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北京大學  
PEKING UNIVERSITY

# Recent Results on CP Violation in Baryon Decays at LHCb

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on behalf of the LHCb collaboration

2025 International Conference on New Frontiers in Physics, Kolymbari  
28.07.2025

- Introduction

- CP violation in charmless beauty baryon decays

➤  $\Lambda_b^0 \rightarrow ph^-$

[PRD 111 (2025), 092004]

➤  $\Lambda_b^0/\Xi_b^0 \rightarrow \Lambda h_1^+ h_2^-$

[PRL 134 (2025) 101802]

➤  $\Lambda_b^0/\Xi_b^0 \rightarrow pK_S^0 h^-$

[LHCb-PAPER-2025-016, in prep.]

➤  $\Lambda_b^0 \rightarrow pK^- \pi^+ \pi^-$

[Nature(2025), arXiv:2503.16954,]

- CP violation in beauty baryon to charmonium decays

➤  $\Lambda_b^0 \rightarrow J/\psi ph^-$

[LHCb-PAPER-2025-021, in prep.]

- CP violation in beauty baryon to open charm decays (decay parameters)

➤  $\Lambda_b^0 \rightarrow \Lambda_c^0 h^-$

[PRL 133 (2024) 261804]

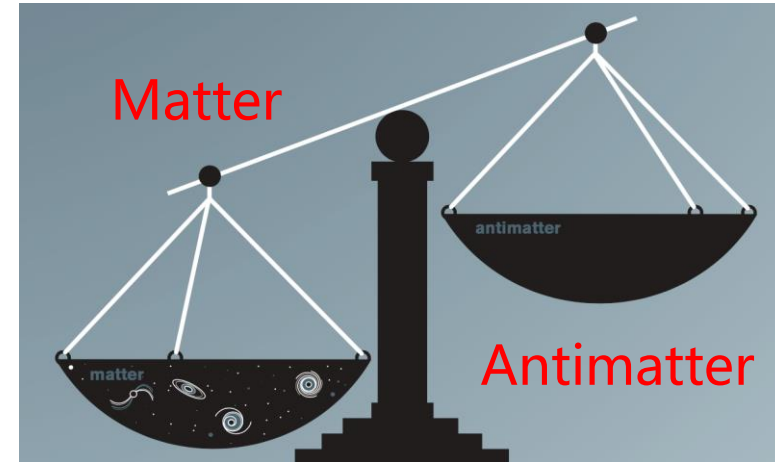
- Conclusions and Outlook

# Introduction

- Violation of CP symmetry (CPV) is essential to explain the observed matter-antimatter asymmetry in the Universe



→  
Sakharov  
conditions



- CPV in Standard Model (SM) is insufficient to account for the observed asymmetry
- Understanding CP violation within the SM (CKM mechanism) and searching for CP violation beyond it are important tasks in particle physics

# CP violation in baryons

- CP violation has been well-established in oscillations and decays of mesons
  - Particularly, B meson decays exhibit CP asymmetries at the level of  $\sim 10\%$
- For baryons, CP violation had never been observed — until recently!
  - **Hyperon:** [\[PRL 129, 131801 \(2022\)\]](#)
    - $A_{CP}(\Lambda \rightarrow p\pi^-) = (-0.25 \pm 0.48)\%$
  - **Charm baryons:** [\[JHEP 03 \(2018\) 182\]](#)
    - $A_{CP}(\Lambda_c^+ \rightarrow pK^+K^-) - A_{CP}(\Lambda_c^+ \rightarrow p\pi^+\pi^-) = (0.30 \pm 1.1)\%$
  - **Bottom baryons:** [\[PRL 134 \(2025\) 101802\]](#)
    - $A_{CP}(\Lambda_b^0 \rightarrow \Lambda K^+K^-) = (-8.3 \pm 2.8)\%$
    - $A_{CP}(\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-) = (2.45 \pm 0.47)\%$  ➔ **First Observation!**  
[\[Nature\(2025\)\]](#)
- CP violation in baryons is complementary to meson studies and essential for comprehensive tests of the CKM mechanism

# LHCb experiment

- Dedicated experiment at CERN for measurement of  $b$ ,  $c$  hadrons

- Single-arm forward spectrometer covers  $2 < \eta < 5$

- Excellent vertex resolution

- $\sigma_{\text{IP}} = 20 \mu\text{m}$

- Excellent momentum resolution

- $\Delta p/p = 0.5 - 1.0\%$  (5 – 200 GeV/c)

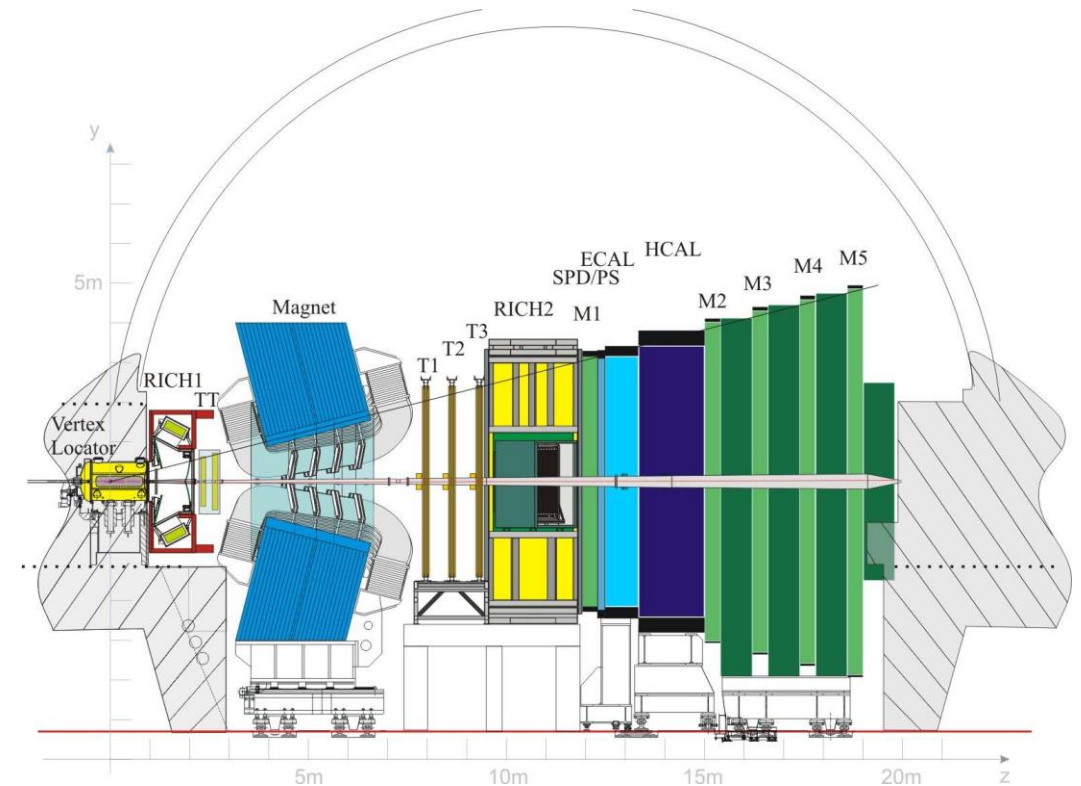
- Efficient particle identification (PID)

- $\epsilon(K \rightarrow K) \sim 95\%$

- $\text{misID}\epsilon(\pi \rightarrow K) \sim 5\%$

## ❖ LHCb Dataset

- ❖ Run1 + Run2 (2011-2018):  $9 \text{ fb}^{-1}$  of pp collisions



[JINST 3 (2008) S08005, Int. J. Mod. Phys. A30, 1530022 (2015)]

# CP violation measurement

- CP violation is manifested as a difference between the decay rate of a particle and that of its antiparticle

$$A_{CP} = \frac{\Gamma(\Lambda_b^0 \rightarrow X) - \Gamma(\bar{\Lambda}_b^0 \rightarrow \bar{X})}{\Gamma(\Lambda_b^0 \rightarrow X) + \Gamma(\bar{\Lambda}_b^0 \rightarrow \bar{X})}$$

- The raw asymmetry is directly measured by determining the yields

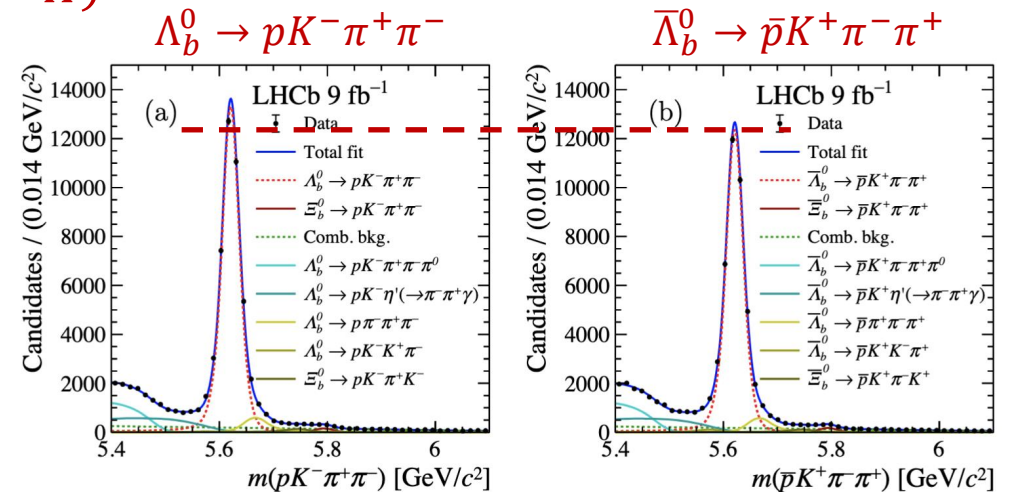
$$A_{raw} = \frac{N(\Lambda_b^0 \rightarrow X) - N(\bar{\Lambda}_b^0 \rightarrow \bar{X})}{N(\Lambda_b^0 \rightarrow X) + N(\bar{\Lambda}_b^0 \rightarrow \bar{X})}$$

- Experimental and production asymmetries need to be subtracted

$$A_{CP} = A_{raw} - A_{exp} - A_P$$

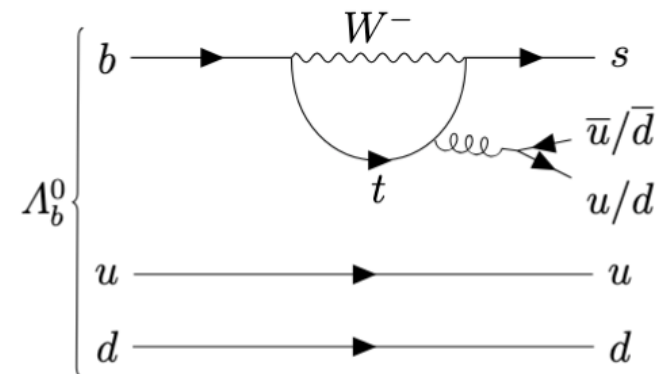
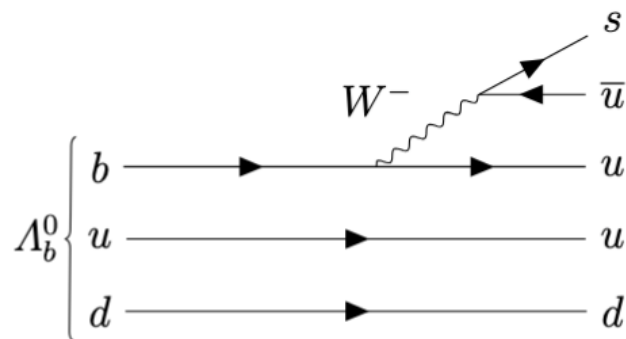
- Control channel is included in some results, and the difference of CPV is measured

$$\Delta A_{CP} = A_{CP}(sig) - A_{CP}(ctrl)$$



[Nature(2025)]

# CP violation in charmless beauty baryon decays



# $A_{CP}$ measurement in $\Lambda_b^0 \rightarrow ph^-$ decays

[PRD 111 (2025), 092004]

- Search for CP violation in  $\Lambda_b^0 \rightarrow pK^-$  and  $\Lambda_b^0 \rightarrow p\pi^-$  decays, using Run1+Run2 samples
- Dynamics analogy to  $B^0 \rightarrow h^+h^-$  decays

Transition	$b \rightarrow u\bar{u}d$		$b \rightarrow u\bar{u}s$	
	$B^0 \rightarrow \pi^+\pi^-$	$B_s^0 \rightarrow \pi^+K^-$	$B^0 \rightarrow K^+\pi^-$	$B_s^0 \rightarrow K^+K^-$
Decays	$B^0 \rightarrow \pi^+\pi^-$	$B_s^0 \rightarrow \pi^+K^-$	$B^0 \rightarrow K^+\pi^-$	$B_s^0 \rightarrow K^+K^-$
Direct CPV (%)	$-31.4 \pm 3.0$	$22.4 \pm 1.2$	$8.31 \pm 0.31$	$16.2 \pm 3.5$

$$\begin{cases} A_{CP}^{p\pi^-} = (-2.5 \pm 2.2)\% \\ A_{CP}^{pK^-} = (-2.5 \pm 2.9)\% \end{cases}$$

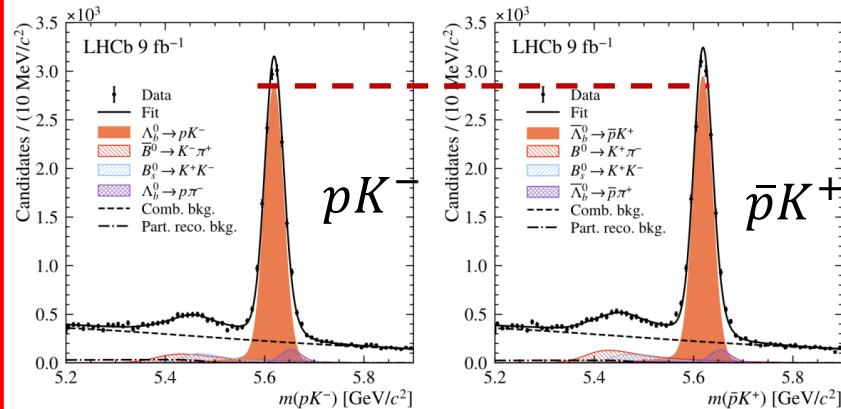
(Dominated by LHCb Run1 measurement)

[PRB 787 (2018) 124-133]

- $A_{CP}$  measurement

$$A_{CP}^{ph^-} = A_{\text{raw}}^{ph^-} - A_D^p - A_D^{h^-} - A_{\text{PID}}^{ph^-} - A_T^{ph^-} - A_P^{\Lambda_b^0}$$

$$A_{\text{raw}} = \frac{N(\Lambda_b^0 \rightarrow ph^-) - N(\bar{\Lambda}_b^0 \rightarrow \bar{p}h^+)}{N(\Lambda_b^0 \rightarrow ph^-) + N(\bar{\Lambda}_b^0 \rightarrow \bar{p}h^+)}$$



## Experimental asymmetries

- Detection asymmetries  
From calibration samples  
 $p \sim 1\%$ ,  $K^+ \sim 0.5\%$ ,  $\pi^+ \sim 0.1\%$
- PID asymmetries  $A_{\text{PID}} \sim 0.1\%$   
From calibration samples
- Trigger asymmetries  $A_T \sim 0.1\%$   
Data driven method

## Production asymmetry

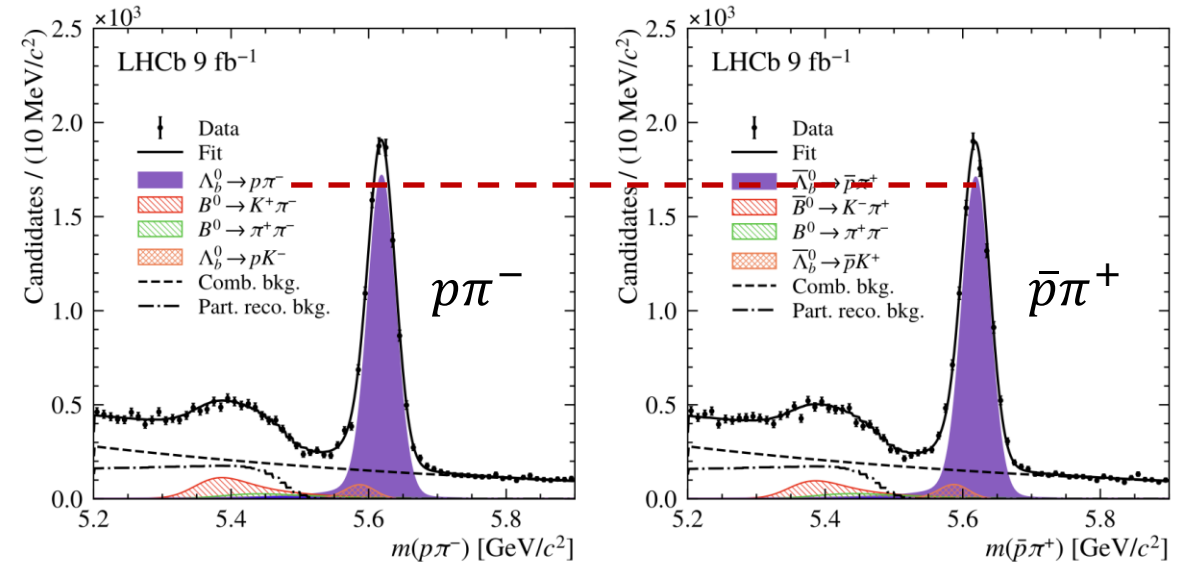
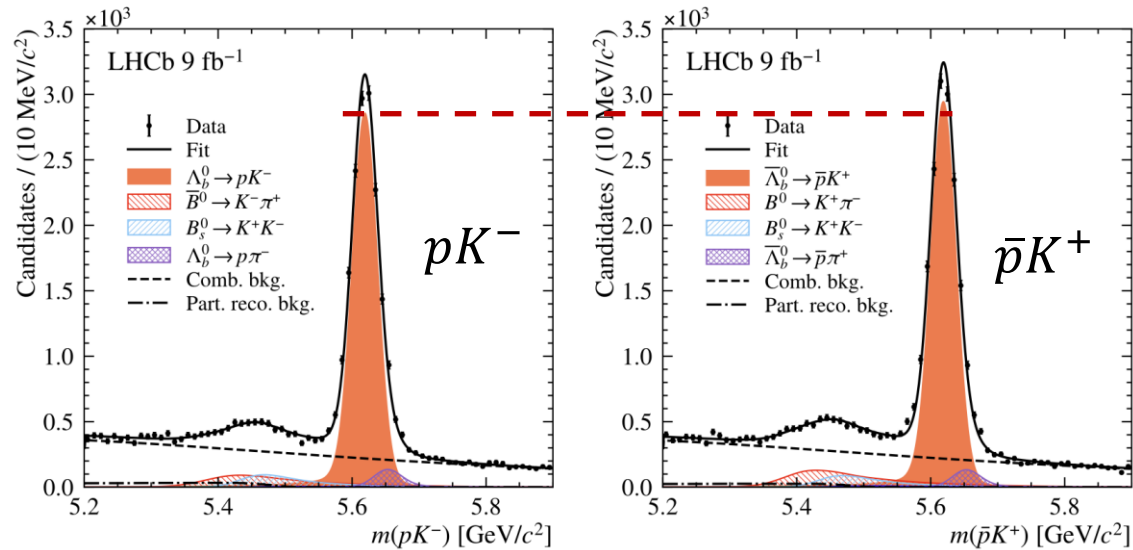
$$A_P \equiv \frac{\sigma(pp \rightarrow \Lambda_b^0 Y) - \sigma(pp \rightarrow \bar{\Lambda}_b^0 Y)}{\sigma(pp \rightarrow \Lambda_b^0 Y) + \sigma(pp \rightarrow \bar{\Lambda}_b^0 Y)}$$

- Measured for Run1  $A_P \sim 1\%$   
[J. High Energy Phys. 10 (2021) 060]
- Control channel for Run2  
 $\Lambda_b^0 \rightarrow \Lambda_c^+ (\rightarrow pK^-\pi^+)\pi^-$

- Sizable CP violation ruled out

$$A_{CP}^{pK^-} = (-1.1 \pm 0.7 \pm 0.4)\%$$

$$A_{CP}^{p\pi^-} = (+0.2 \pm 0.8 \pm 0.4)\%$$



- Most precise result in this mode

- The precision improved by a factor of 3 compared to the PDG value
- Not dominated by systematics anymore

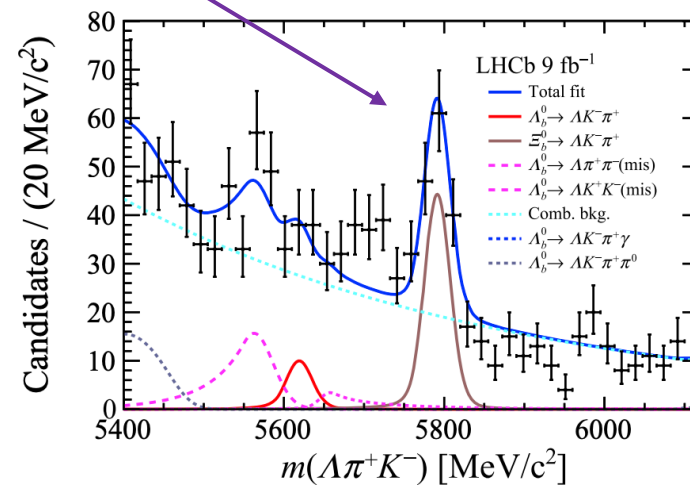
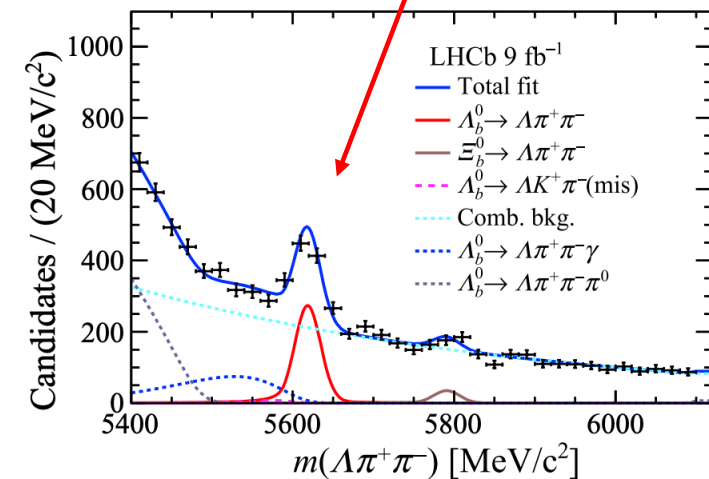
- Study of three  $\Lambda_b^0$  decays  $\Lambda\pi^+\pi^-$ ,  $\Lambda K^+\pi^-$ ,  $\Lambda K^+K^-$ , and  $\Xi_b^0 \rightarrow \Lambda K^-\pi^+$ ,  $\Lambda\pi^+\pi^-$  decay

➤ Run1+Run2

➤ Control channel:  $\Lambda_b^0 \rightarrow \Lambda_c^+(\rightarrow \Lambda\pi^+)\pi^-$

- Measurement of 5 branching fractions

➤  $\Lambda_b^0 \rightarrow \Lambda\pi^+\pi^-$ ,  $\Xi_b^0 \rightarrow \Lambda K^-\pi^+$  are observed for the **first time**



Decay	$\mathcal{B}(\times 10^{-6})$
$\Lambda_b^0 \rightarrow \Lambda\pi^+\pi^-$	$5.3 \pm 0.4 \pm 0.5 \pm 0.5$
$\Lambda_b^0 \rightarrow \Lambda K^+\pi^-$	$4.6 \pm 0.2 \pm 0.4 \pm 0.5$
$\Lambda_b^0 \rightarrow \Lambda K^+K^-$	$10.7 \pm 0.3 \pm 0.4 \pm 1.1$
$\Xi_b^0 \rightarrow \Lambda\pi^+\pi^-$	$11.0 \pm 2.6 \pm 1.4 \pm 3.8$
$\Xi_b^0 \rightarrow \Lambda K^-\pi^+$	$10.4 \pm 1.4 \pm 1.2 \pm 3.5$

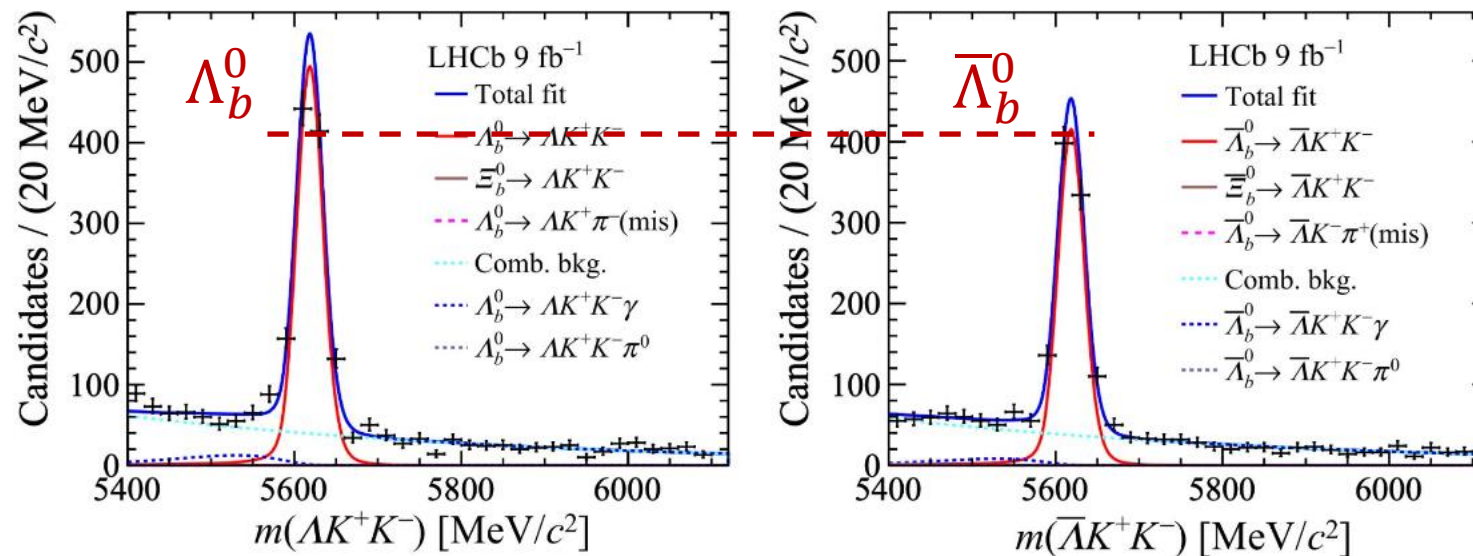
- $\Delta A_{CP}$  measured for 4 channels

➤  $\Delta A_{CP} = A_{\text{raw}}(\text{signal}) - A_{\text{raw}}(\text{control}) - \Delta A_P - \Delta A_{\text{exp}}$

$\Delta \mathcal{A}^{CP} (\Lambda_b^0 \rightarrow \Lambda \pi^+ \pi^-)$	$= -0.013 \pm 0.053 \pm 0.018,$
$\Delta \mathcal{A}^{CP} (\Lambda_b^0 \rightarrow \Lambda K^+ \pi^-)$	$= -0.118 \pm 0.045 \pm 0.021,$
$\Delta \mathcal{A}^{CP} (\Lambda_b^0 \rightarrow \Lambda K^+ K^-)$	$= 0.083 \pm 0.023 \pm 0.016,$
$\Delta \mathcal{A}^{CP} (\Xi_b^0 \rightarrow \Lambda K^- \pi^+)$	$= 0.27 \pm 0.12 \pm 0.05,$

- Evidence ( $3.1\sigma$ ) of direct CP violation is found in  $\Lambda_b^0 \rightarrow \Lambda K^+ K^-$  decay

- Significance calculate using the negative log-likelihood method , confirmed by pseudoexperiments



Recent results on CP violation in baryon decays at LHCb

# $A_{CP}$ measurement in $\Lambda_b^0/\Xi_b^0 \rightarrow \Lambda h_1^+ h_2^-$ decays

- $\Lambda_b^0 \rightarrow \Lambda K^+ K^-$  is dominated by intermediate  $N^{*+}(\rightarrow \Lambda K^+)$  and  $\phi(\rightarrow K^+ K^-)$  resonances
- In the region dominated by the  $N^{*+}$  resonance, local  $A_{CP}$  show  $3.2\sigma$  evidence, examined by pseudoexperiments

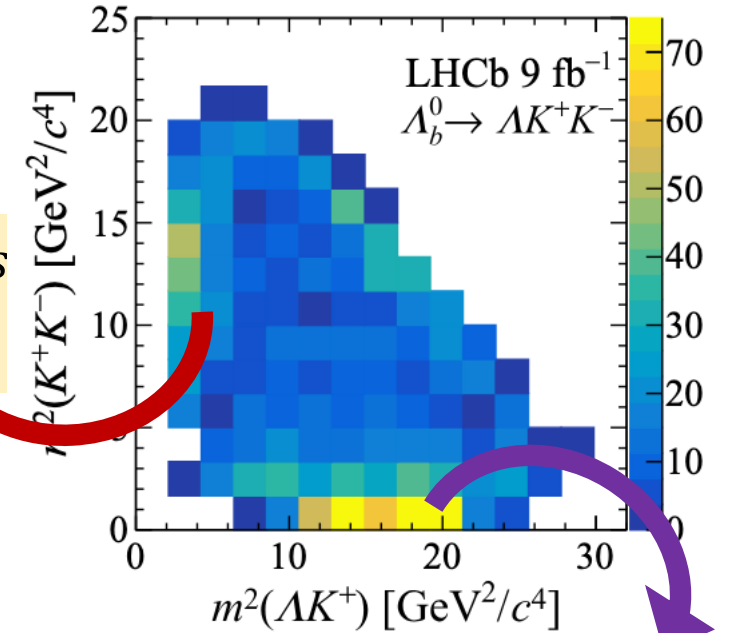
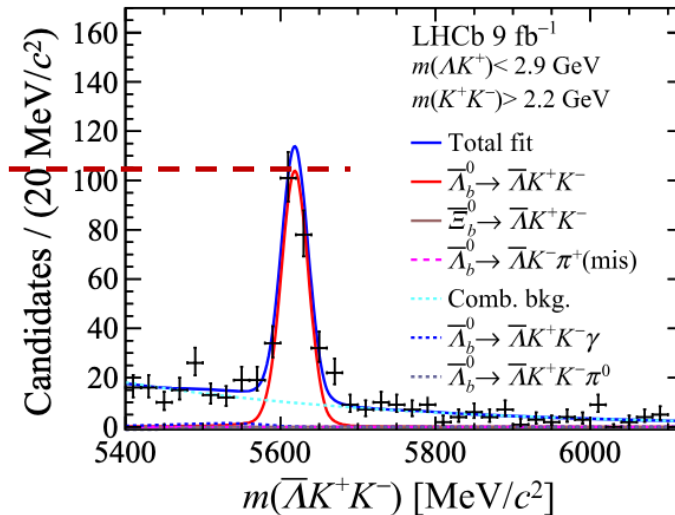
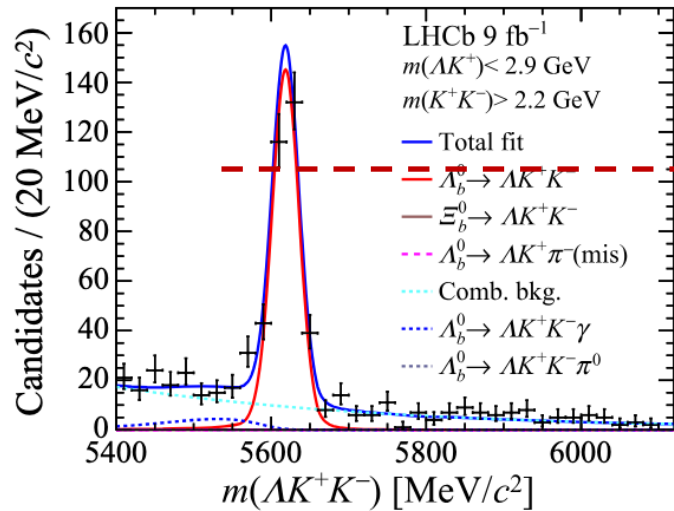
$$m_{\Lambda K^+} < 2.9 \text{ GeV}$$

$\Lambda_b^0 \rightarrow N^{*+}(\rightarrow \Lambda K^+)K^-$ : possibly via  $b \rightarrow u\bar{u}s$

$$\Delta A_{CP}(N^{*+}K^-) = 0.165 \pm 0.048 \pm 0.017$$

$\Lambda_b^0 \rightarrow N^{*+}K^-$

$\bar{\Lambda}_b^0 \rightarrow N^{*-}K^+$



$$m_{K^+K^-} < 1.1 \text{ GeV} \quad (\text{consistent with zero})$$

$\Lambda_b^0 \rightarrow \Lambda\phi(\rightarrow K^+K^-)$  or non-resonant:

$$\Delta A_{CP}(\Lambda\phi) = 0.150 \pm 0.055 \pm 0.021$$

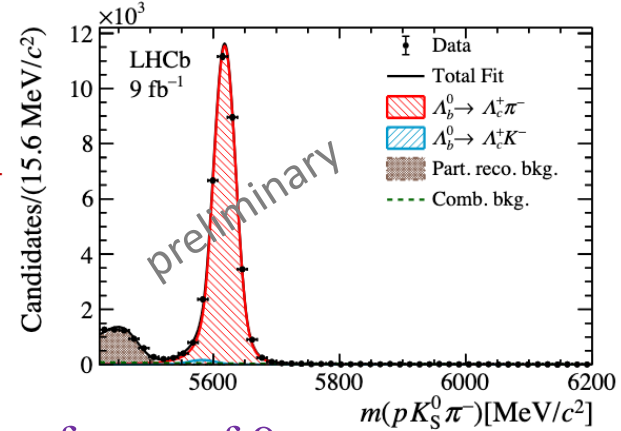
# Study of $\Lambda_b^0/\Xi_b^0 \rightarrow pK_S^0 h^-$ decays

- Study of  $\Lambda_b^0$  and  $\Xi_b^0$  baryon to the final states of  $pK_S^0\pi^-$  and  $pK_S^0K^-$ , Run1+Run2

- Update of previous analysis used only 2011 data

- Control channel:  $\Lambda_b^0 \rightarrow \Lambda_c^+(\rightarrow pK_S^0)\pi^-$

Control channel:  
 $\Lambda_b^0 \rightarrow \Lambda_c^+(\rightarrow pK_S^0)\pi^-$



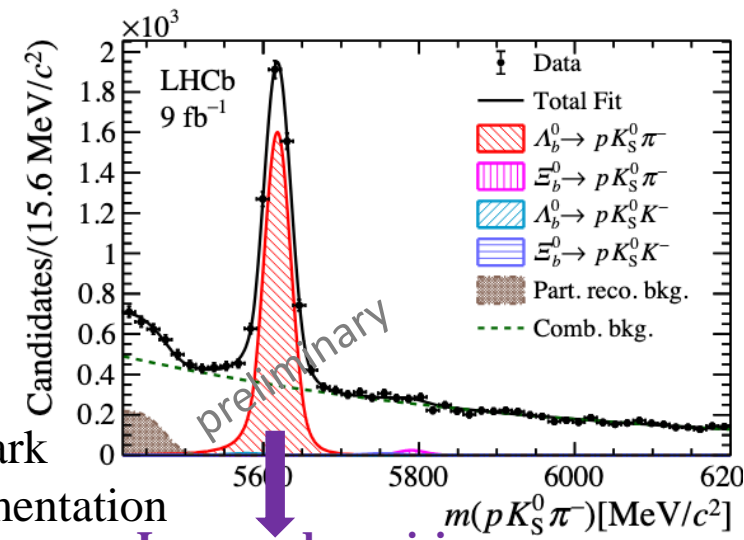
- Measurement of all 4 BFs

- Improved branching fraction measurement of  $\Lambda_b^0 \rightarrow pK_S^0\pi^-$  with a factor of 9

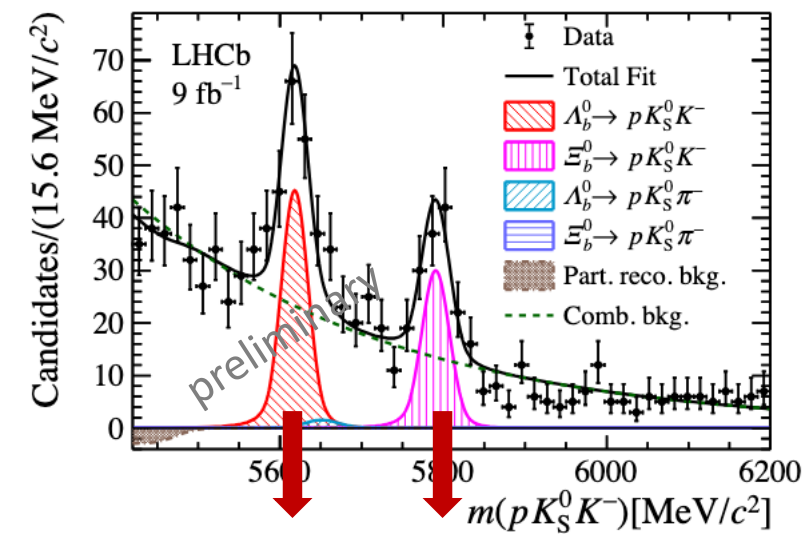
- **First Observation of 2 decays**

	Result [ $\times 10^{-6}$ ]
$\mathcal{B}(\Lambda_b^0 \rightarrow pK_S^0\pi^-)$	$10.62 \pm 0.21 \pm 0.16 \pm 0.98$
$\mathcal{B}(\Lambda_b^0 \rightarrow pK_S^0K^-)$	$0.61 \pm 0.08 \pm 0.06 \pm 0.06$
$\mathcal{B}(\Xi_b^0 \rightarrow pK_S^0\pi^-)$	$< 2.8 (3.2)$ at 90 (95)% CL
$\mathcal{B}(\Xi_b^0 \rightarrow pK_S^0K^-)$	$3.9 \pm 0.6 \pm 0.5 \pm 0.4 \pm 1.4$

stat.    syst.    control mode    b-quark fragmentation fractions



Improved precision



**First Observation!**

- $\Delta A_{CP}$  measurement in 3 observed decays

➤  $\Delta A_{CP} = \Delta A_{\text{raw}} - \Delta A_P - \Delta A_{\text{exp}}$

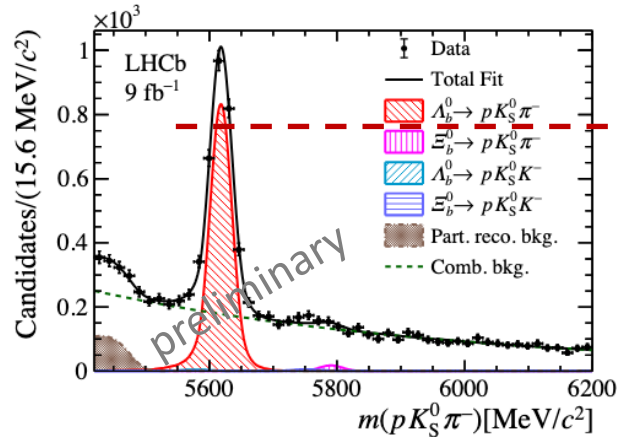
- No CP violation is found

➤ Global  $A_{CP}$  in 3 decay modes

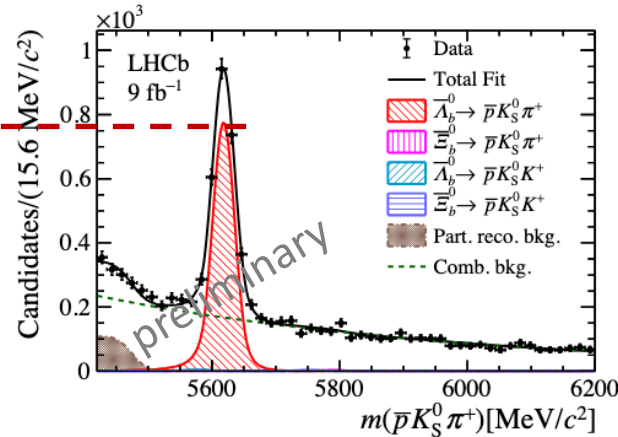
	Result [%]
$\mathcal{A}^{CP} (\Lambda_b^0 \rightarrow pK_S^0 \pi^-)$	$3.4 \pm 1.9 \pm 0.9$
$\mathcal{A}^{CP} (\Lambda_b^0 \rightarrow pK_S^0 K^-)$	$2 \pm 13 \pm 9$
$\mathcal{A}^{CP} (\Xi_b^0 \rightarrow pK_S^0 K^-)$	$22 \pm 15 \pm 11$

➤ Signal channel

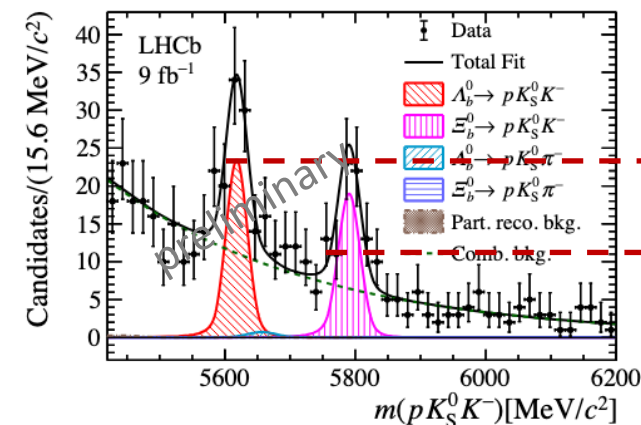
$\Lambda_b^0 \rightarrow pK_S^0 \pi^-$



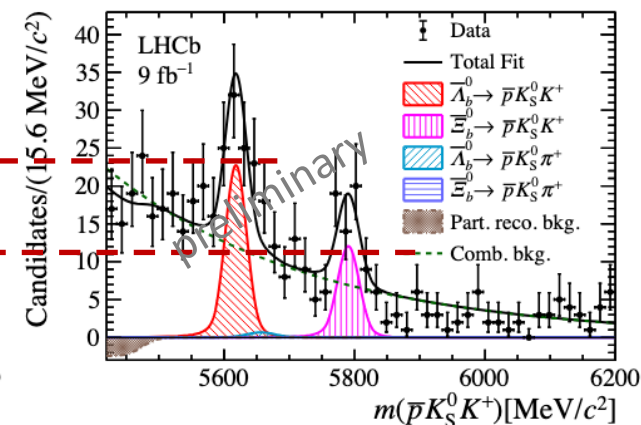
$\bar{\Lambda}_b^0 \rightarrow \bar{p}K_S^0 \pi^+$



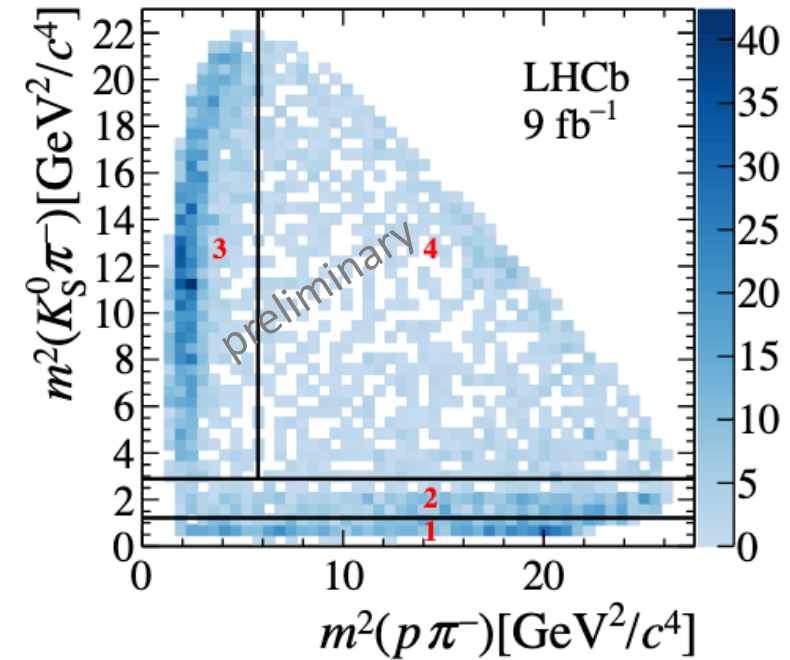
$\Lambda_b^0 \rightarrow pK_S^0 K^-$



$\bar{\Lambda}_b^0 \rightarrow \bar{p}K_S^0 K^+$



- Local  $A_{CP}$  for  $\Lambda_b^0 \rightarrow pK_S^0\pi^-$  investigated
  - $N^*, K^{*-}$  resonances observed
  - $A_{CP}$  measured in 4 bins
- **No CP violation is found**



- Local  $A_{CP}$  in 4 regions of  $\Lambda_b^0 \rightarrow pK_S^0\pi^-$  decay

	$m(p\pi^-)$	$m(K_S^0\pi^-)$	Yield	$\mathcal{A}^{CP}$ [%]
Bin 1	-	$< 1.1 \text{ GeV}/c^2$	$821 \pm 34$	$-0.6 \pm 4.0 \pm 1.9$
Bin 2	-	$[1.1, 1.7] \text{ GeV}/c^2$	$870 \pm 40$	$12.4 \pm 4.2 \pm 1.8$
Bin 3	$< 2.4 \text{ GeV}/c^2$	$> 1.7 \text{ GeV}/c^2$	$2200 \pm 50$	$0.5 \pm 2.4 \pm 1.1$
Bin 4	$> 2.4 \text{ GeV}/c^2$	$> 1.7 \text{ GeV}/c^2$	$840 \pm 50$	$3.3 \pm 5.5 \pm 2.0$

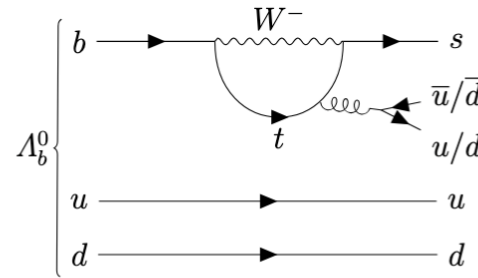
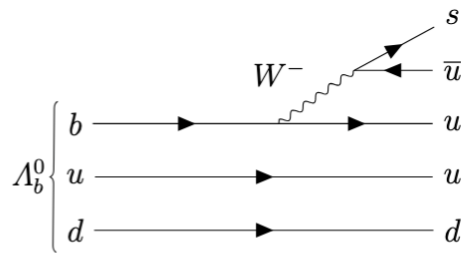
# $A_{CP}$ measurement in $\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-$ decays

[Nature(2025)]

- Search for CP violation in  $\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-$  decays

$$A_{CP} = \frac{\Gamma(\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-) - \Gamma(\bar{\Lambda}_b^0 \rightarrow \bar{p}K^+\pi^-\pi^+)}{\Gamma(\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-) + \Gamma(\bar{\Lambda}_b^0 \rightarrow \bar{p}K^+\pi^-\pi^+)}$$

- Amplitudes of the tree and penguin transitions are expected to have comparable contributions



Sizeable weak phase difference

- Rich resonances

$$\begin{aligned} \Lambda_b^0 &\rightarrow N^{*+}(p\pi^+\pi^-)K^-, & pK^{*-}(K^-\pi^+\pi^-) \\ \Lambda_b^0 &\rightarrow \Lambda^*(pK^-)f(\pi^+\pi^-), & N^{*0}(p\pi^-)K^{*0}(\pi^+K^-) \end{aligned}$$

Possible strong phase difference

- Cancelling production and detection asymmetries:  $A_{CP} = \Delta A_{\text{raw}} - \Delta A_p - \Delta A_{\text{exp}}$

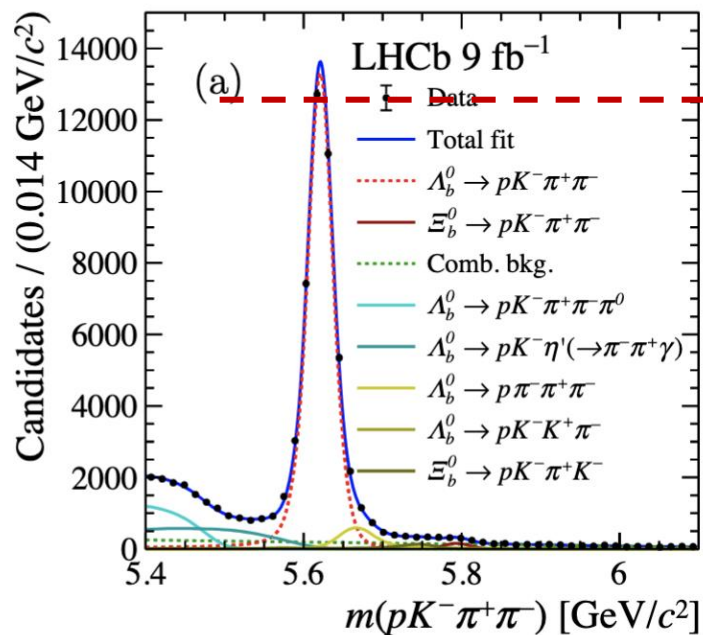
- Control channel:  $\Lambda_b^0 \rightarrow \Lambda_c^+(pK^-\pi^+)\pi^-$
- Same final state, no CP violation expected

## ➤ First observation of CPV in baryonic decays

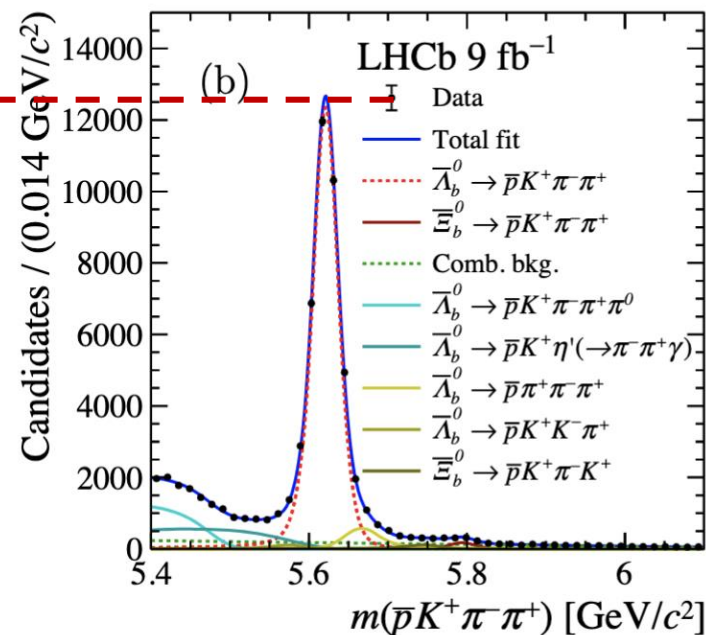
•  $A_{CP} = (2.45 \pm 0.46 \pm 0.10)\% \quad 5.2\sigma$

Using z-score method

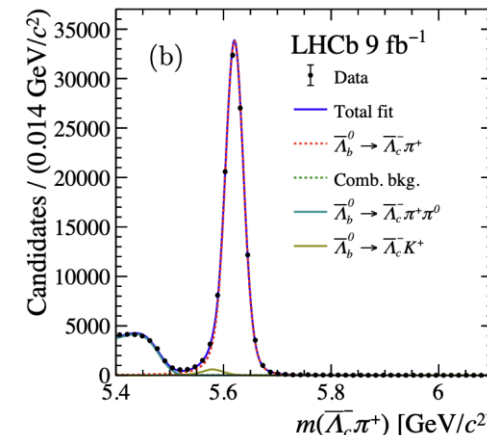
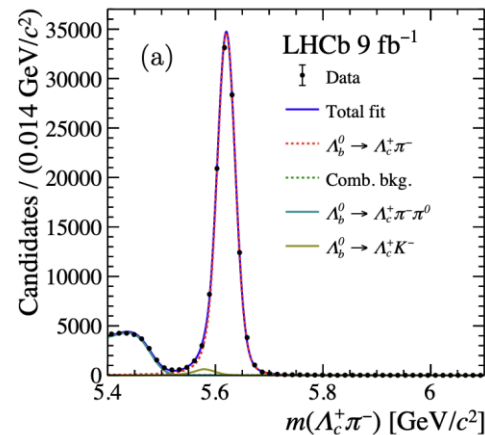
### ➤ Signal channel



$A_{\text{raw}}(\text{signal}) = (3.71 \pm 0.39)\%$



### ➤ Control channel



$A_{\text{raw}}(\text{control}) = (1.25 \pm 0.23)\%$

# $A_{CP}$ measurement in $\Lambda_b^0 \rightarrow pK^-\pi^+\pi^-$ decays

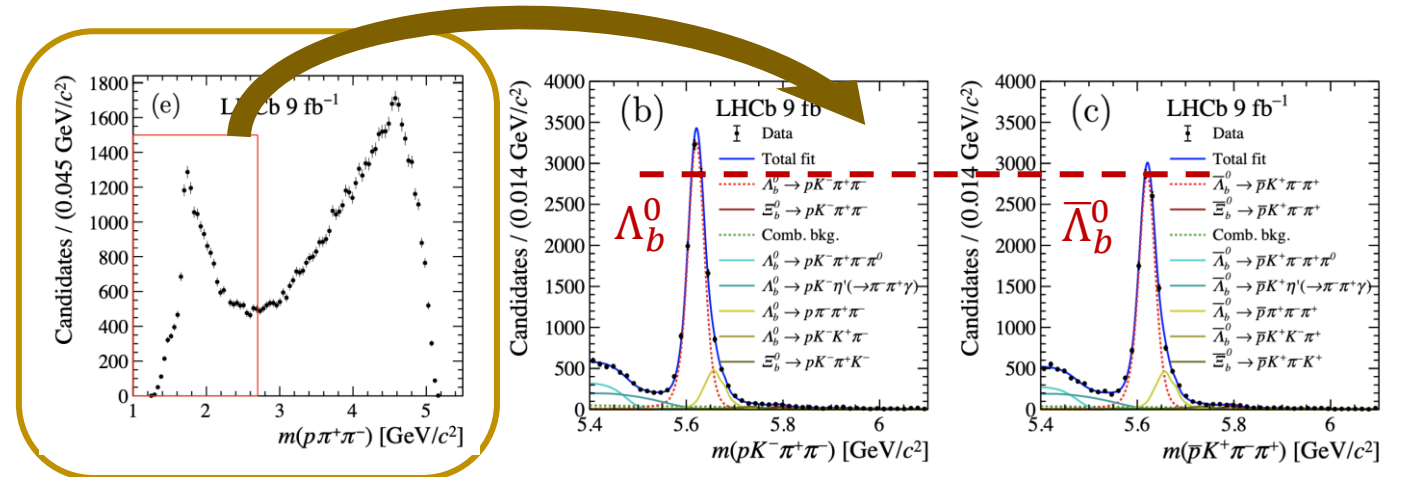
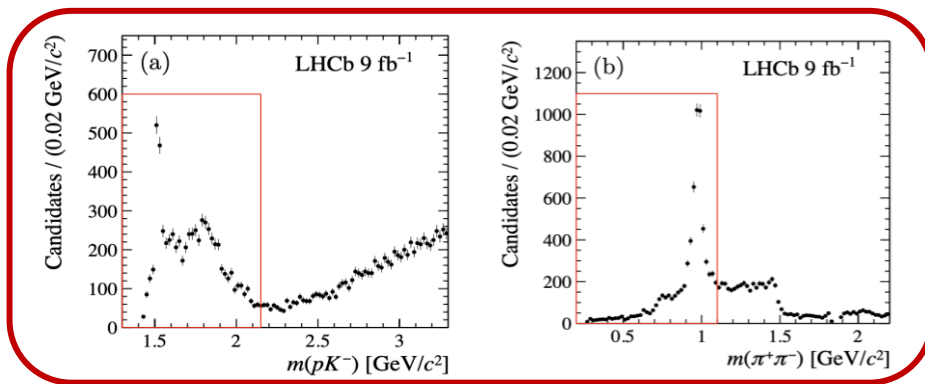
[Nature(2025)]

## ➤ Local $A_{CP}$ reaching $6\sigma$

- Interference between resonance states induces phase-space-dependent CPV
- Most significant local CPV found in  $N^+$  resonances regions
- look-elsewhere effect accounted for the significance

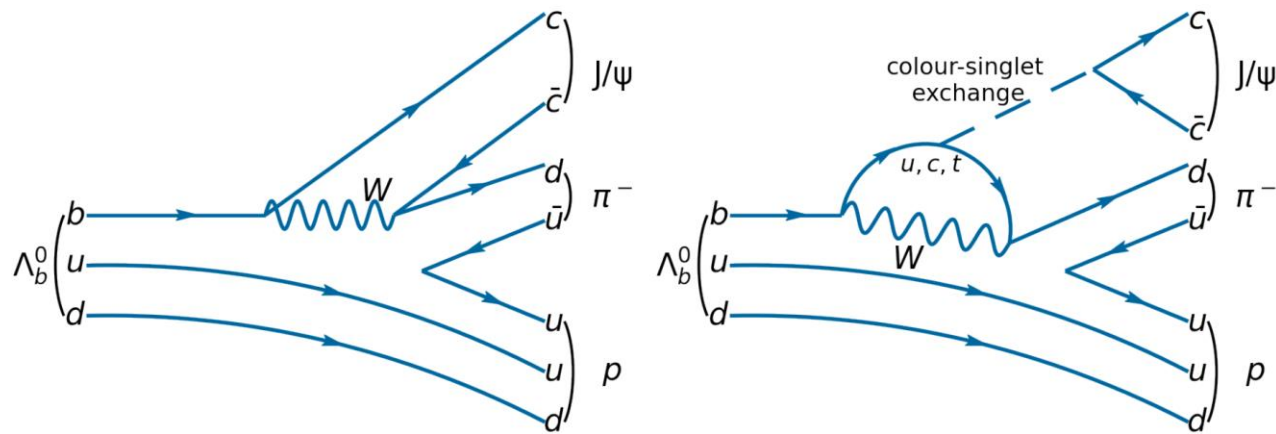
Decay topology	Mass region ( $\text{GeV}/c^2$ )	$A_{CP}$	
$\Lambda_b^0 \rightarrow R(pK^-)R(\pi^+\pi^-)$	$m_{pK^-} < 2.2$ $m_{\pi^+\pi^-} < 1.1$ $m_{p\pi^-} < 1.7$	$(5.3 \pm 1.3 \pm 0.2)\%$	<b>4<math>\sigma</math></b>
$\Lambda_b^0 \rightarrow R(p\pi^-)R(K^-\pi^+)$	$0.8 < m_{\pi^+K^-} < 1.0$ or $1.1 < m_{\pi^+K^-} < 1.6$	$(2.7 \pm 0.8 \pm 0.1)\%$	
$\Lambda_b^0 \rightarrow R(p\pi^+\pi^-)K^-$	$m_{p\pi^+\pi^-} < 2.7$	$(5.4 \pm 0.9 \pm 0.1)\%$	<b>6<math>\sigma</math></b>
$\Lambda_b^0 \rightarrow R(K^-\pi^+\pi^-)p$	$m_{K^-\pi^+\pi^-} < 2.0$	$(2.0 \pm 1.2 \pm 0.3)\%$	

❖  $\Lambda$  resonances      ❖  $f_0(980)$  resonances



❖  $N^+$  resonances

# CP violation in beauty baryon to charmonium decays



- Study of  $\Lambda_b^0 \rightarrow J/\psi p \pi^-$  and  $\Lambda_b^0 \rightarrow J/\psi p K^-$  decays

See more details in Xiaofan's [talk](#)

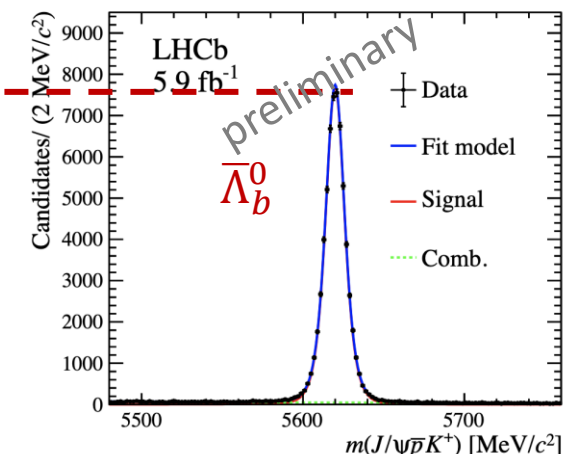
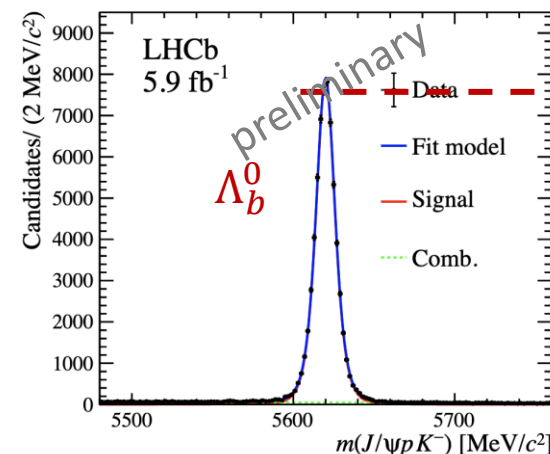
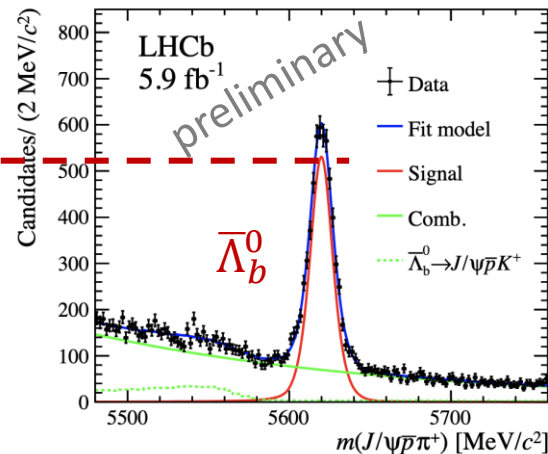
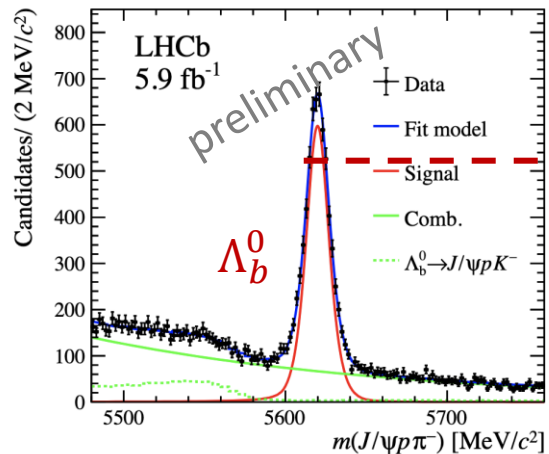
- No CPV observed in Run1 data [JHEP 07 (2014) 103]

- $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \rightarrow J/\psi p \pi^-) - A_{CP}(\Lambda_b^0 \rightarrow J/\psi p K^-) = (5.7 \pm 2.4 \pm 1.2)\%$

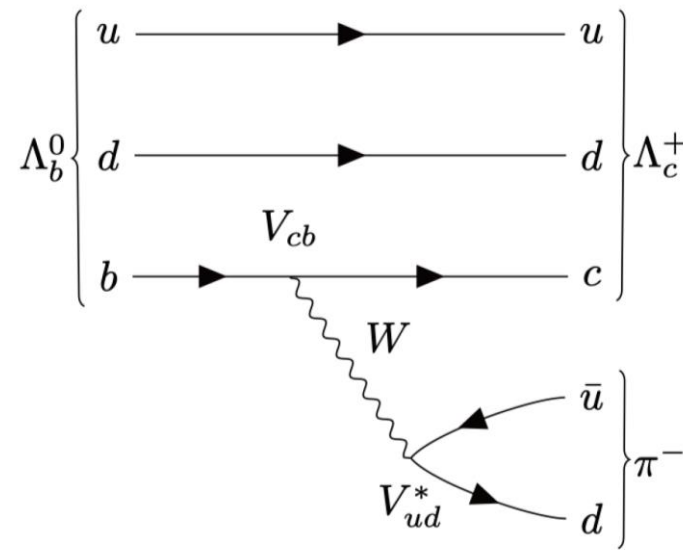
- Measurement of the CP asymmetry difference  $\Delta A_{CP}$  with Run1+Run2 data

- $\Delta A_{CP} = (4.31 \pm 1.06 \pm 0.28)\%$   **$3.9\sigma$**

- **First evidence of CP violation in beauty baryon to charmonium decays!**



# CP violation in beauty baryon to open charm decays



# Decay parameters

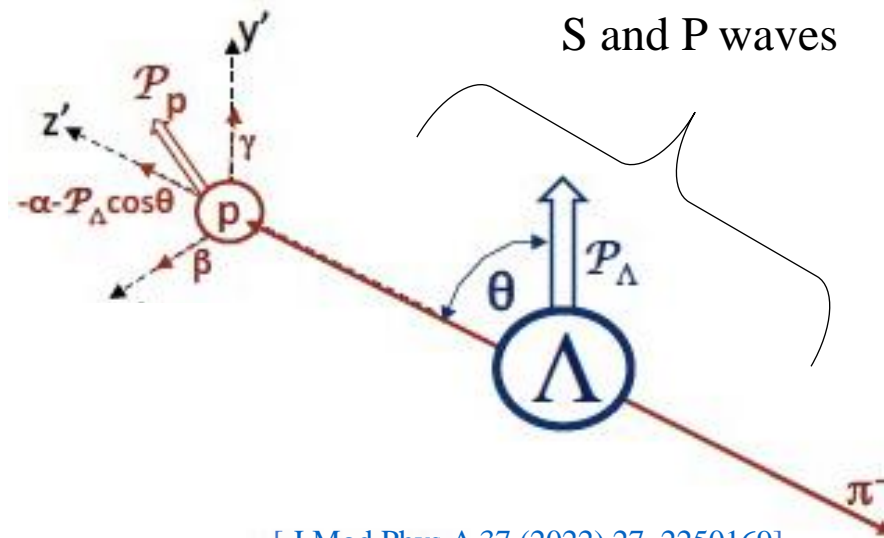
- **Decay parameters**: proposed by Lee & Yang to study P violation in hyperon decay  $\Lambda \rightarrow p\pi^-$ 
  - Between  $p\pi^-$ , there are both P-violating S-wave and P-conserving P-wave [\[Phys. Rev. 108 \(1957\) 1645\]](#)
  - Decay parameters  $\alpha, \beta, \gamma$  indicate the extent of P violation
  - These parameters can be extracted from the angular distribution
  - The same definition in the  $\Lambda_b^0, \Lambda_c^+$  decays from a spin-half baryon to a spin-half baryon and a pseudoscalar meson

$$\alpha \equiv \frac{2\text{Re}(S^*P)}{|S|^2 + |P|^2},$$

$$\beta \equiv \frac{2\text{Im}(S^*P)}{|S|^2 + |P|^2},$$

$$\gamma \equiv \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2},$$

with  $\alpha^2 + \beta^2 + \gamma^2 = 1$ ,



[\[J.Mod.Phys.A 37 \(2022\) 27, 2250169\]](#)

$$\frac{d\Gamma}{d\cos\theta} = \frac{1}{2}\Gamma(1 + \alpha P_\Lambda \cos\theta)$$

$$P_p = \frac{(\alpha + P_\Lambda \cos\theta)z' + \beta P_\Lambda x' + \gamma P_\Lambda y'}{1 + \alpha P_\Lambda \cos\theta}$$

# Probe CPV with decay parameters

- **CPV observables** can also be defined using the decay parameters of CP-conjugated processes
  - $\bar{\alpha}, \bar{\beta}, \bar{\gamma}$  are the decay parameters of anti-baryon decays
  - $\Delta\delta$  ( $\Delta\phi$ ) is the strong (weak) phase difference between S- and P-waves
- Clean observables, less polluted by experimental effects
- Complementary to decay rate asymmetry

[PRL 129 (2022)131801]

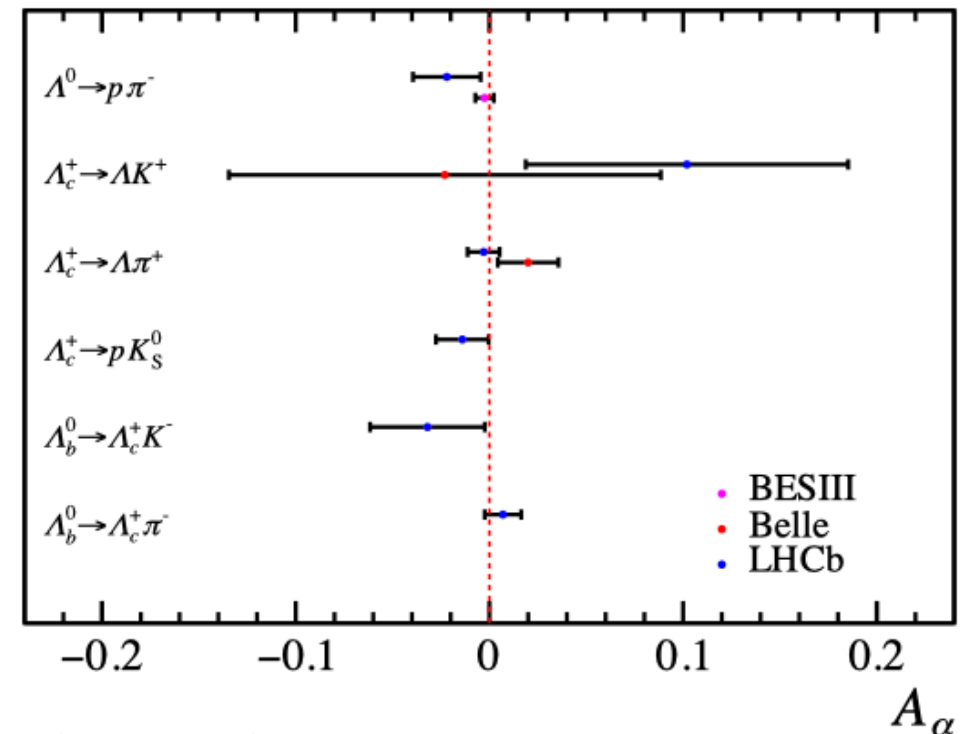
[Sci.Bull. 68 (2023) 583-592]

[PRL 133 (2024) 261804]

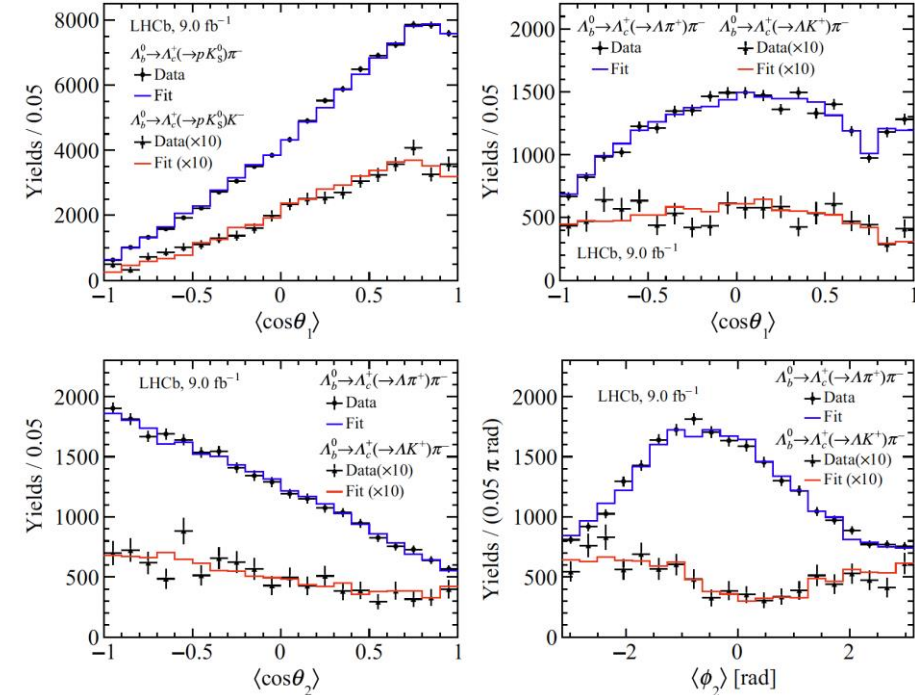
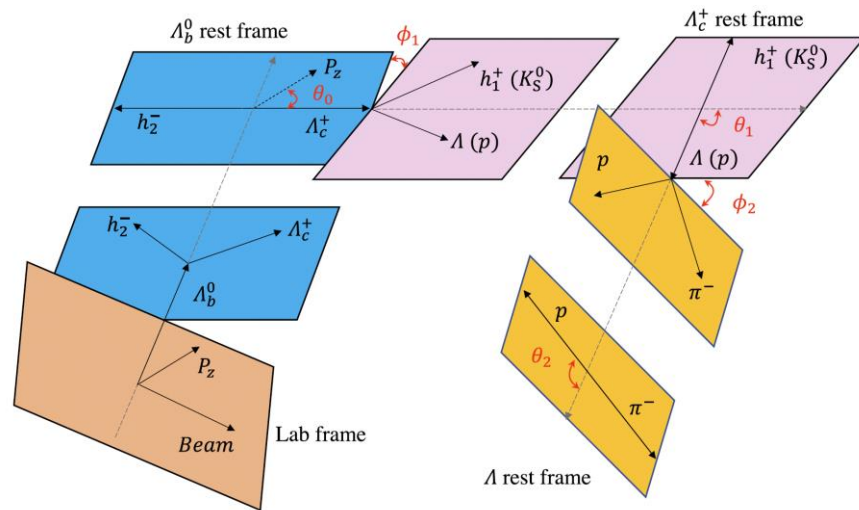
$$A_\alpha = \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}} = -\tan \Delta\delta \tan \Delta\phi$$

$$R_{\beta_1} = \frac{\beta + \bar{\beta}}{\alpha - \bar{\alpha}} = \tan \Delta\phi$$

$$R_{\beta_2} = \frac{\beta - \bar{\beta}}{\alpha - \bar{\alpha}} = \tan \Delta\delta.$$



- Study of  $\Lambda_b^0 \rightarrow \Lambda_c^+ h^-$  ( $h = \pi, K$ ) with  $\Lambda_c^+ \rightarrow \Lambda h^+$ ,  $\Lambda \rightarrow p\pi^-$  or  $\Lambda_c^+ \rightarrow pK_S^0$ , Run1+Run2
- Simultaneous angular analysis of 6 decays



- $\Lambda_b^0 \rightarrow \Lambda_c^+ h^-$  decay parameters are measured for the first time
  - CP violating parameters  $A_{CP}^\alpha$  consistent with CP symmetry
- No CP violation in  $\beta, \gamma$  or phases in  $\Lambda_c^+$  decays as well
  - Weak ( $\Delta\phi$ ) and strong ( $\Delta\delta$ ) phase difference determined:

	$\Lambda_c^+ \rightarrow \Lambda\pi^+$	$\Lambda_c^+ \rightarrow \Lambda K^+$
$\Delta\phi$	$0.01 \pm 0.02$	$-0.03 \pm 0.14$
$\Delta\delta$	$2.693 \pm 0.017$	$2.57 \pm 0.19$

# Conclusions & Outlook

- LHCb provides an excellent environment to study CP violation in baryon decays
  - Numerous new results from Run 1 & 2 data
  - **First observation of CPV in baryonic decays!**
- A major step forward in understanding CP violation
  - While generally smaller than in mesons, **baryonic CPV can be significant under specific conditions**
  - The complex dynamics of baryon decays call for **innovative analysis techniques**
- Future prospects
  - Huge increase in sample size expected for Run 3 with higher hadronic selection efficiencies
  - Exciting opportunities to deepen our understanding of CP violation