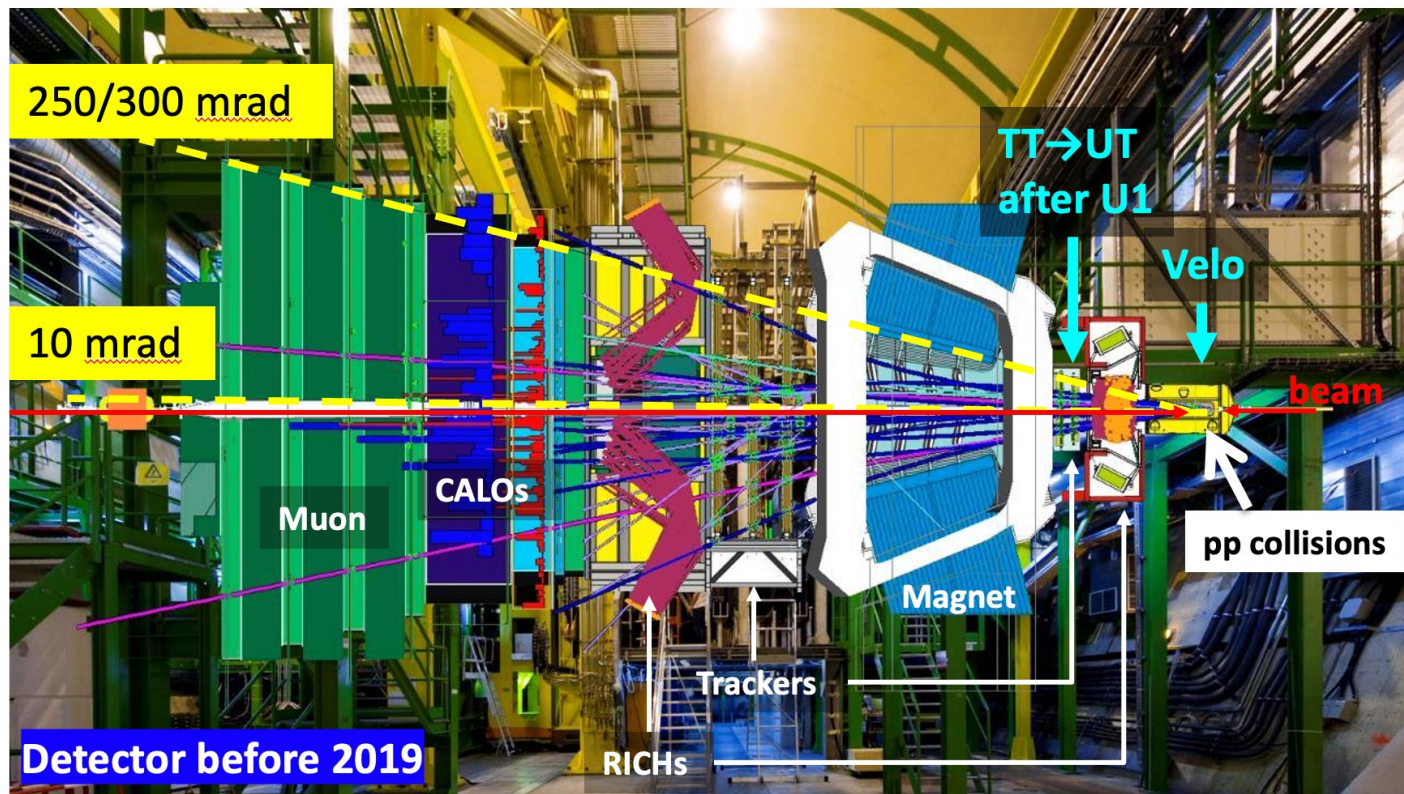


Recent highlights of LHCB

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2026-03-28



$$\mathcal{L}_{\text{inst}} = (2\sim 4) \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \text{ before 2019}$$

Vertex	$\sigma_{\text{IP}} = 20 \mu\text{m}$
Time	$\sigma_{\tau} = 45 \text{ fs}$ for $(B_s \rightarrow J/\psi\phi)$ or $D_s^+ \pi^-$
Momentum	$\Delta p/p = 0.4\sim 0.6 \%$ @ $(5 - 100 \text{ GeV}/c)$
Mass	$\sigma_m = 8 \text{ MeV}/c^2$ for $B \rightarrow J/\psi X$ (constrained $m_{J/\psi}$)
Hadron ID	$\epsilon(K \rightarrow K) \sim 95\%$; mis-ID $\epsilon(\pi \rightarrow K) \sim 5\%$
Muon ID	$\epsilon(\mu \rightarrow \mu) \sim 97\%$; mis-ID $\epsilon(\pi \rightarrow \mu) \sim 1 - 3\%$
ECAL	$\Delta E/E = 1 \oplus 10\%/\sqrt{E(\text{GeV})}$

JINST 3 (2008) S08005

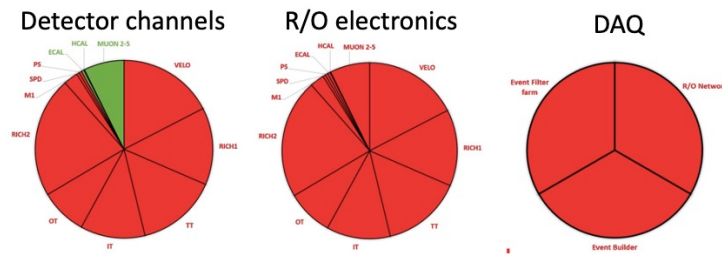
Int. J. Mod. Phys. A 30 (2015) 1530022

Upgrade I: a brand new detector



Readout at the LHC
bunch xing rate (40 MHz)

To be upgraded
To be kept



Higher luminosity ($5 \times \mathcal{L}_{\text{Run1\&2}}$) results in

- Higher rate, pile up, occupancy, fluence

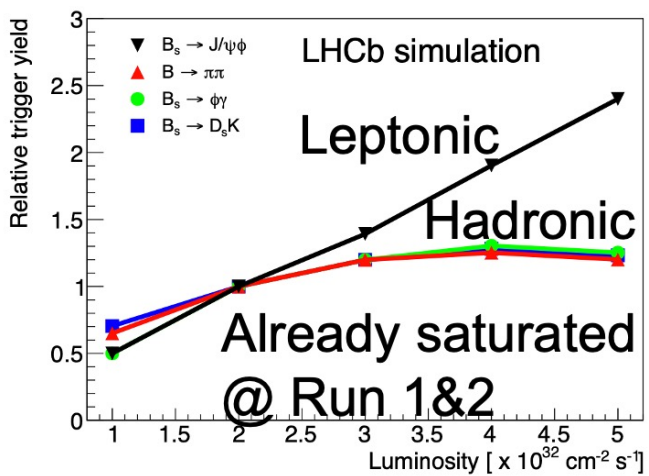
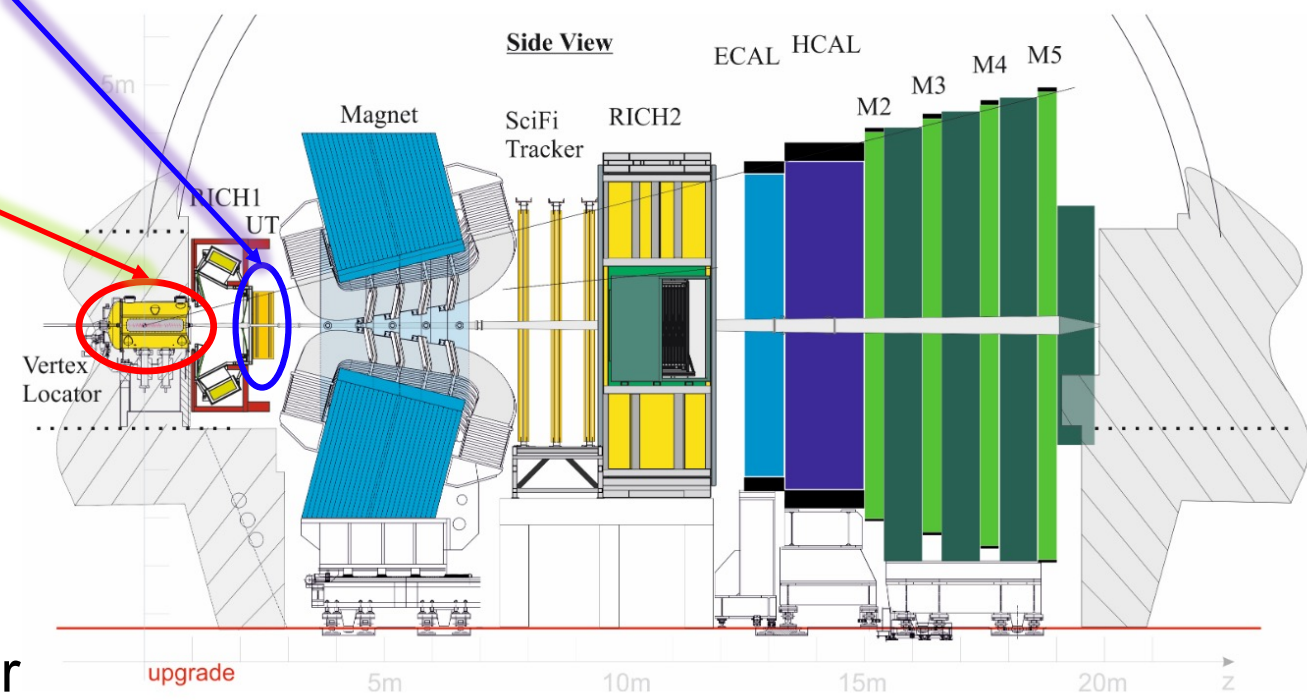
New tracking system

- **VertexLocator (VELO)**, **Upstream Tracker (UT)** and **Scintillating Fiber Tracker (SciFi)**

RICHs: New optics + photon detectors

Calos: Reduce PMT gain + new electronics

MUON: new electronics

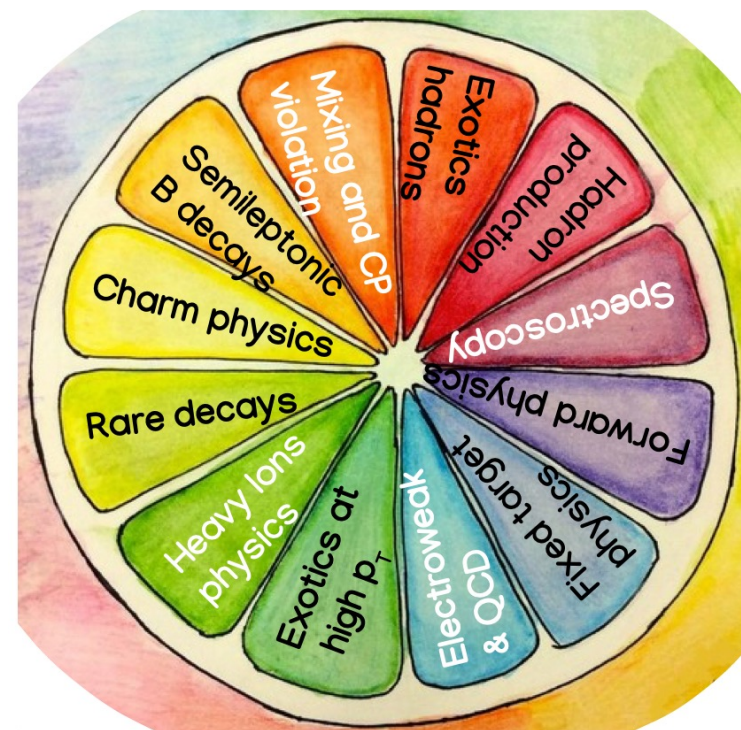
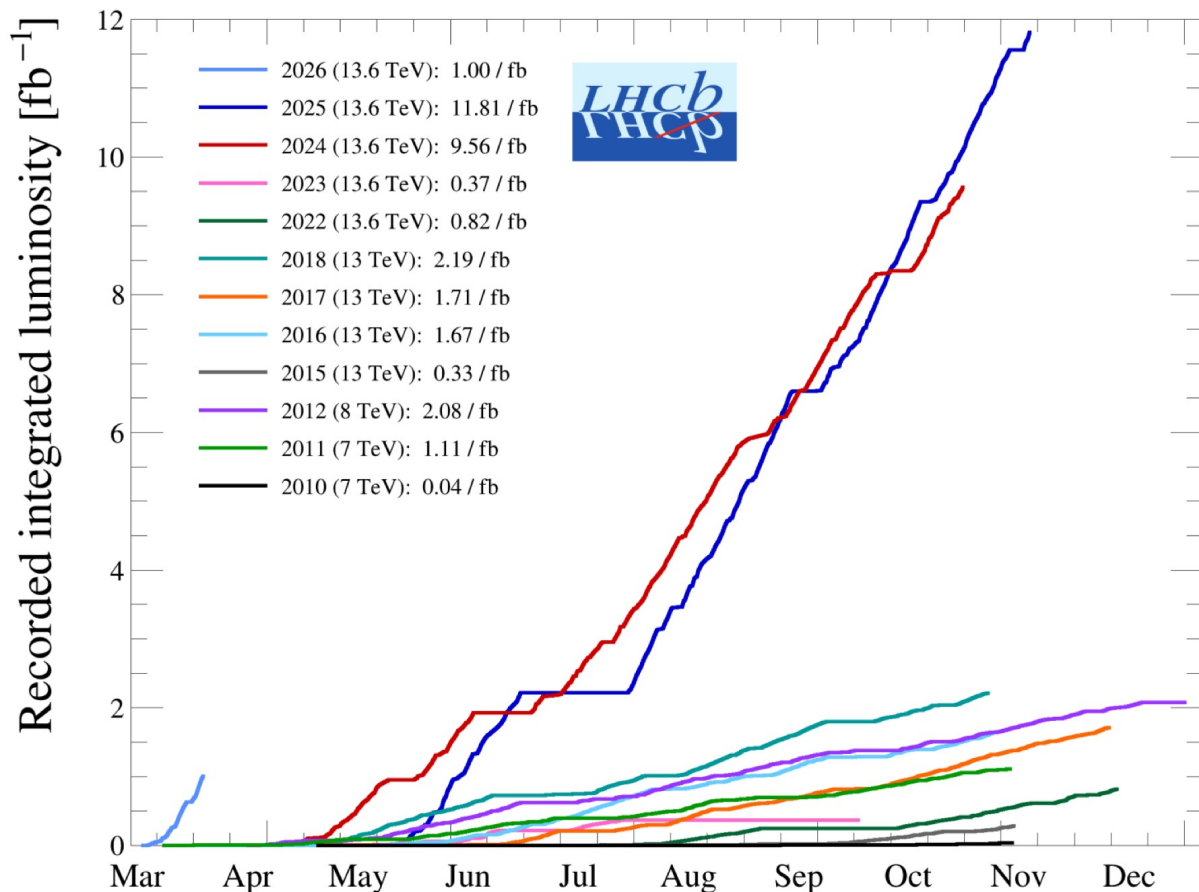


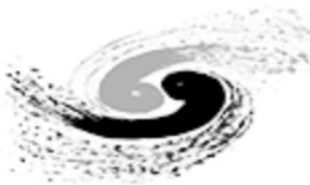
No hardware trigger

- 1st GPU trigger in a HEP experiment



A decade of important discoveries and precision measurements





Selected topics

➤ Spectroscopy

Ξ_{cc}^+

参考俞杰晟、杜大佑的报告

➤ Rare decay (FCNC)

Branching fractions

Angular analyses

CP asymmetries

LFU tests

➤ CP violation

γ

CPV measurement

Double charmed baryon Ξ_{cc}^+

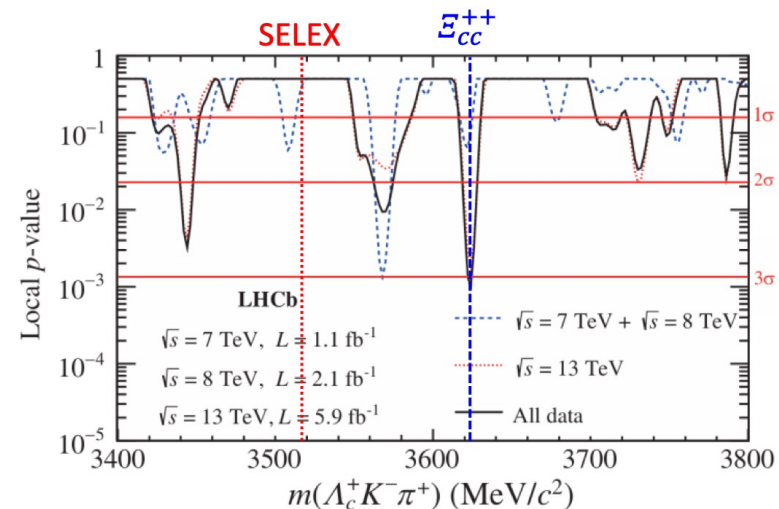
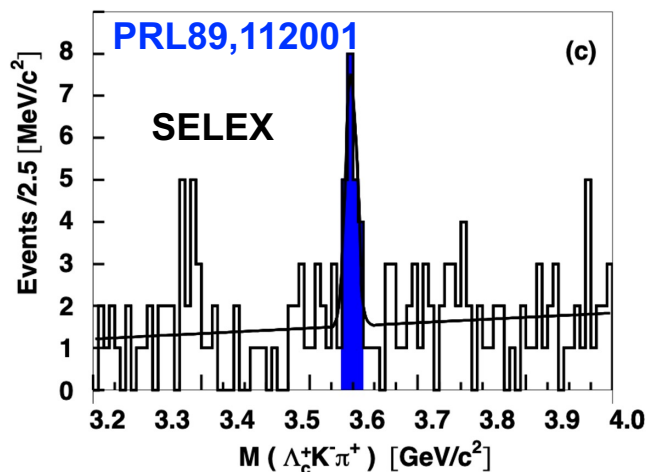
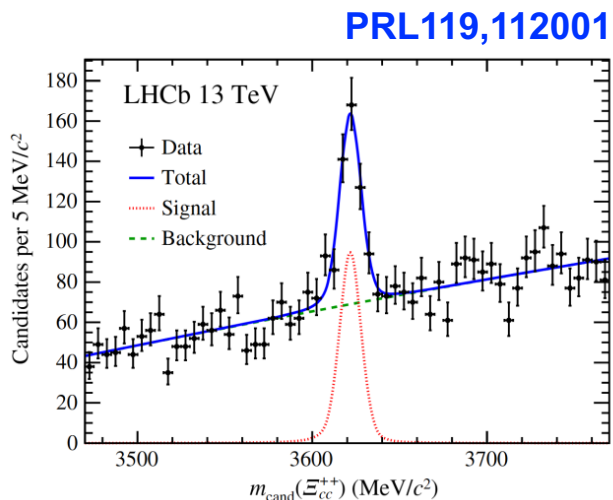
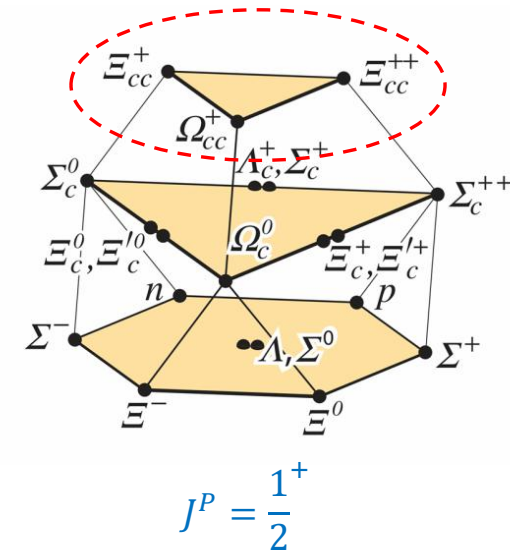


Isospin doublet $\Xi_{cc}^+(ccd)$, $\Xi_{cc}^{++}(ccu)$ and isospin singlet $\Omega_{cc}^+(ccs)$

- Ξ_{cc}^{++} observed with $\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+$ in 2017 [PRL119,112001](#)
- $M(\Xi_{cc}^{++}) = 3621.55 \pm 0.23 \pm 0.30$ MeV [JHEP02\(2020\)049](#)
- $\tau(\Xi_{cc}^{++}) = 256_{-22}^{+24} \pm 14$ fs [PRL121,052002](#)

Previous search for Ξ_{cc}^+ :

- SELEX: 3518.7 ± 1.7 MeV \Rightarrow not confirmed by other experiments [PRL89,112001](#)
- LHCb: $\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$ full Run1 + Run2 data ($\mathcal{L} = 9.0$ fb $^{-1}$)
 - ❑ 3σ local significance near observed Ξ_{cc}^{++} mass peak [SCPMA63\(2020\)221062](#)



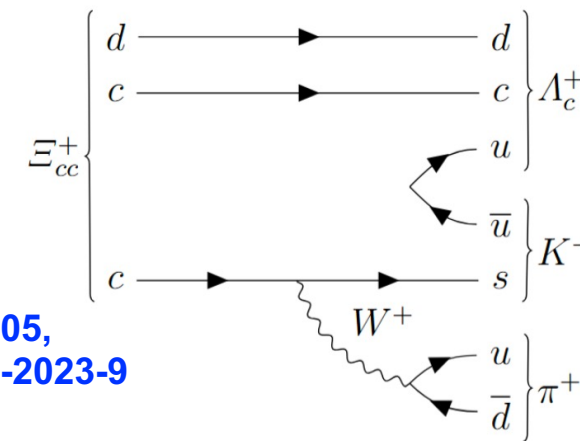


$\Xi_{cc}^+ \rightarrow \Lambda_c^+ K^- \pi^+$ ($\Lambda_c^+ \rightarrow p K^- \pi^+$) with 6.9 fb^{-1} data taken in 2024

$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ K^- \pi^+ \pi^+$ as control channel to study about uncertainties and cross-check the performance of the detectors

- Event selection of Ξ_{cc}^+ is very similar to Ξ_{cc}^{++} , expect one less pion and shorter lifetime

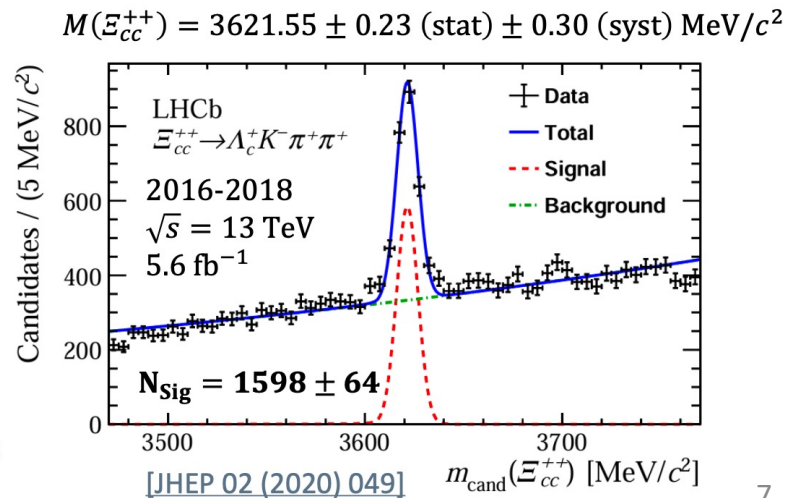
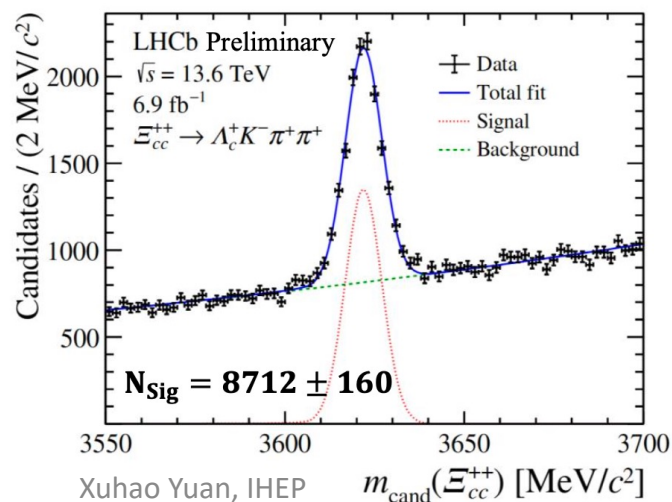
- $\tau(\Xi_{cc}^+)$ assumed in the range (15 ~ 160) ps based on $\tau(\Xi_{cc}^{++})/\tau(\Xi_{cc}^+)$ predictions and $\tau(\Xi_{cc}^{++})$ measured by LHCb [PRD98,113005, RBI-ThPhys-2023-9](#) and [PRL121,052002](#)



Run2 data (2016-2018) as cross check

Validation with control channel

- Signal yield per fb^{-1} : 1262 (2024) vs 285 (Run2)
- Efficiency x4, compared with Run2
- $M_{cc}^{++} = 3621.74 \pm 0.10 \text{ MeV}$, consistent with Run2 result





No fake peak in the WS sample, or at $m(\Xi_{cc}^+)$ reported by SELEX

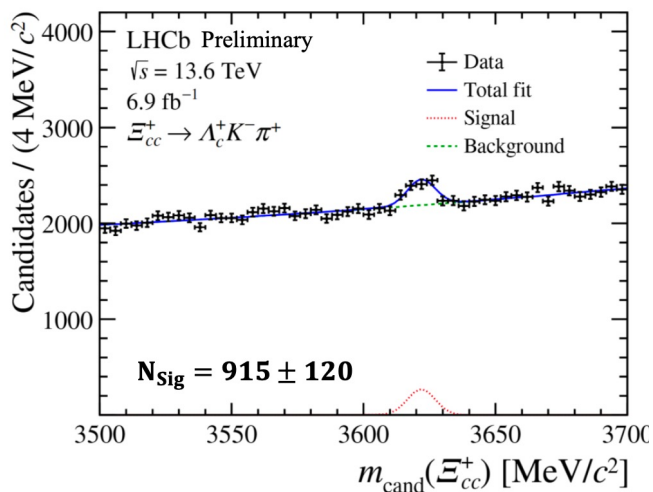
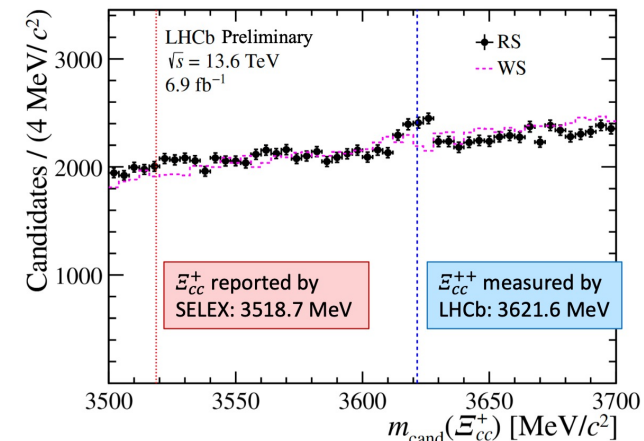
The local significance around 3622 MeV exceeds 7σ , evaluated with a likelihood ratio test

Precise measurement

- Correct the mass bias caused by event selection and final-state photon radiation

$$m(\Xi_{cc}^+) = 3619.97 \pm 0.83 \pm 0.26_{-1.30}^{+1.90} \text{ MeV}$$

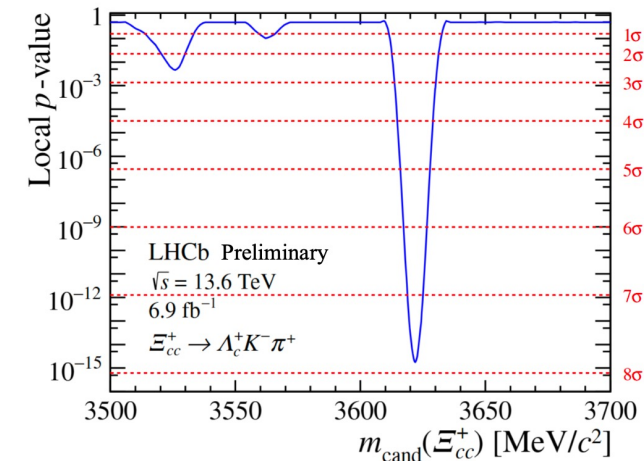
$$\Delta m = m(\Xi_{cc}^+) - m(\Xi_{cc}^{++}) = -1.77 \pm 0.84 \pm 0.15_{-1.30}^{+1.90} \text{ MeV}$$



Systematic uncertainties (in MeV/c^2) on the $M(\Xi_{cc}^+)$ mass and mass difference ΔM

Source	$M(\Xi_{cc}^+)$	ΔM
Momentum-scale calibration	0.14	0.03
Energy loss	0.10	0.05
Selection bias correction	0.10	0.10
Mass fit model	0.10	0.10
Λ_c^+ mass uncertainty	0.14	–
Sum in quadrature	0.26	0.15
Unknown Ξ_{cc}^+ lifetime	$+1.90$ -1.30	$+1.90$ -1.30

The bias due to event selection strongly depends on the lifetime.





Selected topics

- Spectroscopy
 - Ξ_{cc}^+
- **Rare decay (FCNC)**
 - Branching fractions**
 - Angular analyses**
 - CP asymmetries
 - LFU tests
- CP violation
 - γ
 - CPV measurement

参考孙亮的报告

FCNC decays as sensitive probe for NP



FCNC decays heavily (loop-) suppressed in SM

New heavy particles can significantly contribute and effect decay rates, angular distributions ...

Description in effective field theory

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \sum_i C_i O_i$$

Local operator O_i (green box)
Wilson coefficient ("effective coupling") C_i (blue box)

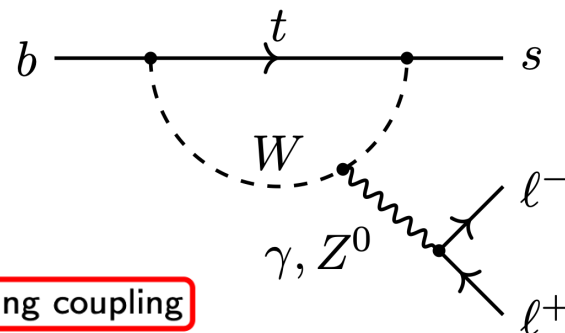
$$\Delta\mathcal{H}_{\text{NP}} = \frac{\kappa}{\Lambda_{\text{NP}}^2} O_i$$

Flavour-violating coupling κ (red box)
NP scale Λ_{NP} (red box)

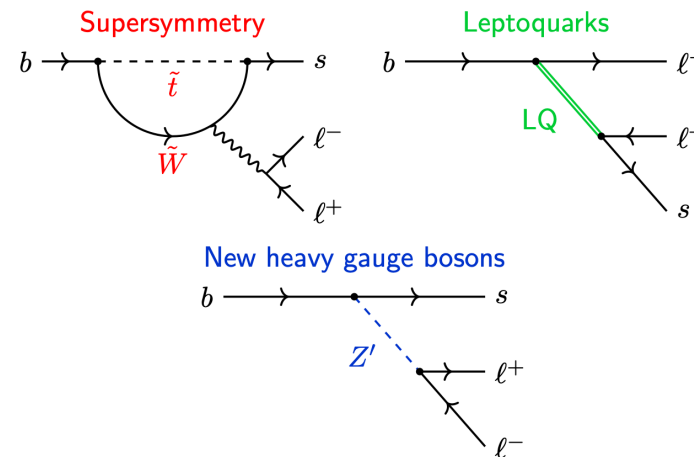
Rare B decays allow to probe $O_i^{(\text{NP})}$
 Λ_{NP} up to $\mathcal{O}(100 \text{ TeV})$ reachable

JHEP 11 (2014) 121

$b \rightarrow sll$ decays in the SM



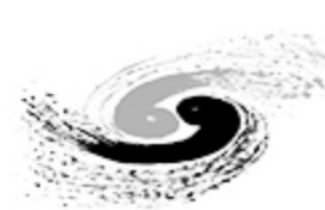
Possible contributions from NP



	Wilson coefficient	Operator
γ -penguin ¹	$C_7^{(l)}$	$\frac{e}{g^2} m_b (\bar{s} \sigma_{\mu\nu} P_{R(L)} b) F^{\mu\nu}$
ew. penguin	$C_9^{(l)}$	$\frac{e^2}{g^2} (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{l} \gamma^\mu l)$
	$C_{10}^{(l)}$	$\frac{e^2}{g^2} (\bar{s} \gamma_\mu P_{L(R)} b) (\bar{l} \gamma^\mu \gamma_5 l)$
scalar	$C_S^{(l)}$	$\frac{e^2}{16\pi^2} m_b (\bar{s} P_{R(L)} b) (\bar{l} l)$
pseudoscalar	$C_P^{(l)}$	$\frac{e^2}{16\pi^2} m_b (\bar{s} P_{R(L)} b) (\bar{l} \gamma_5 l)$

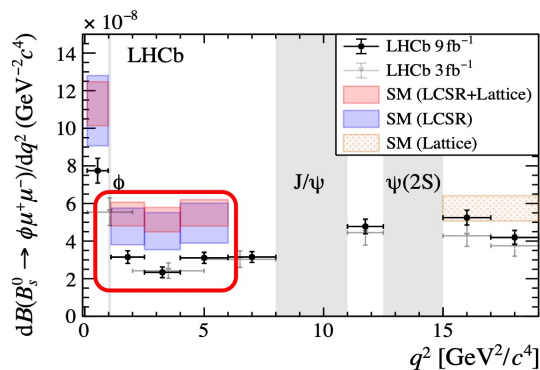
$b \rightarrow s \gamma$
 $B_s^0 \rightarrow \mu^+ \mu^-$
 $b \rightarrow sll$

Consistently low \mathcal{B} for $b \rightarrow s\mu^+\mu^-$ decays

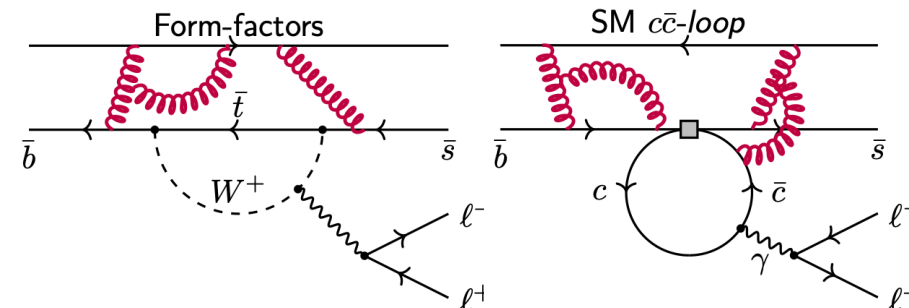
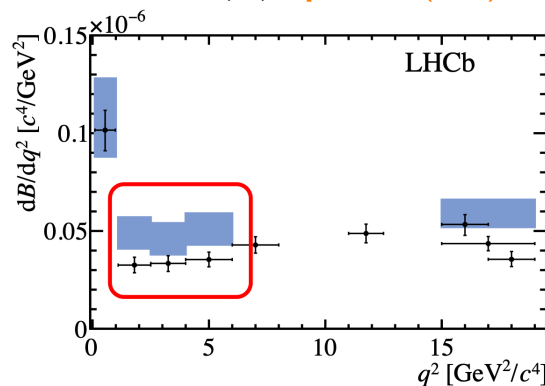


Data consistently below SM predictions, tensions at 1 – 3 σ level
 Significant hadronic uncertainties from form-factor and charm-loop

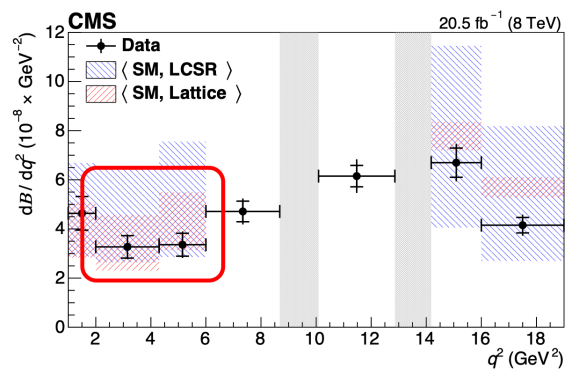
LHCb $B_s^0 \rightarrow \phi\mu^+\mu^-$ [PRL 127 (2021) 151801]



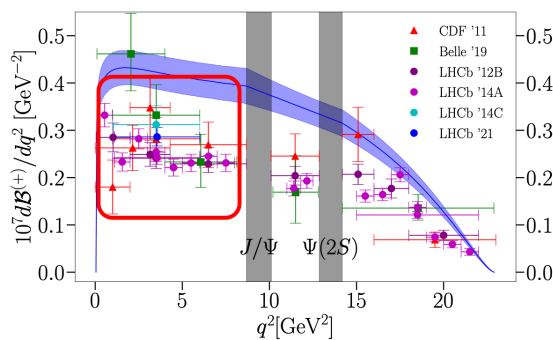
LHCb $B^0 \rightarrow K^{*0}\mu^+\mu^-$ [JHEP 11 (2016) 047]



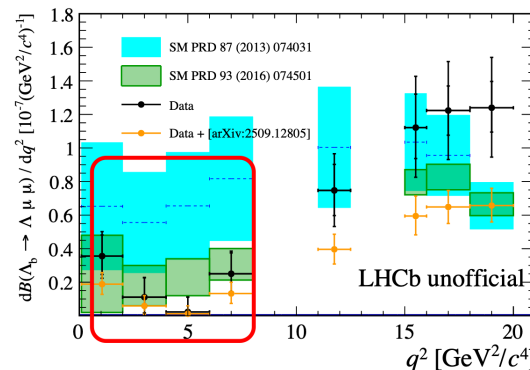
CMS $B^0 \rightarrow K^{*0}\mu^+\mu^-$ [PLB 753 (2016) 424]



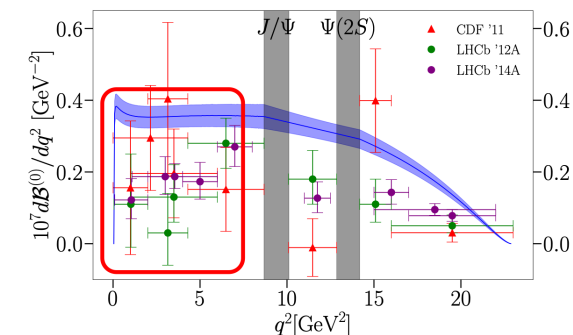
$B^+ \rightarrow K^+\mu^+\mu^-$ [HPQCD, PRD 107 (2023) 1]

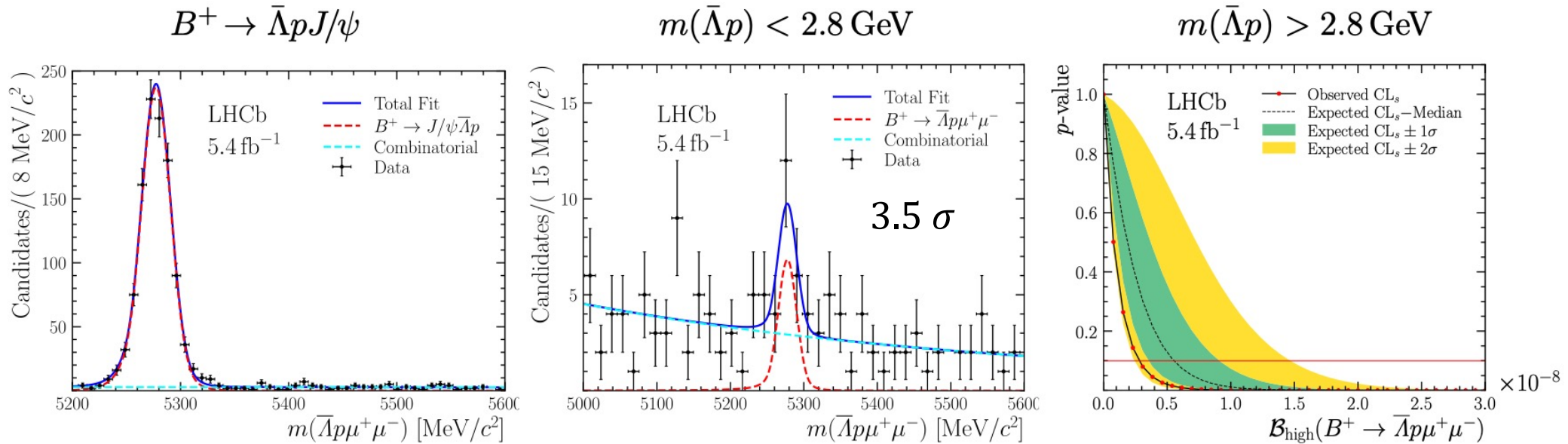
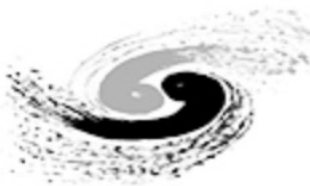


LHCb $\Lambda_b^0 \rightarrow \Lambda\mu^+\mu^-$ [JHEP 06 (2015) 115]



$B^0 \rightarrow K^0\mu^+\mu^-$ [HPQCD, PRD 107 (2023) 1]





- $b \rightarrow s \mu^+ \mu^-$ meson decay with baryonic final state, norm. to $B^+ \rightarrow \bar{\Lambda} p J/\psi$
- Studied in two region $m(\bar{\Lambda} p) < 2.8 \text{ GeV}$ and $m(\bar{\Lambda} p) > 2.8 \text{ GeV}$
 - ❑ $\mathcal{B} = (1.70_{-0.56}^{+0.65} \pm 0.17 \pm 0.14) \times 10^{-8}$ (for $m(\bar{\Lambda} p) < 2.8 \text{ GeV}$)
 - ❑ $\mathcal{B} < 2.8 \times 10^{-9}$ at 90% CL (for $m(\bar{\Lambda} p) > 2.8 \text{ GeV}$)
- In agreement with, but 2σ below SM prediction $1.08_{-0.51}^{+0.82} \times 10^{-7}$

A comprehensive analysis of $B^0 \rightarrow K^{*0} \mu^+ \mu^-$



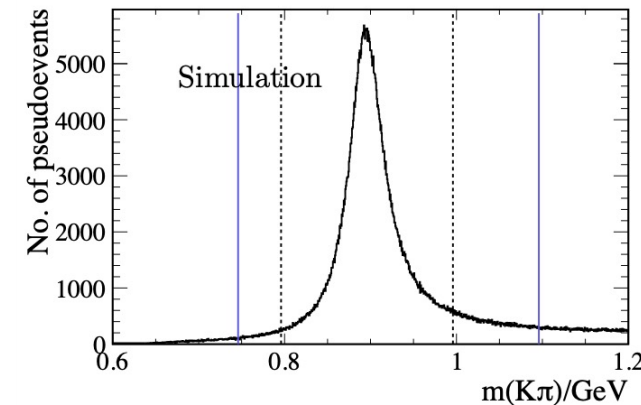
arXiv: 2512.18053

More data

- Full Run 1+2 data, $4.7 \text{ fb}^{-1} \Rightarrow 8.4 \text{ fb}^{-1}$ (signal yield: 4.6 K \Rightarrow 12.4 K)
- Large $m_{K\pi}$ mass window and more optimized selection

More observables from 5D fit

- P-wave, S-wave + interference observables, as well as CP asymmetries
- Provide branching fraction measurement and full set of correlations

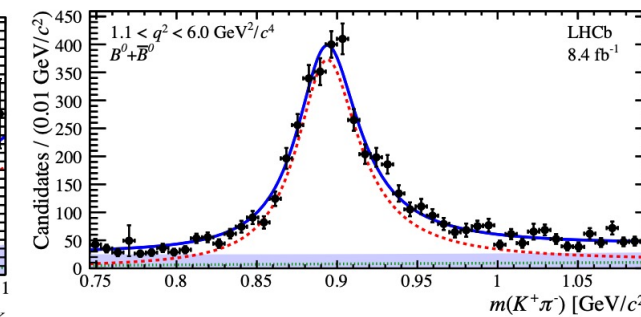
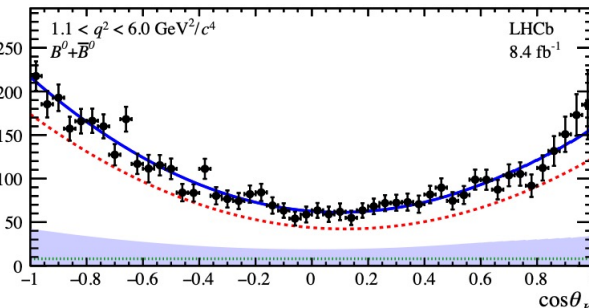
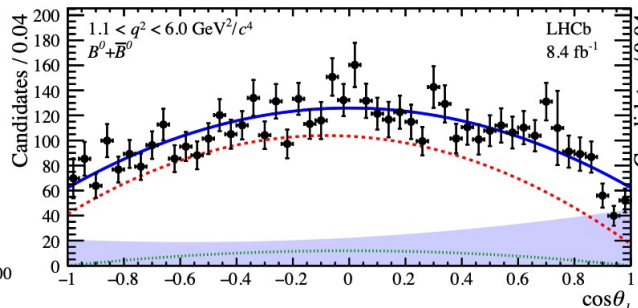
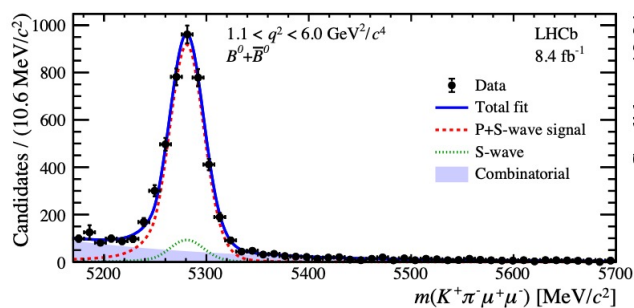
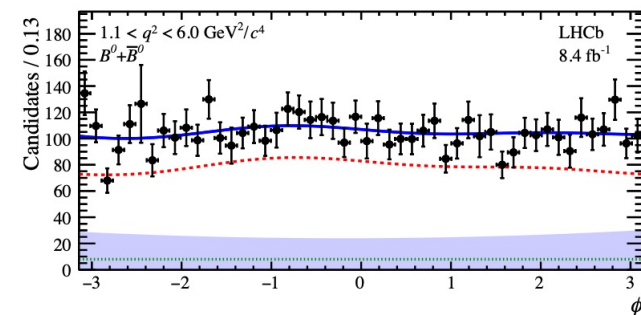


$$\frac{1}{d(\Gamma + \bar{\Gamma})/dq^2} \frac{d^5 \bar{\Gamma}}{dq^2 dm_{K\pi} d\vec{\Omega}} = (1 - \hat{F}_S) \frac{9}{64\pi} \sum_i (S_i \pm A_i) f_i(\vec{\Omega}) |\mathcal{BW}_P(m_{K\pi})|^2 \quad \text{P-wave}$$

$$+ \frac{1}{8\pi} \sum_j (\tilde{S}_j \pm \tilde{A}_j) f_j(\vec{\Omega}) F(m_{K\pi}) \quad \text{S-wave+interference}$$

Few assumptions

- No longer assume massless leptons throughout
- Branching fraction extracted without model assumptions

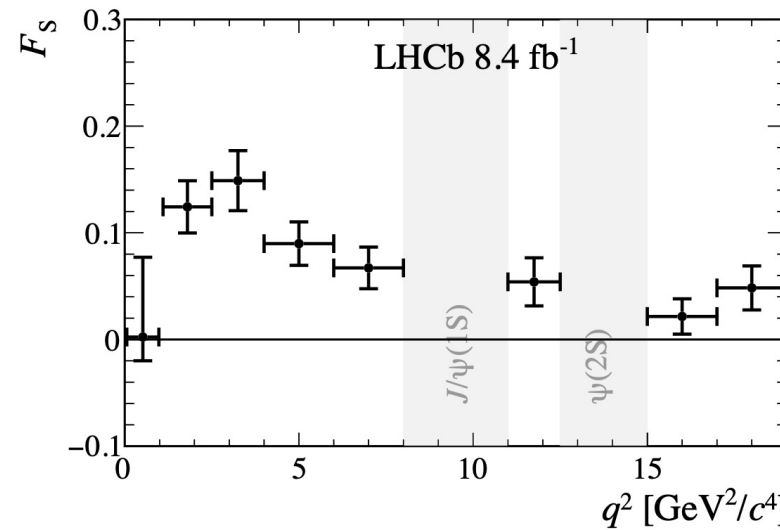
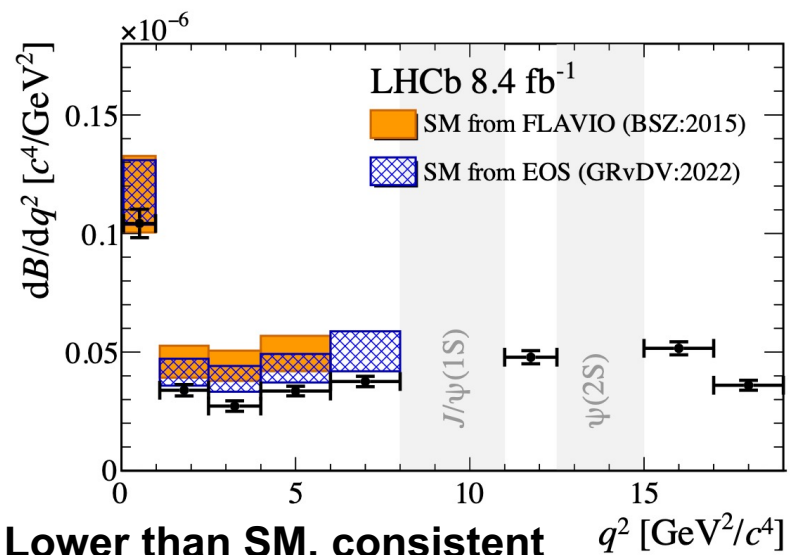
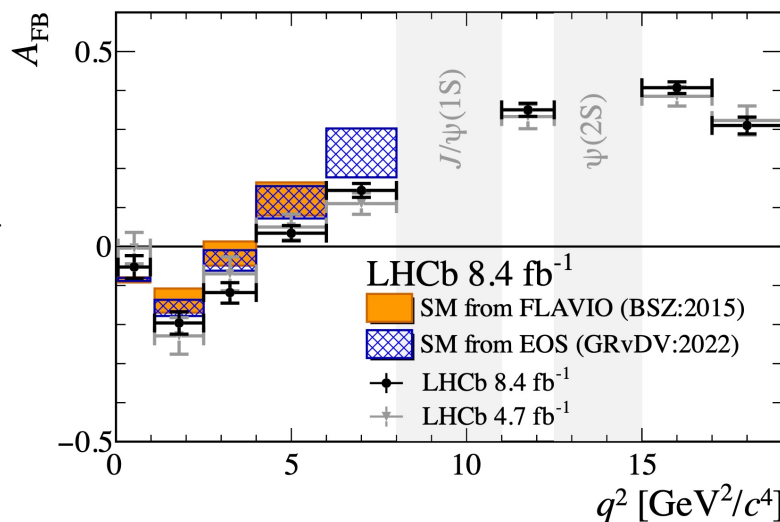
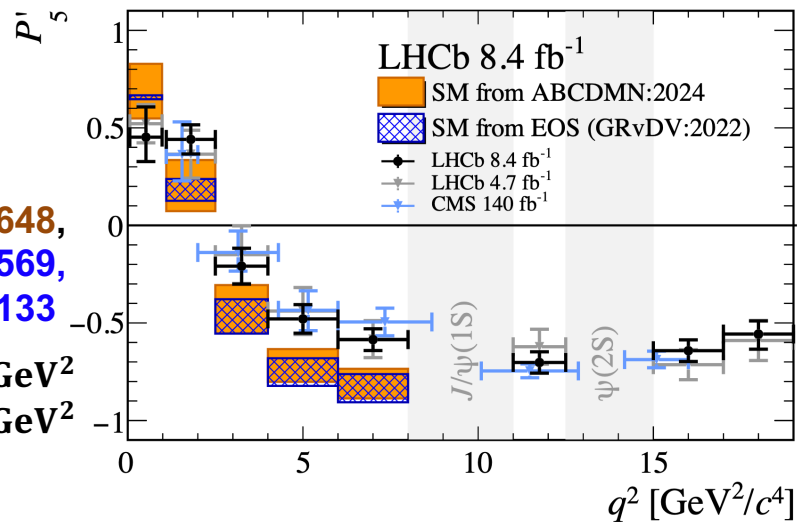




EPJC83(2023)648,
EPJC82(2022)569,
JHEP09(2022)133

arXiv:1810.08132,
JHEP08(2016)098,
EPJC82(2022)569,
JHEP09(2022)133

2.5 (2.2) σ in [2.5, 4] GeV^2
1.9 (1.7) σ in [4, 6] GeV^2



Lower than SM, consistent
with other $b \rightarrow s\mu\mu$

No prediction available for
 F_S and other S-
wave/interference obs.



Selected topics

➤ Spectroscopy

Ξ_{cc}^+

参考俞杰晟、杜大佑的报告

➤ Rare decay (FCNC)

Branching fractions

Angular analyses

CP asymmetries

LFU tests

参考孙亮的报告

➤ **CP violation**

γ

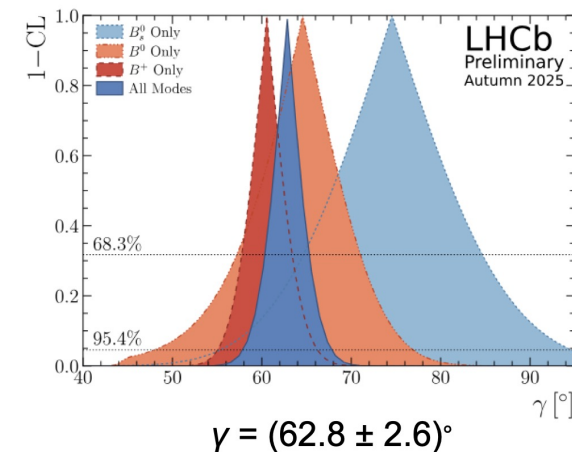
CPV measurement

参考胡晓凡的报告

CKM angle γ



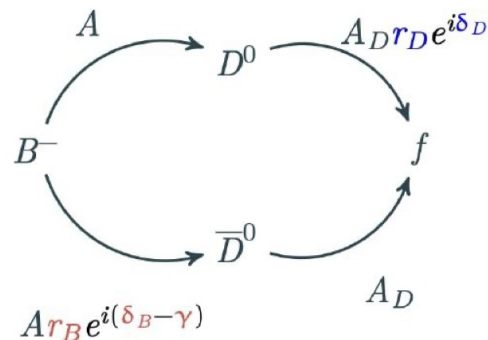
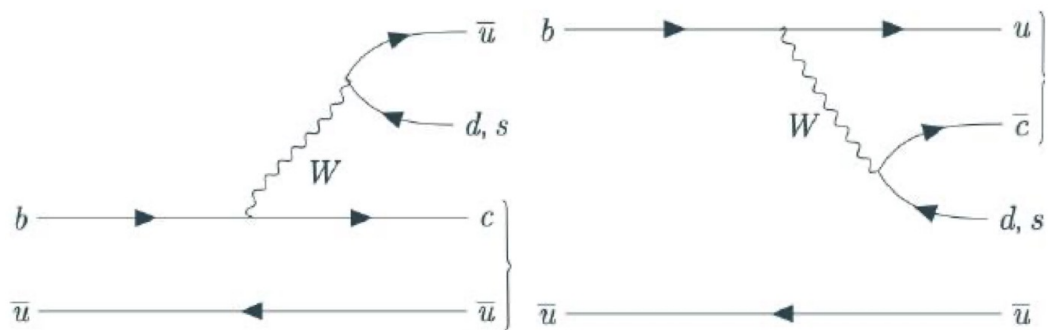
- At LHCb, benefit from large statistics using tree-dominated processes
- Tree-level decays, theoretically clean ($\delta\gamma \sim 10^{-7}$)
- Complementary methods, dependent on combinations of favored and suppressed B and D
- Multi-body D decays are used in combination with input on strong phases from independent measurements (BESIII, CLEO3)
- Final states accessible to both D and \bar{D} to examine interference between $b \rightarrow c$ and $b \rightarrow u$ transitions



LHCb-CONF-2025-003

Combination of LHCb measurements of the CKM angle γ and charm mixing parameters

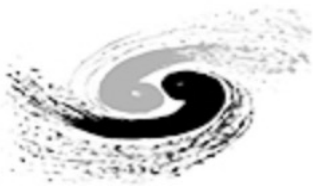
CKM fitter $\gamma = (66.3^{+0.7}_{-1.9})^\circ$



$$|A(B^-)|^2 \propto A_D^2 + r_B^2 A_D^2 + 2A_D A_{\bar{D}} r_B \cos(\delta_B - \gamma)$$

$$|A(B^+)|^2 \propto A_D^2 + r_B^2 A_D^2 + 2A_D A_{\bar{D}} r_B \cos(\delta_B + \gamma)$$

CKM angle γ measurements



- Measurement of γ using $B \rightarrow DK$ and $B \rightarrow D\pi$ decays with $D \rightarrow K_S^0 \pi\pi$ and $D \rightarrow K_S^0 KK$ with Run3 LHCb-PAPER-2026-010
- Unbinned measurement of the CKM angle γ in $B \rightarrow D(\rightarrow K_S^0 hh)h$ decays LHCb-PAPER-2025-063, LHCb-PAPER-2025-064
- A model-independent measurement of the CKM angle γ in the decay $B \rightarrow [KK\pi\pi]_D h$ and $B \rightarrow [\pi\pi\pi\pi]_D h$ JHEP02(2026)253
- Simultaneous determination of the CKM angle γ and parameters related to the mixing and CP violation in the charm sector LHCb-CONF-2025-003

$B \rightarrow Dh$ with $D \rightarrow K_S hh$ (Run3)



LHCb-PAPER-2026-010

Run1+2 analysis currently the most precise single γ measurement (BPGGSZ)

JHEP02(2021)169

Signal yields of B in the i^{th} bin dependent on the CP-violating observables

Fractional yield of $D^0 \rightarrow K_S^0 hh$, common for DK and $D\pi$ (same relative efficiency)

Strong-phase parameters of $D^0 \rightarrow K_S^0 hh$
 c_i and s_i inputs taken from combined measurement of BESIII and CLEO

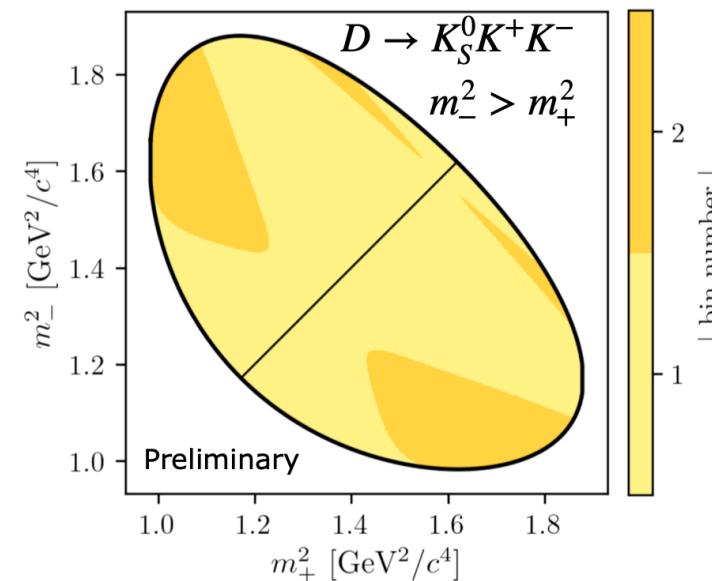
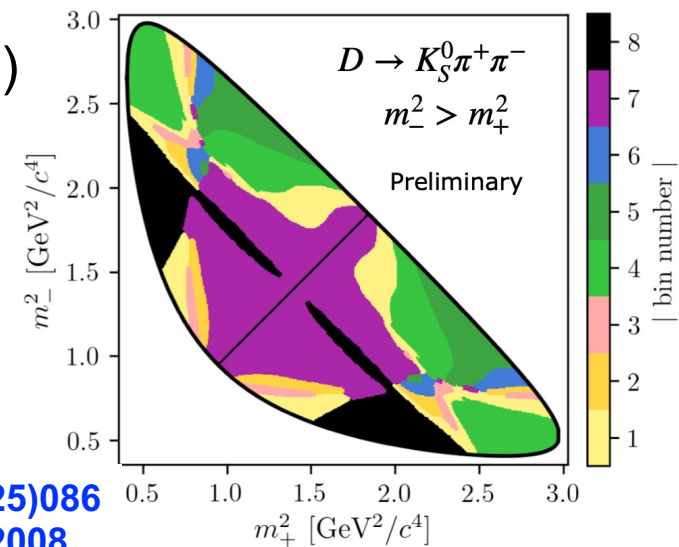
$$N_i(B^\pm) = H^{B^\pm} [F_{\mp i} + (x_\pm^2 + y_\pm^2)F_i + 2\sqrt{F_i F_{-i}}(x_\pm c_i \mp y_\pm s_i)]$$

JHEP06(2025)086
 PRD102.052008

$$x_\pm + iy_\pm = r_B e^{i(\delta_{B^\pm} + \gamma)}$$

The first γ measurement with Run3

- Self normalized
- Reduced impact of detector asymmetries and simulation
- Run3 advantages: higher luminosity, high trigger efficiency



Signal yields of $B \rightarrow Dh$



Based on 2024 5.8 fb^{-1} data

Global mass fit used to determine signal and BKG components

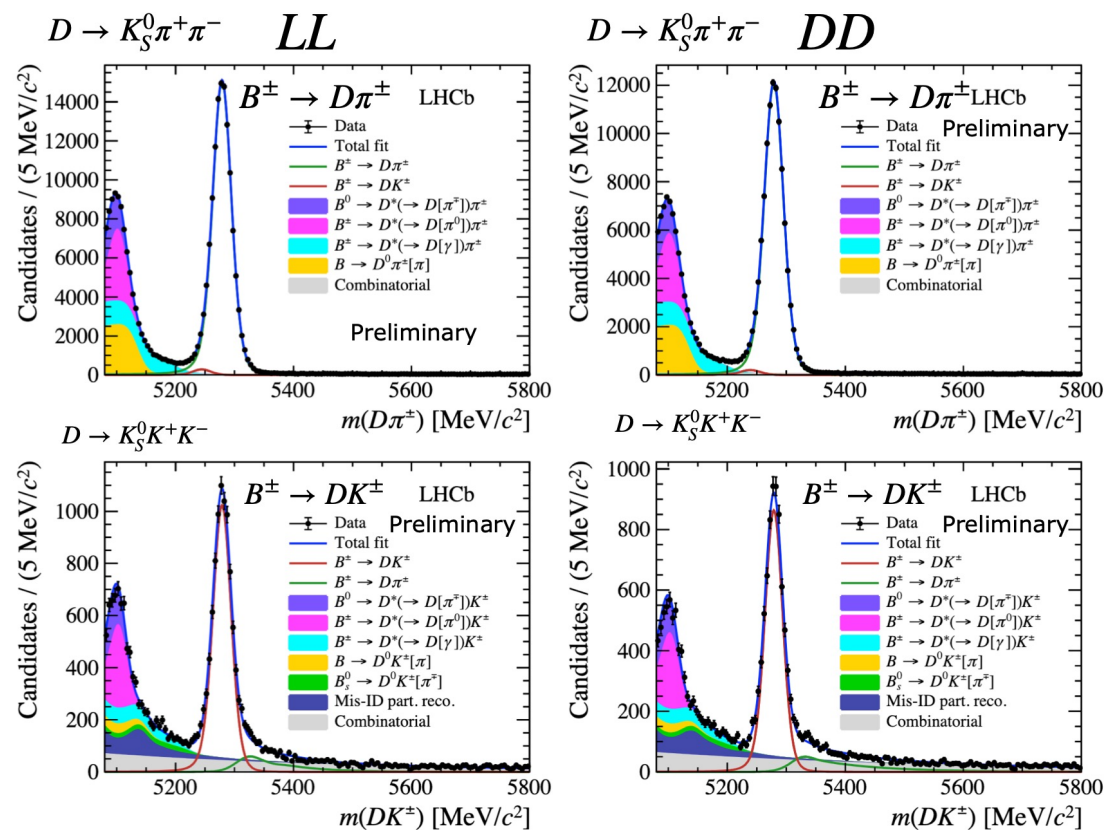
Simultaneous fit performed across categories (8) defined

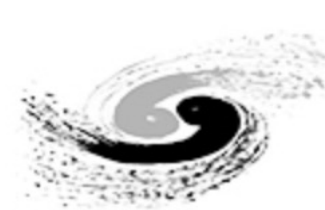
$$[DK, D\pi] \times [K_S^0 \pi\pi, K_S^0 KK] \times [LL, DD]$$

Signal yields from global mass fit $\sim 200 \text{ K}$ (total)

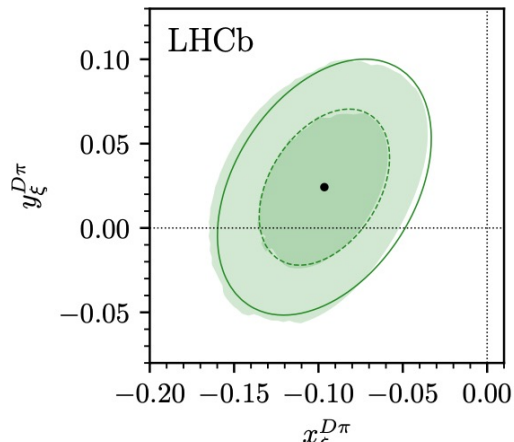
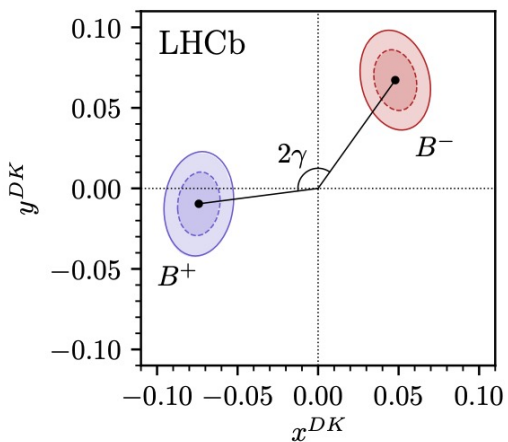
Relative to Run 1+2 measurement

- $\sim 17 \%$ higher signal yield despite low luminosity
- LL yields per lumi is 2.7x of Run2





The vector pointing to (x_{DK}^+, y_{DK}^+) and (x_{DK}^-, y_{DK}^-) form an angle of 2γ



• The resulting CP observables are:

$$\begin{aligned}
 x_-^{DK} &= (4.81 \pm 0.88 \pm 0.20 \pm 0.23) \times 10^{-2}, \\
 y_-^{DK} &= (6.70 \pm 1.26 \pm 0.44 \pm 0.56) \times 10^{-2}, \\
 x_+^{DK} &= (-7.63 \pm 0.88 \pm 0.28 \pm 0.15) \times 10^{-2}, \\
 y_+^{DK} &= (-1.20 \pm 1.34 \pm 0.35 \pm 0.44) \times 10^{-2}, \\
 x_\xi^{D\pi} &= (-9.44 \pm 2.51 \pm 0.57 \pm 0.69) \times 10^{-2}, \\
 y_\xi^{D\pi} &= (2.76 \pm 2.99 \pm 0.19 \pm 1.21) \times 10^{-2},
 \end{aligned}$$

♦ Physics parameters:

$$\begin{aligned}
 \gamma &= (68.1 \pm 6.7)^\circ, \\
 r_B^{DK} &= 0.0781_{-0.0079}^{+0.0078}, \\
 \delta_B^{DK} &= (121.5_{-7.4}^{+6.9})^\circ, \\
 r_B^{D\pi} &= 0.0073_{-0.0015}^{+0.0016}, \\
 \delta_B^{D\pi} &= (286_{-23}^{+20})^\circ,
 \end{aligned}$$

Comparison with Run1+Run2 measurements

- Consistent γ , δ_B^{DK} , $\delta_B^{D\pi}$ values, smaller r_B^{DK} larger $r_B^{D\pi}$
- Higher γ uncertainty from strong-phase inputs and a smaller r_B^{DK}

Comparison with LHCb γ combination

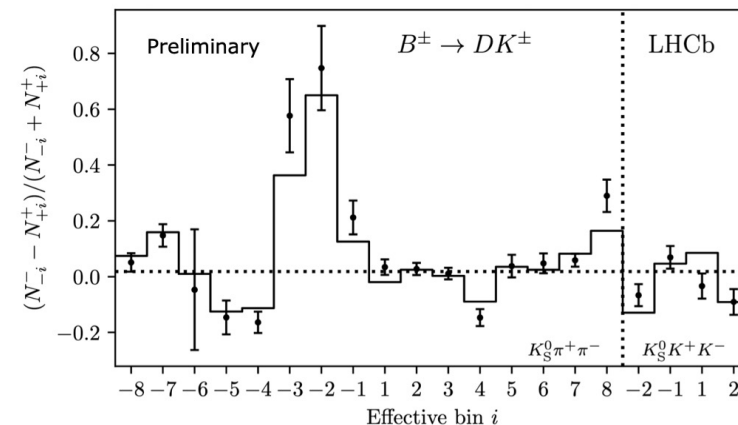
- Good agreement with a p-value of 12% in 5D parameter space

First γ measurement with Run 3

Higher signal yields observed with less integrated luminosity

These results show good agreement with previous measurements

CP asymmetry show good agreement across different fit methods





Upgrade I (U1), started in LS2

$$\mathcal{L}_{\max} \sim 2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

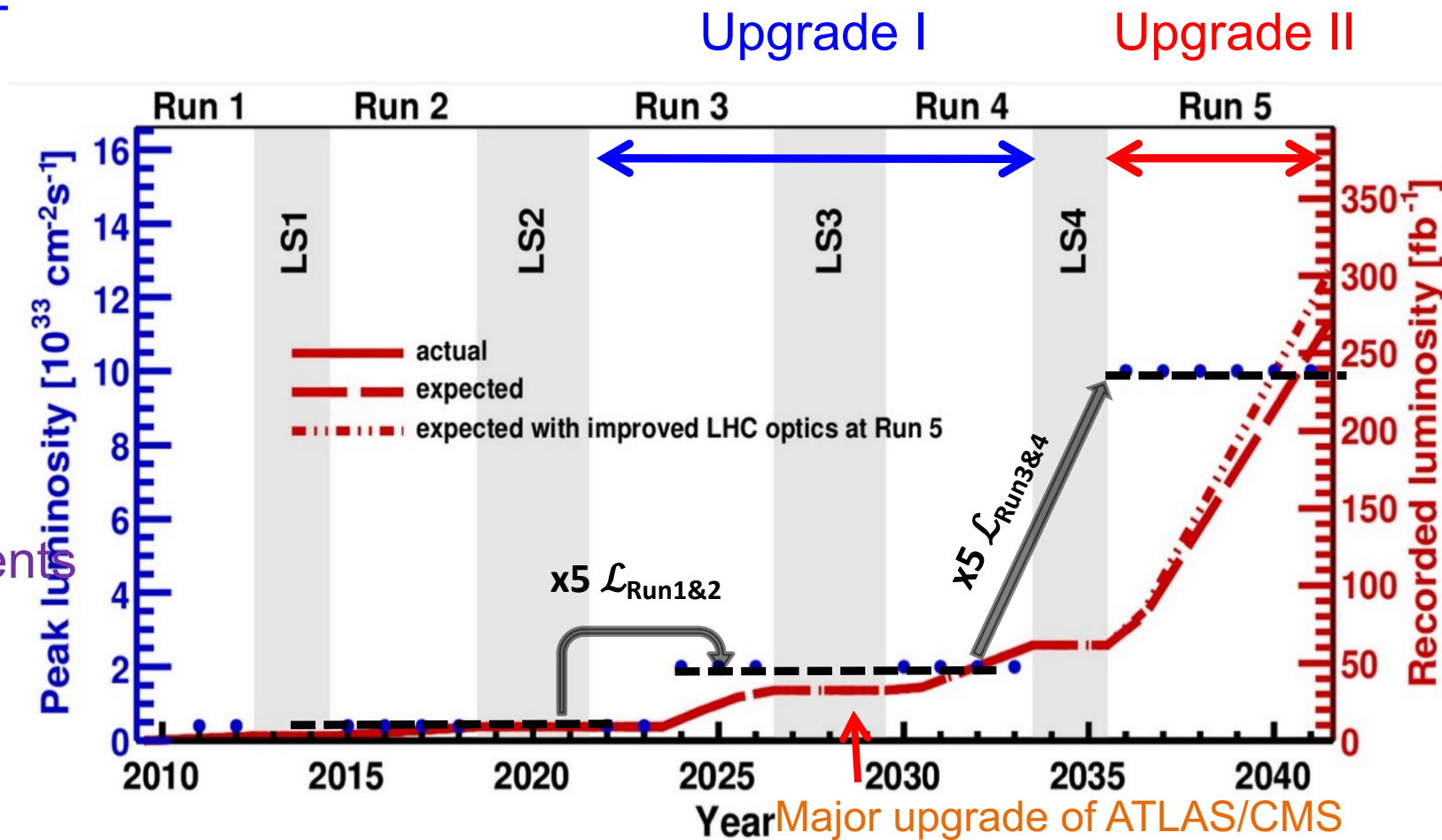
$$\mathcal{L}_{\text{int}} \sim 50 \text{ fb}^{-1}$$

Upgrade II (U2), starts in LS4

$$\mathcal{L}_{\max} \sim 1.0 - 1.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$$

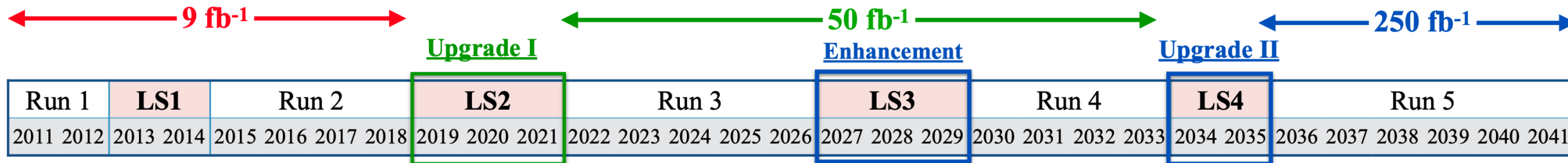
$$\mathcal{L}_{\text{int}} \sim 250 - 300 \text{ fb}^{-1}$$

Some smaller detector consolidation and enhancement in LS3 (2026) \leftrightarrow U1b



Major upgrade of ATLAS/CMS
LHCb also plan enhancements (U1b)

Very large samples of b hadrons



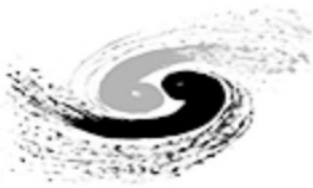
Updated from Bernlochner, MFS, Robinson, Wormser, [RMP, 94, 015003 \(2022\)](#)

Experiment	BABAR	Belle	Belle II	LHCb			
				Run 1	Run 2	Runs 3–4	Run 5
Completion date	2008	2010	2035	2012	2018	2032	2041
Center-of-mass energy	10.58 GeV	10.58/10.87 GeV	10.58/10.87 GeV	7/8 TeV	13 TeV	14 TeV	14 TeV
$b\bar{b}$ cross section [nb]	1.05	1.05/0.34	1.05/0.34	$(3.0/3.4) \times 10^5$	5.6×10^5	6.0×10^5	6.0×10^5
Integrated luminosity [fb^{-1}]	424	711/121	$(50/4) \times 10^3$	3	6	50	250
B^0 mesons [10^9]	0.47	0.77	50	100	350	3,200	16,000
B^+ mesons [10^9]	0.47	0.77	50	100	350	3,200	16,000
B_s^0 mesons [10^9]	-	0.01	0.5	24	84	760	3,800
Λ_b^0 baryons [10^9]	-	-	-	51	180	1,600	8,100
B_c^+ mesons [10^9]	-	-	-	0.8	4.4	24	120

LHCb has access to large samples of b hadrons other than b mesons

Upgrade I Upgrade II

Summary



- Rich flavor physics program of LHCb
 - ❑ Spectroscopy
 - ❑ Rare decay
 - ❑ CP violationIndirect searching for new physics
- Successful operation, good quality data
- Bigger/better dataset, precision, sensitivities
- Many interesting analyses ongoing
- New opportunities with LHCb Upgrade II