Review on hadronic B decays

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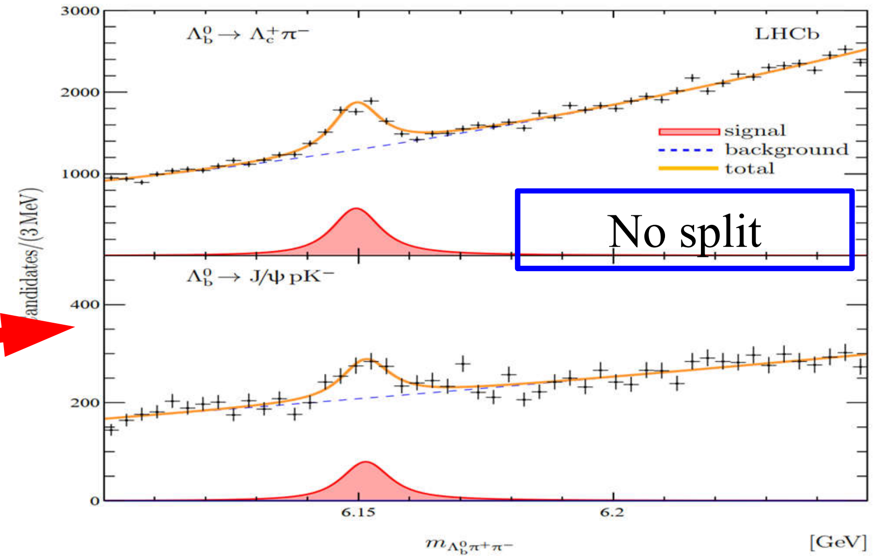
on behalf of the LHCb， including results
from ATLAS and CMS

Outline of the talk

- New resonances: $(\Lambda_b^0\pi^+\pi^-)$, $\left(\Lambda_b^0\pi^\pm\right)$
- Observation of $B_{(s)}^0 \to J/\psi p\bar{p}$, $\Lambda_b^0 \to \chi_{c1}(3872)pK^-$, $B_s^0 \to \bar{D}^{*0}\phi$, excited $B_c^\pm$ state, $B^0 \to (Z_c\to \eta_c(1S))K^+ \pi^-$, $\Lambda_b \to J/\varphi\Lambda\phi$ (CMS)
- Amplitude analysis of $B^\pm \to \pi^\pm K^+K^-$, $B_s^0 \to K^{*0}\bar{K}^{*0}$, $B_s^0 \to K_s^0K^\pm\pi^\mp$
- Several sources of CPV in $B^+ \to \pi^+\pi^+\pi^-$; model independent observation of $B^0 \to J/\psi K^+\pi^-$; CPV phase ϕ_s in $B_s^0 \to J/\psi\phi$ (ATLAS)

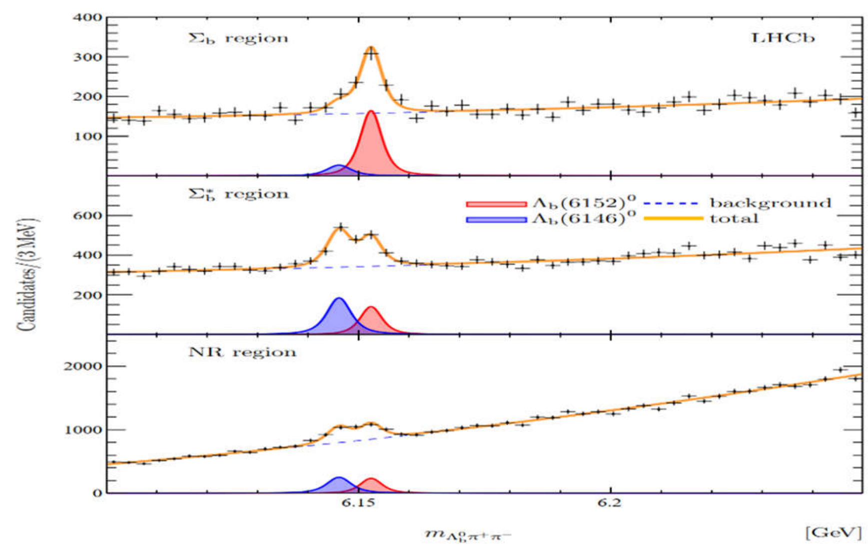
New resonances in the $\Lambda_b^0\pi^+\pi^-$ system

- Excited states to the $\Lambda_b^0\pi^+\pi^-$ has already been studied by the LHCb: e.g. $\Lambda_b(5912)^0$
- More states are predicted in the mass region near/above 6.1 GeV ($>\Sigma_b^{(*)\pm}\pi^{\mp}$).



Split $m_{\Lambda_b^0\pi^\pm}$ into 3 regions:

- Within the natural width of the known $\Sigma_b^\pm$ mass
- Within the natural width of the known $\Sigma_b^{(*)\pm}$ mass
- Remaining nonresonant (NR) region.



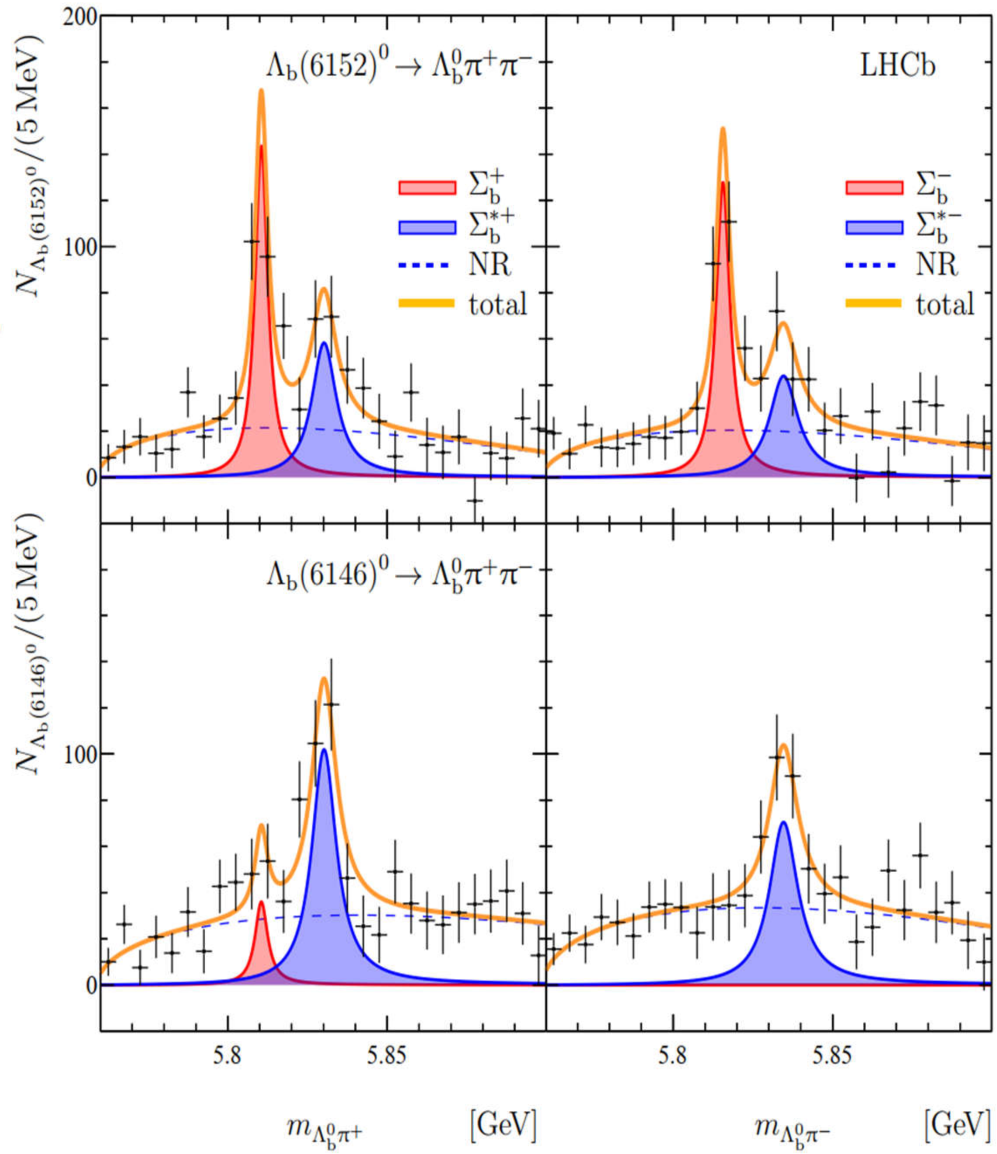
Look different ⟹ two narrow peaks

ARXIV:1907.13598; $9fb^{-1}$

New resonances in the $\Lambda_b^0\pi^+\pi^-$ system

- Significant $\Lambda_b(6152)^0 \to \Sigma_b^{\pm}\pi^{\mp}$ and $\Lambda_b(6152)^0 \to \Sigma_b^{*\pm}\pi^{\mp}$ signals are observed
  - 1/3 and 1/4 of the signal decays in the sample
- $\Lambda_b(6146)^0 \to \Sigma_b^{*\pm}\pi^{\mp}$ decays account for about half of the observed decay rate
- Consistent with the predictions for the doublet of $\Lambda_b(1D)^0$
  - Similar natural widths are expected for the two states of the doublet.
- Interpretation of these states as excited Σ_b^0 states cannot be excluded.

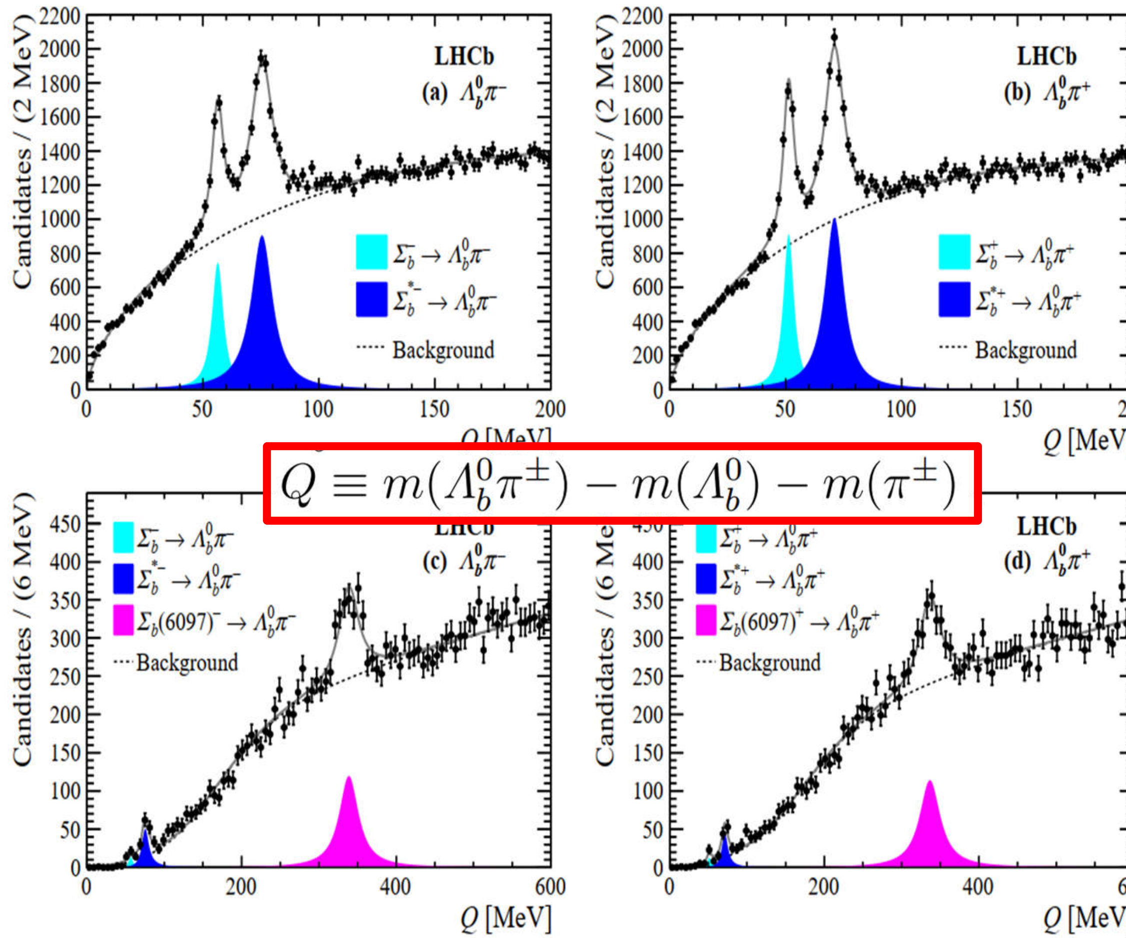
ARXIV:1907.13598 (to PRL); $9fb^{-1}$



Two new resonances in the $(\Lambda_b^0\pi^\pm)$ system

- Beyond these ground states ($\Sigma_b^\pm$, $\Sigma_b^{*\pm}$)
  - Radially/orbitally excited states are expected at higher masses, but only a few observed

- These excited states will cast light on the internal mechanisms governing the dynamics of the constituent quarks



$$Q \equiv m(\Lambda_b^0\pi^\pm) - m(\Lambda_b^0) - m(\pi^\pm)$$

Figure 2: Mass distribution for selected $\Lambda_b^0\pi^\pm$ candidates. The points show experimental data. The left (right) column shows $\Lambda_b^0\pi^-$ ($\Lambda_b^0\pi^+$) combinations. The top row shows the fits to the lower-mass states $\Sigma_b^\pm$ and $\Sigma_b^{*\pm}$. The lower row presents the fits to the new mass peaks with the requirement $p_T(\pi_s^\pm) > 1000$ MeV.

PRL. 122(2019) 012001; $9fb^{-1}$

The measurements of the $(\Lambda_b^0\pi^\pm)$ resonances

- Observation of two new mass peaks in the $\Lambda_b^0\pi^+$ and $\Lambda_b^0\pi^-$ systems
- The ground-states ($\Sigma_b^\pm$, $\Sigma_b^{*\pm}$) are also confirmed and the masses and widths precisely measured.

Quantity	Value [MeV]
$m(\Sigma_b(6097)^-)$	$6098.0 \pm 1.7 \pm 0.5$
$m(\Sigma_b(6097)^+)$	$6095.8 \pm 1.7 \pm 0.4$
$\Gamma(\Sigma_b(6097)^-)$	$28.9 \pm 4.2 \pm 0.9$
$\Gamma(\Sigma_b(6097)^+)$	$31.0 \pm 5.5 \pm 0.7$
$m(\Sigma_b^-)$	$5815.64 \pm 0.14 \pm 0.24$
$m(\Sigma_b^{*-})$	$5834.73 \pm 0.17 \pm 0.25$
$m(\Sigma_b^+)$	$5810.55 \pm 0.11 \pm 0.23$
$m(\Sigma_b^{*+})$	$5830.28 \pm 0.14 \pm 0.24$
$\Gamma(\Sigma_b^-)$	$5.33 \pm 0.42 \pm 0.37$
$\Gamma(\Sigma_b^{*-})$	$10.68 \pm 0.60 \pm 0.33$
$\Gamma(\Sigma_b^+)$	$4.83 \pm 0.31 \pm 0.37$
$\Gamma(\Sigma_b^{*+})$	$9.34 \pm 0.47 \pm 0.26$
$m(\Sigma_b^{*-}) - m(\Sigma_b^-)$	$19.09 \pm 0.22 \pm 0.02$
$m(\Sigma_b^{*+}) - m(\Sigma_b^+)$	$19.73 \pm 0.18 \pm 0.01$
$\Delta(\Sigma_b(6097)^\pm)$	$-2.2 \pm 2.4 \pm 0.3$
$\Delta(\Sigma_b^\pm)$	$-5.09 \pm 0.18 \pm 0.01$
$\Delta(\Sigma_b^{*\pm})$	$-4.45 \pm 0.22 \pm 0.01$

- Compatible with being $\Sigma_b(1P)$ excitations
- Other interpretations, such as molecular states, may also be possible

Observation of $B^0_{(s)} \to J/\psi p\bar{p}$ decays

- Sensitive to pentaquark in the $J/\psi p$ and $J/\psi \bar{p}$ components and to glueball states ($p\bar{p}$)
- Baryonic $B^0_{(s)}$ decays：
  - Study the dynamics of the final baryon-antibaryon system and the threshold enhancement
- Theoretical expectation for the $Br(B^0_{(s)} \to J/\psi p\bar{p})$ is at the level of 10^{-9}.
  - Intermediate pentaquark or glueball state can enhance

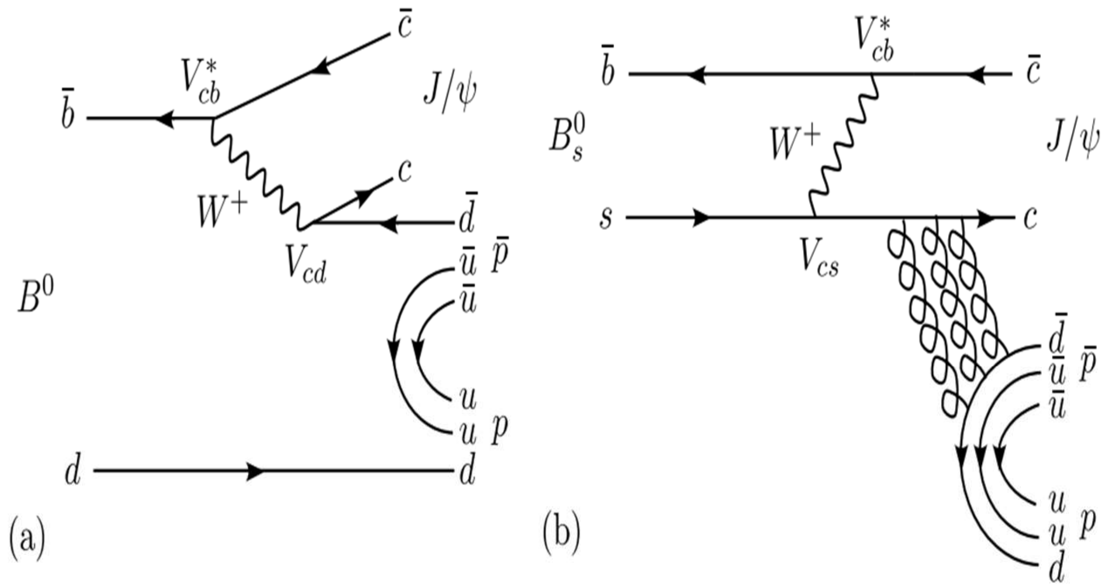


Figure 1: Leading Feynman diagrams for (a) $B^0 \to J/\psi p\bar{p}$ and (b) $B^0_s \to J/\psi p\bar{p}$ decays.

Cabibbo suppressed

OZI suppressed

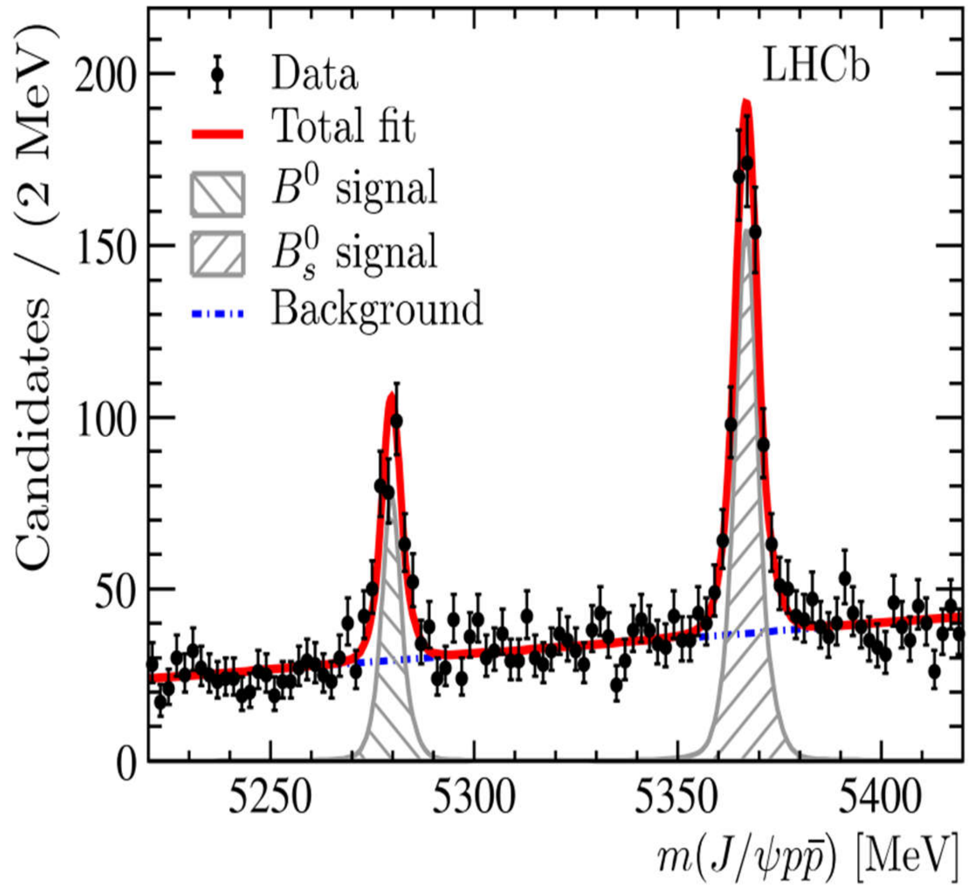
PRL. 122(2019) 191804; $5.2\ fb^{-1}$

Observation of $B^0_{(s)} \to J/\psi p\bar{p}$ decays

- **First observation of :**
  $B^0_{(s)} \to J/\psi p\bar{p}$
- The measured BRs:

$$\mathcal{B}(B^0 \to J/\psi p\bar{p}) = (4.51 \pm 0.40\,(\text{stat}) \pm 0.44\,(\text{syst})) \times 10^{-7},$$
$$\mathcal{B}(B^0_s \to J/\psi p\bar{p}) = (3.58 \pm 0.19\,(\text{stat}) \pm 0.39\,(\text{syst})) \times 10^{-6}.$$

- For the $B^0_{(s)}$ meson, the result is much higher than the expected value of $O(10^{-9})$
- Most precise single measurement of both the B^0 and $B^0_{(s)}$ mass



$$m_{B^0} = 5279.74 \pm 0.30\,(\text{stat}) \pm 0.10\,(\text{syst})\,\text{MeV},$$
$$m_{B^0_s} = 5366.85 \pm 0.19\,(\text{stat}) \pm 0.13\,(\text{syst})\,\text{MeV},$$

PRL. 122(2019) 191804; $5.2\ fb^{-1}$

Observation $\Lambda_b^0 \to \chi_{c1}(3872)pK^-$

$\Lambda_b^0 \to \chi_{c1}(3872)pK^-$ with $\chi_{c1}(3872) \to J/\psi\pi\pi$, observed the first time

- Observing Λ_b^0 decays involving the $\chi_{c1}(3872)$ state will allow comparison of their decay rates to the rates for conventional charmonium states

- The BR with respect to that of the $\Lambda_b^0 \to \psi(2S)pK^-$, where the $\psi(2S) \to J/\psi\pi\pi$ final state, is measured to be:

$$\frac{\mathcal{B}(\Lambda_b^0 \to \chi_{c1}(3872)pK^-)}{\mathcal{B}(\Lambda_b^0 \to \psi(2S)pK^-)} \times \frac{\mathcal{B}(\chi_{c1}(3872) \to J/\psi\pi^+\pi^-)}{\mathcal{B}(\psi(2S) \to J/\psi\pi^+\pi^-)} = (5.4 \pm 1.1 \pm 0.2) \times 10^{-2}$$

JHEP 09 (2019) 028; 1,2,1.9 fb^{-1} at 7,8,13 TeV

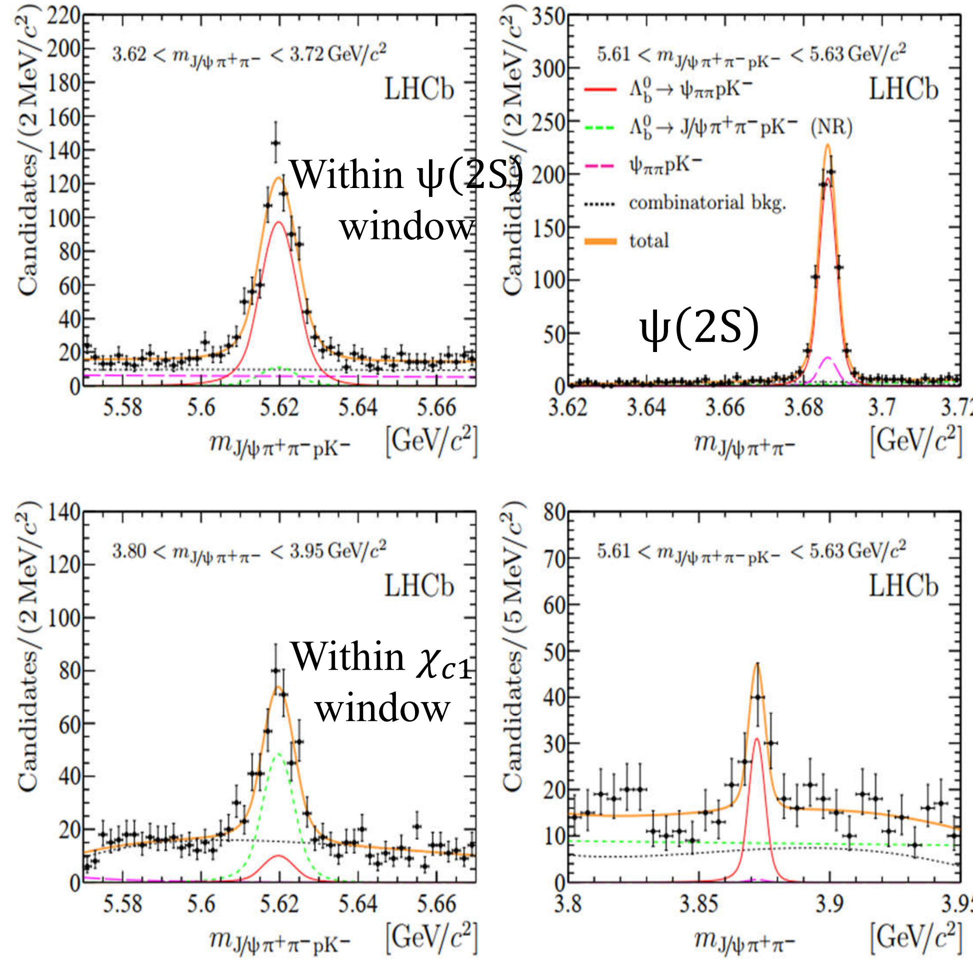
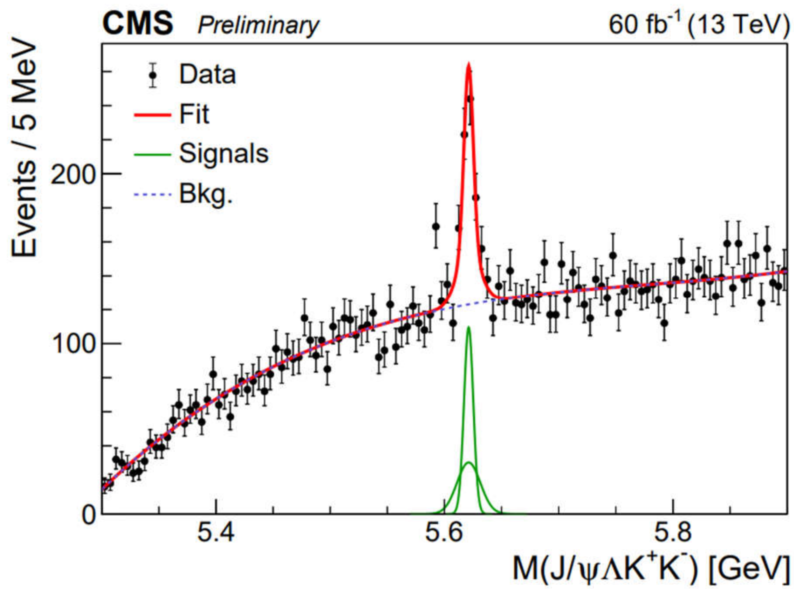


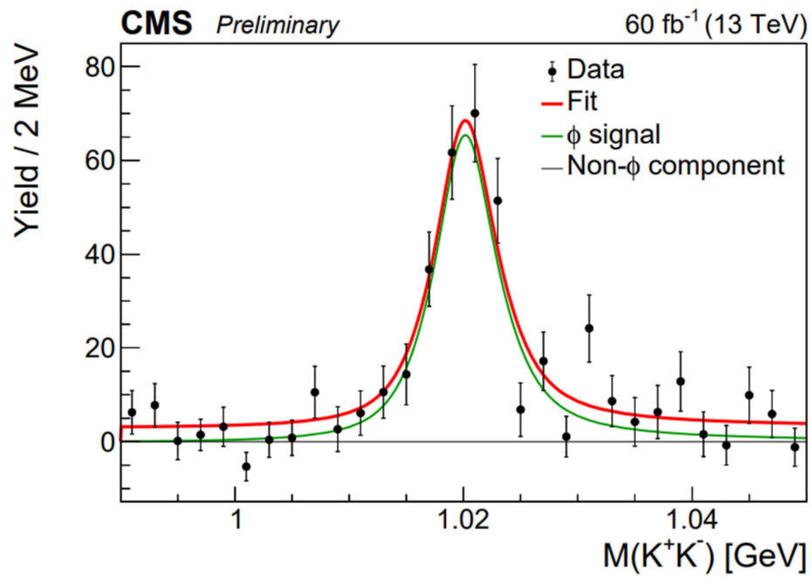
Figure 1: Projection of the two-dimensional distributions of (left) $J/\psi\pi^+\pi^-pK^-$ and (right) $J/\psi\pi^+\pi^-$ masses for the (top) $\Lambda_b^0 \to \psi(2S)pK^-$ and (bottom) $\Lambda_b^0 \to \chi_{c1}(3872)pK^-$ candidates.

Observation $\Lambda_b \to J/\varphi\Lambda\phi$ (CMS)

$\Lambda_b \to J/\psi\Lambda\phi$ observed for the first time, at CMS

- Better understanding of final-state strong interactions in the b-baryon decays and test the heavy-quark effective theory
- Rich resonant structure in the $J/\psi\phi$ system





- **Measured:**

$$\mathcal{B}(\Lambda_b^0 \to J/\tilde{\psi}\Lambda\phi)/\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda) = (8.26 \pm 0.90\,(\text{stat}) \pm 0.68\,(\text{syst}) \pm 0.11(\mathcal{B})) \times 10^{-2}$$

CMS-PAS-BPH-19-002; 60 fb^{-1} at 13 TeV

Observation $B_s^0 \to \overline{D}^{*0}\phi$ and search $B^0 \to \overline{D}^0\ \phi$

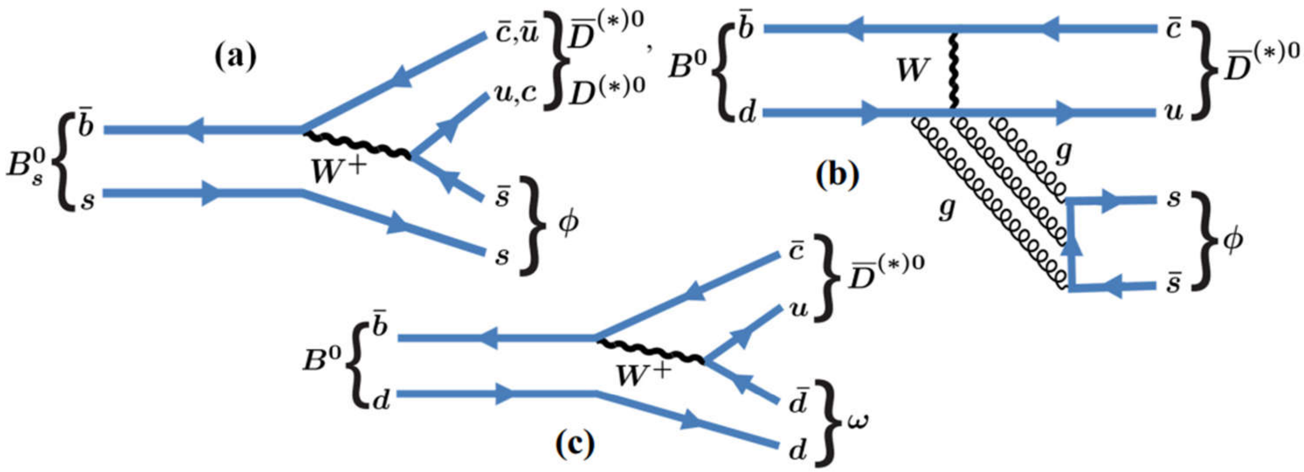
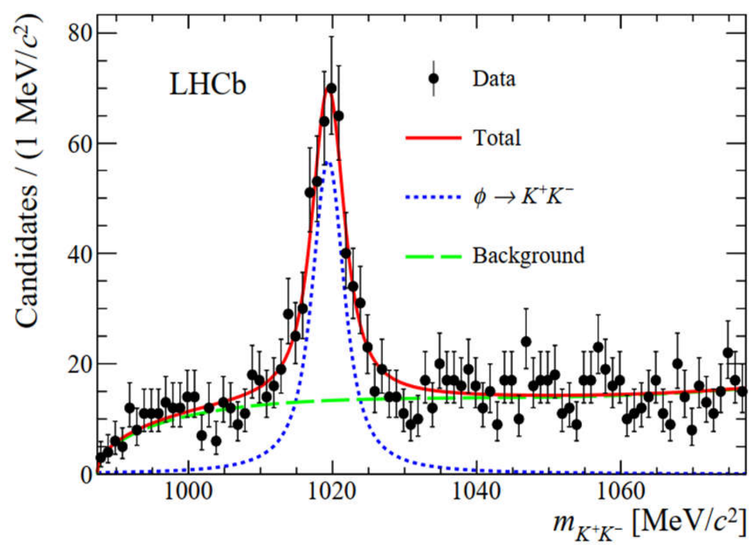


Figure 1: Diagrams that contribute to the (a) colour-suppressed $B_s^0 \to \overline{D}^{(*)0}/D^{(*)0}\phi$, (b) W-exchange OZI-suppressed $B^0 \to \overline{D}^0/D^0\phi$ and the (c) colour-suppressed $B^0 \to \overline{D}^0\omega$ decays.

- No single measurement dominates the world average of angle γ
- Decays $B_s^0 \to \overline{D}^{*0}\phi$ open possibilities to offer competitive experimental precision on the angle γ



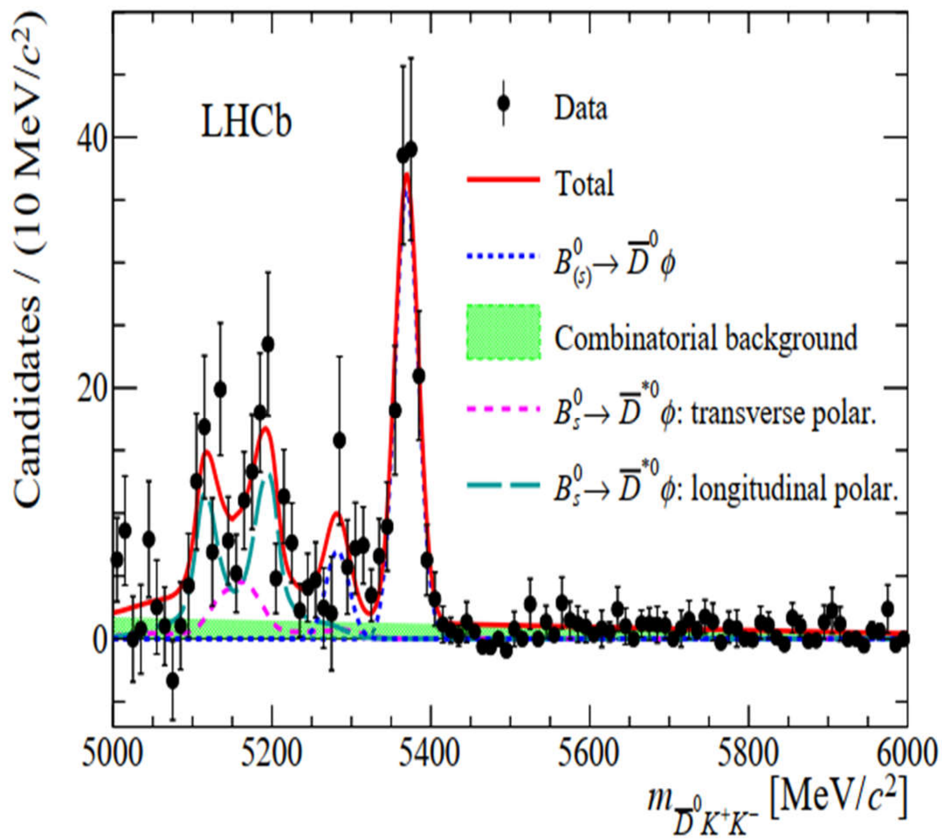
Observation $B_s^0 \to \overline{D}^{*0}\phi$ and search $B^0 \to \overline{D}^0\phi$

- **First obeservation of** $B_s^0 \to \overline{D}^{*0}\phi$:

$$\mathcal{B}(B_s^0 \to \overline{D}^{*0}\phi) = (3.7 \pm 0.5 \pm 0.3 \pm 0.2) \times 10^{-5}$$

  - $B^0 \to \overline{D}^0\pi^+\pi^-$ is taken as reference channel

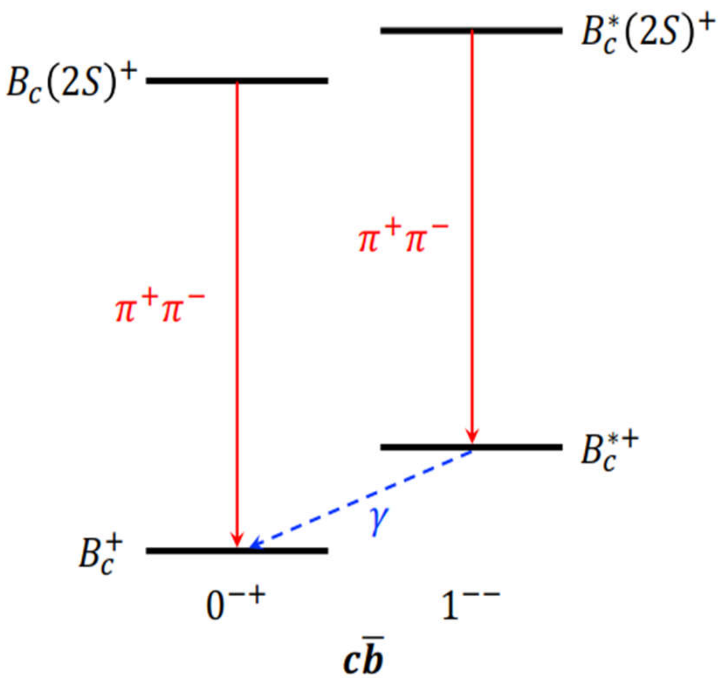
- An upper limit is set: $\text{Br}(B^0 \to \overline{D}^0\phi) < 2.0(2.3) \times 10^{-6})$ at 90% (95%)
  - A factor of six improvement over the previous BaBar result

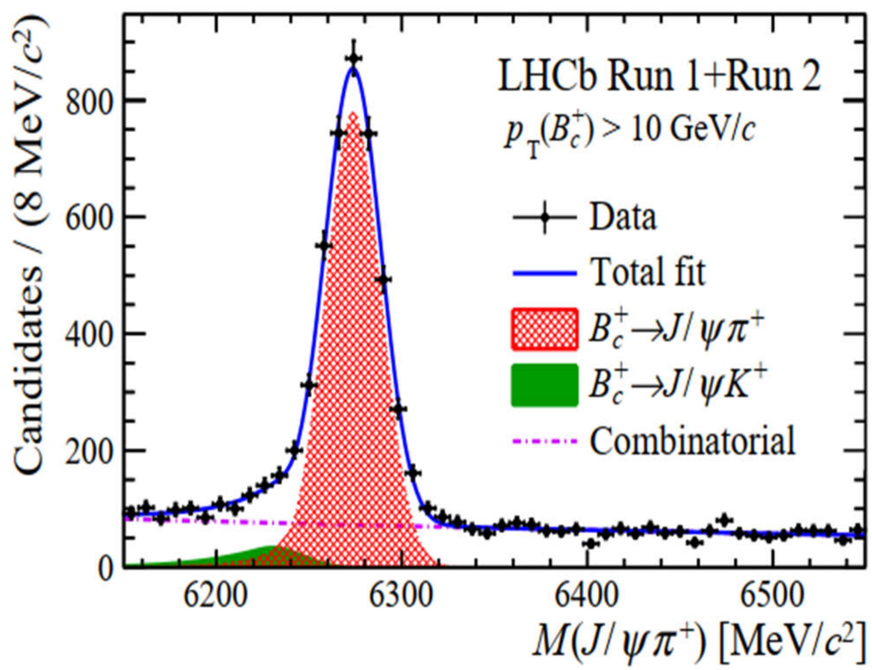


PRD (2018) 028; 3 fb^{-1} at 7,8 TeV

Observation of an excited B_c^+ state

- **An excited B_c^+ in the $B_c^+\pi^+\pi^-$ invariant-mass**:
  - Consistent with the $B_c^*(2^3S_1)$ state reconstructed without the low-energy γ
  - The chain: $B_c^*(2^3S_1)\rightarrow B_c^*(1^3S_1)\,\pi^+\pi^-$, $B_c^*(1^3S_1)\rightarrow B_c^+\gamma$

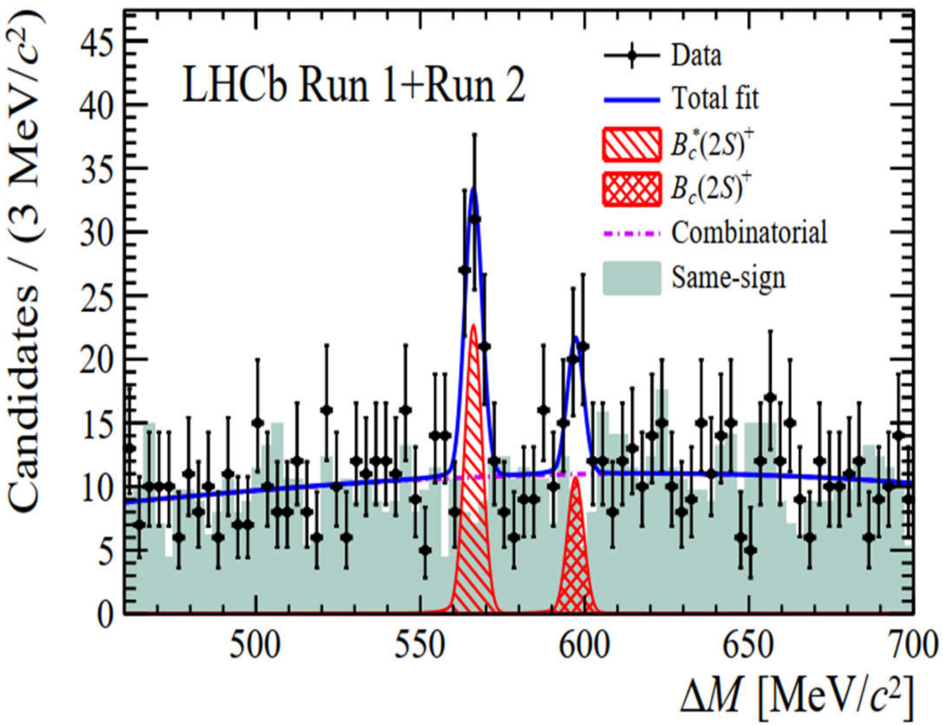




PRL. 122(2019) 232001; 8.5 fb^{-1} at 7,8,13 TeV

Invariant-mass of the selected $\mathbf{B_c^+}$ candidates
Green: K fake as π

Observation of an excited B_c^+ state



Distribution of Δ**M** = **M(** $\mathbf{B_c^+\pi^+\pi^-}$**)** - **M(**$\mathbf{B_c^+}$**)** with the fit results overlaid

	$B_c^*(2S)^+$	$B_c(2S)^+$
Signal yield	51 ± 10	24 ± 9
Peak ΔM value (MeV/c^2)	566.2 ± 0.6	597.2 ± 1.3
Resolution (MeV/c^2)	2.6 ± 0.5	2.5 ± 1.0
Local significance	$6.8\,\sigma$	$3.2\,\sigma$
Global significance	$6.3\,\sigma$	$2.2\,\sigma$

First peak:

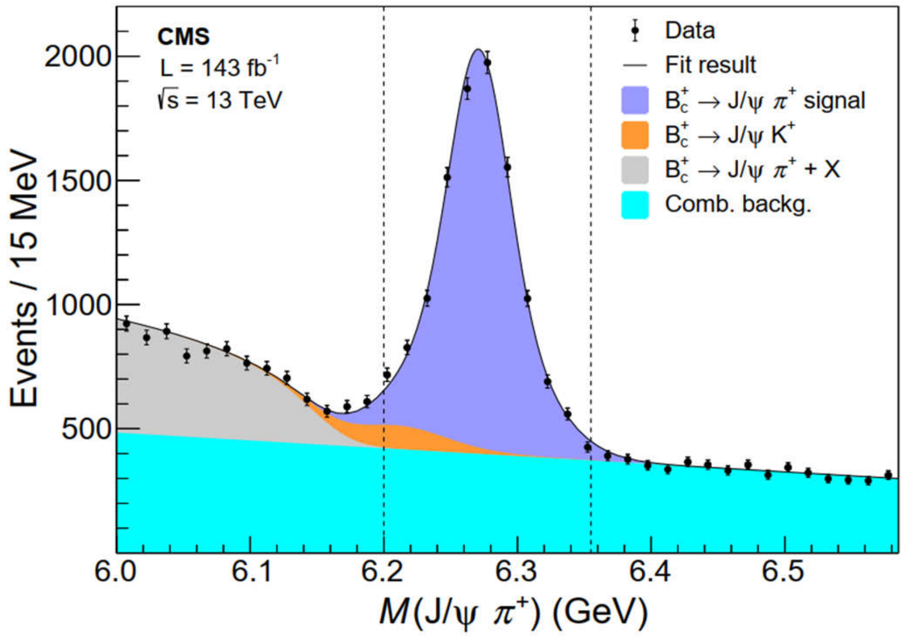
$6841.2 \pm 0.6\,(\text{stat}) \pm 0.1\,(\text{syst}) \pm 0.8\,(B_c^+)\ \text{MeV}/c^2,$

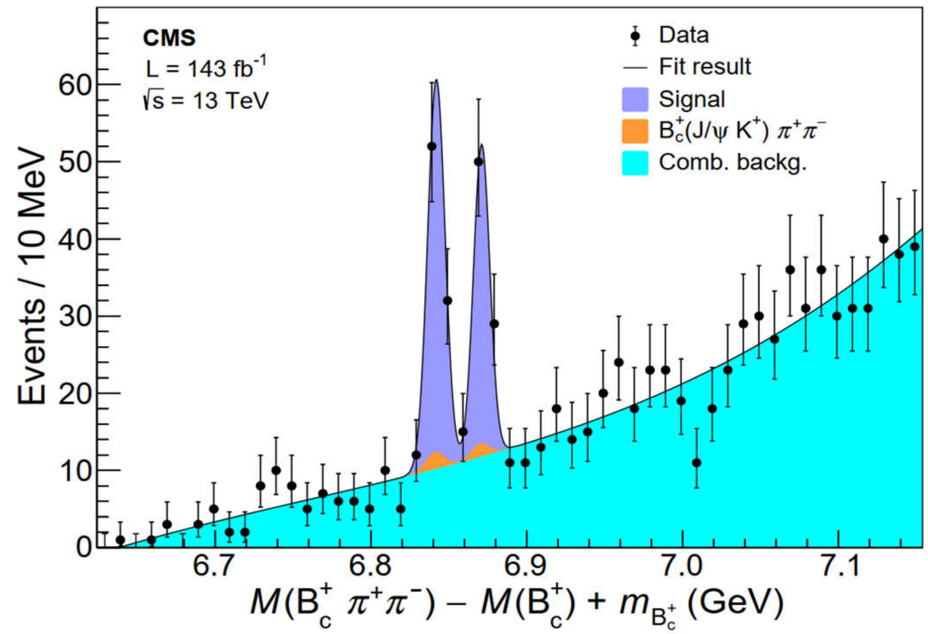
Second peak:

$6872.1 \pm 1.3\,(\text{stat}) \pm 0.1\,(\text{syst}) \pm 0.8\,(B_c^+)\ \text{MeV}/c^2.$

PRL. 122(2019) 232001; 8.5 fb^{-1} at 7,8,13 TeV

Observation of two excited B_c^+ state (CMS)





- **The higher peak mass :**

$6871.0 \pm 1.2\,(\mathrm{stat}) \pm 0.8\,(\mathrm{syst}) \pm 0.8\,(\mathrm{B_c^+})\ \mathrm{MeV}$

- **Mass difference: 29MeV**

$M(B_c^+\pi^+\pi^-)$, $M(B_c^+)$:
reconstructed
$m_{B_c^+}$: the world-average B_c^+ mass
For better resolution

PRL. 122(2019) 132001; 13 fb^{-1} at 13 TeV

$B^0 \rightarrow \eta_c(1S)K^+\pi^-$

- Theory models predict 0^+ candidates below the open-charm threshold that could decay into $\eta_c\pi^-$(e.g. the $Z_c(3900)^-$).
- Therefore discovery of a charged charmonium-like meson in $(\eta_c\pi^-) \Longrightarrow$ important input towards understanding the nature of exotic hadrons.
- **$B^0 \rightarrow \eta_c(1S)K^+\pi^-$ decay is studied for the first time**

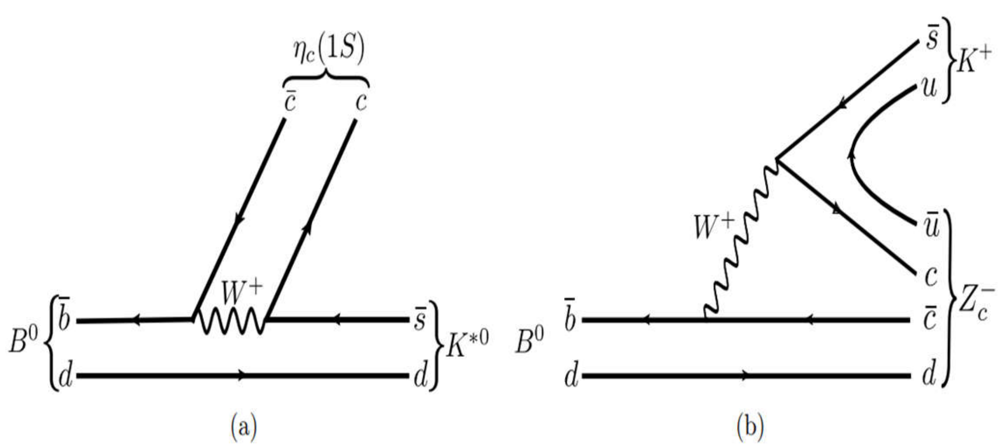
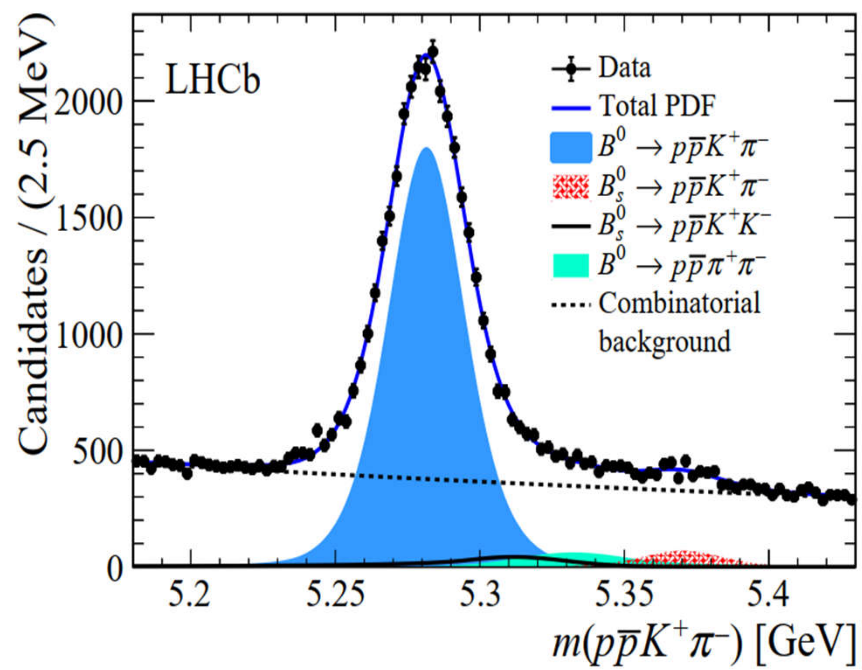


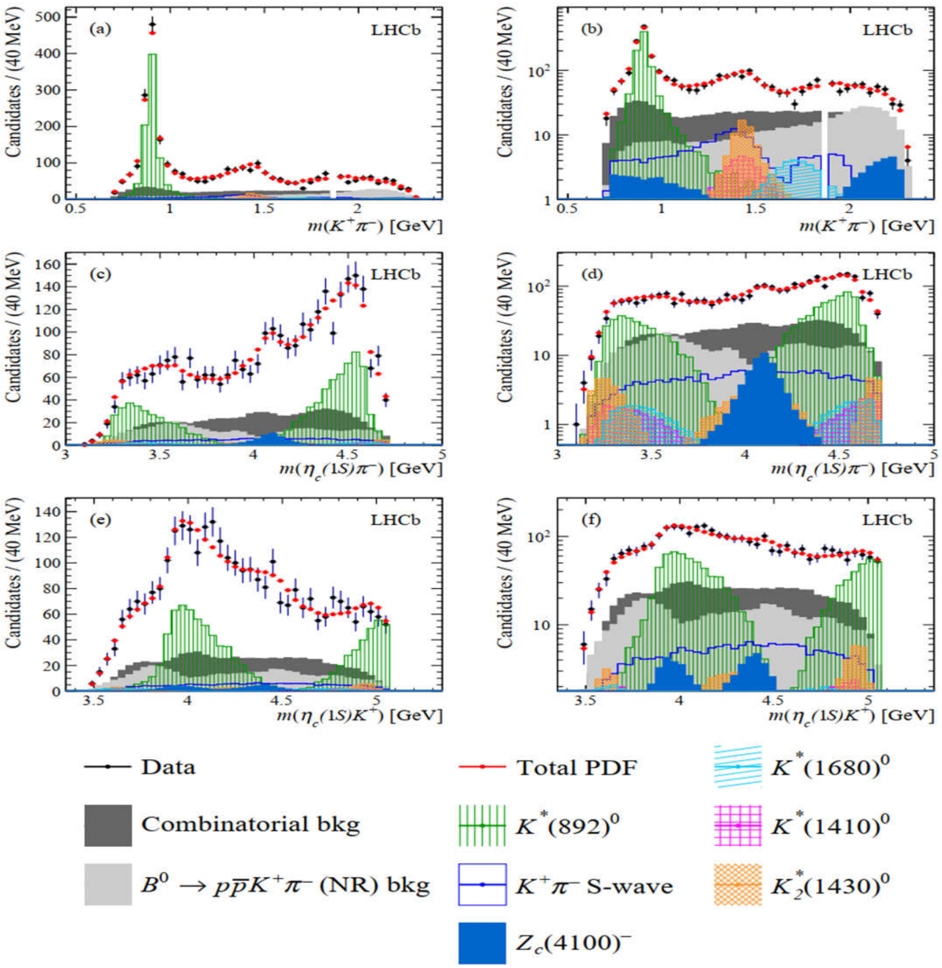
Figure 1: Feynman diagrams for (a) $B^0 \rightarrow \eta_c K^{*0}$ and (b) $B^0 \rightarrow Z_c^- K^+$ decay sequences.



EPJC78 (2018) 1019; 4.7 fb^{-1} at 7,8,13 TeV

$B^0 \to \eta_c(1S)K^+\pi^-$

- Good description is obtained when including an exotic $\boldsymbol{Z_c(\eta_c(1S)\,\pi^-)}$ resonant state($> 3\sigma$)



- First measurement of $B^0 \to \eta_c(1S)K^+\pi^-$ BR:

$$\mathcal{B}(B^0 \to \eta_c K^+\pi^-) = (5.73 \pm 0.24 \pm 0.13 \pm 0.66) \times 10^{-4},$$

- For the resonance:

$$m_{Z_c^-} = 4096 \pm 20\ ^{+18}_{-22}\ \text{MeV and}\ \Gamma_{Z_c^-} = 152 \pm 58\ ^{+60}_{-35}\ \text{MeV}$$

- **The fitted fractions:**

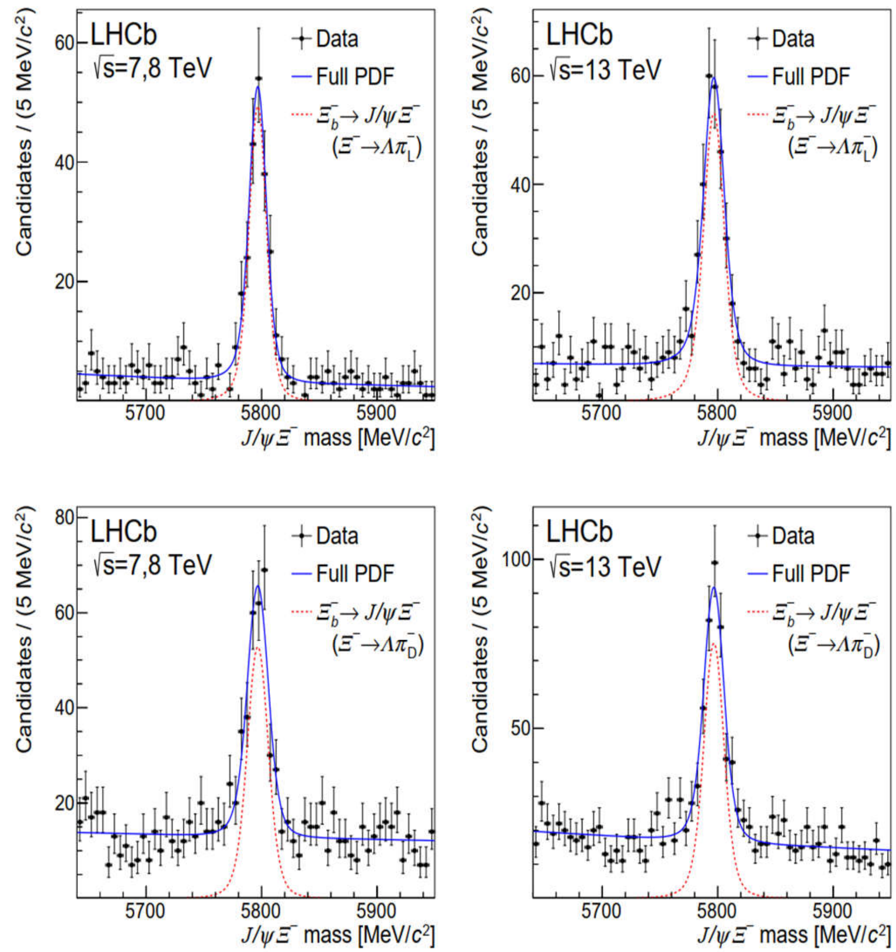
Amplitude	Fit fraction (%)
$B^0 \to \eta_c K^*(892)^0$	$51.4 \pm 1.9\ ^{+1.7}_{-4.8}$
$B^0 \to \eta_c K^*(1410)^0$	$2.1 \pm 1.1\ ^{+1.1}_{-1.1}$
$B^0 \to \eta_c K^+\pi^-$ (NR)	$10.3 \pm 1.4\ ^{+1.0}_{-1.2}$
$B^0 \to \eta_c K_0^*(1430)^0$	$25.3 \pm 3.5\ ^{+3.5}_{-2.8}$
$B^0 \to \eta_c K_2^*(1430)^0$	$4.1 \pm 1.5\ ^{+1.0}_{-1.6}$
$B^0 \to \eta_c K^*(1680)^0$	$2.2 \pm 2.0\ ^{+1.5}_{-1.7}$
$B^0 \to \eta_c K_0^*(1950)^0$	$3.8 \pm 1.8\ ^{+1.4}_{-2.5}$
$B^0 \to Z_c(4100)^- K^+$	$3.3 \pm 1.1\ ^{+1.2}_{-1.1}$

Measurements of Ξ_b^- baryons

- **The first measurement** of the production rate of Ξ_b^- baryons in pp collisions
  - Relative to that of Λ_b^0 baryons

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b^0}} \frac{\mathcal{B}(\Xi_b^- \to J/\psi \Xi^-)}{\mathcal{B}(\Lambda_b^0 \to J/\psi \Lambda)} = (10.8 \pm 0.9 \pm 0.8) \times 10^{-2} \ \ [\sqrt{s} = 7, 8\,\text{TeV}],$$

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b^0}} \frac{\mathcal{B}(\Xi_b^- \to J/\psi \Xi^-)}{\mathcal{B}(\Lambda_b^0 \to J/\psi \Lambda)} = (13.1 \pm 1.1 \pm 1.0) \times 10^{-2} \ \ [\sqrt{s} = 13\,\text{TeV}],$$



- The mass of the Ξ_b^- is also measured relative to that of the Λ_b^0 baryon:

$$m(\Xi_b^-) = 5796.70 \pm 0.39 \pm 0.15 \pm 0.17\,\text{MeV}/c^2,$$

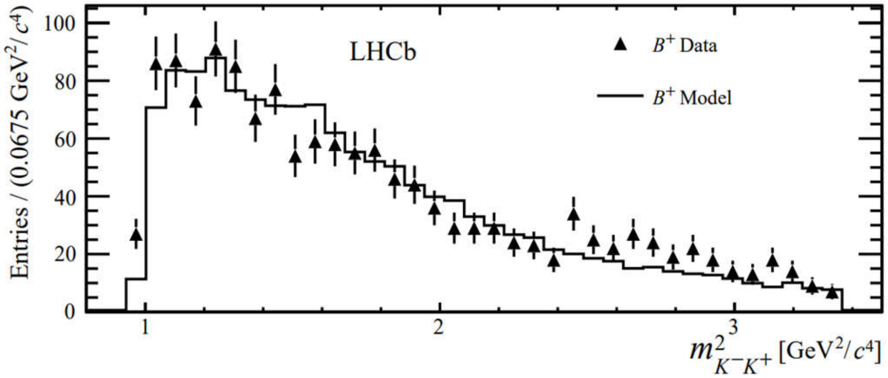
  - The last uncertainty is due to the precision on the known Λ_b^0 mass
  - Most precise determination of Ξ_b^- mass.

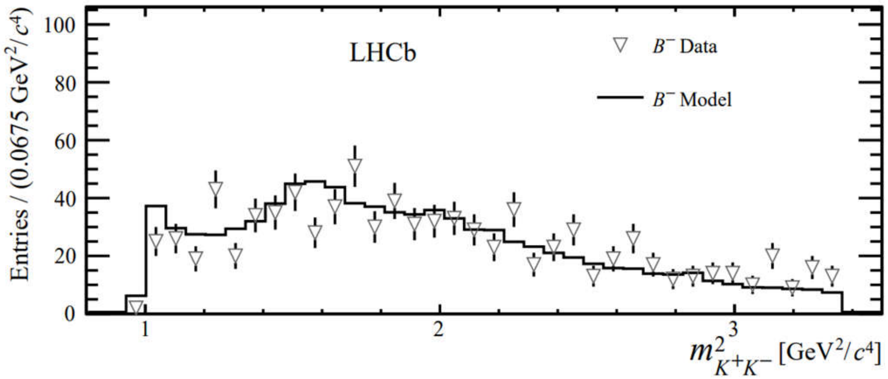
PRD 99052006 (2019); 1,2,1.6 fb^{-1} at 7,8,13 TeV

Amplitude analysis of $B^{\pm} \rightarrow \pi^{\pm} K^{+} K^{-}$

- **The first amplitude analysis of the $B^{\pm} \rightarrow \pi^{\pm} K^{+} K^{-}$**

- The data is best described by a coherent sum of **five resonant structures + a nonresonant component + a $\pi\pi \leftrightarrow KK$ S-wave rescattering**





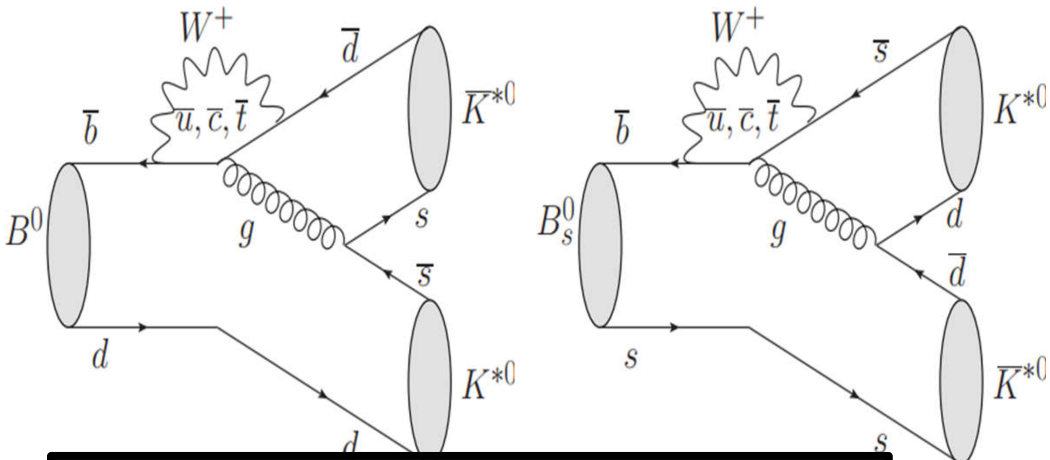
Contribution	Fit Fraction(%)	A_{CP}(%)	Magnitude (B^+/B^-)	Phase[°] (B^+/B^-)
$K^*(892)^0$	$7.5 \pm 0.6 \pm 0.5$	$+12.3 \pm 8.7 \pm 4.5$	$0.94 \pm 0.04 \pm 0.02$	0 (fixed)
			$1.06 \pm 0.04 \pm 0.02$	0 (fixed)
$K_0^*(1430)^0$	$4.5 \pm 0.7 \pm 1.2$	$+10.4 \pm 14.9 \pm 8.8$	$0.74 \pm 0.09 \pm 0.09$	$-176 \pm 10 \pm 16$
			$0.82 \pm 0.09 \pm 0.10$	$136 \pm 11 \pm 21$
Single pole	$32.3 \pm 1.5 \pm 4.1$	$-10.7 \pm 5.3 \pm 3.5$	$2.19 \pm 0.13 \pm 0.17$	$-138 \pm 7 \pm 5$
			$1.97 \pm 0.12 \pm 0.20$	$166 \pm 6 \pm 5$
$\rho(1450)^0$	$30.7 \pm 1.2 \pm 0.9$	$-10.9 \pm 4.4 \pm 2.4$	$2.14 \pm 0.11 \pm 0.07$	$-175 \pm 10 \pm 15$
			$1.92 \pm 0.10 \pm 0.07$	$140 \pm 13 \pm 20$
$f_2(1270)$	$7.5 \pm 0.8 \pm 0.7$	$+26.7 \pm 10.2 \pm 4.8$	$0.86 \pm 0.09 \pm 0.07$	$-106 \pm 11 \pm 10$
			$1.13 \pm 0.08 \pm 0.05$	$-128 \pm 11 \pm 14$
Rescattering	$16.4 \pm 0.8 \pm 1.0$	$-66.4 \pm 3.8 \pm 1.9$	$1.91 \pm 0.09 \pm 0.06$	$-56 \pm 12 \pm 18$
			$0.86 \pm 0.07 \pm 0.04$	$-81 \pm 14 \pm 15$
$\phi(1020)$	$0.3 \pm 0.1 \pm 0.1$	$+9.8 \pm 43.6 \pm 26.6$	$0.20 \pm 0.07 \pm 0.02$	$-52 \pm 23 \pm 32$
			$0.22 \pm 0.06 \pm 0.04$	$107 \pm 33 \pm 41$

The fitted fractions

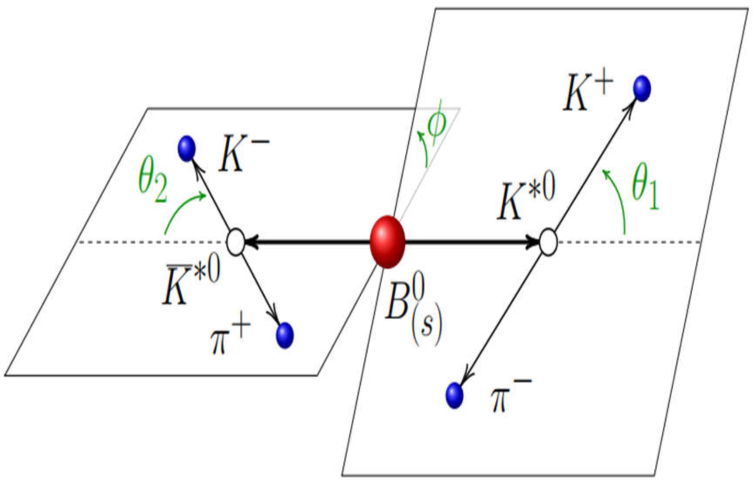
ARXIV:1905.09244(to PRL); $3fb^{-1}$

Amplitude analysis of $B_s^0 \to K^{*0}\bar{K}^{*0}$

- $B_s^0 \to K^{*0}\bar{K}^{*0}$ could be a golden channel for a precision test of the CKM β_s.
- High-precision analyses of it, require to account for subleading amplitudes



Leading order Feymann diagrams; both are dominated by gluonic-penguin



The amplitude analysis outputs:

- Measured observables are compatible with the absence of *CP* violation
- A low polarisation fraction is found
- A large S-wave contribution (60%), is measured in the 150 MeV window around the K^{*0}mass.

JHEP 07 (2019) 032; $3\ fb^{-1}$

Measurement of $B^0 \to K^{*0}\overline{K}^{*0}$

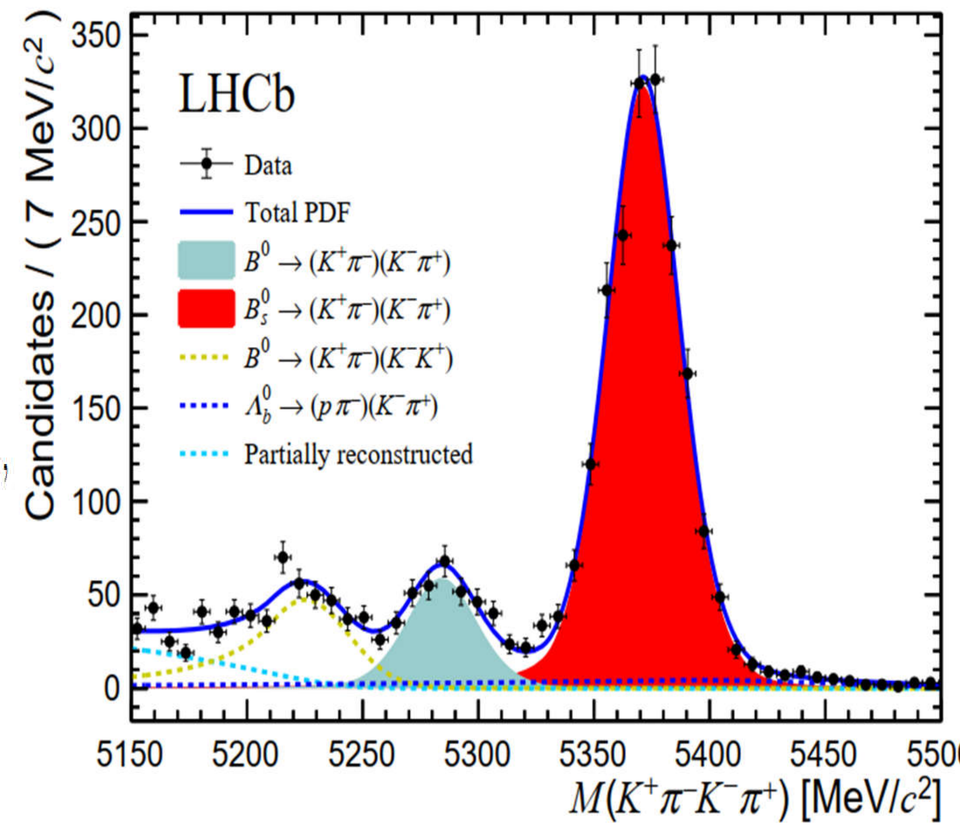
- **The first study of $B^0 \to K^{*0}\overline{K}^{*0}$ decays is performed**
- The ratio of BR:

$$\frac{\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0})}{\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0})} = 0.0758 \pm 0.0057\,(\text{stat}) \pm 0.0025\,(\text{syst}) \pm 0.0016\left(\frac{f_s}{f_d}\right),$$

- With this the $B^0 \to K^{*0}\overline{K}^{*0}$ BR is found to be:

$$\mathcal{B}(B^0 \to K^{*0}\overline{K}^{*0}) = (8.0 \pm 0.9\,(\text{stat}) \pm 0.4\,(\text{syst})) \times 10^{-7}.$$

JHEP 07 (2019) 032; 3 fb^{-1}



Aggregated four-body invariant-mass fit result of the 2011 and 2012 data.

$B_s^0 \to K_S^0 K^{\pm}\pi^{\mp}$ amplitude analysis

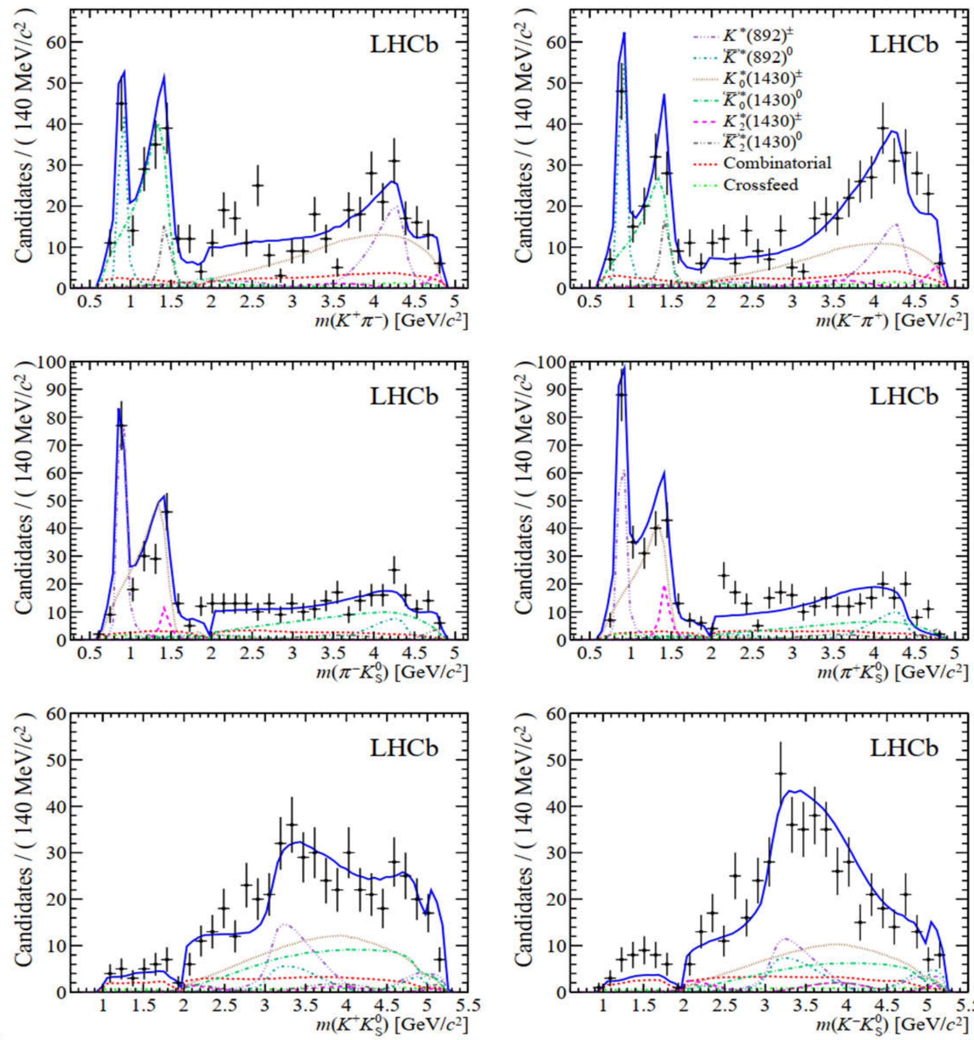
- Undiscovered particles could contribute in the b→s loops and cause the observables to deviate from the values expected in the SM

$K_S^0K^+\pi^-$		$K_S^0K^-\pi^+$	
Resonance	Fit fraction (%)	Resonance	Fit fraction (%)
$K^*(892)^-$	15.6 ± 1.5	$K^*(892)^+$	13.4 ± 2.0
$K_0^*(1430)^-$	30.2 ± 2.6	$K_0^*(1430)^+$	28.5 ± 3.6
$K_2^*(1430)^-$	2.9 ± 1.3	$K_2^*(1430)^+$	5.8 ± 1.9
$K^*(892)^0$	13.2 ± 2.4	$\overline{K}^*(892)^0$	19.2 ± 2.3
$K_0^*(1430)^0$	33.9 ± 2.9	$\overline{K}_0^*(1430)^0$	27.0 ± 4.1
$K_2^*(1430)^0$	5.9 ± 4.0	$\overline{K}_2^*(1430)^0$	7.7 ± 2.8

The fit fractions associated with each resonant component

- **The decays are observed for the first time:**

$$B_s^0 \to K_0^*(1430)^{\pm}K^{\mp} \text{ and } B_s^0 \to \overset{(-)}{K}{}_0^*(1430)^0\, \overset{(-)}{K}{}^0$$

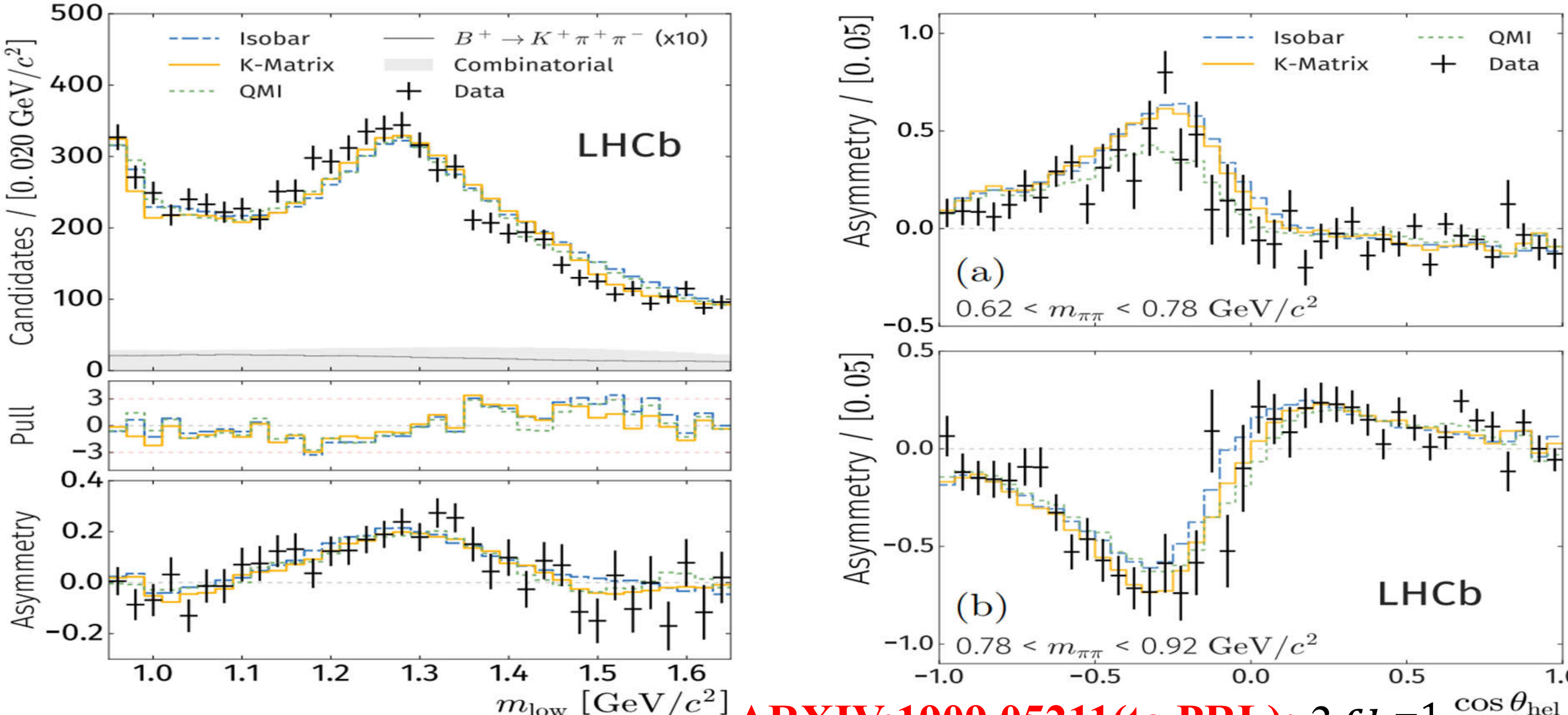


JHEP 06(2019) 114; $3\ fb^{-1}$

Several sources of CPV in $B^+ \to \pi^+\pi^+\pi^-$

Observations of CPV from an amplitude analysis:

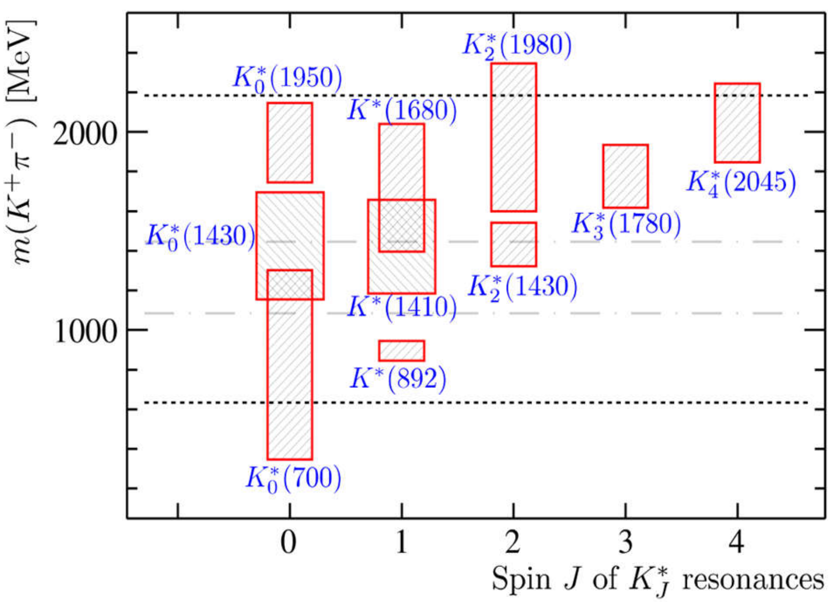
- A large CP asymmetry is observed in the decay amplitude involving the tensor $f_2(1270)$ resonance
- Significant CPV is found in the $\pi^+\pi^-$ S-wave at low invariant mass.
- CPV related to interference between the $\pi^+\pi^-$ S-wave and the P-wave $B^+ \to \rho(770)^0\pi^+$ amplitude is also established

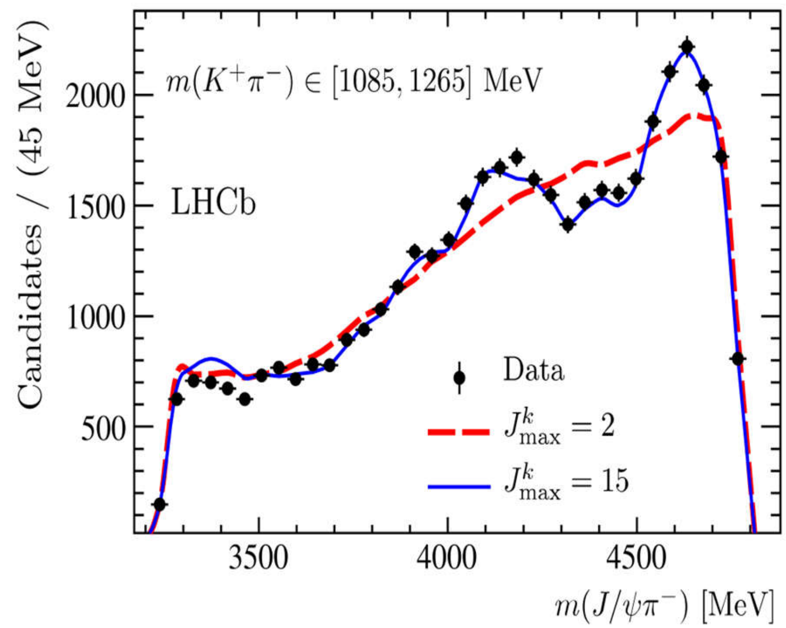


ARXIV:1909.05211(to PRL); $3fb^{-1}$

Model-ind. observation of $B^0 \rightarrow J/\psi K^+\pi^-$

- $K^+\pi^-$ spectrum into 5 bins. In each bin, the hypothesis that the 3-D angular distribution can be described by structures induced only by K^* resonances is examined, making minimal assumptions about the $K^+\pi^-$ system.
- Data reject the K^*-only hypothesis, implying the observation of exotic contributions in a model independent fashion.
- $m(J/\psi\pi^-)$ vs. $m(K^+\pi^-)$ suggests structures near $m(J/\psi\pi^-)$ = 4200 MeV,4600 MeV





PRL. 122(2019) 152002; $3\ fb^{-1}$

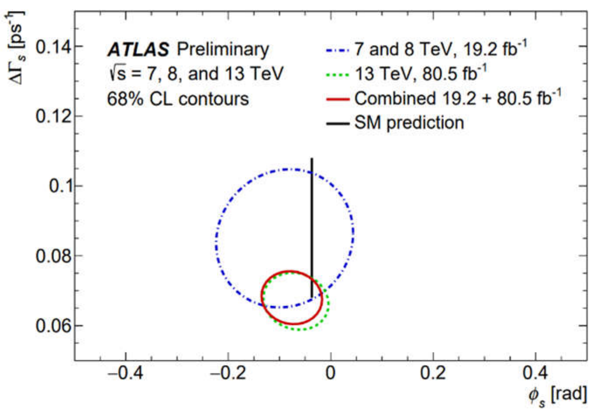
$J_{\max\ k}$ = 2 model clearly misses the peaking structures in the data around 4200, 4600 MeV

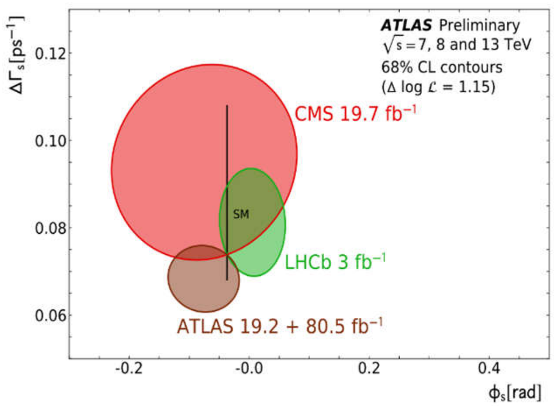
CPV phase ϕ_s in $B_s^0 \to J/\psi\phi$ (ATLAS)

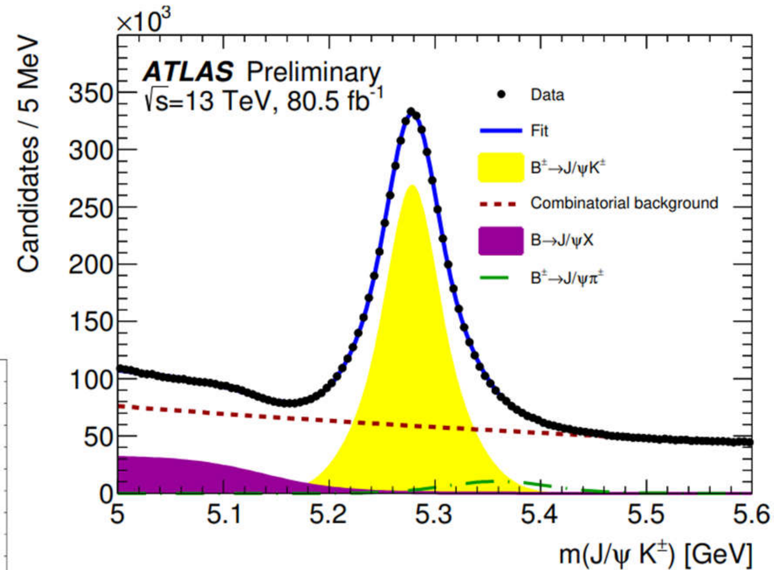
- The CP violating phase ϕ_s is defined as the weak phase difference between the B_s^0-$\bar{B}_s^0$ mixing amplitude and the b → ccs decay amplitude
- NP involved in the mixing may increase by enhancing the mixing phase ϕ_s with respect to the SM

- Combined 7,8 TeV data, **gives the most stringent measurements**

$$\phi_s = -0.076 \pm 0.034\ (\text{stat.}) \pm 0.019\ (\text{syst.})\ \text{rad}$$
$$\Delta\Gamma_s = 0.068 \pm 0.004\ (\text{stat.}) \pm 0.003\ (\text{syst.})\ \text{ps}^{-1}$$
$$\Gamma_s = 0.669 \pm 0.001\ (\text{stat.}) \pm 0.001\ (\text{syst.})\ \text{ps}^{-1}$$







Flavour tagging of B meson: Calibrations from $B^\pm \to J/\psi K^\pm$, applied to $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

ATLAS-CONF-2019-009; 80.5 fb^{-1} at 13TeV

Summary

- Hadronic B decays play a key role in checking the SM. Numerous new results are out sincd PIC 2018, only part of them are shown today.
- We have much more Run2 data to analyze, more results are coming
- LHCb currently ongoing a major upgrade for Run-3 and Run-4
  - Preparations underway for a new era of discoveries taking maximum advantage of the High-Luminosity LHC

Backup Slides

Overview of the timeline

- LHC Run-I (2010-2013) & LHC Run-II (2015-2018)
- LHC Run-III, Run-IV (2021-2023, 2026-2029)
  - based on LHCb Upgrade [I(a), I(b)]
- LHC Run-V (2031-)
  - based on LHCb Upgrade II