Recent results from LHCb

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Outline

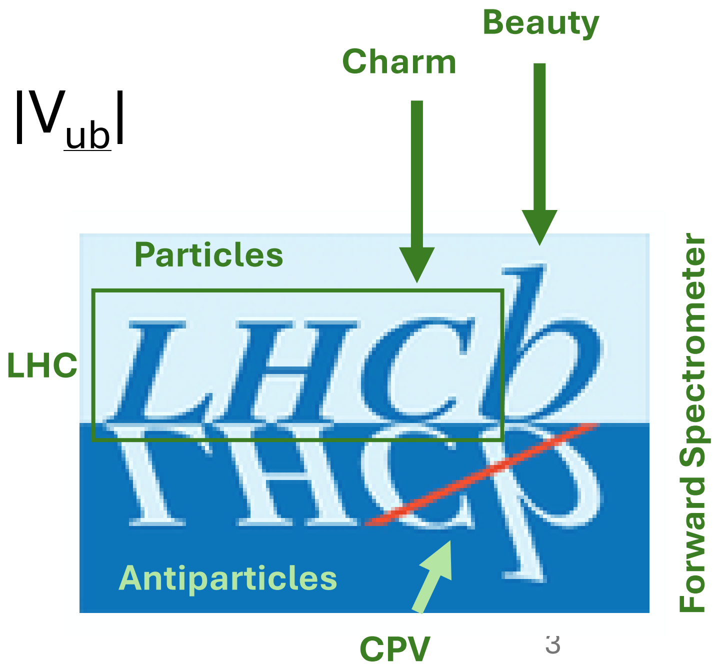
- Brief introduction
- Concept of LHCb detecor at LHC
- LHCb recent results
  - HF spectroscopy
  - CPV at heavy flavor (HF) sector of the Standard Model (SM)
  - Rare decays as a tool to search for the New Physics (NP)
  - Lepton flavor universality
  - Electroweak studies
- LHCb after Upgrade I
  - What's new?
  - How LHCb is performing now?
- Few words about Upgrade II
- Summary

Highlights

For more visit [LHCb papers web-page]

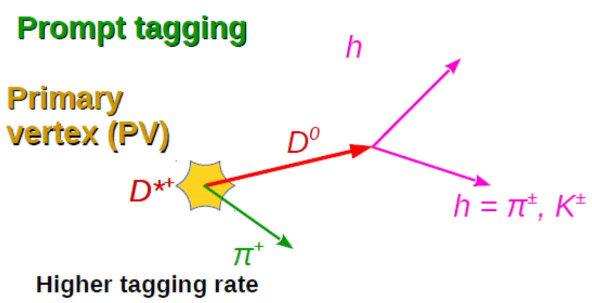
LHCb Physics Program

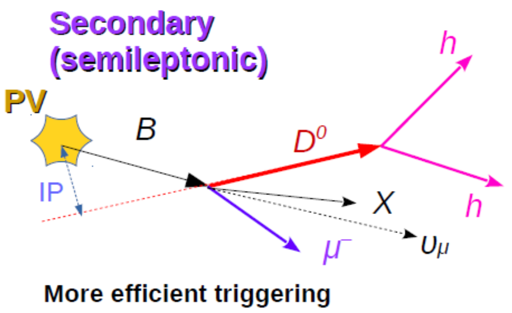
- **GOAL:** Search for evidence of NP in CP violation and rare decays of beauty and charm hadrons.
  - Probing large mass scales *via* study of virtual quantum loops of new particles
- **Main directions of searches:**
  - Rare decays (RD with di-muons)
  - Properties of the B systems (CPV, Δm_s; Γ_s, $\Delta\Gamma$, ϕ_s ; CKM β, γ, $|V_{ub}|$ determination)
  - Mixing and CPV in charm sector (Mixing observ., $\Delta A(CP)$)
  - Spectroscopy and production of heavy quarks + Exotics
  - Electroweak physics (top quark in fd.region, W+c-/b-jet)
  - Soft QCD physics, pA and Ap collisions

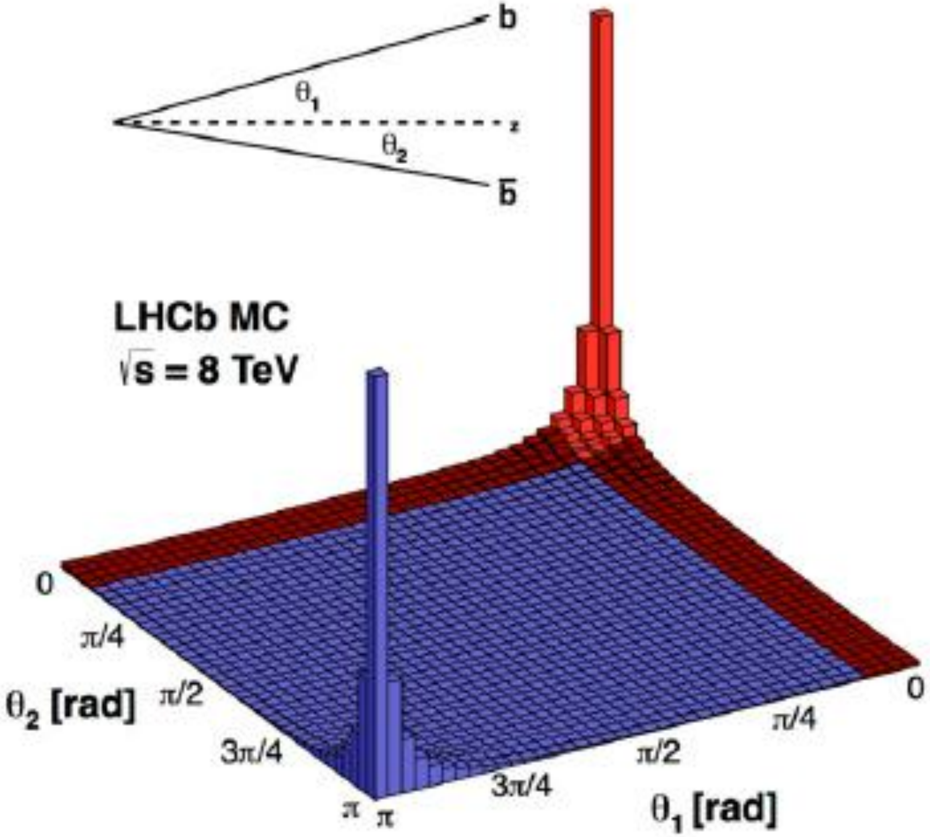


Charm and beauty production into forward region

- Gluon fusion is main production mechanism for pairs of heavy (***c*** & ***b***) quark-antiquark pairs
- Produced heavy hadrons go together in forward direction (LHCb acceptance $2<\eta<5$)
- Lorentz boost provides signature for ***c***- & ***b***-hadrons selection
- Tagging for prompt-***c*** and ***c***-from-***b***



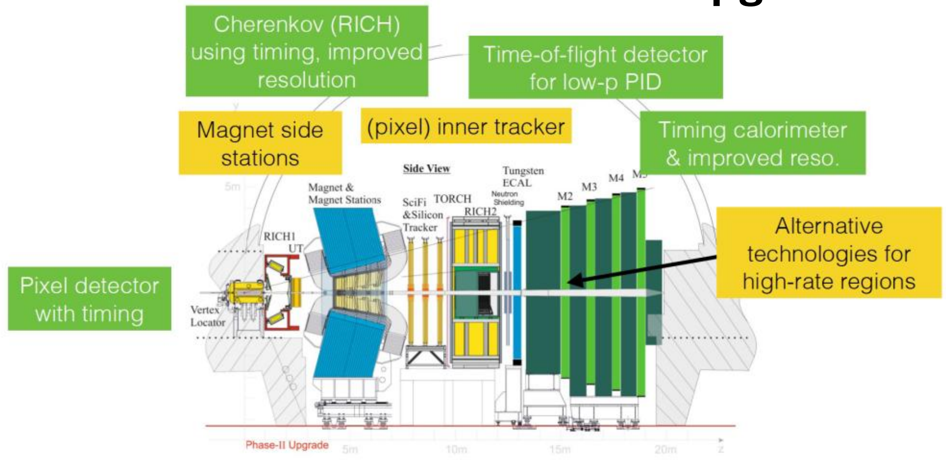




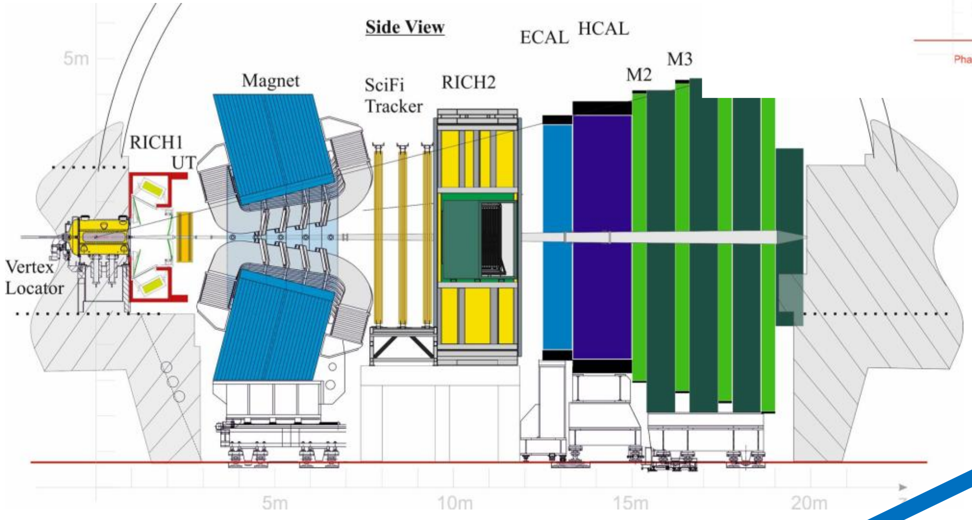
Three editions of LHCb

Consecutive efforts to attack challenges that higher luminosity measurements at forward region are bringing

LHCb at Upgrade II



LHCb at Upgrade I

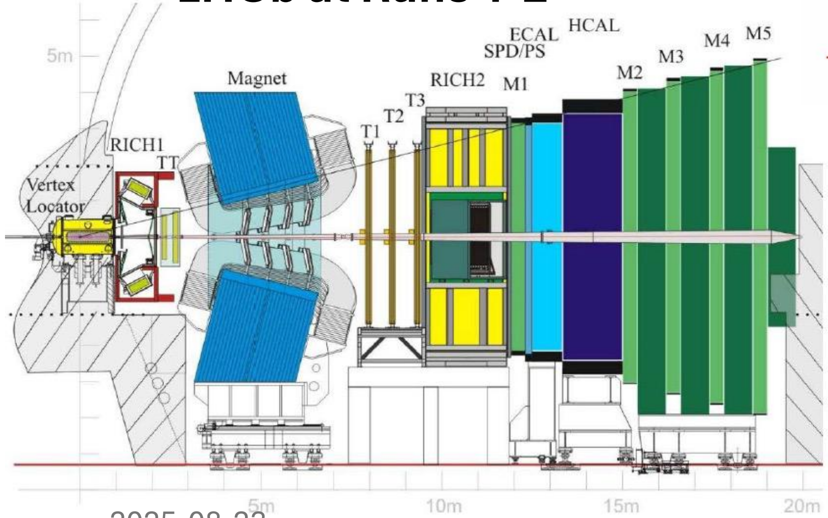


Luminosity

$\mathcal{L} = 1.5{\times}10^{34}\,\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 300\ \text{fb}^{-1}$
$\mu \approx 40$

$\mathcal{L} = 2{\times}10^{33}\,\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 50\ \text{fb}^{-1}$
$\mu \approx 5$

LHCb at Runs 1-2



$\mathcal{L} = 4{\times}10^{32}\,\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 9\ \text{fb}^{-1}$
$\mu \approx 1$

LHCb: Find \ Identify \ Measure

Excellent vertexing allows efficient heavy quark hadrons selection / gives access to decay time distribution / prompt-secondary separation for charm

Protons collision point

$\sigma(IP) \approx 20 \mu m$

$\delta p/p = 0.4 - 0.6~\%$

$\epsilon_{track} > 96~\%$

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

$\epsilon_{PID}(K) \approx 95~\%$

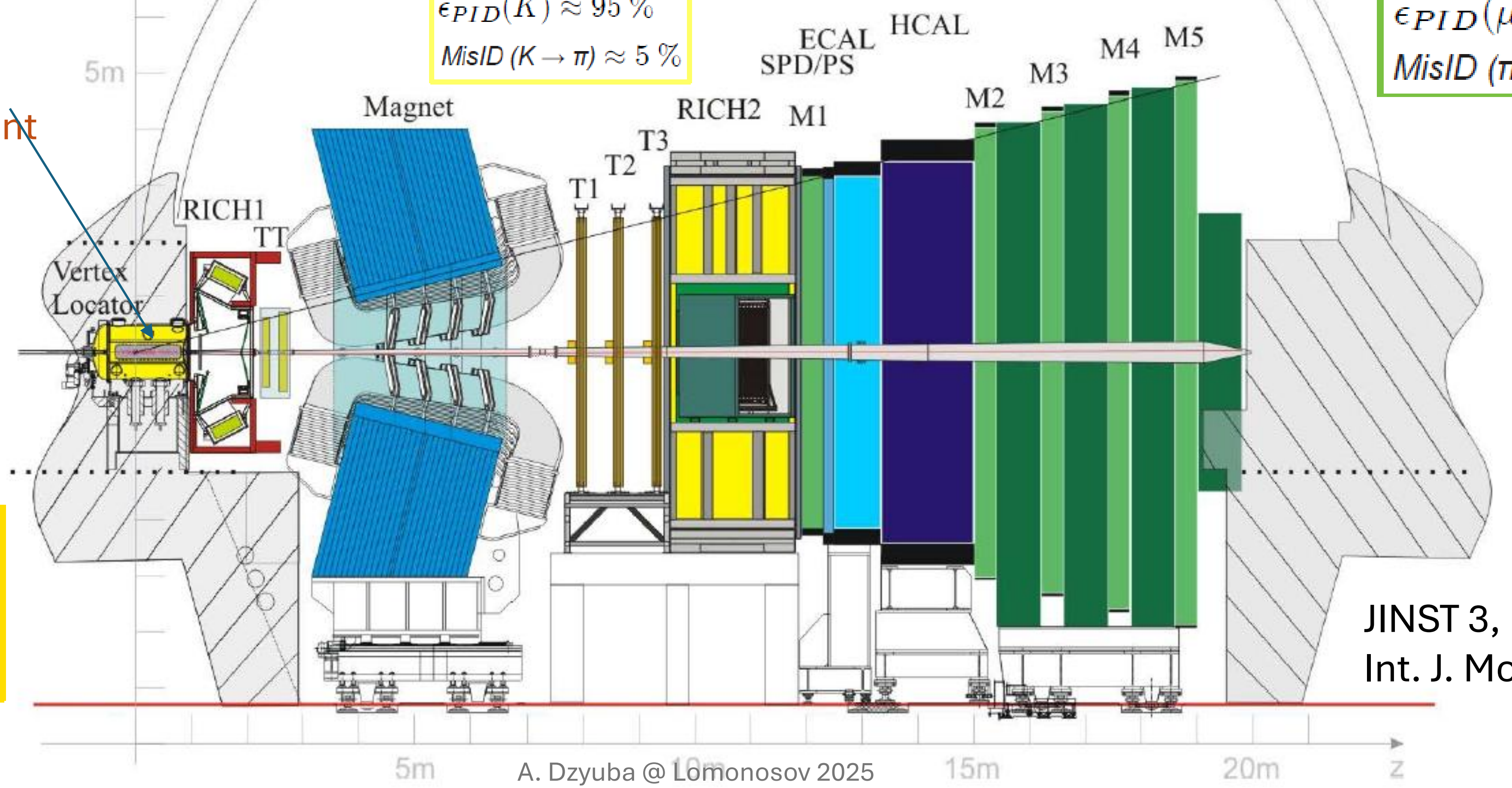
$MisID~(K \to \pi) \approx 5~\%$

Excellent tracking

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

$\epsilon_{PID}(\mu) \approx 97~\%$

$MisID~(\pi \to \mu) \approx 3~\%$



JINST 3, (2008) S08005;
Int. J. Mod. Phys. A 30, (2015) 153022

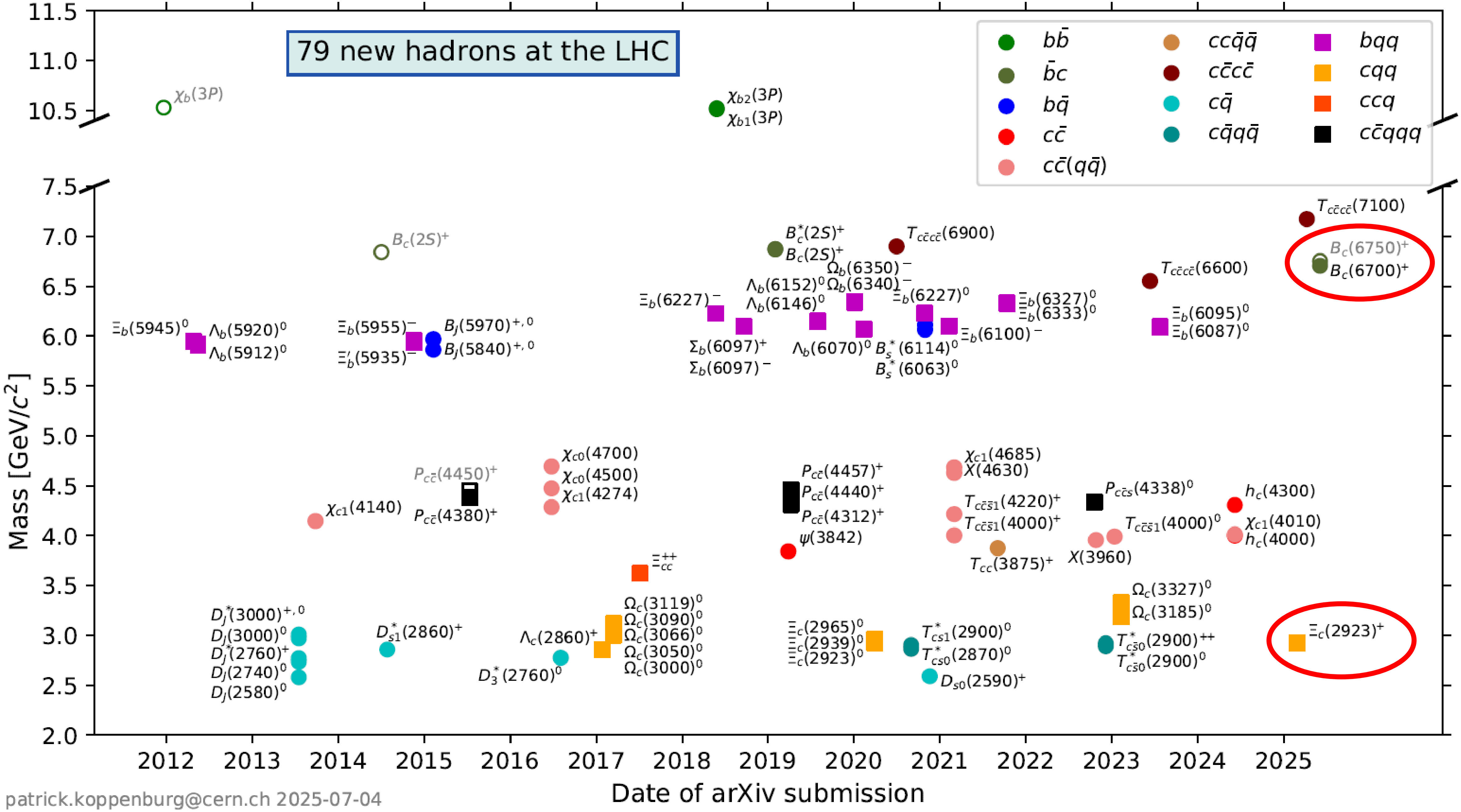
Recent physics results (selected for today)

- New $\Xi_c(2923)^+$ baryon
- New $B_c(1P)^+$ states
- New Ξ_{cc}^{++} decay channel
- Lifetimes of charmed baryons
- Observation of CPV for baryons
- Rare decays with electrons
- Lepton Flavor Universality (LFU): R_K for high-q^2
- Search for Lepton Flavor Violation (LFV)
- *Z* mass measurement
- *D* production asymmetries (**Run-3**)

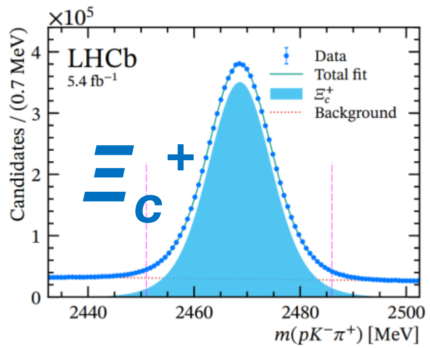
Hadron Spectroscopy

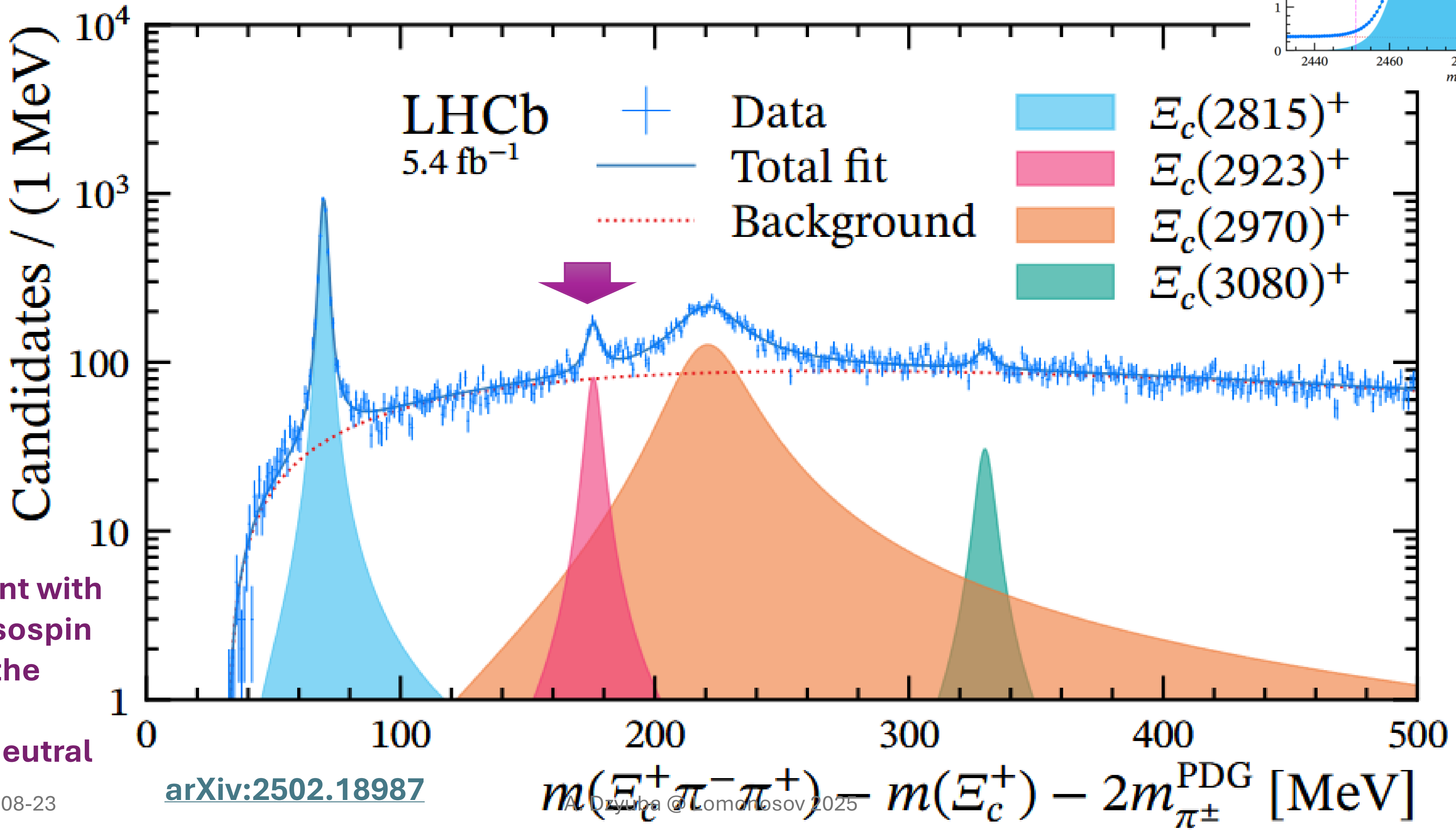
CPV and Rare decays

EW


79 new hadrons at the LHC
Mass [GeV/c²]
Date of arXiv submission
bb̄
b̄c
bq̄
cc̄
cc̄(qq̄)
ccq̄q̄
cc̄cc̄
cq̄
cq̄qq̄
bqq
cqq
ccq
cc̄qqq
χb(3P)
χb2(3P)
χb1(3P)
Bc(2S)+
B*c(2S)+
Bc(2S)+
Tcc̄cc̄(6900)
Tcc̄cc̄(7100)
Bc(6750)+
Bc(6700)+
Tcc̄cc̄(6600)
Ωb(6350)−
Ωb(6340)−
Λb(6152)0
Λb(6146)0
Ξb(6227)−
Ξb(6227)0
Ξb(6327)0
Ξb(6333)0
Ξb(6095)0
Ξb(6087)0
Ξb(5945)0
Λb(5920)0
Λb(5912)0
Ξb(5955)−
Ξ′b(5935)−
BJ(5970)+,0
BJ(5840)+,0
Σb(6097)+
Σb(6097)−
Λb(6070)0
B*s(6114)0
B*s(6063)0
Ξb(6100)−
χc0(4700)
χc0(4500)
χc1(4274)
Pcc̄(4450)+
Pcc̄(4380)+
χc1(4140)
Pcc̄(4457)+
Pcc̄(4440)+
Pcc̄(4312)+
ψ(3842)
χc1(4685)
X(4630)
Tcc̄s̄1(4220)+
Tcc̄s̄1(4000)+
Tcc(3875)+
Pcc̄s(4338)0
Tcc̄s̄1(4000)0
X(3960)
hc(4300)
χc1(4010)
hc(4000)
Ξcc++
Ωc(3327)0
Ωc(3185)0
Ωc(3119)0
Ωc(3090)0
Ωc(3066)0
Ωc(3050)0
Ωc(3000)0
Λc(2860)+
D*3(2760)0
D*J(3000)+,0
DJ(3000)0
D*J(2760)+
DJ(2740)0
DJ(2580)0
D*s1(2860)+
Ξc(2965)0
Ξc(2939)0
Ξc(2923)0
T*cs1(2900)0
T*cs0(2870)0
Ds0(2590)+
T*cs̄0(2900)++
T*cs̄0(2900)0
Ξc(2923)+
patrick.koppenburg@cern.ch 2025-07-04

New hadrons: observation of $\Xi_c(2923)^+$





Is consistent with being the isospin partner of the previously observed neutral state

arXiv:2502.18987

New hadrons: $B_c(1P)^+$ states

- A wide peaking structure is observed in $B_c^+\gamma$ mass spectrum using LHCb Run1+2 data
- Consistent with originating from $B_c(1P)^+$
- **Minimal effective two-peak** model is used to describe the structure

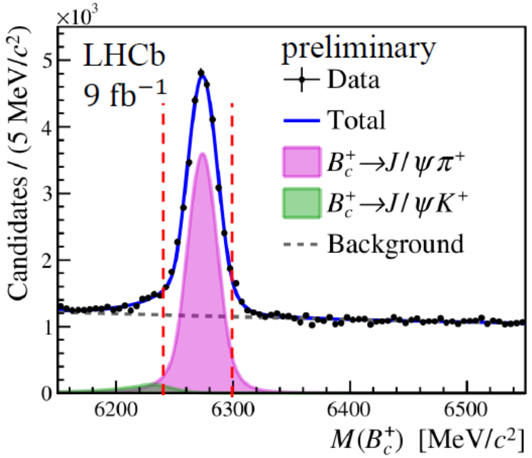
$$M_1 = 6704.8 \pm 5.5(\text{stat.}) \pm 2.8(\text{syst.}) \pm 0.3(B_c^+)\ \text{MeV}/c^2$$
$$M_2 = 6752.4 \pm 9.5(\text{stat.}) \pm 3.1(\text{syst.}) \pm 0.3(B_c^+)\ \text{MeV}/c^2$$

- The production cross-section at 13 TeV is measured relative to in the fiducial region

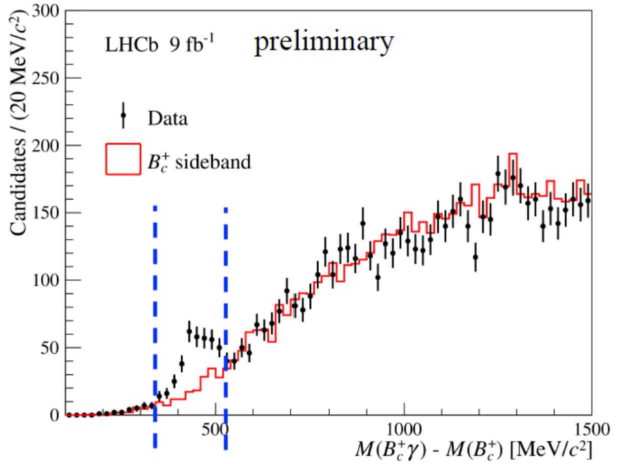
$$\mathcal{R} = 0.20 \pm 0.03(\text{stat.}) \pm 0.02(\text{syst.}) \pm 0.03(\text{theo.})$$

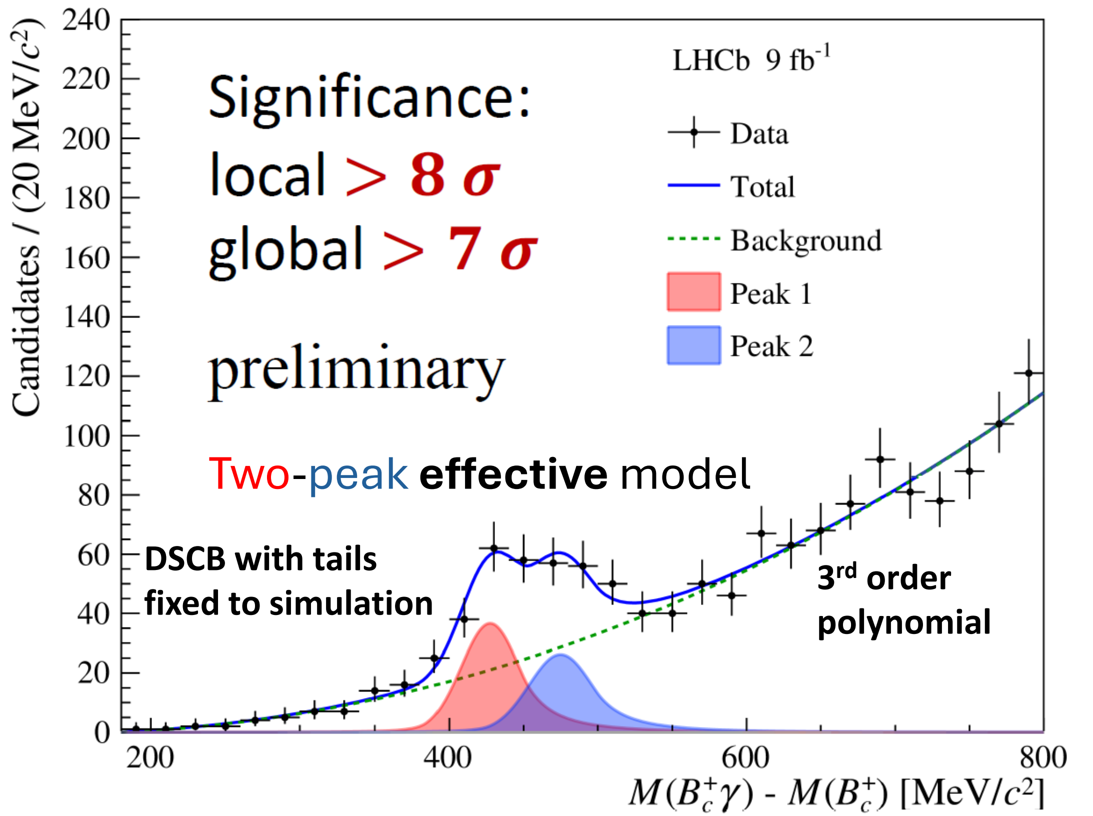
$p_T(B_c^+) < 20\ \text{GeV}/c, 2.0 < y(B_c^+) < 4.5$

- More data is needed to investigate for possible complicated composition of the observed structure (up to 6 resonances).

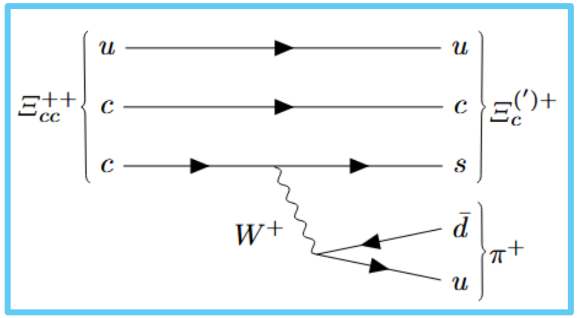


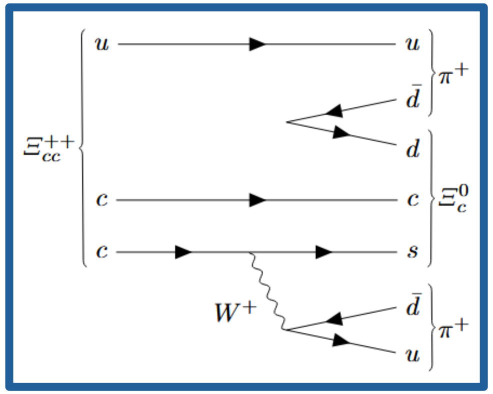
$N = (24.86 \pm 0.24)\times 10^3$

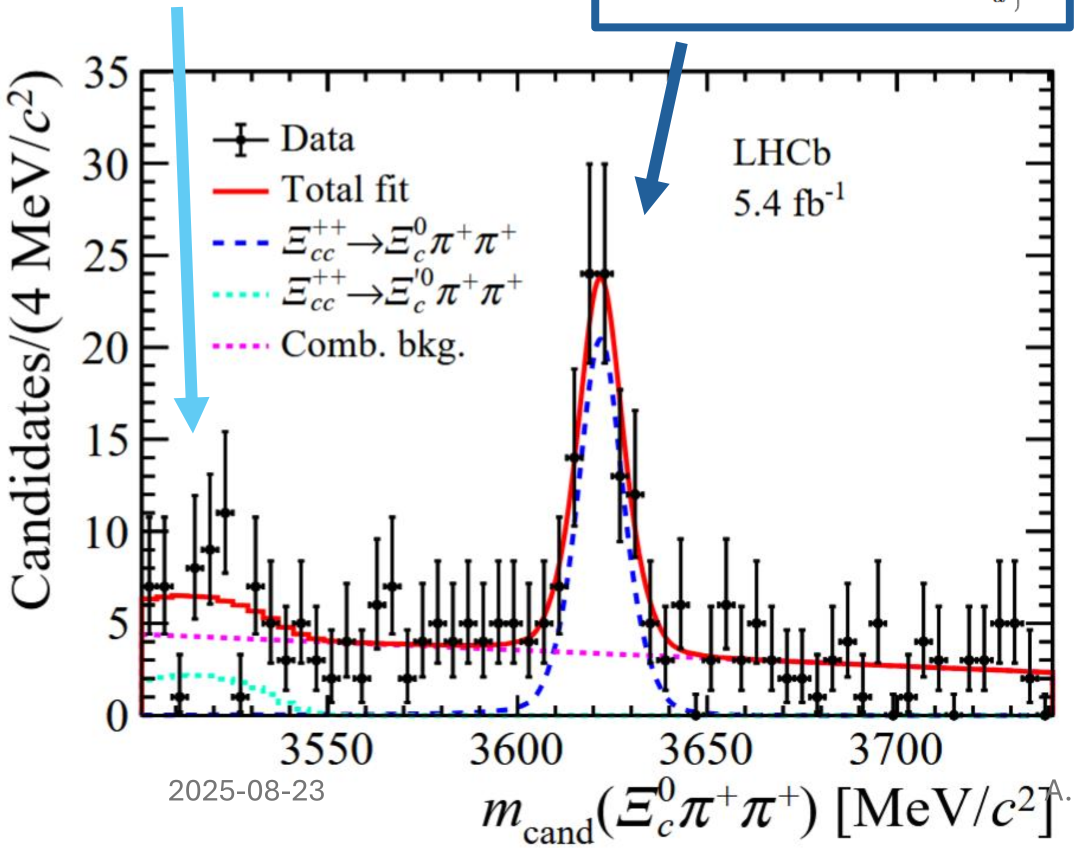




Spectroscopy: new decay channel for Ξ_{cc}^{++}







- Doubly charmed baryon has been discovered by LHCb (PRL 119 (2017) 112001)
- Many decay channels observed
- Cross section, mass and lifetime measurement were done
- A search for the doubly-charmed-baryon decay $\Xi_{cc}^{++} \to \Xi_c^0 (\to pK^- K^- \pi^+) \pi^+ \pi^+$ is performed using ***pp*** collision data collected by the LHCb experiment at $\sqrt{s}$=13 TeV (L_{int}=5.4 fb^{-1}).

$$\frac{\mathcal{B}(\Xi_{cc}^{++} \to \Xi_c^0 \pi^+ \pi^+) \times \mathcal{B}(\Xi_c^0 \to pK^- K^- \pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) \times \mathcal{B}(\Lambda_c^+ \to pK^- \pi^+)} =$$

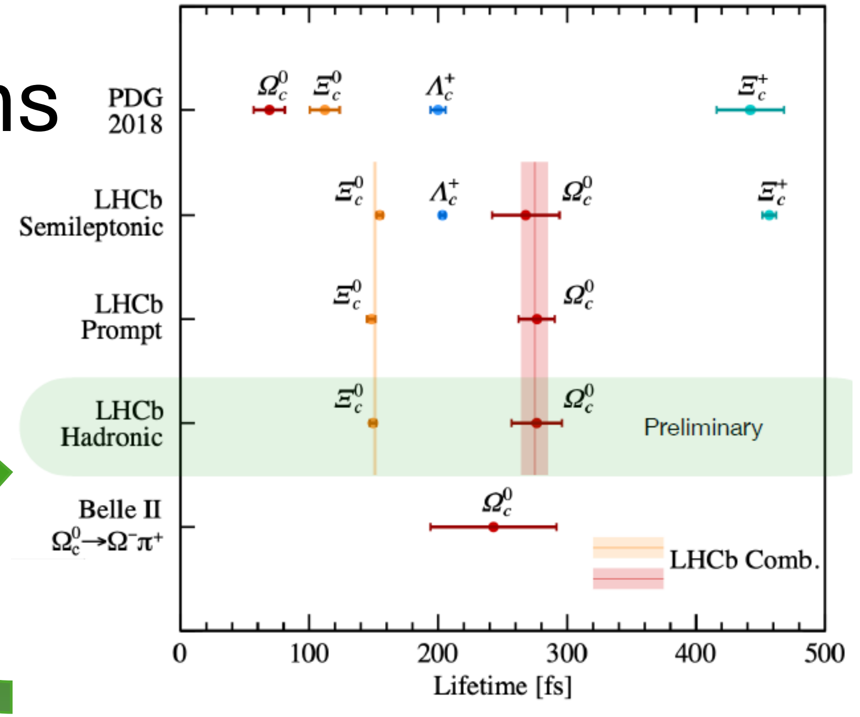
$$= \quad 0.105 \pm 0.014\,(\text{stat}) \pm 0.007\,(\text{syst})$$

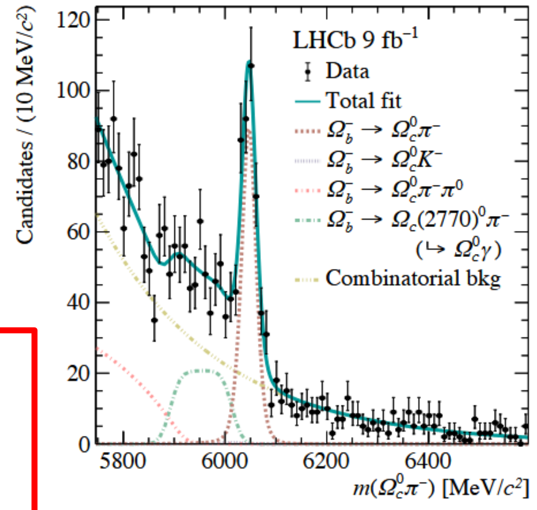
arXiv:2504.05063

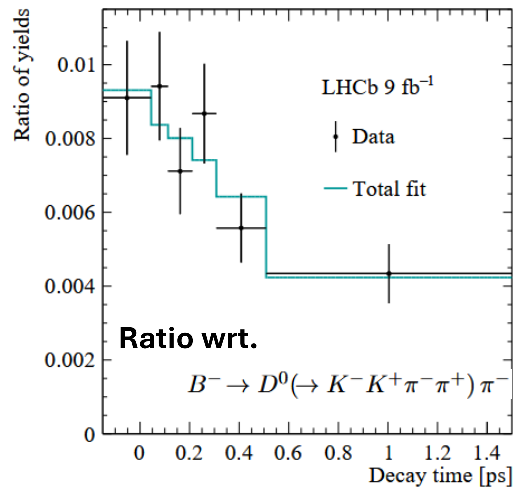
Spectroscopy: lifetimes of charmed baryons

- Muons from **semileptonic** decays of Ω_b baryons and decay vertex of Ω_c baryon provide opportunity for lifetime measurement (**Phys. Rev. Lett. 121 (2018) 092003)**
  - Lifetimes hierarchy was incompatible with reported in PDG
- Measurements done with **prompt baryons** **Science Bulletin 2022, v.67, p.479** confirmed results of the semi-muonic method
- New measurements are performed with the hadronic decay modes of Ξ_b and Ω_b
  - **Confirms hierarchy** $\tau_{\Xi_c^+} > \tau_{\Omega_c^0} > \tau_{\Lambda_c^+} > \tau_{\Xi_c^0}$.

$$\tau_{\Omega_c^0} = 276.3 \pm 19.4\,(\text{stat}) \pm 1.8\,(\text{syst}) \pm 0.7\,(\tau_{D^0})\ \text{fs},$$
$$\tau_{\Xi_c^0} = 149.2 \pm 2.5\,(\text{stat}) \pm 0.9\,(\text{syst}) \pm 0.4\,(\tau_{D^0})\ \text{fs},$$







arXiv:2506.13334

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- Z mass measurement **EW**
- D production asymmetries (**Run-3**)

Hadron Spectroscopy

CPV and Rare decays

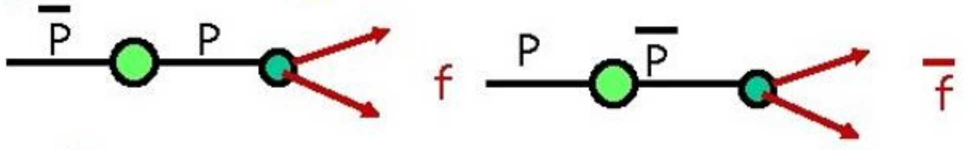
History of experimental CPV discoveries

1964	CP violation (in mixing) in neutral Kaon decays
1999	Direct CP violation in neutral Kaon decays
2001	CP violation in mixing and decay in B^0 decays
2004	Direct CP violation in B^0 decays
2012	Direct CP violation in B^+ decays
2013	Direct CP violation in B_s^0 decays
2018	CP violation in mixing and decay in B_s^0 decays
2019	Direct CP violation in D^0 decays
2025	Direct CP violation in baryon decays

- ~~CP~~ in decay

Direct CPV

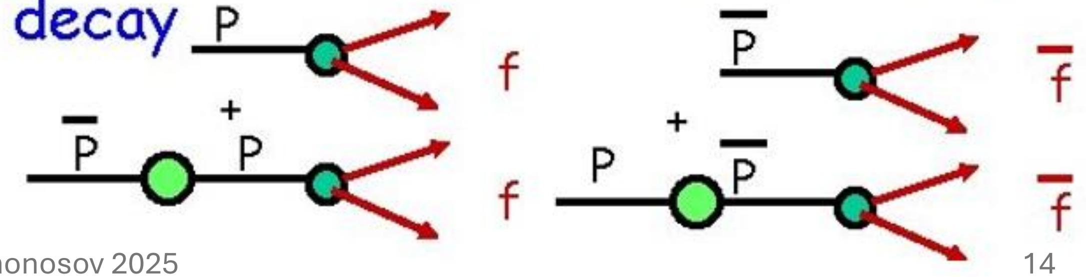
- ~~CP~~ in mixing



CPV in mixing

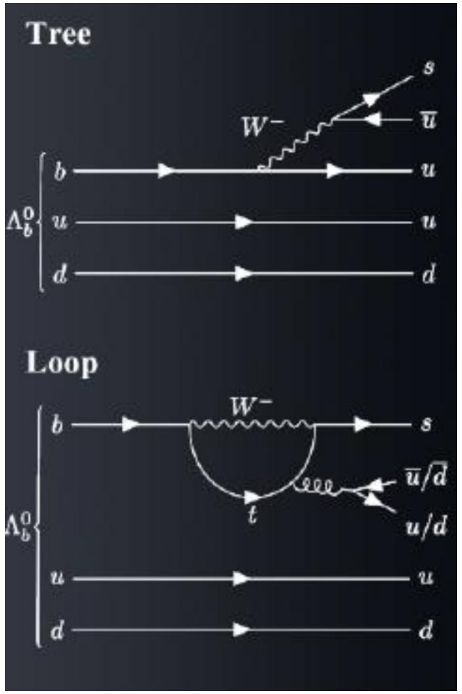
Interference btw, direct and in-mixing CPVs

- ~~CP~~ in interference between mixing and decay



Observation of baryonic CPV

$\Lambda_b{}^0 \to pK^-\pi^+\pi^+$



Two observe direct CPV one needs at least two amplitudes (smallness of $|V_{ub}|$ helps here)

$$A_1 = \rho_1 e^{i\delta_1} e^{i\theta_1} \qquad \bar{A}_1 = \rho_1 e^{i\delta_1} e^{-i\theta_1}$$

CP

Weak phases change sign under CP, but strong ones not

$$A_2 = \rho_2 e^{i\delta_2} e^{i\theta_2} \qquad \bar{A}_2 = \rho_2 e^{i\delta_2} e^{-i\theta_2}$$

$$|\bar{A}_1 + \bar{A}_2|^2 - |A_1 + A_2|^2 = 4\rho_1\rho_2 \sin(\theta_1 - \theta_2)\sin(\delta_1 - \delta_2)$$

- **Direct CPV manifests itself in the asymmetry of rates**
- **Difficult to calculate theoretically due to the presence of the strong phases**

$$\Delta = \frac{|A_f|^2 - |\bar{A}_{\bar{f}}|^2}{|A_f|^2 + |\bar{A}_{\bar{f}}|^2}$$

Huge recent LHCb progress on the topic

- Measurement of CP asymmetries in $\Lambda_b^0 \to ph^-$ decays — LHCb-PAPER-2024-048, arXiv:2412.13958
- Observation of charge-parity symmetry breaking in baryon decays — LHCb-PAPER-2024-054, arXiv:2503.16954, *Nature* 643 (2025) 1223-1228
- Study of Λ_b^0 and Ξ_b^0 decays to $\Lambda h^+ h'^-$ and evidence for CP violation in $\Lambda_b^0 \to \Lambda K^+ K^-$ — LHCb-PAPER-2024-043, Phys. Rev. Lett. 134 (2025) 101802

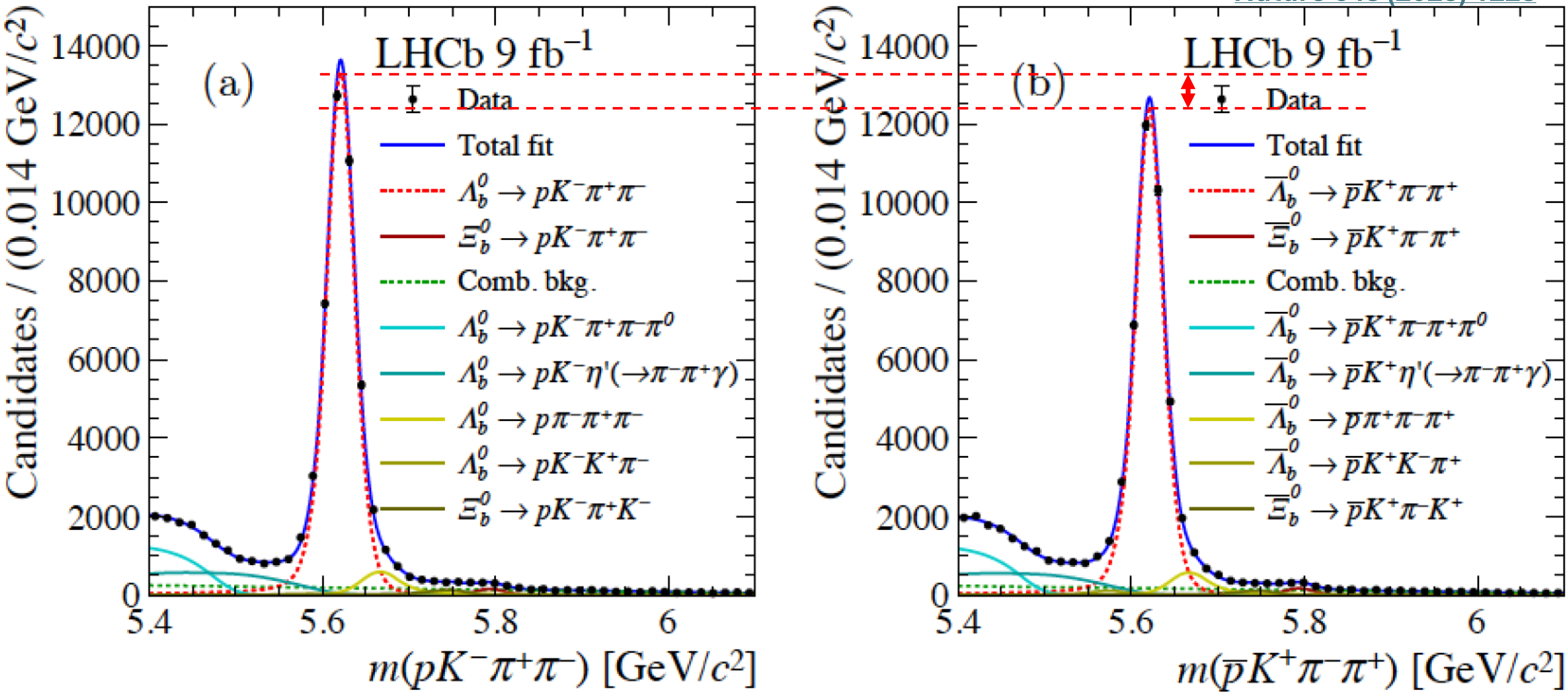
Decay topology	Mass region (GeV/c^2)	A_{CP}
$\Lambda_b^0 \to (pK^-)(\pi^+\pi^-)$	$m_{pK^-} < 2.2$ $m_{\pi^+\pi^-} < 1.1$	$(5.24 \pm 1.29 \pm 0.21)\%$
$\Lambda_b^0 \to (p\pi^-)(K^-\pi^+)$	$m_{p\pi^-} < 1.7$ $m_{\pi^+K^-} \in [0.8, 1.0] \cup [1.1, 1.6]$	$(2.73 \pm 0.82 \pm 0.14)\%$
$\Lambda_b^0 \to (p\pi^-\pi^+)K^-$	$m_{p\pi^-\pi^+} < 2.7$	$(5.39 \pm 0.86 \pm 0.10)\%$
$\Lambda_b^0 \to (K^-\pi^+\pi^-)p$	$m_{K^-\pi^+\pi^-} < 2.0$	$(2.01 \pm 1.16 \pm 0.30)\%$

Nature 643 (2025) 1223

The CP asymmetry in $\Lambda_b^0 \to pK^-\pi^+\pi^+$ is found to be: $A_{CP} = 2.45 \pm 0.46 \pm 0.10\ \%$

5.2 σ significance

Nature 643 (2025) 1223



Study the CP asymmetry in different regions of the Dalitz plot (resonance substructure) is also performed $\Delta A_{CP}(N^{*+}K^-) = 0.165 \pm 0.048 \pm 0.017$ Phys.Rev.Lett. 134 (2025) 101802

NP and flavor symmetry / Wilson coefficients → Rare decays

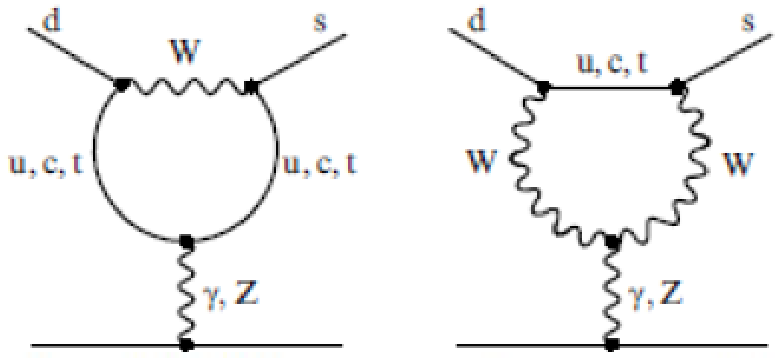
- **Progress of theory calculations allows to take into account QCD corrections needed for SM FCNC implementation to decays. (Calculation of C_i in SM as well as quite precise predictions for certain processes)**
- **H_{eff} is an effective way to test different classes of possible NPs, because C_i depend on their flavour structures.**
- **Minimal Flavour Violation (MFV) paradigm: NP has same source of FV as SM => real numbers, same CPV effects, relations like:**

$$\frac{\mathrm{BR}(B_s \to \mu^+\mu^-)}{\mathrm{BR}(B_d \to \mu^+\mu^-)} = \frac{\tau_{B_s} f_{B_s}^2 m_{B_s} |V_{ts}|^2}{\tau_{B_d} f_{B_d}^2 m_{B_d} |V_{td}|^2}$$

$\Delta F = 1$ operators in the SM and in MFV

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

Example



$O_9 = (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \ell)$ $\quad O_{10} = (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \gamma_5 \ell)$

- **If NP contains additional FV sources of C_i become complex as well as new CPV effects might appear!**

Rare decays: R_K at high q^2

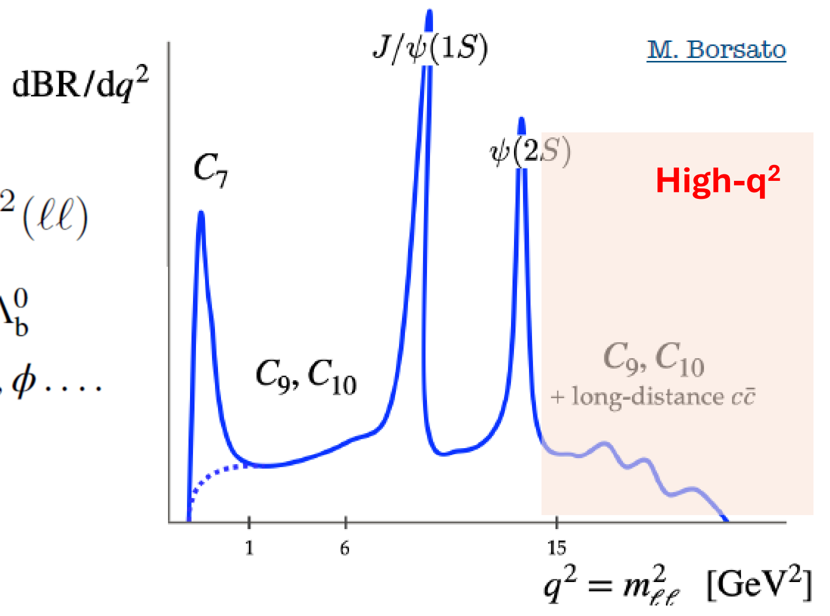
- Saga with ratios measurements
- New analysis targets q^2>14.3 GeV^2 (9 fb^{-1})

$$R_{\mathrm{H}}\left[q^2_{\mathrm{min}}, q^2_{\mathrm{max}}\right] = \frac{\int_{q^2_{\mathrm{min}}}^{q^2_{\mathrm{max}}} \mathrm{d}q^2 \frac{\mathrm{d}\Gamma(B\to H\mu^+\mu^-)}{\mathrm{d}q^2}}{\int_{q^2_{\mathrm{min}}}^{q^2_{\mathrm{max}}} \mathrm{d}q^2 \frac{\mathrm{d}\Gamma(B\to He^+e^-)}{\mathrm{d}q^2}}, \quad q^2 = m^2(\ell\ell)$$

B: $B^+, B^0, B^0_s, \Lambda^0_b$

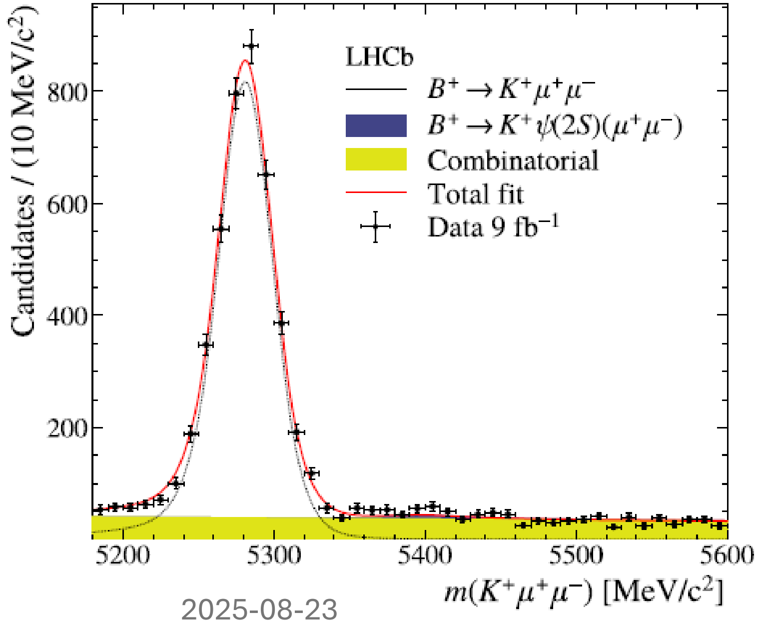
H: $K^+, K^{*0}, pK, \phi \ldots$

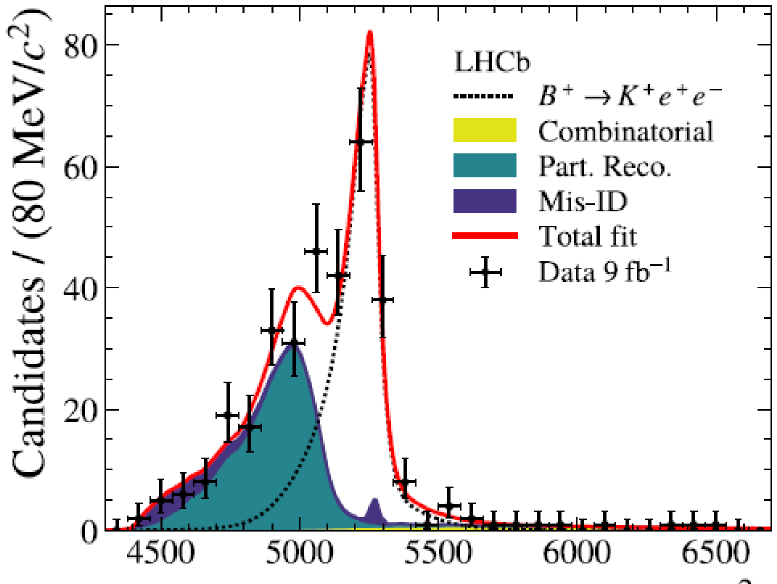
In SM R_H = 1, if one neglects lepton mass difference!

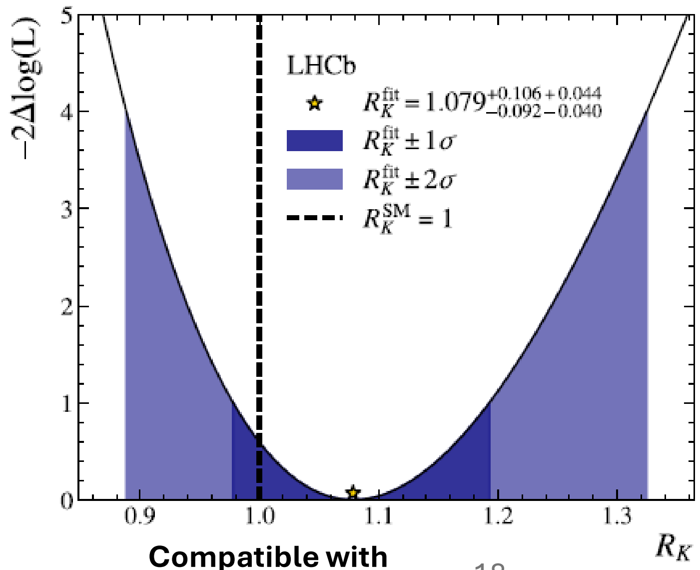


- Challenges from electron bremsstrahlung corrections and distorted phase-space distribution at high-q^2

$$R_K(q^2 > 14.3\ \mathrm{GeV}^2/c^4) = 1.079^{+0.106\ +0.044}_{-0.092\ -0.040}$$







Compatible with SM expectations

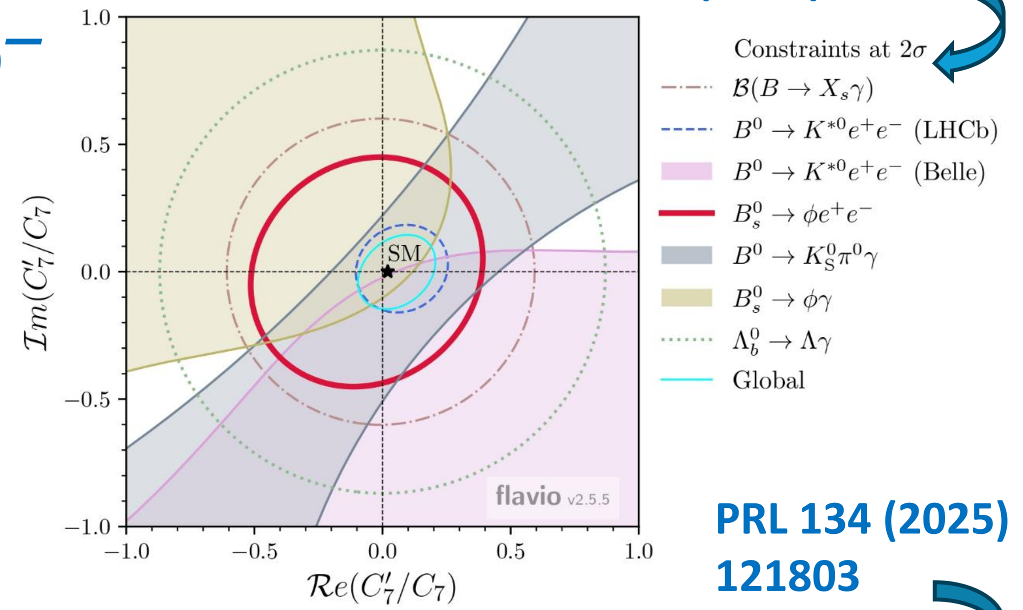
JHEP 07 (2025) 198

Rare decays: studies $B_s^0 \to \phi e^+e^-$

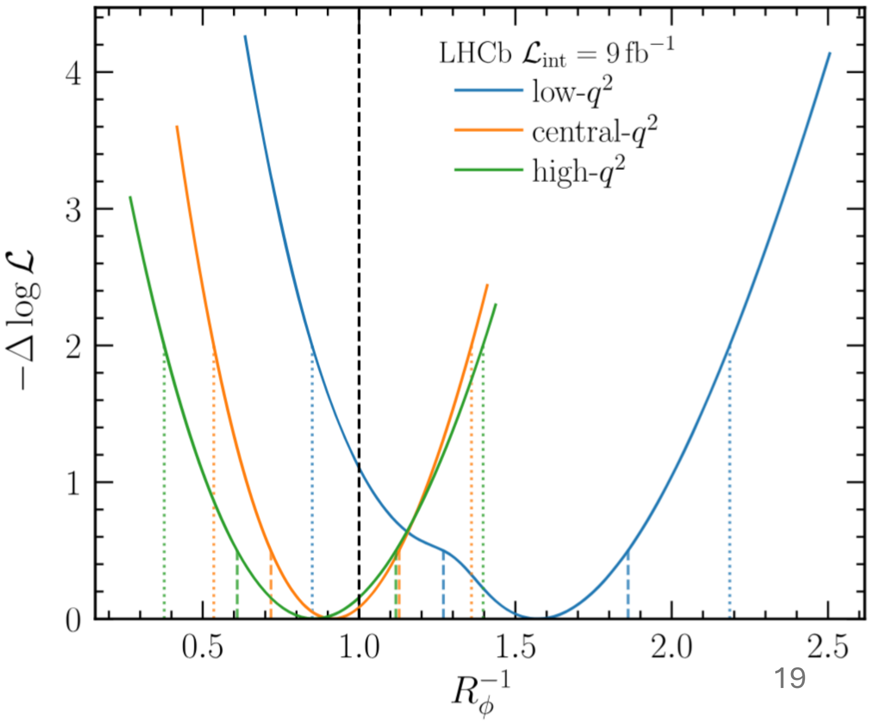
- Constraints on the photon polarization in ***b→sγ*** transitions using $B_s^0 \to \phi e^+e^-$
- Sensitive to form factors and right-handed currents $\boldsymbol{C_7^{(\prime)}}$
- ~100 signal events candidates for Run-1&2 data (L_{int} = 9 fb $^{-1}$)
- $0.0009 < q^2 < 0.2615$ GeV^2

- First LFU tests with B_s^0 using $B_s^0 \to \phi l^+l^-$
- Limited sample size, but efficient selection and clean data sample
- All possible q^2 regions

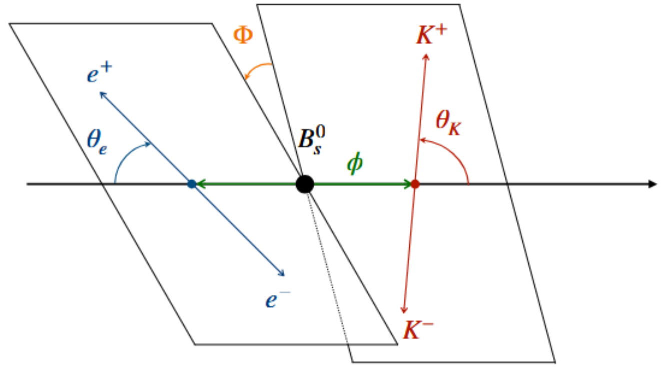
JHEP 03 (2025) 047



PRL 134 (2025) 121803



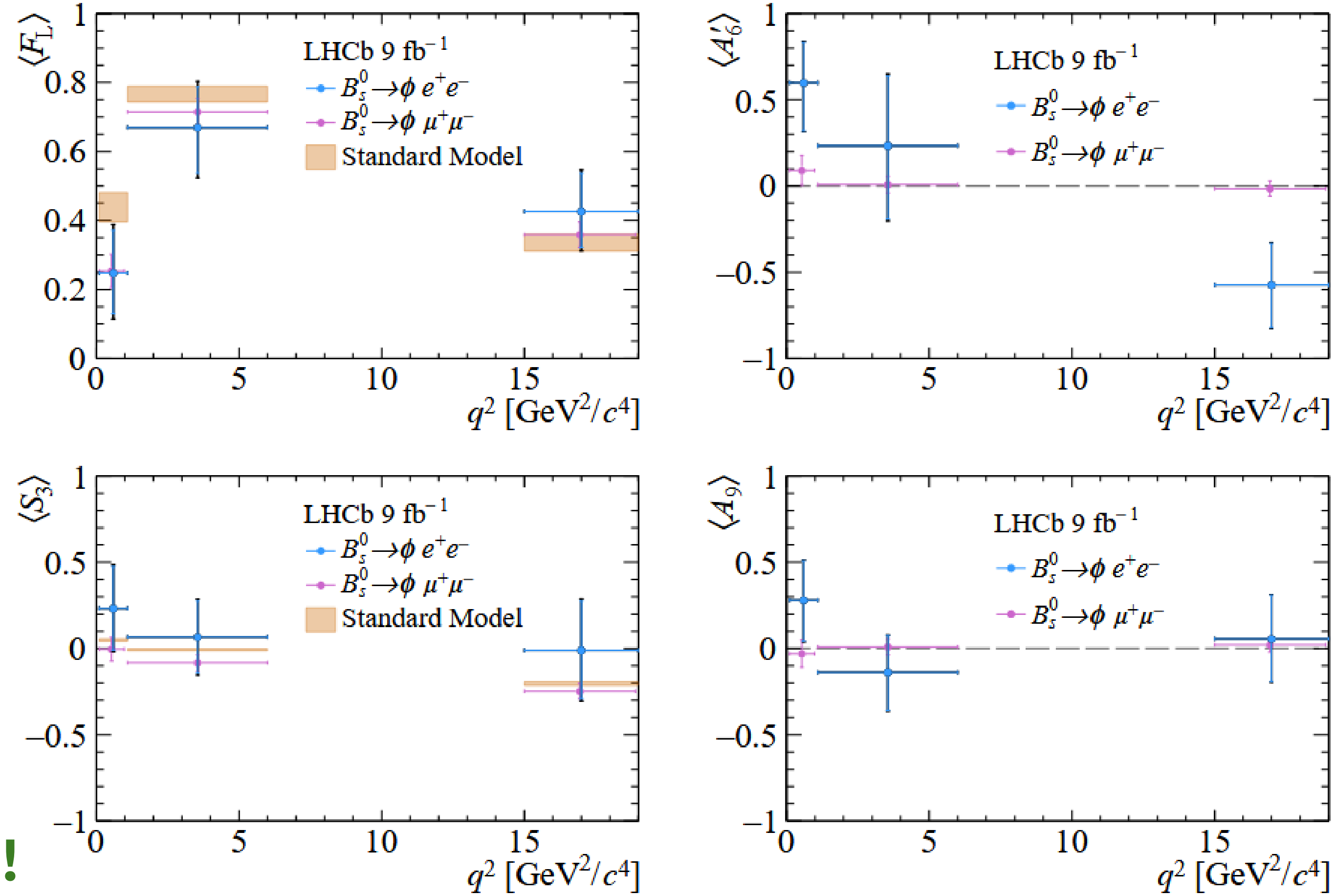
Rare decays: studies $B_s^0 \to \phi e^+ e^-$



- Angular analysis of the $B_s^0 \to \phi e^+ e^-$
- All possible q^2 regions
- Fit results compatible with the muon mode and the SM predictions

- Limited signal sample size (Runs 1+2):
  - No flavor tagging feasible:
    - CP averaged and decay-time-integrated fit
  - Folding of different projections
    - q^2 and one of {$\cos\theta_K$, $\cos\theta_e$, ϕ}

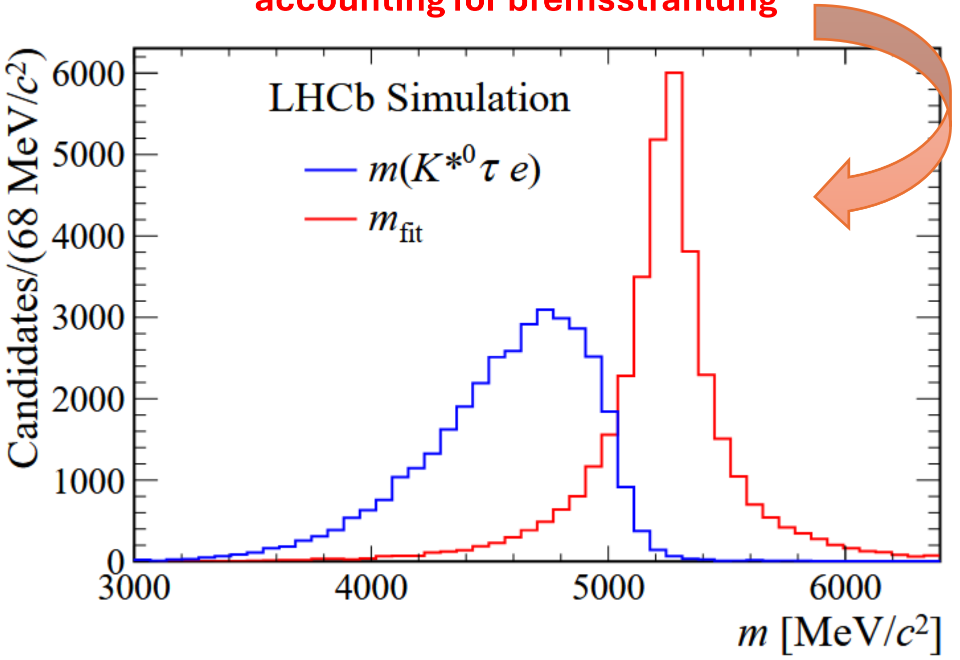
- **Expect >3x in sample size with Run-3 !**



JHEP 07 (2025) 069

Rare decays: search for LFV decays

Accounting for the missing neutrino using kinematics constraints and accounting for bremsstrahlung



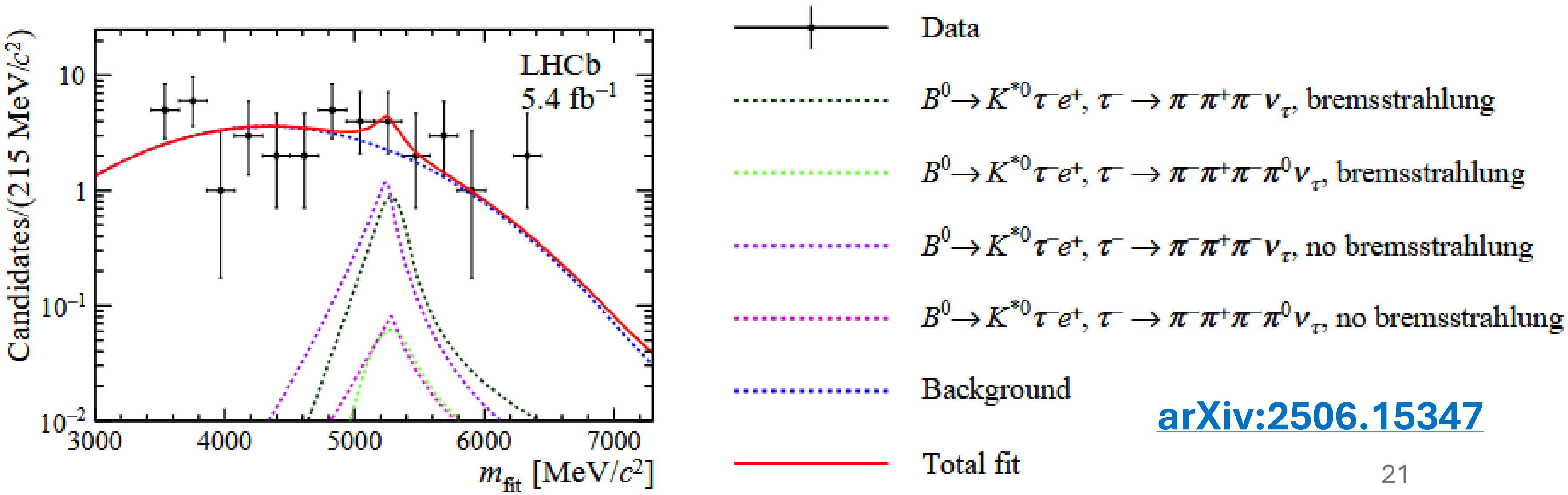
- Lepton Flavour Violating decays would be enabled/enhanced by leptoquarks or models Z'
- Some New Physics models predict branching ratio up to 10^{-6} for $B^0 \to K^{*0}\tau^{\pm}e^{\mp}$
- New LHCb measurement set the best experimental limits

$$\mathcal{B}(B^0 \to K^{*0}\tau^- e^+) < 5.9\ (7.1) \times 10^{-6}$$

$$\mathcal{B}(B^0 \to K^{*0}\tau^+ e^-) < 4.9\ (5.9) \times 10^{-6}$$

at the 90% (95)% confidence level,

Result firs to SM expectations



arXiv:2506.15347

Recent physics results (selected for today)

- New ***$\Xi_c(2923)^+$*** baryon
- New ***$B_c(1P)^+$*** states
- New ***Ξ_{cc}^{++}*** decay channel
- Lifetimes of charmed baryons
- Observation of CPV for baryons
- Rare decays with electrons
- Lepton Flavor Universality (LFU): R_K for high-q^2
- Search for Lepton Flavor Violation (LFV)
- ***Z*** mass measurement **EW**
- ***D*** production asymmetries (**Run-3**)

Hadron Spectroscopy

CPV and Rare decays

EW: *Z* mass at LHCb

- **The first dedicated Z-boson mass measurement at the LHC**
- The dataset uses ***pp*** collisions at $\sqrt{s}$=13 TeV (2016, 1.7 fb $^{-1}$)
- A combination of excellent detector calibration and innovative bias correction technique

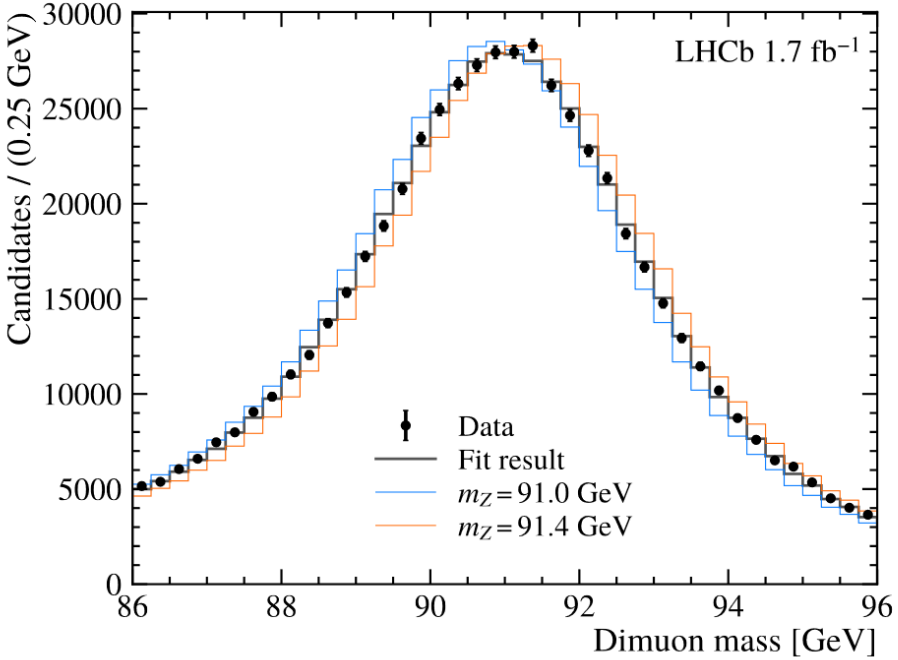
$$m_Z = 91184.2 \pm 8.5 \pm 3.8\text{MeV},$$

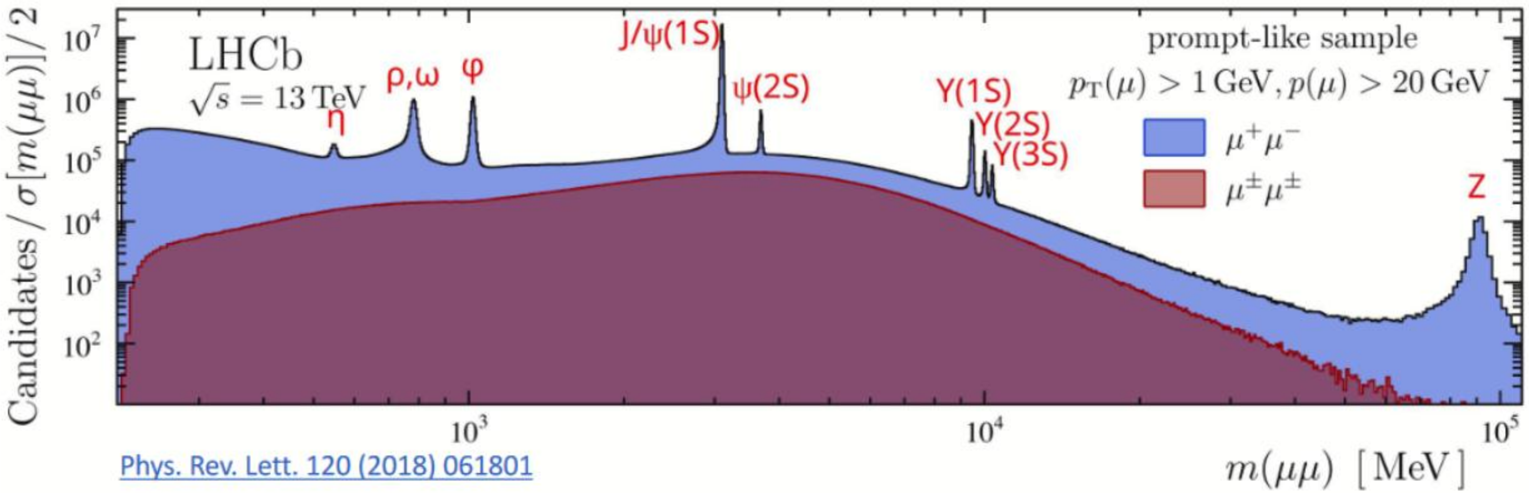
<10 $^{-4}$ precision achieved !

Still statistical uncertainty dominates!

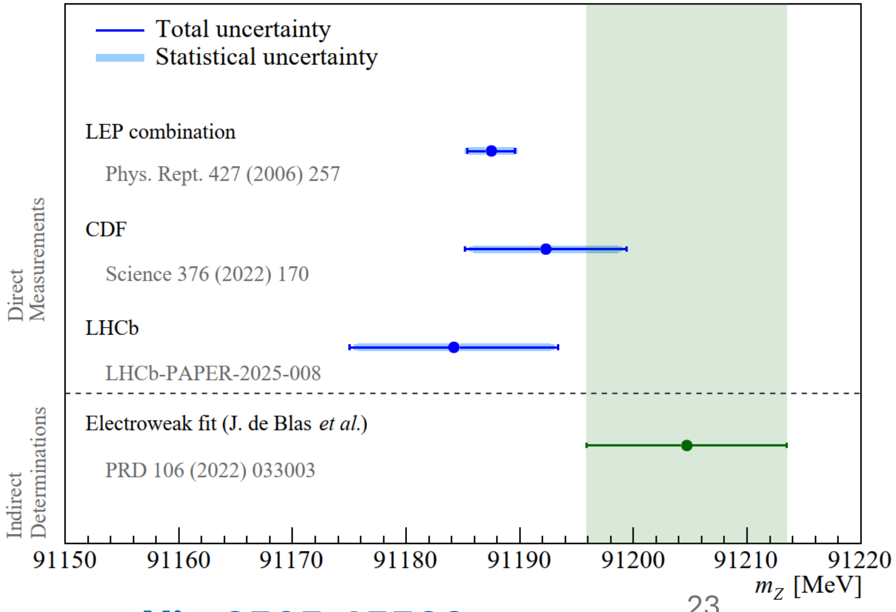
- Result is consistent with previous measurements and predictions from global electroweak fits.

Scan of the dimuon mass distribution with simulation at varying masses to determine the boson mass *Z*



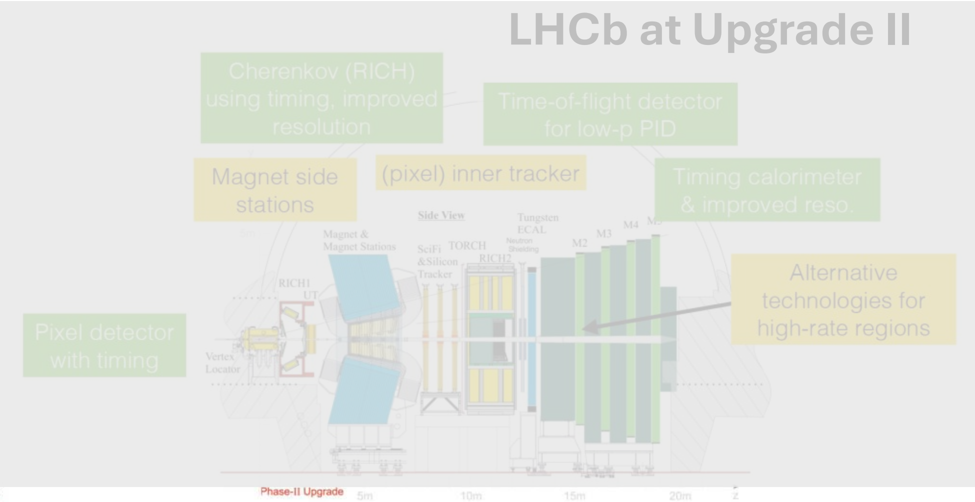


Phys. Rev. Lett. 120 (2018) 061801



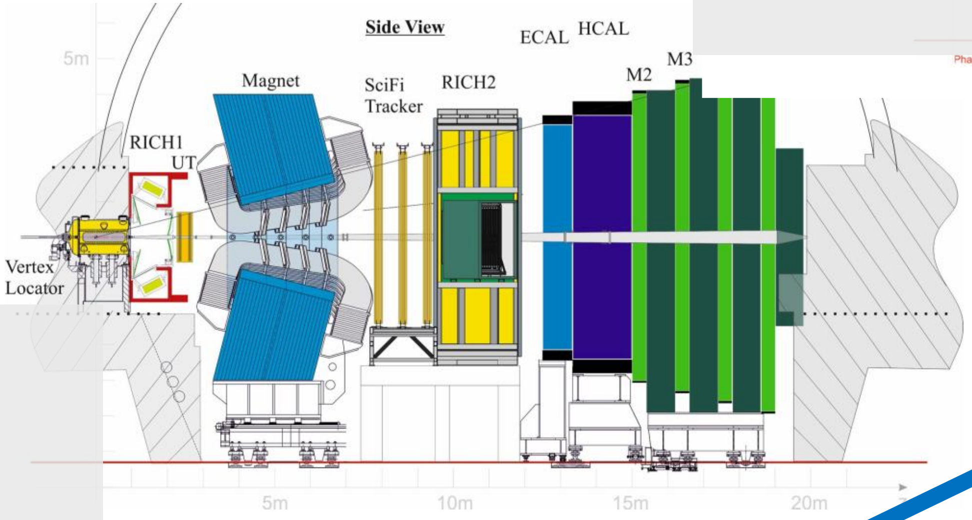
arXiv:2505.15582

LHCb Upgrade I (Runs 3 & 4)



Higher luminosity (roughly factor 5)
+ higher sensitivity
40 MHz redout
Software trigger

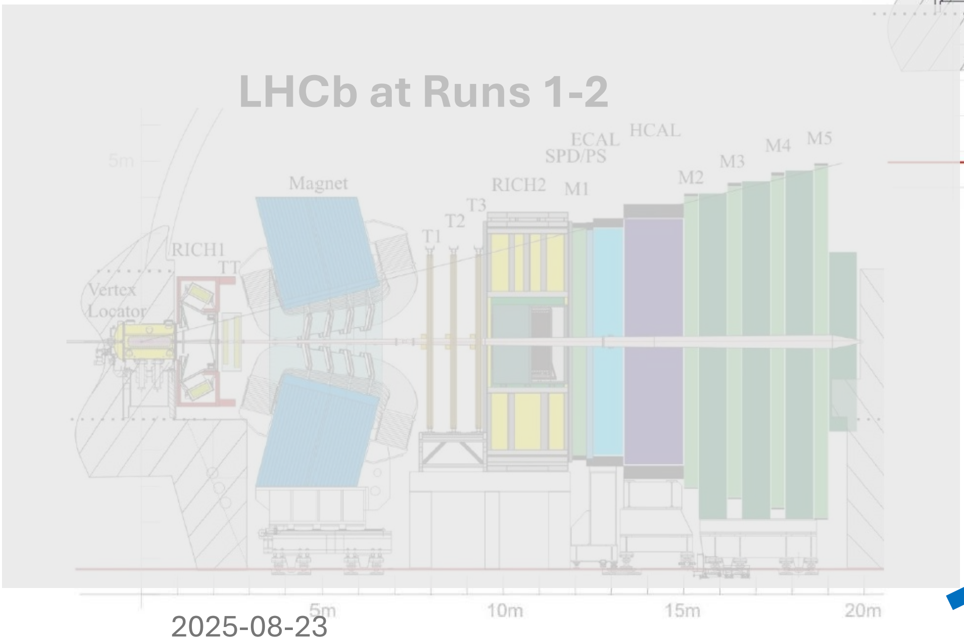
LHCb at Upgrade I



Luminosity

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

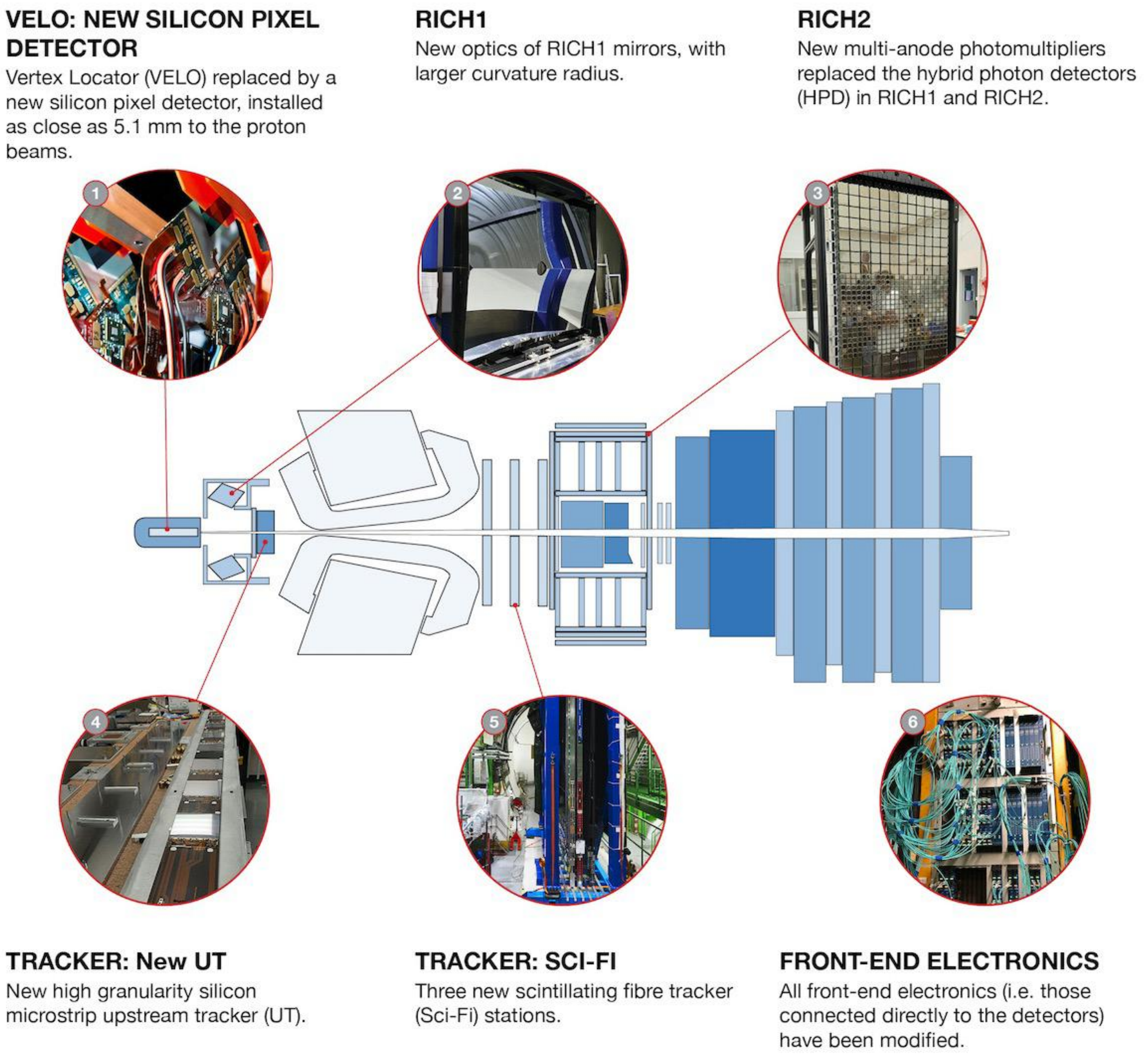
$\mathcal{L} = 2\times10^{33}\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 50\text{ fb}^{-1}$
$\mu \approx 5$



$\mathcal{L} = 4\times10^{32}\text{cm}^{-2}\text{s}^{-1}$
$\mathcal{L}_{int} = 9\text{ fb}^{-1}$
$\mu \approx 1$

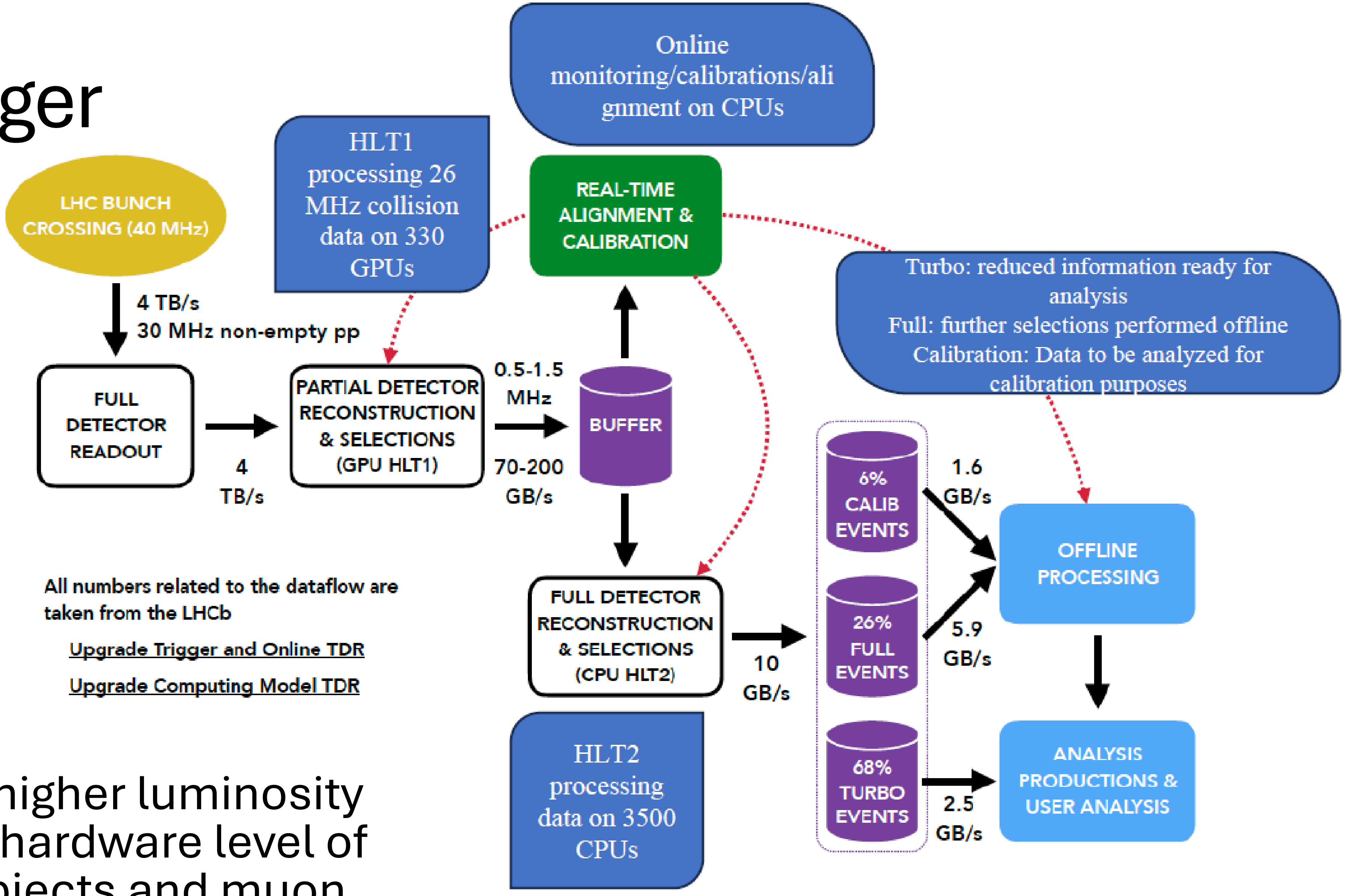
What’s new?

- Pixel-based VELO closer to the beam pipe:
    - 8.2mm→ 5.1mm
- Upstream tracker with higher granularity
- New SciFi tracker
- RICH with new mechanics, optics and PMT readout
- PLUME new detector to measure luminosity
- New SMOG2 system for fixed target physics



arXiv:2305.10515

Software trigger

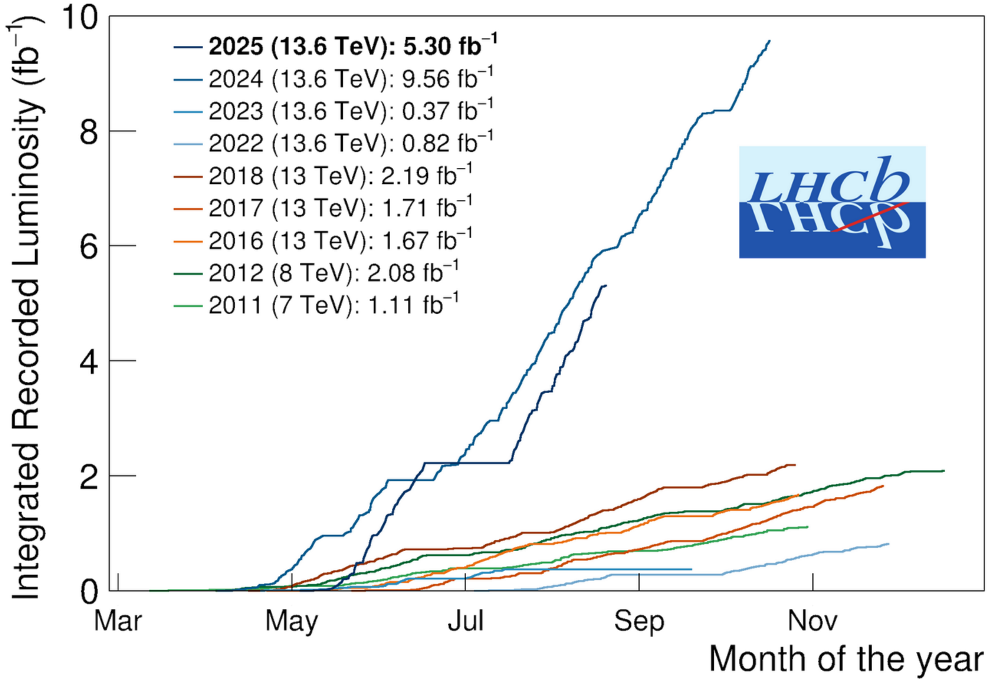


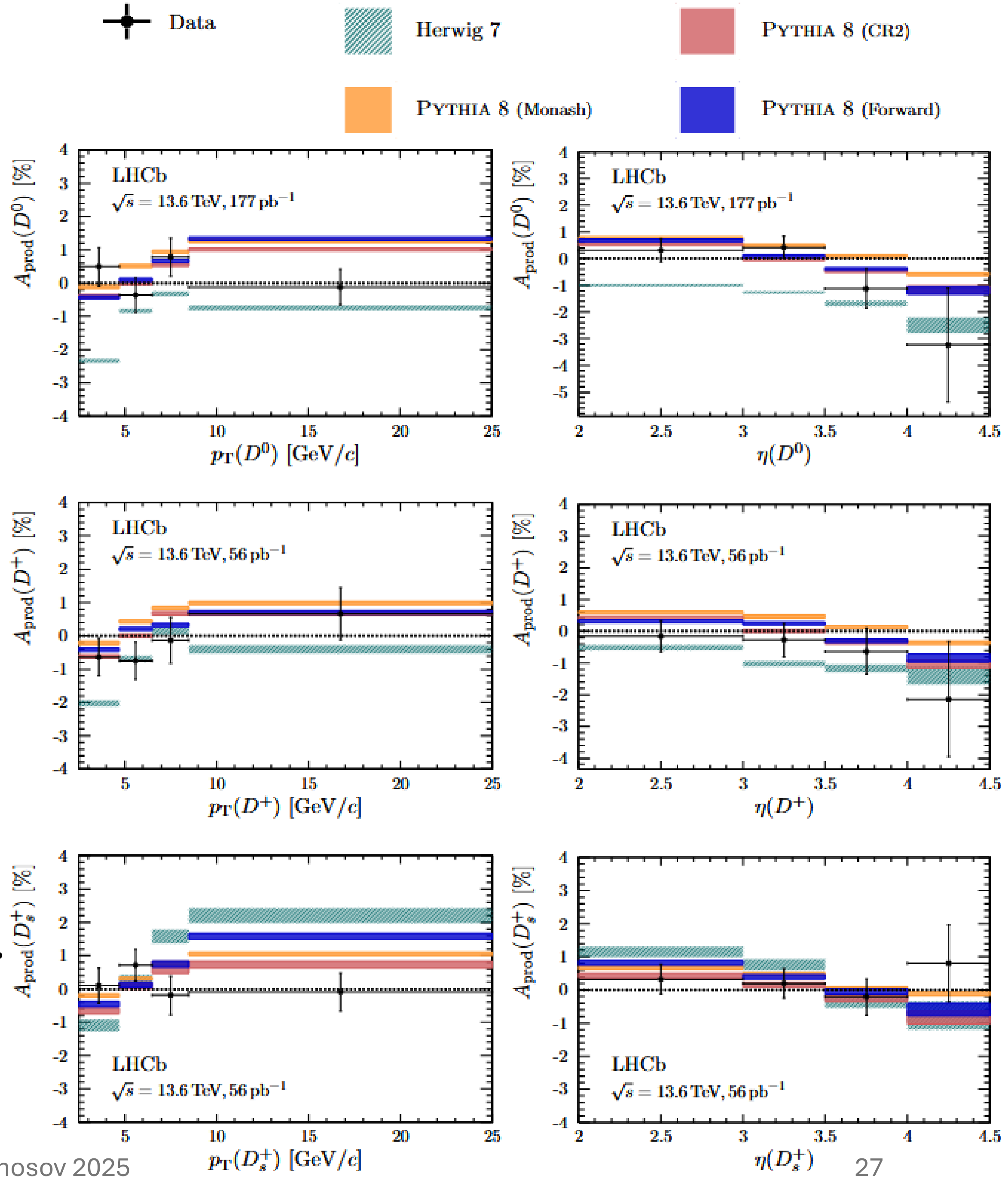
arXiv:1903.01360

- We can’t run into a higher luminosity regime with the old hardware level of the trigger (HCAL objects and muon thresholds) → **Software trigger!**

Write ~10GB/s at 1 MHz

First paper after Upgrade I



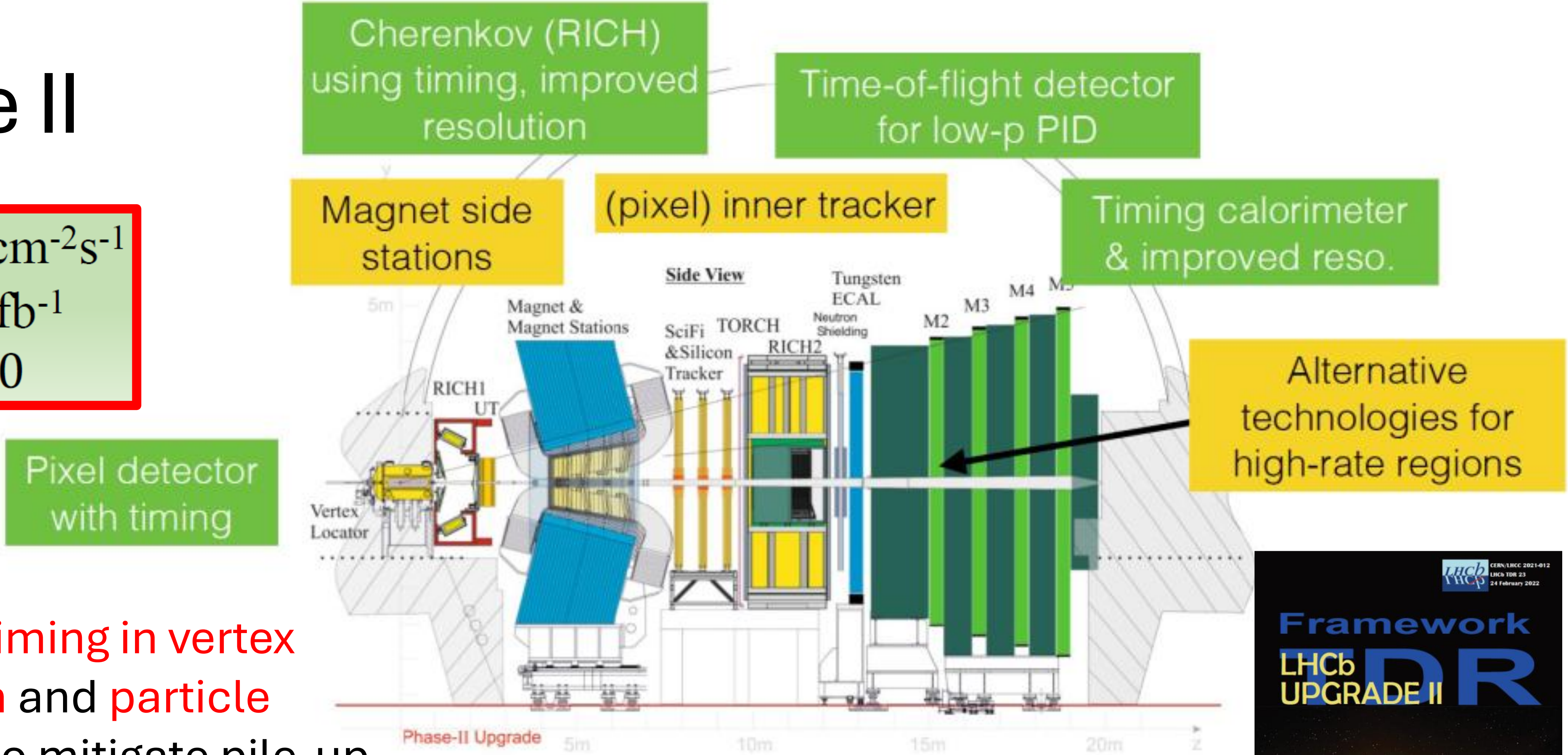


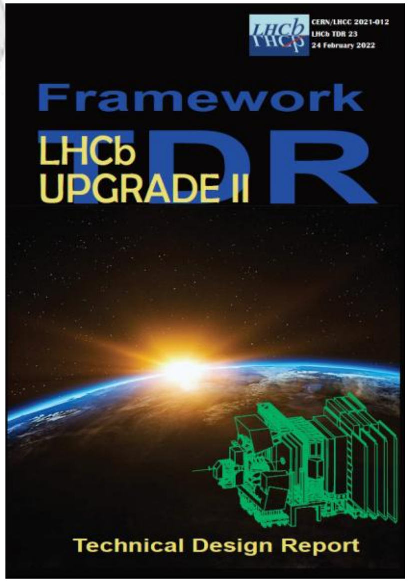
- The asymmetries of ***D***$^+$, ***D***^{0} and ***D***$_s^+$ mesons are measured for two-dimensional intervals in transverse momentum and pseudorapidity.
- **No significant production asymmetries are observed.**

arXiv:2505.14494

Upgrade II

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





- Use O(10 ps) timing in vertex reconstruction and particle identification to mitigate pile-up

- Increase granularity of trackers (UT ans MAPs sectors in SciFi)
- Add tracking stations in the magnet to increase efficiency for low-momentum tracks

Sensitivity projections

LHCb goal is to fully exploit the HL-LHC discovery potential using flavor as a probe of quantum imprints of new phenomena and, more broadly, LHCb as a general-purpose detector in the forward direction exploiting a trigger strategy that can adapt the experiment strategy to the lesson learned during the data taking

arXiv:1808.08865

Current LHCb

Observable	~~Current~~ LHCb (up to 9 fb^{-1})		Upgrade I (23 fb^{-1})	(50 fb^{-1})	Upgrade II (300 fb^{-1})
<u>CKM tests</u>					
γ ($B \to DK$, *etc.*)	4°	[9, 10]	1.5°	1°	0.35°
ϕ_s ($B_s^0 \to J/\psi\phi$)	32 mrad	[8]	14 mrad	10 mrad	4 mrad
$\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ ($\Lambda_b^0 \to p\mu^-\overline{\nu}_\mu$, *etc.*)	6%	[29, 30]	3%	2%	1%
$a_{\rm sl}^d$ ($B^0 \to D^-\mu^+\nu_\mu$)	36×10^{-4}	[34]	8×10^{-4}	5×10^{-4}	2×10^{-4}
$a_{\rm sl}^s$ ($B_s^0 \to D_s^-\mu^+\nu_\mu$)	33×10^{-4}	[35]	10×10^{-4}	7×10^{-4}	3×10^{-4}
<u>Charm</u>					
ΔA_{CP} ($D^0 \to K^+K^-, \pi^+\pi^-$)	29×10^{-5}	[5]	13×10^{-5}	8×10^{-5}	3.3×10^{-5}
A_Γ ($D^0 \to K^+K^-, \pi^+\pi^-$)	11×10^{-5}	[38]	5×10^{-5}	3.2×10^{-5}	1.2×10^{-5}
Δx ($D^0 \to K_s^0\pi^+\pi^-$)	18×10^{-5}	[37]	6.3×10^{-5}	4.1×10^{-5}	1.6×10^{-5}
<u>Rare Decays</u>					
$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	69%	[40, 41]	41%	27%	11%
$S_{\mu\mu}$ ($B_s^0 \to \mu^+\mu^-$)	—		—	—	0.2
$A_{\rm T}^{(2)}$ ($B^0 \to K^{*0}e^+e^-$)	0.10	[52]	0.060	0.043	0.016
$A_{\rm T}^{\rm Im}$ ($B^0 \to K^{*0}e^+e^-$)	0.10	[52]	0.060	0.043	0.016
$\mathcal{A}_{\phi\gamma}^{\Delta\Gamma}$($B_s^0 \to \phi\gamma$)	$^{+0.41}_{-0.44}$	[51]	0.124	0.083	0.033
$S_{\phi\gamma}$($B_s^0 \to \phi\gamma$)	0.32	[51]	0.093	0.062	0.025
α_γ($\Lambda_b^0 \to \Lambda\gamma$)	$^{+0.17}_{-0.29}$	[53]	0.148	0.097	0.038
<u>Lepton Universality Tests</u>					
R_K ($B^+ \to K^+\ell^+\ell^-$)	0.044	[12]	0.025	0.017	0.007
R_{K^*} ($B^0 \to K^{*0}\ell^+\ell^-$)	0.12	[61]	0.034	0.022	0.009
$R(D^*)$ ($B^0 \to D^{*-}\ell^+\nu_\ell$)	0.026	[62, 64]	0.007	0.005	0.002

Summary

- LHCb – the forward spectrometer for precision studies in flavor physics domain

- Excellent performance of the LHC and LHCb has led to **a lot of physics results**:
  - Test of SM
  - Search for NP
  - Make CP violation measurements in b- and c-sectors
  - Spectroscopy measurements
- World best quality of the results in charm and beauty physics!
- Most measurements agree with SM predictions

  → Further studies certainly needed and are in progress!

- Upgrade I is finished and **upgraded detector takes data**
- Upgrade II – **ambitious plan** to have **up to 300 fb^{-1}** of integrated luminosity