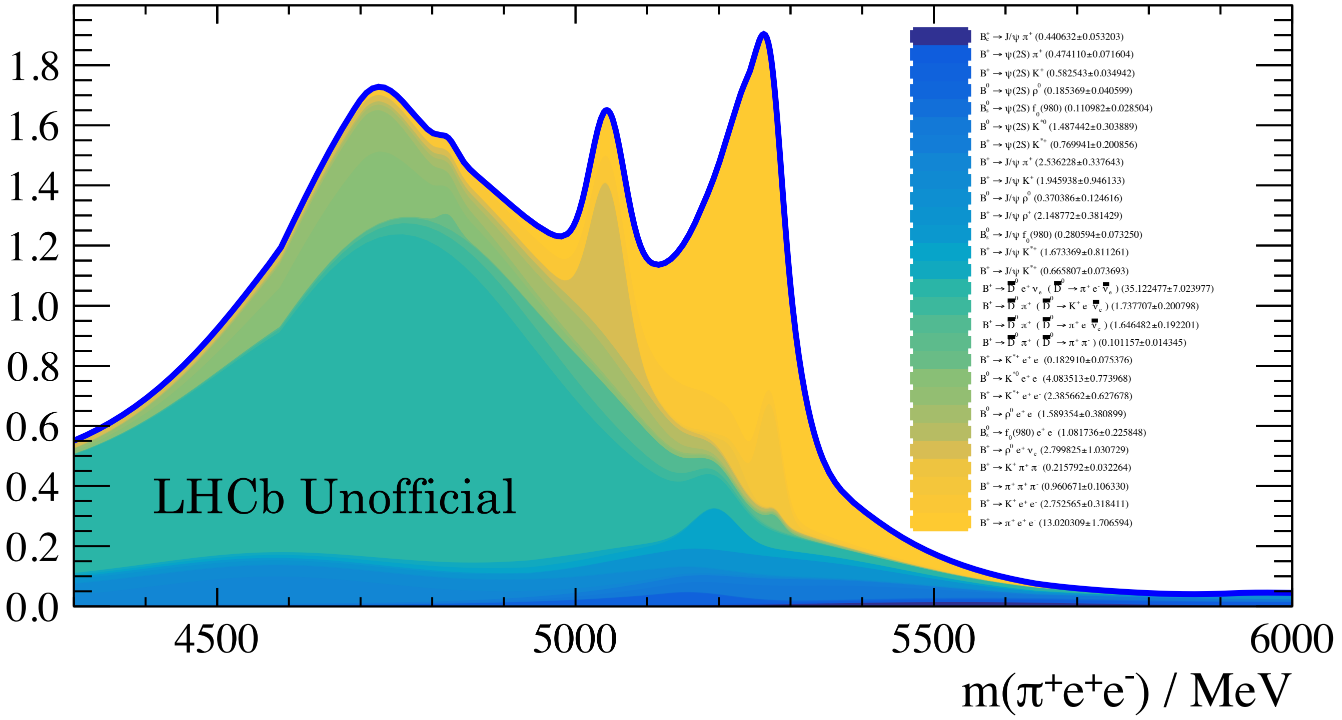
$$\mathcal{B}\left(B^0 \to K^{*0}\,\overline{K^{*0}}\right) = (4.69 \pm 0.29 \pm 0.43 \pm 0.16)\times 10^{-7}$$

LHCb-PAPER-2025-046

Search for $B^+ \to \pi^+ e^+ e^-$

Experimentally challenging:

1. Poor mass resolution due to bremsstrahlung of electrons
2. Low predicted branching fraction ~2×10^{-8}
3. Significant backgrounds:
   - Combinatorial
   - $b \to s e^+ e^-$ decays with $K \to \pi$ misID
   - **Misidentified hadronic decays**



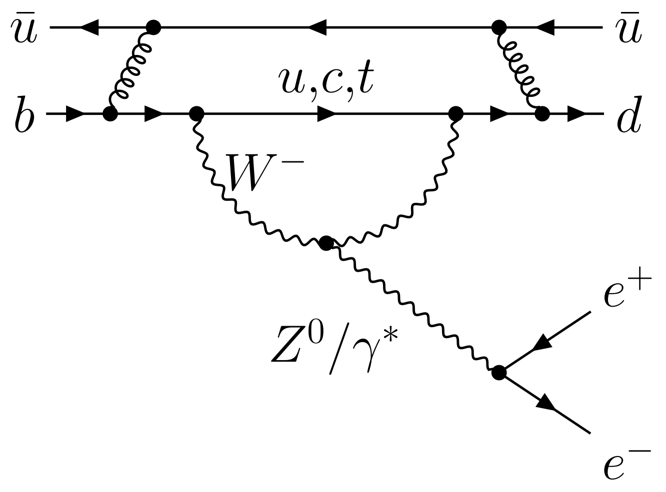
Approach:

- Stringent PID selection
- Extensive background studies
- Complex multi-region fit

Search for $B^+ \to \pi^+ e^+ e^-$

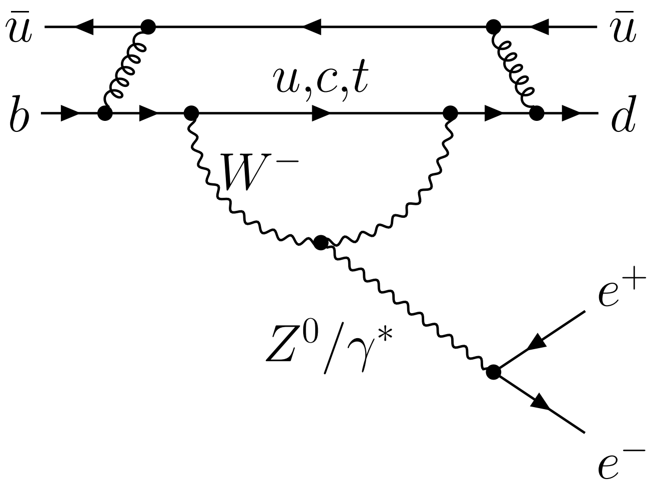
Extremely rare $b \to d\ell^+\ell^-$ transition, supressed vs $b \to s\ell^+\ell^-$ by a factor:

$$\frac{|V_{td}|^2}{|V_{ts}|^2} \sim 23$$



Sensitive to NP in branching ratio, CP asymmetry, and LFU observables, and to NP that doesn't preserve flavour structure of SM.

Search for $B^+ \to \pi^+ e^+ e^-$

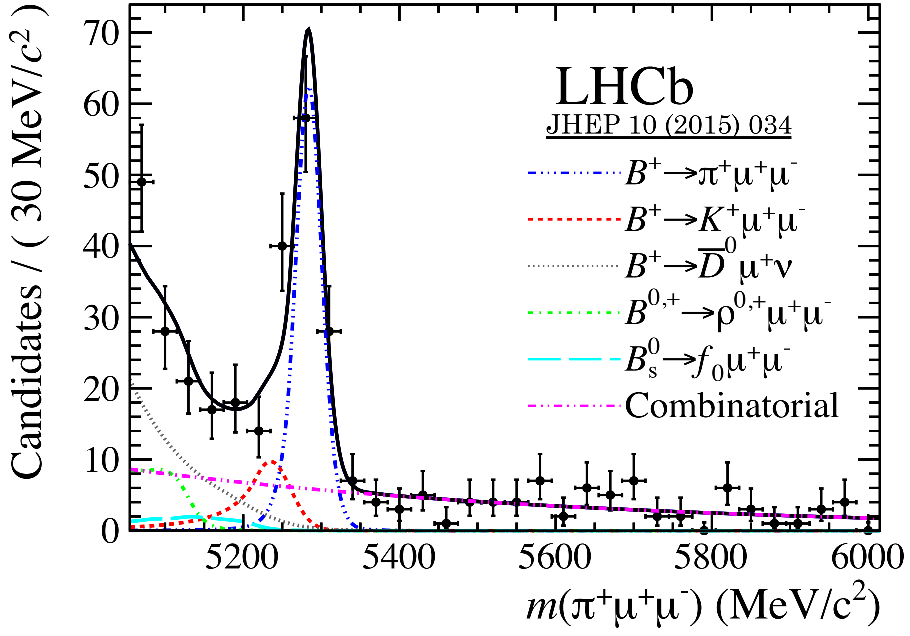


Extremely rare $b \to d\ell^+\ell^-$ transition, supressed vs $b \to s\ell^+\ell^-$ by a factor:

$$\frac{|V_{td}|^2}{|V_{ts}|^2} \sim 23$$

Sensitive to NP in branching ratio, CP asymmetry, and LFU observables, and to NP that doesn't preserve flavour structure of SM.

$B^+ \to \pi^+\mu^+\mu^-$ discovered by LHCb in Run 1 but no $b \to de^+e^-$ transitions yet observed.



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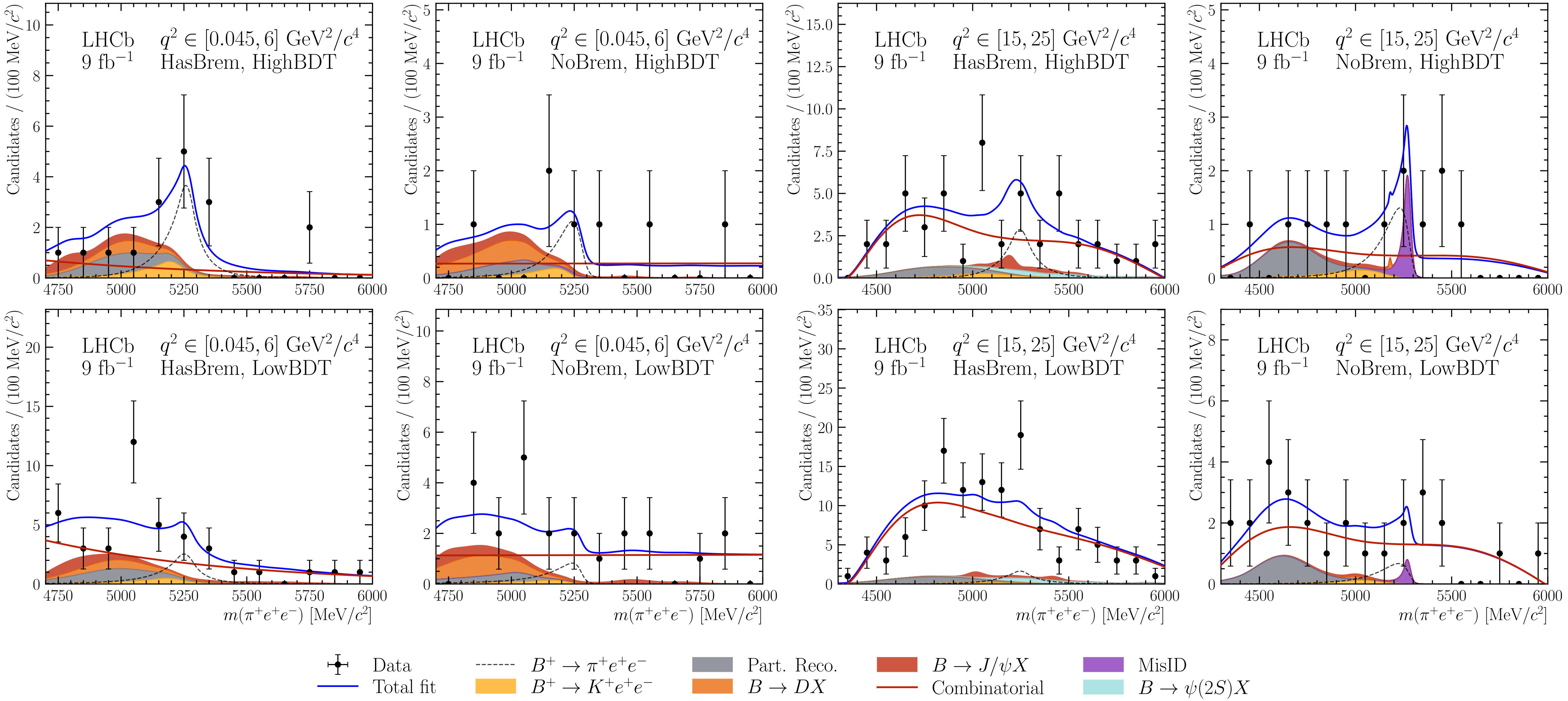
Search for $B^+ \to \pi^+ e^+ e^-$

EVEN HOTTER OFF THE PRESS!



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