B meson decays to charmless baryonic final states at LHCb: results and future prospects

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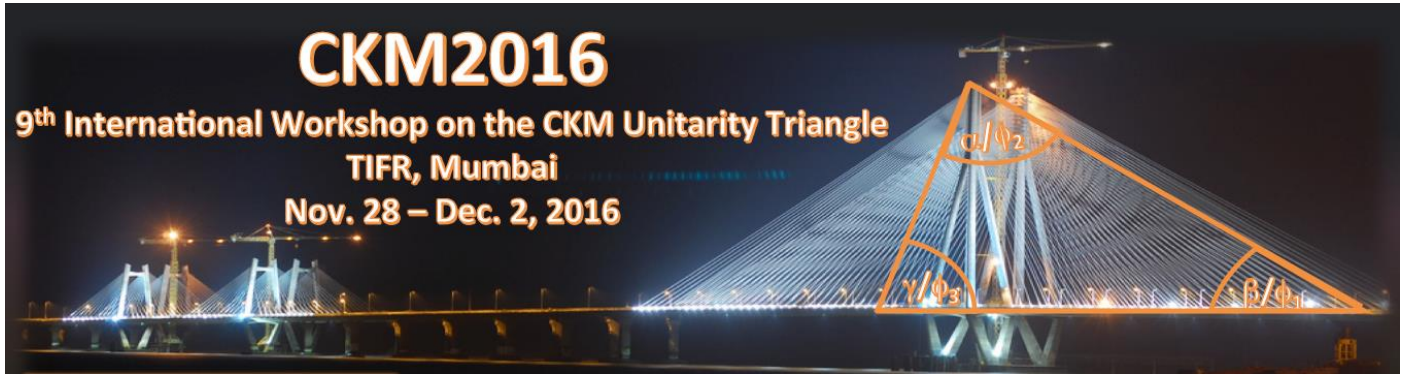
On behalf of the LHCb collaboration



Baryonic B decays – motivation

- Inclusive branching fraction to baryonic final states ~ 7% of B total width !
  - Most decay modes still to be studied / observed

- Threshold enhancement in baryon-antibaryon system observed in many decay modes
  [see e.g. “The physics of the B factories”, Eur. Phys. J. C74 (2014) 3026]

- Many-body final states tend to have a larger BF than 3- and 2-body final states

$$\mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}\pi^+\pi^-) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}\pi^0) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}),$$

$$\begin{aligned} \mathcal{B}(\overline{B} \to \mathfrak{B}_{1c}\overline{\mathfrak{B}}_{2c}) &\sim 10^{-3} \\ \gg \mathcal{B}(\overline{B} \to \mathfrak{B}_c\overline{\mathfrak{B}}) &\sim 10^{-5} \\ \gg \mathcal{B}(\overline{B} \to \mathfrak{B}_1\overline{\mathfrak{B}}_2) &\lesssim 10^{-6} \end{aligned}$$

- Theoretical description is a challenge and various models “in competition”

Baryonic B decays – short history

B factories

- 2002: 1st observation of a baryonic B decay
- Many B^0 and B^+ baryonic decays observed and studied, with charm in the final state, or charmless
- Experimental observation of threshold enhancement in baryon-antibaryon invariant mass in several decay modes

LHC(b)

- 2013: 1st observation of a 2-body charmless baryonic mode: $B^+ \to p\,\bar{\Lambda}(1520)$ [PRL 113, 141801 (2014)]
- 2013: 1st evidence for CP violation in a baryonic B decay, seen in $B^+ \to p\,\bar{p}\,K^+$ [PRL 113, 141801 (2014)]
- 2013: 1st evidence for very suppressed $B^0 \to p\,\bar{p}$ with 2011 data analysis [JHEP 10 (2013) 005]
- 2014: 1st observation of a baryonic B_c decay [PRL 113, 152003 (2014)]

First evidence for the $B^+ \to p\,\bar{\Lambda}$ decay

LHCb-PAPER-2016-048. ArXiv:1611.07805

Search for $B^+ \to p\,\overline{\Lambda}$ – motivation

- 2-body baryonic B decays are rather suppressed ⇒ need LHCb, as not seen @ B factories
- 1st evidence for $B^0 \to p\,\bar{p}$ with 2011 data analysis **[JHEP 10 (2013) 005]**
- 1st observation of a 2-body charmless baryonic mode: $B^+ \to p\,\overline{\Lambda}(1520)$ **[PRL 113, 141801 (2014)]**

- $B^+ \to p\,\overline{\Lambda}$ seems like the next obvious decay to look for

- Experimental data :

	Belle	CLEO
90% C.L. upper limit	3.2×10^{-7}	2.6×10^{-6}
Reference	PRD 75 (2007) 111101	PRD 59 (1999) 111101

- Calculations predict a BF ~ 10^{-8}-10^{-7}

[PRD 91 (2015) 077501; PRD 89 (2014) 056003; PRD 66 (2002) 014020; NPB 345 (1990) 137]

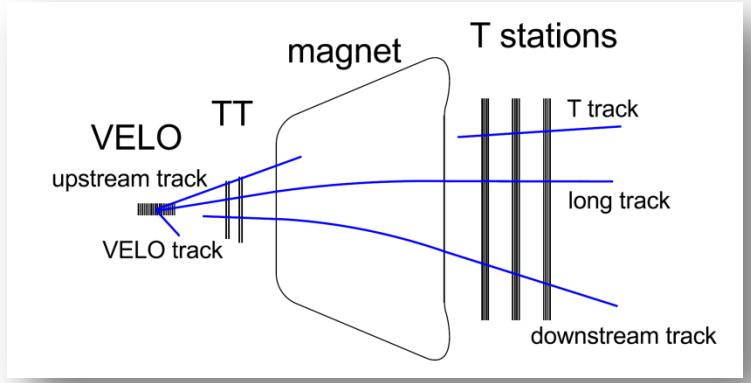
Search for $B^+ \to p\,\overline{\Lambda}$ – analysis

Analysis strategy

- **Blinded search**
- **Branching fraction measured relative to normalisation mode $B^+ \to K_S\,\pi^+$**
  - **Topologically identical decay, large BF**

$$\mathcal{B}(B^+ \to p\overline{\Lambda}) = \frac{N(B^+ \to p\overline{\Lambda})}{N(B^+ \to K^0_S\pi^+)} \frac{\epsilon_{B^+\to K^0_S\pi^+}}{\epsilon_{B^+\to p\overline{\Lambda}}} \frac{\mathcal{B}(K^0_S \to \pi^+\pi^-)}{\mathcal{B}(\Lambda \to p\pi^-)} \mathcal{B}(B^+ \to K^0_S\pi^+)$$

- **Similar selection for both decay modes**



Data

- **Analysis on full run-I data sample**
- **Data split according to year and V^0 reconstruction category (*long* or *downstream* tracks)**
  - **Studies proved a viable procedure to merge all subsamples for the mass fit**
- **Decay chain fitted with V^0 mass constrained**

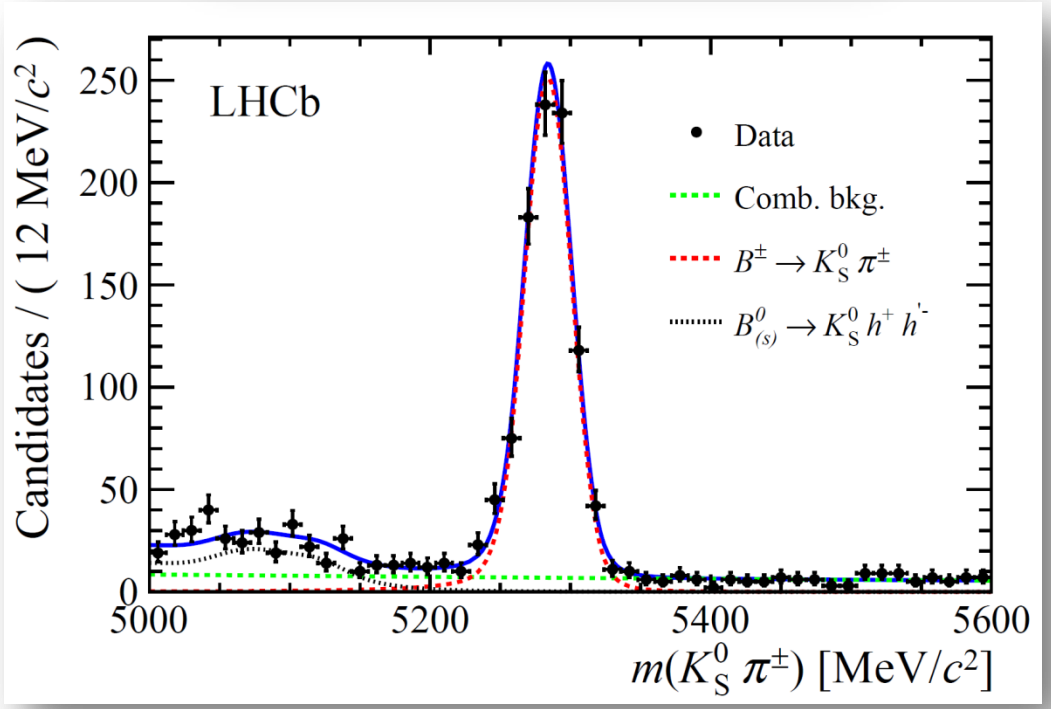
Search for $B^+ \to p\,\overline{\Lambda}$ – normalisation mode fit

LHCb-PAPER-2016-048

- Extended maximum likelihood fit considering
  signal, cross-feed (very small), partially reconstructed backgrounds, combinatorial background

$$N(B^+ \to K^0_S \pi^+) = 930 \pm 34$$

- Double Crystal Ball functions for
  $B^+ \to K_S\, h^+$ decays
- Partially reconstructed backgrounds
  from $B_{(s)} \to K_S\, h^+\, h^{(\prime)-}$ decays
- Exponential for combinatorial
  background



Search for $B^+ \to p\,\overline{\Lambda}$ – signal fit

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- Extended maximum likelihood fit considering signal and combinatorial background

- Fitted yield :

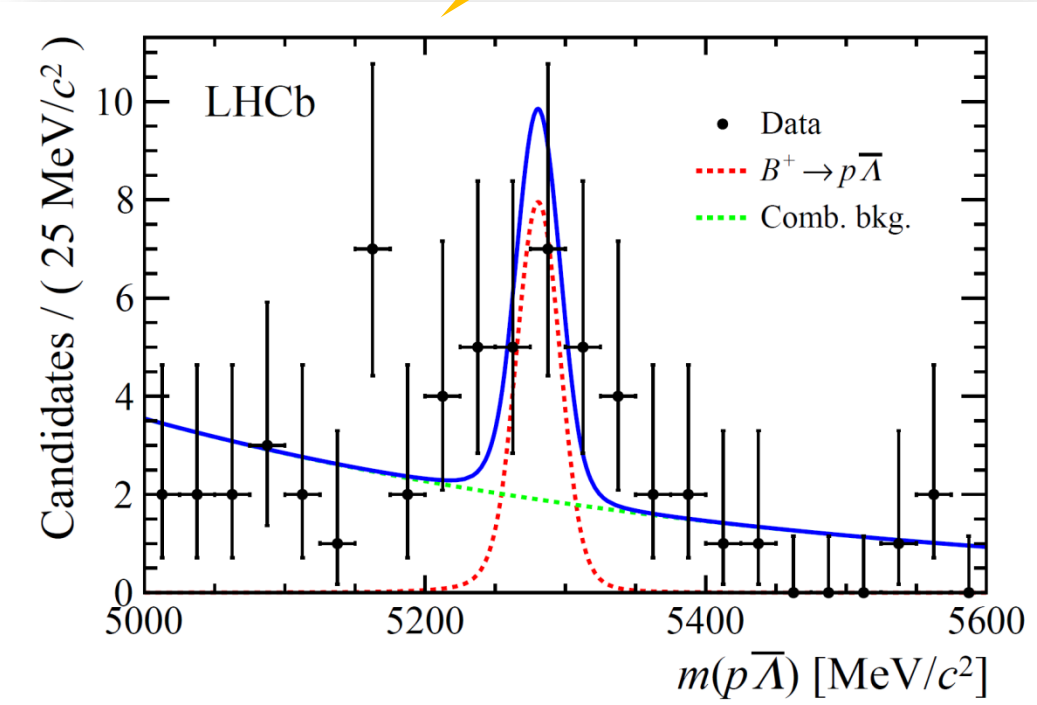
$$N(B^+ \to p\overline{\Lambda}) = 13.0^{+5.1}_{-4.3}$$

- Statistical significance of 4.1 σ calculated with toys
  - Marginal change when including systematic uncertainties of 6.7% affecting the signal yield

- Fit systematics (6.7%) are dominant, together with systematics on ratio of tracking efficiencies (6%)

- Total systematic uncertainties = 12.0%

Evidence for $B^+ \to p\,\overline{\Lambda}$!



First evidence for $B^+ \to p\,\overline{\Lambda}$

LHCb-PAPER-2016-048

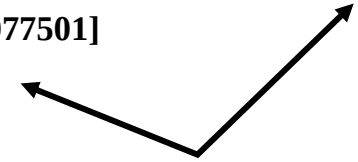
- Run-I blind search

- First evidence for rare 2-body charmless baryonic decay $B^+ \to p\ \overline{\Lambda}$ decay
- With a statistical significance of 4.1σ

- Branching fraction measured to be

$$\mathcal{B}(B^+ \to p\overline{\Lambda}) \quad = \quad (2.4\,^{+1.0}_{-0.8} \pm 0.3) \times 10^{-7}$$

  - Compatible with most recent theoretical predictions [PRD 66 (2002) 014020; PRD 89 (2014) 056003]
  - In tension with predictions in [NPB 345 (1990) 137; PRD 91 (2015) 077501]



Work triggered by publication of 1st evidence for $B^0 \to p\,\bar{p}$ by LHCb.

- Submitted to JHEP

First observation of a baryonic B_s decay

LHCb-CONF-2016-016

Search for baryonic B_s decays – motivation

- Baryonic B decays observed for all B species *except* the B_s meson !

- 2-body modes are rather suppressed ⇒ exploit 3-body final states

- $B_s^0 \to p\,\bar{\Lambda}\,K^-$ is a good candidate given that the related mode $B^0 \to p\,\bar{\Lambda}\,\pi^-$ has a large branching fraction ~ 3 x 10^{-6} and is well studied

- Experimental data :

Decay Channel	BaBar $\mathcal{B}$ or UL	Belle $\mathcal{B}$ or UL
$B^0 \to p\bar{\Lambda}\pi^-$	$(3.07 \pm 0.39) \times 10^{-6}$	$(3.23\,^{+0.33}_{-0.29} \pm 0.29) \times 10^{-6}$
$B^0 \to p\bar{\Lambda}K^-$	-	$< 8.2 \times 10^{-7}$
$B_s^0 \to p\bar{\Lambda}K^-$	-	-
$B_s^0 \to p\bar{\Lambda}\pi^-$	-	-
$B^0 \to p\bar{\Sigma}^0\pi^-$	-	$< 3.8 \times 10^{-6}$
$B_s^0 \to p\bar{\Sigma}^0 K^-$	-	-

- No theoretical predictions available to date

Search for $B_s^0 \to p\,\overline{\Lambda}\,K^-$ – analysis

LHCb-CONF-2016-016

Analysis strategy

- Branching fraction measured relative to normalisation mode $B^0 \to p\,\overline{\Lambda}\,\pi^-$
  - Topologically identical decay, large BF

$$\mathcal{B}(B_s^0 \to p\overline{\Lambda}K^-) = \frac{f_d}{f_s}\,\frac{N(B_s^0 \to p\overline{\Lambda}K^-)}{N(B^0 \to p\overline{\Lambda}\pi^-)}\,\frac{\epsilon_{B^0 \to p\overline{\Lambda}\pi^-}}{\epsilon_{B_s^0 \to p\overline{\Lambda}K^-}}\,\mathcal{B}(B^0 \to p\overline{\Lambda}\pi^-)$$

- Similar selection for both decay modes

Data

- Analysis on full run-I data sample
- Data split according to year and V^0 reconstruction category
  - Studies proved a viable procedure to merge all subsamples for the mass fit
- Decay chain fitted with V^0 mass constrained

- Long or downstream tracks

Search for $B_s^0 \to p\,\bar{\Lambda}\,K^-$ – analysis

LHCb-CONF-2016-016

Background studies

- Non resonant decays mode $B \to p\,\bar{p}\,\pi h$ ⇒ suppressed by Λ selection
- Resonant decays:
  - Charmonia decaying to $p\,\bar{p}$ ⇒ suppressed by Λ selection
  - Final states with a K_S instead of a Λ baryon ⇒ no contribution from such decays found in data
- Cross-feed from misidentification:
  - Pion-kaon misID between signal and control modes ⇒ crucial in fits since part of signal model
  - Proton-pion/kaon misID from $\Lambda_b \to \Lambda\,p\,\bar{p}$ ⇒ suppressed thanks to small branching fraction & small tails into signal region
- Partially reconstructed backgrounds:
  - $B_{(s)} \to p\,\bar{\Sigma}^0\,h^-$ ⇒ can sneak under signal peaks given small Σ-L mass difference ~ 77 MeV
  - $B^0 \to p\,\bar{\Lambda}\,\rho^-$, $B_s \to p\,\bar{\Lambda}\,K^*$ ⇒ largely suppressed by selection

Fit strategy

- Simultaneous fit to the 8 spectra : 2 final states x 2 years x 2 Λ reconstruction categories

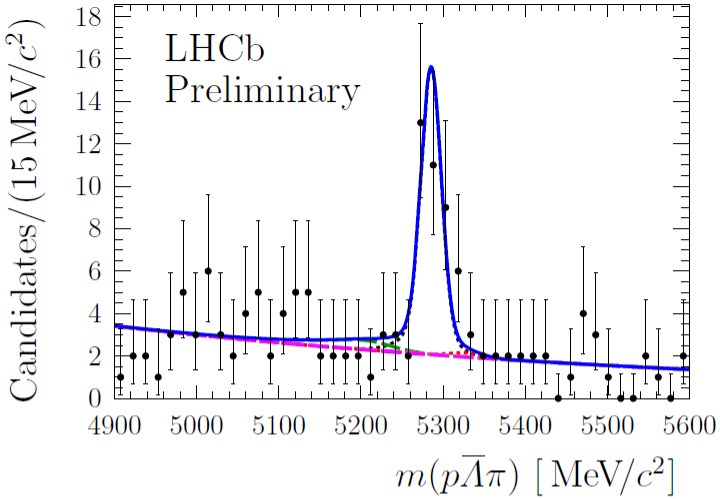
1st obs. of a baryonic B_s decay – 2011 fit proj.

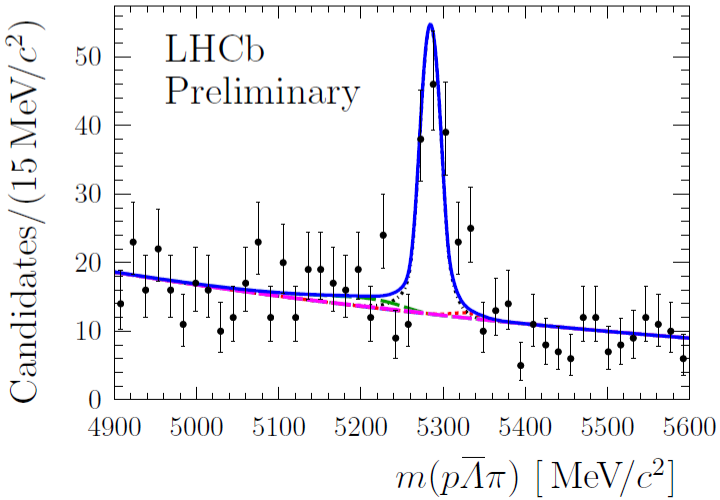
LHCb-CONF-2016-016

Long sample

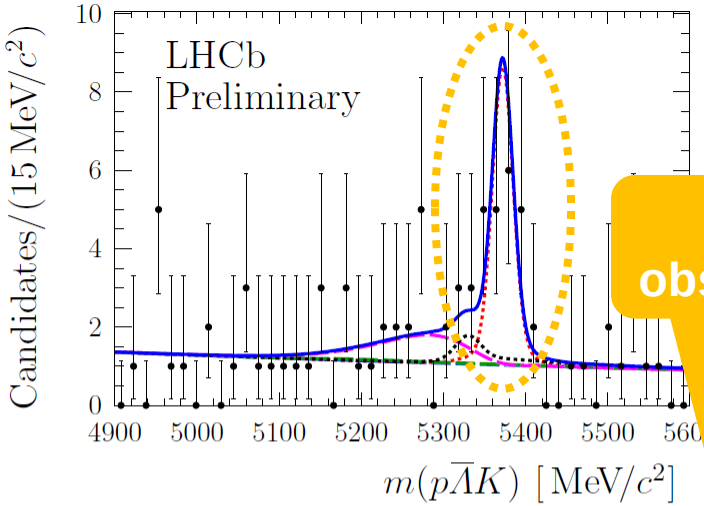
Downstream sample

$p\bar{\Lambda}\pi$

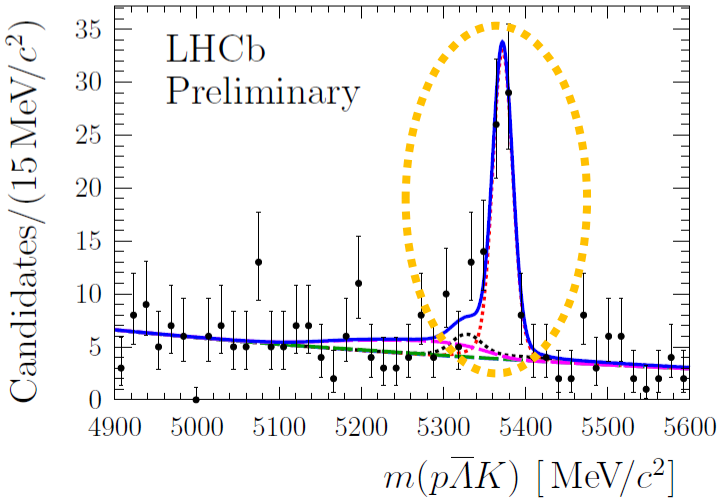




$p\bar{\Lambda}K$



1st observation !



1st obs. of a baryonic B_s decay – 2012 fit proj.

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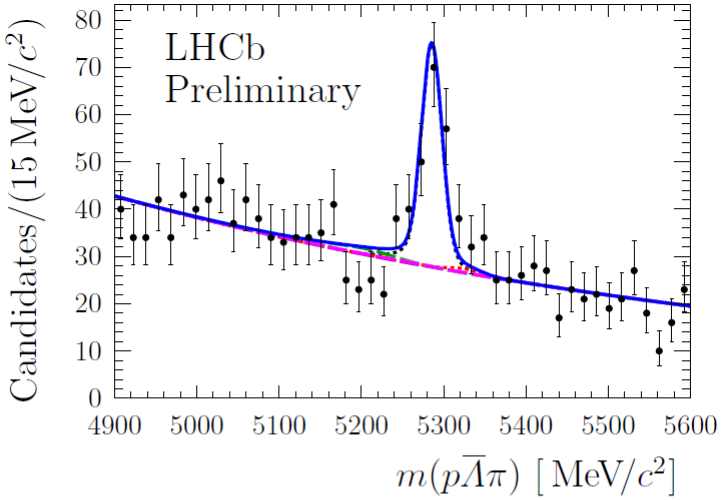
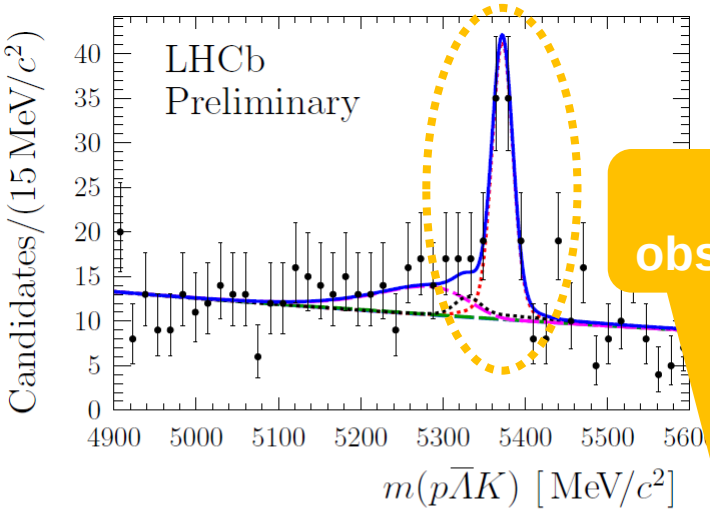
$p\bar{\Lambda}\pi$ | $p\bar{\Lambda}K$

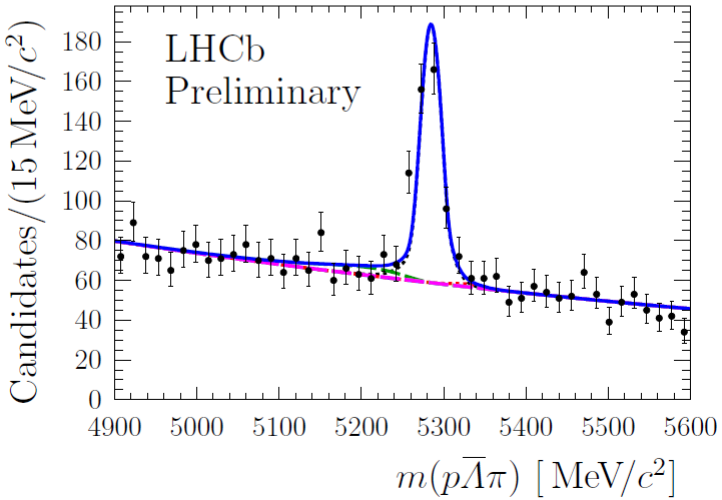
Long sample

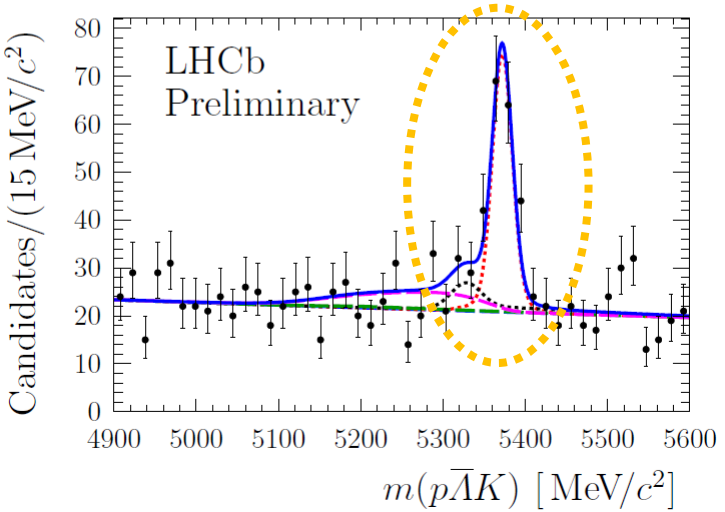




1st observation !

Downstream sample





1st obs. of a baryonic B_s decay – 2-part. proj.

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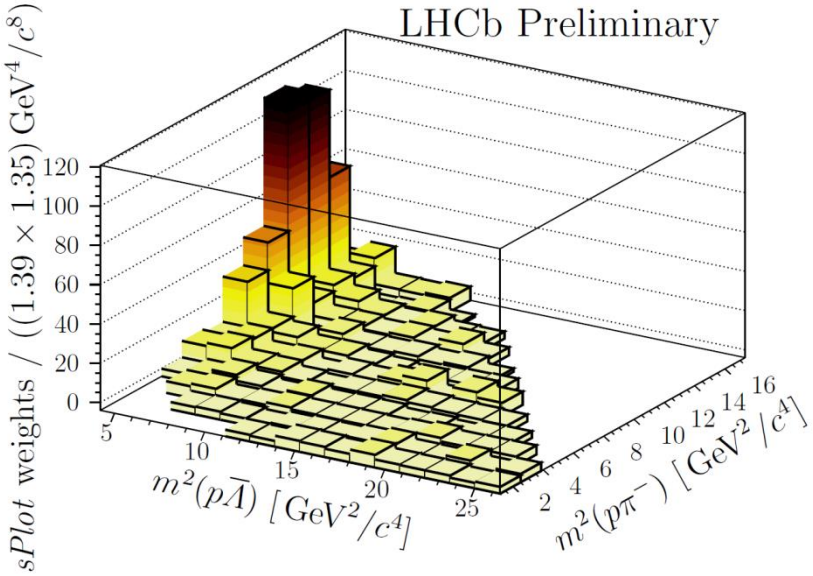
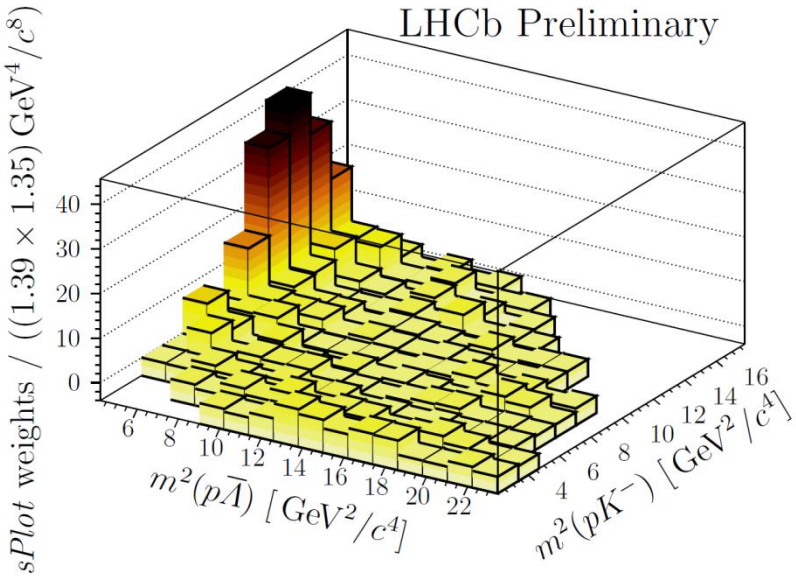
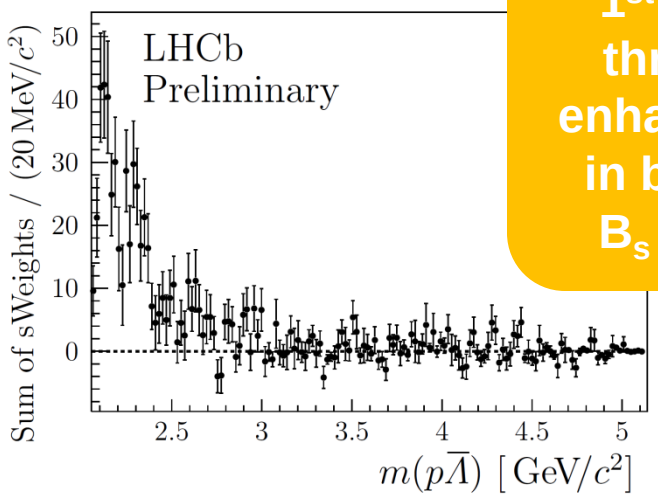
$B^0 \to p\bar{\Lambda}\pi$

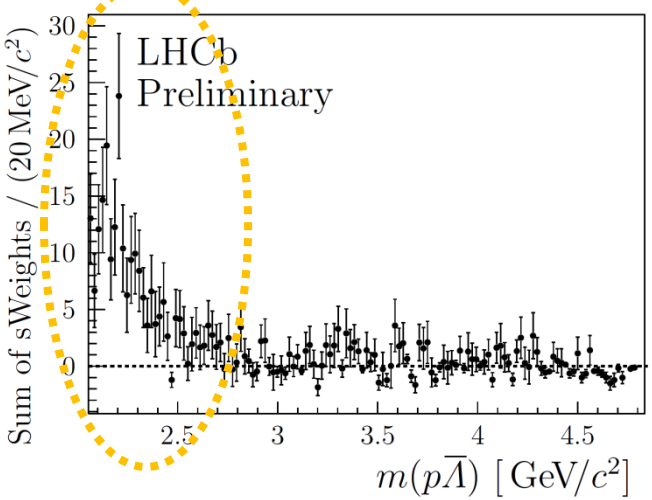


$B_s \to p\bar{\Lambda}K$





1st obs. of threshold enhancement in baryonic B_s decays



First observation of a baryonic B_s decay

LHCb-CONF-2016-016

- First observation of a baryonic B_s decay !
- With a statistical significance of > 15σ

- Branching fraction measured to be

  (Note: BF calculated assuming that effective lifetime is the average B_s lifetime)

$$\mathcal{B}(B_s^0 \to p\overline{\Lambda}K^-) = \left[5.48^{+0.82}_{-0.80}\,(\text{stat}) \pm 0.60\,(\text{syst}) \pm 0.51(\mathcal{B}) \pm 0.32(f_s/f_d)\right] \times 10^{-6}$$

Uncertainty on $B^0 \to p\overline{\Lambda}\pi$ branching fraction

Uncertainty on ratio of fragmentation probabilities

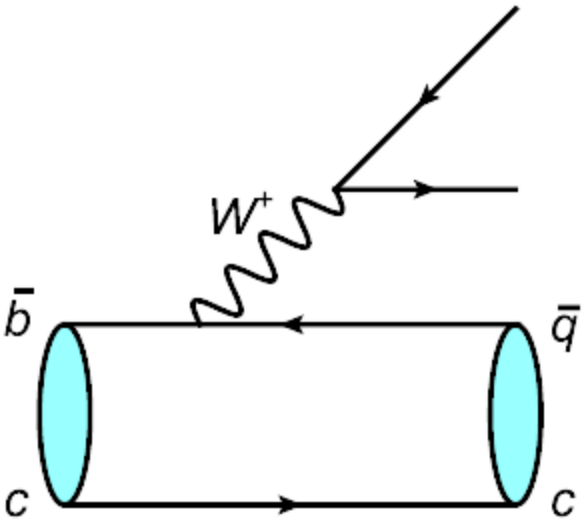
Result opens a new area of research on baryonic B decays

- So far baryonic Bs decays only studied theoretically **[PRD 91 (2015) 077501; PRD 89 (2014) 056003]** in case of 2-body final states following the 1st evidence for $B^0 \to p\,\overline{p}$ reported by LHCb in 2013 **[JHEP10(2013)005]**

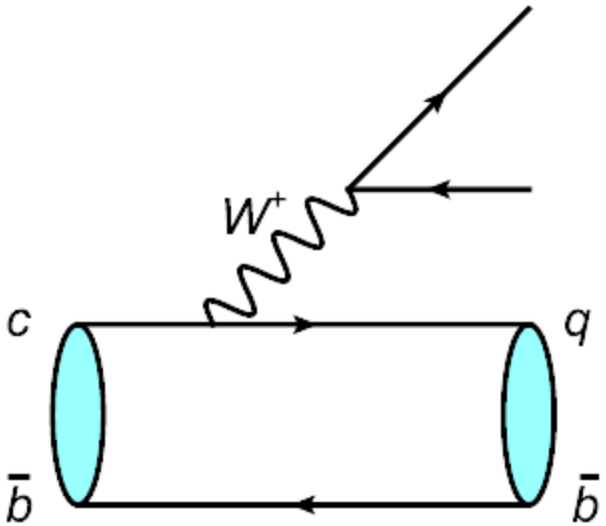
Searches for charmless B_c decays

Search for charmless B_c decays - motivation

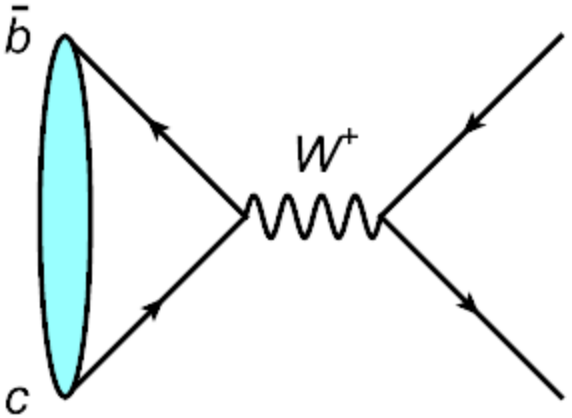
$b \to c, u$



$c \to s, d$



$c\bar{b}$ annihilation



Charmless B_c decays proceed exclusively through annihilation !

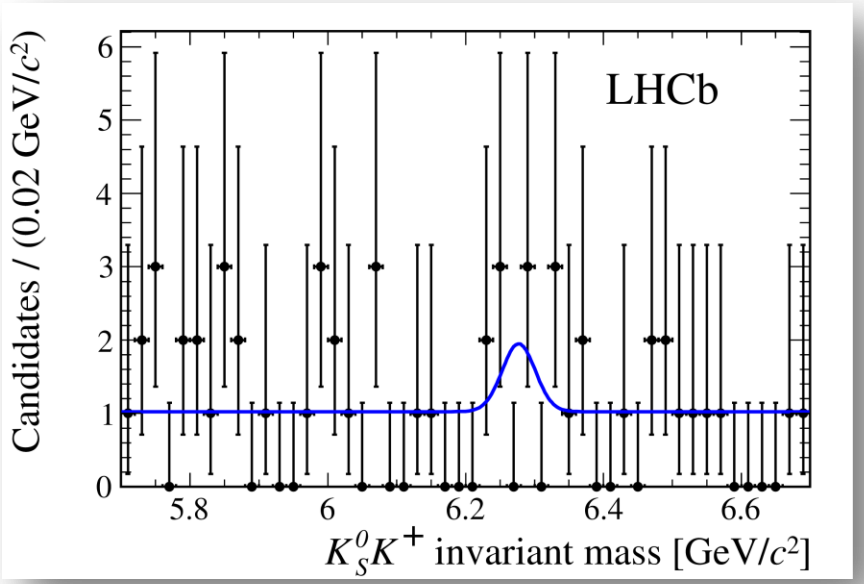
Rather suppressed but natural ground to study annihilation processes …

Search for charmless (baryonic) B_c decays - motivation

- LHCb already performed search for 2-body decay $B_c^+ \to K_S^0 K^+$
  - 90% C. L. upper limit

Phys. Lett. B 726 (2013) 646-655

$$\frac{f_c}{f_u} \cdot \frac{\mathcal{B}(B_c^+ \to K_S^0 K^+)}{\mathcal{B}(B^+ \to K_S^0 \pi^+)} < 5.8 \times 10^{-2}$$



- Searches for 3-body modes seem natural
- Decays $B_c^+ \to K\,K\,\pi^+$ and $B_c^+ \to p\,\bar{p}\,\pi^+$ among simplest modes
  - Due to Cabibbo suppression $\left|\frac{V_{us}}{V_{ud}}\right| \sim 0.2$, final states with no net strangeness dominate

Search for $B_c^+ \to p\,\bar{p}\,\pi^+$

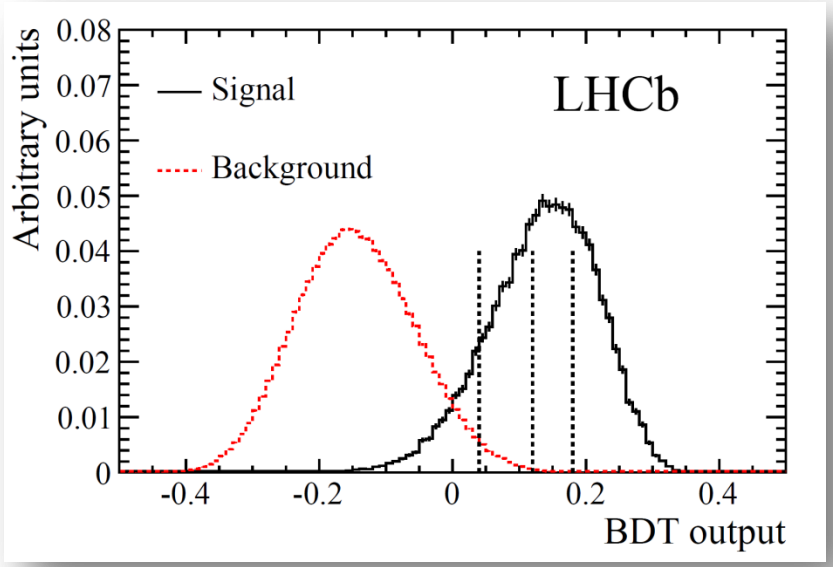
PLB 759 (2016) 313-321

Motivation

- 1st search for a charmless baryonic B_c decay

Analysis

- Full run-I data sample (3 fb^{-1})
- Branching fraction relative to that of $B^+ \to p\,\bar{p}\,\pi^+$
- Measurement sensitivity enhanced by considering 3 MVA regions
- Focus on charmless region $m(p\bar{p}) < 2.85$ GeV, i.e. the annihilation region

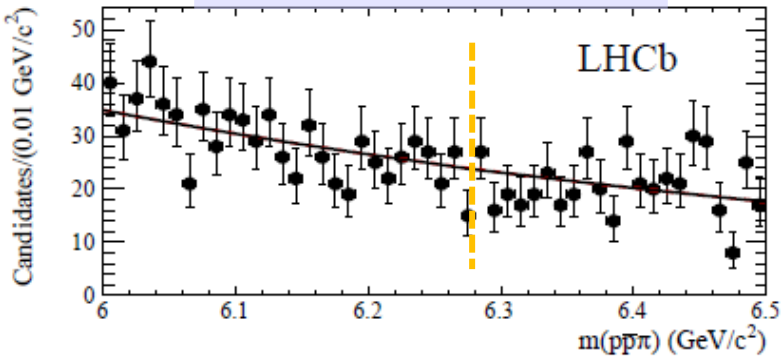


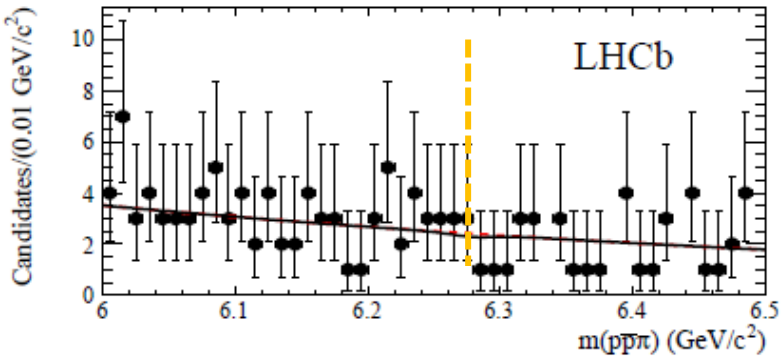
Search for $B_c^+ \to p\,\bar{p}\,\pi^+$

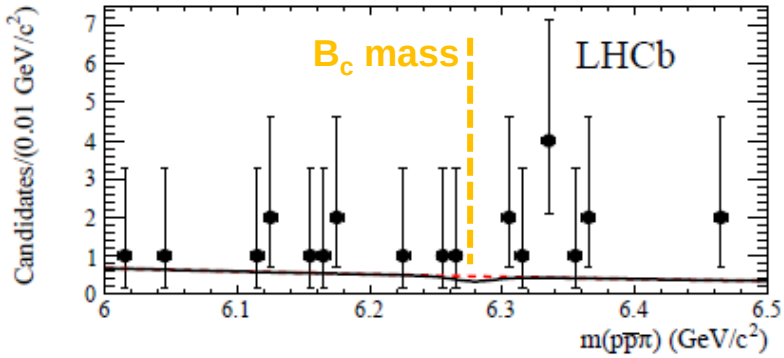
PLB 759 (2016) 313-321

MVA selection regions

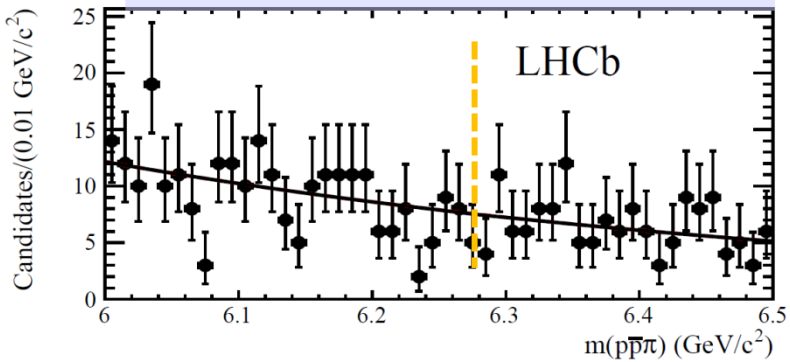
$m(p\bar{p}) < 2.85$ GeV

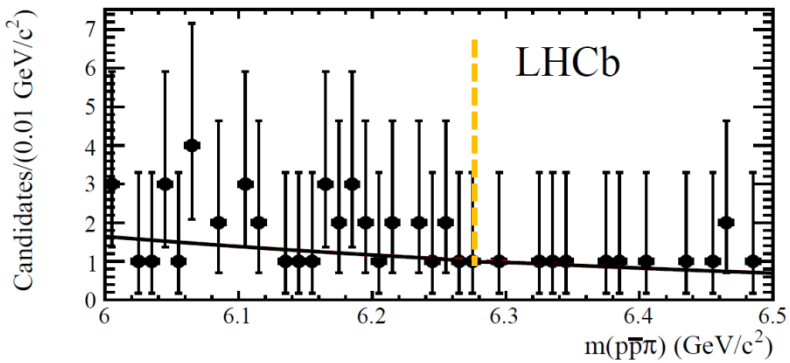


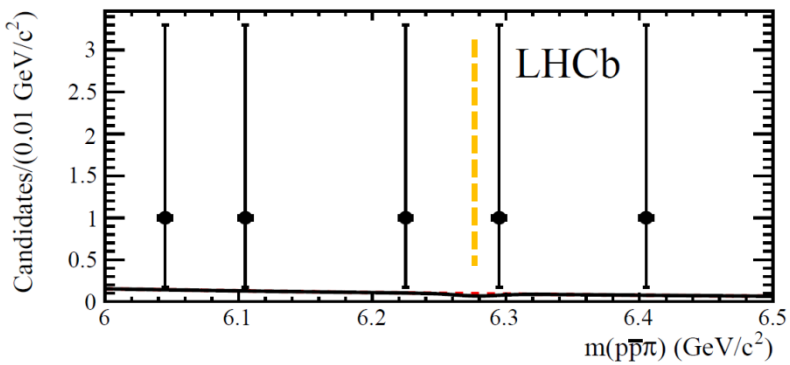




$2.85 < m(p\bar{p}) < 3.15$ GeV







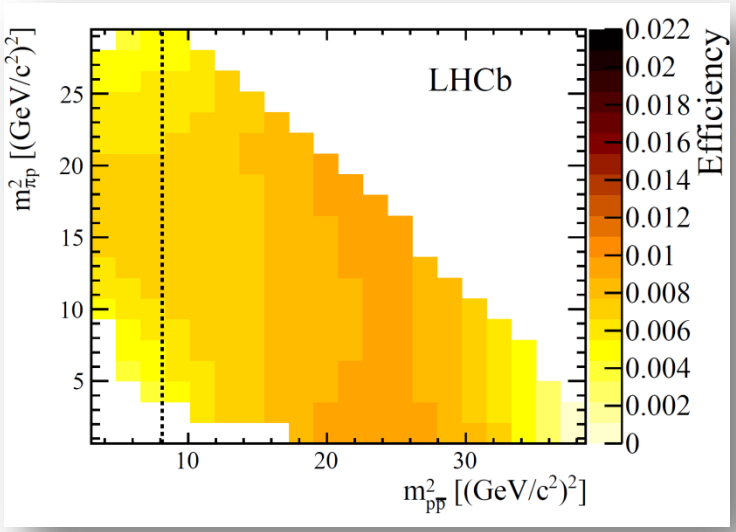
Search for $B_c^+ \to p\,\bar{p}\,\pi^+$

PLB 759 (2016) 313-321

- Systematics totally dominated by
  lack of knowledge of distribution of events
  and variation of efficiency
  over the phase space of the decay

Source	$B_c^+ \to p\bar{p}\pi^+$, $m(p\bar{p}) < 2.85$ GeV/c^2
PID	3.0
B_c^+ lifetime	2.0
Simulation	0.8
Detector acceptance	0.6
BDT shape	1.5
Hardware trigger correction	0.8
Fiducial cut	0.1
Modelling	15
$\mathcal{B}(B^+ \to p\bar{p}\pi^+)$	15
$\mathcal{B}(J/\psi \to p\bar{p})$	–

$B_c^+ \to p\,\bar{p}\,\pi^+$



- 95% C.L. upper limit

$$\frac{f_c}{f_u} \times \mathcal{B}(B_c^+ \to p\bar{p}\pi^+) < 3.6 \times 10^{-8}$$

- In the charmless region $\mathrm{m}(p\bar{p}) < 2.85$ GeV
- In the kinematic region $p_T(B) < 20$ GeV and region $2.0 < \mathrm{y}(B) < 4.5$

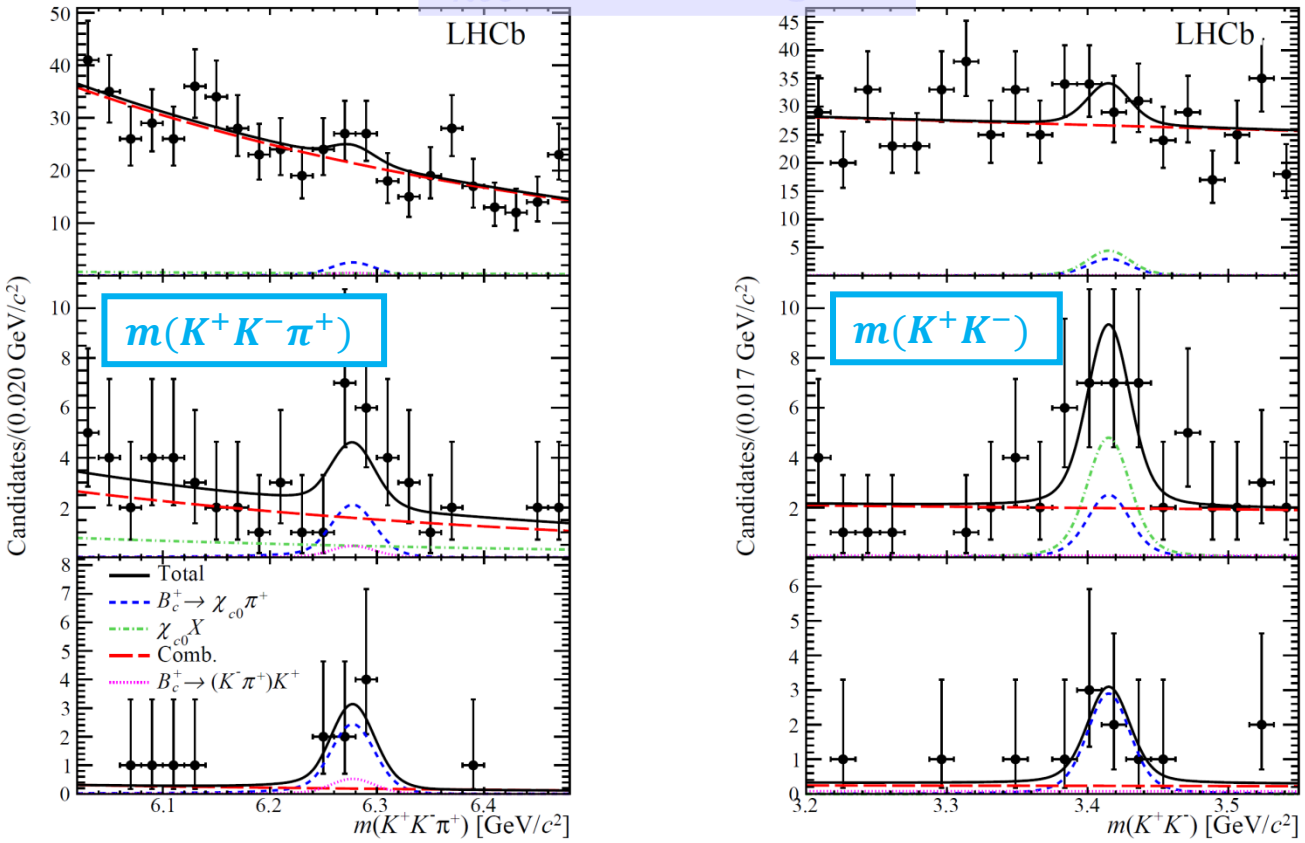
Search for $B_c^+ \to K^+ K^- \pi^+$

arXiv:1607.06134

- Analysis strategy very similar to that of the search for $B_c^+ \to p \bar{p} \pi^+$
- Very rich physics expected in the very large phase space available

4σ evidence for $B_c^+ \to \chi_{c0} \pi^+$

$\chi_{c0} \to K^+ K^-$ region



MVA selection regions

$$\frac{\sigma(B_c^+)}{\sigma(B^+)} \times \mathcal{B}(B_c^+ \to \chi_{c0}\pi^+) = (9.8^{+3.4}_{-3.0}(\text{stat}) \pm 0.8(\text{syst})) \times 10^{-6}$$

Outlook

Search for charmless (baryonic) B_c decays - prospects

- These 2 recent LHCb searches for charmless B_c decays open a new area of activity
- In run II the selection efficiencies are expected to improve by a factor 2 !
  $\Rightarrow$ up to ~ 50-100 mesonic annihilation decays ?
- Physics potential of these decays can be better exploited with an upgraded dectector and 50 fb^{-1} of collected data, though
  $\Rightarrow$ up to ~ 1k events depending on the decay modes … ?
- Baryonic modes likely to be suppressed wrt mesonic modes by ~ 1 order of magnitude

Outlook

- Run I has been providing an amazing number of results !
  - Some totally unexpected, e.g the discovery of pentaquarks
  - At times in areas where LHCb was not expected to be able to perform the analyses
- Study of baryonic B decays not an exception

- Run II will provide a lot more statistics
- The LHCb detector and data collection flow is much improved also !
- *Expect a lot and hope for surprises !*

Thank you

Back-up slides

First evidence for $B^+ \to p\,\overline{\Lambda}$ – systematic uncertainties

Assessed with calibration samples

From V^0 reconstruction studies, Geant4 data-simulation agreement, etc.

Source	Value [%] $B^+ \to p\overline{\Lambda}$	Value [%] $B^+ \to K^0_S\pi^+$
$\mathcal{B}(B^+ \to K^0_S\pi^+)$	-	3.2
Trigger efficiencies ratio	3.5	-
Selection efficiencies ratio	2.2	-
PID uncertainties	1.2	3.5
Tracking efficiencies ratio	6.0	-
Yields from mass fits	6.7	3.0
Simulation statistics	1.7	3.3
Total	10.1	6.5

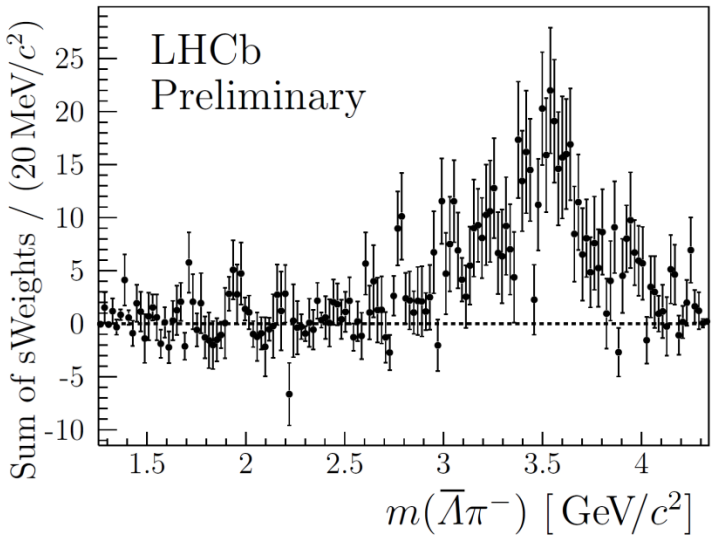
From limited knowledge or from choice of mass models, and from uncertainties on values of fixed parameters in fits

Assessed with simulation and from data-simulation agreement in control mode

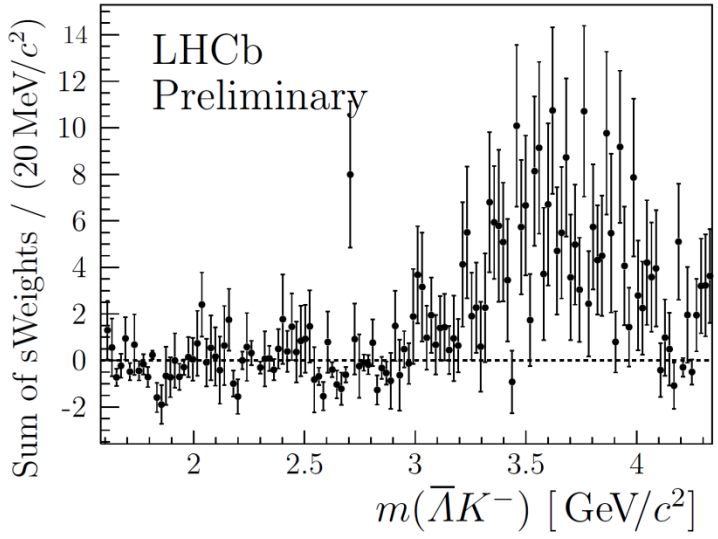
1st obs. of a baryonic B_s decay – 2-part. proj.

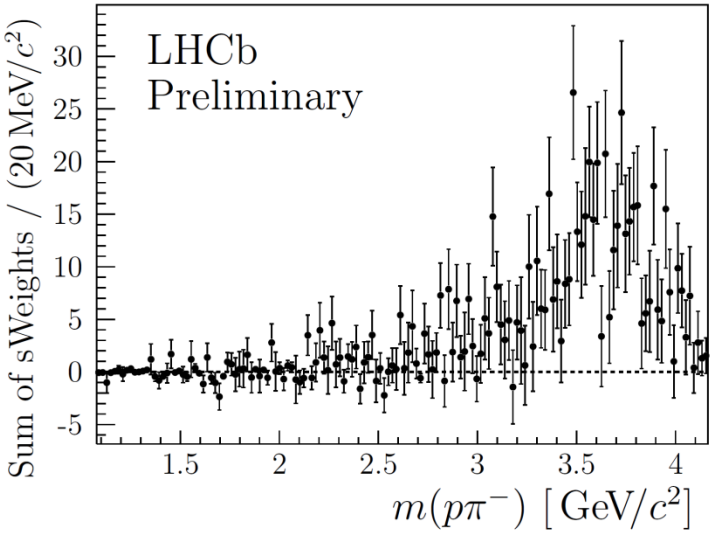
LHCb-CONF-2016-016

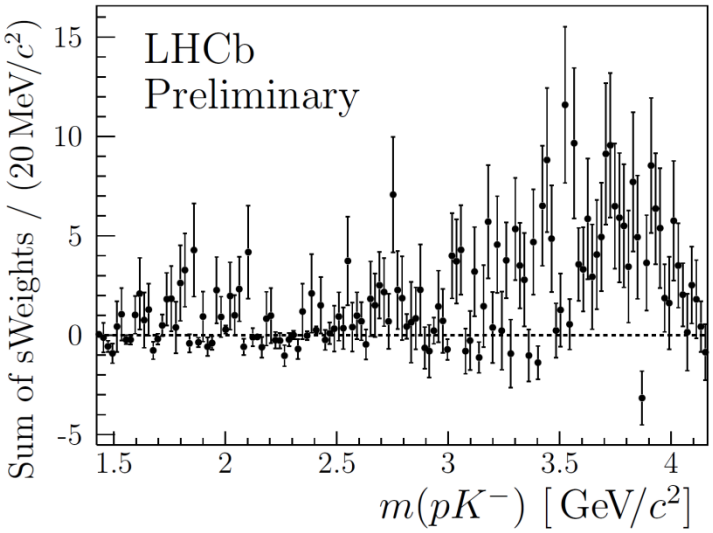
$B^0 \to p\bar{\Lambda}\pi$



$B_s \to p\bar{\Lambda}K$







Charmless B_c decays … realistically …

- Typical BFs for charmless modes are in the range 10^{-8}-10^{-6}
  - With large theoretical uncertainties depending on the calculation approach

Phys. Rev. D 81, 014022 (2010)

Decay modes ($\Delta S = 0$)	BRs (10^{-7})
$B_c \to \rho^+ \pi^0$	$0.5^{+0.1}_{-0.1}(m_c)^{+0.3}_{-0.2}(a_i)^{+0.2}_{-0.3}(m_0)$
$B_c \to \rho^+ \eta$	$5.4^{+2.1}_{-1.2}(m_c)^{+0.9}_{-1.4}(a_i) \pm 0.0(m_0)$
$B_c \to \rho^+ \eta'$	$3.6^{+1.4}_{-0.8}(m_c)^{+0.6}_{-0.9}(a_i) \pm 0.0(m_0)$
$B_c \to \bar{K}^{*0} K^+$	$10.0^{+0.5}_{-0.6}(m_c)^{+1.7}_{-3.3}(a_i)^{+0.0}_{-0.2}(m_0)$

pQCD approach
Chin. Sci. Bull. 59 (2014) 3748-3759; arXiv:1401.0151 [hep-ph]

Decay Modes	BRs(10^{-7})	f_L(%)	$\phi_{\|\|}$ (rad)	$\phi_\perp$ (rad)
$B_c \to \rho^+ \rho^0$	0	–	–	–
$B_c \to \rho^+ \omega$	$10.6^{+3.8}_{-0.3}$	$92.9^{+2.0}_{-0.1}$	$3.86^{+0.40}_{-0.32}$	$4.43^{+0.30}_{-0.25}$
$B_c \to \overline{K}^{*0} K^{*+}$	$10.0^{+8.1}_{-4.8}$	$92.0^{+3.6}_{-7.1}$	$3.68^{+0.51}_{-0.25}$	$3.76^{+0.51}_{-0.20}$
$B_c \to K^{*0} \rho^+$	$0.6^{+0.2}_{-0.1}$	$94.9^{+2.2}_{-1.5}$	$4.11^{+0.34}_{-0.28}$	$4.20^{+0.33}_{-0.22}$
$B_c \to K^{*+} \rho^0$	$0.3^{+0.1}_{-0.1}$	$94.9^{+1.4}_{-1.5}$	$4.11^{+0.34}_{-0.28}$	$4.20^{+0.33}_{-0.22}$
$B_c \to K^{*+} \omega$	$0.3^{+0.0}_{-0.2}$	$94.8^{+1.2}_{-1.3}$	$4.15^{+0.28}_{-0.35}$	$4.23^{+0.28}_{-0.26}$
$B_c \to \phi K^{*+}$	$0.5^{+0.1}_{-0.3}$	$86.4^{+4.9}_{-9.1}$	$3.80^{+0.51}_{-0.39}$	$3.89^{+0.48}_{-0.28}$

- Assuming ~ 10^9 B_c events produced per year at LHCb interaction point
- And a selection efficiency ~ 1%
- One cannot realistically probe below ~ 10^{-6}
- Modes $B_c \to K^{*0}$bar K^+ , K_S K^+ seen as most promising … and some being looked at …

➡ *A broad study of charmless B_c decays requires the LHCb upgrade …*

1st evidence for a B decay to a baryonic final state

(Belle Collaboration)

We report the observation of the decay mode $B^{\pm} \to p\bar{p}K^{\pm}$ based on an analysis of 29.4 fb^{-1} of data collected by the Belle detector at KEKB. This is the first example of a $b \to s$ transition with baryons in the final state. The $p\bar{p}$ mass spectrum in this decay is inconsistent with phase space and is peaked at low mass. The branching fraction for this decay is measured to be $\mathcal{B}(B^{\pm} \to p\bar{p}K^{\pm}) = (4.3^{+1.1}_{-0.9}(\text{stat}) \pm 0.5(\text{syst})) \times 10^{-6}$. We also report upper limits for the decays $B^0 \to p\bar{p}K_S$ and $B^{\pm} \to p\bar{p}\pi^{\pm}$.

$$\mathcal{B}(B^{+} \to p\bar{p}K^{+}) = (4.3^{+1.1}_{-0.9}(\text{stat}) \pm 0.5(\text{syst})) \times 10^{-6}$$

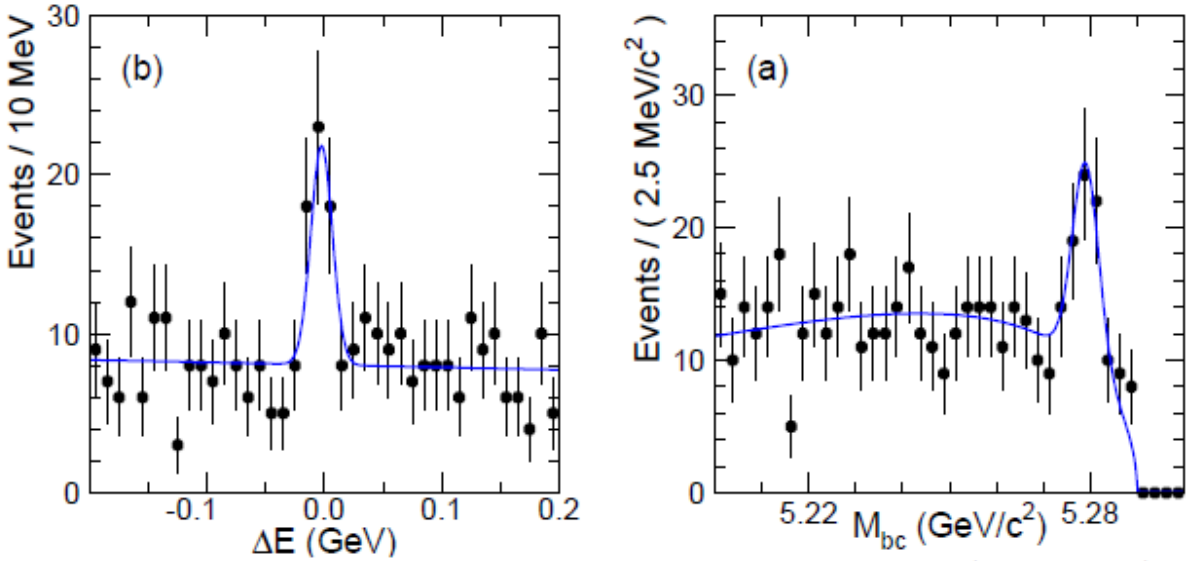


FIG. 1. (a) ΔE and (b) $M_{\rm bc}$ distributions for $B^{+} \to p\bar{p}K^{+}$ candidates.

Phys. Rev. Lett. 88, 181803 (2002)

Baryonic B decays – experimental facts

- Many-body final states tend to have a larger BF than 3- and 2-body final states

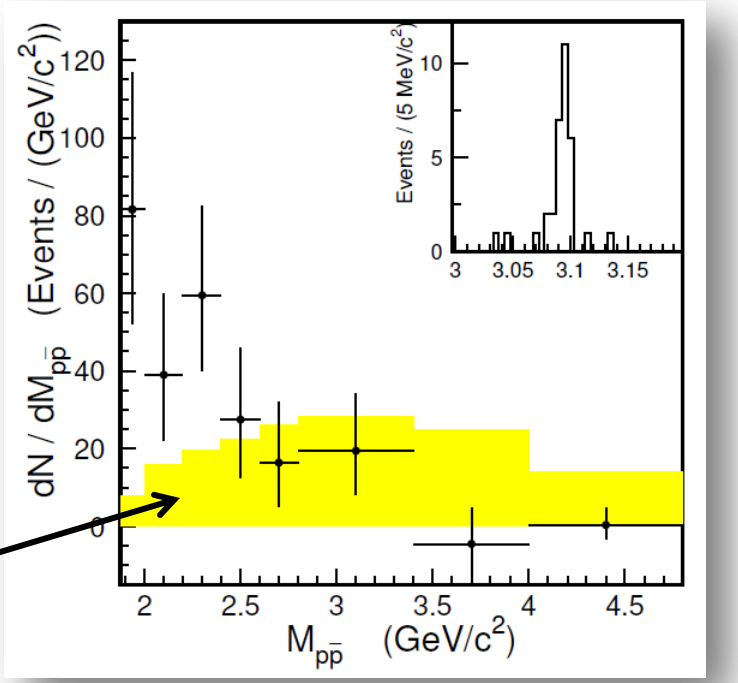
$$\mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}\pi^+\pi^-) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}\pi^0) \gg \mathcal{B}(\overline{B}^0 \to \Lambda_c^+ \overline{p}),$$

$$\begin{aligned} \mathcal{B}(\overline{B} \to \mathfrak{B}_{1c}\overline{\mathfrak{B}}_{2c}) &\sim 10^{-3} \\ \gg \mathcal{B}(\overline{B} \to \mathfrak{B}_c\overline{\mathfrak{B}}) &\sim 10^{-5} \\ \gg \mathcal{B}(\overline{B} \to \mathfrak{B}_1\overline{\mathfrak{B}}_2) &\lesssim 10^{-6} \end{aligned}$$

- Observation of threshold enhancement in baryon-antibaryon system
  - Example in $B^+ \to p\overline{p}K^+$

⇒ fast recoiling meson against baryon-antibaryon system

Prediction for phase-space decay



Baryonic B-meson decays – the rare $B^0 \to p\bar{p}$

JHEP 10 (2013) 005

- First evidence for a 2-body charmless baryonic B^0 decay ! (significance: 3.3σ)

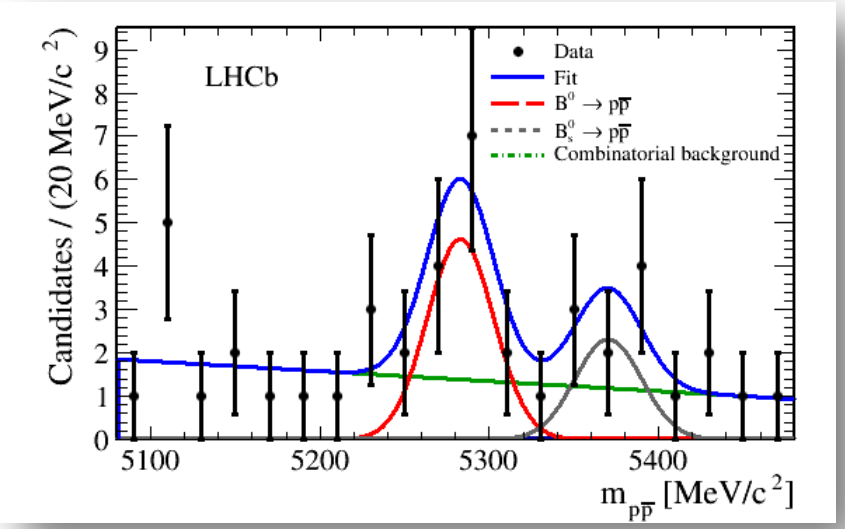
- No significant B_s signal observed and published result improved previous search by 3 orders of magnitude

$$\mathcal{B}(B^0 \to p\bar{p}) = \left(1.47\,^{+0.62}_{-0.51}\,^{+0.35}_{-0.14}\right) \times 10^{-8} \text{ at } 68.3\% \text{ CL}$$

$$\mathcal{B}(B^0 \to p\bar{p}) = \left(1.47\,^{+1.09}_{-0.81}\,^{+0.69}_{-0.18}\right) \times 10^{-8} \text{ at } 90\% \text{ CL}$$

$$\mathcal{B}(B^0_s \to p\bar{p}) = \left(2.84\,^{+2.03}_{-1.68}\,^{+0.85}_{-0.18}\right) \times 10^{-8} \text{ at } 68.3\% \text{ CL}$$

$$\mathcal{B}(B^0_s \to p\bar{p}) = \left(2.84\,^{+3.57}_{-2.12}\,^{+2.00}_{-0.21}\right) \times 10^{-8} \text{ at } 90\% \text{ CL}$$

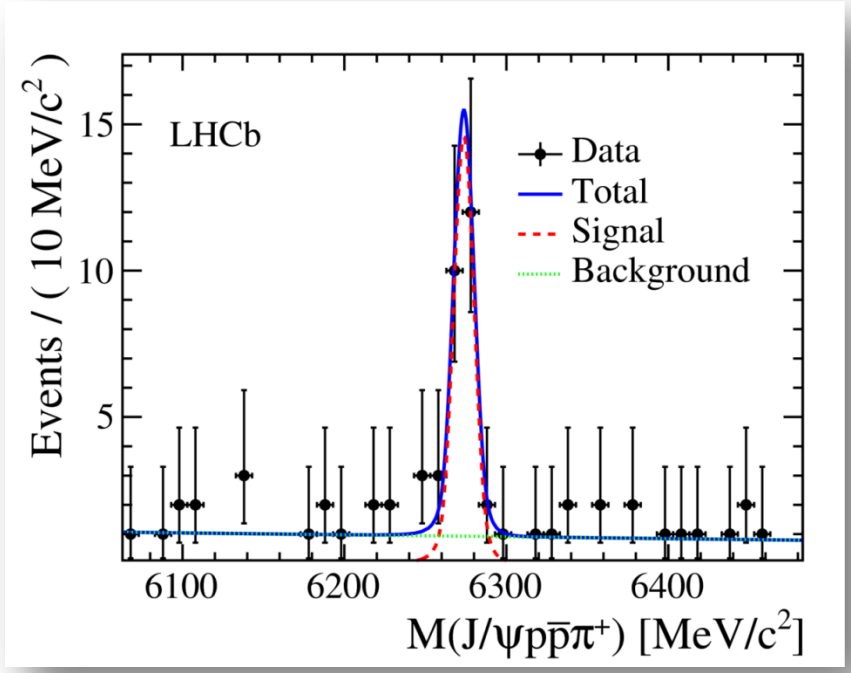


- This $B^0 \to p\bar{p}$ branching fraction excluded all theoretical predictions by 1-2 orders of magnitude
  - Motivated newer calculations (see e.g. previous page)

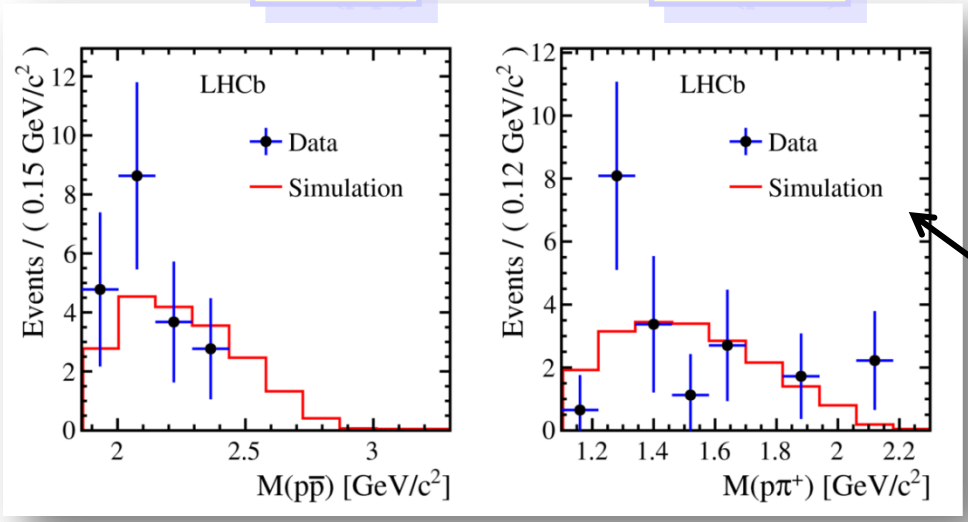
1st observation of a baryonic B_c decay

PRL 113 (2014) 153003

- Signal significance : 7.3σ
- Full run-I data sample (3 fb^{-1})



$m(p\bar{p})$ $m(p\pi^+)$



Simulation =
using a phase space model

LHCb tracking detectors and track types