SEARCH FOR CP VIOLATION IN BARYONS WITH THE LHCb DETECTOR

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INTRODUCTION

Why studying CP violation?

- Important phenomenon in the Standard Model (SM)
- Accomodated in the SM with the **CKM matrix**
- **Well enstablished in mesons** and consistent with the predictions
- Predicted for baryons, **never observed**

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

$$= \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

Outline

- Search for CP violation and observation of P violation in $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$ [Phys. Rev. D **102**, 051101]
- Observation of the suppressed $\Lambda_b^0 \to D^0 \mathrm{pK}^-$ decay with $D^0 \to K^+\pi^-$ and measurement of its CP asymmetry [arXiv:2109.02621]
- Search for CP violation in $\Xi_b^- \to pK^-K^-$ decays [Phys Rev D 104, 052010 (2021)]

b-BARYONS @LHCb

- In contrast with the study of CP violation in beauty-meson decays, the sector of **beauty baryons** remains **almost unexplored**

- Thanks to the **large production cross-section** of beauty baryons in pp collisions at the LHC, the LHCb experiment is the only experiment capable of expanding our knowledge in this sector

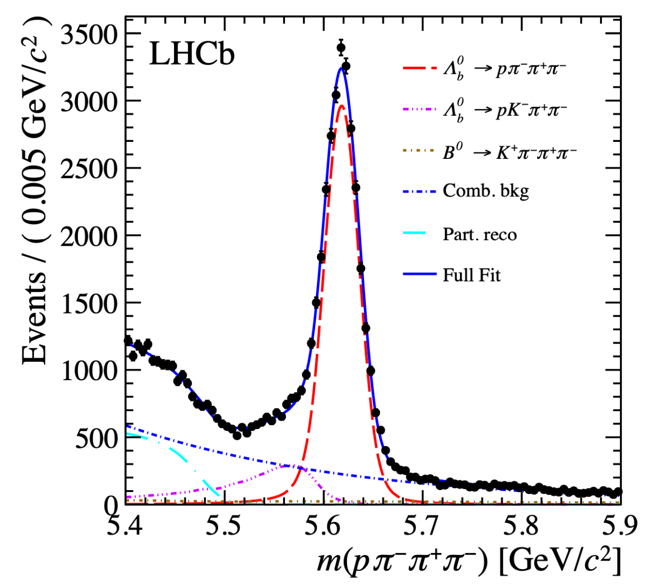
- The first observation of CP violation in a baryon decay is already within the reach of LHCb with the data collected during the Run 2 of the LHC, considering that a first hint for CP violation in baryon decays has been reported in $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$ decays [Phys. Rev. D **102**, 051101]

SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$

[Phys. Rev. D **102**, 051101]

- Analysis performed using data coming from *pp* collisions corresponding to an integrated luminosity of 6.6 fb^{-1} collected from 2011 to 2017 at √s = 7, 8 and 13 TeV

- The measurement is performed using two different independent techniques:
  - Studying **Triple Product Asymmetries** (TPA)
  - Unbinned **energy test method**



Starting point: $N_{\Lambda_b^0+\overline{\Lambda}_b^0} = 27\,600 \pm 200$

- The searches for CP violation are performed by separating the **P-odd** and **P-even** contributions

- In these studies, a large **control sample** of Cabibbo-favored $\Lambda_b^0 \to \Lambda_c^+ (\to pK^-\pi^+)\,\pi^-$ decays is used, where **no CP violation** is expected, to assess potential experimental **biases** and **systematic effects**

SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$

[Phys. Rev. D **102**, 051101]

Two cents on TPA:

- Considers both **local** and **integrated asymmetries**
- The **scalar triple products** are built in the Λ_b^0 rest frame and correspond to

$$C_{\hat{T}} \equiv \vec{p}_p \cdot \left(\vec{p}_{\pi^-_{\text{fast}}} \times \vec{p}_{\pi^+}\right) \qquad \overline{C}_{\hat{T}} \equiv \vec{p}_{\overline{p}} \cdot \left(\vec{p}_{\pi^+_{\text{fast}}} \times \vec{p}_{\pi^-}\right)$$

These quantities are odd under $\hat{T}$ operator transormations

CP- and P-violating effects appear as differences between the triple product observables related by CP and P transformations.

Finally, the TPA are defined as

$$A_{\hat{T}} = \frac{N(C_{\hat{T}} > 0) - N(C_{\hat{T}} < 0)}{N(C_{\hat{T}} > 0) + N(C_{\hat{T}} < 0)} \qquad \overline{A}_{\hat{T}} = \frac{\overline{N}(-\overline{C}_{\hat{T}} > 0) - \overline{N}(-\overline{C}_{\hat{T}} < 0)}{\overline{N}(-\overline{C}_{\hat{T}} > 0) + \overline{N}(-\overline{C}_{\hat{T}} < 0)}$$

And it follows that the **CP- and P-violating asymmetries** are

$$a_{CP}^{\hat{T}\text{-odd}} = \frac{1}{2}\left(A_{\hat{T}} - \overline{A}_{\hat{T}}\right) \qquad a_{P}^{\hat{T}\text{-odd}} = \frac{1}{2}\left(A_{\hat{T}} + \overline{A}_{\hat{T}}\right)$$

SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\, \pi^- \pi^+ \pi^-$

[Phys. Rev. D **102**, 051101]

Caveat:

- It has been shown that it exists a **dependence** of the CP asymmetry as a function of $|\Phi|$, the absolute value of the angle between the planes defined by the $p\,\pi^-_{fast}$ and $\pi^+\pi^-_{slow}$ systems in the Λ_b^0 rest frame

A rich resonant structure:

Makes the decay investigated particularly well-suited for CPV searches. The dominant contributions are:

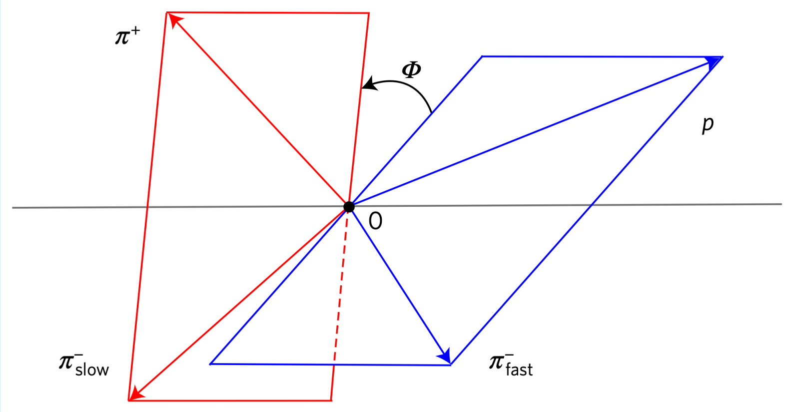
- $\Lambda_b^0 \to N^{*+}\pi^-$, with $N^{*+} \to \Delta^{++}(1234)\pi^-$, and $\Delta^{++}(1234) \to p\,\pi^+$

- $\Lambda_b^0 \to p\, a_1^-(1260)$, with $a_1^-(1260) \to \rho^0(770)\pi^-$, and $\rho^0(770) \to \pi^-\pi^+$

Two phase space binning schemes are adopted:

- A: 16 subsamples to explore the distribution of the **polar** and **azimuthal angles** of the proton in the Δ^{++} rest frame

- B: 10 subsamples uniformly distributed between $[0, \pi]$ used to probe the asymmetries as a function of $|\Phi|$



SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$

[Phys. Rev. D **102**, 051101]

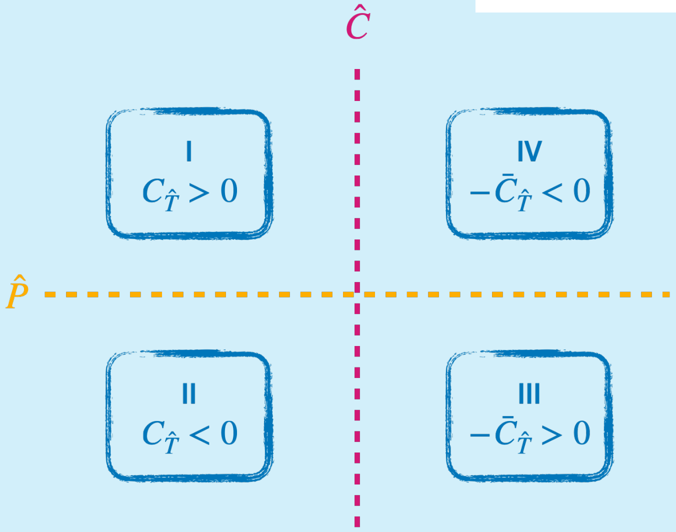
Two cents on the Energy Test method:

- It is a **model-independent unbinned test** sensitive to local differences between two samples

- The test is performed through the calculation of a test statistic

$$T \equiv \frac{1}{2n(n-1)}\sum_{i\neq j}^{n}\psi_{ij} + \frac{1}{2\bar{n}(\bar{n}-1)}\sum_{i\neq j}^{\bar{n}}\psi_{ij} - \frac{1}{n\bar{n}}\sum_{i=1}^{n}\sum_{j=1}^{\bar{n}}\psi_{ij}$$

$\psi_{ij} = e^{-d_{ij}^2/2\delta^2}$, with d_{ij} the **Euclidean distance** between two candidates in the phase space and δ the **distance scale** probed in the Energy Test



The comparison between the regions allows several tests:

- Region I and IV compared to II and III: P-odd and CP-odd test
- Region I and II compared to III and IV: P-even and CP-odd test
- Region I and III compared to II and IV: P violation test

The **length scale** at which CP violation might appear is **not known**: three scales are probed $\delta = 1.6\ \mathrm{GeV}^2/c^4,\ 2.7\ \mathrm{GeV}^2/c^4,\ 13\ \mathrm{GeV}^2/c^4$

SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\, \pi^- \pi^+ \pi^-$

[Phys. Rev. D **102**, 051101]

Results:

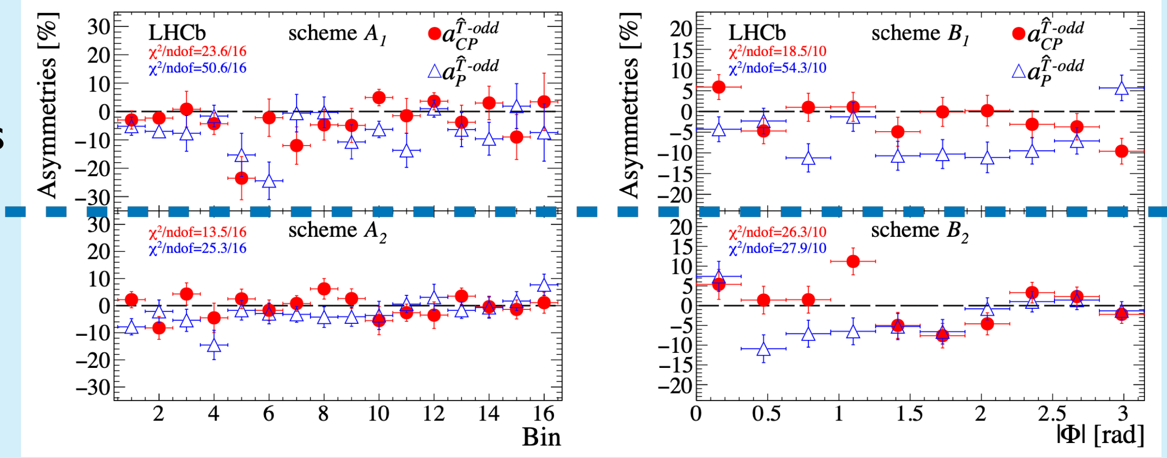
- The two observables $A_{\hat{T}}$ and $\bar{A}_{\hat{T}}$ are **uncorrelated** from one other
- The **reconstruction efficiency** for signal candidates with $C_{\hat{T}} > 0$ is **consistent** with that for candidates with $C_{\hat{T}} < 0$., i.e. the detector and the reconstruction algorithms do not bias the measurements (same for $\bar{C}_{\hat{T}}$)
- The main sources of **systematic uncertainties** in the TPA analysis are selection criteria, reconstruction and detector acceptance
- The Energy Test method is **insensitive to global asymmetries**, and so is not affected by differences between Λ_b^0 and $\bar{\Lambda}_b^0$ production rates

TPA results

$$a_{CP}^{\hat{T}\text{-odd}} = (-0.7 \pm 0.7 \pm 0.2)\%$$

$$a_{P}^{\hat{T}\text{-odd}} = (-4.0 \pm 0.7 \pm 0.2)\%$$

$m(p\pi^+\pi^-_{\text{slow}}) > 2.8\ \text{GeV}/c^2$



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SEARCH FOR CP VIOLATION AND OBSERVATION OF P VIOLATION IN $\Lambda_b^0 \to p\,\pi^-\pi^+\pi^-$

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Energy Test results

Distance scale δ	$1.6\ \mathrm{GeV}^2/c^4$	$2.7\ \mathrm{GeV}^2/c^4$	$13\ \mathrm{GeV}^2/c^4$
p-value (CP conservation, P even)	3.1×10^{-2}	2.7×10^{-3}	1.3×10^{-2}
p-value (CP conservation, P odd)	1.5×10^{-1}	6.9×10^{-2}	6.5×10^{-2}
p-value (P conservation)	1.3×10^{-7}	4.0×10^{-7}	1.6×10^{-1}

b-BARYONS @LHCb

- In contrast with the study of CP violation in beauty-meson decays, the sector of **beauty baryons** remains **almost unexplored**

- Thanks to the **large production cross-section** of beauty baryons in pp collisions at the LHC, the LHCb experiment is the only experiment capable of expanding our knowledge in this sector

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- The unprecedented number of beauty baryons available with the data sample expected to be collected in the LHCb Upgrade I and later with UpgradeII phase, will allow a precision measurement programme of CP violation observables in b-baryon decays to be pursued

[arXiv:2109.02621]

- As for b → u and b → c **tree-level transitions**, like the decays $\Lambda_b^0 \to D\Lambda$ and $\Lambda_b^0 \to DpK^-$. These decays can be used to measure the CKM angle γ as it is done with $B^0 \to DK^+\pi^-$ decays

OBSERVATION OF THE SUPPRESSED $\Lambda_b^0 \to D^0 \mathrm{pK}^-$ DECAY WITH $D^0 \to K^+\pi^-$ AND MEASUREMENT OF ITS CP ASYMMETRY [arXiv:2109.02621]

- Analysis performed using data coming from *pp* collisions corresponding to an integrated luminosity of 9 fb $^{-1}$ collected from 2011 to 2018 at √s = 7, 8 and 13 TeV

- Study of $\Lambda_b^0 \to Dp\mathrm{K}^-$, with $D \to K^-\pi^+$ and $D \to K^+\pi^-$, D is a superposition of D^0 and $\overline{D}^0$ states

- The ratio of branching fractions of the two decays is measured, and the CP asymmetry of the suppressed mode is also reported

- $\Lambda_b^0 \to [K^+\pi^-]_D \mathrm{pK}^-$ is **suppressed** by a factor $R \approx \left| \frac{V_{cb}V_{us}^*}{V_{ub}V_{cs}^*} \right|^2 = 6.0$

- **CP observable** $$A = \frac{\mathcal{B}(\Lambda_b^0 \to [K^+\pi^-]_D pK^-) - \mathcal{B}(\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p}K^+)}{\mathcal{B}(\Lambda_b^0 \to [K^+\pi^-]_D pK^-) + \mathcal{B}(\overline{\Lambda}_b^0 \to [K^-\pi^+]_D \overline{p}K^+)}$$

- The ratio of branching fractions R and the CP asymmetry A are measured separately in the **full phase space** and in a **restricted** phase space region $m^2(K^-p) < 5\ GeV^2/c^4$
  - Region which involves $\Lambda_b^0 \to D\Lambda^*$ decays, where an enhanced sensitivity to γ is expected

OBSERVATION OF THE SUPPRESSED $\Lambda_b^0 \to D^0 pK^-$ DECAY WITH $D^0 \to K^+\pi^-$ AND MEASUREMENT OF ITS CP ASYMMETRY

[arXiv:2109.02621]
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Physical background:

- Charmless background removed reducing the D^0 mass window and selection on D^0 decay time
- Contributions from $\Lambda_b^0 \to \Lambda_c^+ h^-$ are vetoed
- Double misidentified background: considered in the systematics

Observables and correction factors

$$R = \frac{\sum_i w^i_{\mathrm{FAV}}/\epsilon^i}{\sum_i w^i_{\mathrm{SUP}}/\epsilon^i}$$

Relative **efficiencies** computed with Λ_b^0 phase space variables

Obtained with the *sPlot* technique

$$A = \frac{\sum_i w^i_{\mathrm{SUP},\Lambda_b^0}/\epsilon^i - \sum_i w^i_{\mathrm{SUP},\overline{\Lambda}_b^0}/\epsilon^i}{\sum_i w^i_{\mathrm{SUP},\Lambda_b^0}/\epsilon^i + \sum_i w^i_{\mathrm{SUP},\overline{\Lambda}_b^0}/\epsilon^i}$$

The sums are over the selected candidates

Systematic uncertainties

- Many systematic effects **cancel** in the ratios
- Description of signal and background contributions in the invariant mass **fit model**
- **Particle identification** in the detector assessed with specific tools
- Asymmetry in Λ_b^0 and $\overline{\Lambda}_b^0$ production
- Asymmetry in p and $\bar{p}$ detection

OBSERVATION OF THE SUPPRESSED $\Lambda_b^0 \to D^0 pK^-$ DECAY WITH $D^0 \to K^+\pi^-$ AND MEASUREMENT OF ITS CP ASYMMETRY [arXiv:2109.02621]

- Suppressed decay $\Lambda_b^0 \to [K^+\pi^-]_D pK^-$ seen for the first time

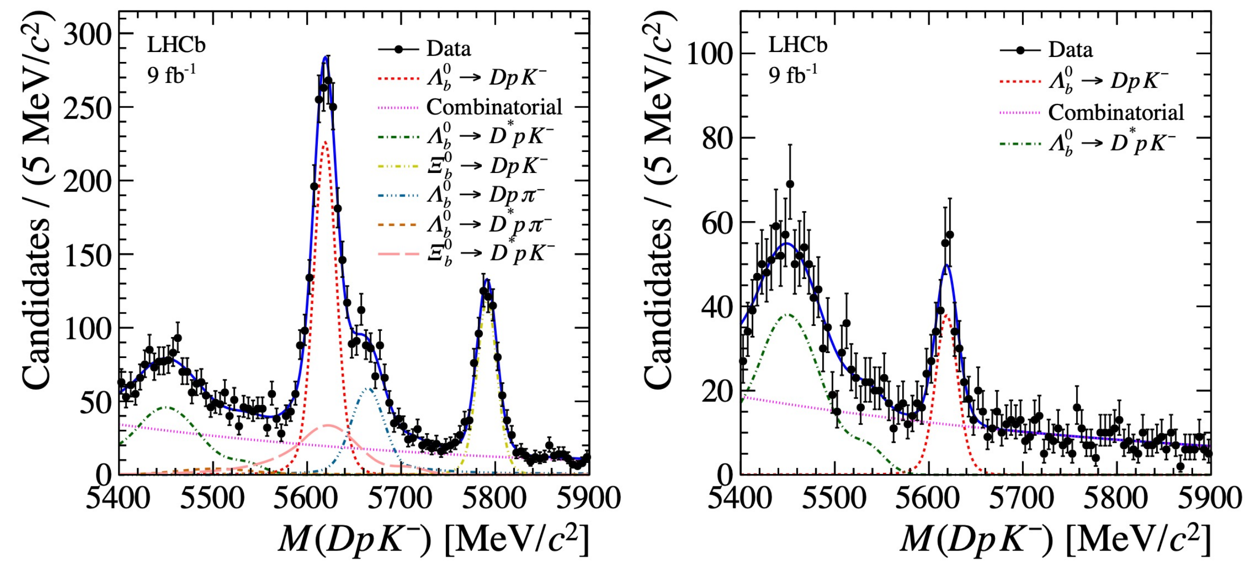
- The measured **yield** in the **full phase space** is:
  - 1437 ± 92 for the favoured mode
  - 241 ± 22 for the suppressed mode

- Favoured-to-suppressed $\mathcal{B}$ ratio

$$R = 7.1 \pm 0.8\,(\text{stat.})^{+0.4}_{-0.3}\,(\text{syst.})$$

- CP asymmetry

$$A = 0.12 \pm 0.09\,(\text{stat.})^{+0.02}_{-0.03}\,(\text{syst.})$$



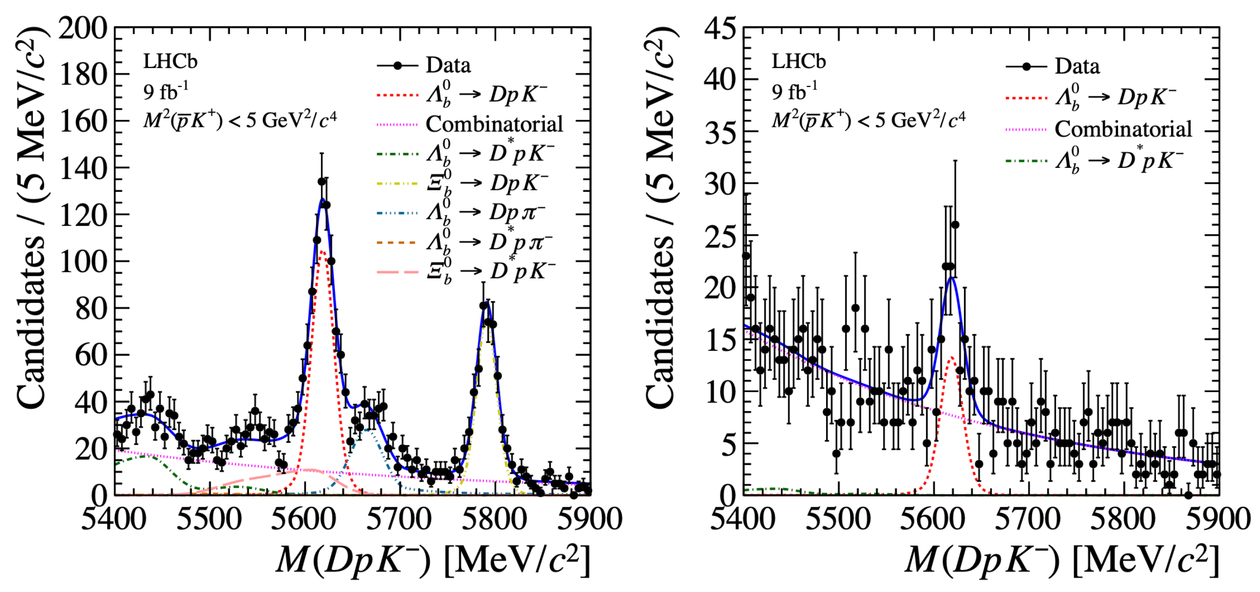
OBSERVATION OF THE SUPPRESSED $\Lambda_b^0 \to D^0 \mathrm{p}\mathrm{K}^-$ DECAY WITH $D^0 \to K^+\pi^-$ AND MEASUREMENT OF ITS CP ASYMMETRY [arXiv:2109.02621]

- Suppressed decay $\Lambda_b^0 \to [K^+\pi^-]_D \mathrm{p}\mathrm{K}^-$ seen for the first time
- The measured **yield** in the **restricted phase space** is:
  - 664 ± 36 for the favoured mode
  - 84 ± 14 for the suppressed mode
- Favoured-to-suppressed $\mathcal{B}$ ratio

$$R = 8.6 \pm 1.5\,(\mathrm{stat.})^{+0.4}_{-0.3}\,(\mathrm{syst.})$$

- CP asymmetry

$$A = 0.01 \pm 0.16\,(\mathrm{stat.})^{+0.03}_{-0.02}\,(\mathrm{syst.})$$



b-BARYONS @LHCb

- Another sector explored by the LHCb collaboration is that of beauty baryons decaying to **final states without a charm quark**
  - relevant contributions from $b \to d, s$ loop-level transitions

- Very large signal yields are also expected in several **multibody final states** of Λ_b^0 and Ξ_b^0 decays
  - Besides the already seen $\Lambda_b^0 \to p\, \pi^- \pi^+ \pi^-$, also $\Lambda_b^0 \to p\, K^- K^+ K^-$ decays are investigated for CPV searches, as Ξ_b^0 3- and 4-body decays

SEARCH FOR CP VIOLATION IN $\Xi_b^- \to pK^-K^-$ DECAYS

[Phys Rev D 104, 052010 (2021)]

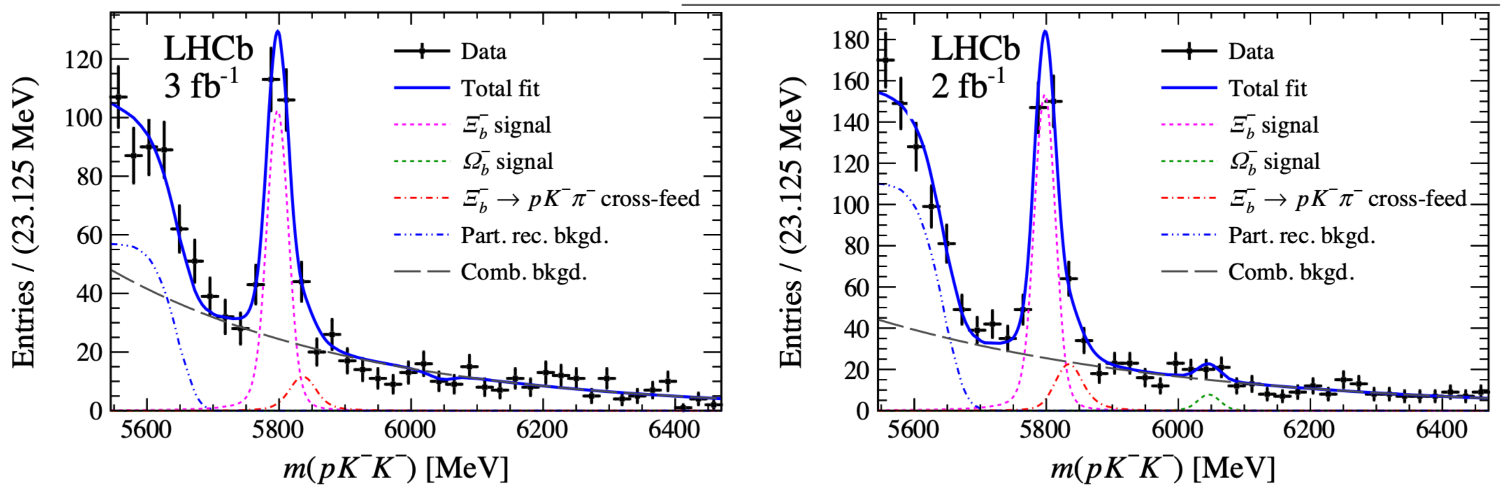
- Analysis performed using data coming from *pp* collisions corresponding to an integrated luminosity of 5 fb $^{-1}$ collected from 2011 to 2016 at √s = 7, 8 and 13 TeV

- **First amplitude analysis** of any baryon decay mode whose model allows for CP-violation effects

- Only candidates in the m(pK^-K^-) signal region of ±40 MeV around the Ξ_b^- mass are retained for the amplitude analysis

- Signal purities of (63 ± 3)% and (70 ± 2)% for Run 1 and Run 2, respectively

Parameter	Run 1	Run 2
$\Xi_b^- \to pK^-K^-$ yield	193 ± 21	297 ± 23
$\Omega_b^- \to pK^-K^-$ yield	-4 ± 6	15 ± 9
Partially reconstructed background yield	231 ± 34	442 ± 36
Combinatorial background yield	721 ± 50	775 ± 51

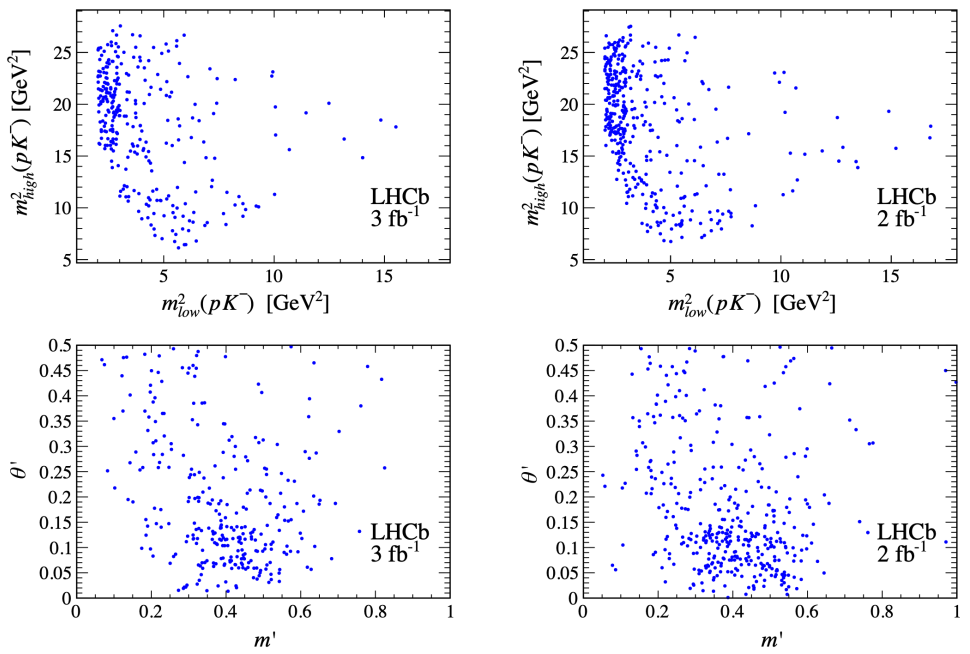


SEARCH FOR CP VIOLATION IN $\Xi_b^- \rightarrow pK^-K^-$ DECAYS

[Phys Rev D 104, 052010 (2021)]

Dalitz Plot Analysis

- It is assumed that Ξ_b^- baryons produced in pp collisions within the LHCb acceptance have **negligible polarization**
  - As a result, the phase space of the $\Xi_b^- \rightarrow pK_1^-K_2^-$ decay is characterized by two independent kinematic variables $\mathrm{m}^2(pK_1^-)$ and $\mathrm{m}^2(pK_2^-)$



- The **Bose symmetry** implies that the decay amplitudes must be invariant under the exchange of the two kaons
  - The variables m^2_{low} and m^2_{high} are used, which denote the lower and higher of $\mathrm{m}^2(pK_1^-)$ and $\mathrm{m}^2(pK_2^-)$, respectively

- Other two variables are used, the **Squared Dalitz** ones

$$m' = \frac{1}{\pi}\arccos\left(2\frac{m(K^-K^-) - m_{\min}(K^-K^-)}{m_{\max}(K^-K^-) - m_{\min}(K^-K^-)}\right)$$

$$\theta' = \frac{1}{\pi}\theta(K^-K^-)$$

SEARCH FOR CP VIOLATION IN $\Xi_b^- \to pK^-K^-$ DECAYS

[Phys Rev D 104, 052010 (2021)]

Helicity formalism

- The main characters of this amplitude analysis are $\boldsymbol{\Sigma}^*$ and $\boldsymbol{\Lambda}^*$ **resonances** via the decay chain $\Xi_b^- \to (R \to pK^-)K^-$

- The **differential decay densities** are expressed as

$$\frac{d\Gamma^Q}{d\Omega} = \frac{1}{(8\pi m_{\Xi_b})^3} \sum_{M_{\Xi_b},\lambda_p} \left| \sum_R A^Q_{R,M_{\Xi_b},\lambda_p}(\Omega) \right|^2$$

where $A^Q_{R,M_{\Xi_b},\lambda_p}(\Omega)$ denotes the **symmetrized decay amplitude** for a given intermediate state R, which is itself expressed as

$$A^Q_{R,M_{\Xi_b},\lambda_p}(m^2_{\text{low}}, m^2_{\text{high}}) = T^Q_{R,M_{\Xi_b},\lambda_p}(m^2_{\text{low}}, m^2_{\text{high}}) + (-1)^{M_{\Xi_b}+\lambda_p} T^Q_{R,M_{\Xi_b},\lambda_p}(m^2_{\text{high}}, m^2_{\text{low}})$$

- Resonances are parametrized with **Relativistic Breit–Wigner** (RBW) functions, F_{RBW}, that are modified by Blatt–Weisskopf barrier factors, $B_{L_{\Xi_b}}$ and B_{L_R} , and are given by

$$R(m_x^2) = B_{L_{\Xi_b}}(p|p_0, d)\left(\frac{p}{m_{\Xi_b}}\right)^{L_{\Xi_b}} F_{\text{RBW}}(m_x^2|m_0, \Gamma_0) \times B_{L_R}(q|q_0, d)\left(\frac{q}{m_0}\right)^{L_R}$$

SEARCH FOR CP VIOLATION IN $\Xi_b^- \to pK^-K^-$ DECAYS

[Phys Rev D 104, 052010 (2021)]

Name	J^P	Mass (MeV)	Width (MeV)	Main decay channels
			****	
† $\Lambda(1405)$	$\frac{1}{2}^-$	$1405.1^{+1.3}_{-1.0}$	50.5 ± 2.0	$\Sigma\pi$
† $\Lambda(1520)$	$\frac{3}{2}^-$	1518 to 1520	15 to 17	$N\bar{K}$, $\Sigma\pi$
† $\Lambda(1670)$	$\frac{1}{2}^-$	1660 to 1680	25 to 50	$N\bar{K}$, $\Sigma\pi$, $\Lambda\eta$
$\Lambda(1690)$	$\frac{3}{2}^-$	1685 to 1695	50 to 70	$N\bar{K}$, $\Sigma\pi$, $\Lambda\pi\pi$, $\Sigma\pi\pi$
$\Lambda(1820)$	$\frac{5}{2}^+$	1815 to 1825	70 to 90	$N\bar{K}$
$\Lambda(1830)$	$\frac{5}{2}^-$	1810 to 1830	60 to 110	$\Sigma\pi$
$\Lambda(1890)$	$\frac{3}{2}^+$	1850 to 1910	60 to 200	$N\bar{K}$
† $\Sigma(1385)$	$\frac{3}{2}^+$	1383.7 ± 1	36 ± 5	$\Lambda\pi$, $\Sigma\pi$
$\Sigma(1670)$	$\frac{3}{2}^-$	1665 to 1685	40 to 80	$\Sigma\pi$
† $\Sigma(1775)$	$\frac{5}{2}^-$	1770 to 1780	105 to 135	$N\bar{K}$, $\Lambda^{(*)}\pi$
† $\Sigma(1915)$	$\frac{5}{2}^+$	1900 to 1935	80 to 160	not clear
			***	
$\Lambda(1600)$	$\frac{1}{2}^+$	1560 to 1700	50 to 250	$N\bar{K}$, $\Sigma\pi$
$\Lambda(1800)$	$\frac{1}{2}^-$	1720 to 1850	200 to 400	$N\bar{K}^{(*)}$, $\Sigma\pi$, $\Lambda\eta$
$\Lambda(1810)$	$\frac{1}{2}^+$	1750 to 1850	50 to 250	$N\bar{K}^{(*)}$, $\Sigma\pi$, $\Lambda\eta$, ΞK
$\Lambda(2110)$	$\frac{5}{2}^+$	2090 to 2140	150 to 250	$N\bar{K}^{(*)}$, $\Sigma\pi$, $\Lambda\Omega$
$\Sigma(1660)$	$\frac{1}{2}^-$	1630 to 1690	40 to 200	$N\bar{K}$, $\Sigma\pi$, $\Lambda\pi$
$\Sigma(1750)$	$\frac{1}{2}^-$	1730 to 1800	60 to 160	$N\bar{K}$, $\Sigma\pi$, $\Lambda\pi$, $\Sigma\eta$
$\Sigma(1940)$	$\frac{3}{2}^-$	1900 to 1950	150 to 300	$N\bar{K}$, $\Sigma\pi$, $\Lambda\pi$
$\Sigma(2250)$	??	2210 to 2280	60 to 150	$N\bar{K}$, $\Sigma\pi$, $\Lambda\pi$

A zoo of particles taken into consideration

- The $\Lambda(1520)$ resonance is chosen as the **reference component**, and the helicity couplings of all other resonant and nonresonant components are left free to vary in the fit
- Baseline model obtained by adding resonances iteratively to **maximise the change in $-2\ln\mathcal{L}$**
- This approach leads to a model that contains $\Sigma(1385)$, $\Lambda(1405)$, $\Lambda(1520)$, $\Lambda(1670)$, $\Sigma(1775)$ and $\Sigma(1915)$ components
- The potential for additional components to be present in the chosen model is considered as a source of **systematic uncertainty**

SEARCH FOR CP VIOLATION IN $\Xi_b^- \to pK^-K^-$ DECAYS

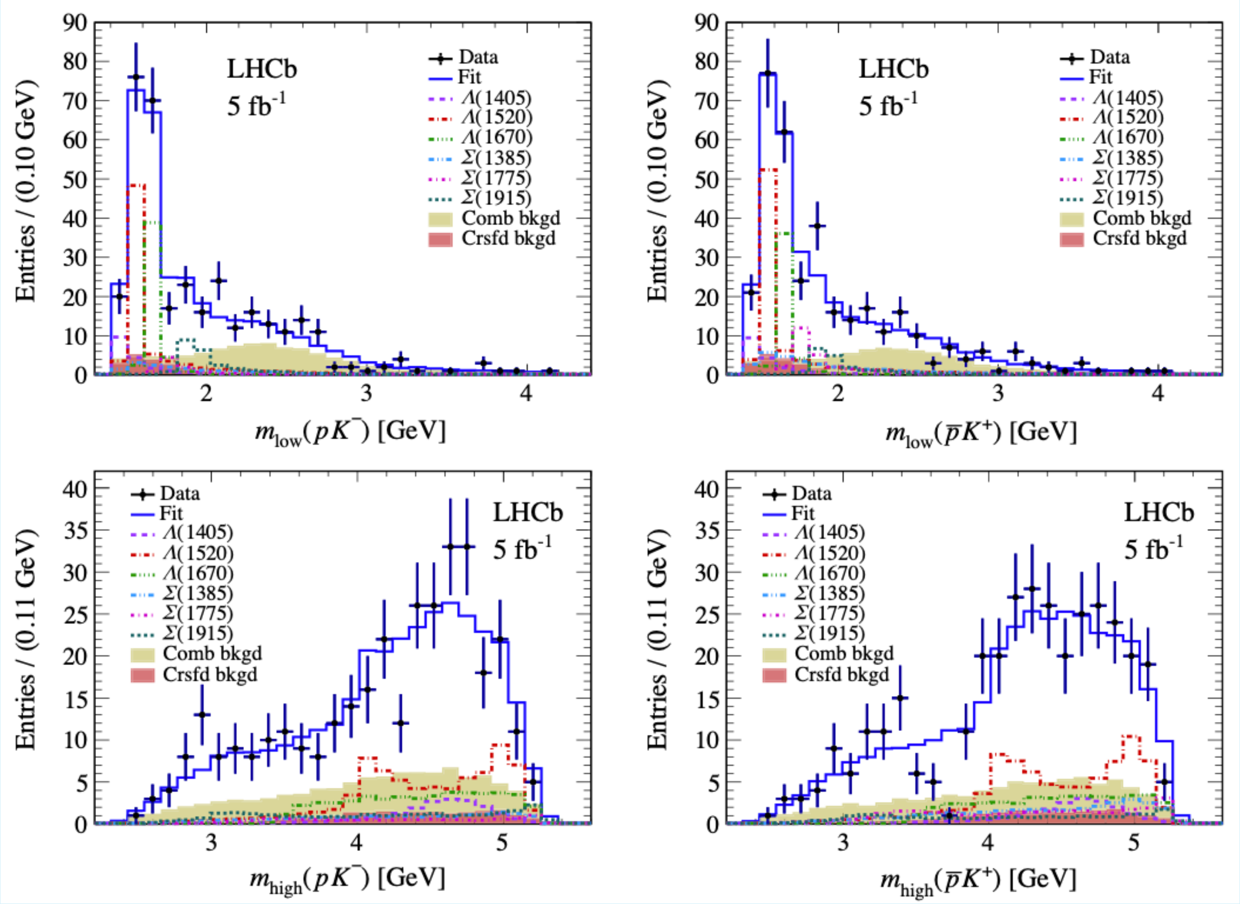
[Phys Rev D 104, 052010 (2021)]

Fit results

- The fit is performed **simultaneously** on Run1 and Run2 data

- There is **no indication of CP violation** in the distributions, i.e., no significant difference between Ξ_b^- and $\bar{\Xi}_b^+$ decays

Component	A^{CP} (10^{-2})
$\Sigma(1385)$	$-27 \pm 34\,(\text{stat}) \pm 73\,(\text{syst})$
$\Lambda(1405)$	$-1 \pm 24\,(\text{stat}) \pm 32\,(\text{syst})$
$\Lambda(1520)$	$-5 \pm 9\,(\text{stat}) \pm 8\,(\text{syst})$
$\Lambda(1670)$	$3 \pm 14\,(\text{stat}) \pm 10\,(\text{syst})$
$\Sigma(1775)$	$-47 \pm 26\,(\text{stat}) \pm 14\,(\text{syst})$
$\Sigma(1915)$	$11 \pm 26\,(\text{stat}) \pm 22\,(\text{syst})$



CONCLUSIONS

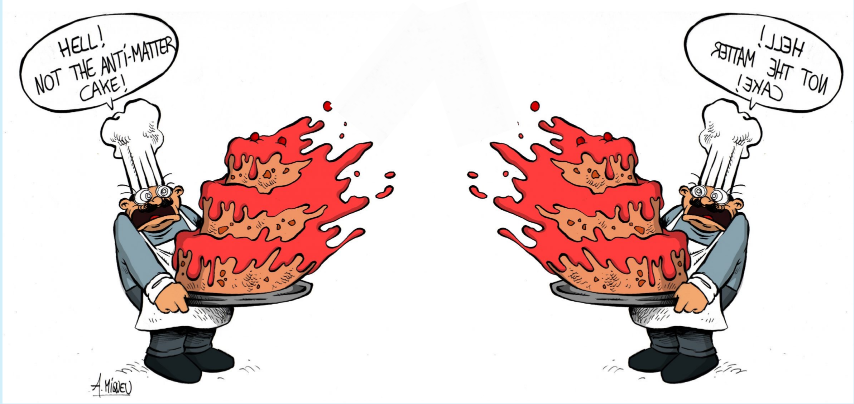
Summary of this talk

- The LHCb collaboration is putting a lot of effort into the search for CP violation in baryons
  - UpgradeI and II will allow to have much more statistics for these studies!

- Up-to-now many channels are being investigated, 3- and 4-body decays of both Ξ_b and Λ_b
  - Also exploring never tried techniques

- Unfortunately, only hints of CP violation have been found, but an evidence of P violation was found

- Many analysis are in the pipeline! The search is not stopping



THANKS FOR LISTENING! QUESTIONS?