北京大学 PEKING UNIVERSITY

中国科学院大学 University of Chinese Academy of Sciences

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CP violation in baryon decays @ BESIII & LHCb

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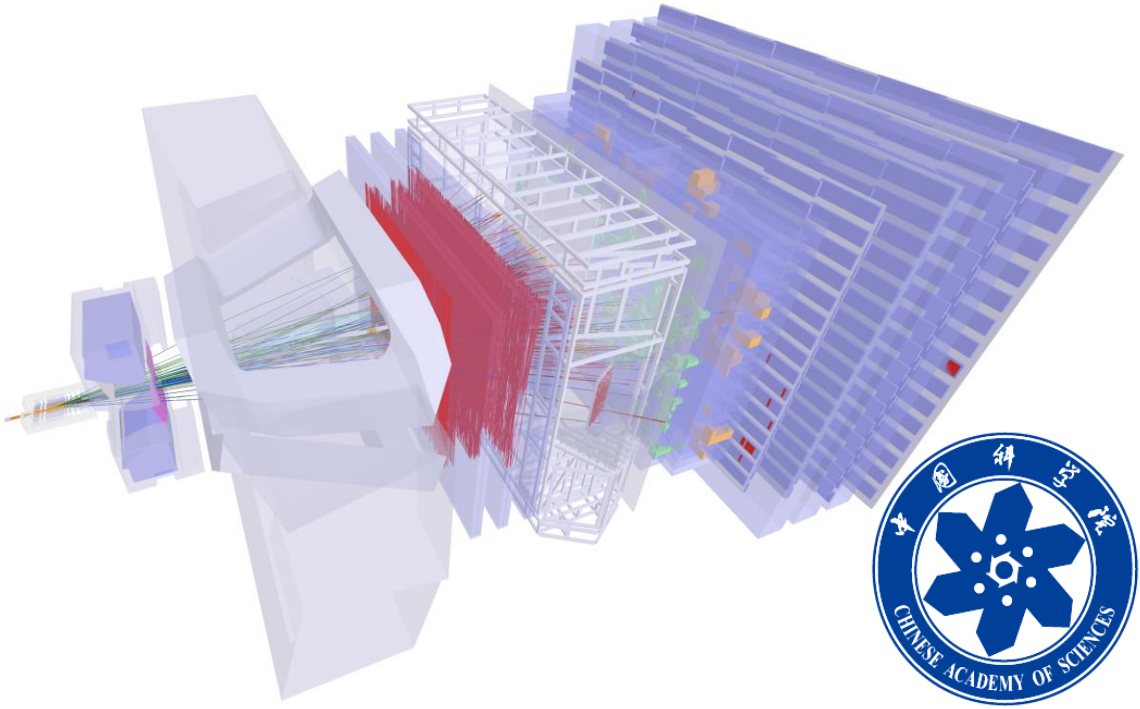
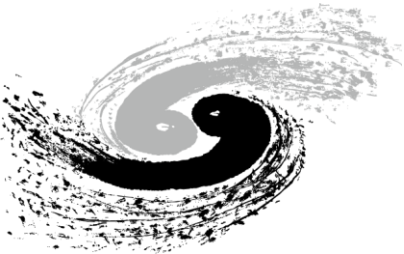
IHEP, CAS

15 September 2025





Baryon asymmetry in the Universe

- "Why is there more matter than antimatter?"
  - "baryogenesis"
  - One of the 125 questions listed by *Sciences* in 2005
- Sakharov conditions for baryogenesis:
  - Baryon number violation
  - C and CP violation
  - Out of thermal equilibrium
- CP violation

  Has been widely studied by flavor factories

BESIII Belle II BABAR Collaboration Home Page LHCb

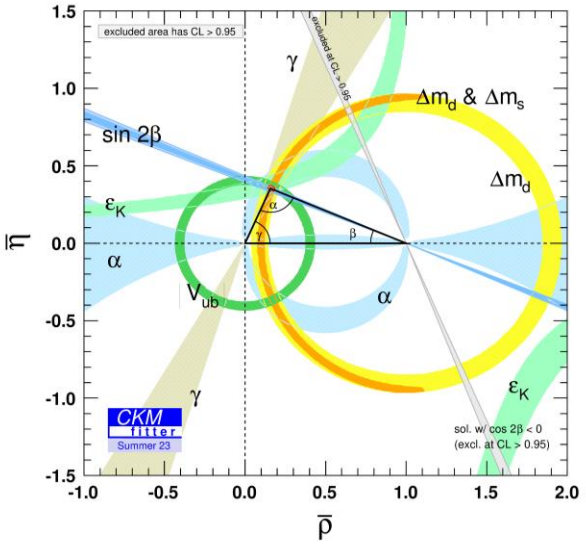
CP violation

- The only source of CP violation in the Standard Model is through CKM mechanism

CKM mechanism: *CPV* from phase δ

$$V_{\mathrm{CKM}} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$

  - Quark mixing matrix
  - A single phase parameter gives rise to quark CPV
  - Well tested
- But not sufficient to explain matter and antimatter asymmetry in Universe



CP violation in meson decays

- Well established, in K, B, B_s, and D systems

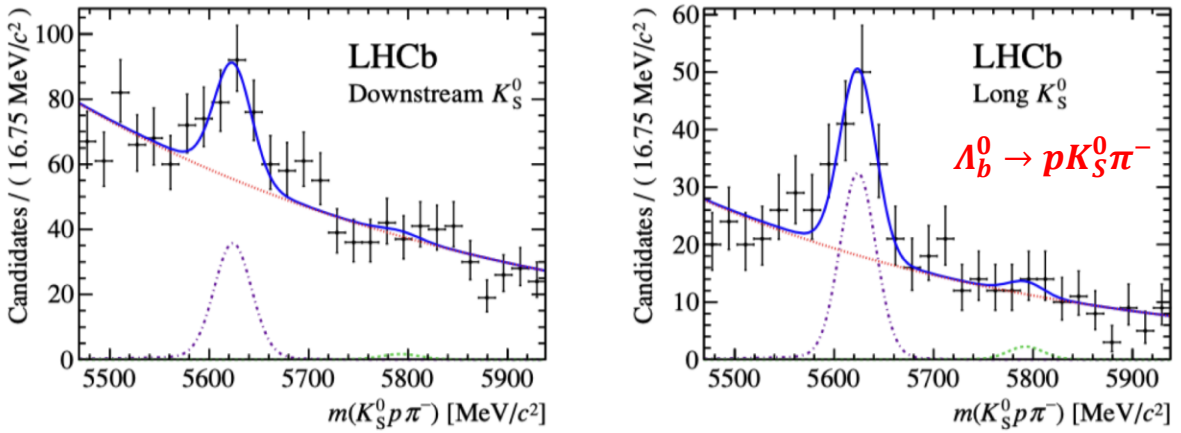
- Only found in meson systems before 2025
- Baryon CPV could appear in decays mediated by similar quark transition as known CP-violating meson decays

Methods to search for baryonic CP violation

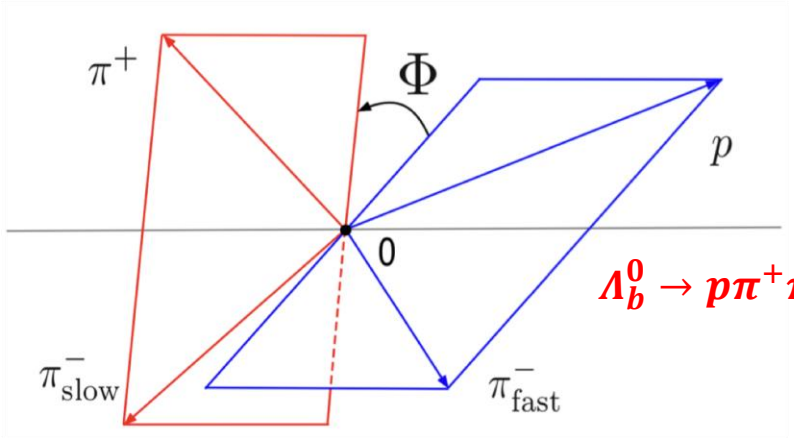
JHEP04(2014)087
PRD108(2023)L011101
PRL133 (2024) 101902
Nature Phys.13(2017)391

- Many methods have been explored to search for CP violation in baryon decays

Direct CP violation ($\propto \sin(\Delta\delta_{ST})\sin(\Delta\phi_{EW})$)

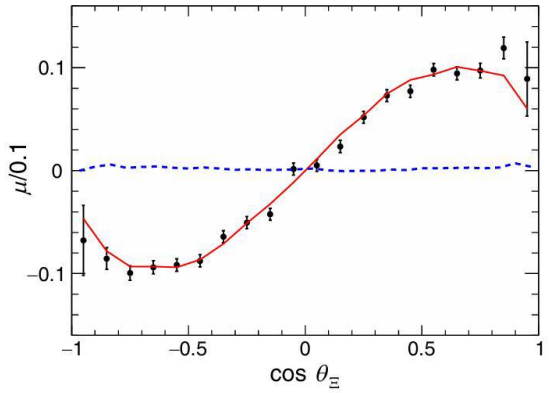


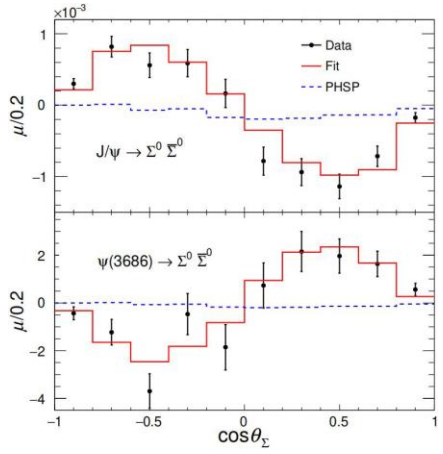
Triple-product asymmetry ($\propto \cos(\Delta\delta_{ST})\sin(\Delta\phi_{EW})$)



Decay parameters asymmetry

$J/\psi \to \Xi^0\bar{\Xi}^0, \Xi^0 \to \Lambda\pi^0$

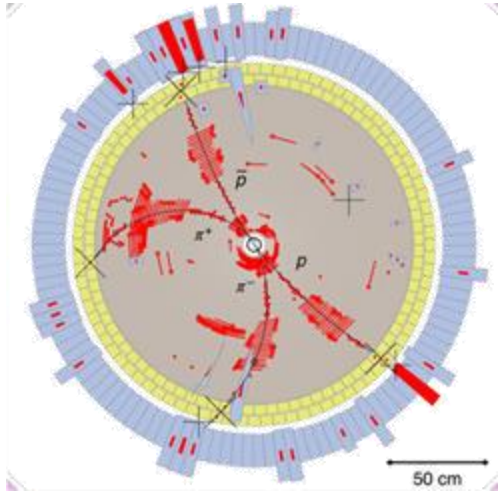




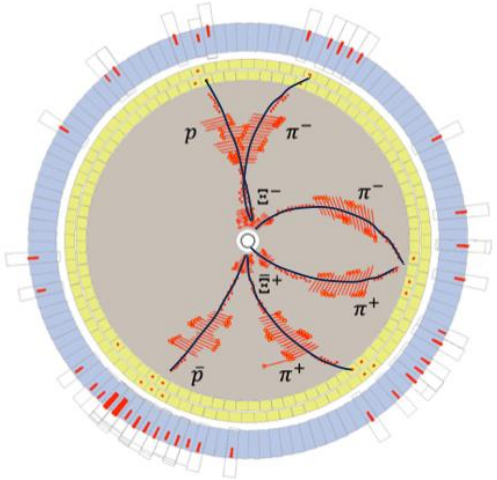
- Important to investigate phase space dependence (amplitude analysis, binned method, energy test etc.)
- CPV: b baryon $\mathcal{O}(1\% - 10\%)$, c baryon $\mathcal{O}(0.1\%)$, hyperon $\mathcal{O}(0.001\% - 0.01\%)$ [Phys. Rev. D 34(1986) 833]

Hyperon studies @ BESIII

- With 10 billion J/ψ and 3 billion $\psi(3686)$ collected at BESIII, ~10^7 entangled hyperon pairs can be produced which enables precise studies of the hyperons
- More $\psi(3686)$ data will be taken after the upgrade of BEPCII and BESIII inner tracker



$e^-e^+ \to \Lambda\bar{\Lambda}$



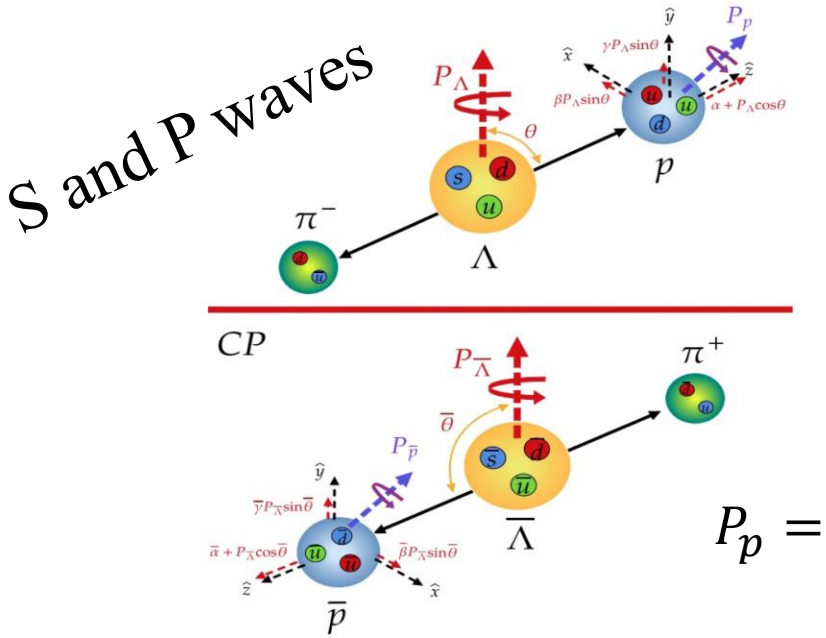
$e^-e^+ \to \Xi^-\bar{\Xi}^+$

Table 2 Hyperon production from the J/ψ or $\psi(2S)$ two-body decays with 10^{10} events on the J/ψ peak and 3×10^9 events on the $\psi(2S)$ peak. N_B is the number of the expected hyperon events. Data are from the Particle Data Group (PDG2016) [3]. [Front. Phys. 12(5), 121301 (2017)]

Decay mode	$\mathcal{B}(\times 10^{-3})$	N_B $(\times 10^6)$
$J/\psi \to \Lambda\bar{\Lambda}$	1.61 ± 0.15	16.1 ± 1.5
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	1.29 ± 0.09	12.9 ± 0.9
$J/\psi \to \Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.10 ± 0.12	11.0 ± 1.2
$J/\psi \to \Xi^0\bar{\Xi}^0$	1.20 ± 0.24	12.0 ± 2.4
$J/\psi \to \Xi^-\bar{\Xi}^+$	0.86 ± 0.11	8.6 ± 1.0
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.05 ± 0.01	0.15 ± 0.03

Baryon decay parameters

- Proposed by Lee & Yang to study parity (P) violation in hyperon decay $\Lambda \to p\pi^+$ [Phys. Rev. 108, 1645 (1957)]



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

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

$$\alpha \equiv \frac{2\mathrm{Re}(S^*P)}{|S|^2 + |P|^2},$$
$$\beta \equiv \frac{2\mathrm{Im}(S^*P)}{|S|^2 + |P|^2},$$
$$\gamma \equiv \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2},$$
$$\text{with } \alpha^2 + \beta^2 + \gamma^2 = 1,$$

Parity violating observables: $\alpha(\Lambda/\bar{\Lambda})$, $\beta(\Lambda/\bar{\Lambda})$, $\gamma(\Lambda/\bar{\Lambda})$

CP violating observables: $A_{CP}^{\alpha} = \frac{\alpha(\Lambda)+\alpha(\bar{\Lambda})}{\alpha(\Lambda)-\alpha(\bar{\Lambda})}$ …

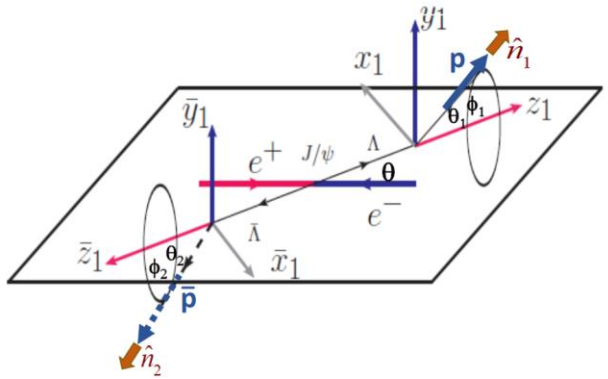
Complementary to decay rate asymmetry

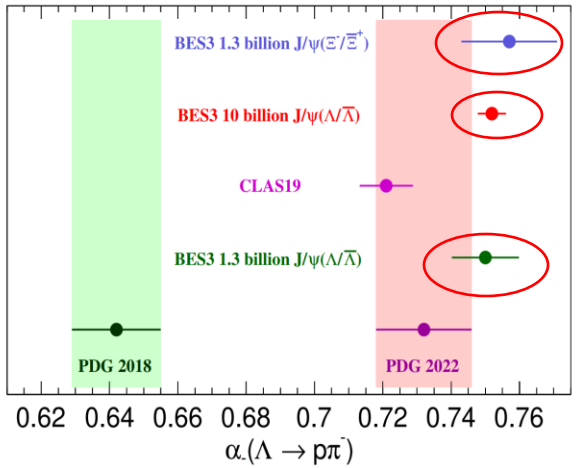
Decay parameters and CPV in hyperons

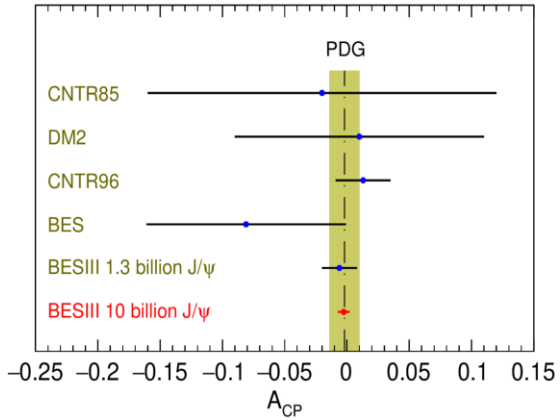
- Pioneering work to probe CPV in $J/\psi \to \Lambda\bar{\Lambda}$

[Nat. Phys. 15 (2019) 631]
[PRL129(2022) 131801]

Entangled Λ and $\bar{\Lambda}$







- Many other ψ to hyperon channels explored, no sign of CP violation

Decay	$J/\psi \to \Lambda\bar{\Lambda}$	$\psi \to \Sigma^+\bar{\Sigma}^-$	$J/\psi \to \Sigma^+\bar{\Sigma}^-$	$J/\psi \to \Xi^-\bar{\Xi}^+$	$\psi(2S) \to \Xi^-\bar{\Xi}^+$	$J/\psi \to \Xi^0\bar{\Xi}^0$
A_{CP}	-0.0025 ± 0.0046 ± 0.0012	-0.004 ± 0.037 ± 0.010	-0.080 ± 0.052 ± 0.028	-0.006 ± 0.013 ± 0.006	-0.015 ± 0.051 ± 0.010	-0.0054 ± 0.0065 ± 0.0031
	PRL129 (2022) 131801	PRL125 (2020) 052004	PRL131(2023) 191802	Nature 606 (2022) 64	PRD106(2022) L091101	PRD108 (2023) L031106

Baryonic CP violation searches @ LHCb

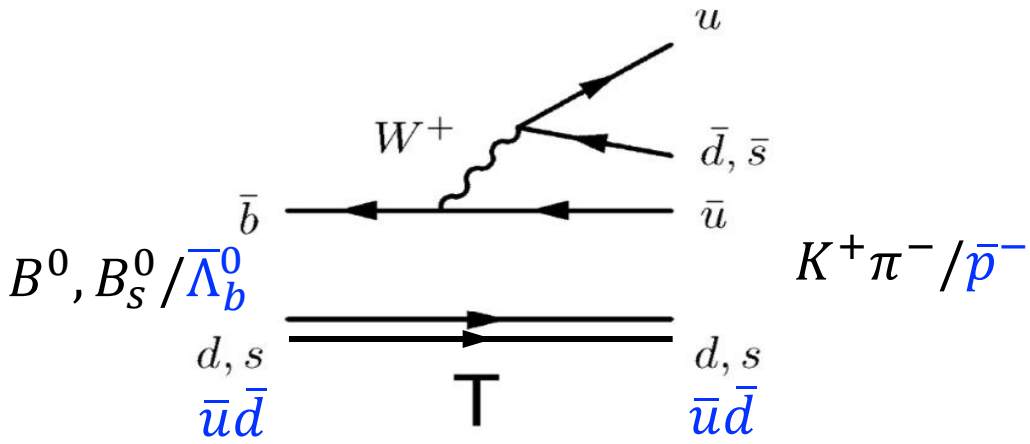
Decay	Methods	Data	Reference
$\Lambda_b^0 \to pK_S^0\pi^-$	A_{CP}	1 fb^{-1}	JHEP 04 (2014) 087
$\Lambda_b^0 \to \Lambda hh'$	A_{CP}	3 fb^{-1}	JHEP 05 (2016) 081
$\Lambda_b^0 \to p\pi^-\pi^+\pi^-$	TPA, energy test	3 fb^{-1} 6.6 fb^{-1}	Nature Physics 13 (2017) 391 PRD 102 (2020) 051101
$\Lambda_b^0 \to pK^-\mu^+\mu^-$	A_{CP}	3 fb^{-1}	JHEP 06 (2017) 108
$\Lambda_c^+ \to ph^-h^+$	A_{CP}	3 fb^{-1}	JHEP 03 (2018) 182
$\Lambda_b^0 \to pK^-/p\pi^-$	A_{CP}	3 fb^{-1}	PLB 787 (2018) 124
$\Lambda_b^0 \to ph^-h^+h^-$	TPA	3 fb^{-1}	JHEP 08 (2018) 039
$\Lambda_b^0 \to ph^-h^+h^-$	A_{CP}	3 fb^{-1}	EPJC 79 (2019) 745
$\Xi_b^- \to pK^-K^-$	Amplitude	5 fb^{-1}	PRD 104 (2020) 052010
$\Xi_c^+ \to pK^-\pi^+$	kNN	3 fb^{-1}	EPJC 80 (2020) 986
$\Lambda_b^0 \to pD^0K^-$	Miranda S_{CP}^i	9 fb^{-1}	PRD104 (2021) 112008
$\Lambda_b^0 \to \Lambda\gamma$	photon polarization	3 fb^{-1}	PRD105 (2022) L051104
$\Lambda_b^0 \to \Lambda_c^+h^-$	Decay parameter	9 fb^{-1}	PRL 133 (2024) 261804
$\Lambda_b^0 \to ph^-$	A_{CP}	9 fb^{-1}	PRD 111(2025) 092004
$\Lambda_b^0 \to \Lambda hh'$	A_{CP}	9 fb^{-1}	PRL 134 (2025) 101802
$\Lambda_b^0 \to pK^-\pi^+\pi^-$	A_{CP}	9 fb^{-1}	Nature 643 (2025) 1223
$\Lambda_b^0, \Xi_b^0 \to pK_S^0h^-$	A_{CP}	9 fb^{-1}	arXiv:2508.17836
$\Lambda_b^0 \to J/\psi ph^-$	A_{CP}, TPA	6 fb^{-1}	LHCb-PAPER-2025-021, in preparation

[PRD 111 092004]

CP violation in $\Lambda_b^0 \to ph^-$ decays

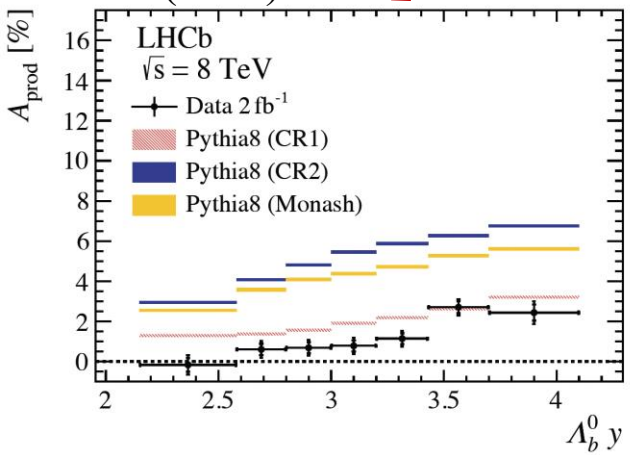
- Large yield and high purity
- CP violation predicted: ~5%

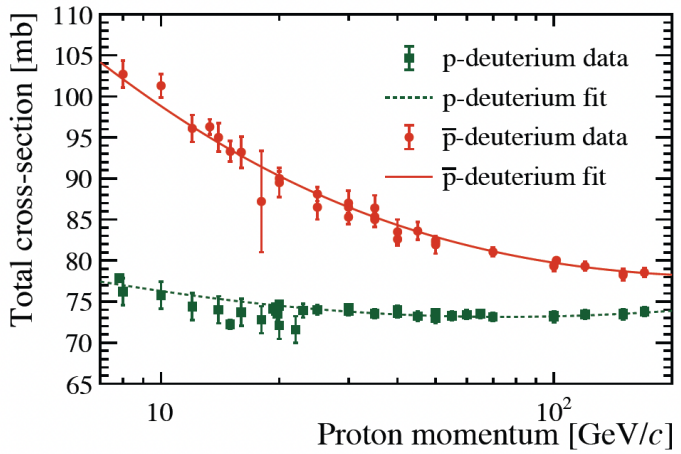
PRD 102 (2012) 034033
PRD 95 (2017) 093001

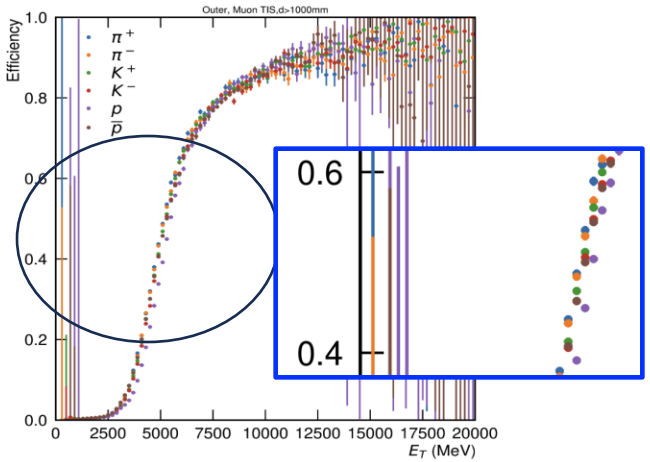


- Crucial to control systematics
- $A_{CP} = A_{raw} - A_{\text{prod}} - A_{\text{detection}} - A_{\text{PID}} - A_{\text{trigger}}$

JHEP 10 (2021) 060







[PRD 111 092004]

CP violation in $\Lambda_b^0 \to ph^-$ decays

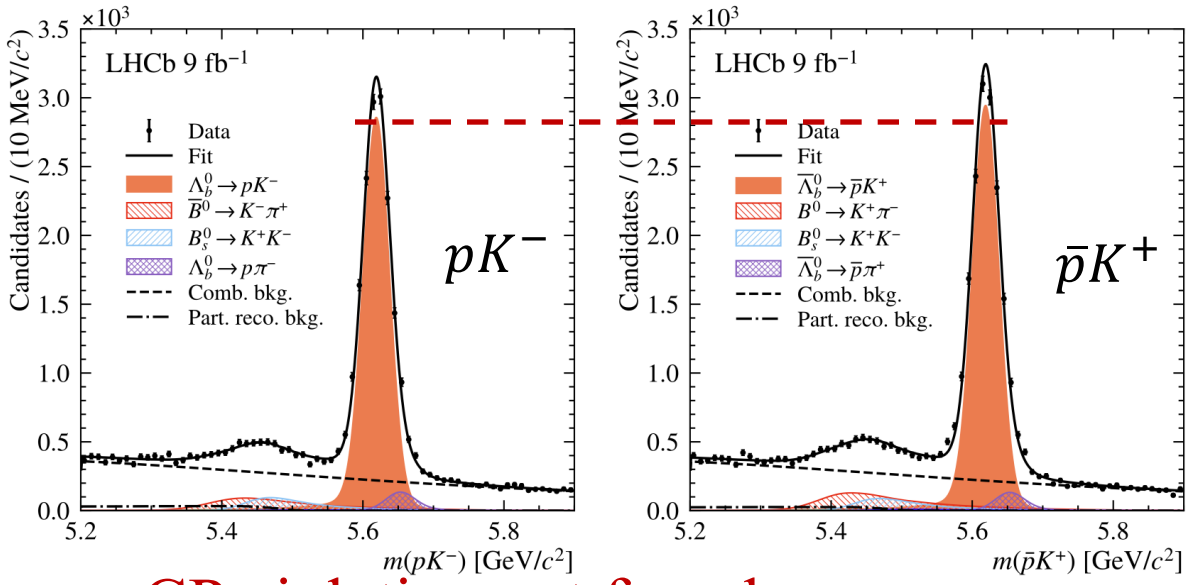
- Data driven corrections and use control mode $\left(\Lambda_b^0 \to \Lambda_c^+(pK^-\pi^+)\pi^-\right)$ to cancel nuisance asymmetries

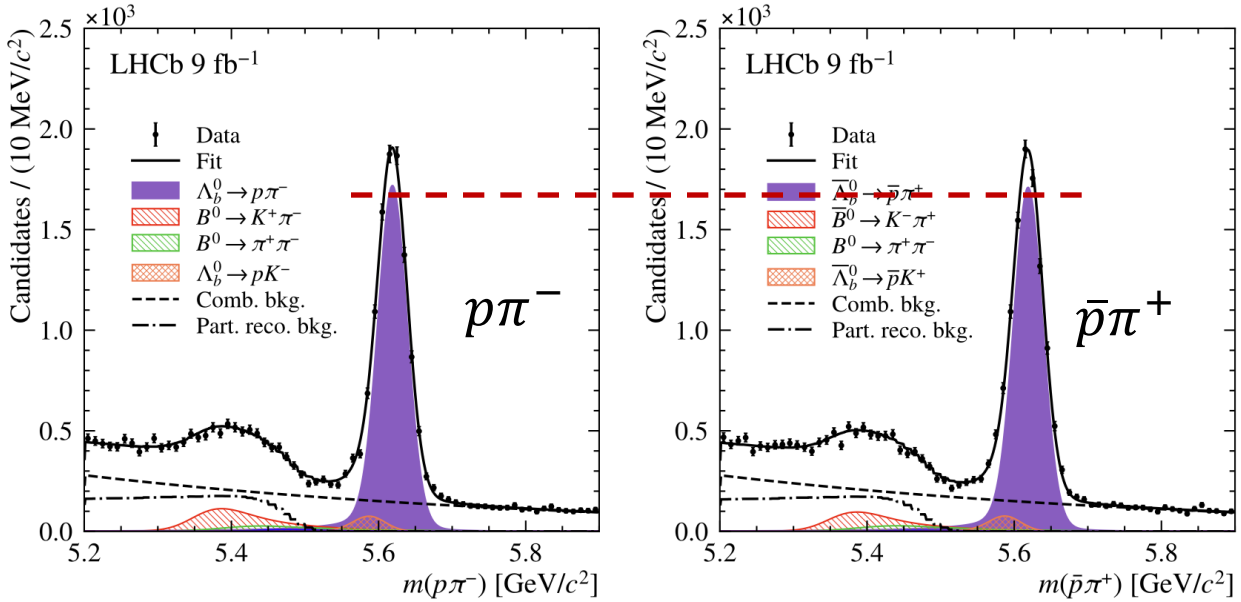
$$A_{CP}^{pK^-} = \Delta A_{\text{raw}} - \Delta A_{\text{D}}^{p} - \Delta A_{\text{D}}^{K^-} - \Delta A_{\text{PID}} - \Delta A_{\text{P}}^{\Lambda_b^0} - \Delta A_{\text{T}} - A_{\text{D}}^{\pi^-} - A_{\text{D}}^{\pi^+} + A_{CP}^{\Lambda_c^+\pi^-}$$

$$A_{CP}^{p\pi^-} = \Delta A_{\text{raw}} - \Delta A_{\text{D}}^{p} - \Delta A_{\text{D}}^{\pi^-} - \Delta A_{\text{PID}} - \Delta A_{\text{P}}^{\Lambda_b^0} - \Delta A_{\text{T}} - A_{\text{D}}^{K^-} - A_{\text{D}}^{\pi^+} + A_{CP}^{\Lambda_c^+\pi^-}$$

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

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

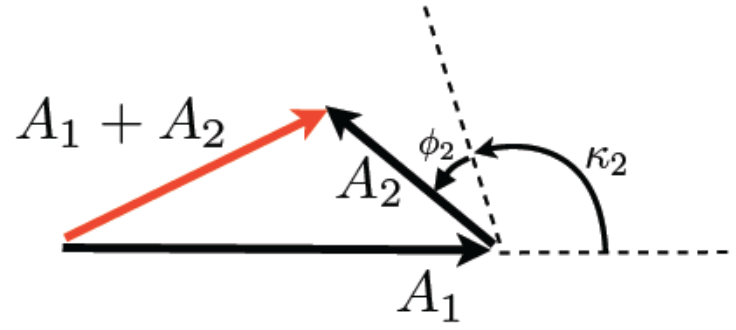


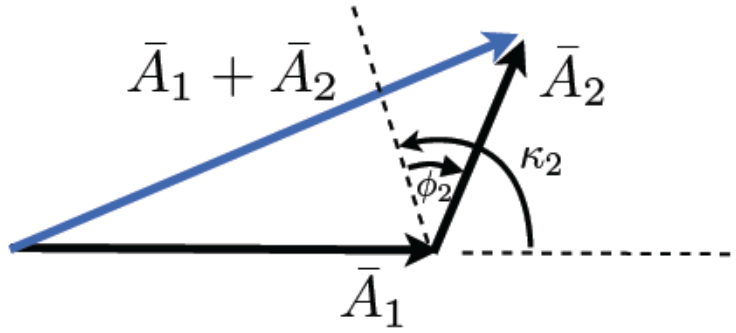


- CP violation not found

Why so small? Source of CP violation in SM

$$A_j = |A_j| e^{i(+\phi_j^{\text{weak}} + \kappa_j)} \quad \overset{CP}{\Leftrightarrow} \quad \bar{A}_j = |A_j| e^{i(-\phi_j^{\text{weak}} + \kappa_j)}$$





$$P(i \to f) = |A_1 + A_2|^2 \qquad P(\bar{i} \to \bar{f}) = |\bar{A}_1 + \bar{A}_2|^2$$

$$= |A_1|^2 + 2|A_1||A_2| \cos(\phi_2 \pm \kappa_2) + |A_2|^2$$

$$P(i \to f) - P(\bar{i} \to \bar{f}) = -4|A_1||A_2| \sin(\phi_2) \sin(\kappa_2)$$

Strong phase difference

Weak phase difference

Requires a strong phase difference does not flip sign under CP operation, a weak phase difference flips sign under CP operation, and interference between at least two decay amplitudes

Why so small?

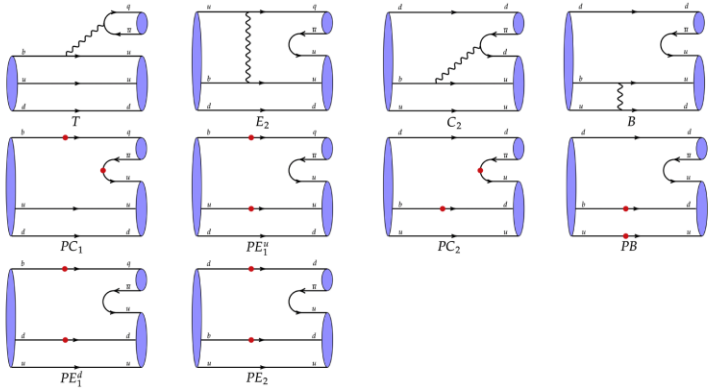
[PRL 134 (2025) 221801]

- $P(i \to f) - P(\bar{i} \to \bar{f}) = -4|A_1||A_2| \sin(\phi_2) \sin(\kappa_2)$

From CKM matrix, same for B^0 and Λ_b^0

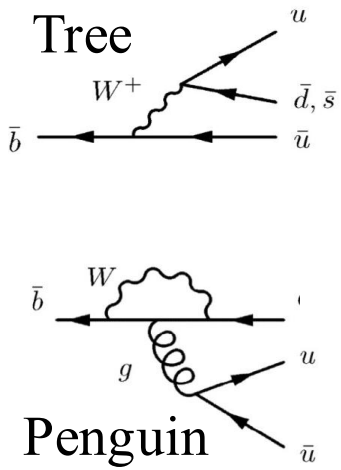
- One diagram dominates? small strong phase difference?

- Dynamics more complex than mesons



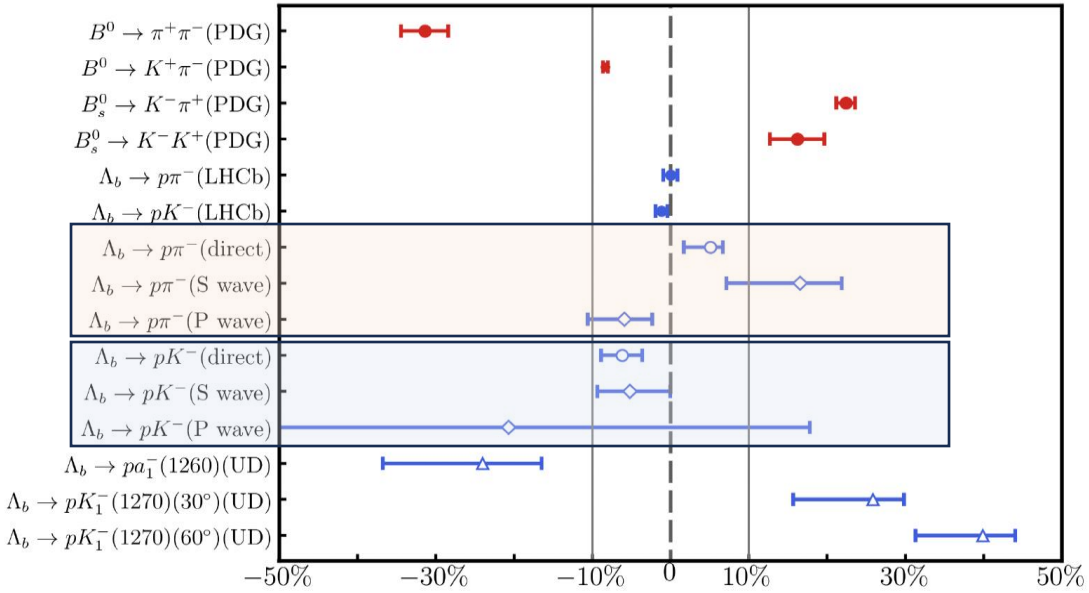
➢ Tree amplitudes may dominate

	$\Lambda_b \to pK^-$			
T	853.60	−52.08	1190.21	−340.84
E_2	−66.28	−59.48	−50.31	79.56
Tree $\mathcal{T}$	787.31	−111.55	1139.90	−261.28
PC_1	75.64	−0.82	−4.35	−13.81
PE_1^u	0.10	−11.80	−4.76	9.93
PE_1^d	−1.50	−7.38	1.66	2.09
Penguin $\mathcal{P}$	74.23	−20.00	−7.45	−1.79



➢ Possible cancellation of S and P amplitudes

$$A_{CP}^{\text{dir}} \approx \kappa_S A_{CP}^{S\text{-wave}} + \kappa_P A_{CP}^{P\text{-wave}}$$

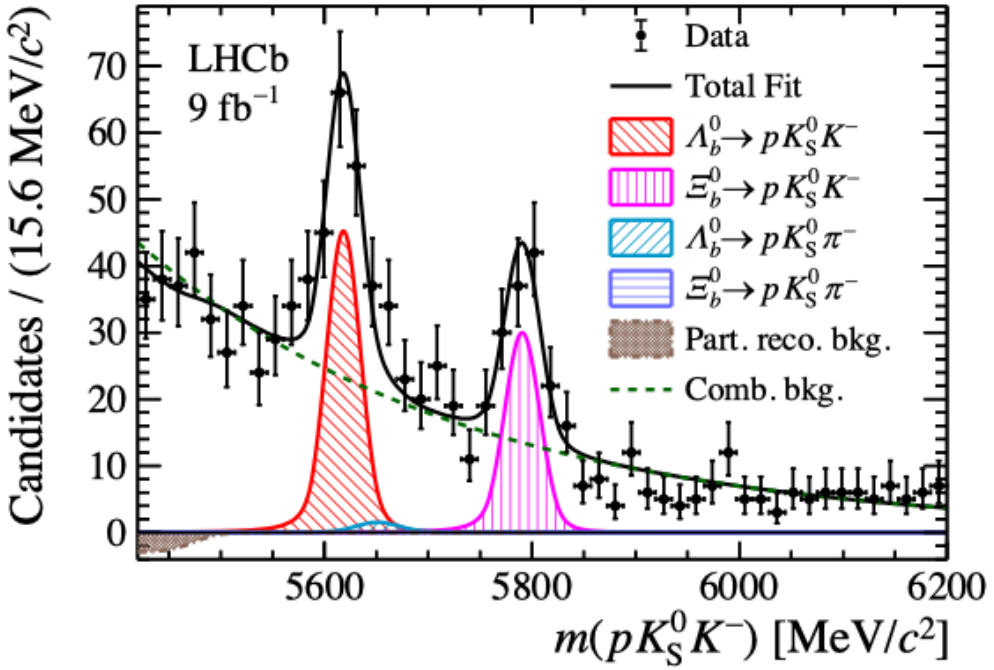


Favoring multi-body decays

[arXiv:2508.17836]

CP violation in $\Lambda_b^0/\Xi_b^0 \to pK_S^0h^-$ decays

- CP asymmetry in $\Lambda_b^0 \to pK^*(892)$ decay is predicted to be large
  - ~20% - 30% by several models
- Control channel: $\Lambda_b^0 \to \Lambda_c^+(\to pK_S^0)\pi^-$
- First observed $\Lambda_b^0 \to pK_S^0K^-$ and $\Xi_b^0 \to pK_S^0K^-$ decays



$$\mathcal{B}(\Lambda_b^0 \to pK_S^0\pi^-) = (10.62 \pm 0.21 \pm 0.16 \pm 0.98) \cdot 10^{-6}$$

$$\mathcal{B}(\Lambda_b^0 \to pK_S^0K^-) = (0.61 \pm 0.08 \pm 0.06 \pm 0.06) \cdot 10^{-6}$$ First observation $(8.1\sigma)^2$

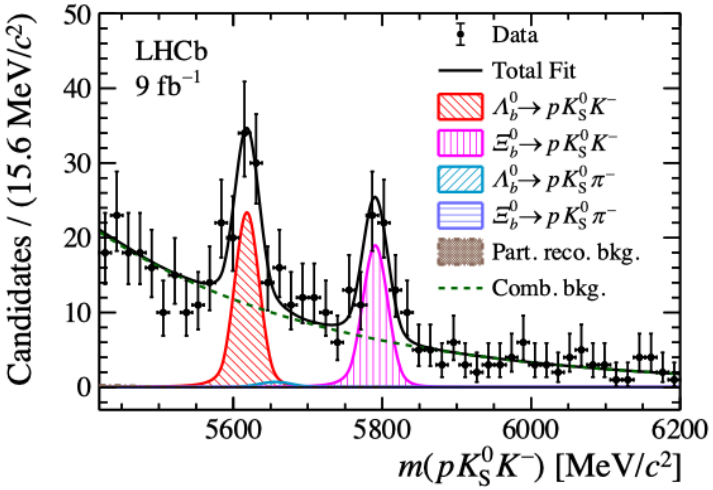
$$\mathcal{B}(\Xi_b^0 \to pK_S^0\pi^-) < 2.8\,(3.2) \cdot 10^{-6}$$ at 90 (95)% CL

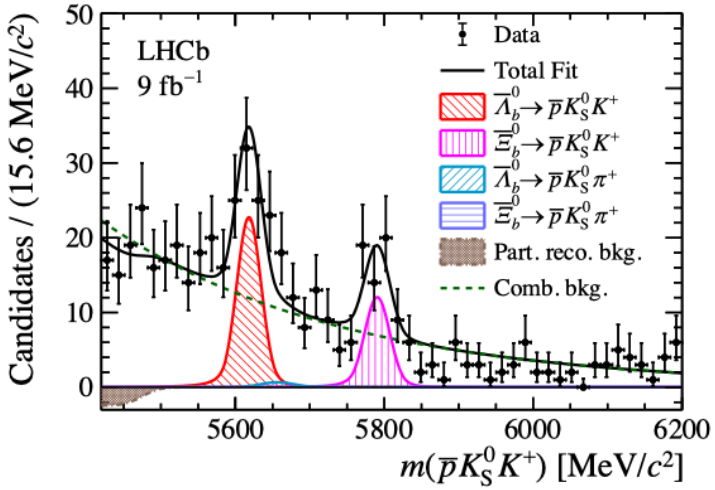
$$\mathcal{B}(\Xi_b^0 \to pK_S^0K^-) = (3.9 \pm 0.6 \pm 0.5 \pm 0.4 \pm 1.4) \cdot 10^{-6}$$ First observation $(8.0\sigma)^2$

Stat. Syst. control mode b-quark Fragmentation fractions

[arXiv:2508.17836]

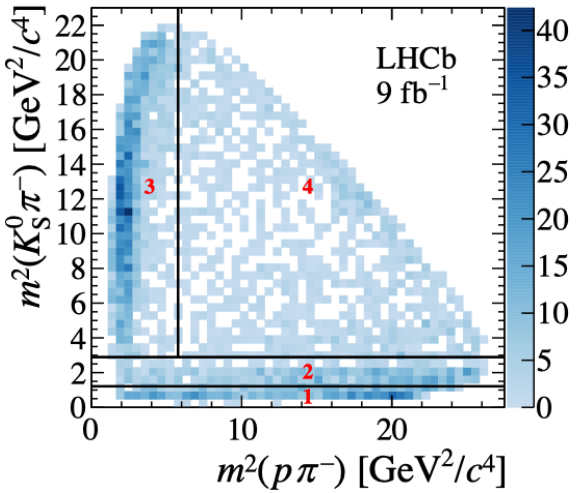
CP violation in $\Lambda_b^0/\Xi_b^0 \to pK_S^0h^-$ decays





Global A_{CP} in 3 decay modes

Channel	ΔA_{CP} [%]
$\Lambda_b^0 \to pK_S^0\pi^-$	$3.4 \pm 1.9 \pm 0.9$
$\Lambda_b^0 \to pK_S^0K^-$	$2 \pm 13 \pm 9$
$\Xi_b^0 \to pK_S^0K^-$	$22 \pm 15 \pm 11$



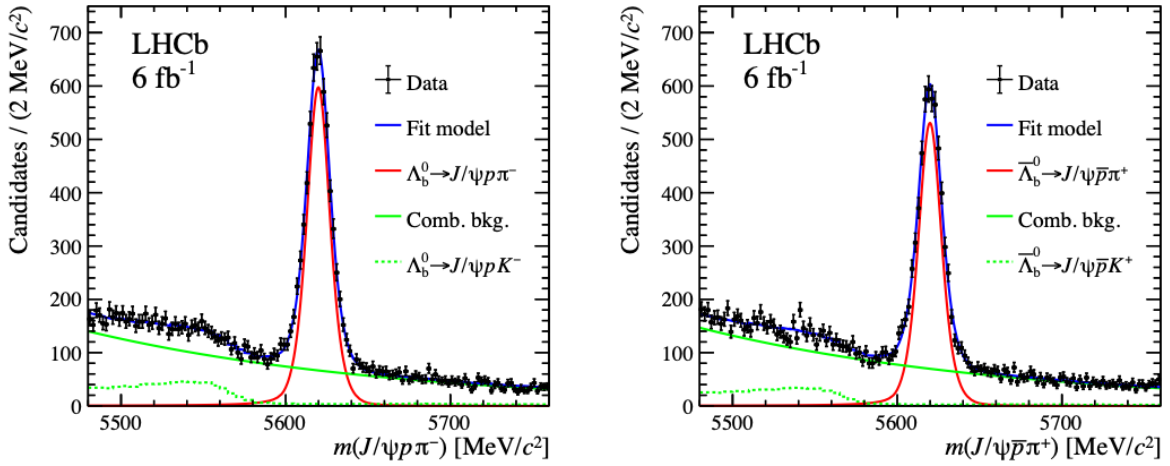
Local A_{CP} in 4 regions of $\Lambda_b^0 \to pK_S^0\pi^-$ decay

Bin	ΔA_{CP} [%]
1	$-0.6 \pm 4.0 \pm 1.9$
2	$12.4 \pm 4.2 \pm 1.8$
3	$0.5 \pm 2.4 \pm 1.1$
4	$3.3 \pm 5.5 \pm 2.0$

- No hints for CP violation

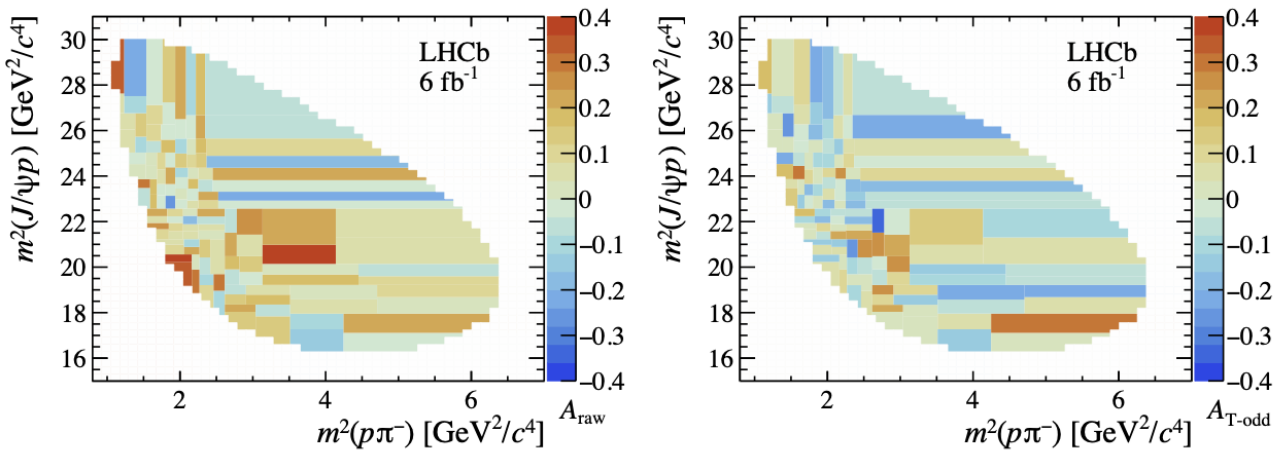
CP violation in $\Lambda_b^0 \to J/\psi p h^-$ decays

- $b \to c\bar{c}q$ transition, first evidence of CP violation in B meson decays to charmonium recently found by LHCb [PRL 134, 101801 (2025)]
  - $A_{CP}(B^+ \to J/\psi\pi^+) - A_{CP}(B^+ \to J/\psi K^+) = (1.29 \pm 0.49 \pm 0.08)\%$, **$3.2\sigma$**
- Similar decay in baryon sector with $b \to c\bar{c}q$ transition studied
  - No CP violation in b-baryon decays to charmonium found using LHCb Run1 data [JHEP 07 (2014) 103]
  - $\Delta A_{CP} = A_{CP}(\Lambda_b^0 \to J/\psi p\pi^+) - A_{CP}(\Lambda_b^0 \to J/\psi p K^+) = (5.7 \pm 2.4 \pm 1.2)\%$,
- Preliminary Run2 update: $\Delta A_{CP} = (4.03 \pm 1.18 \pm 0.23)\%$
  - Combine with Run1 results, $\Delta A_{CP} = (4.31 \pm 1.06 \pm 0.28)\%$, **$3.9\sigma$**
  - **First evidence of CP violation in beauty baryon to charmonium!**



CP violation in $\Lambda_b^0 \to J/\psi p h^-$ decays

- Triple-product asymmetry (TPA)
- $A_{\hat{T}} = \frac{\Gamma(C_T>0)-\Gamma(C_T<0)}{\Gamma(C_T>0)+\Gamma(C_T<0)}$, where $\begin{matrix}\Lambda_b^0: C_T \equiv \vec{p}_{\mu+}\cdot(\vec{p}_p \times \vec{p}_{\pi-}) \\ \overline{\Lambda_b^0}: \bar{C}_T \equiv \vec{p}_{\mu-}\cdot(\vec{p}_{\bar{p}} \times \vec{p}_{\pi+})\end{matrix}$
- CP violation variable: $A_{T-odd} = \frac{1}{2}(A_{\hat{T}} - \bar{A}_{\hat{T}})$
- Preliminary results: $A_{T-odd}(J/\psi p\pi^-) = (-1.37 \pm 1.15)\%$
  $A_{T-odd}(J/\psi pK^-) = (-0.04 \pm 0.28)\%$
- Investigation of the phase space for local CPV enhancement
- Binning schemes
  - 4 and 128 equally populated bins of the Dalitz plot
  - Resonant structures $\Lambda_b^0 \to J/\psi N$ (total of 4 m($p\pi^-$) bins)
  - $\Lambda_b^0 \to J/\psi N$ resonances + $p\pi^-$ pair helicity angle θ (8 total bins, 4 mass, 2 cos $\theta \gtrless 0$)
- No evidence of TPA found,
  No variation of the asymmetries in phase space found

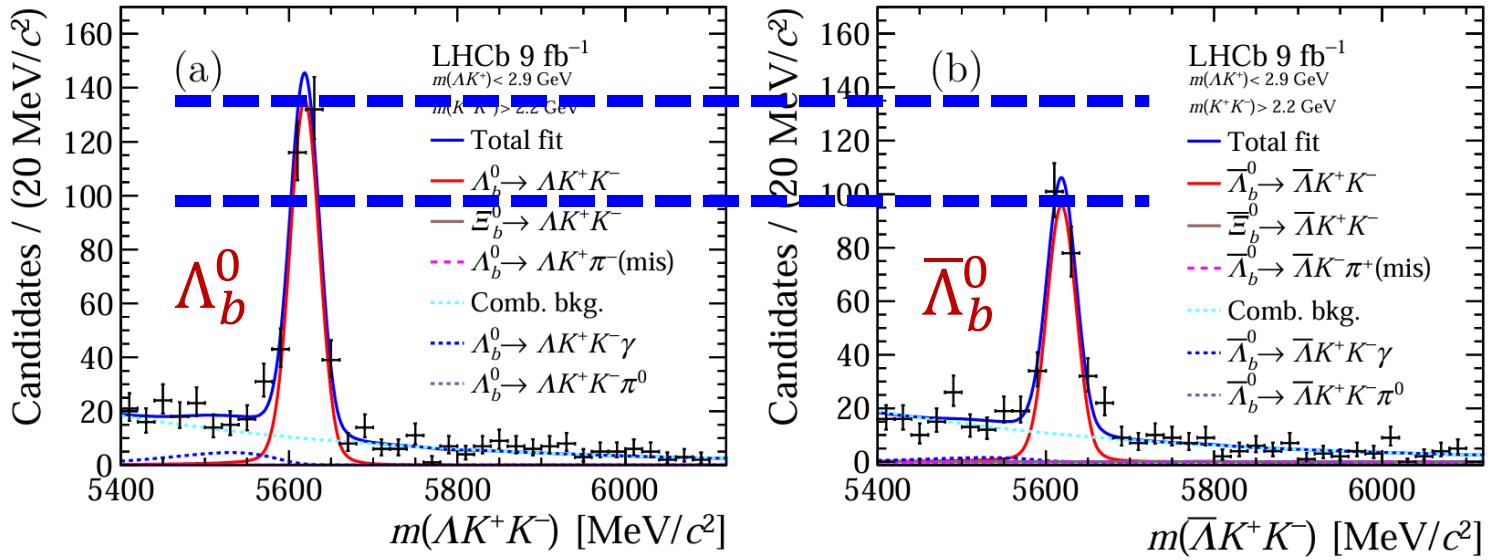


CP asymmetry in $\Lambda_b^0 \to \Lambda h_1^+ h_2^-$ decays

- Three Λ_b^0 decays $\Lambda\pi^+\pi^-$、 $\Lambda K^+\pi^-$、 ΛK^+K^-; one Ξ_b^0 decay
- $\Lambda_b^0 \to \Lambda_c^+(\to \Lambda\pi^+)\pi^-$ as control channel

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

3.1σ, first evidence for CPV in baryon



$\Lambda_b^0 \to \Lambda K^+K^-$ decay

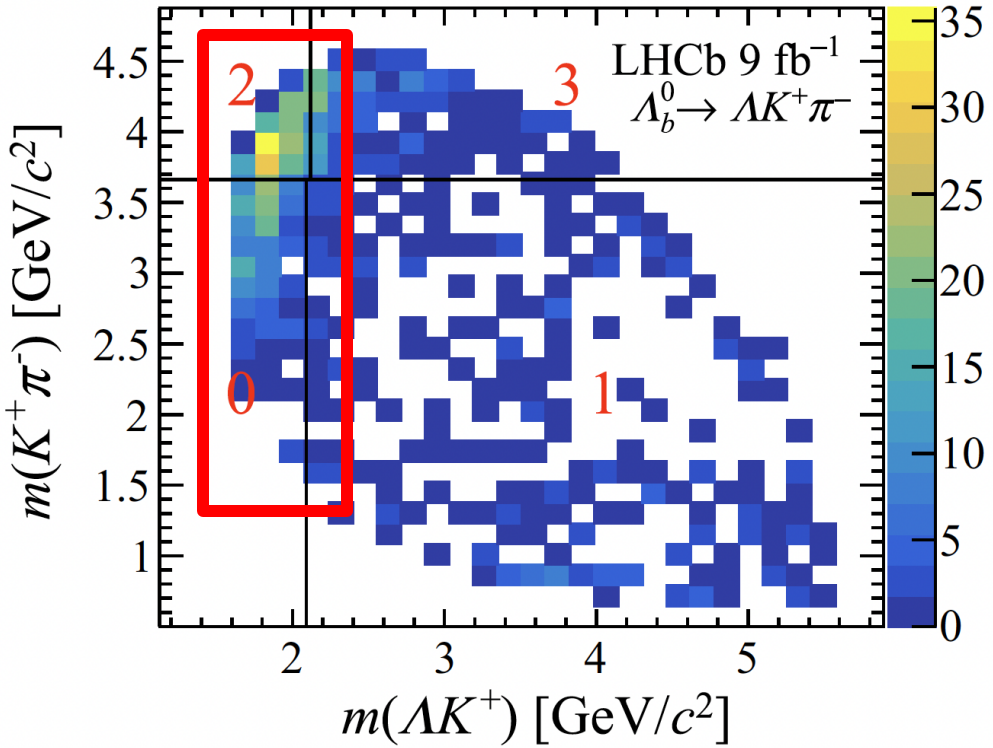
PRL 134 (2025) 101802

Local CP asymmetry for $\Lambda_b^0 \to \Lambda K^+\pi^-$ / $\Lambda_b^0 \to \Lambda\pi^+\pi^-$

$m_{\Lambda K^+} < 2.3$ GeV

$\Lambda_b^0 \to N^{*+}(\to \Lambda K^+)\pi^-$

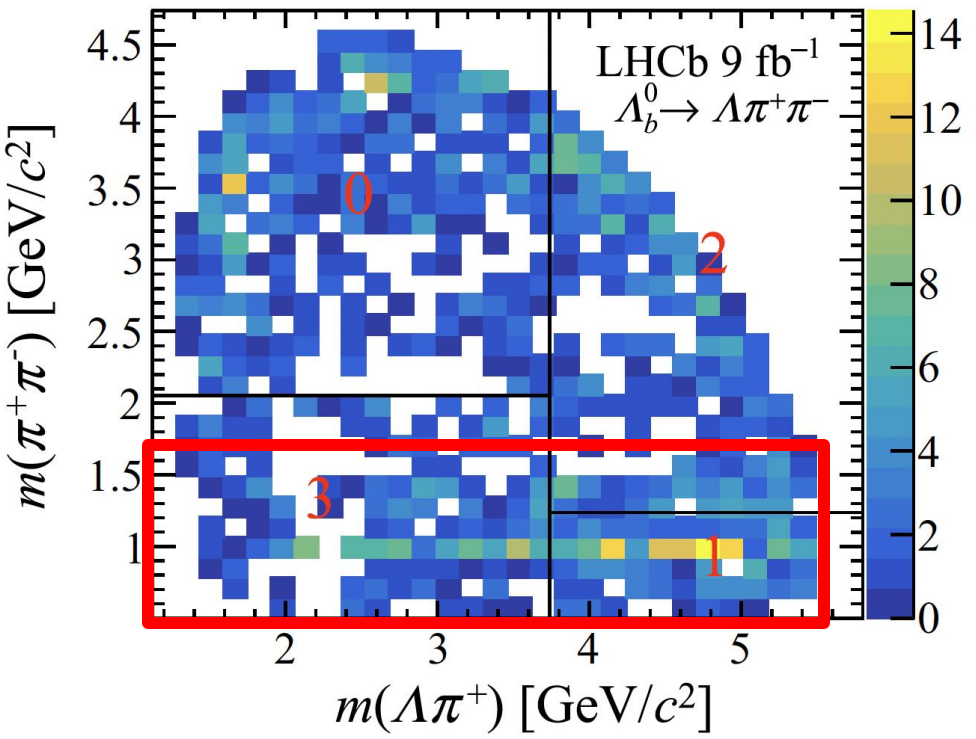
$\Delta A_{CP}(N^{*+}\pi^-) = -0.078 \pm 0.051 \pm 0.027$



$m_{\pi^+\pi^-} < 1.7$ GeV

$\Lambda_b^0 \to \Lambda f(\pi^+\pi^-)$

$\Delta A_{CP}(\Lambda f) = 0.088 \pm 0.069 \pm 0.021$



Local CP asymmetry for $\Lambda_b^0 \to \Lambda K^+ K^-$

- Two resonance-dominated regions

$m_{K^+K^-} < 1.1$ GeV

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

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

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

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

$\Delta A_{CP}(N^{*+}K^-) = 0.165 \pm 0.048 \pm 0.017$ (local 3.2σ)

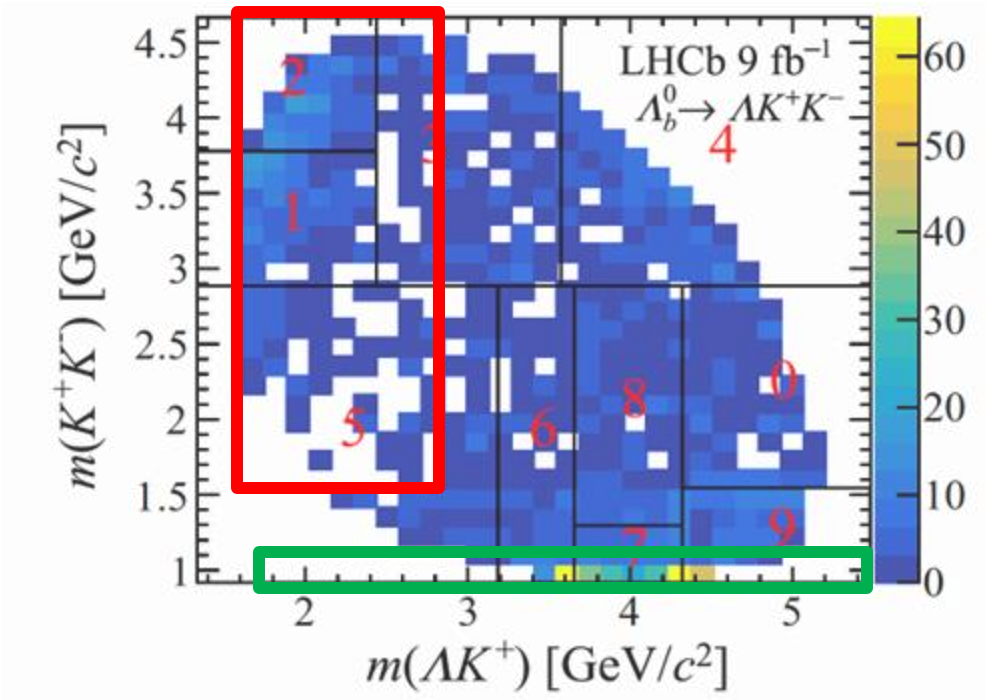
- Many N^{*+} may contribute to $\Lambda_b^0 \to N^{*+}K^-$

  Several related N^{*+} channels to cross-check

  $N^{*+} \to \Lambda K^+ \quad \Rightarrow \Lambda_b^0 \to N^{*+}(\Lambda K^+)K^-$

  $N^{*+} \to p\pi^+\pi^- \quad \Rightarrow \Lambda_b^0 \to N^{*+}(p\pi^+\pi^-)K^-$

  $N^{*+} \to p\pi^0 \quad \Rightarrow \Lambda_b^0 \to N^{*+}(\to p\pi^0)K^-$

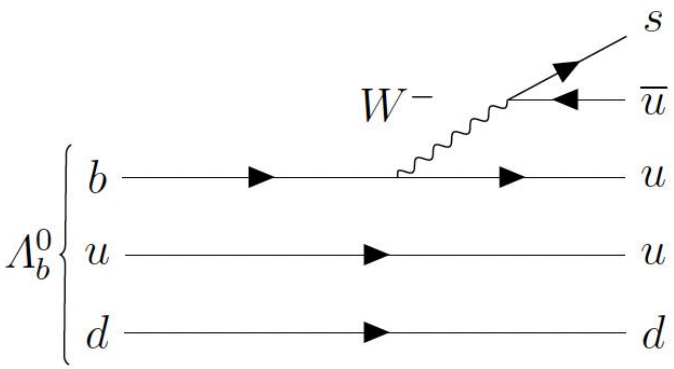


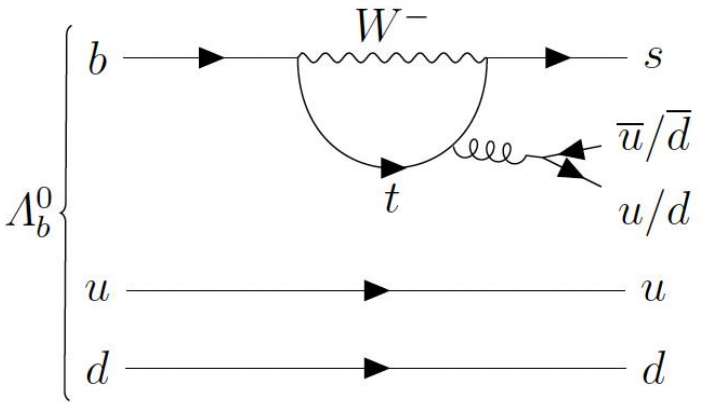
J.P. Wang, F.S. Yu, CPC 48 (2024) 101002

[Nature 643 (2025) 1223]

CP asymmetry in $\Lambda_b^0 \to p\, K^-\pi^+\pi^-$

- A_{CP} arises from interference between the tree- and loop-level amplitudes





- Rich resonance structures
  - $\Lambda_b^0 \to N^{*+}(p\,\pi^+\pi^-)K^-,\ p\,K^{*-}(K^-\pi^+\pi^-),\ \Lambda(p\,K^-)f(\pi^+\pi^-),$ $N^{*0}(p\,\pi^-)K^{*0}(K^-\pi^+)$
- Control channel $\Lambda_b^0 \to \Lambda_c^+(p\,K^-\pi^+)\pi^-$ to subtract nuisance asymmetries

CP asymmetry in $\Lambda_b^0 \to p\,K^-\pi^+\pi^-$

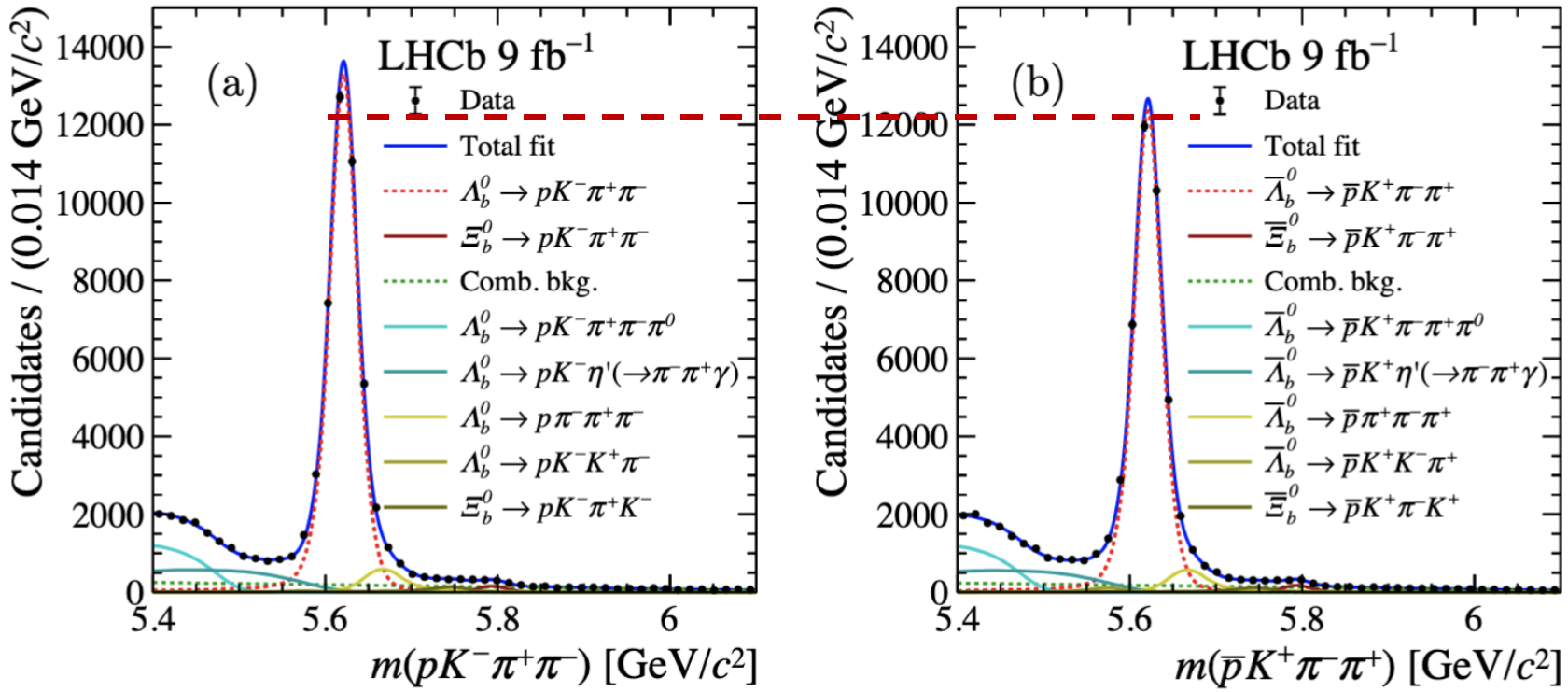
[Nature 643 (2025) 1223]

$$A_{CP} = (2.45 \pm 0.46 \pm 0.10)\%$$

$(5.2\sigma$ significance$)$

First observation of baryon CP violation!

$\Lambda_b^0 \to p\,K^-\pi^+\pi^-$ $\qquad$ $\bar{\Lambda}_b^0 \to \bar{p}\,K^+\pi^-\pi^+$

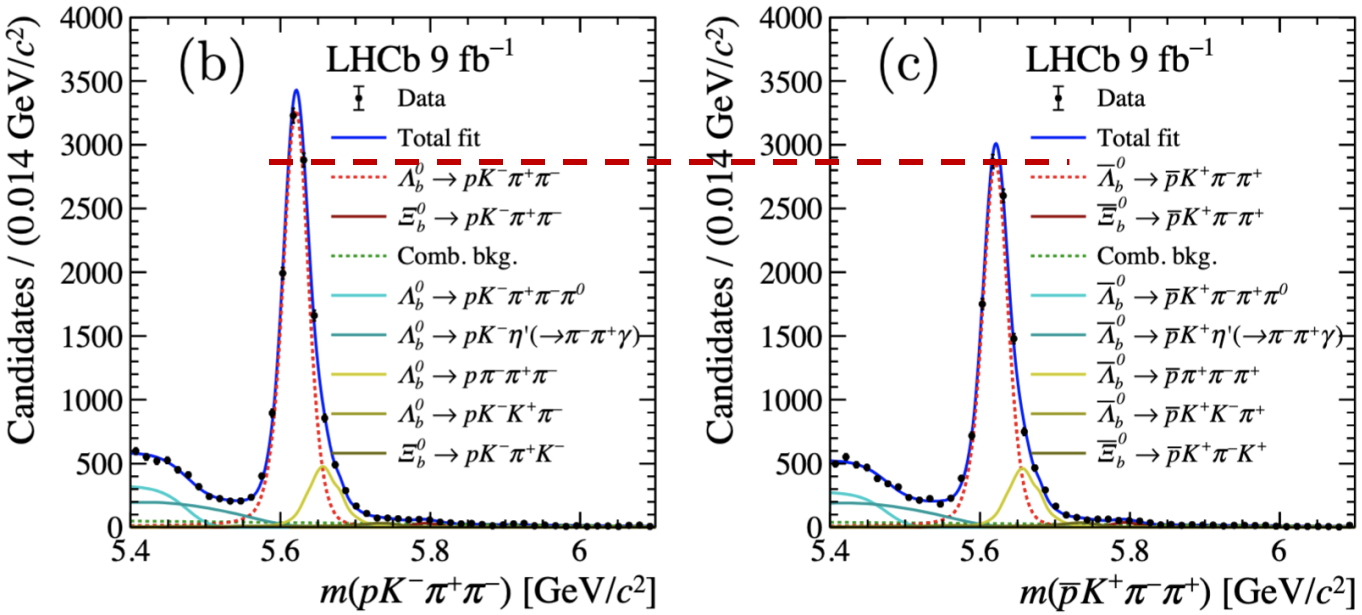


[Nature 643 (2025) 1223]

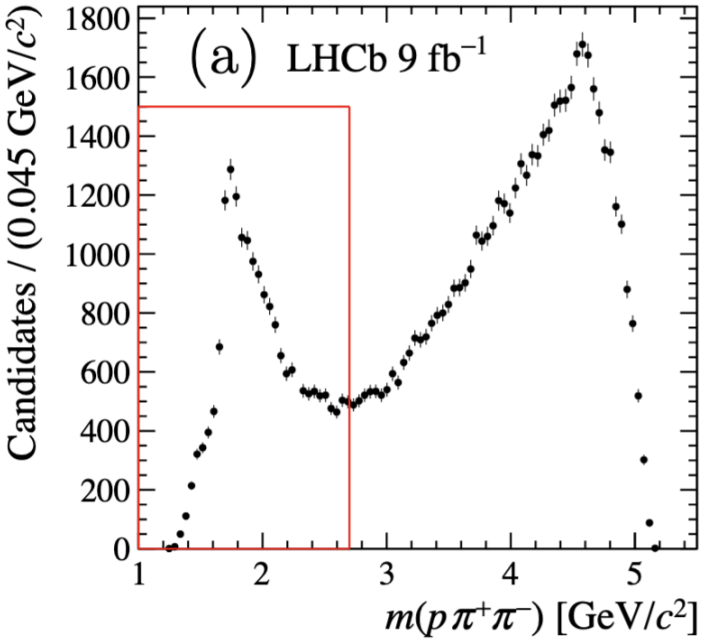
Local CP violation in selected regions of the phase space

Decay topology	Mass region (GeV/c^2)	$\mathcal{A}_{CP}$
$\Lambda_b^0 \to R(pK^-)R(\pi^+\pi^-)$	$m_{pK^-} < 2.2$ $m_{\pi^+\pi^-} < 1.1$	$(5.3 \pm 1.3 \pm 0.2)\%$
$\Lambda_b^0 \to R(p\pi^-)R(K^-\pi^+)$	$m_{p\pi^-} < 1.7$ $0.8 < m_{\pi^+K^-} < 1.0$ or $1.1 < m_{\pi^+K^-} < 1.6$	$(2.7 \pm 0.8 \pm 0.1)\%$
$\Lambda_b^0 \to R(p\pi^+\pi^-)K^-$	$m_{p\pi^+\pi^-} < 2.7$	$(5.4 \pm 0.9 \pm 0.1)\%$
$\Lambda_b^0 \to R(K^-\pi^+\pi^-)p$	$m_{K^-\pi^+\pi^-} < 2.0$	$(2.0 \pm 1.2 \pm 0.3)\%$

(6.0σ)



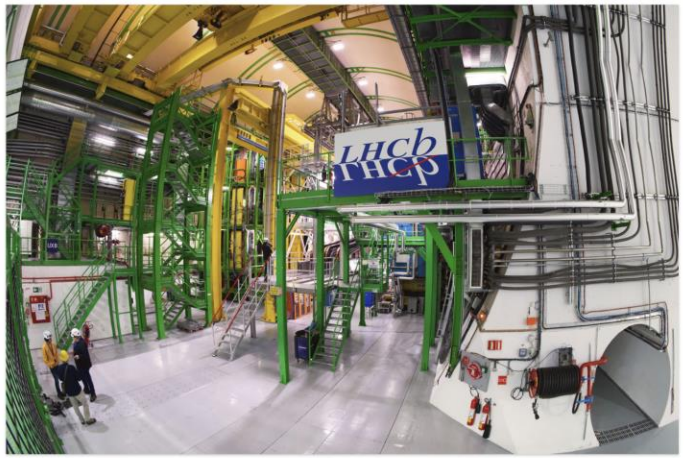
N^{*+} resonance region



A new piece in the matter–antimatter puzzle

The LHCb experiment at CERN has revealed a fundamental asymmetry in the behaviour of particles called baryons

25 MARCH, 2025



View of the LHCb experiment in its underground cavern (image: CERN)

Conclusions and prospects

- CP violation is a rich field of study
- Essential to precisely test the SM and constraint/guide New Physics models
- Direct CP violation in baryon decays observed

- BEPCII and BESIII inner tracker upgraded
- In LHCb Run 3, int. luminosity in 1 year comparable to the sum of Run 1&2

- More results will come!