Hadron Spectroscopy and Exotic States at LHCb

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LHCb

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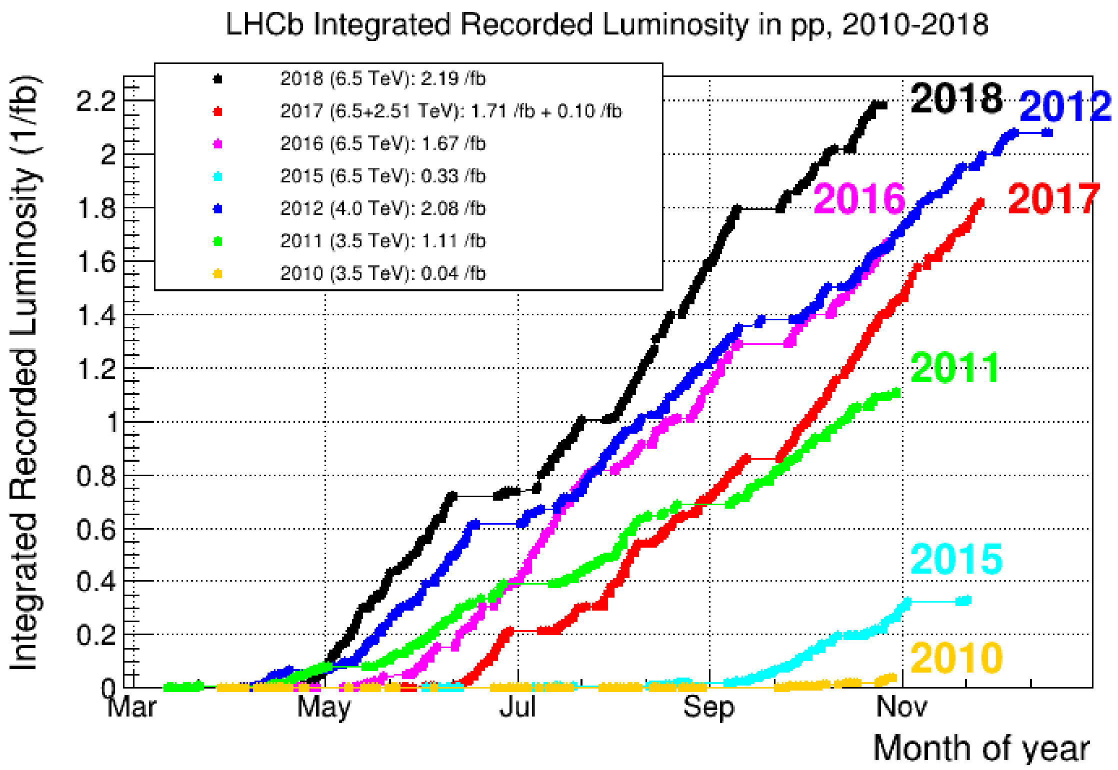
Outline

- Introduction
- Recent LHCb results on hadron spectroscopy and exotic states
- Summary

Introduction

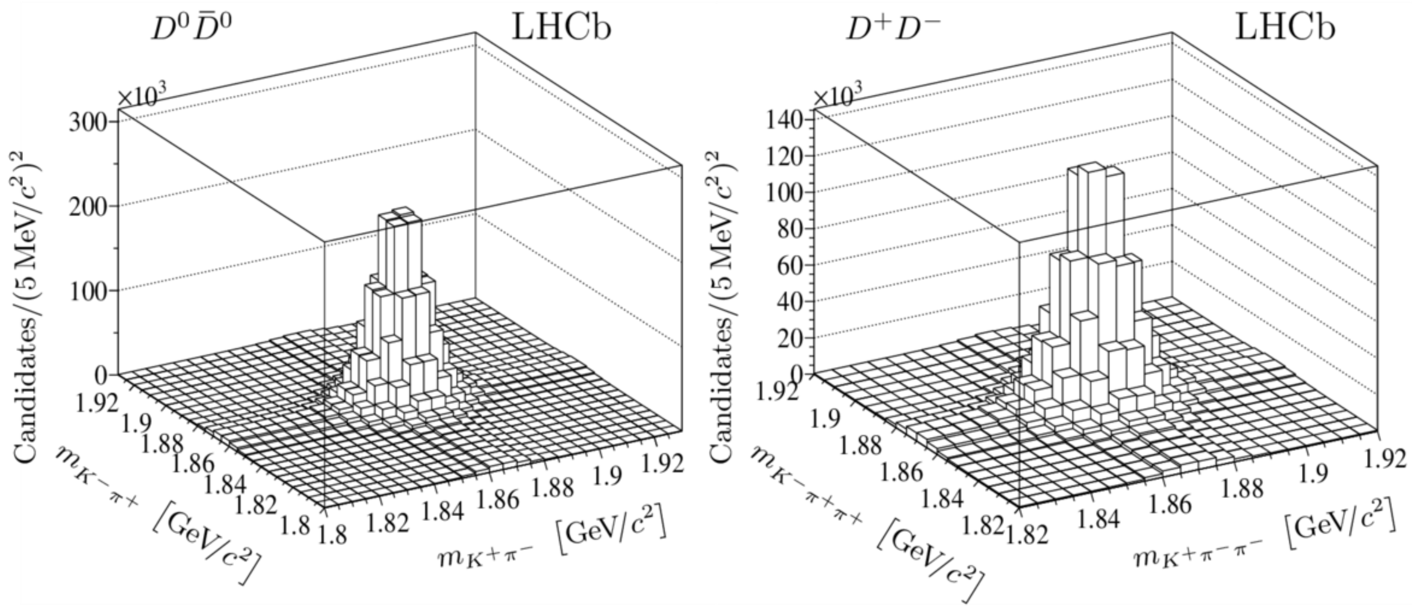
- LHCb is an factory for "standard" and "exotic" spectroscopy
- High cross-section allows high yield of heavy hadrons
  - 10^{11} $b\bar{b}$ / year
  - $c\bar{c}$ 20 times more
- Heavy flavor production and spectroscopy is a broad topic
- This talk only covers a selection of recent results



New charmonium state in $D\bar{D}$

JHEP 07 (2019) 035

- First LHCb analysis using Run1+ Run2 data: 9 fb^{-1}
- Combined analysis of prompt D^+D^- and $D^0\overline{D^0}$
- Scan wide region of Q value above threshold



Strategy:

Reduce combinatorics background exploiting D lifetime

Tight $\pm$20 MeV mass cuts

D mass constrained to known values

Fits performed in different mass regions for better paramerisation of background components

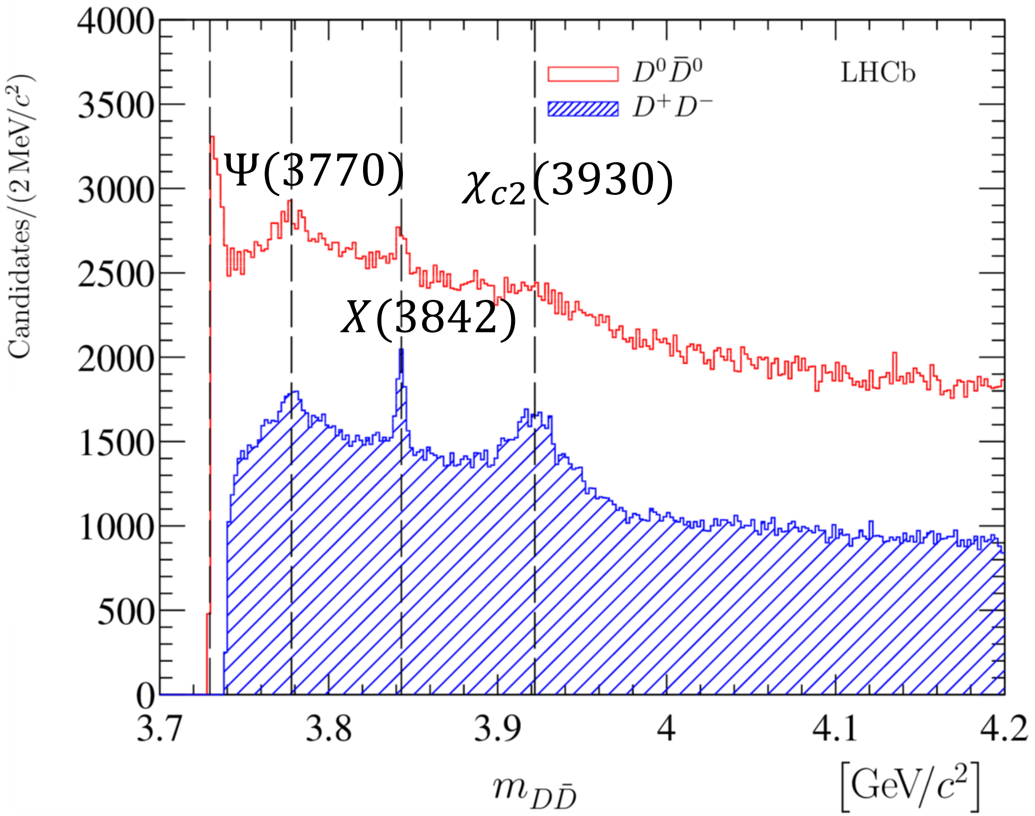
New charmonium state in $D\bar{D}$

JHEP 07 (2019) 035

- Narrow charmonium state $X(3842)$ found in both channels
- Interpretation as the unobserved $\Psi_3(1^3D_3)$ with $J^{PC} = 3^{--}$
- First observations of prompt hadron production of $\Psi(3770)$ and $\chi_{c2}(3930)$

Properties:

$$m_{X(3842)} = 3842.71 \pm 0.16 \pm 0.12\,\mathrm{MeV}/c^2\,,$$
$$\Gamma_{X(3842)} = 2.79 \pm 0.51 \pm 0.35\,\mathrm{MeV}\,,$$



New charmonium state in $D\bar{D}$

JHEP 07 (2019) 035

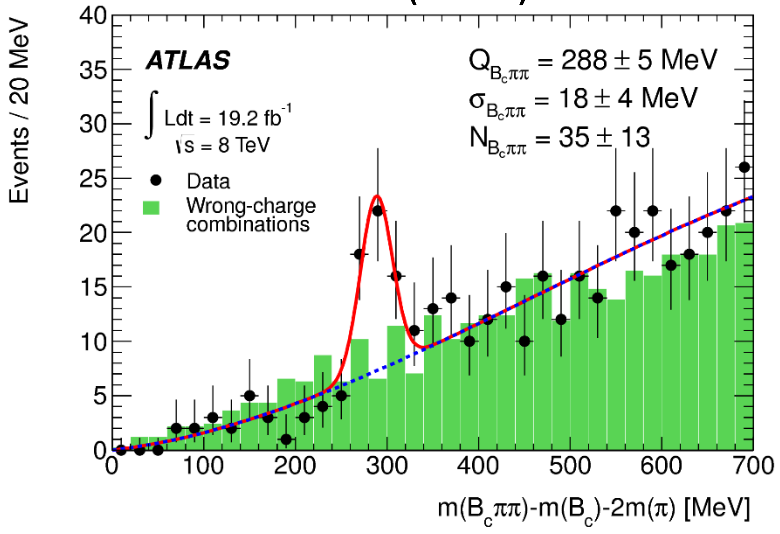
- The mass of $\chi_{c2}(3930)$ is 2σ lower than current world average
- The width of $\chi_{c2}(3930)$ is 2σ higher than current WG
- Mass value is in the middle between mass of this state and for the X(3915)
- Are they two distinct $c\bar{c}$ states or only one? [PRL 115(2015) 0220001]

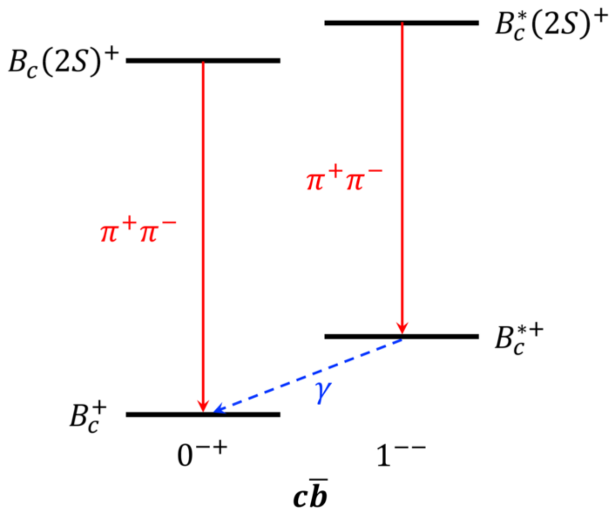
		$m_{\chi_{c2}(3930)}$ [MeV/c^2]	$\Gamma_{\chi_{c2}(3930)}$ [MeV
Belle	[17]	$3929 \pm 5 \pm 2$	$29 \pm 10 \pm 2$
BaBar	[18]	$3926.7 \pm 2.7 \pm 1.1$	$21.3 \pm 6.8 \pm 3.6$
This analysis		$3921.9 \pm 0.6 \pm 0.2$	$36.6 \pm 1.9 \pm 0.9$

Observation of excited B_c^+ state

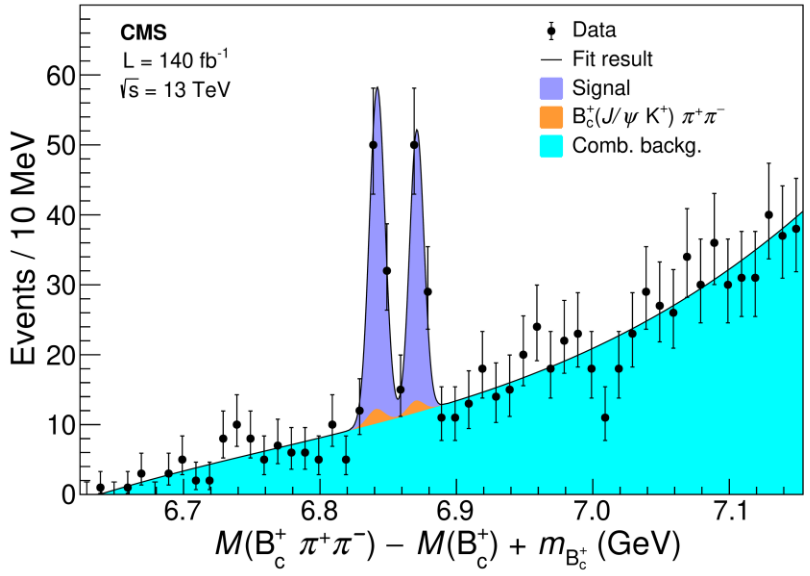
- B_c spectroscopy
  - First observation of B_c (CDF 1998)
  - First observation of excited $B_c(2S)$ (ATLAS 2014)
  - Resolving two radial-excited states, $(\uparrow\downarrow)^*$ and $(\uparrow\uparrow)^*$ (CMS 2019)
  - Confirming of two states (LHCb 2019)

PRL 113 (2014) 212004





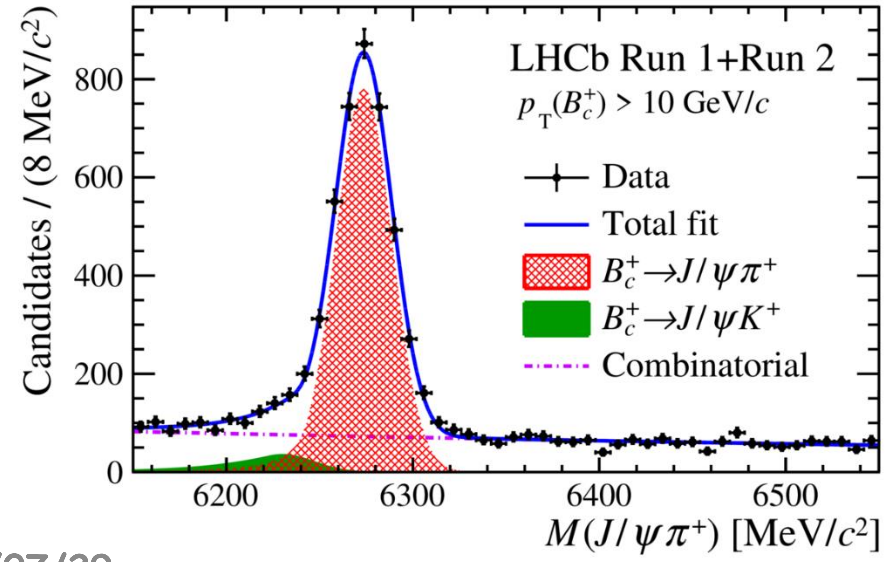
PRL 122 (2019), 132001

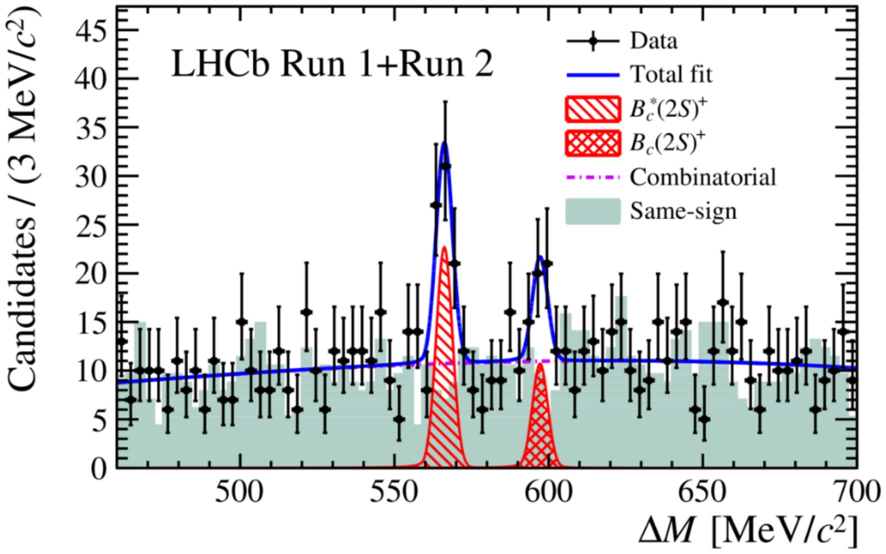


Observation of excited B_c^+ state

PRL 113 (2014) 212004

- Look for $\pi\pi$ transitions
- Main decay mode: $B_c(2S) \to B_c\pi^+\pi^-$, $B_c^*(2S) \to B_c^*(\to B_c\gamma)\pi^+\pi^-$
- Low energy photon (not reconstructed)
- $B_c^*(2S)^+$: > 5σ
- $B_c(2S)^+$: 2.2(3.2) σ global(local) significance



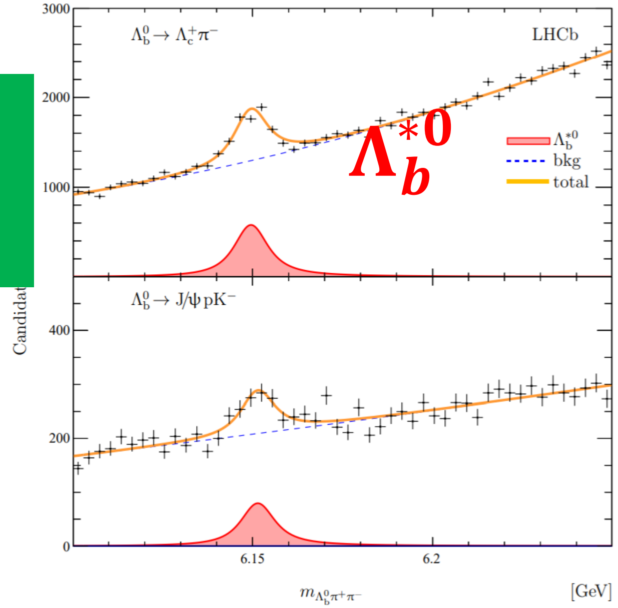


Observation of new resonances in $\Lambda_b^0\pi^+\pi^-$

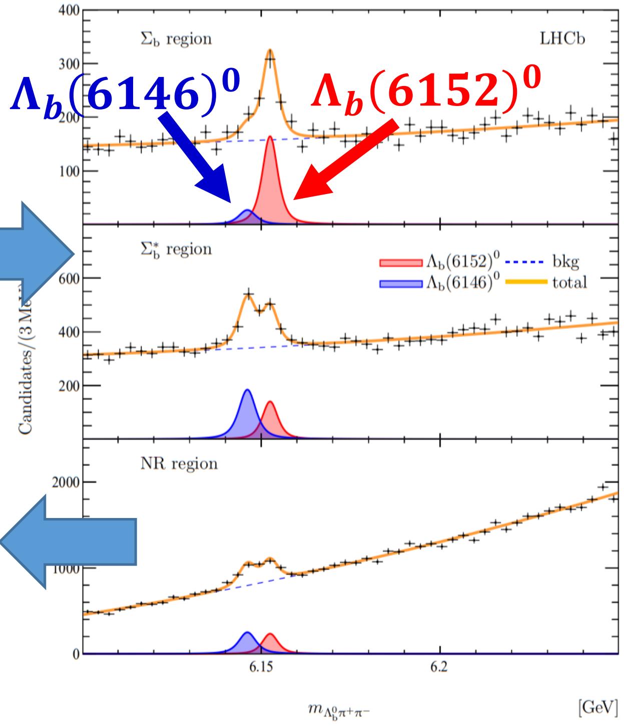
LHCb-PAPER-2019-025

- Previous study of Λ_b spectrum at LHCb: 1 fb^{-1} of data
  - Discovery of $\Lambda_b(5912)^0$ and $\Lambda_b(5920)^0$ — PRL 109 172003, 2012
  - Confirmed by CDF — PRD 88 071101, 2013
- New results with Run-1 and Run-2 data sample: 9 fb^{-1} of data
  - Two decay modes: $\Lambda_b^0 \to \Lambda_c^+\pi^-$ and $\Lambda_b^0 \to J/\Psi pK$

Clear excess around 6.15 GeV in both distribution



In regions of $M(\Lambda_b^0\pi^+)$: Resonant (Σ_b^+ and Σ_b^{*+}) and non-resonant



Two peaks hypothesis favored, With 7σ significance

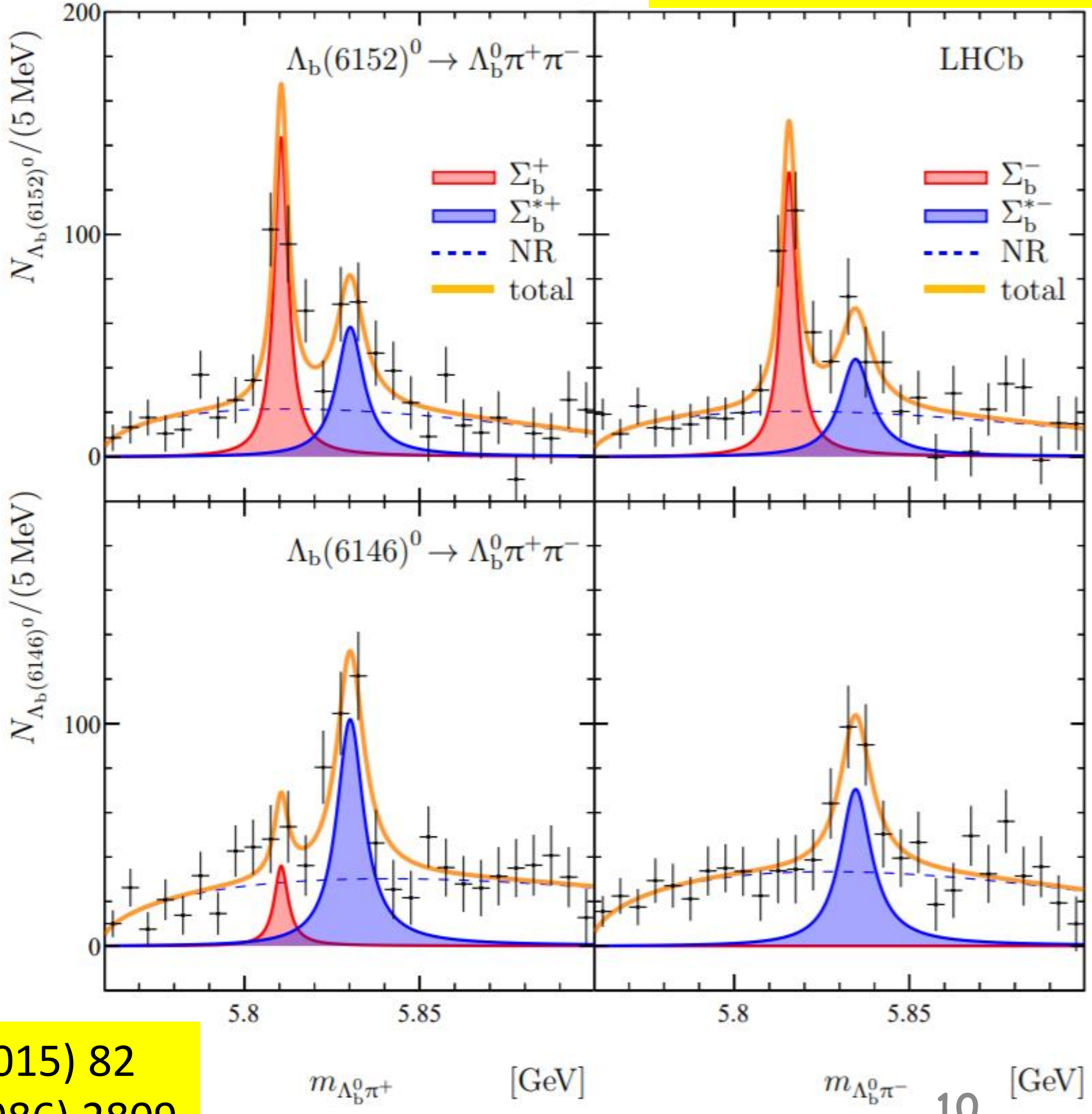
Observation of new resonances in $\Lambda_b^0\pi^+\pi^-$

LHCb-PAPER-2019-025

- $M(\Lambda_b^0\pi^+)$ after background subtraction
- Different decay rates via Σ_b^+ and Σ_b^{*+} for observed states
- Results:

$$m_{\Lambda_b(6146)^0} = 6146.17 \pm 0.33 \pm 0.22 \pm 0.16\,\text{MeV}\,,$$
$$m_{\Lambda_b(6152)^0} = 6152.51 \pm 0.26 \pm 0.22 \pm 0.16\,\text{MeV}\,,$$

- Possible interpretation of the new states as a doublet of $\Lambda_b(1D)^0$ states with $J^P = \frac{3}{2}^+$ and $\frac{5}{2}^+$

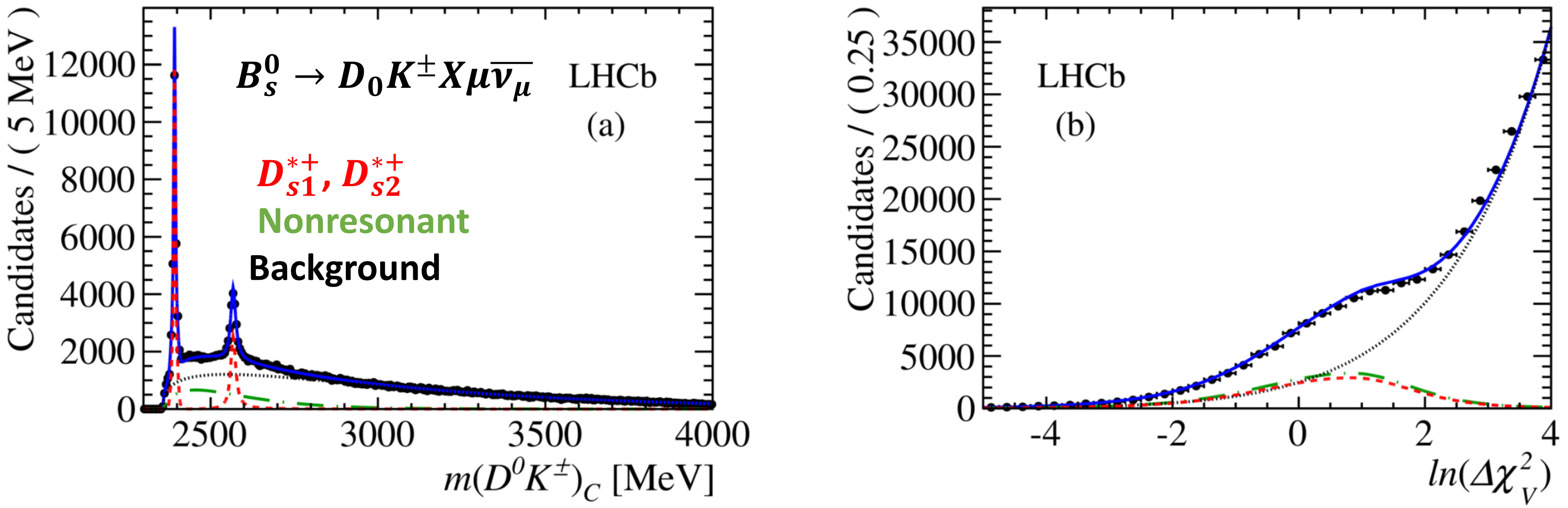


EPJA 51 (2015) 82
PRD 34 (1986) 2809

Measurement of b–hadron fractions at 13 TeV

ARXIV:1902.06794

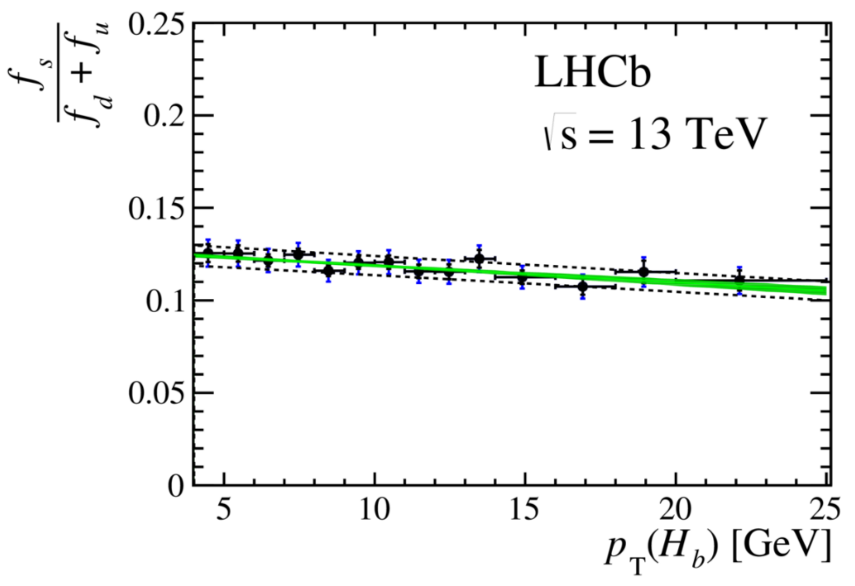
- Part of Run-2 data, 1.67 fb^{-1}
- Inclusive semileptonic decays to $H_c X \mu \overline{\nu_\mu}$ are used to reconstruct b hardons
- 2D fit to distinguish signal and background in decays to $H_c h X \mu \overline{\nu_\mu}$

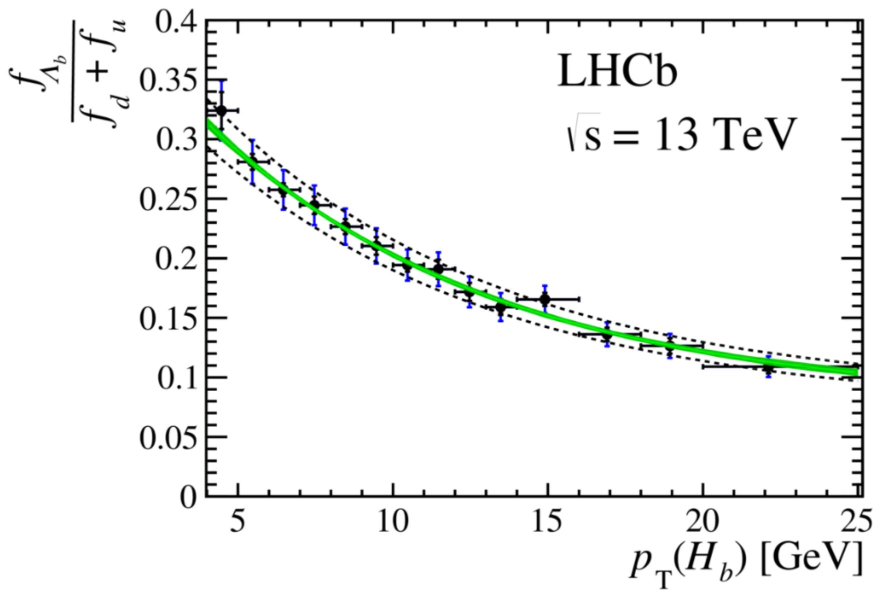


Measurement of b–hadron fractions at 13 TeV

ARXIV:1902.06794

- First measurement of b hadron fractions at 13 TeV
  - $\frac{f_s}{f_u+f_d} = 0.122 \pm 0.006$, $\frac{f_{\Lambda_b^0}}{f_u+f_d} = 0.259 \pm 0.018$
  - Fragmentation fractions extracted as a function of p_T

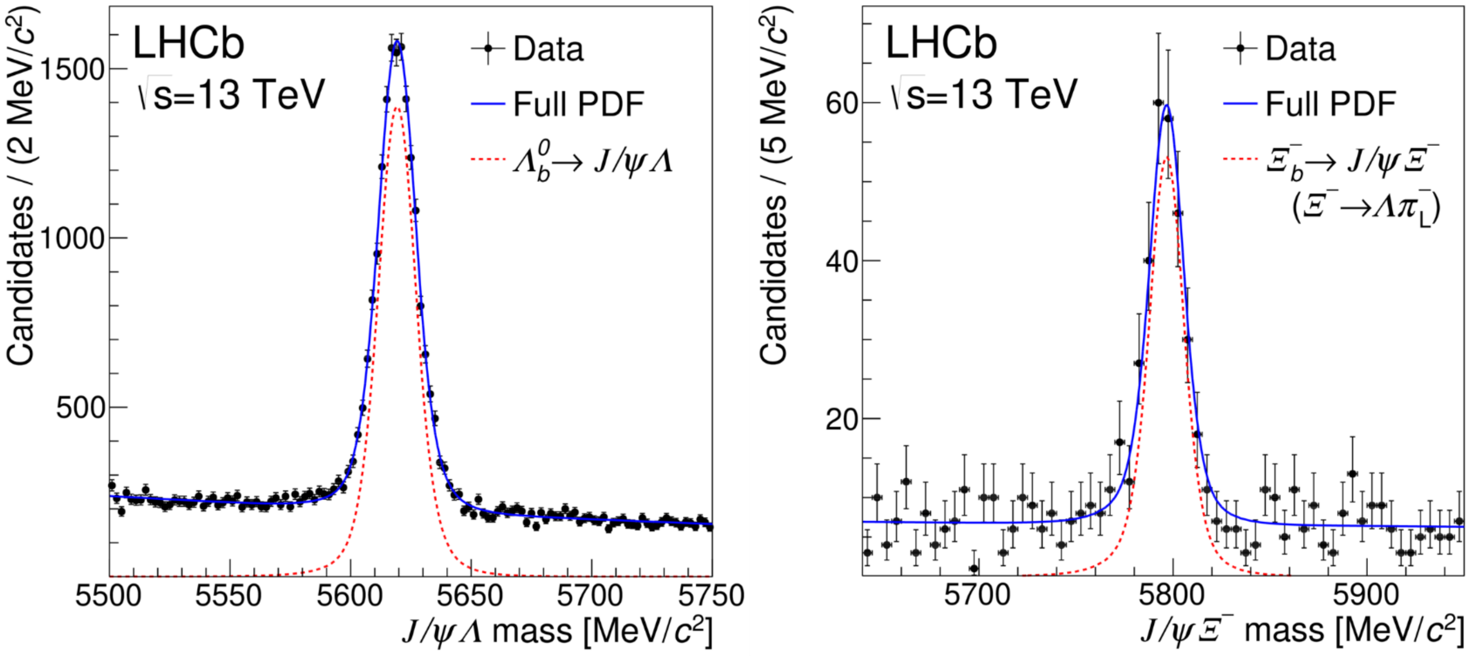




Measurement of the mass and production rate of Ξ_b^- baryons

PRD 99 (2019) 052006

- 3 fb^{-1} @7, 8 TeV + 1.8 fb^{-1} @13 TeV
- Ξ_b^- reconstructed via $\Xi_b^- \to J/\Psi\Xi^-$, normalization: $\Lambda_b^0 \to J/\Psi\Lambda$



First measurement of Ξ_b^- production

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

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

Measurement of the mass and production rate of Ξ_b^- baryons

PRD 99 (2019) 052006

- Assuming SU(3) symmetry, the fragmentation fraction is obtained

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b^0}} = (6.7 \pm 0.5 \pm 0.5 \pm 2.0) \times 10^{-2} \quad [\sqrt{s} = 7, 8\,\text{TeV}],$$

$$\frac{f_{\Xi_b^-}}{f_{\Lambda_b^0}} = (8.2 \pm 0.7 \pm 0.6 \pm 2.5) \times 10^{-2} \quad [\sqrt{s} = 13\,\text{TeV}].$$

- No significant production asymmetry observed

$$A_{\text{prod}}(\Xi_b^-) = (\ \ 1.1 \pm 5.6 \pm 1.9)\% \quad [\sqrt{s} = 7, 8\,\text{TeV}],$$

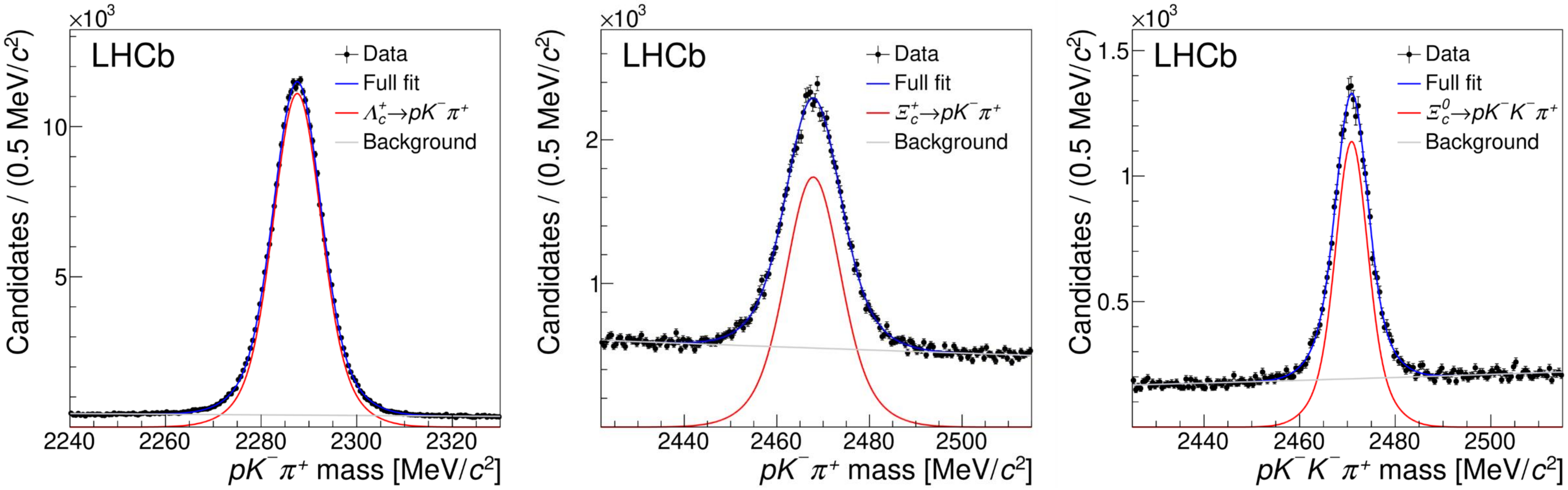
$$A_{\text{prod}}(\Xi_b^-) = (-3.9 \pm 4.9 \pm 2.5)\% \quad [\sqrt{s} = 13\,\text{TeV}].$$

- The most precise measurement of Ξ_b^- mass

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

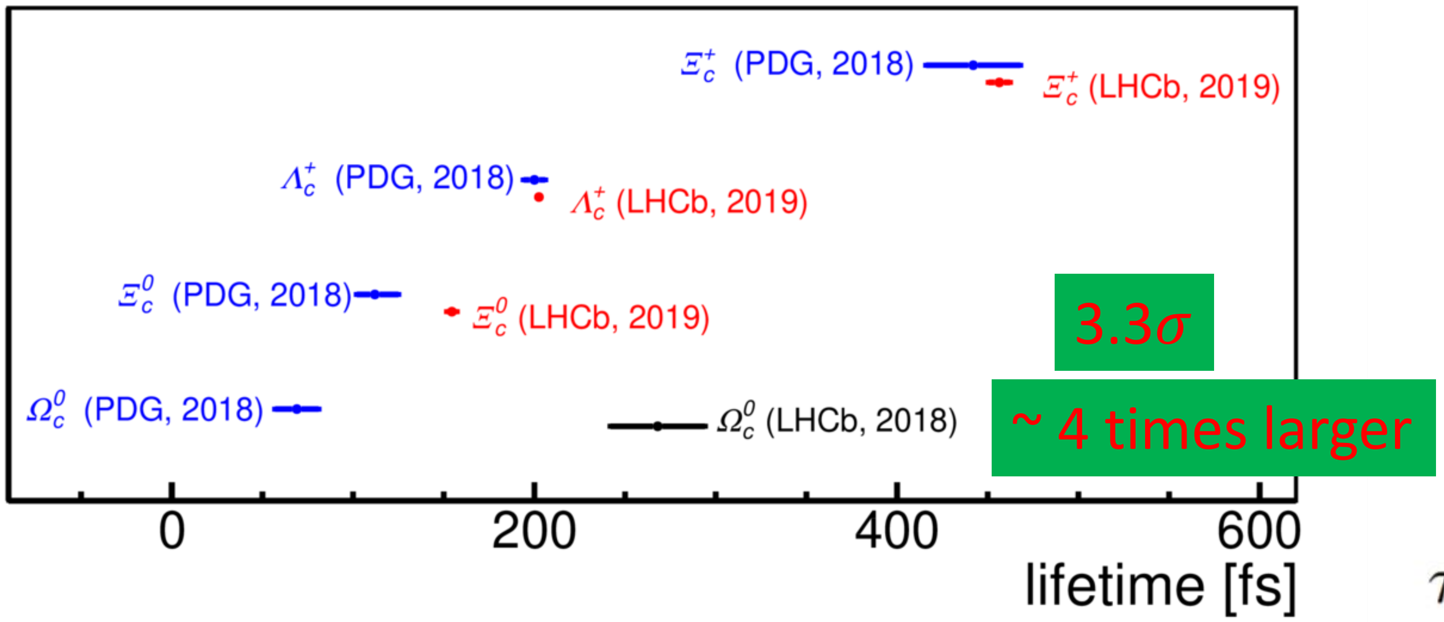
Precision measurement of the Λ_c^+, Ξ_c^0, and Ξ_c^+ baryons lifetimes

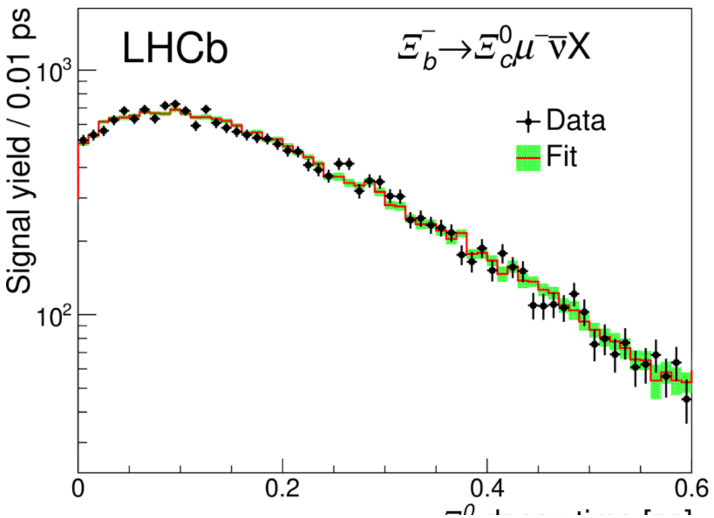
- Use Run-1 data set: 3.0 fb^{-1}
- Decay channels: $\Lambda_c^+ \to pK^-\pi^+$, $\Xi_c^+ \to pK^-\pi^+$, $\Xi_c^0 \to pK^-K^-\pi^+$



Precision measurement of the Λ_c^+, Ξ_c^0, and Ξ_c^+ baryons lifetimes

- Fit decay time spectra to get lifetime information

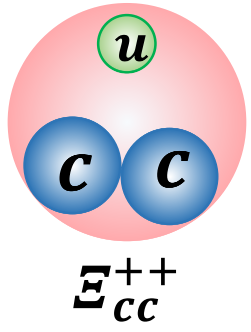




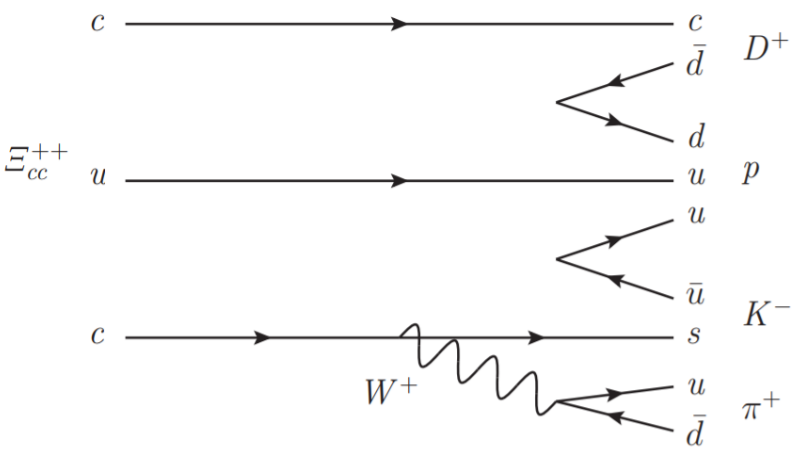
$$\tau_{\Lambda_c^+} = 203.5 \pm 1.0 \pm 1.3 \pm 1.4 \text{ fs},$$
$$\tau_{\Xi_c^+} = 456.8 \pm 3.5 \pm 2.9 \pm 3.1 \text{ fs},$$
$$\tau_{\Xi_c^0} = 154.5 \pm 1.7 \pm 1.6 \pm 1.0 \text{ fs},$$

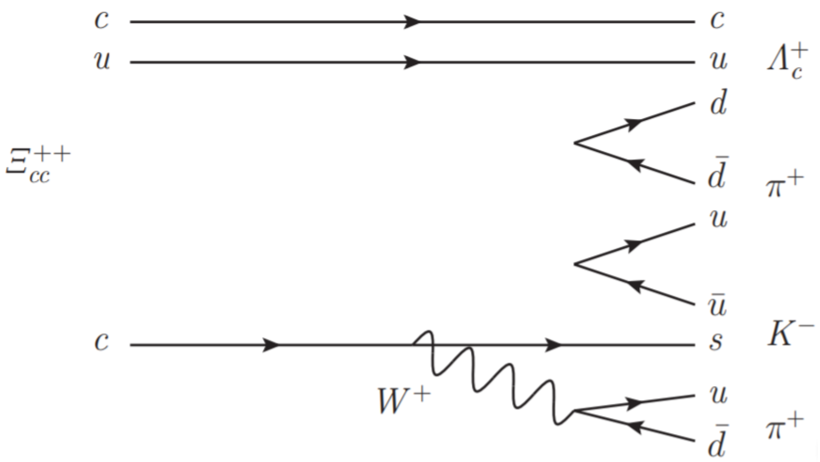
The measurements are approximately 3–4 times more precise than the current world average values

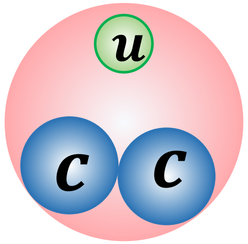
A search for $\Xi_{cc}^{++} \to D^+ p K^- \pi^+$



- First observation of double charmed baryon triggered a lot of theoretical attention
- At LHCb: $D^+ \to K^- \pi^+ \pi^+$ trigger is very efficient
- Similar tree level amplitudes of the inclusive decay of these channels: but smaller phase space due to lesser energy release





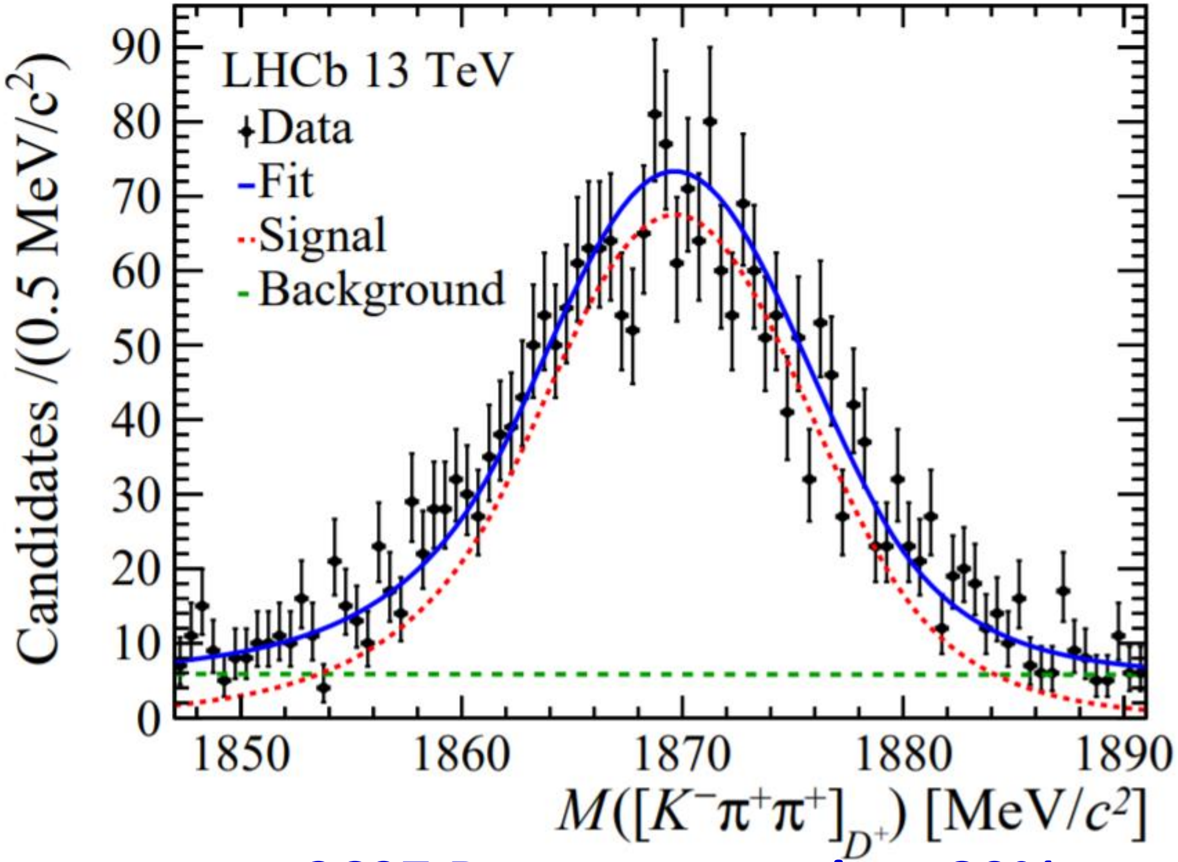


Ξ_{cc}^{++}

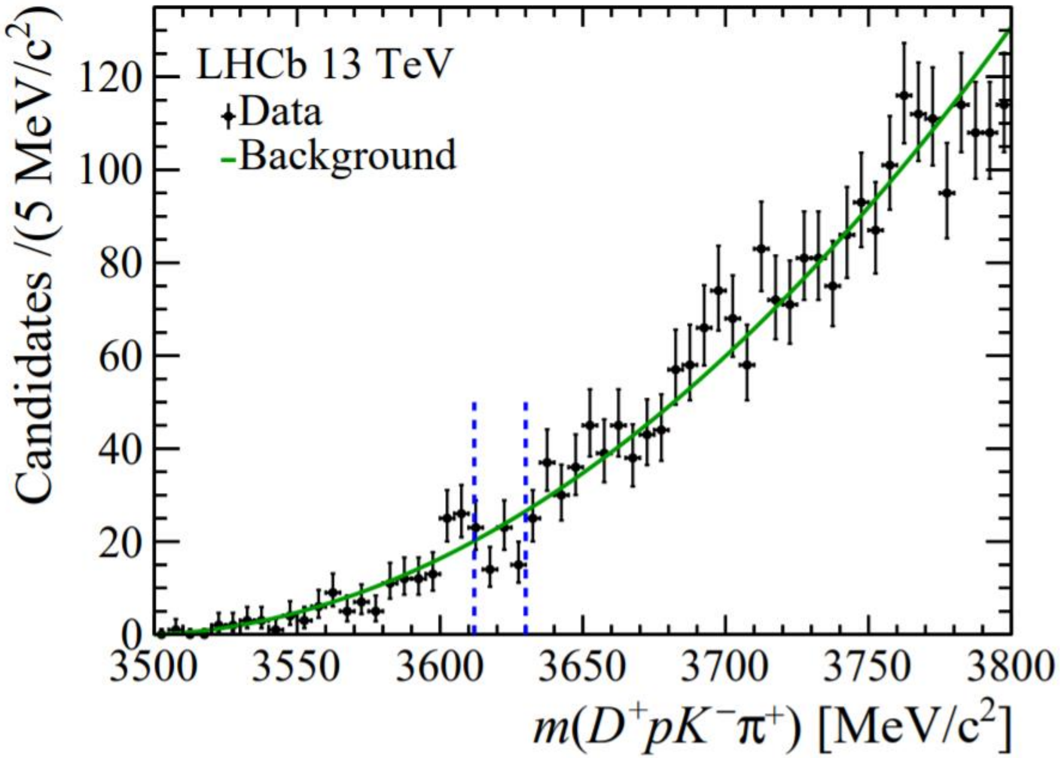
Mass distributions

PAPER-2019-011 arXiv:1905.02421

- After event selection

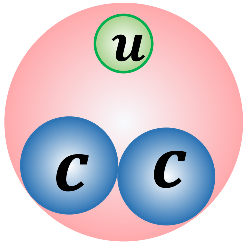


2697 D+ events, purity ~80%

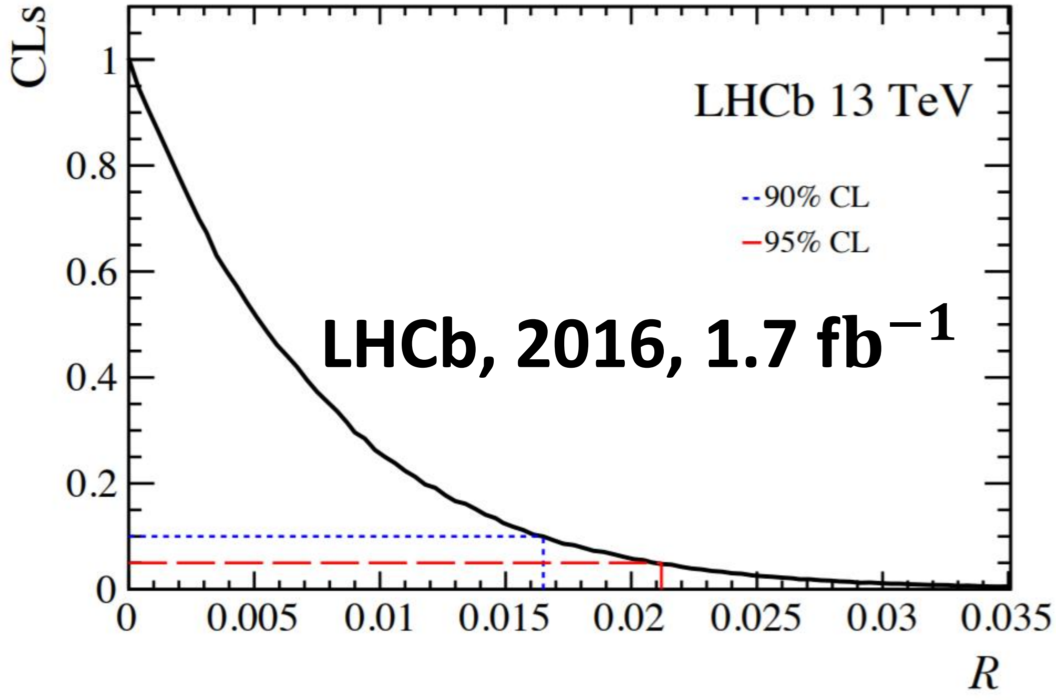


Upper limit

PAPER-2019-011 arXiv:1905.02421



- No significant signal is found in the mass range 330-3800 MeV Ξ_{cc}^{++}
- Set Upper limit using CLs method:
  - $R < 1.7(2.1) \times 10^{-2}$ at 90% (95%) CL level

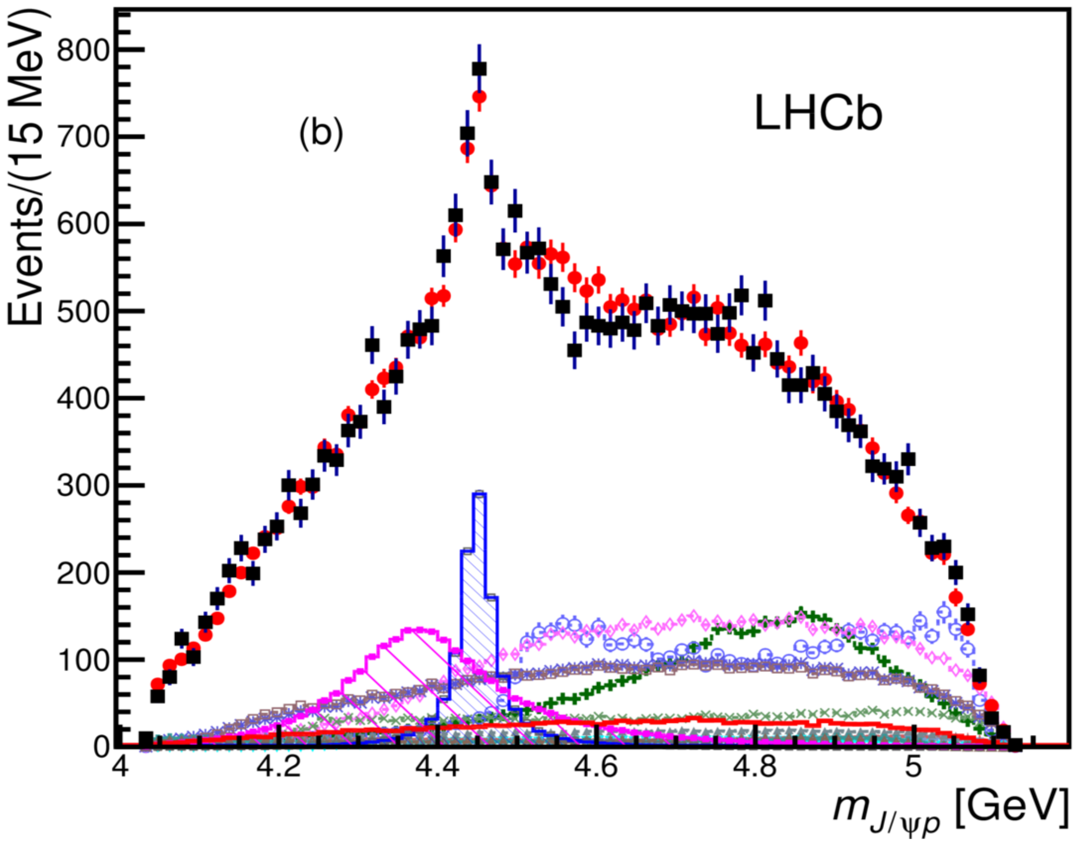


$$\mathcal{R} = \frac{\mathcal{B}(\Xi_{cc}^{++} \to D^+ p K^- \pi^+)}{\mathcal{B}(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+)}$$

Experimental history of pentaquarks

- In 2015 LHCb report the observation of two pentaquark candidates
- Analysis performed with Run-1 data 3 fb^{-1} using $\Lambda_b \to J/\Psi p K$
  - 26k signal candidates with 5.4% background
- Dalitz plot analysis (6D amplitude fit) confirmed 2 new states
- Followed by a model independent analysis to exclude reflections from Λ^* resonances
- Two exotic states with opposite parities

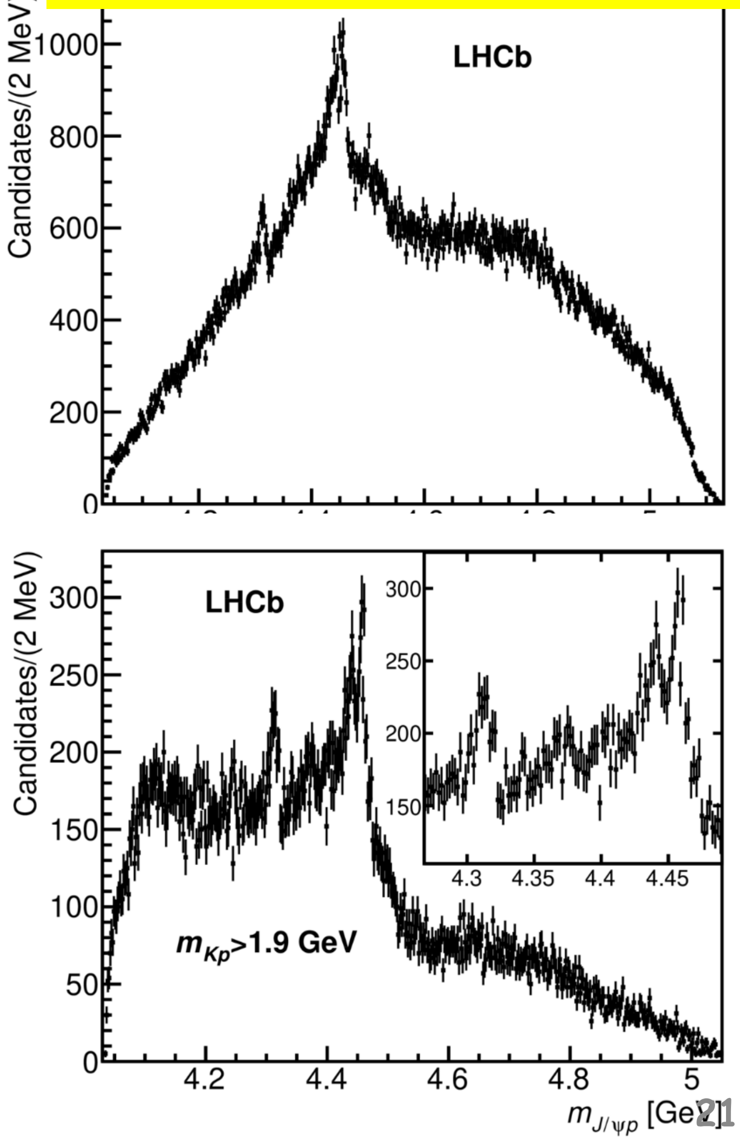
PRL 115 (2015) 072001, PRL 117 (2016) 082002



Narrow $P_c(4312)^+$ and two-peak structure

Phys. Rev. Lett. 122 (2019) 222001

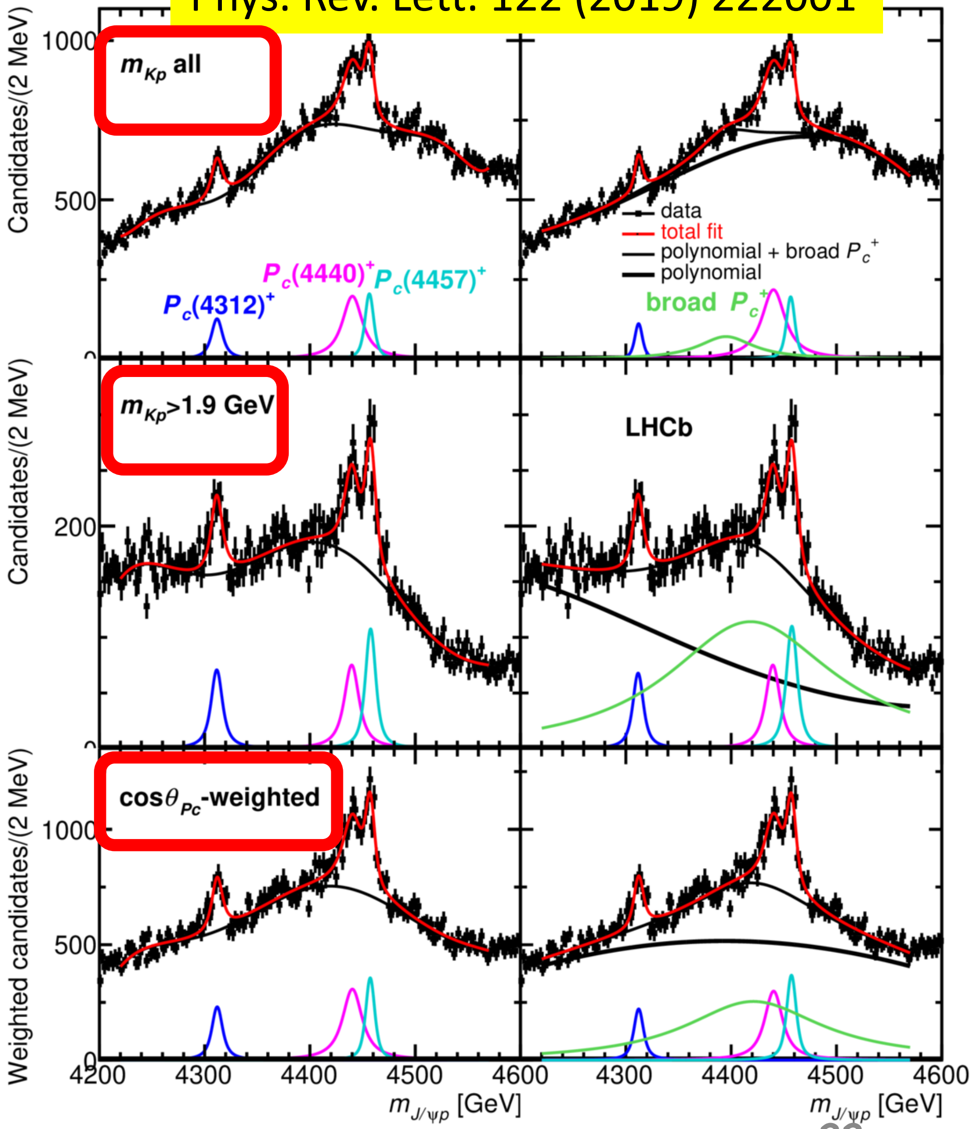
- Update of the analysis with full Run-1 and Run-2 data set
- 246k signal events of nice $\Lambda_b \to J/\Psi p K$
  - more than 9× statistics used in previous analysis
- More statistics → finer binning
  - Reveals more complicate structures in the $J/\Psi p$ system
- Summary:
  - Narrow peak at 4312 MeV: width comparable with experimental resolution (2-3 MeV)
  - The structure at 4450 MeV now resolved into two narrow peaks at 4440 and 4457 MeV
  - All statistical significance are well above 5σ



Narrow $P_c(4312)^+$ and two-peak structure

Phys. Rev. Lett. 122 (2019) 222001

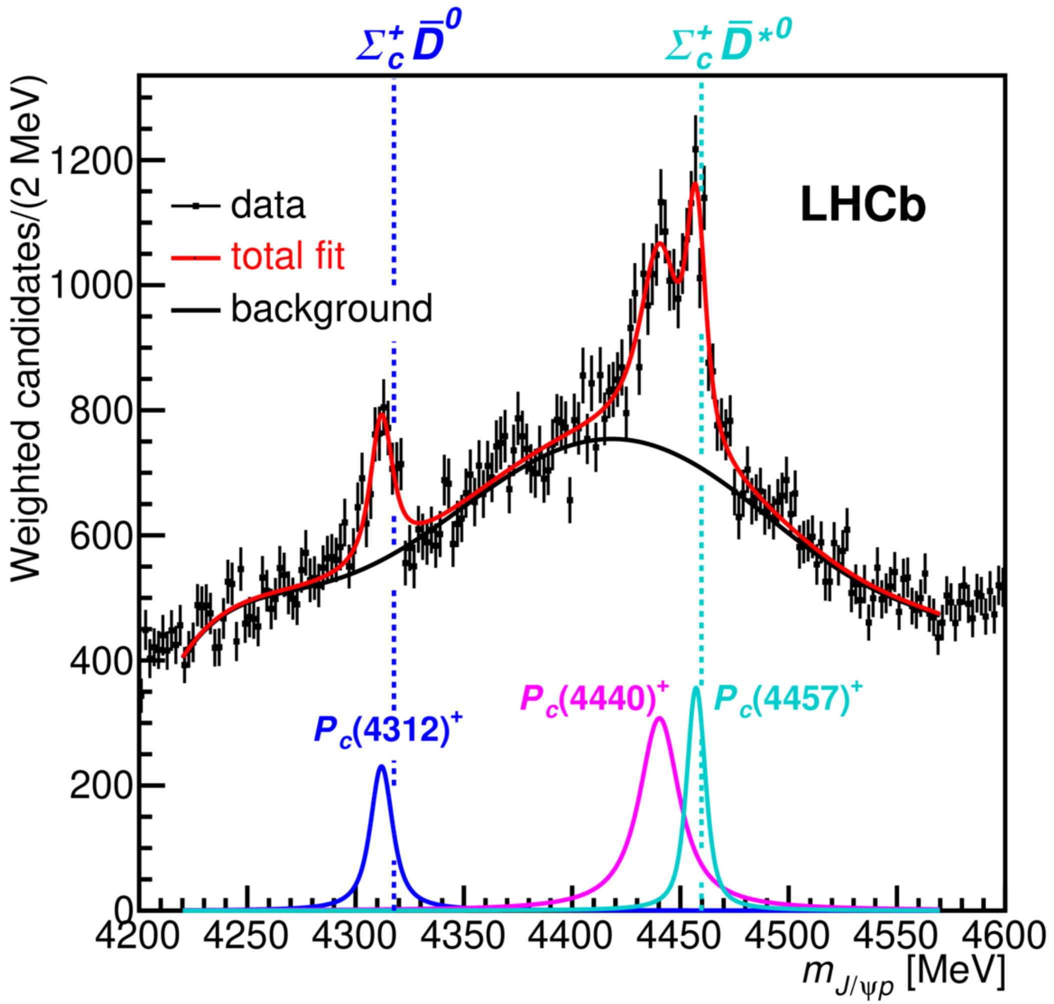
- Amplitude analysis is challenging
  - size of sample
  - amplitude model
  - mass resolution
- Can reduce the contribution from Λ^* reflections with Λ^* p_T cuts
- Other cross checks performed
- For narrow peaks perform 1D fit to mass



Narrow $P_c(4312)^+$ and two-peak structure

Phys. Rev. Lett. 122 (2019) 222001

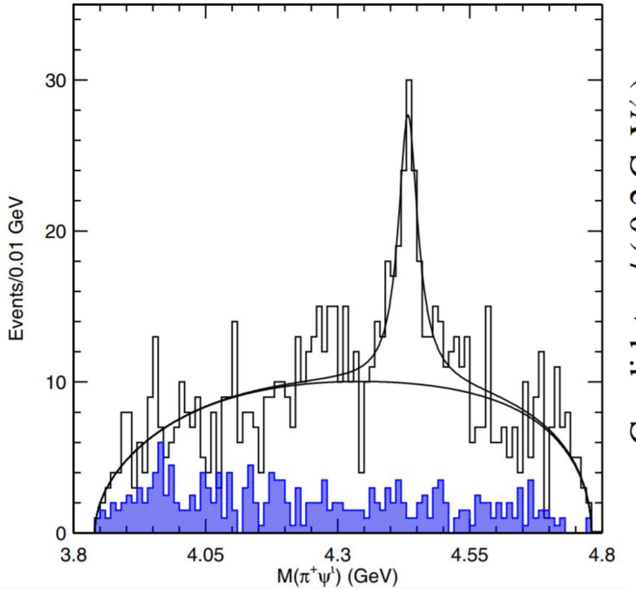
- Wide P_c does not perturbate the fit to the lower mass states
- $P_c(4312)^+$ and $P_c(4440)^+$ are not near triangle diagram thresholds
- $P_c(4457)^+$ close to thresholds
- Data are described by BW than triangle-diagram terms
- Narrow widths and masses close to thresholds points toward baryon-meson bound states interpretation

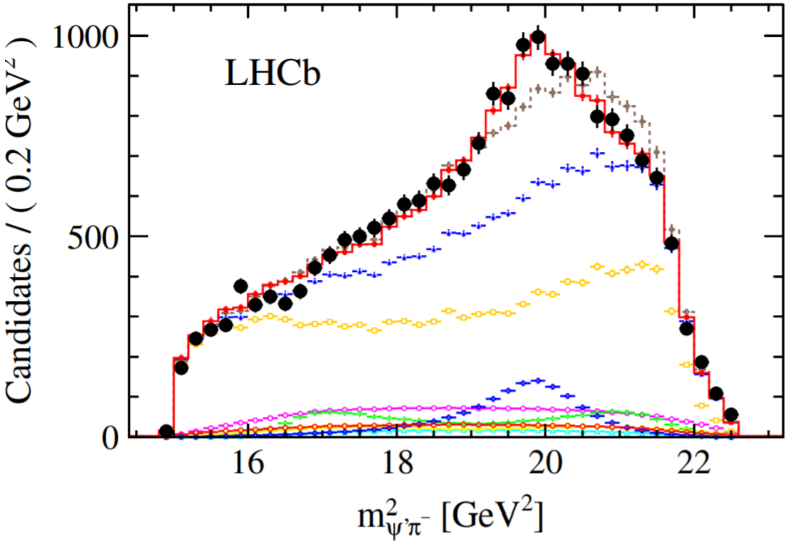


Study of the $B^0 \to J/\Psi\, K^+\pi^-$ decay

- The $Z(4430)^-$ is the only confirmed exotic state, and it couples to the excited $\Psi(2S)$, rather than the ground state J/Ψ
  - Discovered by Belle experiment: $B^0 \to Z(4430)^-(\to \Psi\,(2S)\pi^-)K^+$
  - Not confirmed by the Babar Collaboration
  - Confirmed by the LHCb Collaboration

PRL 100 142001, 2008
PRD 79 112001, 2009
PRL 112 222002, 2014





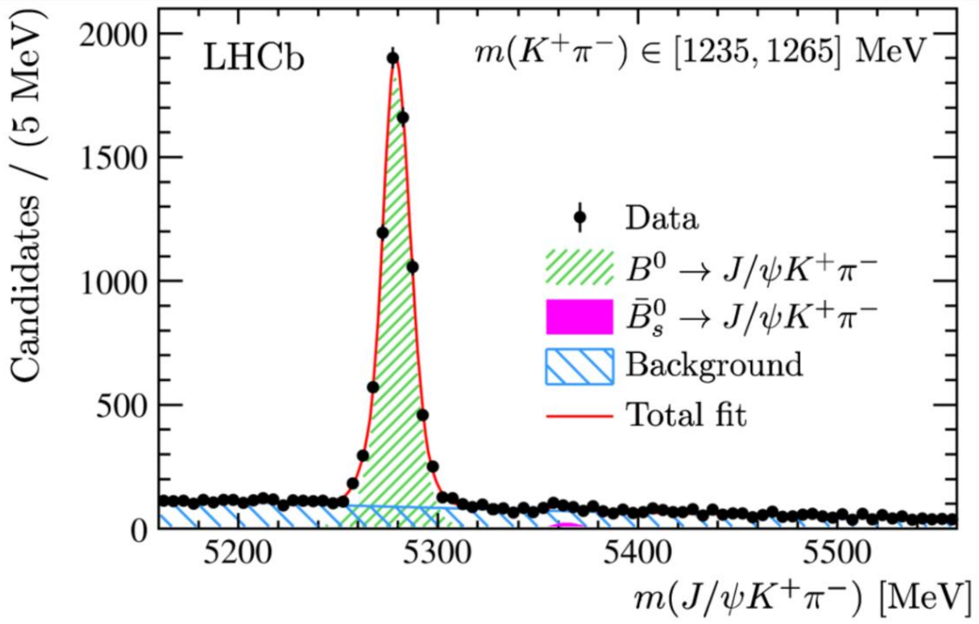
- Evidence for $Z(4430)^-$ is found the $B^0 \to J/\Psi\, K^+\pi^-$ decay by Belle
  - Suppressed by at least a factor of 10
  - A new exotic hadron is observed: $B^0 \to Z(4200)^-(\to J/\Psi\pi^-)\,K^+$

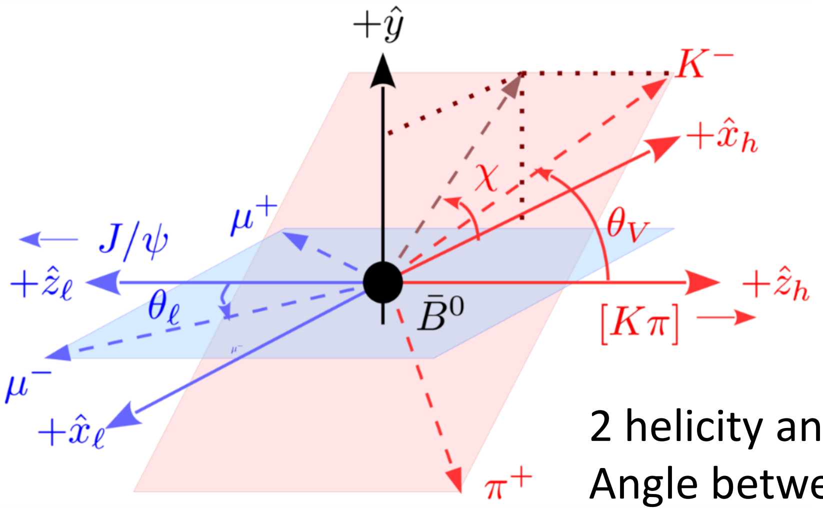
PRD 90 112009, 2014

Study of the $B^0 \to J/\Psi\, K^+\pi^-$ decay

PRL 122 152002, 2019

- Run-1, 3 fb^{-1}: Signal yield $B^0 \to J/\Psi\, K^+\pi^-$ ~ 5×10^5
  - 40 times larger than in Babar study
  - 20 times larger than in Belle study
- Angular analysis in 35 $K^+\pi^-$ mass bins
  - Signal purity above 90% in every bin, 3D angular fit in each bin



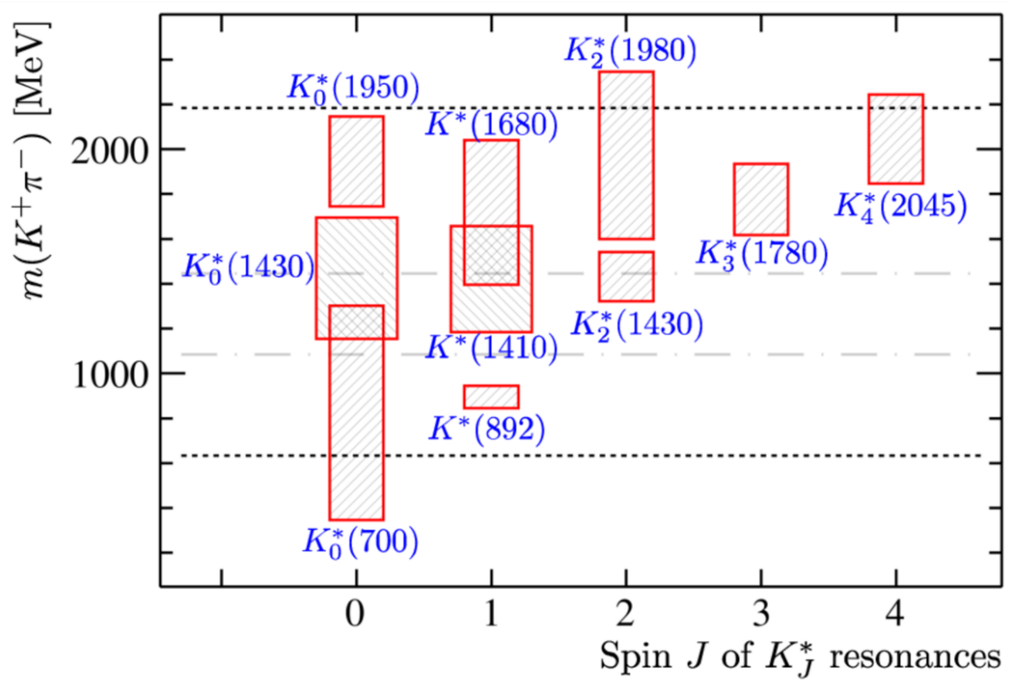


2 helicity angles: θ_l, θ_v
Angle between ($\mu^+\mu^-$) and ($K^+\pi^-$) decay planes χ

Study of the $B^0 \to J/\Psi\, K^+\pi^-$ decay

PRL 122 152002, 2019

- Parameters of K^* spectrum are not very well experimentally measured
  - Model-independent analysis – relying only on highest allowed spin, J_{max}



Kinematic allowed region

This anlaysis

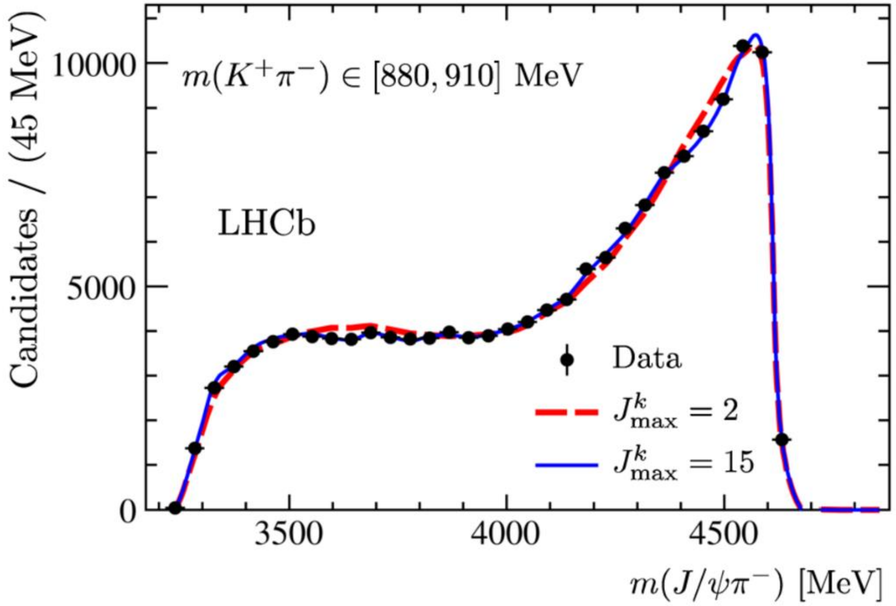
K^*-only model:

$$J_{max}^{k} = \begin{cases} 2 \text{ if } 1085 \le m(K^+\pi^-) \le 1265 \\ 3 \text{ if } 1265 \le m(K^+\pi^-) \le 1445 \end{cases} \text{ MeV}$$

Study of the $B^0 \to J/\Psi\, K^+\pi^-$ decay

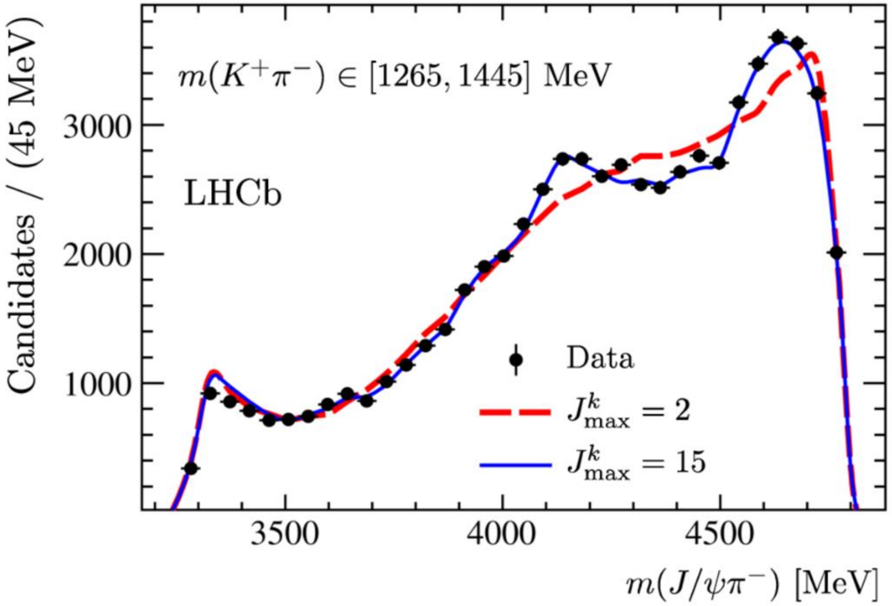
PRL 122 152002, 2019

In the $K^*(892)$ mass region



Well described by contributions with $J_{max} = 2$ only

After vetoing $K^*(892)$ mass region



Unphysical $J_{max} = 15$ is needed to describe the data $m(J/\Psi\pi) \sim$ 4200 and 4600 MeV regions

Significance well exceeds 5σ

Model-dependent amplitude analysis is needed to determine the nature of these states

Summary

- LHCb detector is designed for the heavy flavour physics

- The first analyses using the full Run-1+Run-2 datasets
  - Significant LHCb contribution to study heavy flavour production and spectroscopy
  - The exotic studies sector at LHCb is rapidly developing
  - Many new states confirmed/unconfirmed/waiting for confirmation
  - Still a large area for studies both from experimental and theoretical sides

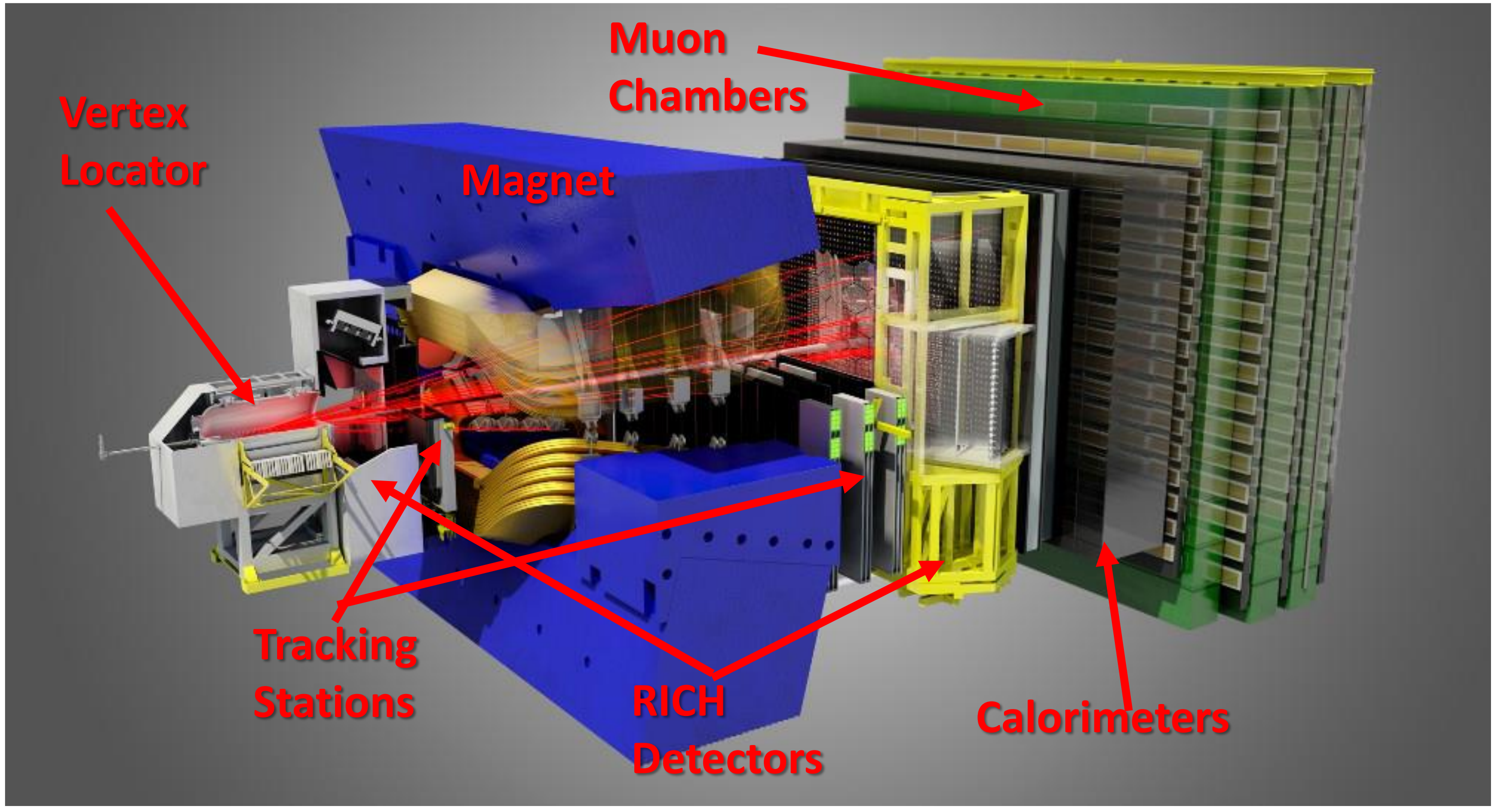
- Many updates in the future, and many Dalitz analyses become feasible

Stay tuned for new results !

Backup

LHCb detector

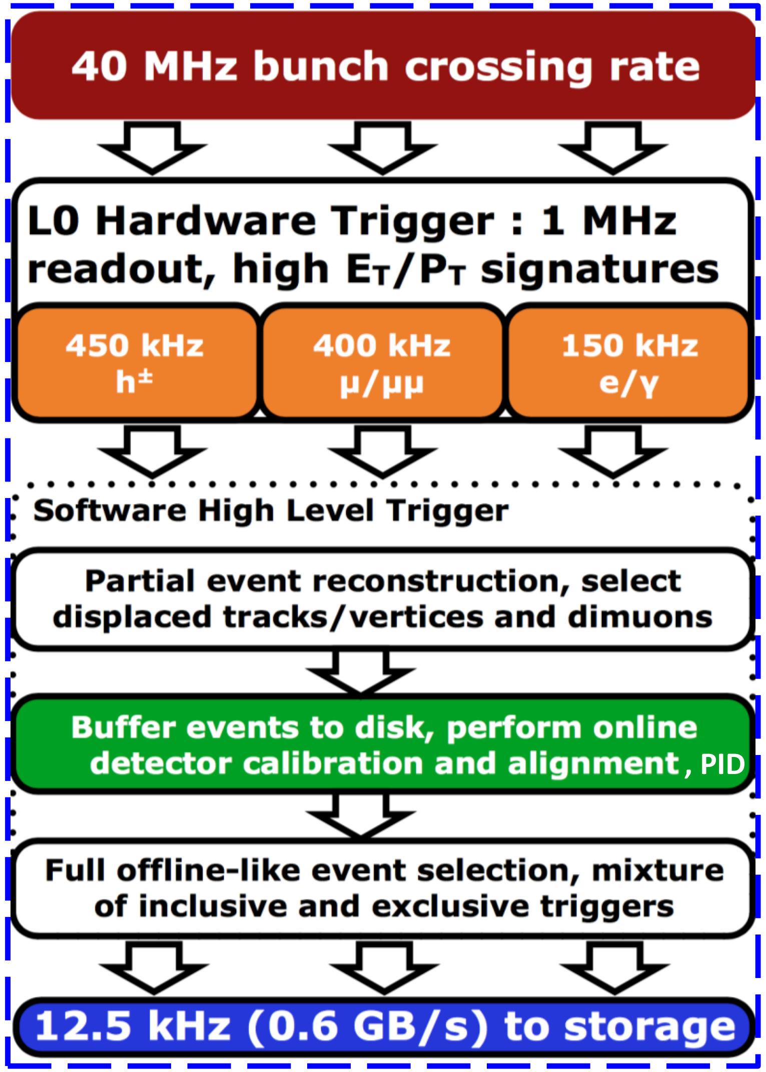
JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022



- LHCb is a forward spectrometer suited for b, c hadrons: $2 < \eta < 5$
- Momentum resolution:
  - 0.5% at 5 GeV, 1.0% at 200 GeV
- Excellent track and vertex reconstruction
- Good particle-ID separation

Comput. Phys. Commun. 208 (2016) 35-42
Int. J. Mod. Phys. A 30, 1530022 (2015)

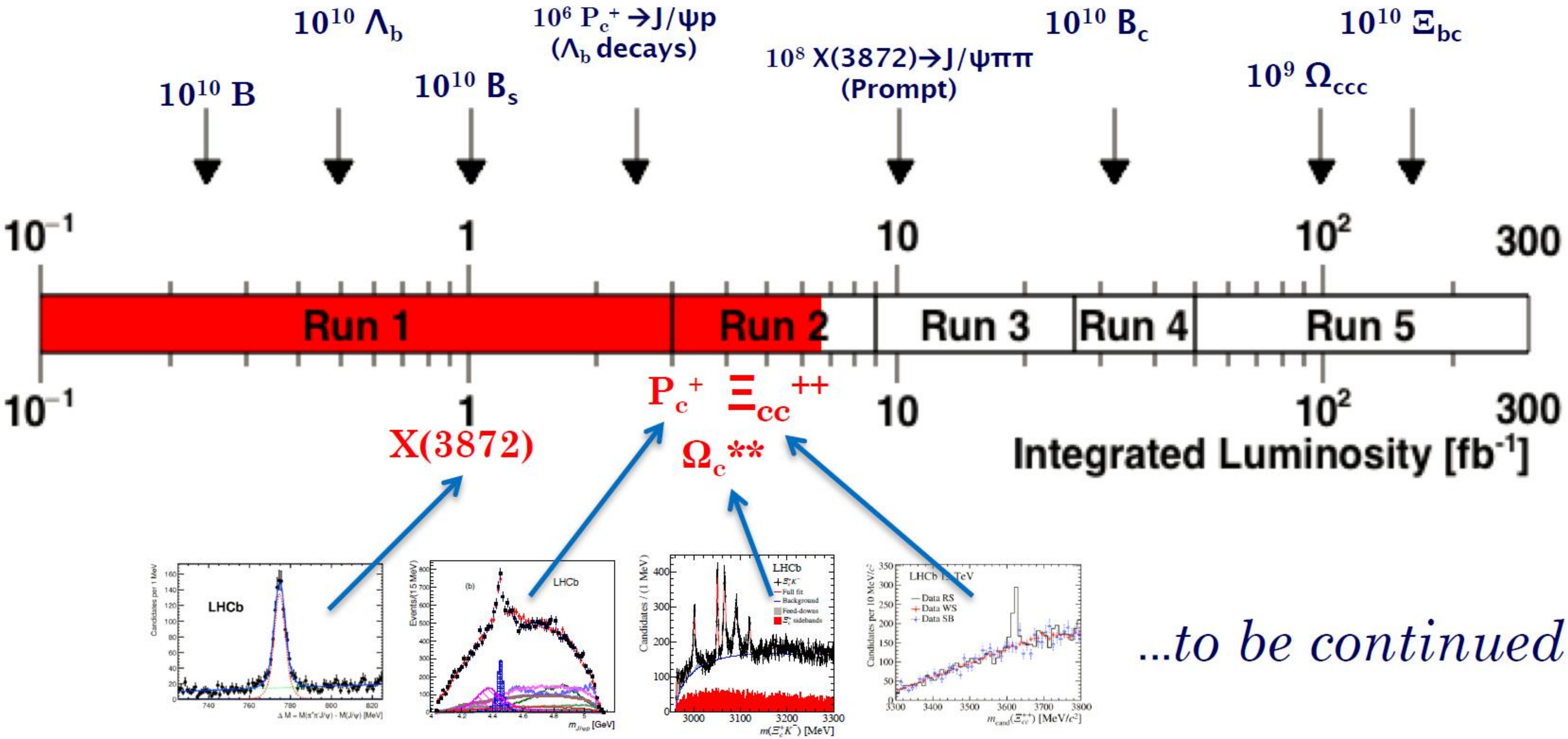
LHCb trigger



- Run real-time alignment and calibration of the detector
- Data buffered out of first software trigger stage
- Second software trigger runs asynchronously
- Permits Turbo real-time analysis strategy
  - Candidates reconstructed at the trigger level saved directly for offline analysis + (online alignment and calibration)

The first two analyses of today's talk benefit from the Turbo stream.

Hadron spectroscopy @ LHCb

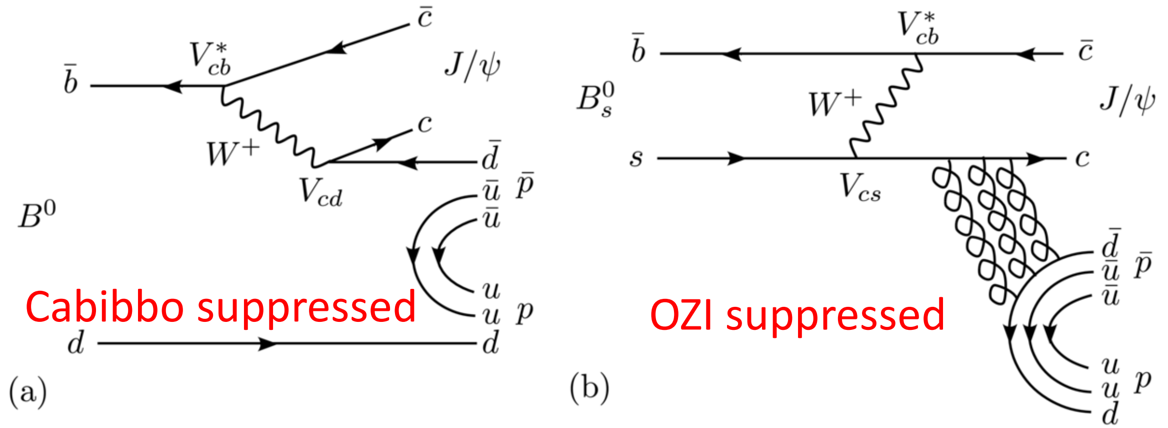


...to be continued

Get from M. Pappagallo

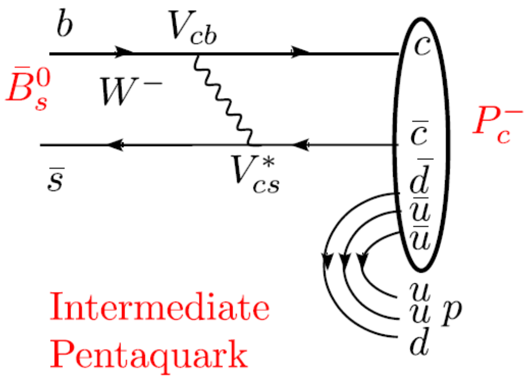
$B_s^0 \to J/\Psi p\bar{p}$ decay

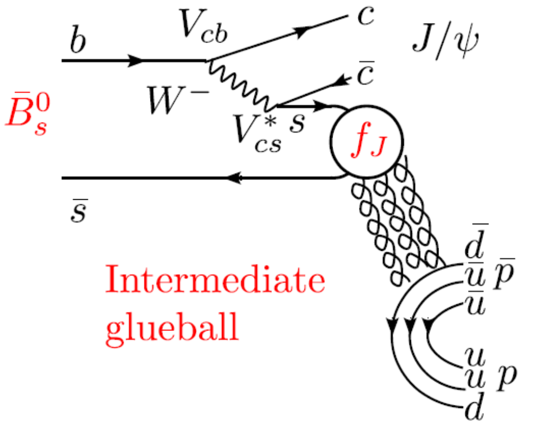
- Rare baryonic B-decay
- Phase-space suppression
- pQCD: $Br(B^0) > Br(B_s^0)$ [EPJC 75, 101 (2015), Hsiao]



- Suppression can be lifted by pentaquark in $[J/\Psi p]$ or glueball in $[p\bar{p}]$
- LHCb set upper limit using Run-1 data

JHEP 09 (2013) 006





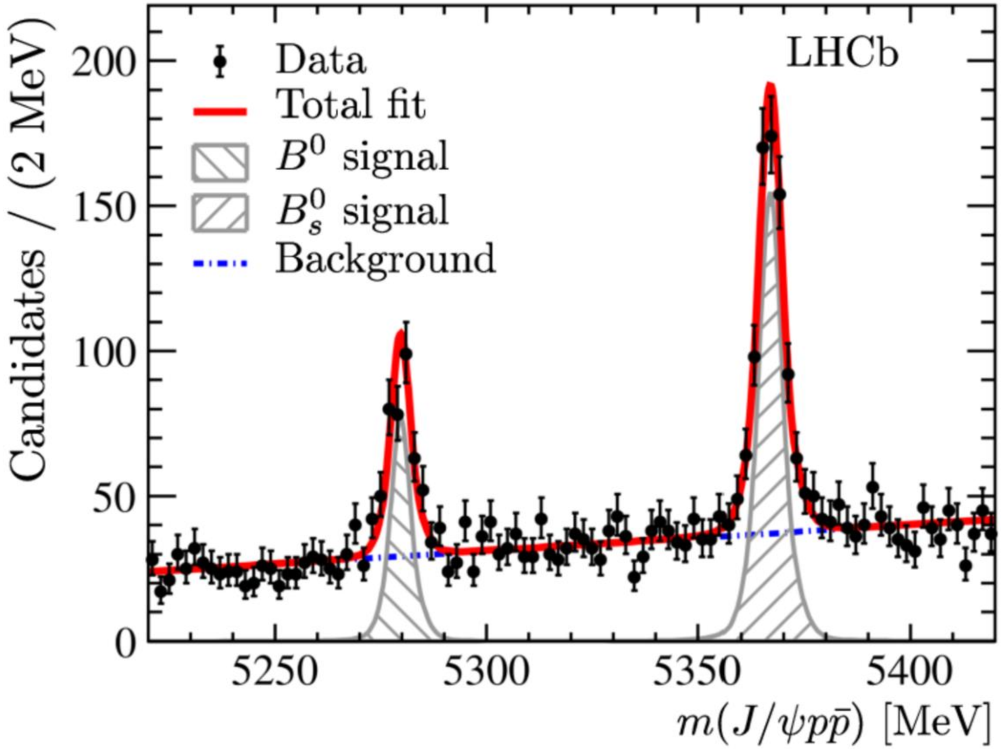
$B_s^0 \to J/\Psi p\bar{p}$ decay

PRL 122 (2019) 191804

- 2011-2016 data sets
- Powerful new BDT with proton PID + kinematic variables
- First observation of these modes: $\gg 10\sigma$ significance

$$\mathcal{B}(B^0 \to J/\psi\, p\bar{p}) = (4.51 \pm 0.40\ (\text{stat}) \pm 0.44\ (\text{syst})) \times 10^{-7},$$
$$\mathcal{B}(B_s^0 \to J/\psi\, p\bar{p}) = (3.58 \pm 0.19\ (\text{stat}) \pm 0.33\ (\text{syst})) \times 10^{-6},$$

- Inverted $Br(B_s^0) > Br(B^0)$ hierarchy confirmed in data



$Z_c(4100)^-$ in $B^0 \to \eta_c(1S)K^+\pi^-$ EPJC 78 (2018) 1019

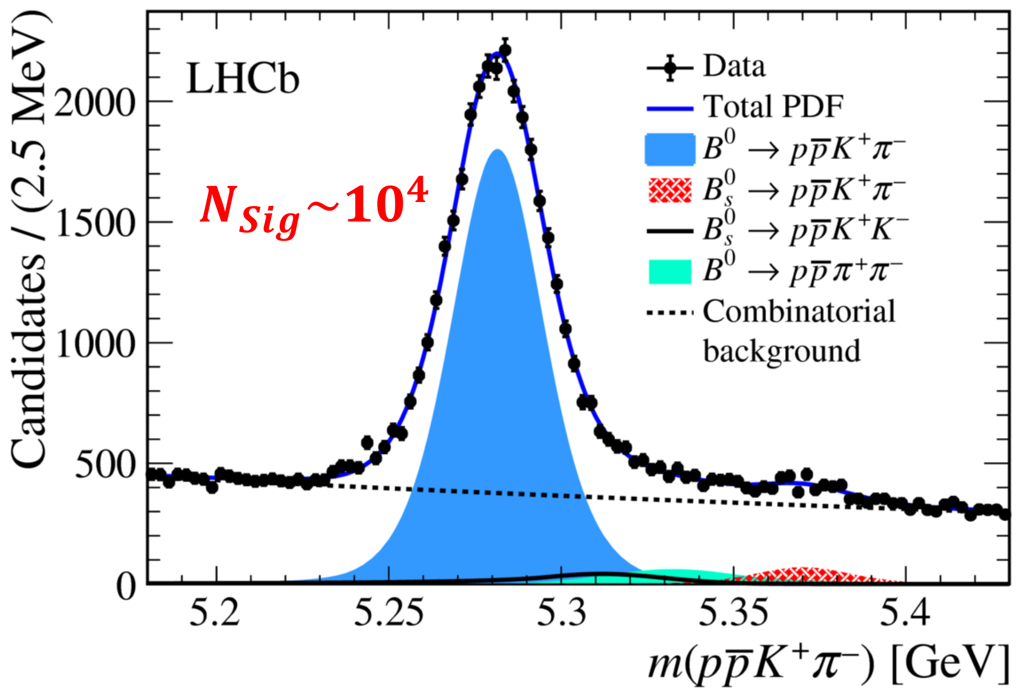
- Understand pattern of Z_c^- states
  - $Z_c(3900)^-$ seen by BES III, and Belle
- Charmonium-like charged stats: exotic
- $\eta_c\pi^-$ accesses J^P other than 1^+, that several Z_c^- confirmed to be

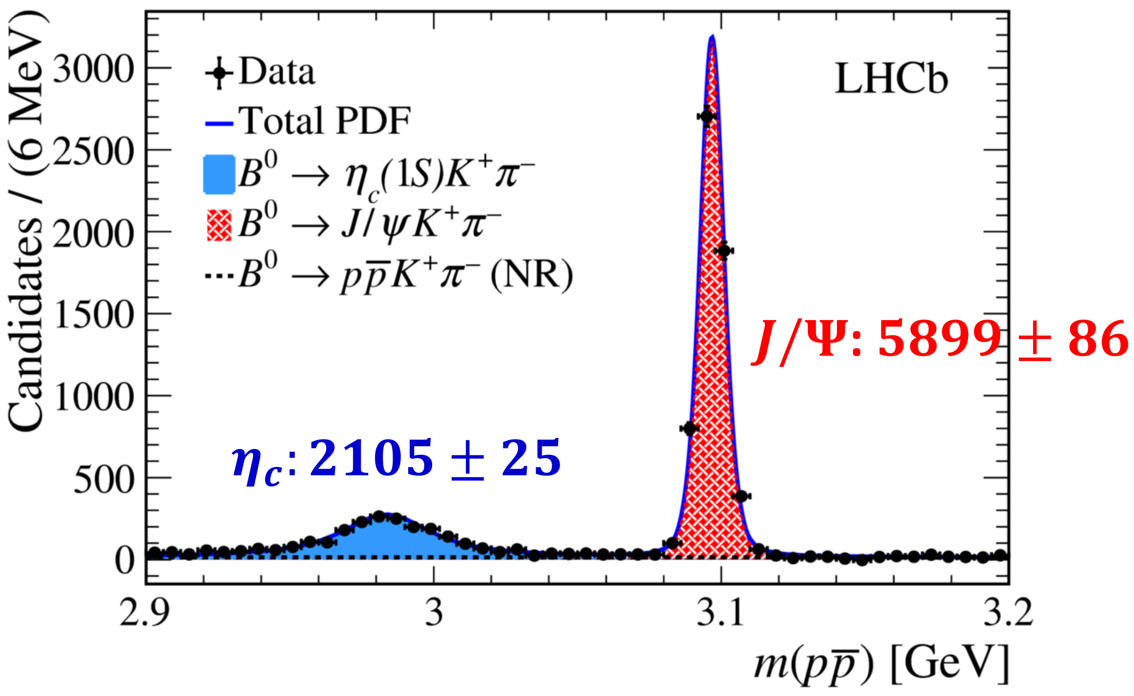
$Z_c^{+,0}(3900)$	3886.6 ± 2.4	28.1 ± 2.6	1^{+-}	$e^+e^- \to \pi^{-,0} + (J/\psi\,\pi^{+,0})$	BESIII (92; 101), Belle (88)
				$e^+e^- \to \pi^{-,0} + (D\bar{D}^*)^{+,0}$	BESIII (102; 103)
$Z_c^{+,0}(4020)$	4024.1 ± 1.9	13 ± 5	$1^{+-}(?)$	$e^+e- \to \pi^{-,0} + (h_c\,\pi^{+,0})$	BESIII (93; 104)
				$e^+e^- \to \pi^{-,0} + (D^*\bar{D}^*)^{+,0}$	BESIII (105; 106)
$Z^+(4050)$	4051^{+24}_{-43}	82^{+51}_{-55}	$?^{?+}$	$B \to K + (\chi_{c1}\,\pi^+)$	Belle (107), BaBar (108)
$Z^+(4200)$	4196^{+35}_{-32}	$370^{+\ 99}_{-149}$	1^+	$B \to K + (J/\psi\,\pi^+)$	Belle (51)
				$B \to K + (\psi'\pi^+)$	LHCb (46)
$Z^+(4250)$	$4248^{+185}_{-\ 45}$	$177^{+321}_{-\ 72}$	$?^{?+}$	$B \to K + (\chi_{c1}\,\pi^+)$	Belle (107), BaBar (108)
$Z^+(4430)$	4477 ± 20	181 ± 31	1^+	$B \to K + (\psi'\,\pi^+)$	Belle (45; 109; 110), LHCb (46; 111)
				$B \to K + (J\psi\,\pi^+)$	Belle (51)

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

EPJC 78 (2018) 1019

- L = 4.7 fb^{-1}, including Run-1 + Run-2 (2011-2016) data
- Multi-stage signal/bkg separation fits in $m(p\bar{p}K^+\pi^-)$ and $m(p\bar{p})$

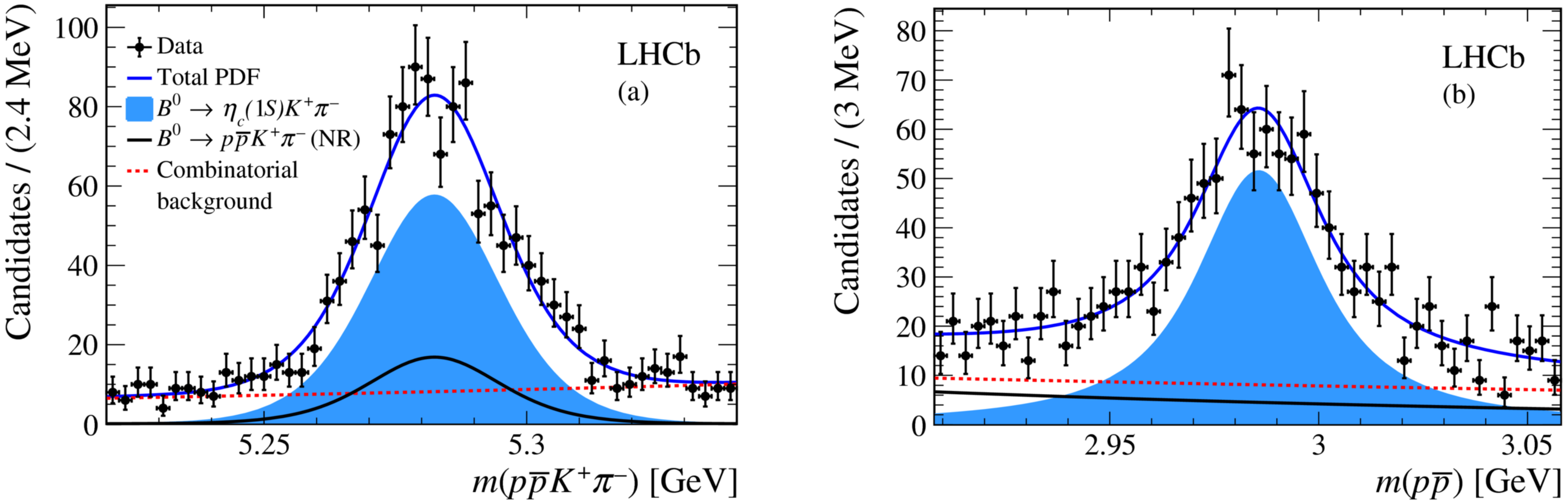




$B^0 \to \eta_c(1S)K^+\pi^-$ 2D mass fit

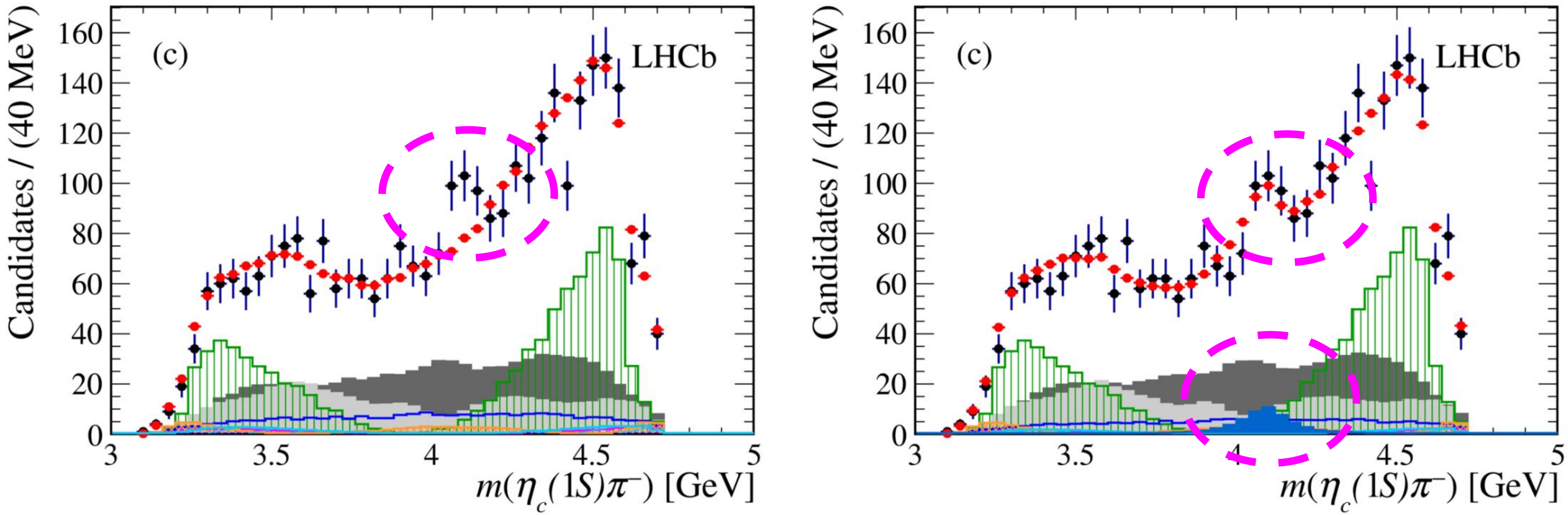
EPJC 78 (2018) 1019

- Unlike narrow $J/\Psi, \Psi(2S)$, η_c has $\Gamma_0 \sim$ 32 MeV
- 2D fit in $m(p\bar{p}K^+\pi^-)$ and $m(p\bar{p})$
- Dalitz analysis: K^* resonances + "non-resonant" $K\pi$ and $p\bar{p}$ S-waves



Evidence for an exotic $Z_c(4100)^-$ EPJC 78 (2018) 1019

- Good description in all variables after adding an exotic Z_c component



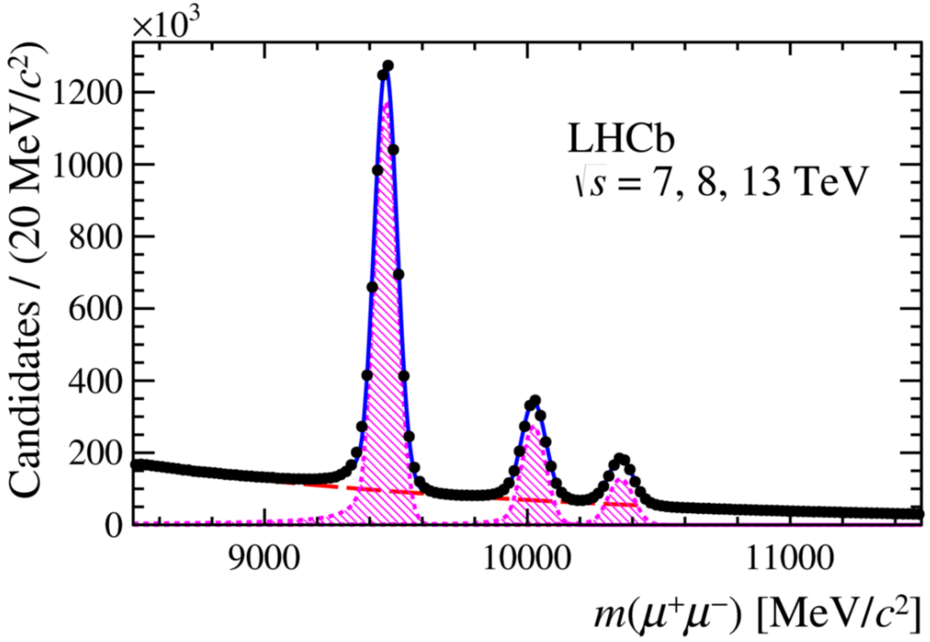
- $Z_c(4100)^-$: $J^P = 1^-$ significance is 3.4σ after considering systematics
- Only 1.2σ difference with alternative $J^P = 0^+$ assignment
- Mass $m_0 = 4096 \pm 20^{+18}_{-22}$ MeV, $\Gamma = 152 \pm 58^{+80}_{-35}$ MeV

Search for beauty teraquarks: $X_{b\bar{b}b\bar{b}}$

JHEP 10 (2018) 086

- No hadron containing > 2 heavy quarks has been observed so far
- Theoretical prediction:
  - Mass within [18.4, 18.8] GeV, $\sigma \times B(\Upsilon l^+ l^-) \sim 1$ fb
  - Typically below $\eta_b \eta_b$ threshold: could decay to $\Upsilon l^+ l^-$ $(l = e, \mu)$
  - Lattice QCD calculation do not find evidence for this state

Phys. Rev. D97 (2018) 054505



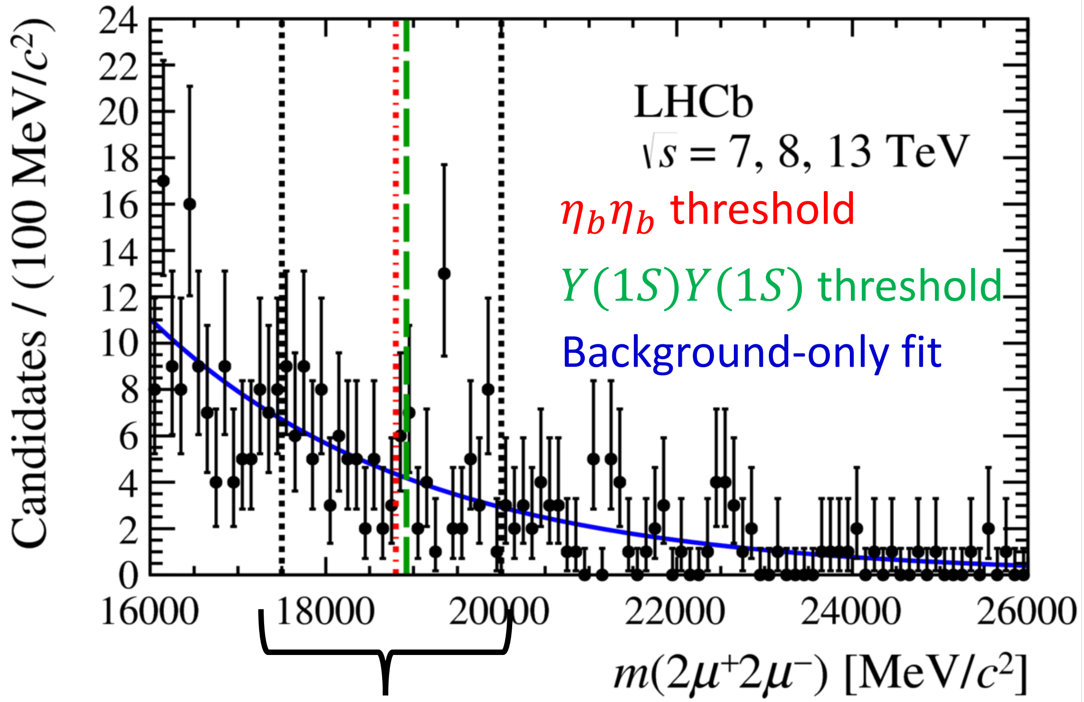
LHCb search:

- $X_{b\bar{b}b\bar{b}} \to \Upsilon(1S)\mu^+\mu^-$, where $\Upsilon(1S) \to \mu^+\mu^-$
- Mass range : 17.5 – 20.0 GeV
- Run-1 + Run-2 data

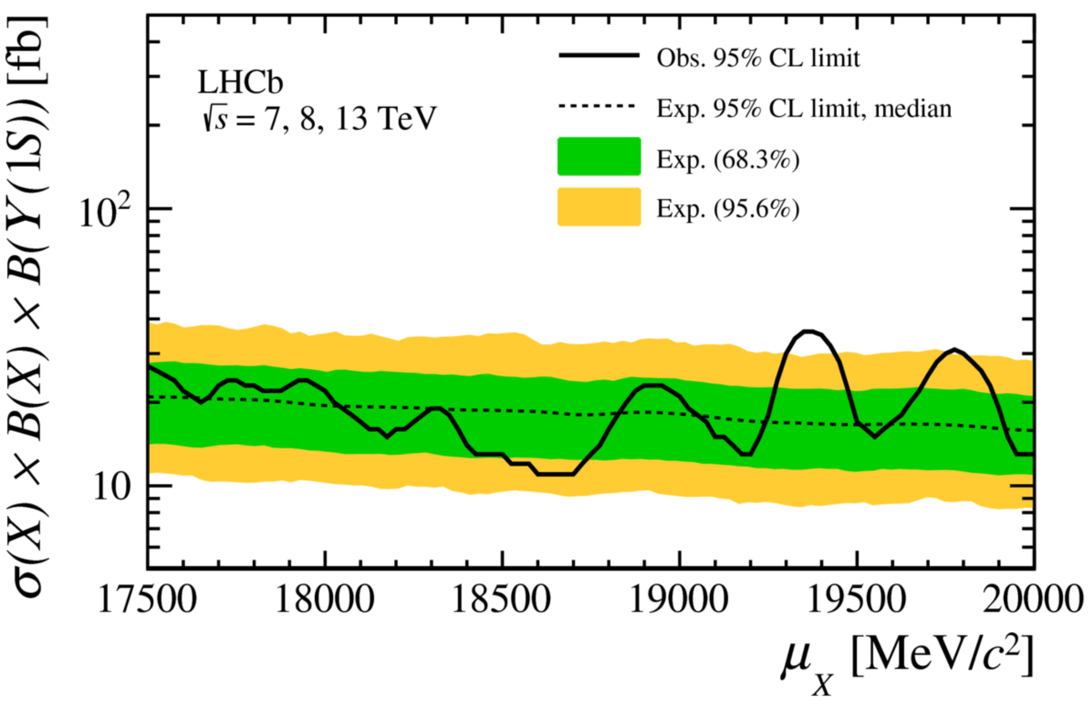
Search for beauty teraquarks: $X_{b\bar{b}b\bar{b}}$

JHEP 10 (2018) 086

- Cut-based selection, with J/Ψ mass veto
- $\Upsilon(1S)$ yields after selection ($\pm 2.5\sigma$ region): ~6×10^6
- No significant excess is seen in data, upper limit are set



Limits setting region

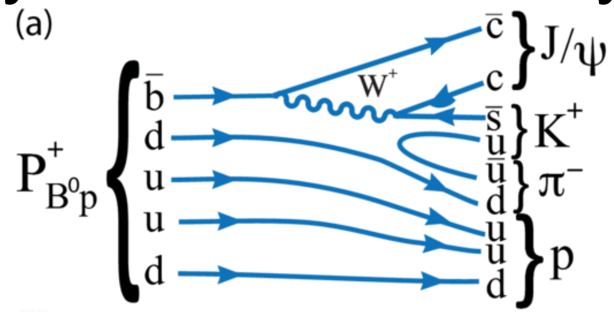


Weakly decaying *b*-flavoured pentaquarks

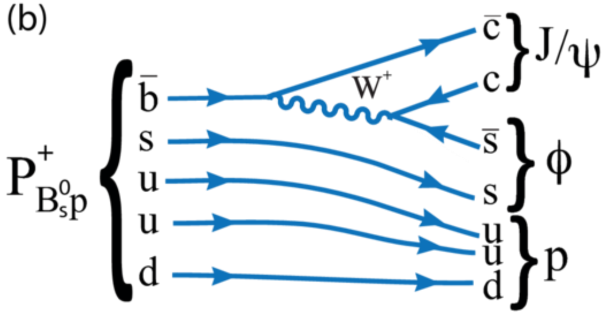
PRD 97 (2018) 032010

- Skyrme model: heavy quarks give tightly bound pentaquarks

(a)



(b)



PLB 590(2004) 185;
PLB 586(2004)337;
PLB 331(1994)362

- Search for mass peaks below strong decay threshold

Mode	Quark content	Decay mode	Search window
I	$\bar{b}duud$	$P^+_{B^0p} \to J/\psi K^+\pi^- p$	4668–6220 MeV
II	$b\bar{u}udd$	$P^-_{\Lambda^0_b\pi^-} \to J/\psi K^-\pi^- p$	4668–5760 MeV
III	$b\bar{d}uud$	$P^+_{\Lambda^0_b\pi^+} \to J/\psi K^-\pi^+ p$	4668–5760 MeV
IV	$\bar{b}suud$	$P^+_{B^0_sp} \to J/\psi \phi p$	5055–6305 MeV

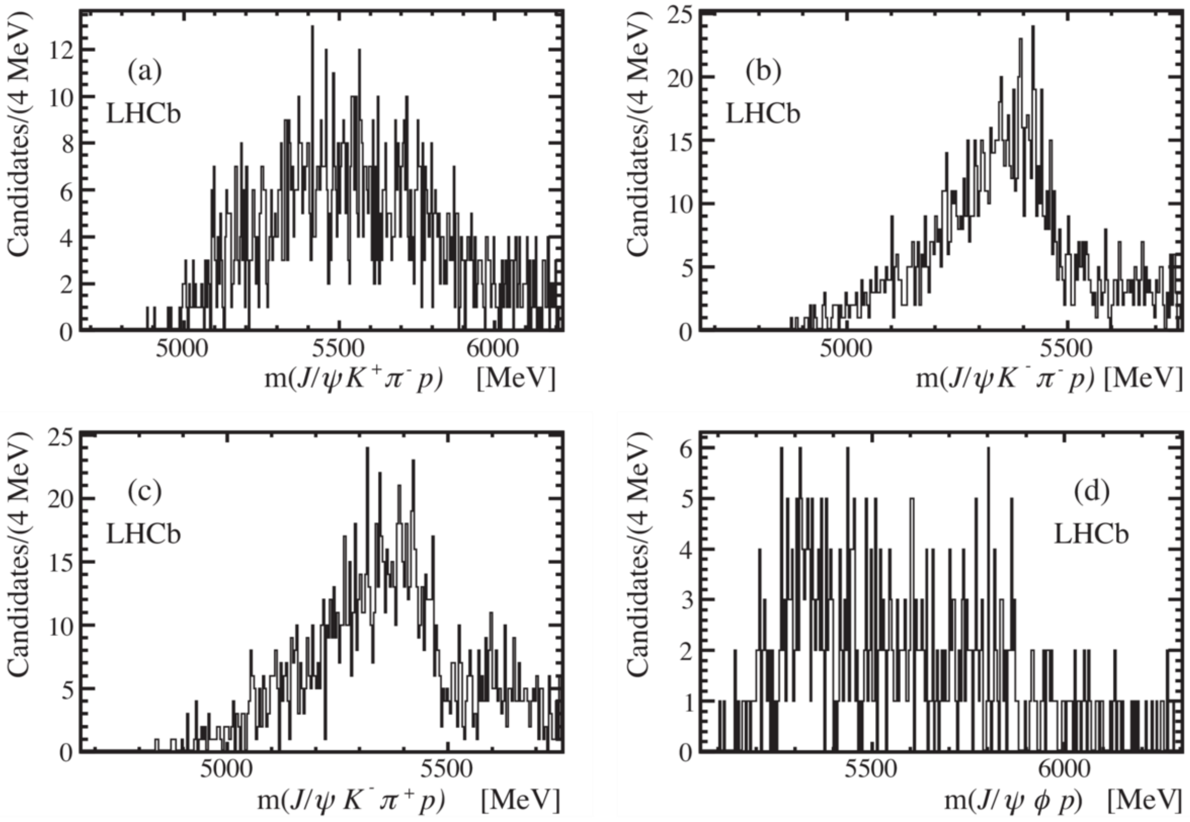
- Upper limit on production ratio $\sigma \cdot B$ wrt $\Lambda_b^0 \to J/\Psi K^- p$

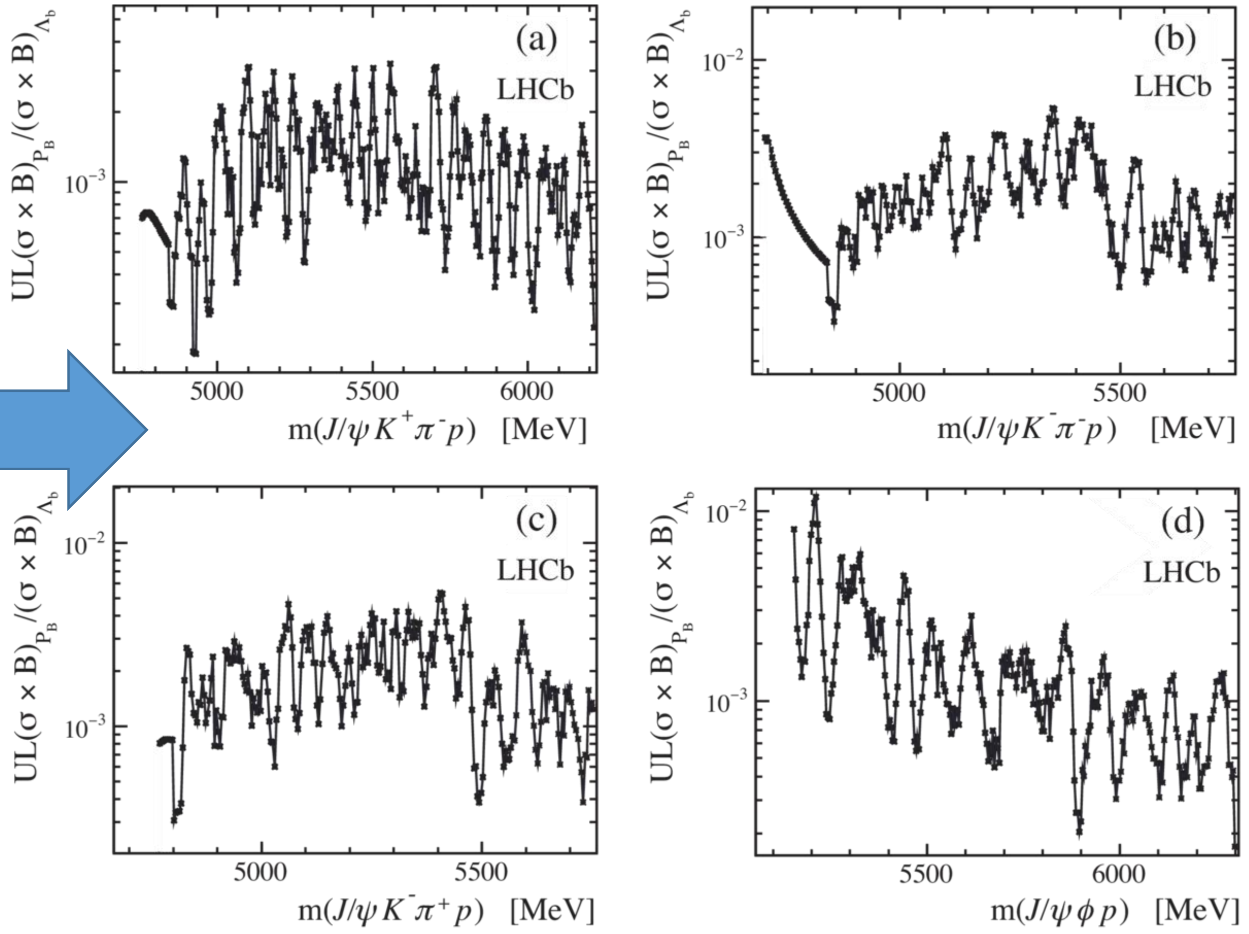
$$R = \frac{\sigma(pp \to P_B X) \cdot \mathcal{B}(P_B \to J/\psi X)}{\sigma(pp \to \Lambda_b^0 X) \cdot \mathcal{B}(\Lambda_b^0 \to J/\psi K^- p)}$$

Weakly decaying *b*-flavoured pentaquarks

PRD 97 (2018) 032010

- No evidence for signal, 90% CL upper limits are set for the ratio

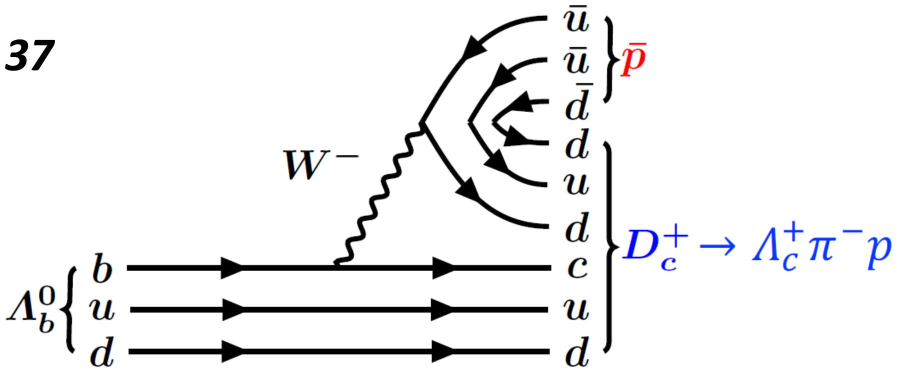




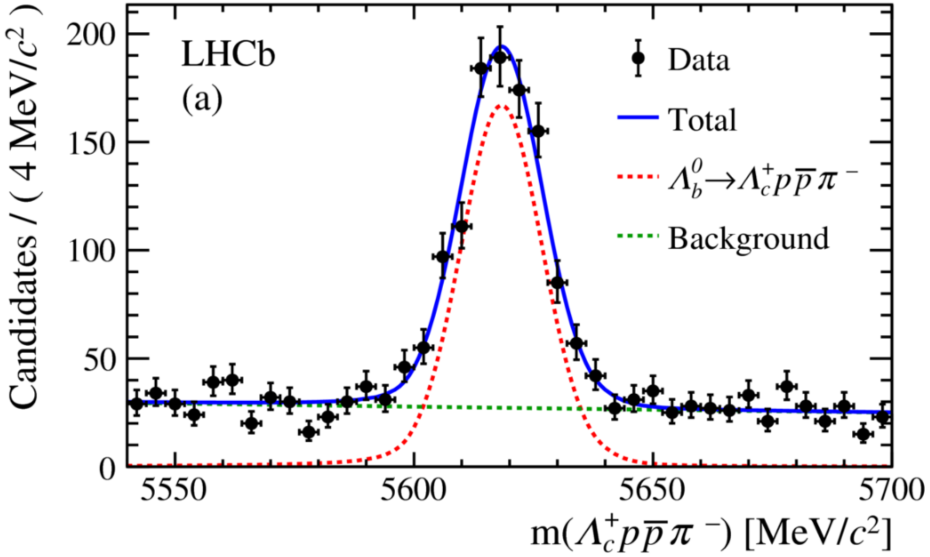
Search for dibaryon state

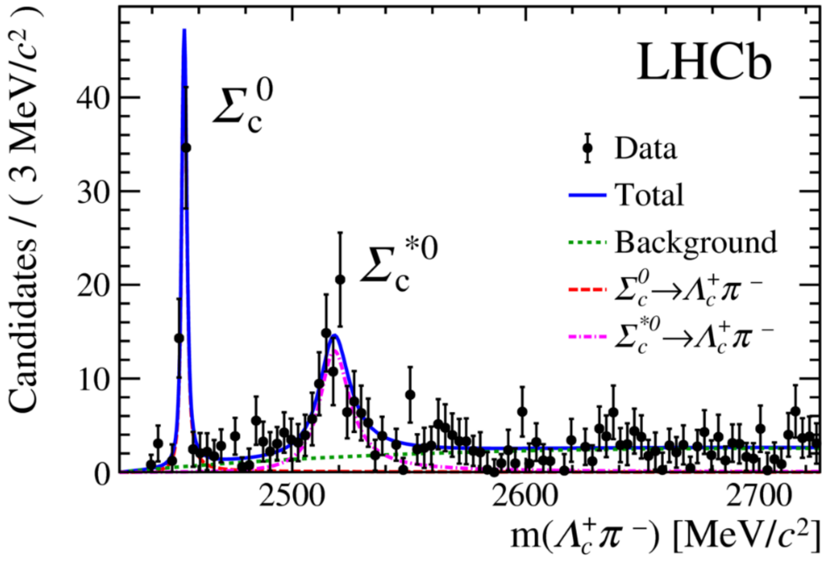
PHYS. LETT. B784 (2018) 101

- A dibaryon state $[cd][ud][ud]$ could be produced in Λ_b^0 decays to final state $\Lambda_c^+\pi^+p\bar{p}$ **L. Maiani, et al. PLB 750 (2015) 37**



- LHCb has discovered the decay $\Lambda_b^0 \to \Lambda_c^+\pi^+p\bar{p}$





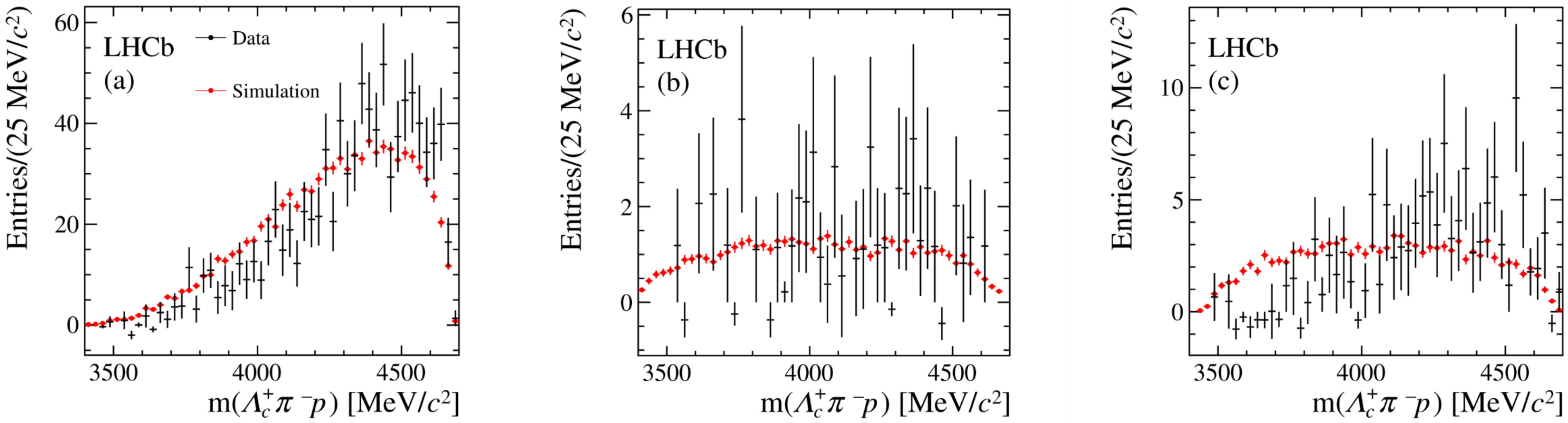
Search for dibaryon state

PHYS. LETT. B784 (2018) 101

- Ratio of branching fractions

$$\frac{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ p\bar{p}\pi^-)}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-)} = 0.0540 \pm 0.0023 \pm 0.0032$$

- No obvious dibaryon peak in $m(\Lambda_c^+\pi^- p)$ spectra



All signals | Σ_c^0 region signals | Σ_c^{*0} region signals