Results on baryon spectroscopy from LHCb

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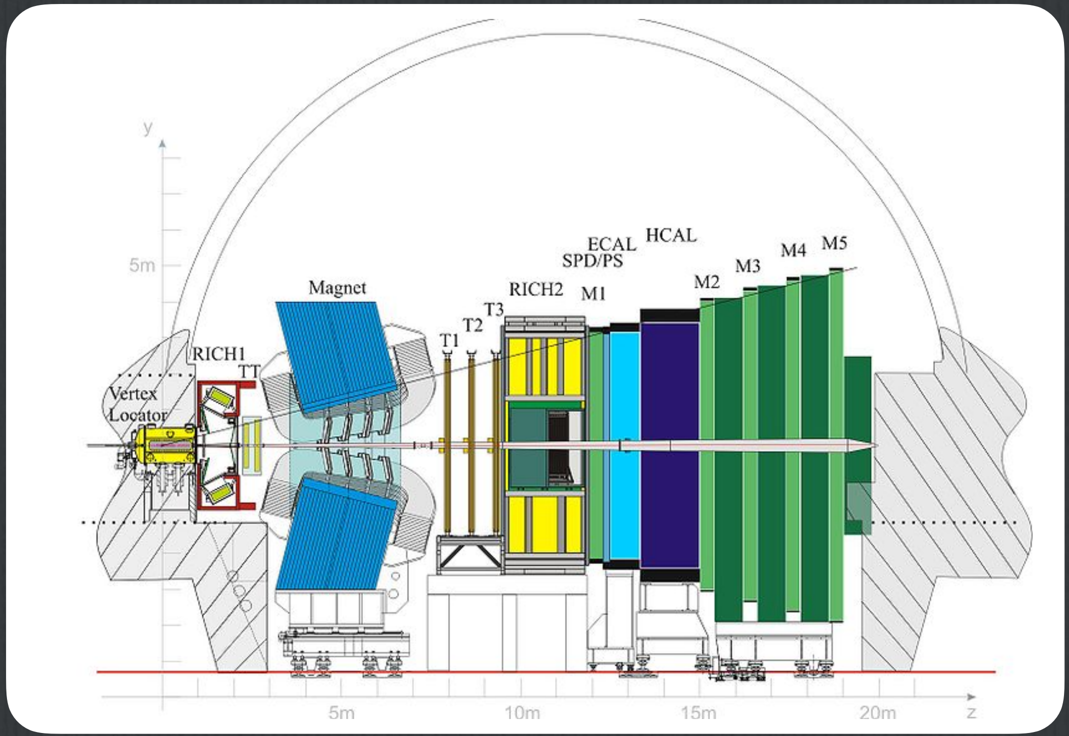
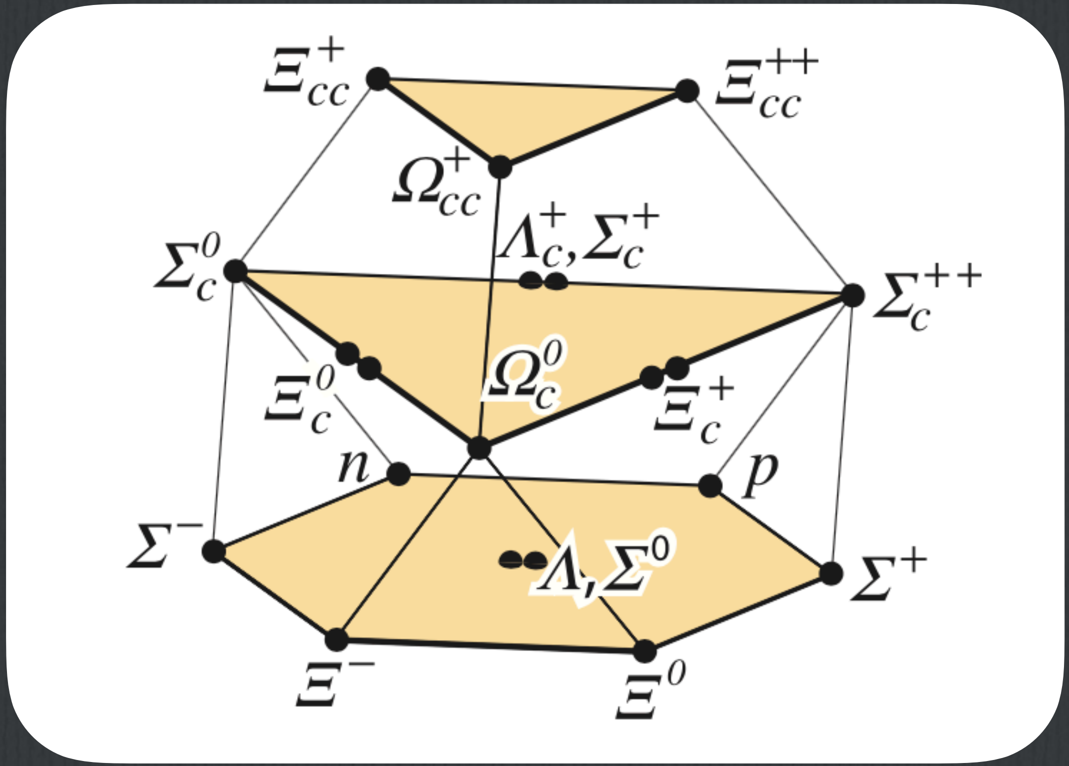
Outline

- Introduction
- Study of D^0p amplitude in $\Lambda^0_b \to D^0 p \pi^-$
- Measurement of the $\Lambda^0_b \to \Lambda^+_c \mu^- \bar{\nu}_\mu$ differential decay rates
- Observation of Five New Narrow Ω^0_c States
- Conclusion

Introduction

- LHC is a heavy baryon factory
- LHCb can provide unique datasets
- Baryon spectroscopy and precision measurements are an important test for the standard model

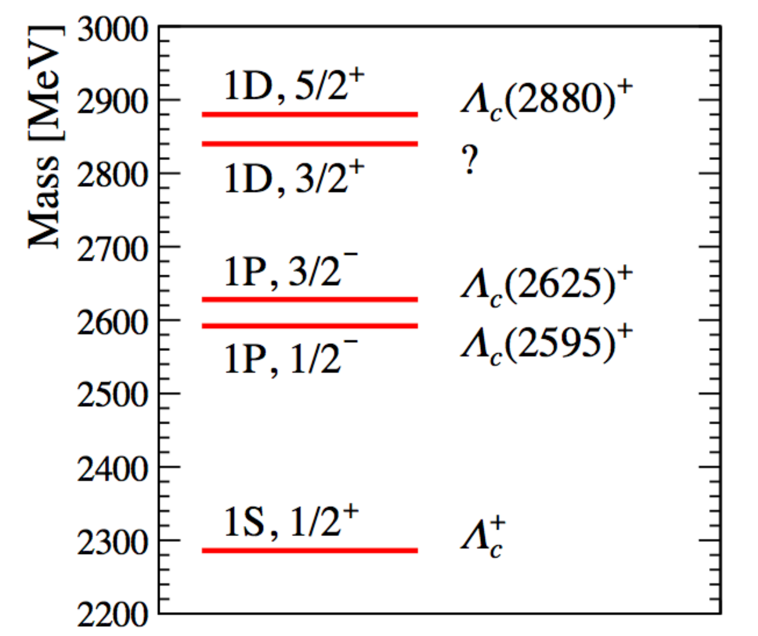




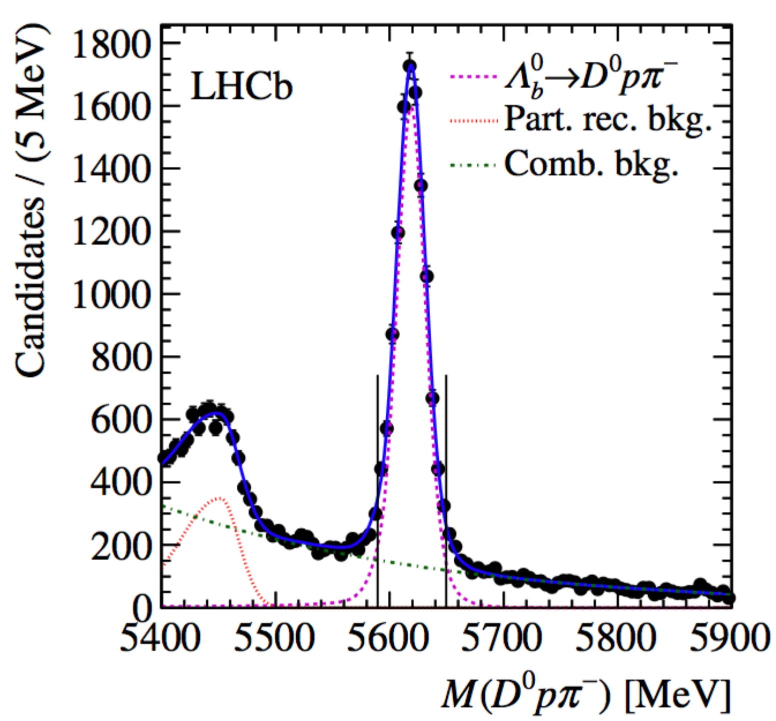
D^0p amplitude analysis in $\Lambda^0_b \to D^0 p \pi^-$

J. High Energ. Phys. (2017) 2017: 30

- Run I dataset (3.0 fb^{-1})
- $D^0 \to K^- \pi^+$
- Selection:
  - ✓ Preselection
  - ✓ Kinematical fit
  - ✓ BDT: Kinematical properties, reconstruction, refit quality and PID
- ~11k Λ^0_b events



[1,2]



Formalism

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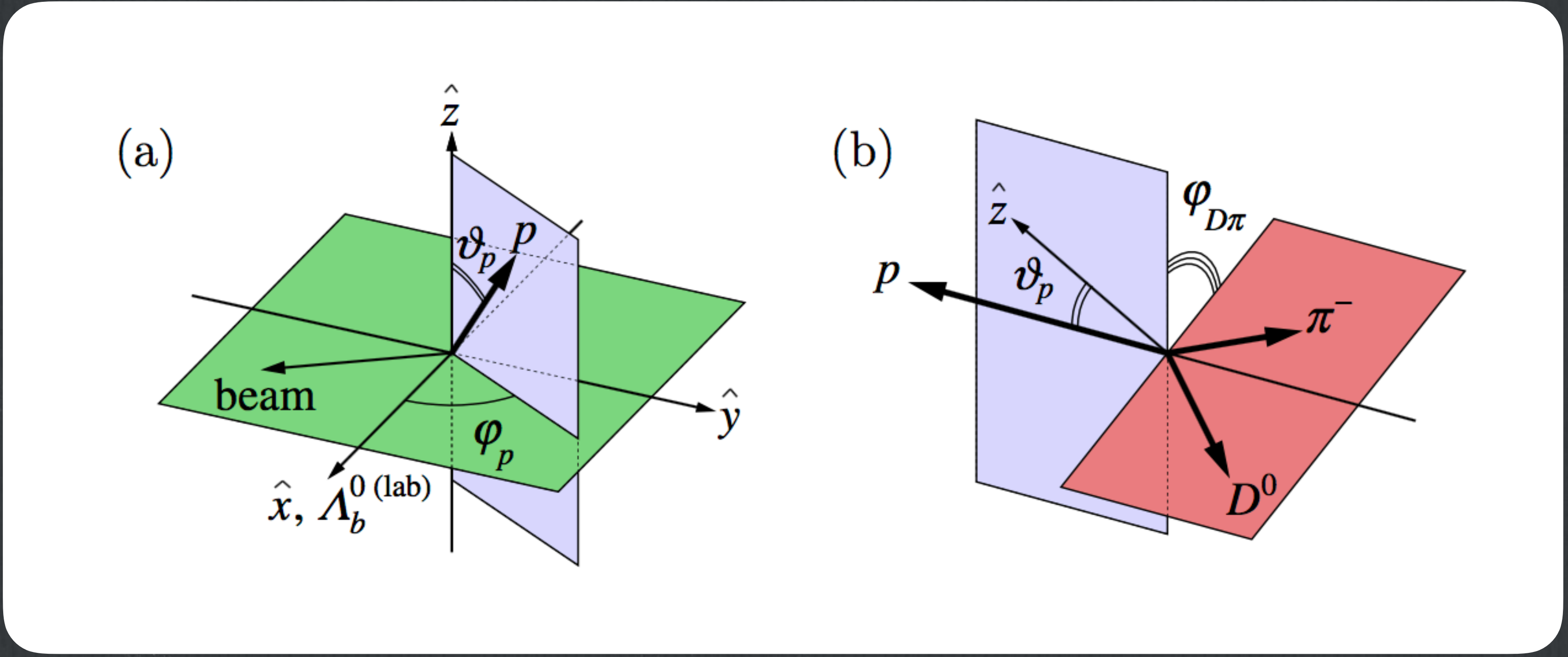
- 5D phase space
- Helicity formalism
- Fit can be done only in $M^2(D^0p)$ and $M^2(p\pi^-)$



Fit procedure

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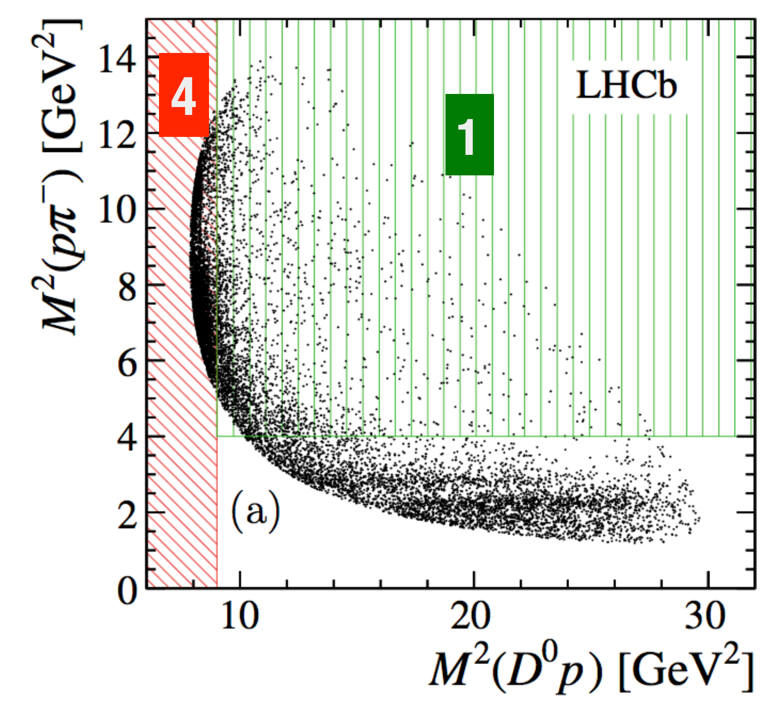
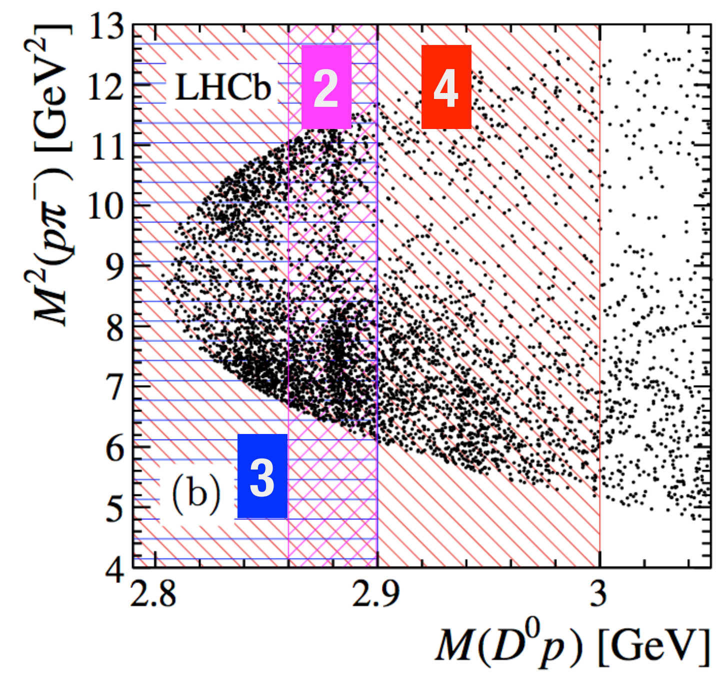
- ☐ Resonances parametrised with relativistic Breit-Wigner
- ☐ Efficiency taken from MC
- ☐ Background taken from sidebands
- ☐ D^0p resonances well separated from $p\pi^-$ resonances
- ☐ Fit performed in regions





Fit Results

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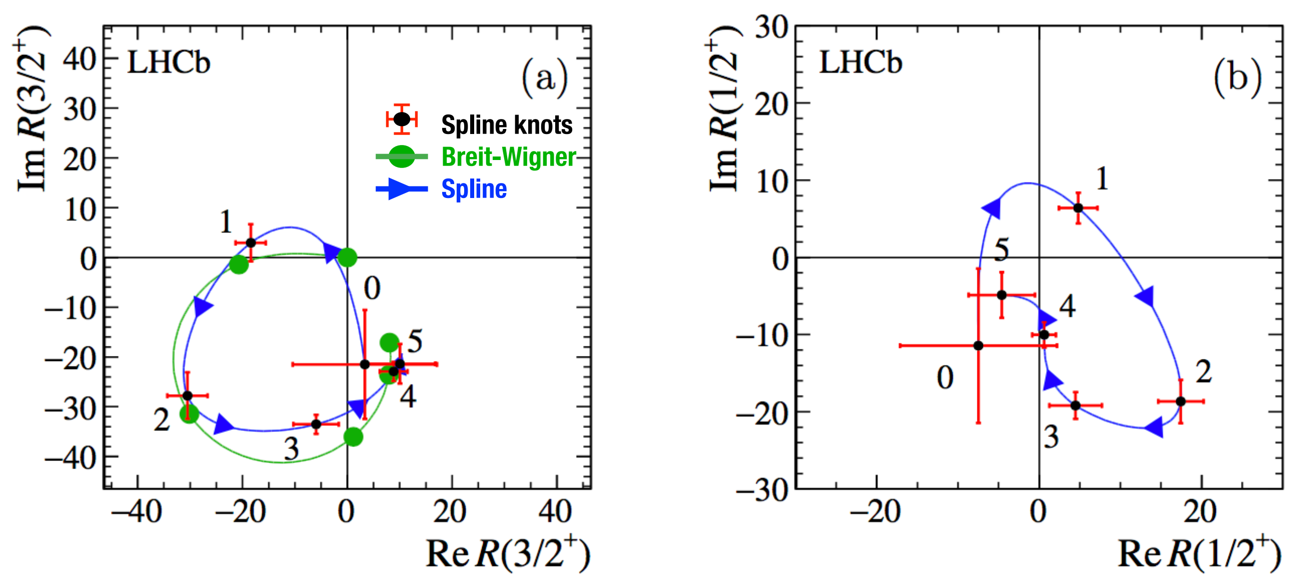
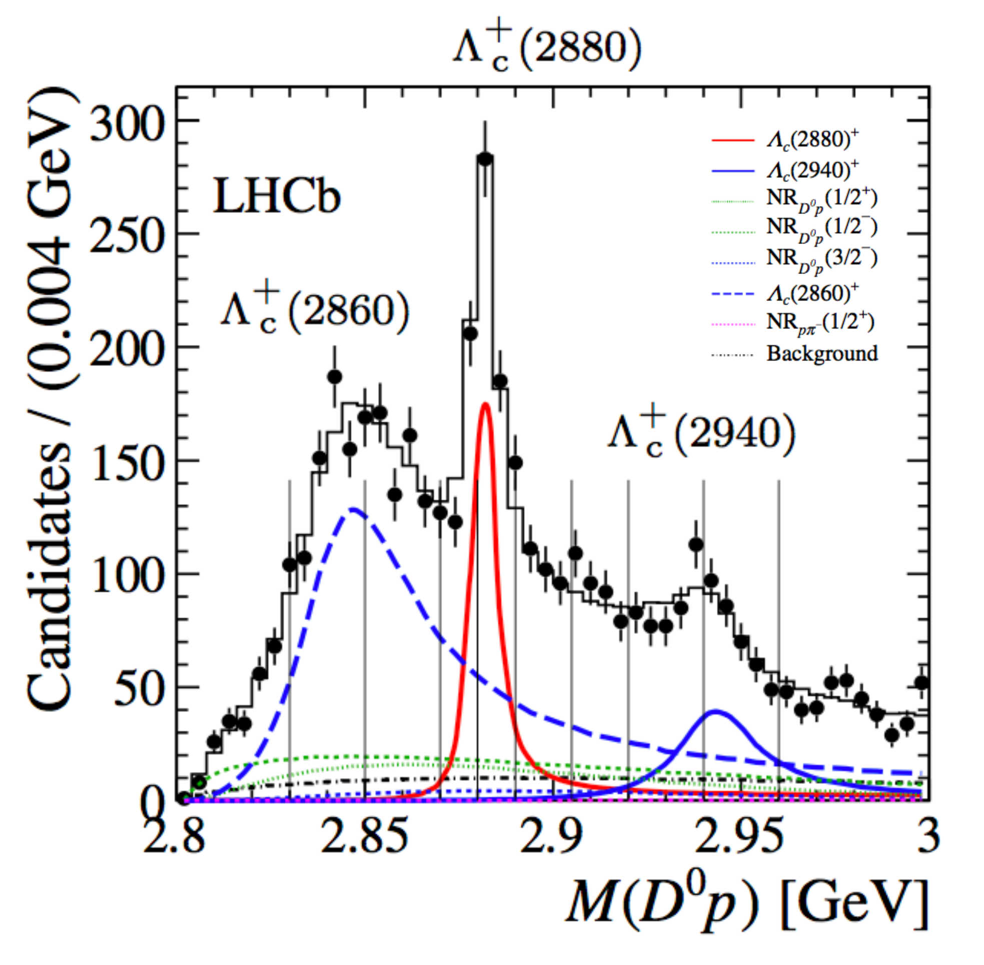
- ☐ New Λ^{*}_{c} state
- ☐ First constraint on Λ^{+}_{c} (2940) spin
- ☐ Λ^{+}_{c} (2880), Λ^{+}_{c} (2940) in agreement with previous measurements

Resonance	M [MeV]	Γ [MeV]	J^P
$\Lambda_c^+(2860)$	2856	67	$3/2^+$ (Preferred w/ $> 6\sigma$)
$\Lambda_c^+(2880)$	2881	5.4	$5/2^+$
$\Lambda_c^+(2940)$	2945	28	$3/2^-$ (Preferred w/ $> 3\sigma$)





Measurement of the form factor in $\Lambda^0_b \to \Lambda^+_c \mu^- \bar{\nu}_\mu$

arXiv:1709.01920

- Precise measurements of CKM parameters are an important test of the Standard model
- Understanding the form factors used to describe hadronic currents can help with these measurements
- Heavy Quark Effective Theory provides the framework to parametrise the form factors in the infinite heavy quark-mass limit
- Proportional to the universal Isgur-Wise (IW) Function

$$w = (m^2_{\Lambda^0_b} + m^2_{\Lambda^+_c} - q^2)/(2m_{\Lambda^0_b} m_{\Lambda^+_c}),$$

$$\frac{d\Gamma}{dw} = GK(w)\xi^2_B(w),$$

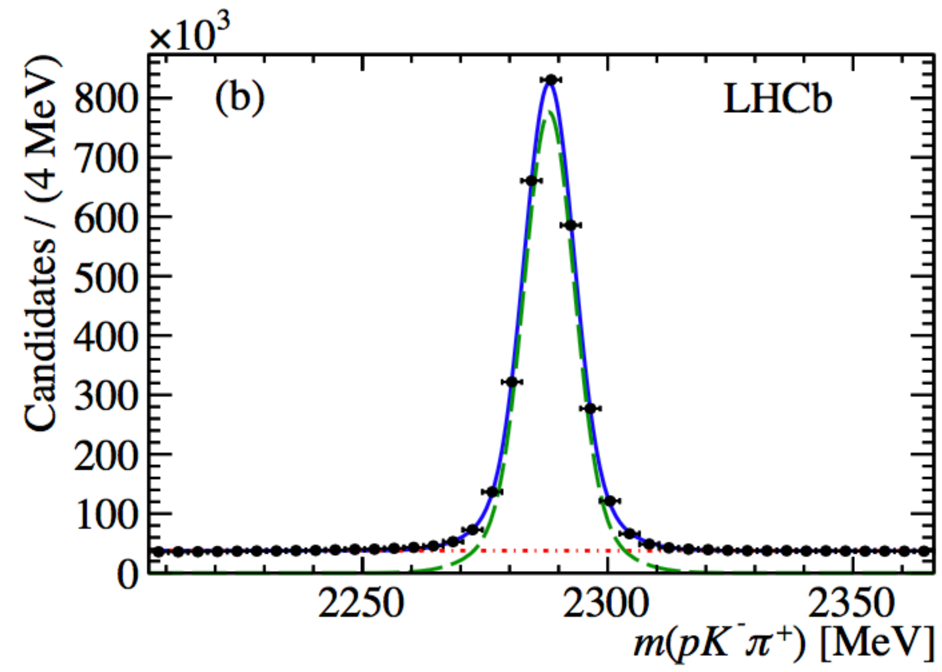
$$\xi_B(w) = -\underbrace{\rho^2}_{\textbf{Slope}}(w-1) + \frac{1}{2}\underbrace{\sigma^2}_{\textbf{Curvature}}(w-1)^2 + \ldots,$$

ρ^2	Approach	Reference
1.35 ± 0.13	QCD sum rules	(3)
$1.2^{+0.8}_{-1.1}$	Lattice QCD (static approach)	(4)
1.51	HQET + Relativistic wave function	(5)

Data samples

arXiv:1709.01920

- Run I dataset (3.0 fb^{-1})
- 2.74 M raw events
- $\Lambda^+_c \rightarrow p K^- \pi^+$
- Selection: Kinematical properties and reconstruction quality
- Λ^*_c contributions also estimated using $\Lambda^0_b \rightarrow \Lambda^+_c \pi^+\pi^-\mu^-\bar{\nu}_\mu$



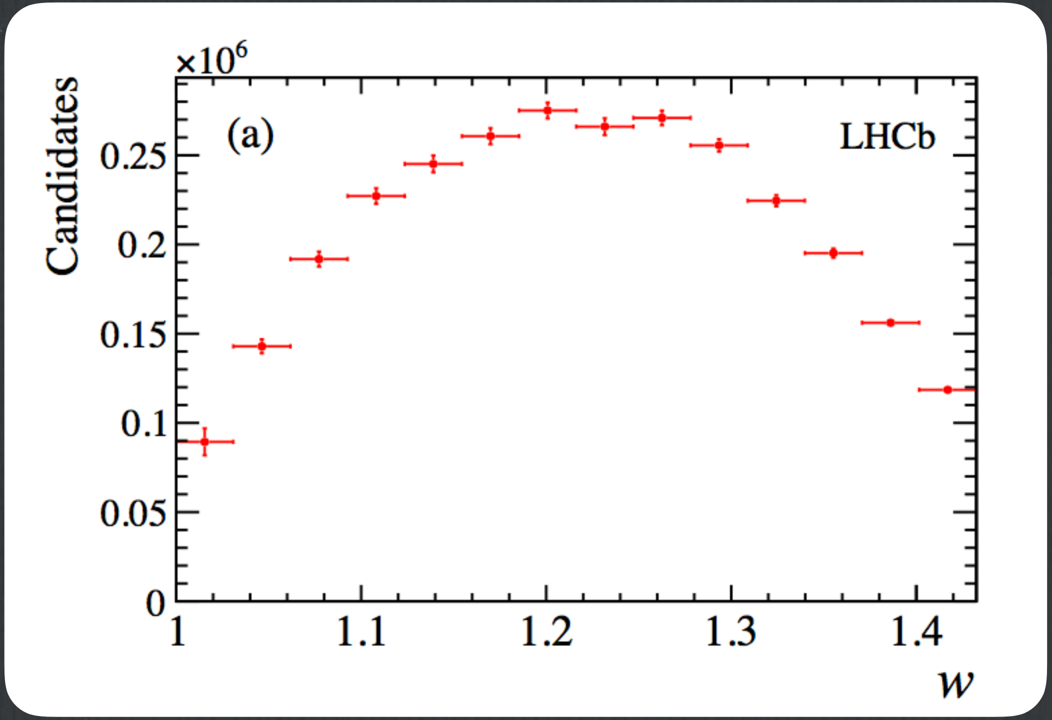
Final state	Yield
$\Lambda_c(2595)^+\mu^-\overline{\nu}_\mu$	8569 ± 144
$\Lambda_c(2625)^+\mu^-\overline{\nu}_\mu$	22965 ± 266
$\Lambda_c(2765)^+\mu^-\overline{\nu}_\mu$	2975 ± 225
$\Lambda_c(2880)^+\mu^-\overline{\nu}_\mu$	1602 ± 95
$\Lambda_c^+\mu^-\overline{\nu}_\mu X$	$(2.74\pm0.02)\times10^6$

The spectral distribution $dN_{corr}/d\omega(\Lambda^0_b \to \Lambda^+_c \mu^- \bar{\nu}_\mu)$

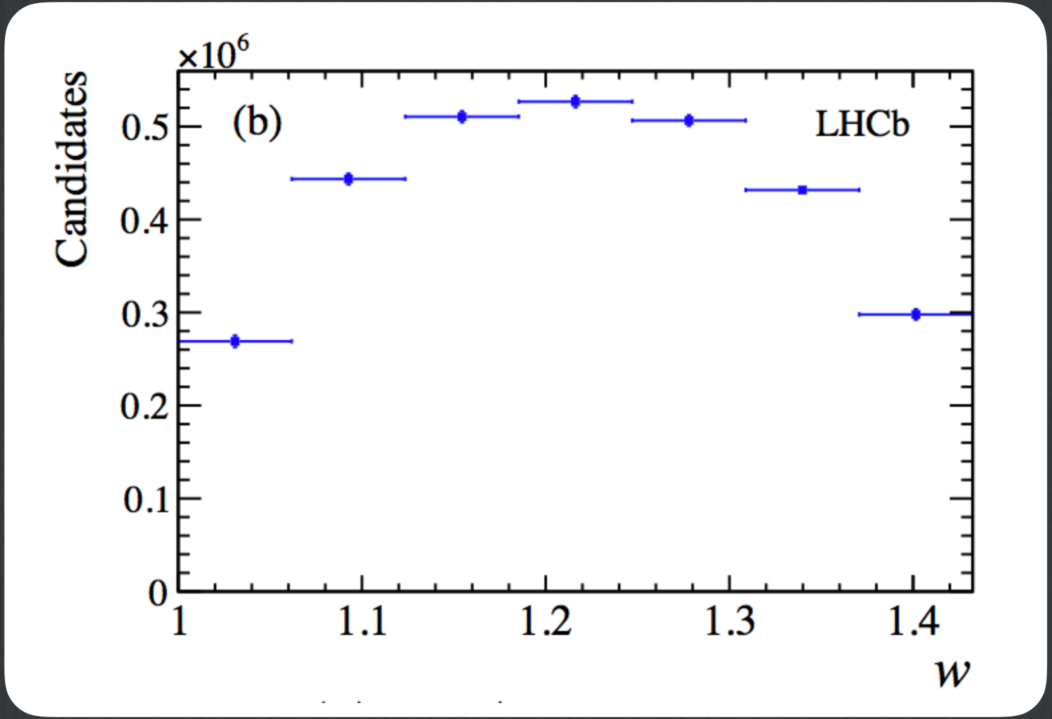
arXiv:1709.01920

- Efficiency taken from MC
- Λ^*_c contributions subtracted
- Combinatorial background shape from wrong-sign sample subtracted
- Unfolding based on the single value decomposition (SVP) method to take detector resolution and other effects into account

Before unfolding



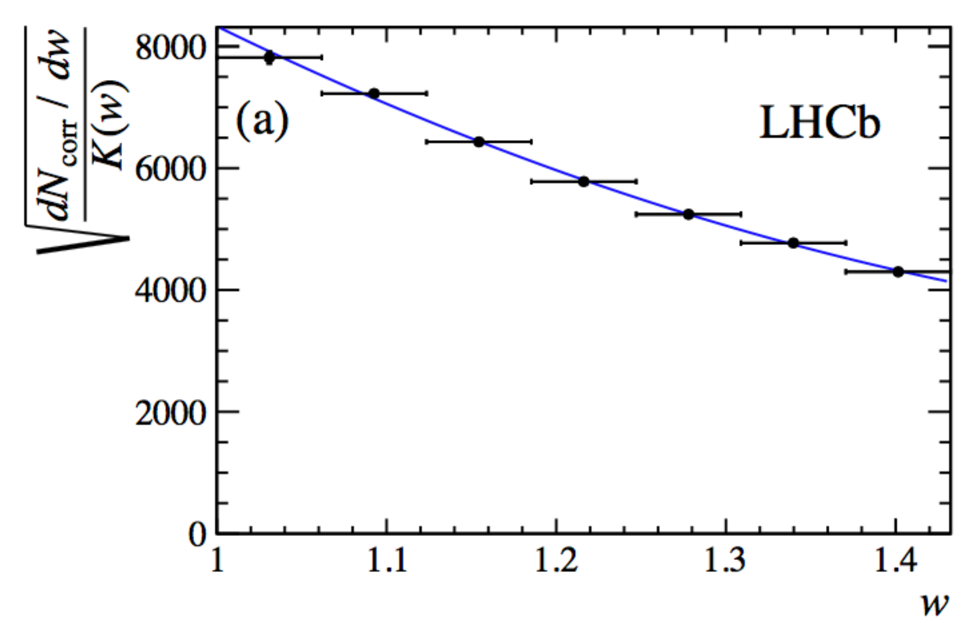
After unfolding



IW Fit results

arXiv:1709.01920

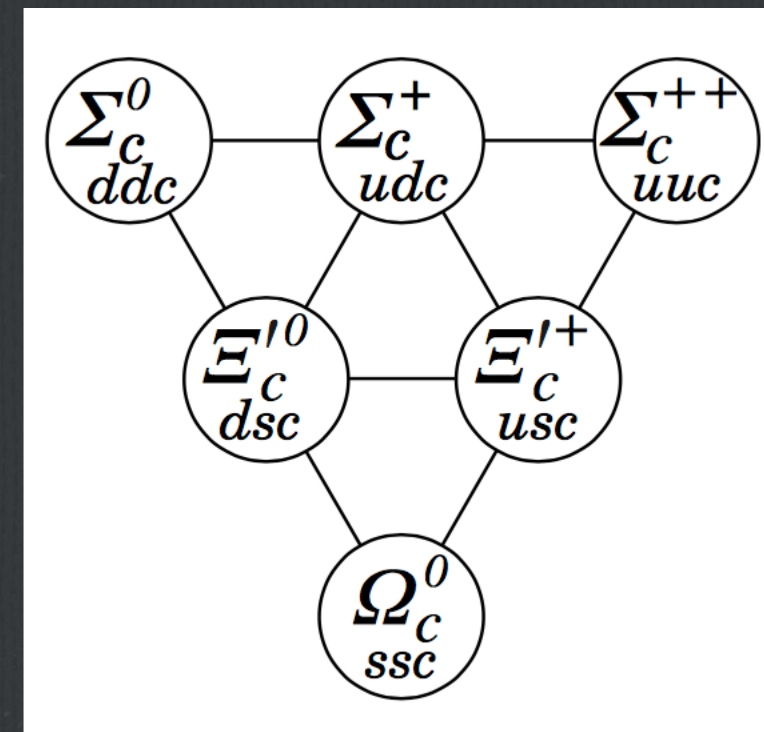
- Three parametrisations attempted:
  - ✓ Exponential
  - ✓ Dipole
  - ✓ Taylor series
- Good agreement with predictions of HQET, sum rules, and relativistic quark model.



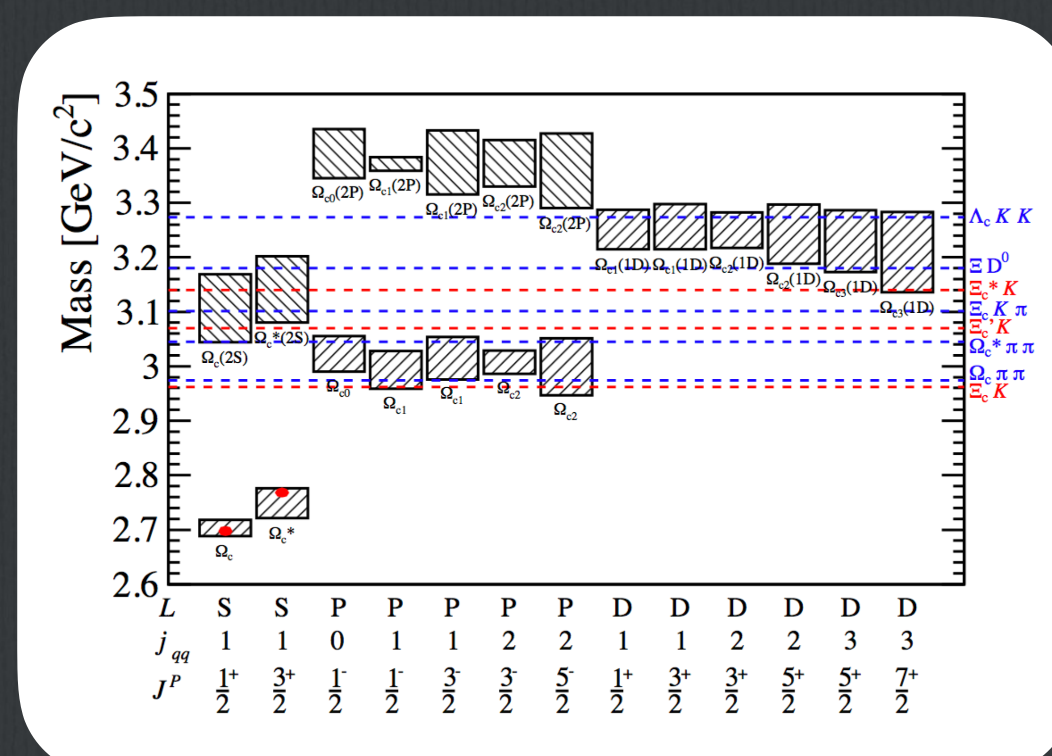
Shape	ρ^2	σ^2	correlation coefficient	χ^2/ DOF
Exponential*	1.65 ± 0.03	2.72 ± 0.10	100%	5.3/5
Dipole*	1.82 ± 0.03	4.22 ± 0.12	100%	5.3/5
Taylor series	1.63 ± 0.07	2.16 ± 0.34	97%	4.5/4

Observation of Five New Narrow Ω^0_c States

PRL118, 182001 (2017)



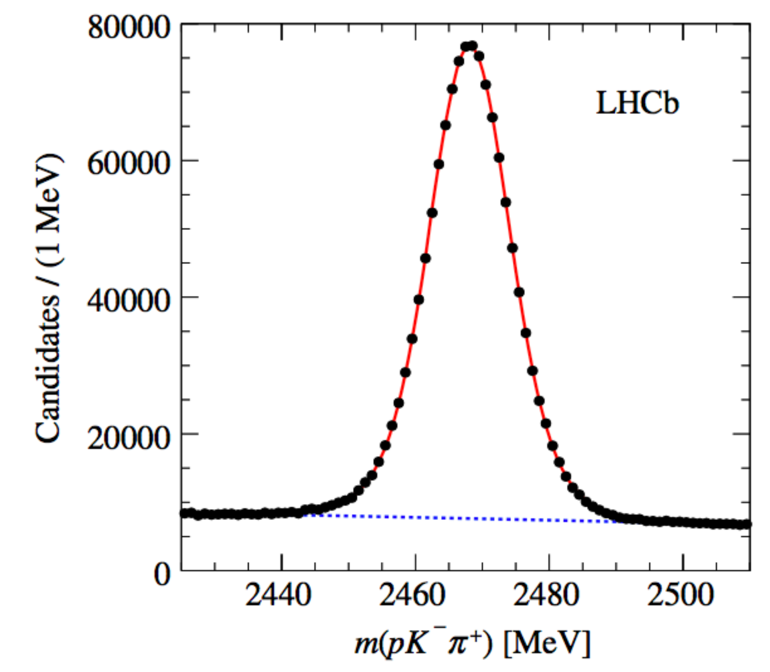
- Many baryon states are expected
- Ground states already observed
- Regarding Ω_c only Ω^0_c and $\Omega^0_c(2770)$ have already been observed
- Several theoretical approaches: HQET, lattice QCD…

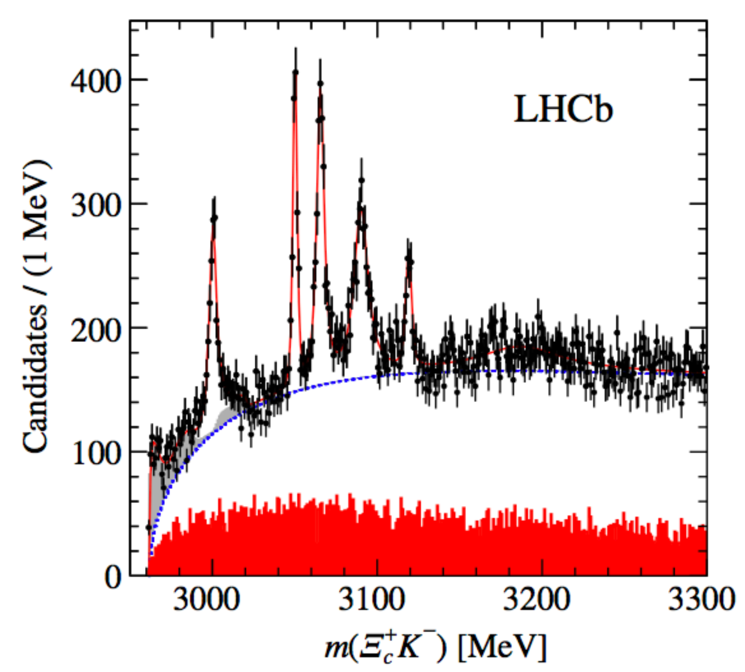


Dataset & reconstruction

PRL118, 182001 (2017)

- Run I + 2015 data sets ($3.3\ fb^{-1}$)
- $pp \rightarrow \Xi^+_c K^-$ spectrum
- $\Xi^+_c \rightarrow p\, K^-\, \pi^+$
- Ξ^+_c combined with K^-
- Primary vertex refit





Fit Results

PRL118, 182001 (2017)

Resonance	Mass (MeV)	Γ (MeV)	Yield	N_σ
$\Omega_c(3000)^0$	$3000.4 \pm 0.2 \pm 0.1^{+0.3}_{-0.5}$	$4.5 \pm 0.6 \pm 0.3$	$1300 \pm 100 \pm 80$	20.4
$\Omega_c(3050)^0$	$3050.2 \pm 0.1 \pm 0.1^{+0.3}_{-0.5}$	$0.8 \pm 0.2 \pm 0.1$	$970 \pm 60 \pm 20$	20.4
		<1.2 MeV, 95% C.L.		
$\Omega_c(3066)^0$	$3065.6 \pm 0.1 \pm 0.3^{+0.3}_{-0.5}$	$3.5 \pm 0.4 \pm 0.2$	$1740 \pm 100 \pm 50$	23.9
$\Omega_c(3090)^0$	$3090.2 \pm 0.3 \pm 0.5^{+0.3}_{-0.5}$	$8.7 \pm 1.0 \pm 0.8$	$2000 \pm 140 \pm 130$	21.1
$\Omega_c(3119)^0$	$3119.1 \pm 0.3 \pm 0.9^{+0.3}_{-0.5}$	$1.1 \pm 0.8 \pm 0.4$	$480 \pm 70 \pm 30$	10.4
		<2.6 MeV, 95% C.L.		
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$	$1670 \pm 450 \pm 360$	

- Resonant states modeled with Relativistic Breit-Wigners + Resolution + feed-down components
- 5 new states (plus hints of a broader contribution)
- Does not allow to determine quantum numbers
- Possible interpretations already under discussion [6,7]

Conclusions

- LHC and LHCb provide an excellent environment for baryon spectroscopy and precision measurements
- The D^0p amplitude analysis in $\Lambda^0_b \to D^0 p \pi^-$ presents a first observation of a new Λ^*_c state, provides more information about $\Lambda^+_c(2940)$ and confirms previous measurements on $\Lambda^+_c(2880)$.
- The measurement of the form factor of the $\Lambda^0_b \to \Lambda^+_c \mu^- \bar{\nu}_\mu$ presents a precise measurement in agreement with theoretical predictions
- The observation of five new narrow Ω^0_c states was reported
- Many more baryon studies to be performed in LHCb (Run II dataset)

References

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