Recent Results from LHCb

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on behalf of the LHCb Collaboration

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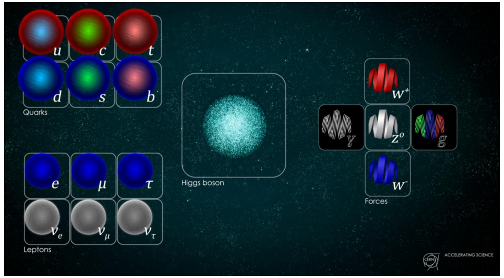
Corfu2024 Workshop on Standard Model and Beyond

Why flavour physics

- Flavour physics is crucial in establishing the SM
- Difficult questions of flavour physics
  - why are there so many different fermions?
  - what is responsible for their organisation into generations/families?
  - why are there are 3 (only 3) generations/families each of quarks and leptons?
  - why are there flavour symmetries?
  - what breaks the flavour symmetries?
  - what causes matter - antimatter asymmetry?



Flavour in the SM

- In the SM, the vacuum expectation value of the **Higgs field** breaks the electroweak symmetry
- Fermion masses arise from the Yukawa couplings of the quarks and charged leptons to the Higgs field
- **The CKM matrix arises from the relative misalignment of the Yukawa matrices for the up- and down-type quarks**
- The only flavour-changing interactions are the charged current weak interactions

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

- CKM is a 3×3 complex unitary matrix
- Without unobservable phases which appear in any quantum theory, CKM can be written in four free parameters
  - three Euler mixing angles parameters
  - **the fourth makes the CKM matrix complex, CP violation**

Parameterization and the unitarity of CKM matrix

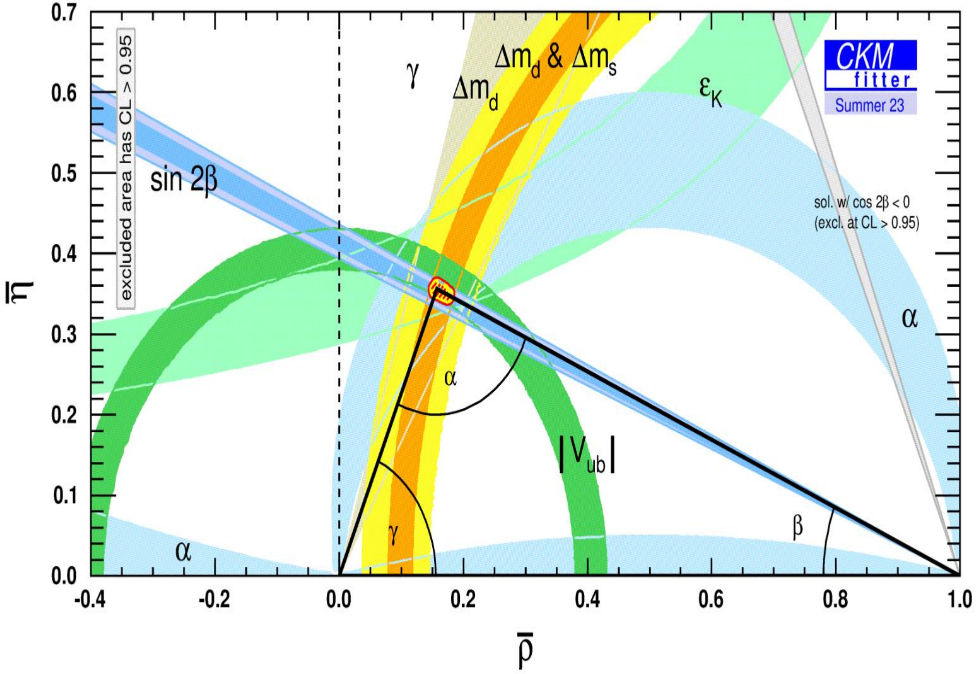
- Using Wolfenstein parameterization (λ, A, ρ, η):
  - $\lambda = \sin\theta_C \approx V_{us}$ measured precisely in K semileptonic decays

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}\left(\lambda^4\right)$$

- The CKM matrix must be unitary
  - provides numerous tests of constraints between independent observables

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

The Unitarity Triangle



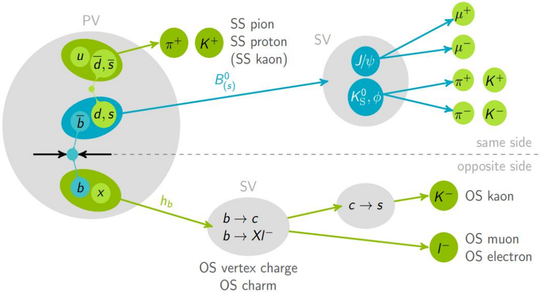
- In SM, all measurements must agree on the position of the apex of the Unitarity Triangle

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

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

$$\beta = \arg(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}), B \to J/\psi K_S$$

What do we need?



- High statistics of B mesons
- Trigger sensitive to final states with leptons and only hadrons
- Excellent proper time resolution to measure the CP violating oscillation amplitudes of the B_s system
- Good $\pi/K/\mu/e$ separation to reduce the combinational background and other B meson decays. K-id is also very useful for flavour tagging
- Good momentum and vertex resolution to reduce background

CERN/LHCC 95-5
LHCC/ I 8
25 August 1995

Last update
28 March 1996

LHC-B

LETTER OF INTENT

A Dedicated LHC Collider Beauty Experiment for Precision Measurements of CP-Violation

Abstract

The LHC-B Collaboration proposes to build a forward collider detector dedicated to the study of CP violation and other rare phenomena in the decays of Beauty particles. The forward geometry results in an average 80 GeV momentum of reconstructed B-mesons and, with multiple, efficient and redundant triggers, yields large event samples. B-hadron decay products are efficiently identified by Ring-Imaging Cerenkov Counters, rendering a wide range of multi-particle final states accessible and providing precise measurements of all angles, α, β and γ of the unitarity triangle. The LHC-B microvertex detector capabilities facilitate multi-vertex event reconstruction and proper-time measurements with an expected few-percent uncertainty, permitting measurements of B_s-mixing well beyond the largest conceivable values of x_s. LHC-B would be fully operational at the startup of LHC and requires only a modest luminosity to reveal its full performance potential.

The Run2 LHCb detector

Excellent vertexing allows efficient heavy quark hadrons selection, high decay time resolution of $\sigma_t \approx 45$ fs, prompt-secondary separation for charm $\sigma(IP_X) \approx 35\ \mu m$

Excellent PID allows to suppress background dramatically and explore many decay modes

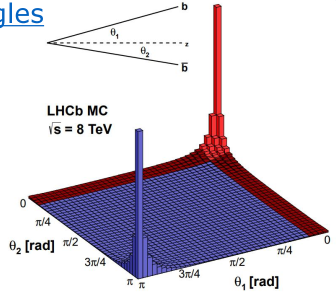
- $\varepsilon_{PID}(K) > 95\%$
- MisID $(K \to \pi) < 5\%$

Excellent tracking system, momentum resolution $\approx 0.5\%$

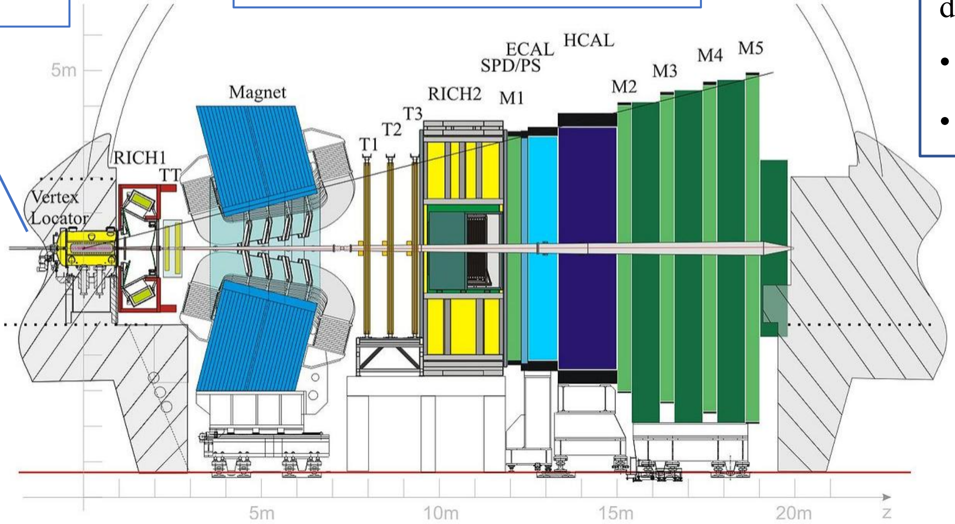
Muon system - nice tagging & great potential to search for rare decays with di-muons

- $\varepsilon_{PID}(\mu) > 97\%$
- MisID $(\pi \to \mu) < 3\%$

bbangles



$2 < \eta < 5$

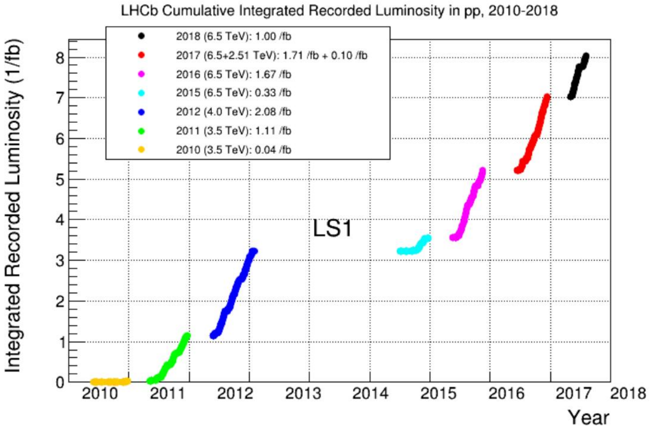


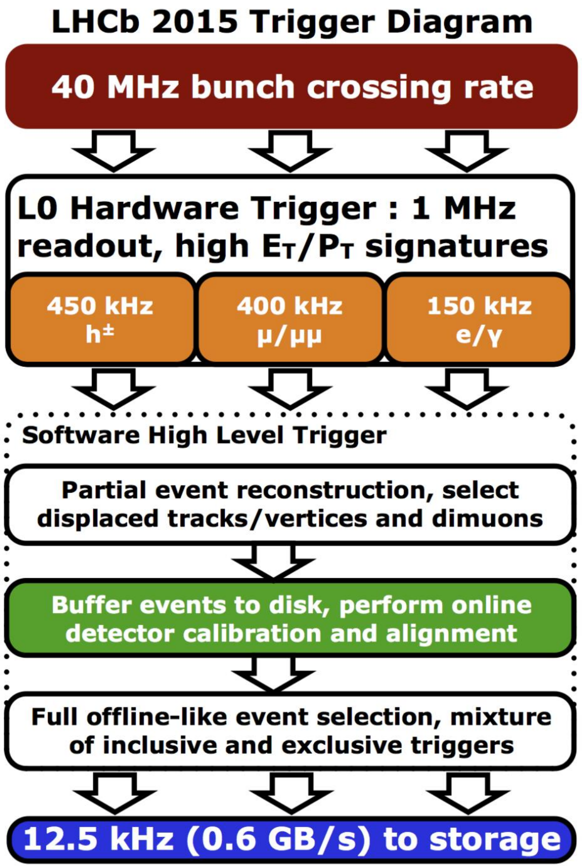
JINST 3 (2008) S08005

Run2 luminosity and trigger

- LHCb operated in constant instantaneous luminosity mode, 1.1 visible interactions per bunch crossing
- Two stage trigger, which is efficient for hadrons and muons

Run 2 (2015-2018): 6 fb^{-1}



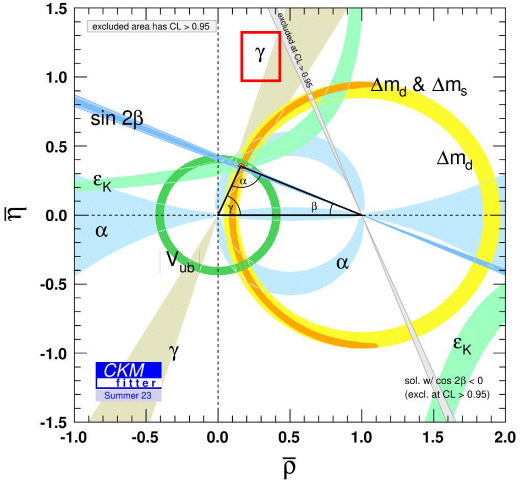


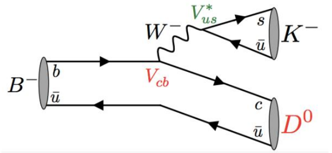
Recent LHCb results on CKM (selected)

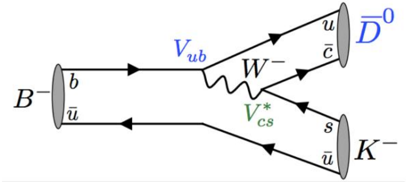
γ measurement

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

- The only angle that can be measured purely from tree-level, theoretically clean observable
- Discrepancies between the direct and indirect measurements would be a sign of beyond SM effects
  - 2024 W.A. for direct measurement: $(66.4^{+2.8}_{-3.0})^\circ$
  - CKMfitter 2023: $(66.3^{+0.7}_{-1.9})^\circ$







γ measurement

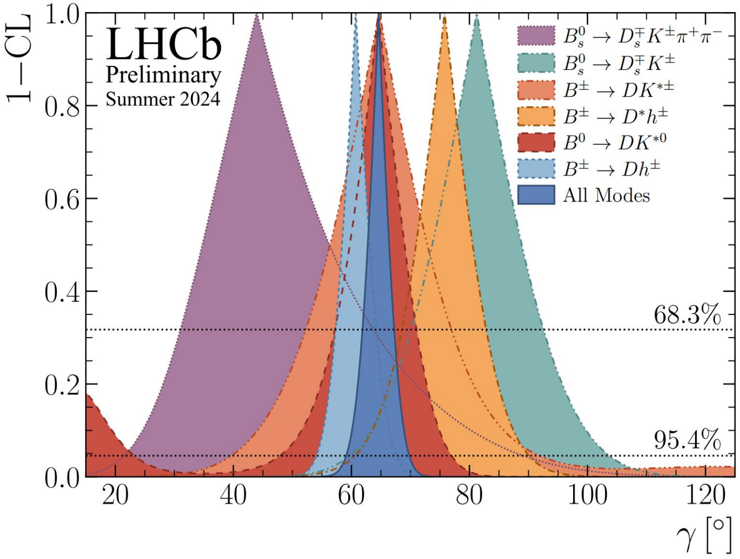
- γ can be determined by exploiting the interference effects in $B \longrightarrow DK$ type decays
  - $B^0 \to DK^{*0}, D \to h^+h^-(\pi^+\pi^-)$: $\gamma = (61.7 \pm 8.9)^\circ$ [1]
  - $B^0 \to DK^{*0}, D \to K_S^0 h^+h^-$, combination with $D \to h^+h^-(\pi^+\pi^-)$: $\gamma = (63.2^{+6.9}_{-8.1})^\circ$ [2]
  - first time for $B^\pm \to DK^{*\pm}, D \to K_S^0 h^+h^-$: $\gamma = (63 \pm 13)^\circ$ [3]
  - $B_S^0 \to D_S^\mp K^\pm$, combination of Run1 and Run2 yields: $\gamma = (81^{+12}_{-11})^\circ$ [4]
    - ➢ the most precise measurement of γ in B_S^0 decays from a single experiment

[1] JINST 02 (2024) 118 [2] Eur. Phys. J. C 84, 206 (2024)
[3] LHCB-PAPER-2024-023, in preparation [4] LHCB-PAPER-2024-020, in preparation

2024 LHCb γ

$(64.6 \pm 2.8)^{\circ}$

LHCb-CONF-2024-004

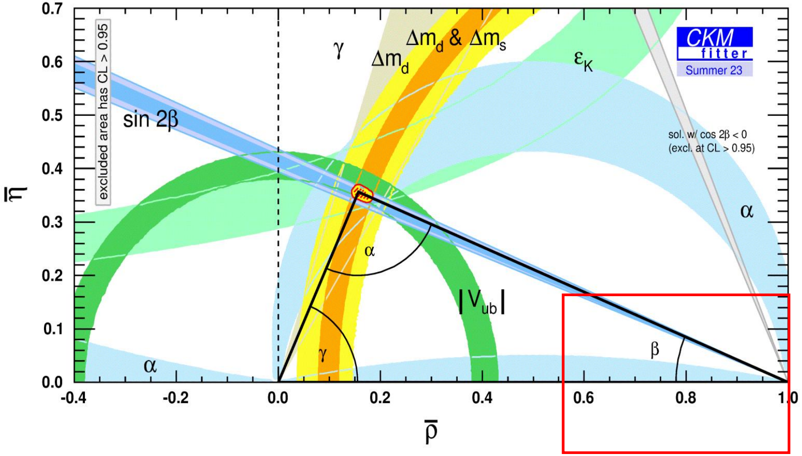


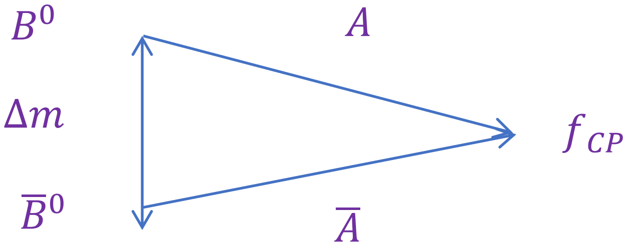
- Combination of
  - 19 LHCb B decay results
  - 11 LHCb D decay results
  - external constrains: a new measurement of the CP-even fraction and updates to the β and ϕ_s
- 20% improved precision compared with LHCb 2022 combination [1] and consistent with global CKM fit predictions
- Statistically limited, Run 3 will be even better!

[1] LHCb-CONF-2022-003

β

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





- Involving top quark, loop processes required
- The particular type of loop process that is used is the oscillation of a B^0 into $\overline{B}^0$ and back
- For a B meson known to be B^0 or $\overline{B}^0$ at time $t = 0$, then at later time t :

$$\mathcal{A}^{CP}(t) = \frac{\Gamma(\overline{B}^0(t)\to f) - \Gamma(B^0(t)\to f)}{\Gamma(\overline{B}^0(t)\to f) + \Gamma(B^0(t)\to f)} = \frac{S\sin(\Delta m_d t) - C\cos(\Delta m_d t)}{\cosh\left(\frac{1}{2}\Delta\Gamma_d t\right) + \mathcal{A}_{\Delta\Gamma}\sinh\left(\frac{1}{2}\Delta\Gamma_d t\right)}$$

- For $B^0 \to J/\psi K_S^0$, $S = \sin(2\beta + \Delta\phi_d + \Delta\phi_d^{\mathrm{NP}})$, penguin contributions are small: $\Delta\phi_d \approx 0.5^{\circ}$

sin(2β)≠0 → CP violation

New LHCb measurement of sin(2β)

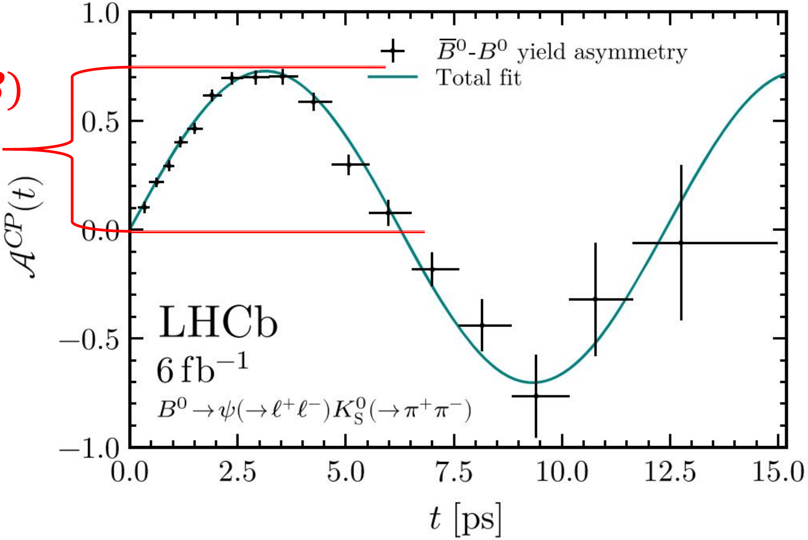
- Most precise single measurement of sin(2β) to date

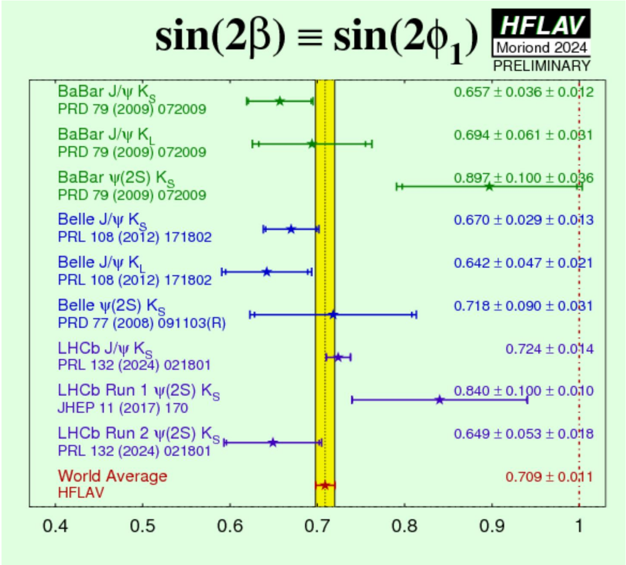
$$0.716 \pm 0.013\ (\text{stat.}) \ \pm\ 0.008\ (\text{syst.})$$

HFLAV

Phys. Rev. Lett. 132 (2024) 021801

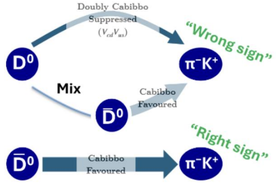
sin(2β)





LHCb dominates the average!

CPV in charm sector



- In SM, charm CPV effects are predicted to be very small, $\mathcal{O}(10^{-4} - 10^{-3})$
- Direct CPV in charm has been observed by LHCb in $D^0 \rightarrow h^+h^-$, $A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) \neq 0$ [1]
- $D^0 \rightarrow K^+\pi^-$ allows us to measure mixing and all types of CPV
- Measure the time dependence of WS/RS yield ratio

arXiv: 2407.18001

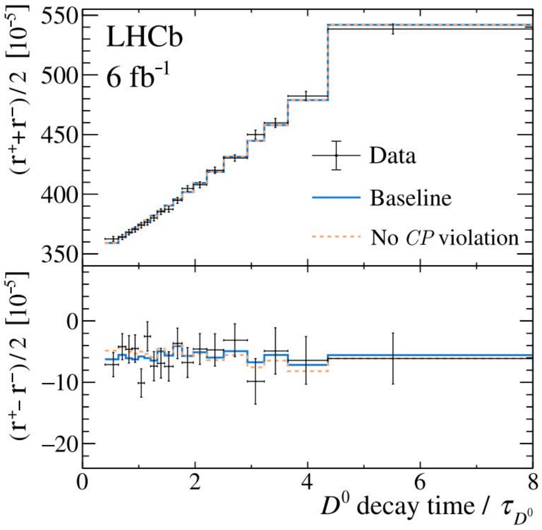
$$R^+_{K\pi}(t) \equiv \frac{\Gamma(D^0(t) \to K^+\pi^-)}{\Gamma(\overline{D}^0(t) \to K^+\pi^-)} \qquad R^-_{K\pi}(t) \equiv \frac{\Gamma(\overline{D}^0(t) \to K^-\pi^+)}{\Gamma(D^0(t) \to K^-\pi^+)}$$

$$R^{\pm}_{K\pi}(t) \approx R_{K\pi}(1 \pm A_{K\pi}) + \sqrt{R_{K\pi}(1 \pm A_{K\pi})}(c_{K\pi} \pm \Delta c_{K\pi})\, t + (c'_{K\pi} \pm \Delta c'_{K\pi})\, t^2$$

$R_{K\pi}$	$(343.1 \pm 2.0) \times 10^{-5}$	$A_{K\pi}$	$(-7.1 \pm 6.0) \times 10^{-3}$
$c_{K\pi}$	$(51.4 \pm 3.5) \times 10^{-4}$	$\Delta c_{K\pi}$	$(3.0 \pm 3.6) \times 10^{-4}$
$c'_{K\pi}$	$(13.1 \pm 3.7) \times 10^{-6}$	$\Delta c'_{K\pi}$	$(-1.9 \pm 3.8) \times 10^{-6}$

→ CPV in decay

CPV in mixing



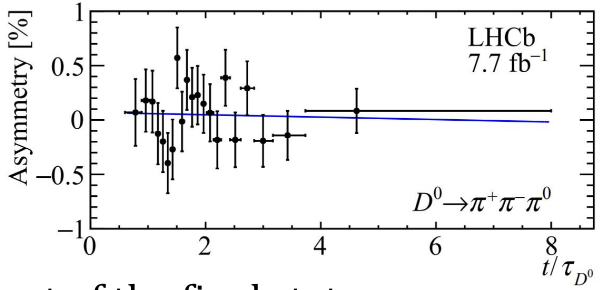
no evidence of CPV

[1] PRL 122 (2019) 211803

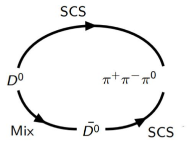
First measurement of CPV in $D^0 \to \pi^+\pi^-\pi^0$

arXiv: 2405.06556

$$A_{CP}(f_{CP},t) \equiv \frac{\Gamma_{D^0\to f_{CP}}(t) - \Gamma_{\overline{D}^0\to f_{CP}}(t)}{\Gamma_{D^0\to f_{CP}}(t) + \Gamma_{\overline{D}^0\to f_{CP}}(t)} \approx a^{\rm dir}_{f_{CP}} + \boxed{\Delta Y_{f_{CP}} \frac{t}{\tau_{D^0}}},$$



- Neglecting direct CP violation, gradient $\Delta Y_{f_{CP}}$ becomes independent of the final state
- The gradient of the time-dependent CP asymmetry $\Delta Y \equiv \Delta Y_{f_{CP}}\eta_{f_{CP}}$
  - $\eta_{f_{CP}}$: the CP eigenvalue of the final state



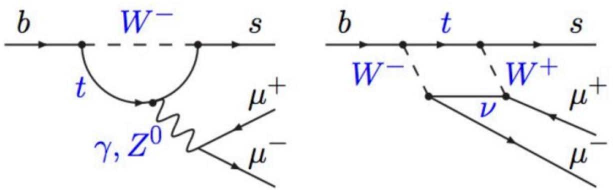
- For muti-boday decays, due to a mixture of CP-even and CP-odd contributions from intermediate states, $\Delta Y^{\rm eff}_f = (2F^f_+ - 1)\Delta Y$
  - $F^f_+ = 0.974 \pm 0.017$ [1], is the CP even-fraction of the $D^0 \to f$
- $\Delta Y = (-1.3 \pm 6.3 \pm 2.4) \times 10^{-4}$, constant with W.A, no CPV

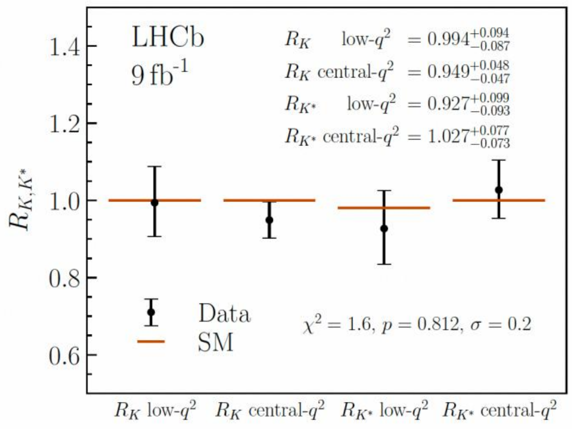
[1] arXiv: 1504.05878

Recent LHCb results on Flavour anomalies (selected)

$b \to \boldsymbol{s l^+ l^-}$ decays

- Decays mediated by the $b \to \boldsymbol{s l^+ l^-}$ quark transitions are suppressed in SM due to the absence of Flavor-changing neutral current (FCNC) process
- Measurements of the properties are sensitive to new particles with masses up to around 100 TeV
  - branching fraction
  - $\mathcal{R}_K = \mathcal{B}(B^+ \to K^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+e^+e^-)$
  - angular analysis of the decay $B^0 \to K^* l^+ l^-$

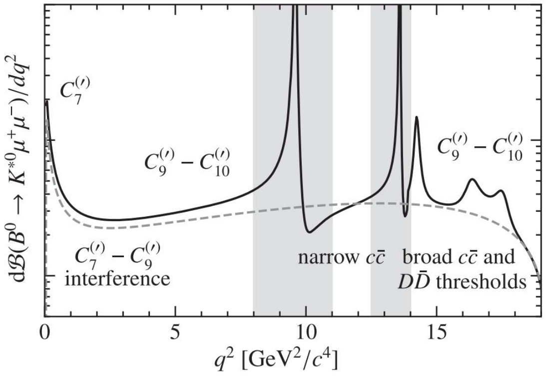




Phys. Rev. D 109 (2024) 052009

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

- In Effective Try: $$\mathcal{H}_{\mathrm{WET}} = \frac{-4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_i \mathcal{C}_i^{(\prime)}(\mu)\mathcal{O}_i^{(\prime)}(\mu),$$
  - Wilson coefficients [observables], depending on their flavour structures, correspond to an energy scale well above the beauty hadron masses and are where NP might manifest itself
  - non-local hadronic contributions
- It is found a 3.4σ tension with the SM value of $\mathcal{C}_9$, which reflects the interference effect between transverse and longitudinal polarizations [1]
- The nonlocal contributions manifest as resonances in the q^2 spectrum

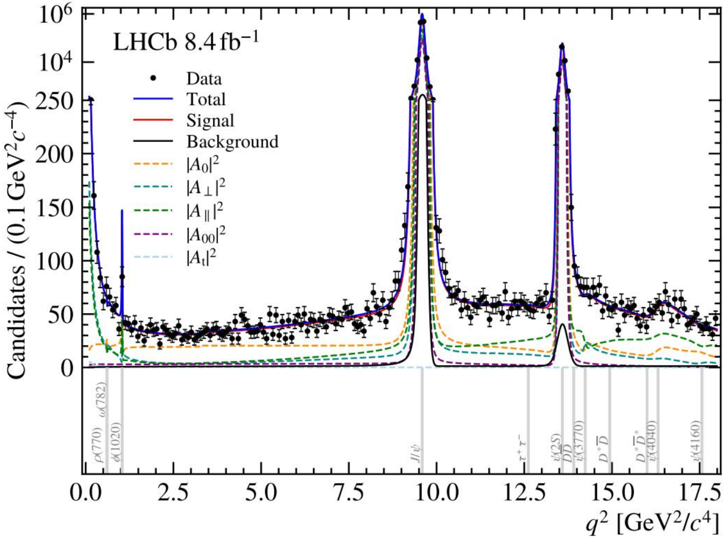


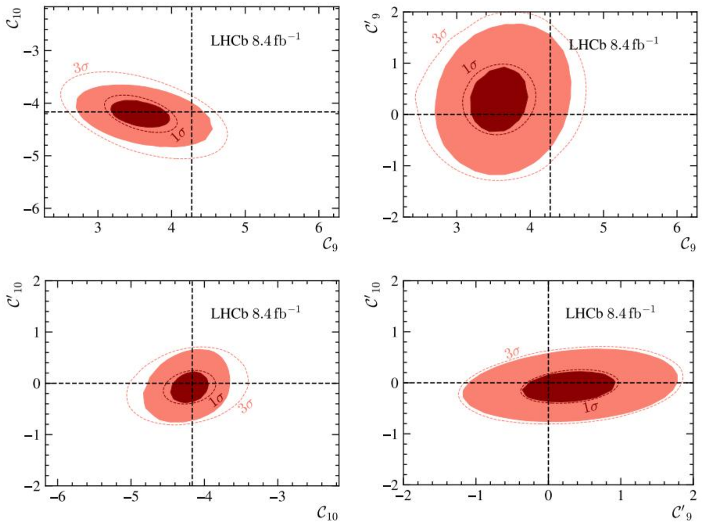
[1] Phys. Rev. Lett. 125, 011802 (2020)

Phys. Rev. D 109 (2024) 052009

New approach to account of non-local form factors

- Simultaneously determine the nonlocal contributions and $\mathcal{C}_i^{(\prime)}$
- $\mathcal{C}_9$ exhibits a 2.1σ deviation from the SM, other coefficients are in better agreement with the SM

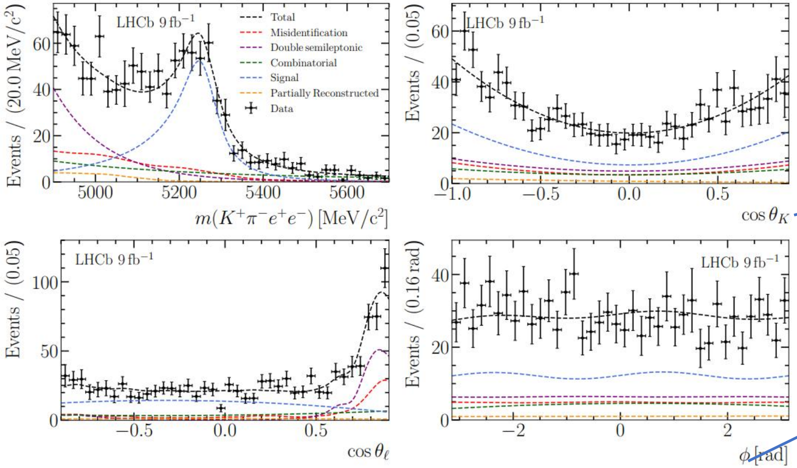


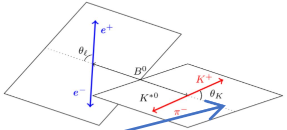


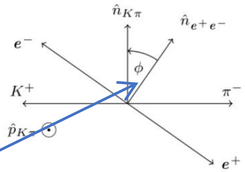
Phys. Rev. D 109 (2024) 052009

Angular analysis of $B^0 \to K^{*0} e^+ e^-$

- Allows the extraction of the angular observable in the central q^2 region
- Most precise determination of angular observables and no sign of lepton flavour violating effects are observed

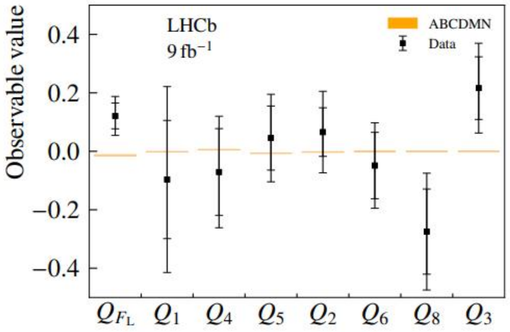






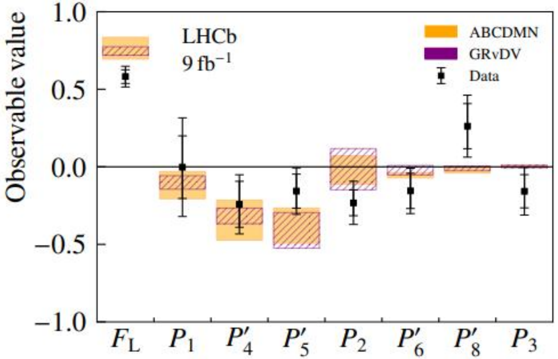
LHCb-PAPER-2024-022 in preparation

lepton flavor universality observables



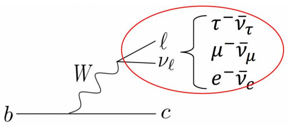
F_L: the fraction of longitudinally polarised

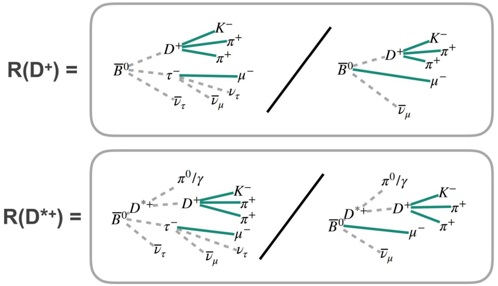
P: P-basis angular observables



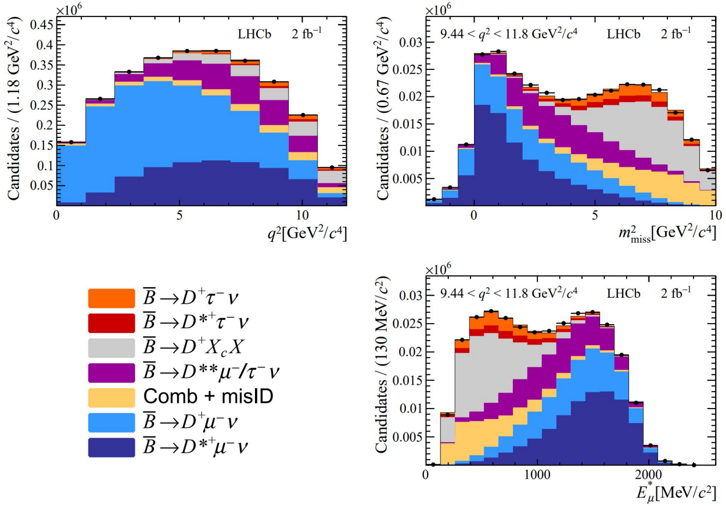
New LHCb measurement of $R(D^{(*)+})$

- First LHCb measurement using the D^+ ground state with $D^+ \to K^-\pi^+\pi^+$, muonic-tau decay
  - Primary goal is to measure $\boldsymbol{R(D^+)}$
  - Feed down from $\boldsymbol{D^{*+}} \to \boldsymbol{D^+}\pi^0/\gamma$ with not reconstructed π^0/γ gives also access to $\boldsymbol{R(D^{*+})}$ in the same final state
- Data sample: 2 fb^{-1} at 13TeV
- 3D template fit to q^2, the energy of the muon in the B meson rest frame (E^*_μ) and the squared invariant mass missing from the visible system (m^2_{miss})





arXiv: 2406.03387



New LHCb measurement of $R(D^{(*)+})$

- Results compatible with the SM at the 0.78 σ level
- Results compatible with the (previous) World Average (W.A.) at the 1.09 σ level
- Main systematic uncertainties from form-factor parameterisation & background modelling

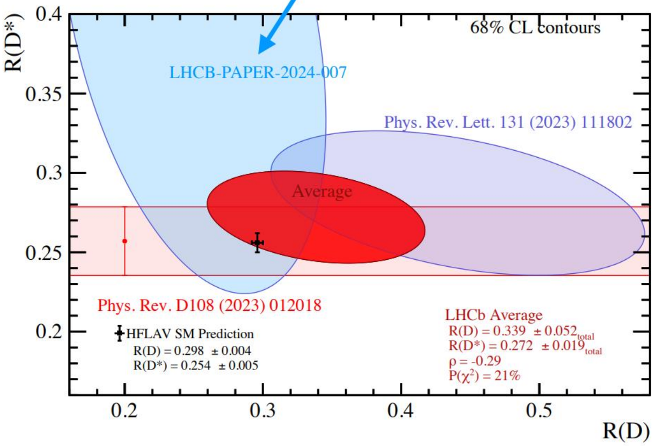
$$R(D^+) = 0.249 \pm 0.043\ (\text{stat.}) \pm 0.047\ (\text{syst.})$$
$$R(D^{*+}) = 0.402 \pm 0.081\ (\text{stat.}) \pm 0.085\ (\text{syst.})$$
$$\rho = \text{-}0.39$$

arXiv: 2406.03387

Combination with other LHCb measurements

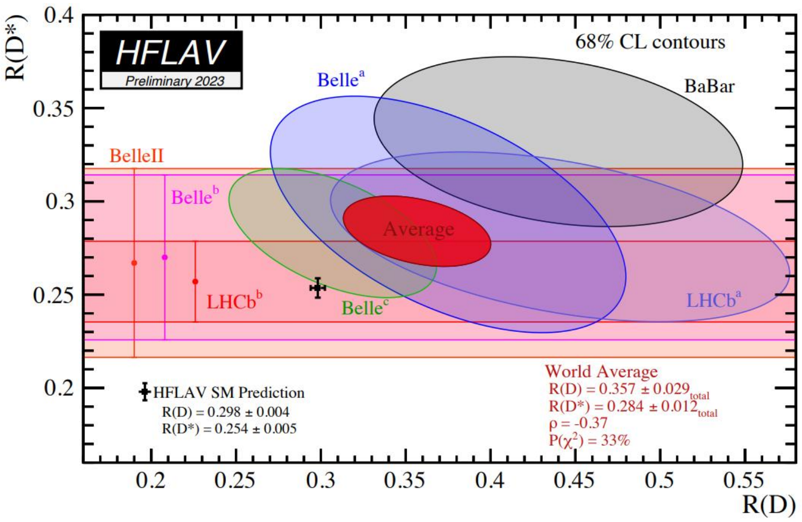
$$R(D^+) = 0.335 \pm 0.052$$
$$R(D^{*+}) = 0.279 \pm 0.019$$
$$\rho = \text{-}0.30$$

This result
[LHCb preliminary]



New $R(D^{(*)})$ W.A.

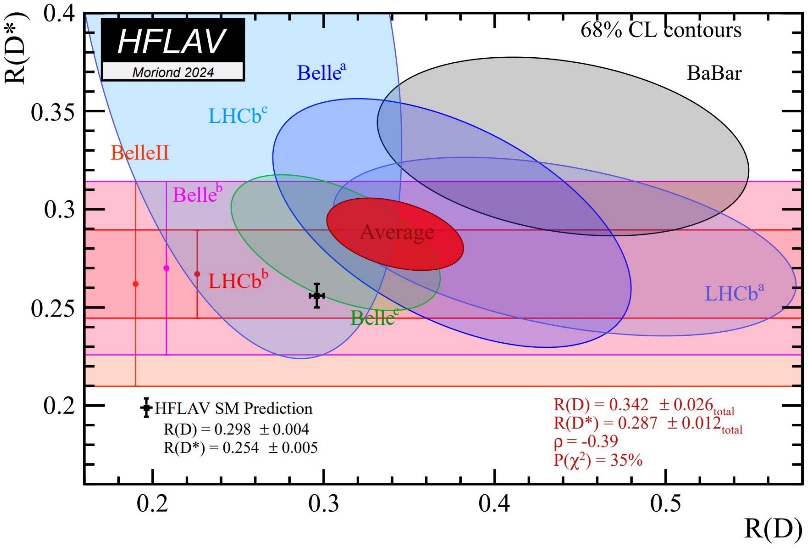
HFLAV



Previous W.A.

Tension with SM at the level of 3.34 σ

HFLAV

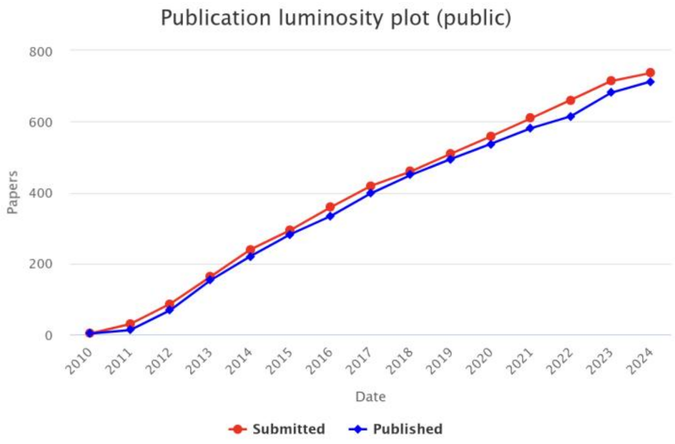


New W.A.

Tension with SM at the level of 3.17 σ

LHCb: a general purpose detector

lhcb publications, link



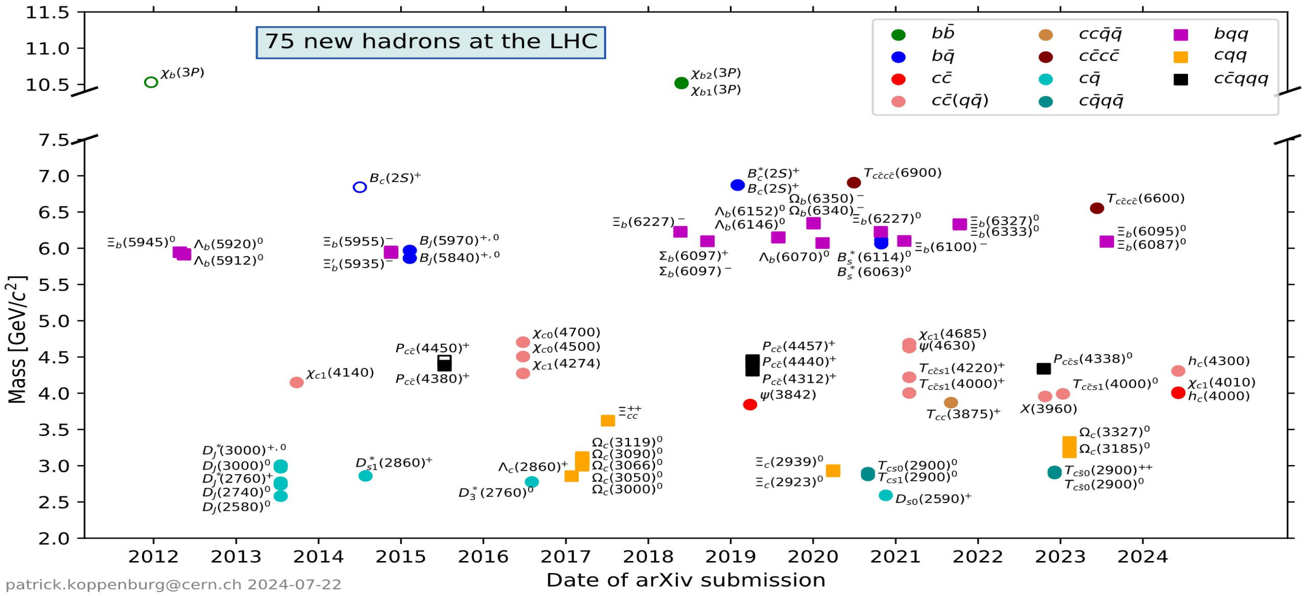
LHCb Physics

- ✓ Heavy ions and Fixed target physics
- ✓ Forward physics
- ✓ Electroweak, QCD and exotics
- ✓ Mixing and CP violation in b and c decays
- ✓ Spectroscopy and exotic hadrons
- ✓ Hadron production
- ✓ Charm physics
- ✓ Semileptonice decays
- ✓ Rare decays

Recent LHCb results on Spectroscopy (selected)

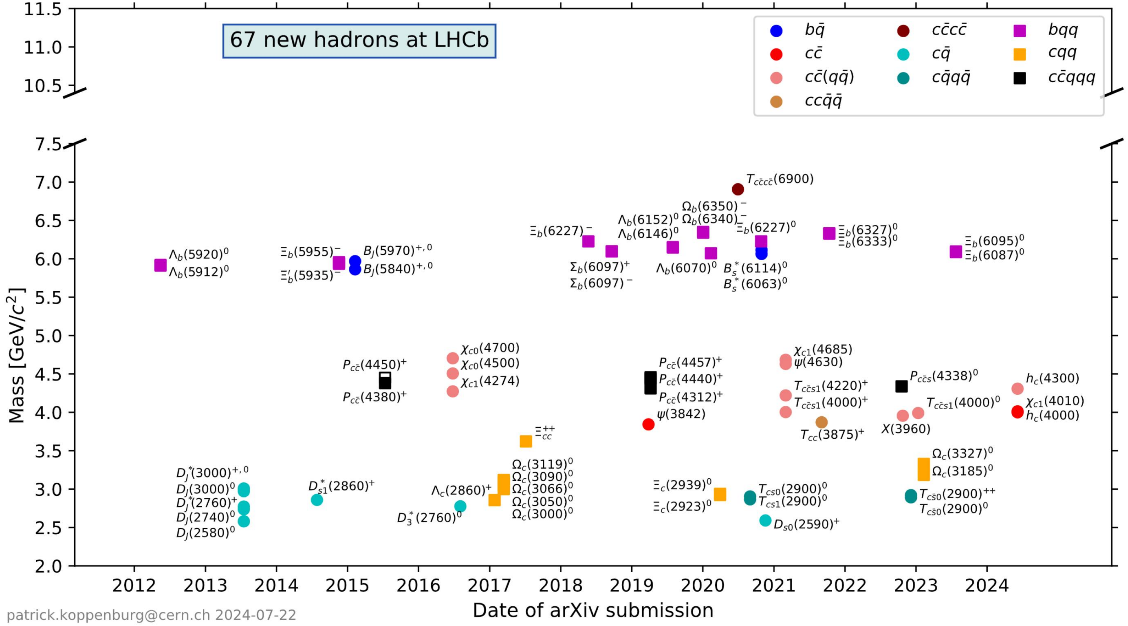
Spectroscopy

- LHC is an ideal laboratory to study spectroscopy



Spectroscopy

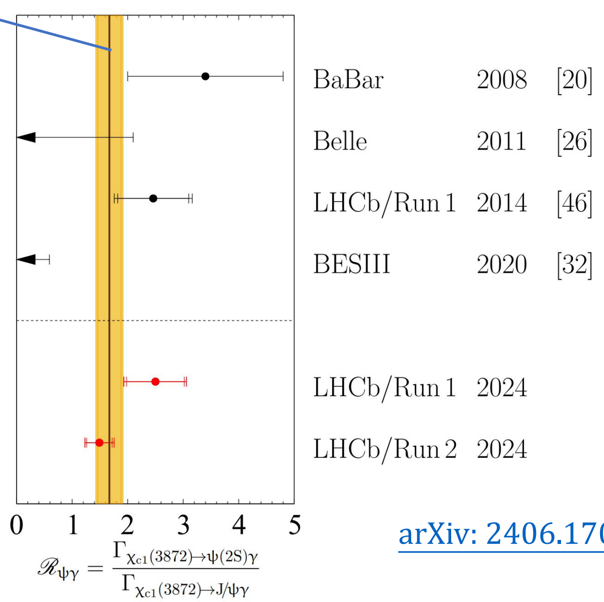
- LHCb's unique detection capability has led to a wealth of remarkable discoveries



Probing the nature of the $\chi_{c1}(3872)$

$$\mathcal{R}_{\psi\gamma}^{\text{Run 1 \& Run2 average}} = \frac{\Gamma_{\chi_{c1}(3872)\to\psi(2S)\gamma}}{\Gamma_{\chi_{c1}(3872)\to J/\psi\gamma}}$$

$$= 1.67 \pm 0.21(\text{stat.}) \pm 0.06(\text{syst.}) \pm 0.04\ (BR(\psi \to l^+l^-))$$

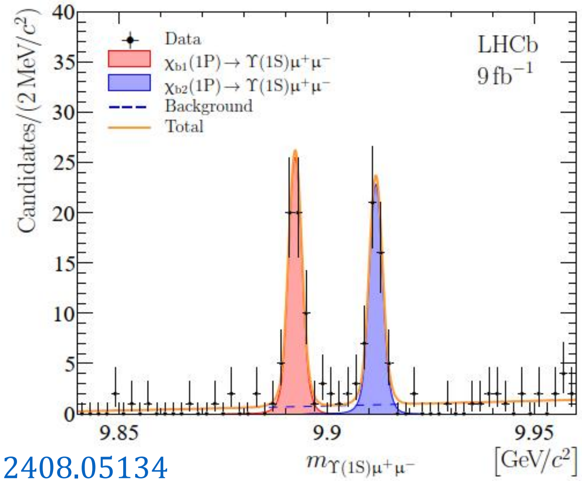


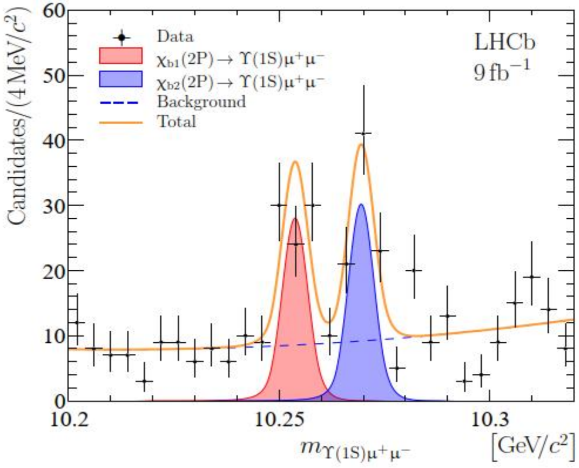
- Generally inconsistent with the calculations based on the pure $D\bar{D}^*$ molecular hypothesis for the $\chi_{c1}(3872)$
- Likely sign of conventional $c\bar{c}$ charmonium, $c\bar{c}q\bar{q}$ tetraquark and molecules mixed with sizeable compact component

arXiv: 2406.17006

First observation of muonic Dalitz decays of χ_b mesons

- Radiative transitions between different J^{PC} levels have been intensively studied in the past
- LHCb firstly reports the muonic Dalitz decays from the χ_b levels to the $\Upsilon(1S)$
- The measured masses and mass difference between different $b\bar{b}$ energy levels forming the bottonium system are competitive and in agreement with the world averages





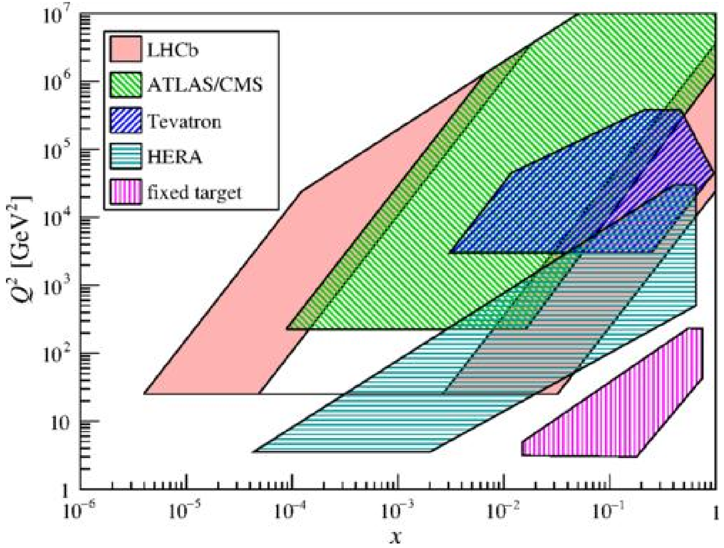
$$
\begin{aligned}
m_{\chi_{b1}(1P)} &= 9\,892.50 \pm 0.26 \pm 0.10 \pm 0.10\,\mathrm{MeV}/c^2\,,\\
m_{\chi_{b2}(1P)} &= 9\,911.92 \pm 0.29 \pm 0.11 \pm 0.10\,\mathrm{MeV}/c^2\,,\\
m_{\chi_{b1}(2P)} &= 10\,253.97 \pm 0.75 \pm 0.22 \pm 0.09\,\mathrm{MeV}/c^2\,,\\
m_{\chi_{b2}(2P)} &= 10\,269.67 \pm 0.67 \pm 0.22 \pm 0.09\,\mathrm{MeV}/c^2\,,
\end{aligned}
$$

Parameter		PDG'22 [69]	PDG'24 [57]
$m_{\Upsilon(1S)}$	[MeV/c^2]	$9\,460.30 \pm 0.26$	$9\,460.4 \pm 0.1$
$m_{\Upsilon(2S)}$	[MeV/c^2]	$10\,023.26 \pm 0.31$	$10\,023.4 \pm 0.5$
$m_{\Upsilon(3S)}$	[MeV/c^2]	$10\,355.2 \pm 0.5$	$10\,355.1 \pm 0.5$
$m_{\Upsilon(3S)} - m_{\Upsilon(2S)}$	[MeV/c^2]	331.50 ± 0.13	331.50 ± 0.13

arXiv: 2408.05134

Recent LHCb results on Electroweak Physics (selected)

Phys. Rev. D 93, 074008 (2016)

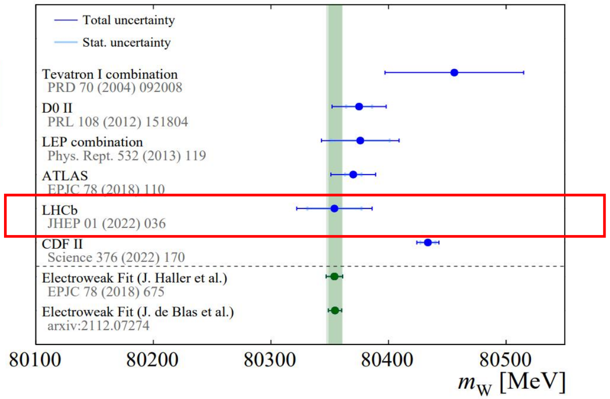


W mass measurement

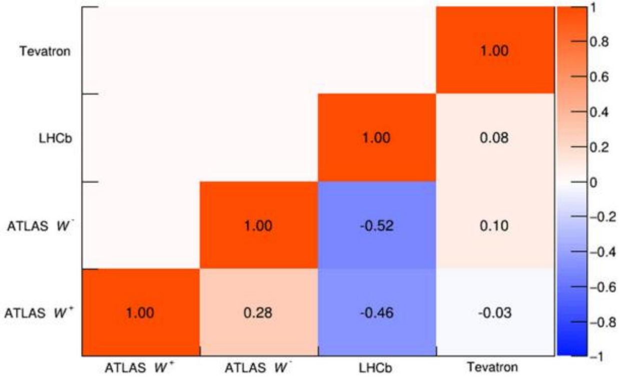
LHCB-FIGURE-2022-003

$$m_W = 80354 \pm 23_{\text{stat}} \pm 10_{\text{exp}} \pm 17_{\text{theory}} \pm 9_{\text{PDF}}\ \text{MeV}$$

- First measurement of m_W from LHCb using 2016 data with 32 MeV uncertainty is consistent with the prediction
- A more precise measurement with a total uncertainty of $\lesssim$ 20 MeV looks achievable with Run2 data
- The determination in the forward acceptance strongly suppresses the PDF uncertainty in an LHC m_W average due to complementary geometry
    - LHC combination: 80369.2 ± 13.3 MeV (CT18)



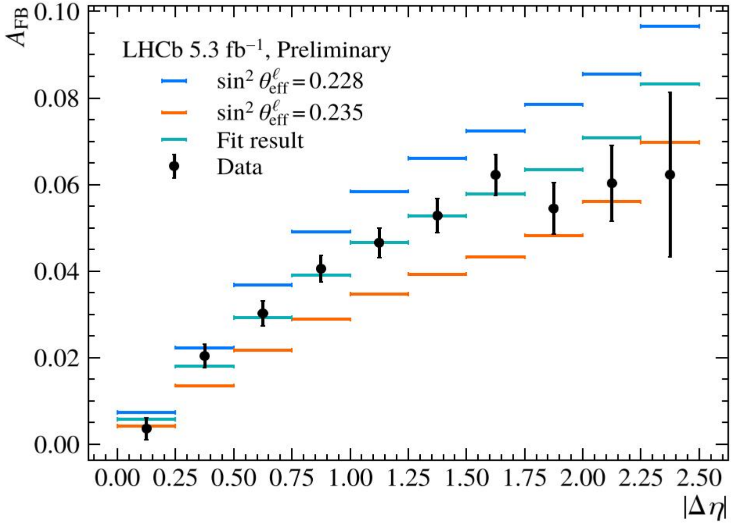
Eur. Phys. J. C (2024) 84



The effective leptonic weak mixing angle

- A fermion of charge (Q) and third weak-isospin component (I_3) has both vector and axial-vector couplings to the Z boson
    - vector coupling: $v = I_3 - 2Q\sin^2\theta_w$
    - axial-vector coupling: $a = I_3$
- Presence of vector and axial-vector couplings introduces $A_{\mathrm{FB}} = \frac{\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}}}{\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}}}$
- The linear term (A_{FB}) is sensitive to $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$, since it arises in the "cross term" between vector and axial-vector couplings

LHCb-PAPER-2024-028 in preparation

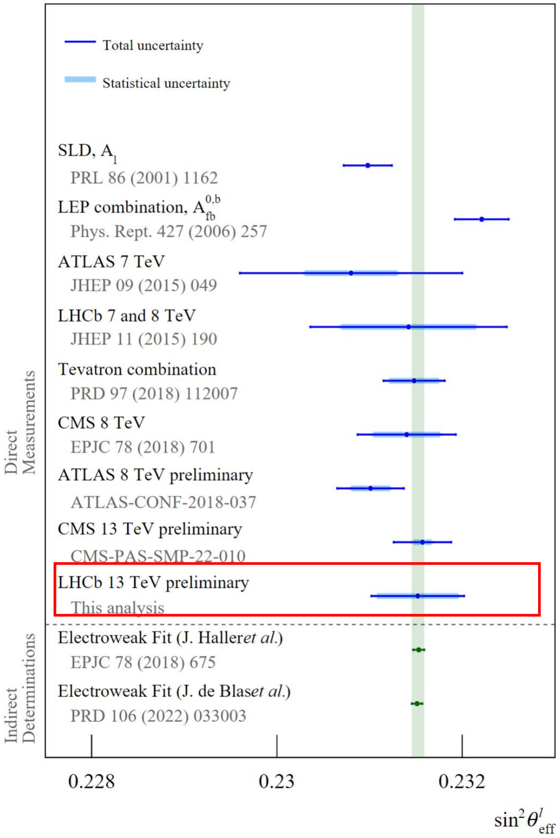


LHCb $\sin^2\theta^{\text{lept}}_{\text{eff}}$ measurement

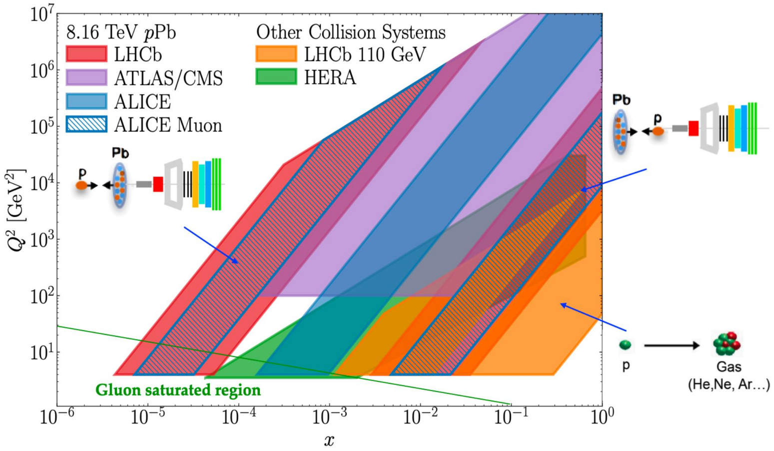
LHCb-PAPER-2024-028 in preparation

- A_{FB} in $pp \longrightarrow Z/\gamma^* \rightarrow \mu^+\mu^-$ is measured using LHCb 2016-2018 data within $\mathbf{2.0 < \eta_\mu < 4.5, p_T^\mu > 20\ GeV\ and\ 66 < M_{\mu\mu} < 116\ GeV}$
- $\sin^2\theta^{\text{lept}}_{\text{eff}}$ is extracted using predictions at NLO in the strong and EW couplings
- The result is consistent with other direct measurements and with predictions from the global EW fit

$$\mathbf{0.23152\ \pm 0.00044\ (stat.) \pm 0.00005\ (syst.) \pm 0.00022\ (theory)}$$



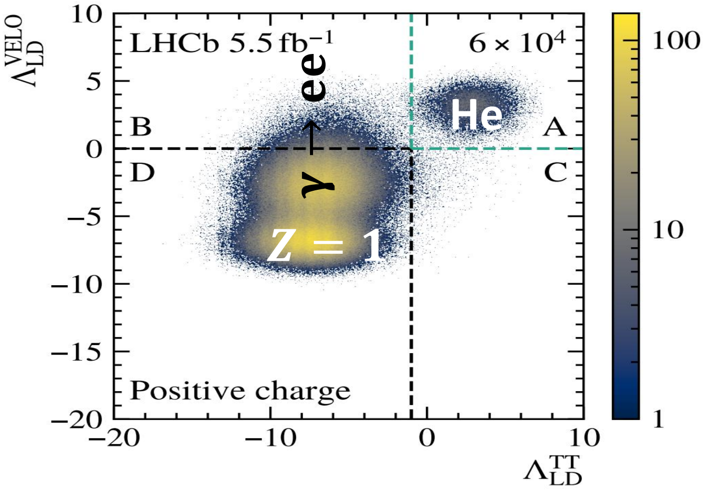
Recent LHCb results on Heavy ions (selected)



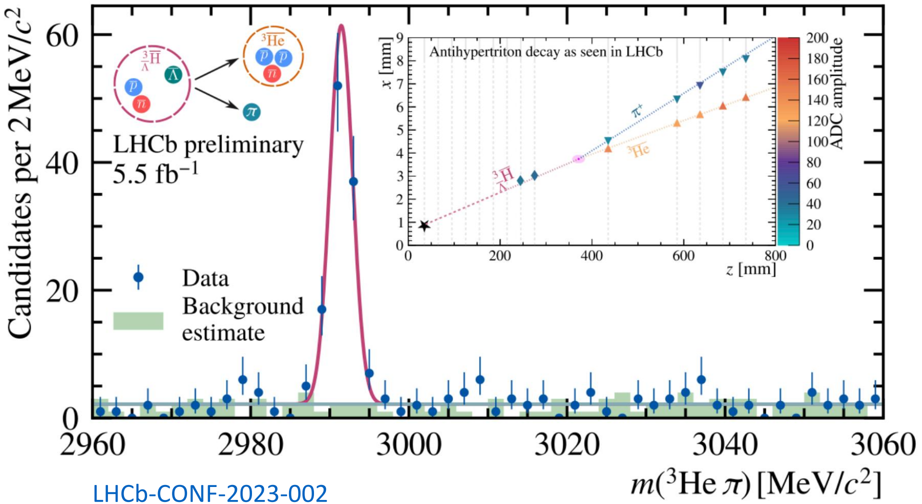
New area of physics with heavy ions and fixed targets

- The observation of antihelium in Cosmic Rays could be a signature of physics BSM
- LHCb can measure helium production in the forward region that is unexplored by other experiments

LHCb-DP-2023-002



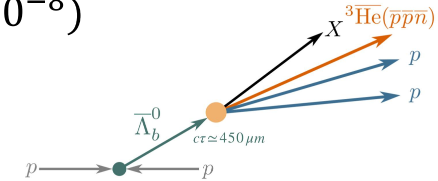
PoS EPS-HEP2023 (2024) 254

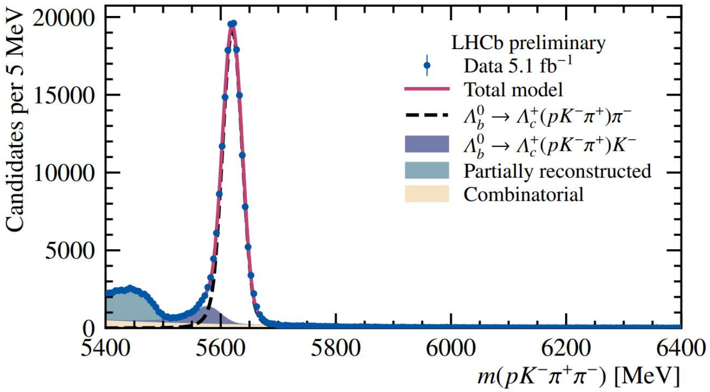


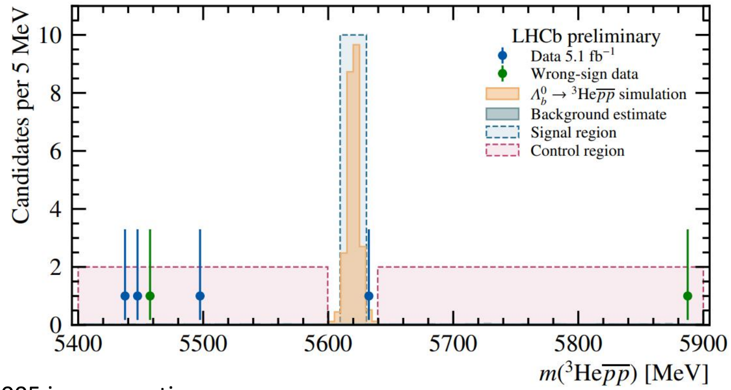
LHCb-CONF-2023-002

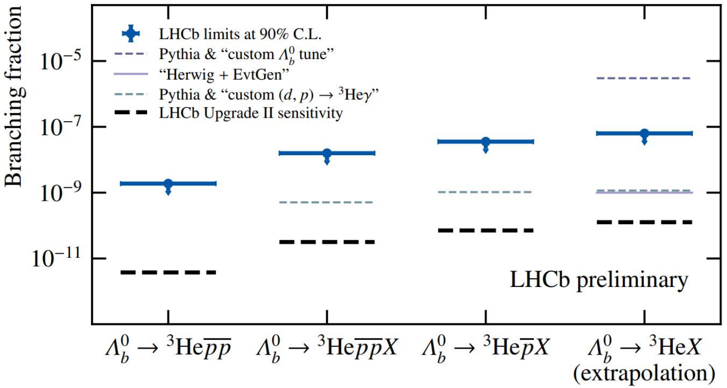
Antihelium production in $\overline{\Lambda}_b^0$ decays

- ~ $\mathcal{O}(10^{11})$ Λ_b^0 produced at 13TeV ⇒ measure Λ_b^0 branching fraction down to $\mathcal{O}(10^{-8})$









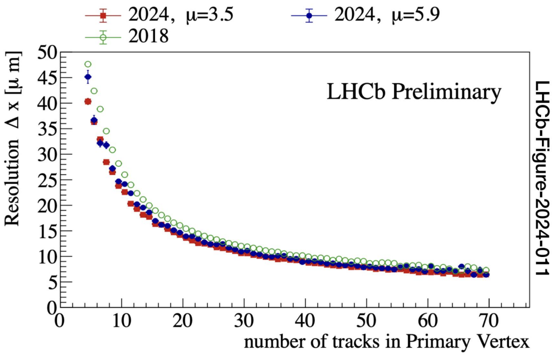
LHCb-PAPER-2024-005 in preparation

LHCb Upgrade I

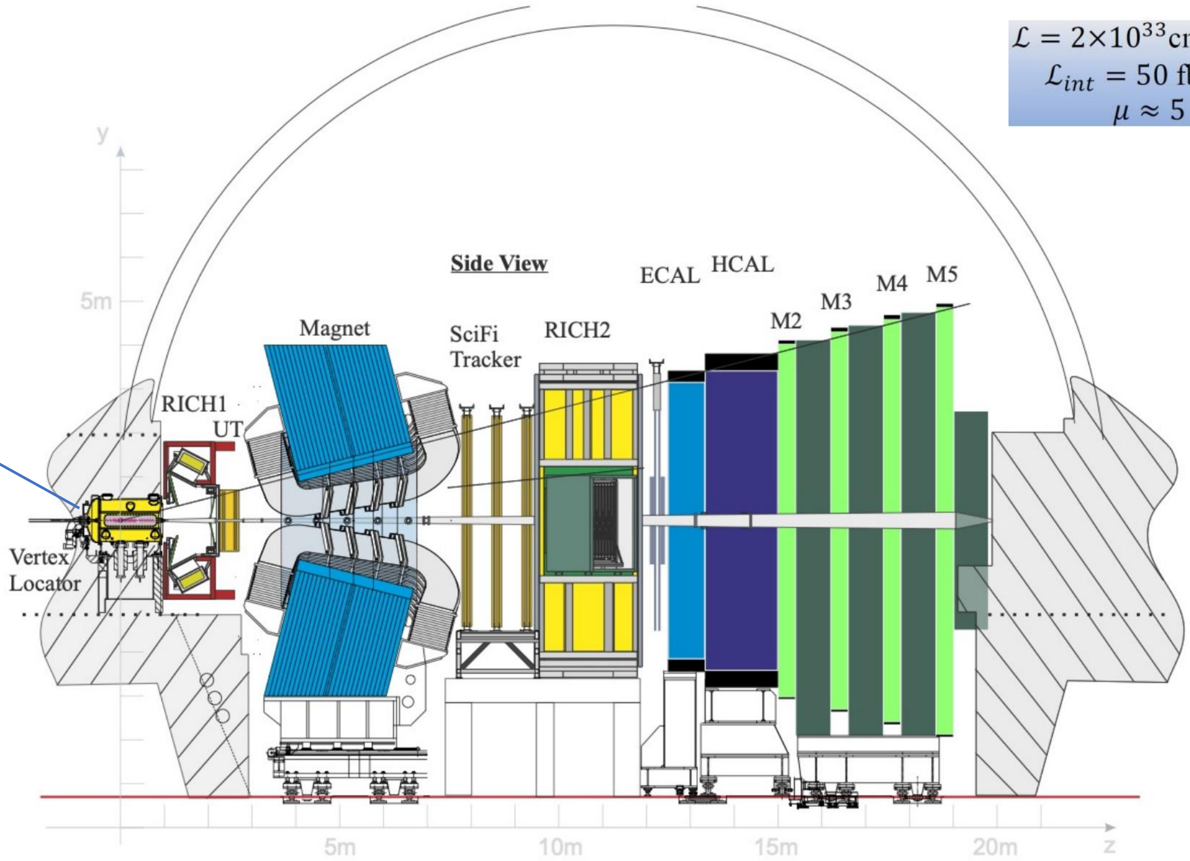
$\mathcal{L} = 2\times10^{33}\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 50\ \text{fb}^{-1}$
$\mu \approx 5$

New VELO Pixel detector leads to improved vertexing resolution

μ: the average number of visible pp interactions per bunch crossing



LHCb – FIGURE – 2024 – 011

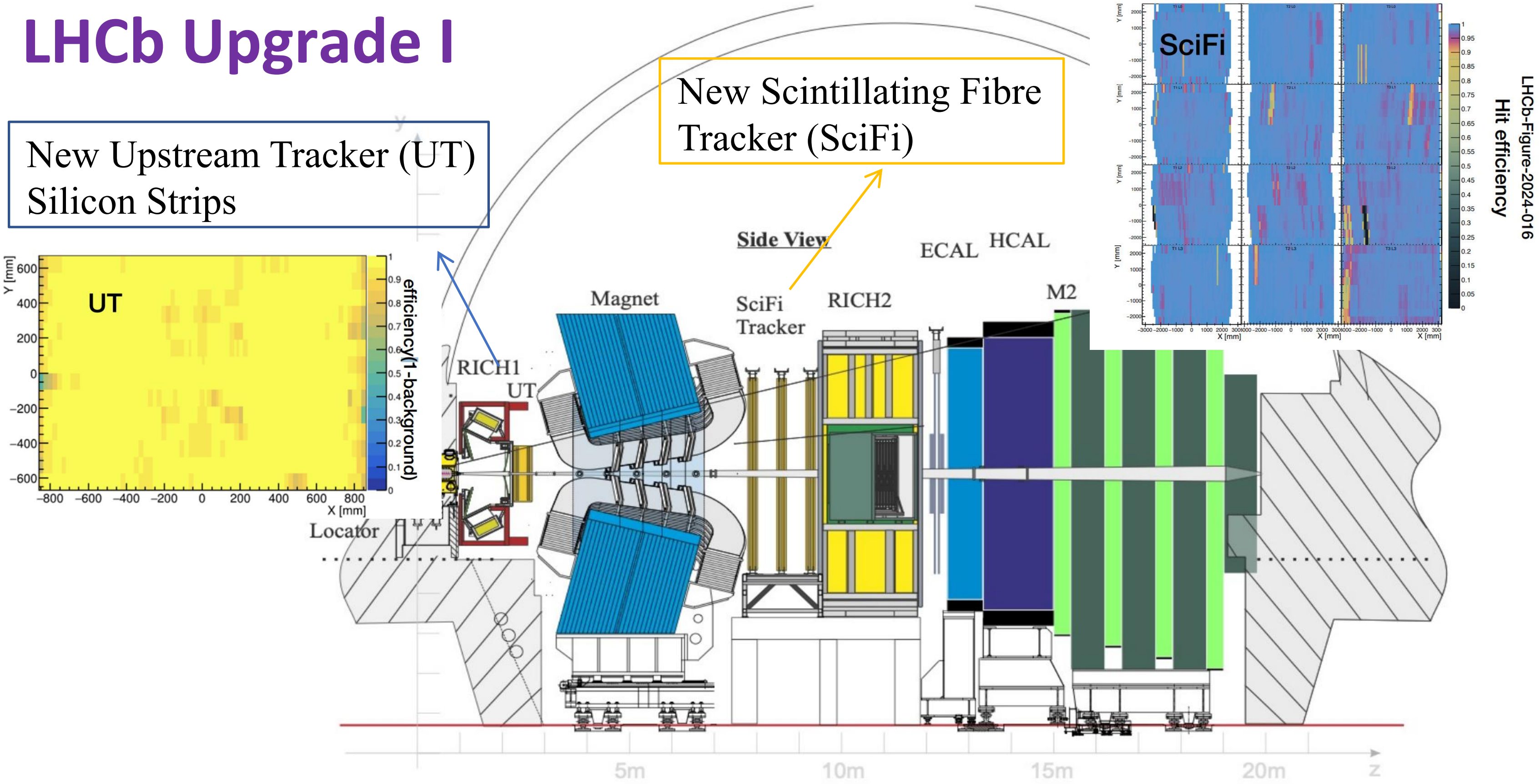


JINST 19 (2024) P05065

LHCb Upgrade I

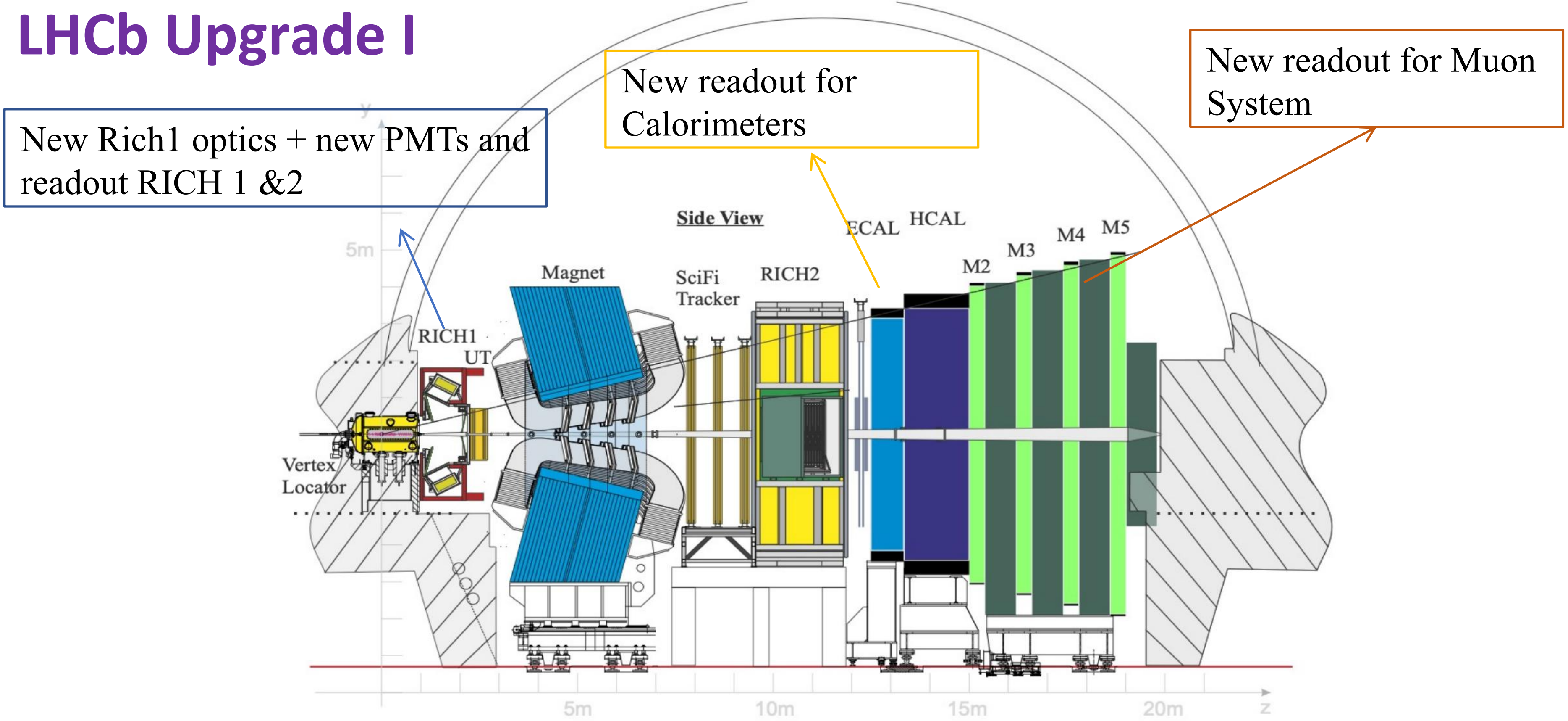
New Upstream Tracker (UT) Silicon Strips

New Scintillating Fibre Tracker (SciFi)



JINST 19 (2024) P05065

LHCb Upgrade I

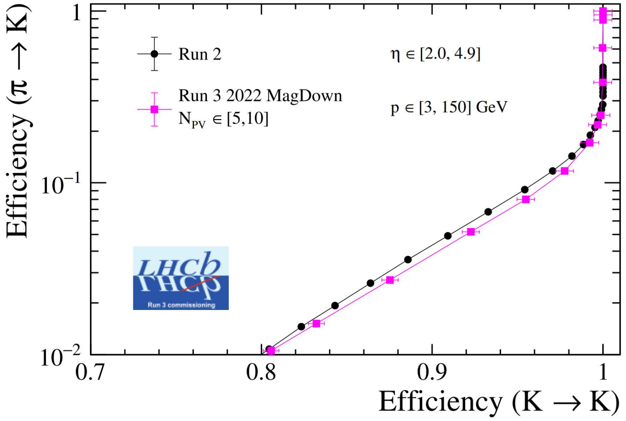


JINST 19 (2024) P05065

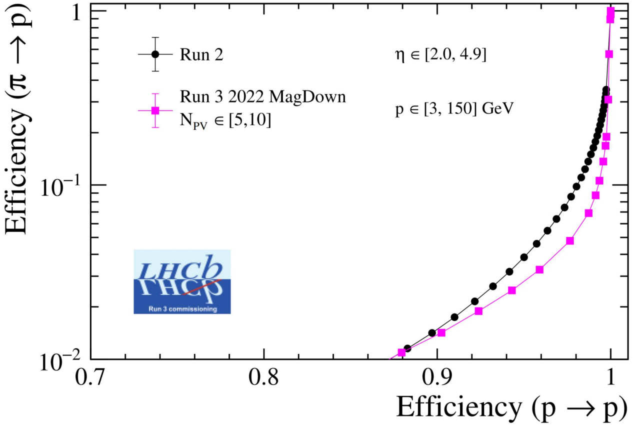
Better particle identification

muon ID performance maintained at higher pileup

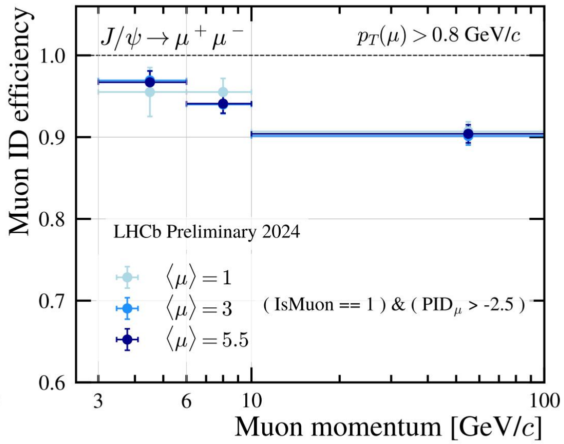
LHCb-Figure-2023-019



LHCb-Figure-2023-019



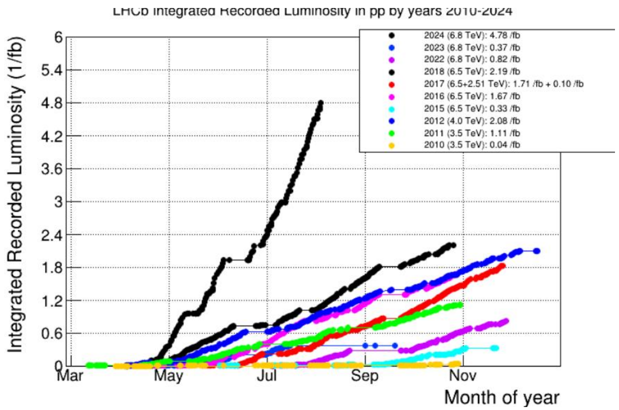
LHCb-Figure-2024-010

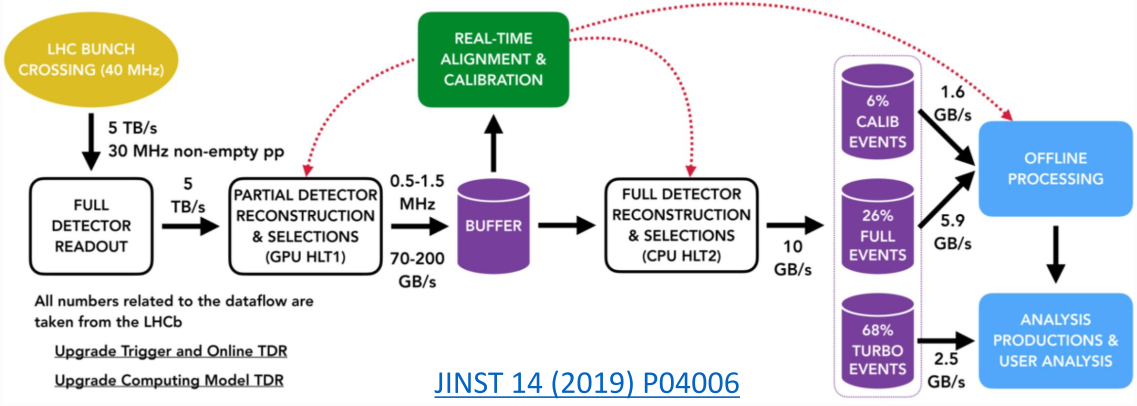


Improved hadron-ID

New triggering and processing

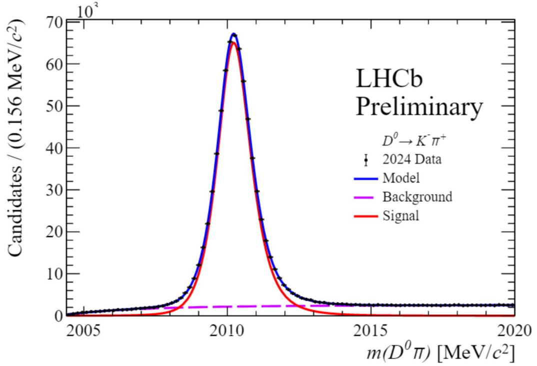
- Removal of L0 hardware trigger, readout at full 30MHz rate
- HLT1 based on GPUs
    - align and calibrate in real time and partial reconstruction
- HLT2 based on CPUs
    - full reconstruction and selection lines

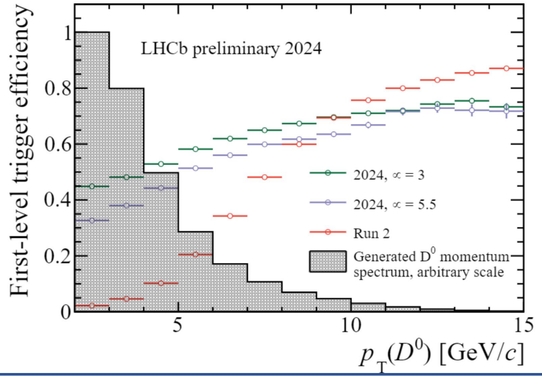




JINST 14 (2019) P04006

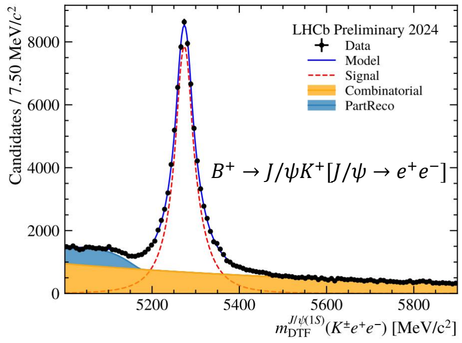
Run3 is here

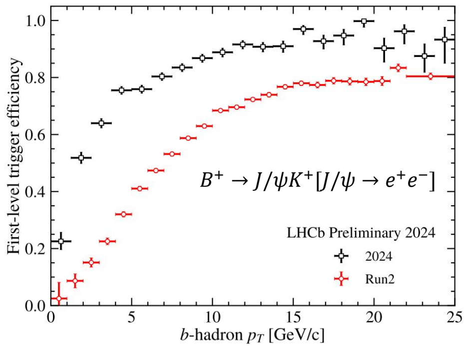




[LHCb-Figure-2024-006]

Improving charm reconstruction efficiency with respect to Run 2 at low values of p_T where most of the D^0 mesons are produced

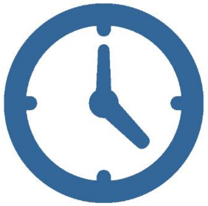




[LHCb-Figure-2024-007]

Huge improvement of trigger efficiency for elections together with higher luminosity will bring new opportunities for studies of rare decays

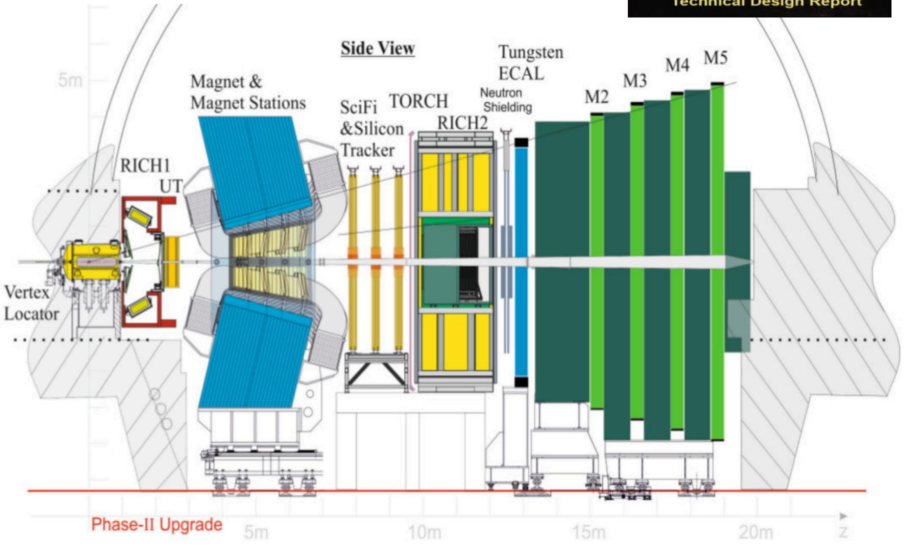
Upgrade II



$$\mathcal{L} = 1.5\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$
$$\mathcal{L}_{int} = 300\ \mathrm{fb}^{-1}$$
$$\mu \approx 40$$

LHCb-TDR-023

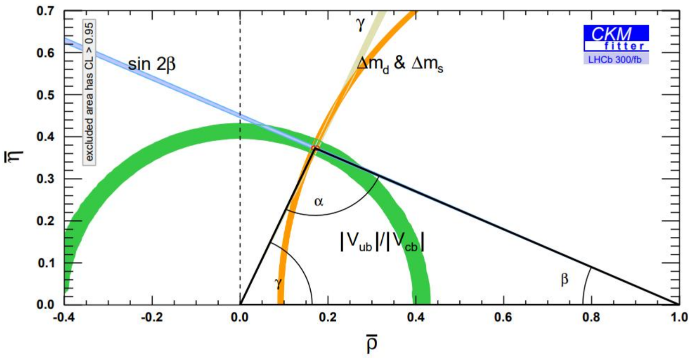
- Timing Cherenkov improve resolution
- Timing calorimeter improve reconstruction
- Timing Pixel detector
- Time-of-flight detector for low-p PID
- Add tracking stations in the magnet to increase efficiency for low-momentum tracks



Conclusion

- LHCb pushes flavour physics to a new frontier
- The LHCb programme is in constant evolution, more than a flavour detector
- Run3 is coming, detector is stably operating, more results are on the road
- Already preparing Upgrade II

LHCB-PUB-2018-009
arXiv:1808.08865



Very good opportunities to join!

WARWICK
THE UNIVERSITY OF WARWICK

Back up

Categories of CP violation

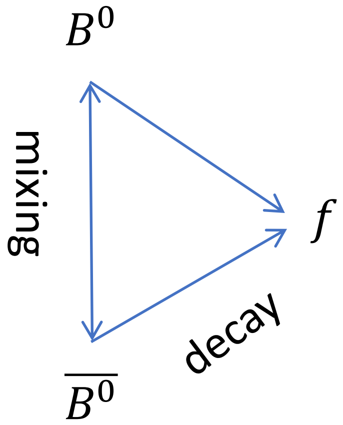
- CP violation in mixing

$$P(B^0 \to \overline{B^0}) \neq P(\overline{B^0} \to B^0)$$

- CP violation in decay

$$P(B^0 \to f) \neq P(\overline{B^0} \to \bar{f})$$

- CP violation in interference between mixing and decay



SMOG

LHCb-FIGURE-2024-005

- LHCb can inject gas into the beam pipe to act as a fixed target collision experiment
- Successfully collected samples in different fixed-target-configurations