Joint Workshop on Charm Hadron Decays @ BESIII, BELLE, LHCb

LHCb

Charm spectroscopy at LHCb: results and prospects

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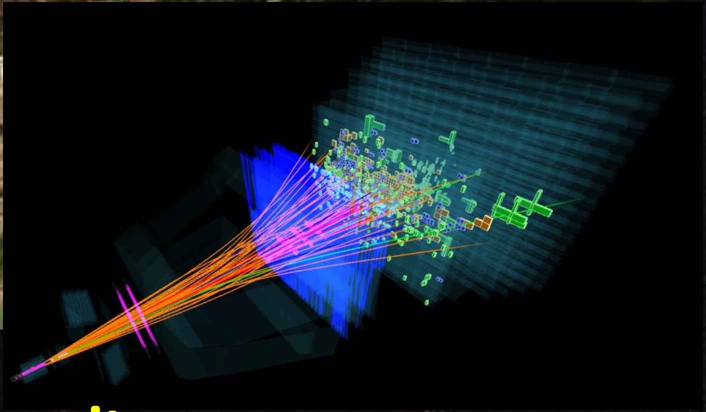


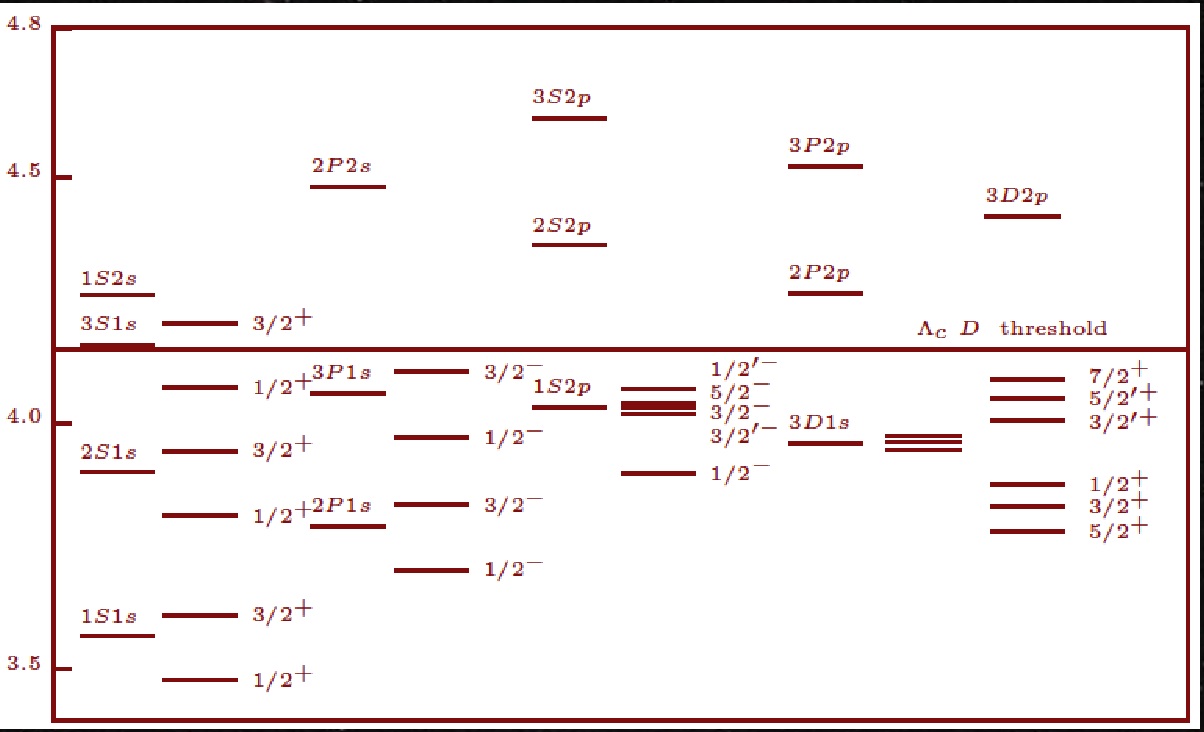
23 September 2017, Nankai University

Outline

- Introduction
- LHCb detector
- Observation of the Ξ_{cc}^{++} baryon [PRL 119 (2017) 112001]
- Observation of the excited Ω_c^0 states [PRL 118 (2017) 182001]
- Prospects and summary

Spectroscopy

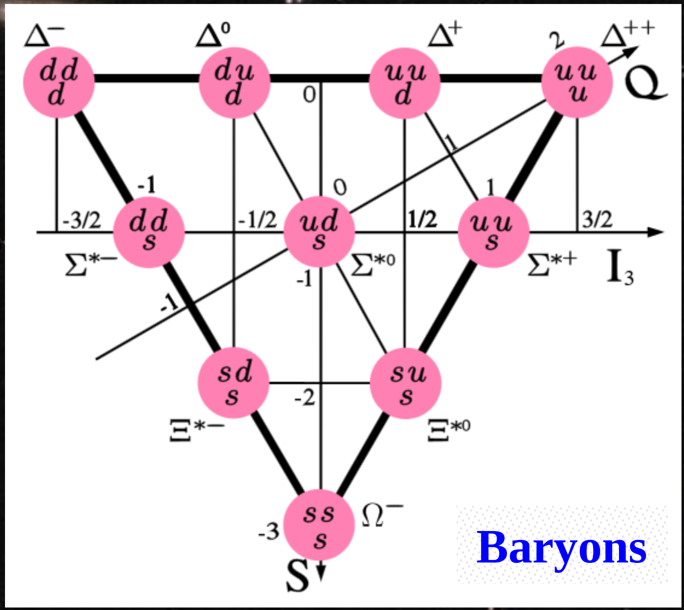
- Spectroscopy: collecting and sorting energy levels
- An indispensable procedure to elucidate the underlying dynamics of complex phenomena
- Study of hadron spectroscopy can reveal properties of strong interactions between quarks

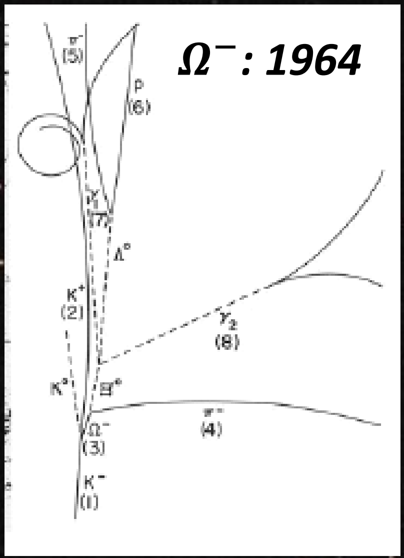


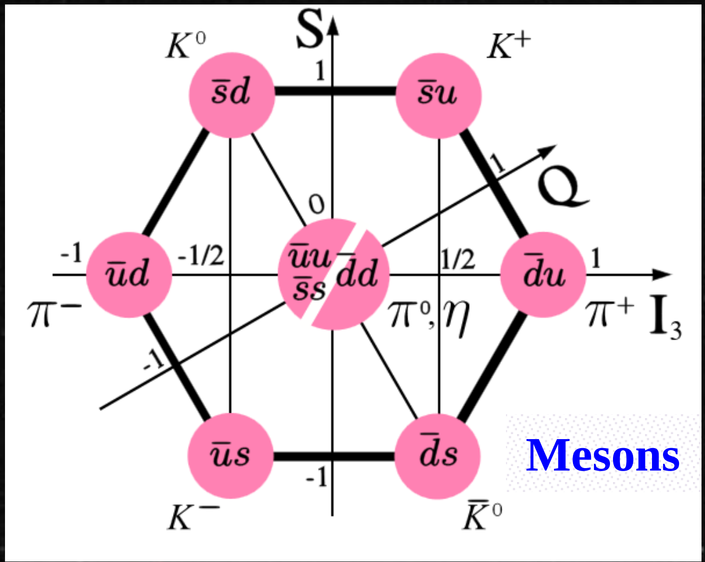
Quark model: SU(3)

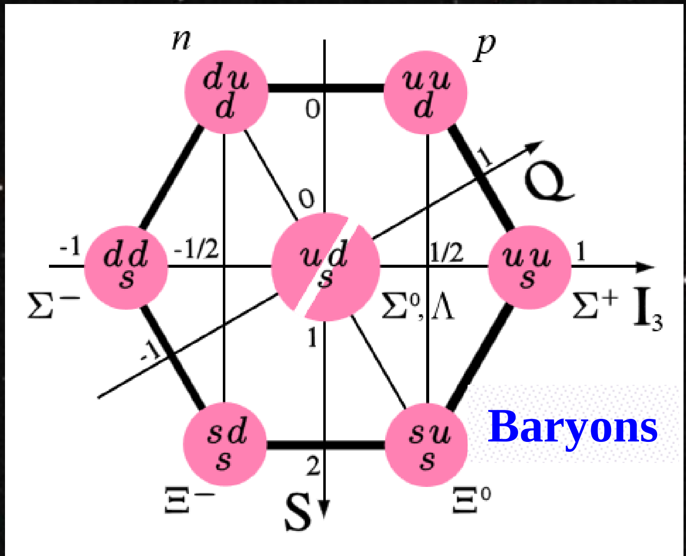
- Hadrons are composed of (invisible) quarks (u, d, s)
- Mesons $(q\bar{q}')$ and baryons $(qq'q'')$ are SU(3) multiplets

Numerous hadrons are well classified, and predictions confirmed





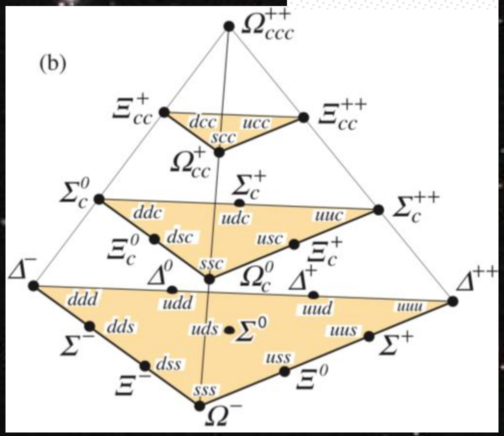


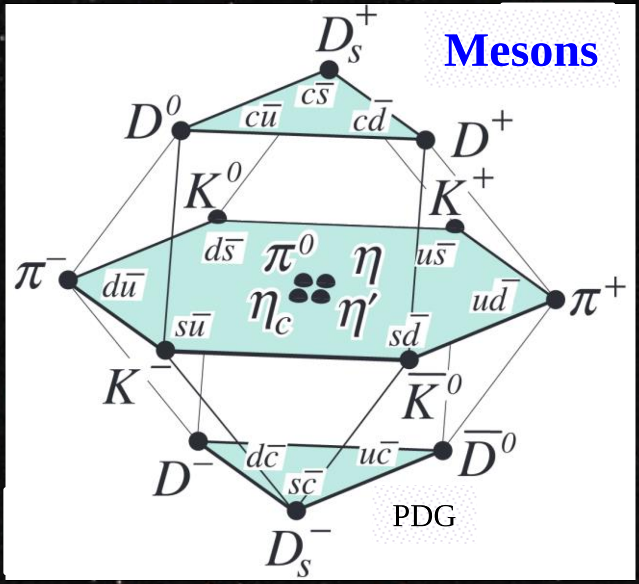


SU(4) quark model

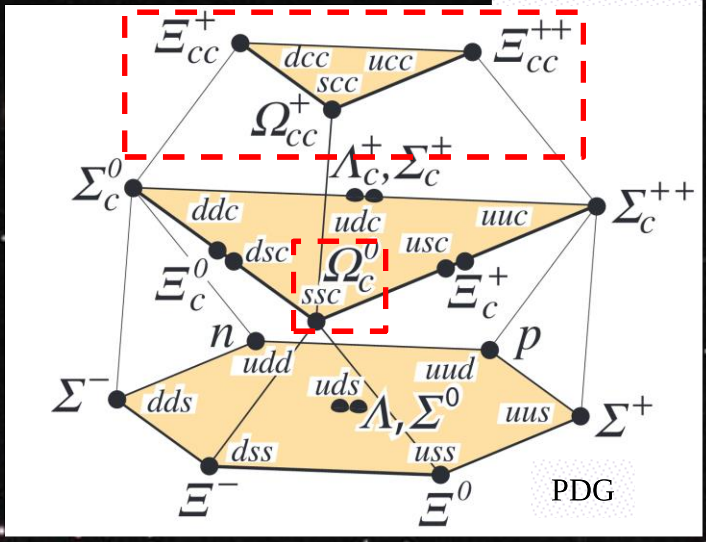
- When extended to (u, d, s, c) quarks, hadrons form SU(4) multiplets
- All $C = 0$ and $C = 1$ ground states observed
- $C = 2$ baryons
  - Isospin doublet: $\Xi_{cc}^{+}(ccd)$ and $\Xi_{cc}^{++}(ccu)$
  - Isospin singlet: $\Omega_{cc}^{+}(ccs)$
  - Three with $J^P = 1/2^+$ and three with $3/2^+$

$J^P = \frac{3}{2}^+$ Baryons



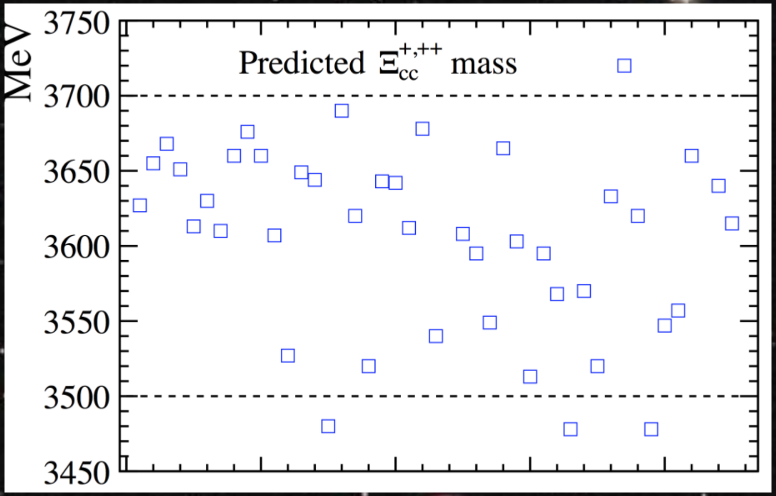


$J^P = \frac{1}{2}^+$ Baryons

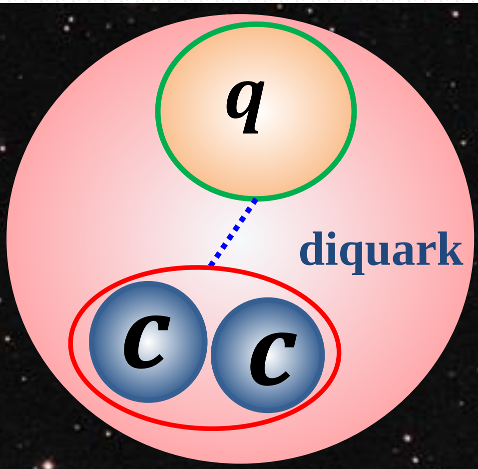


Theoretical calculations of Ξ_{cc}

- Many models calculated the masses: (non-)relativistic QCD potential models, QCD sum rules, bag model …
  - $m(\Xi_{cc}^{+,++}) \in (3.5, 3.7)$ GeV, $m(\Omega_{cc}^{+}) \approx m(\Xi_{cc}) + 0.1$ GeV
  - Mass splitting between Ξ_{cc}^{+} and Ξ_{cc}^{++}: a few MeV
- Lattice QCD: $M(\Xi_{cc}) \approx 3.6$ GeV, $M(\Omega_{cc}^{+}) \approx 3.7$ GeV



HQET: two charm quarks considered as a heavy diquark, doubly heavy baryon similar to a heavy meson Qq

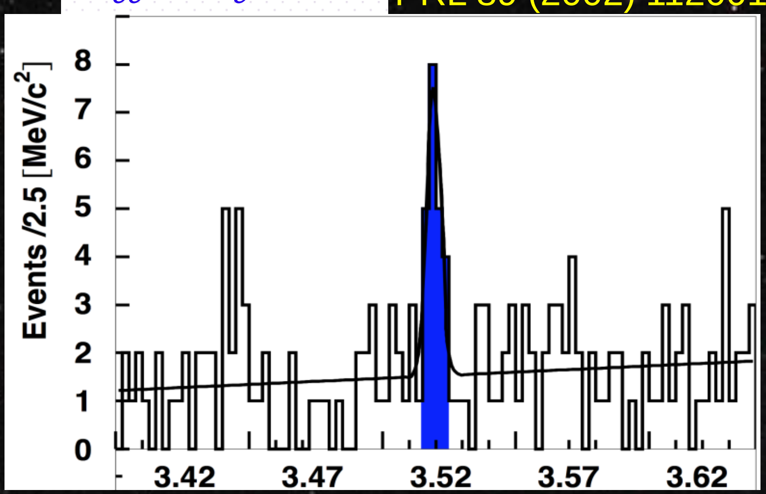


- Lifetime: $\tau(\Xi_{cc}^{++}) \gg \tau(\Xi_{cc}^{+})$
  - $\tau(\Xi_{cc}^{++}) \in (200 - 700)$ fs
  - $\tau(\Xi_{cc}^{+}) \in (50 - 250)$ fs

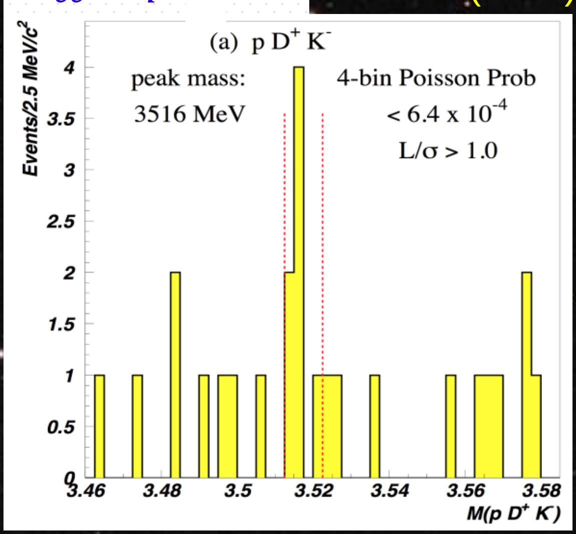
Experimental results

- SELEX (Fermilab E781) collides high energy hyperon beams (Σ^-, p) with targets, dedicated to study charm baryons
- Observed Ξ_{cc}^+ in $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ and $\Xi_{cc}^+ \to p D^+ K^-$ decays
  - Signal yields: $15.9\ (\Lambda_c^+ K^- \pi^+)$ and $5.62\ (p D^+ K^-)$
  - Short lifetime: $\tau(\Xi_{cc}^+) < 33$ fs @90% CL, but not zero
  - Large production: $R = \frac{\sigma(\Xi_{cc}^+) \times \mathrm{BF}(\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+)}{\sigma(\Lambda_c^+)} \sim 20\%$
  - Mass (combined): 3518.7 ± 1.7 MeV

$\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ PRL 89 (2002) 112001



$\Xi_{cc}^+ \to p D^+ K^-$ PLB 628 (2005) 18



Experimental results (cont.)

- SELEX (Fermilab E781) collides high energy hyperon beams (Σ^-, p) with targets, dedicated to study charm baryons
- Observed Ξ_{cc}^+ in $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ and $\Xi_{cc}^+ \to p D^+ K^-$ decays
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  - Short lifetime: $\tau(\Xi_{cc}^+) < 33$ fs @90% CL, but not zero
  - Large production: $R = \frac{\sigma(\Xi_{cc}^+)\times \mathrm{BF}(\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+)}{\sigma(\Lambda_c^+)} \sim 20\%$
  - Mass (combined): $3518.7 \pm 1.7\ \mathrm{MeV}/c^2$

Comment on "First observation of doubly charmed baryon Ξ_{cc}^+"

V.V.Kiselev* and A.K.Likhoded,
State Research Center "Institute for High Energy Physics"
Protvino, Moscow region, 142280 Russia
Fax: +7-0967-744739

We speculate on a possible interpretation of events selected by the SELEX collaboration and stress an insufficient evidence for the observation of doubly charmed baryon.

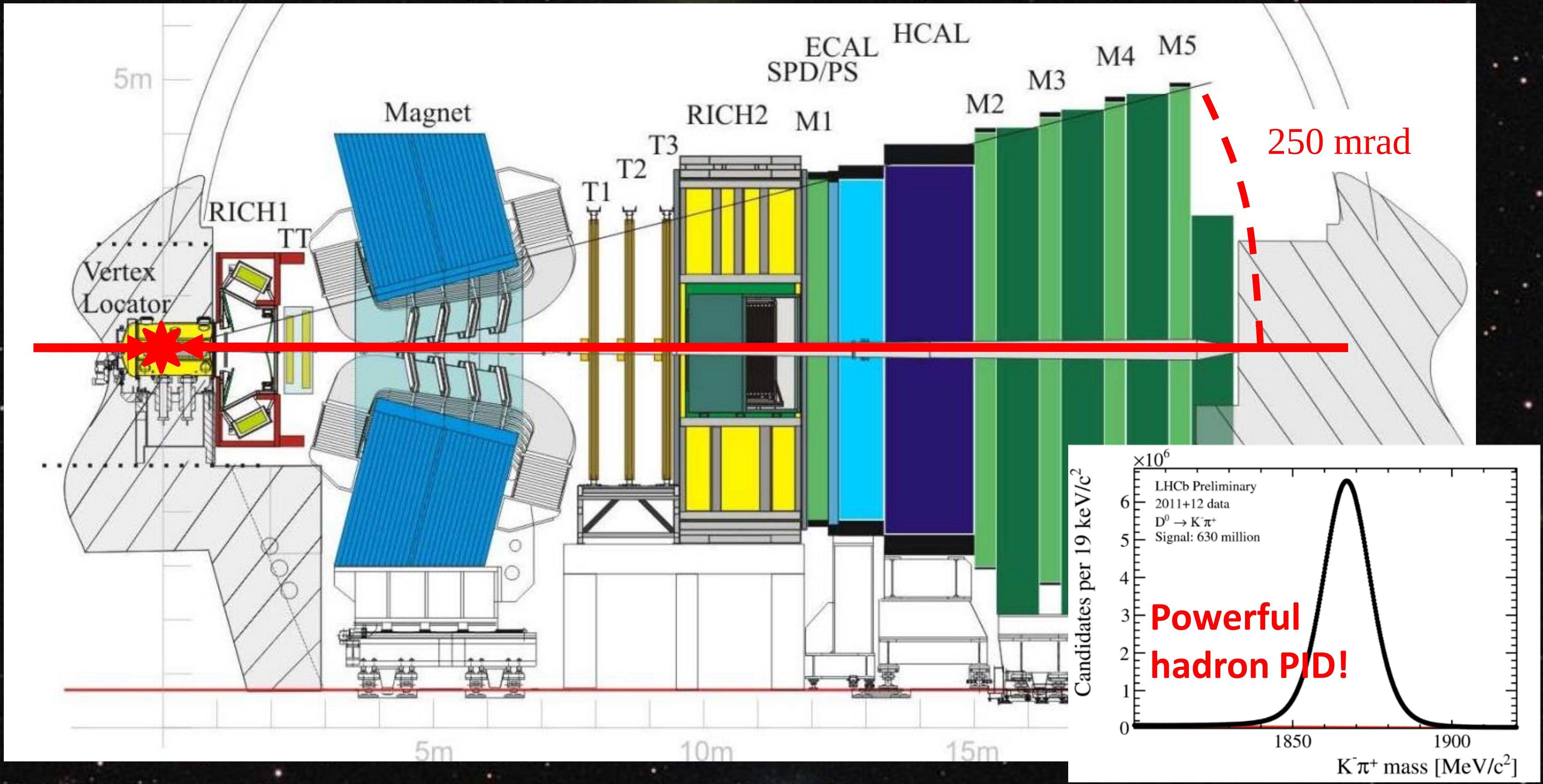
PACS numbers: 14.20.Lq, 13.30.-a, 13.85.Ni

No evidence observed by FOCUS, BaBar, Belle, and LHCb

The LHCb detector

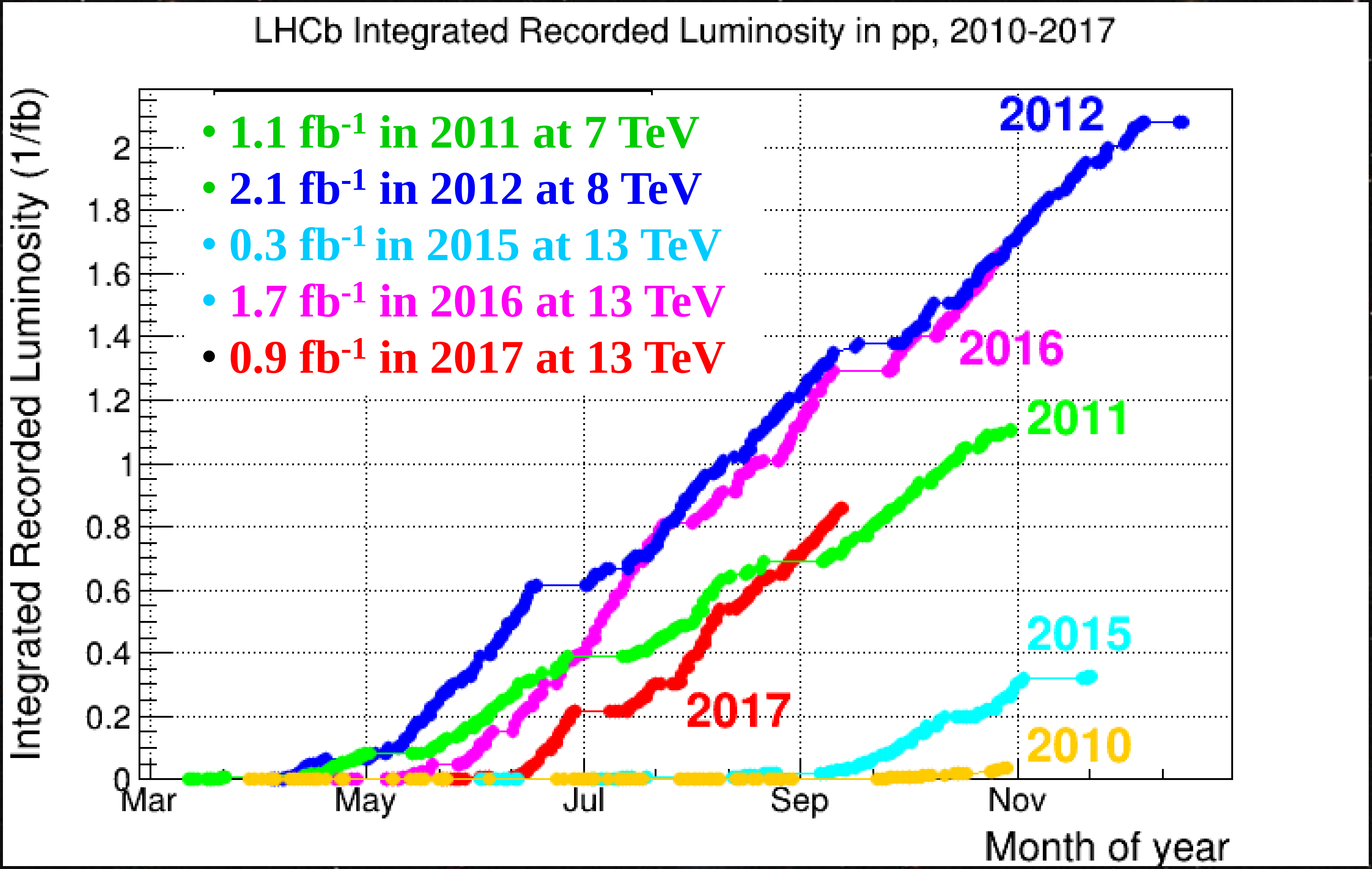
JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

Designed for precision measurements in b, c flavor sectors
Acceptance: $2 < \eta < 5$



Excellent vertex, tracking and hadron ID

LHCb data taking



Search for Ξ_{cc} at LHCb

JHEP 12 (2013) 090

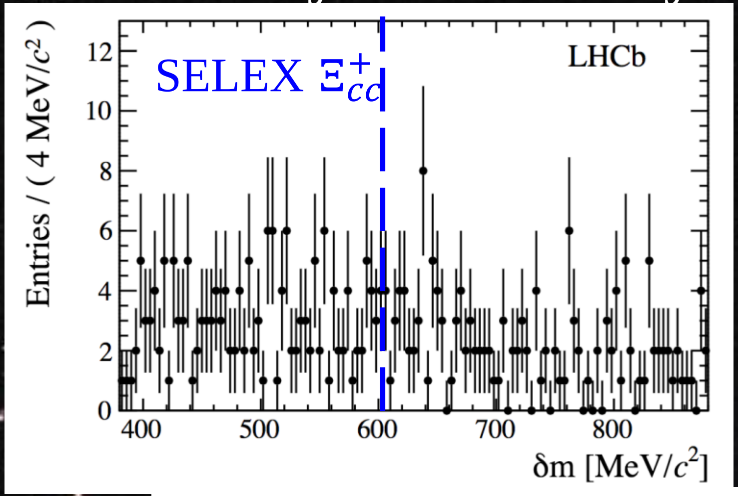
- Search for $\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-} \pi^{+}$ at 7 TeV, $\mathcal{L} = 0.65\ \mathrm{fb}^{-1}$
  - $N(\Lambda_c^{+}) \approx 0.8$ M, requiring high-p_{T}
  - No significant peaking structure observed in the range $[3.3, 3.8]$ GeV
  - Experiment sensitivity strongly depends on the Ξ_{cc}^{+} lifetime

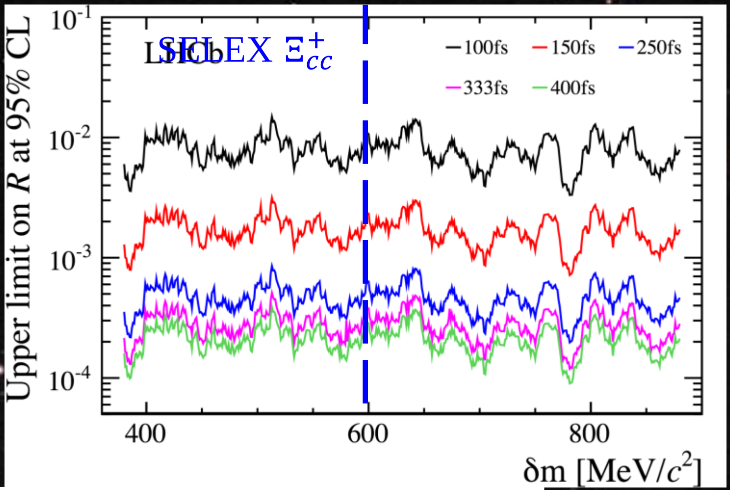
$$R \equiv \frac{\sigma(\Xi_{cc}^{+}) \times \mathrm{BF}(\Xi_{cc}^{+} \to \Lambda_c^{+} K^{-} \pi^{+})}{\sigma(\Lambda_c^{+})} < 1.5 \times 10^{-2} \text{ for } \tau = 100 \text{ fs},$$

$$< 3.9 \times 10^{-4} \text{ for } \tau = 400 \text{ fs} \quad @95\%$$

Significantly below the value given by SELEX than

Sensitivity increased by ~40 from 100 fs to 400 fs





$$\delta m = m\left([pK^{-}\pi^{+}]_{\Lambda_c^{+}} K^{-}\pi^{+}\right) - m\left([pK^{-}\pi^{+}]_{\Lambda_c^{+}}\right) - m(K^{-}) - m(\pi^{+})$$

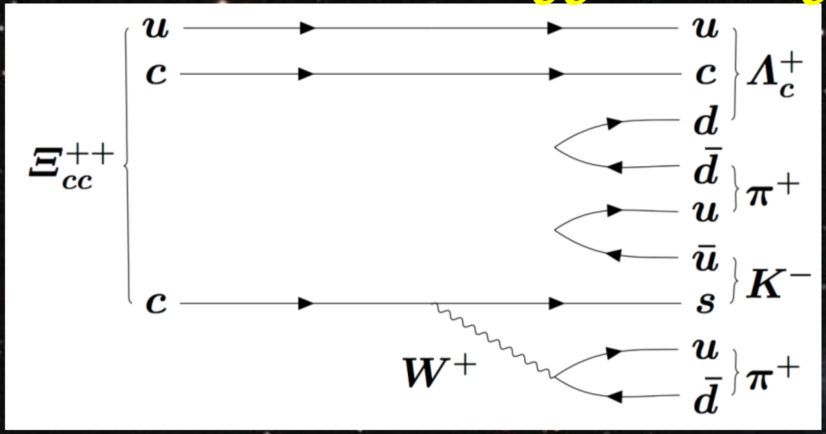
Search for Ξ_{cc} at LHCb (cont.)

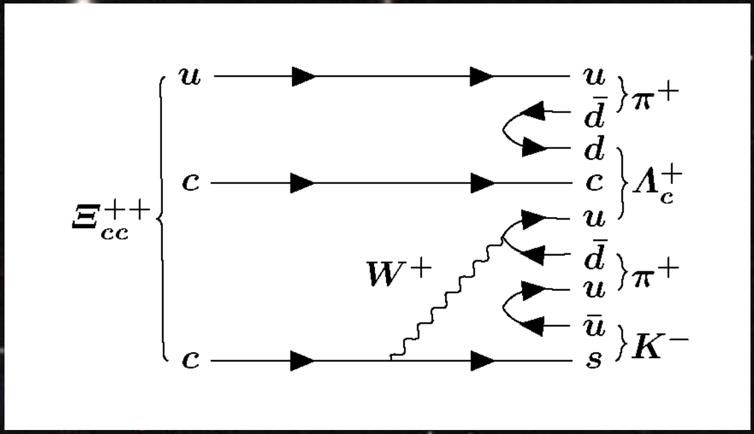
- **Planned in 2014 to make full search**
  - Searching for both Ξ_{cc}^{+} and Ξ_{cc}^{++} with more decays
  - No progress due to lack of MC (tech. issue) and manpower
- **Analysis restarted in the summer 2016**
  - Still focusing on Ξ_{cc}^{+}
- **In a seminar by Fu-Sheng Yu in UCAS in Dec. 2016 (invited by Jibo), $\Xi_{cc}^{++} \to \Lambda_c^{+} K^{-} \pi^{+} \pi^{+}$ is labelled as the most promising channel**
  - Owing to longer lifetime of Ξ_{cc}^{++} and the large branching fraction

Search for the $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$

- **Longer lifetime** than Ξ_{cc}^{+} ➔ **higher sensitivity at LHCb**
- **Decay:** $\mathcal{B}(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) \sim 10\%, \Lambda_c^+ \to p K^- \pi^+$
  - F.-S. Yu, arXiv:1703.09086
- **Data sample:** LHCb Run-II at $\sqrt{s} = 13$ TeV, $\sim 1.7\ \text{fb}^{-1}$
  - Dedicated exclusive trigger ensuring high efficiency, full event reconstruction at trigger level
  - Run-I data (2012) also analyzed for cross-check

$$\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$$

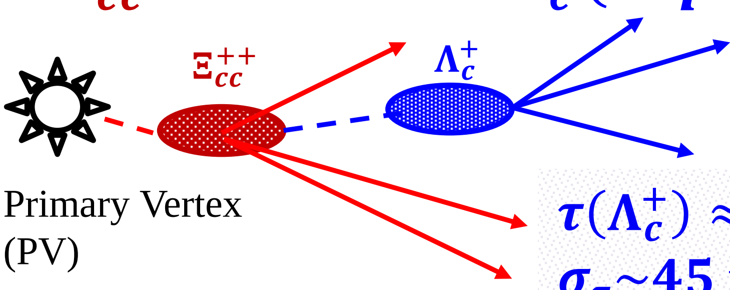




Preselections

- Huge hadronic background expected
- Online selection to select clean $\Lambda_c^+ \to pK^-\pi^+$ and reasonably reject Ξ_{cc}^{++} background
  - Tracks with good track-fit quality, good PID, and away from PV
  - Good vertices, large decay length significance, large p_{T}
  - Clone tracks removed
- Loose offline preselection to remove obvious background

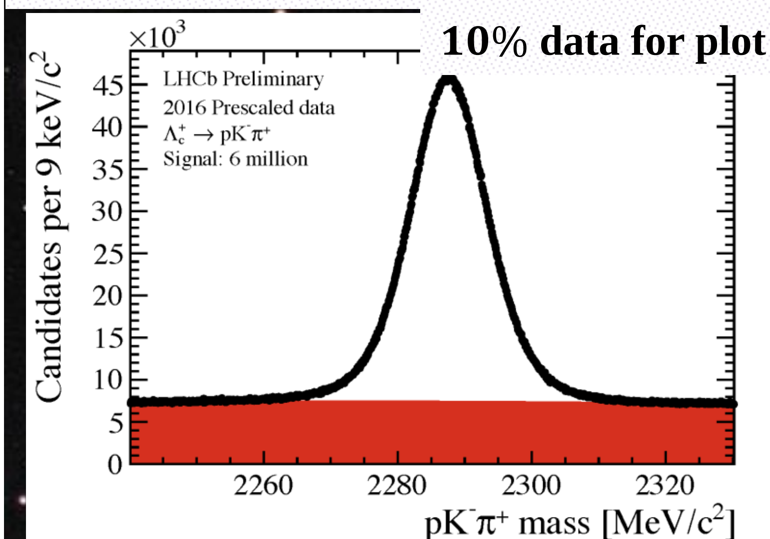
$$\Xi_{cc}^{++} \to K^-\pi^+\pi^+\Lambda_c^+(\to pK^-\pi^+)$$



$\tau(\Lambda_c^+) \approx 200$ fs
$\sigma_\tau \sim 45$ fs

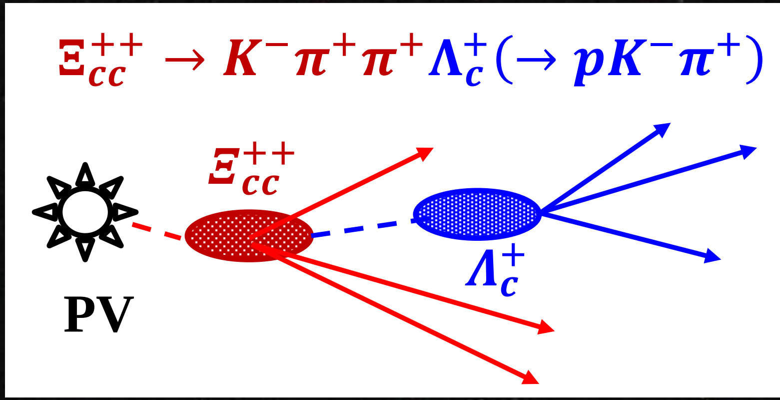
60 M fully reconstructed $\Lambda_c^+ \to pK^-\pi^+$ signal decays

Background strongly suppressed

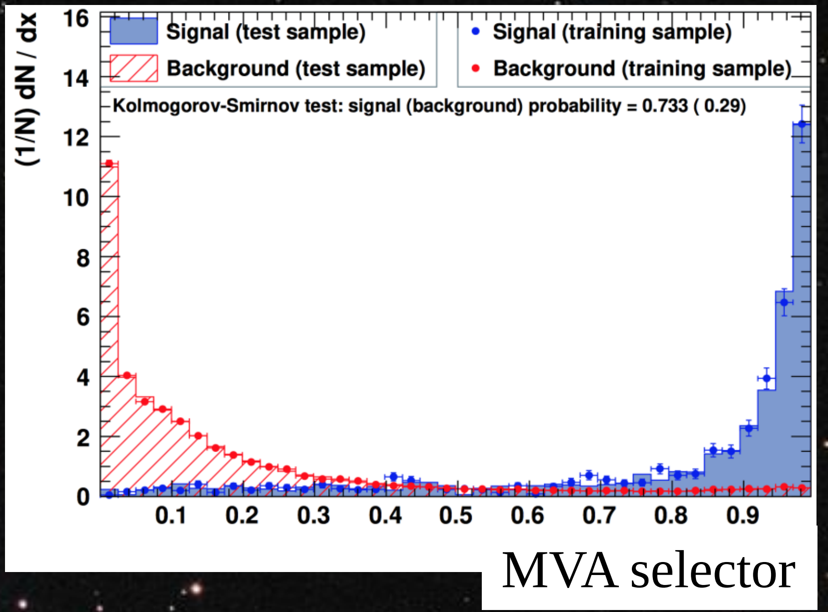


Multivariate analysis

- MVA used to further suppress background
- 10 kinematic and topological variables as input
- In the training and optimization
  - signals from simulation
  - Background from wrong-sign (WS) control sample ($\Lambda_c^+ K^- \pi^+ \pi^-$)



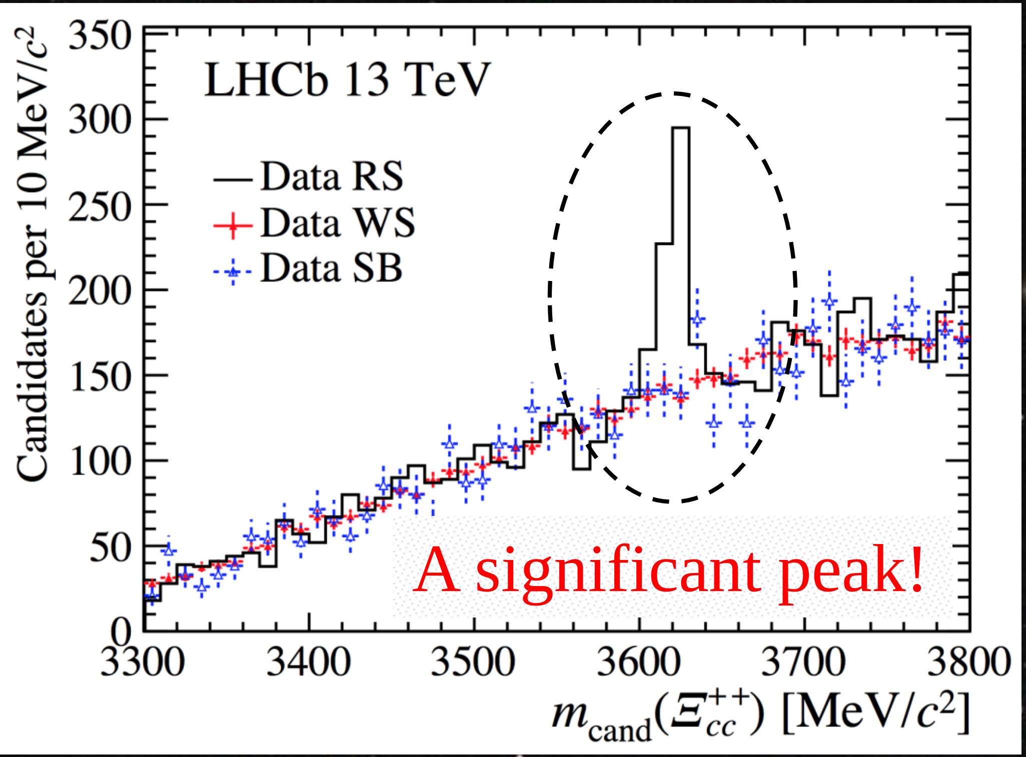
- FoM $F(t) \equiv \epsilon(t)/\left(\frac{a}{2} + \sqrt{B(t)}\right)$ used to optimise the MVA cut
  - t: a given MVA cut
  - $\epsilon(t)$: signal efficiency
  - $B(t)$: expected number of background in the signal region
  - $a = 5$ aiming at a discovery

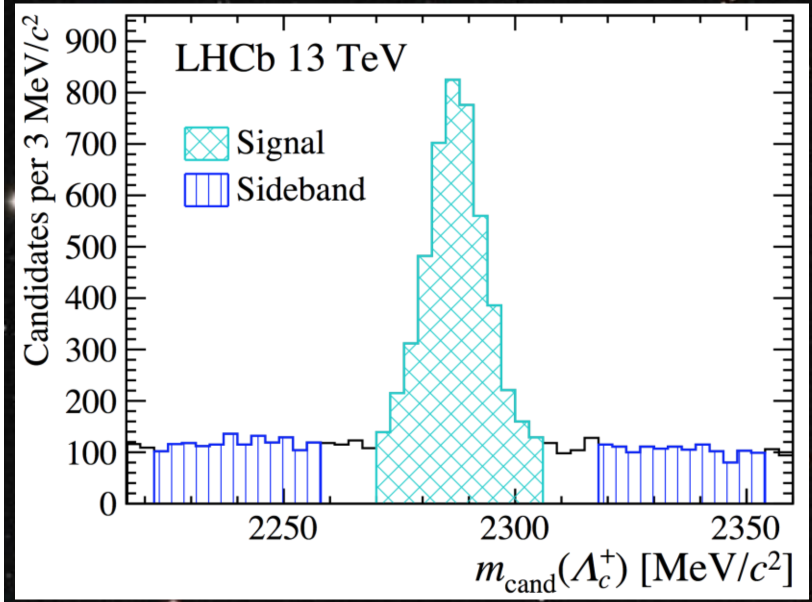


Mass spectrum after selection

PRL119(2017)112001

- A significant structure in right sign (RS) combinations at around $3620\ \mathrm{MeV}/c^2$
- Not present in wrong sign (WS) combinations
- Not observed for Λ_c^+ sidebands candidates
- Distributions similar except the peak in RS





Fit to the peak structure

PRL119(2017)112001

$$m_{\text{cand}}(\Xi_{cc}^{++}) = m(\Lambda_c^+ K^- \pi^+ \pi^+) - m_{\text{cand}}(\Lambda_c^+) + m_{\text{PDG}}(\Lambda_c^+)$$

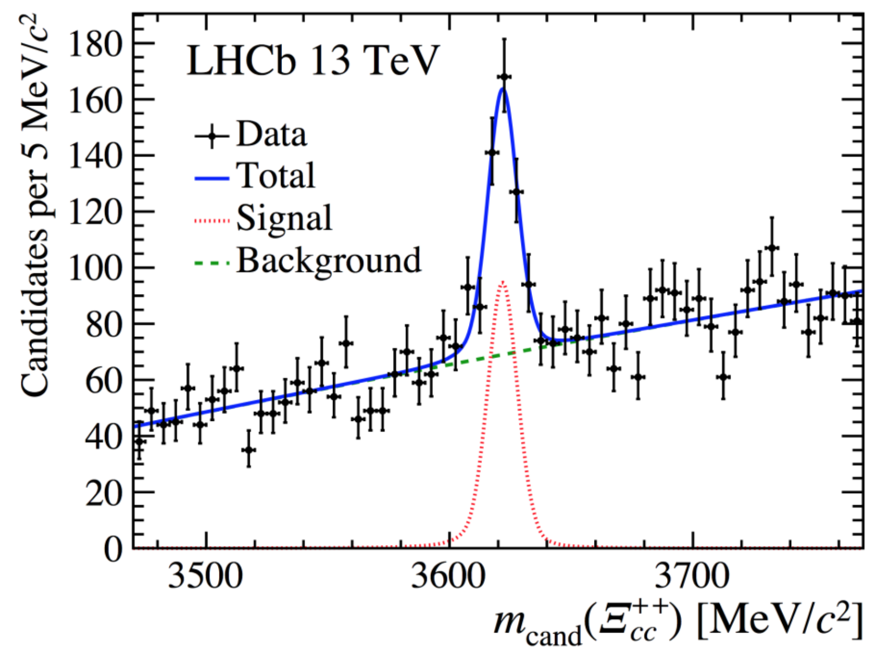
Default fit range: $3620 \pm 150\ \text{MeV}/c^2$

- Signal: DSCB function + Gaussian
  - Mass, yield and overall resolution free, others fixed to simulation
- Bkg: 2nd order Chebychev polynomial
  - All parameters free

$$N_{\text{sig}} = 313 \pm 33$$
$$m = 3621.80 \pm 0.72\ \text{MeV}/c^2$$
$$\sigma = 6.63 \pm 0.82\ \text{MeV}/c^2$$

Mass resolution consistent with simulation

Local stat. significance above 12σ



Mass result

PRL119(2017)112001

- After corrections to biases due to selection and final-state radiation

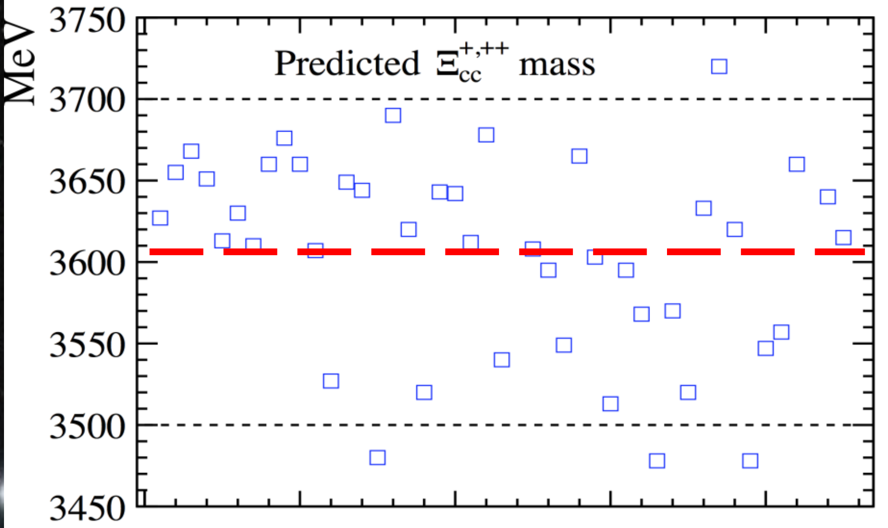
$$m(\Xi_{cc}^{++}) = 3621.40 \pm 0.72(\text{stat}) \pm 0.27(\text{syst}) \pm 0.14(\Lambda_c^+)\ \text{MeV}$$

$$m(\Xi_{cc}^{++}) - m(\Lambda_c^+) = 1134.94 \pm 0.72(\text{stat}) \pm 0.27(\text{syst})\ \text{MeV}$$

Systematic uncertainties

Source	Value [MeV/c^2]
Momentum-scale calibration	0.22
Selection bias correction	0.14
Unknown Ξ_{cc}^{++} lifetime	0.06
Mass fit model	0.07
Sum of above in quadrature	0.27
Λ_c^+ mass uncertainty	0.14

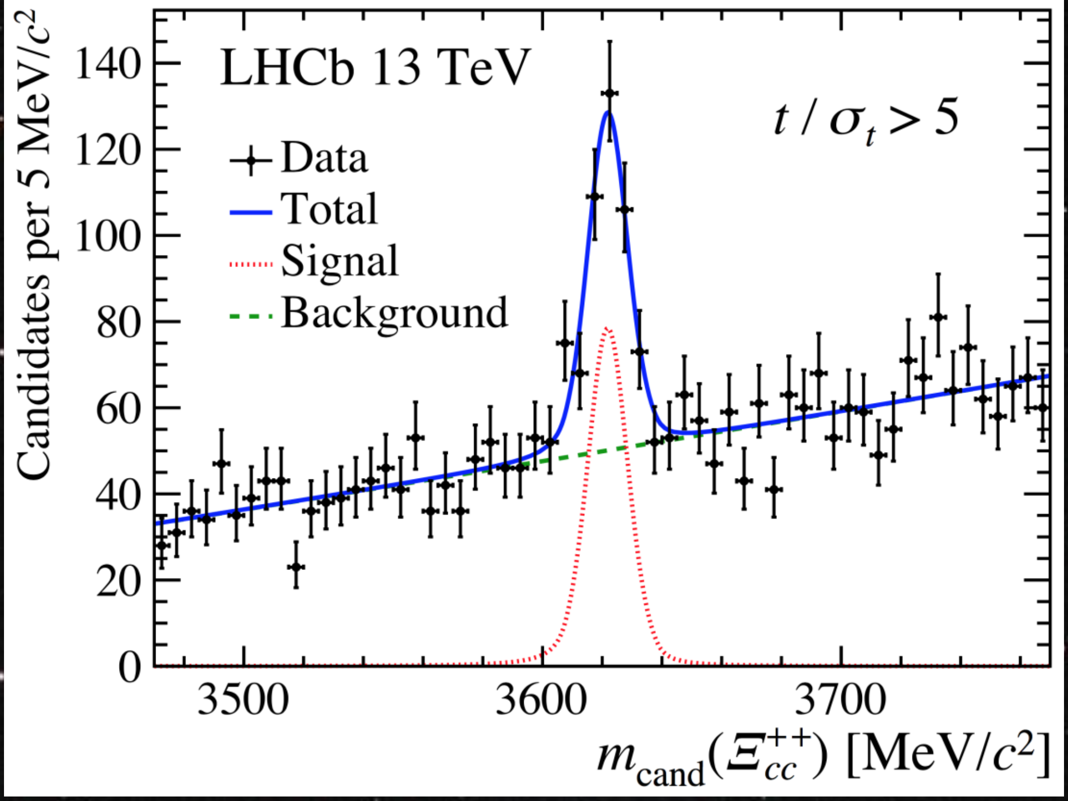
Value consistent with many theoretical calculations



Signal properties: weakly decay

PRL119(2017)112001

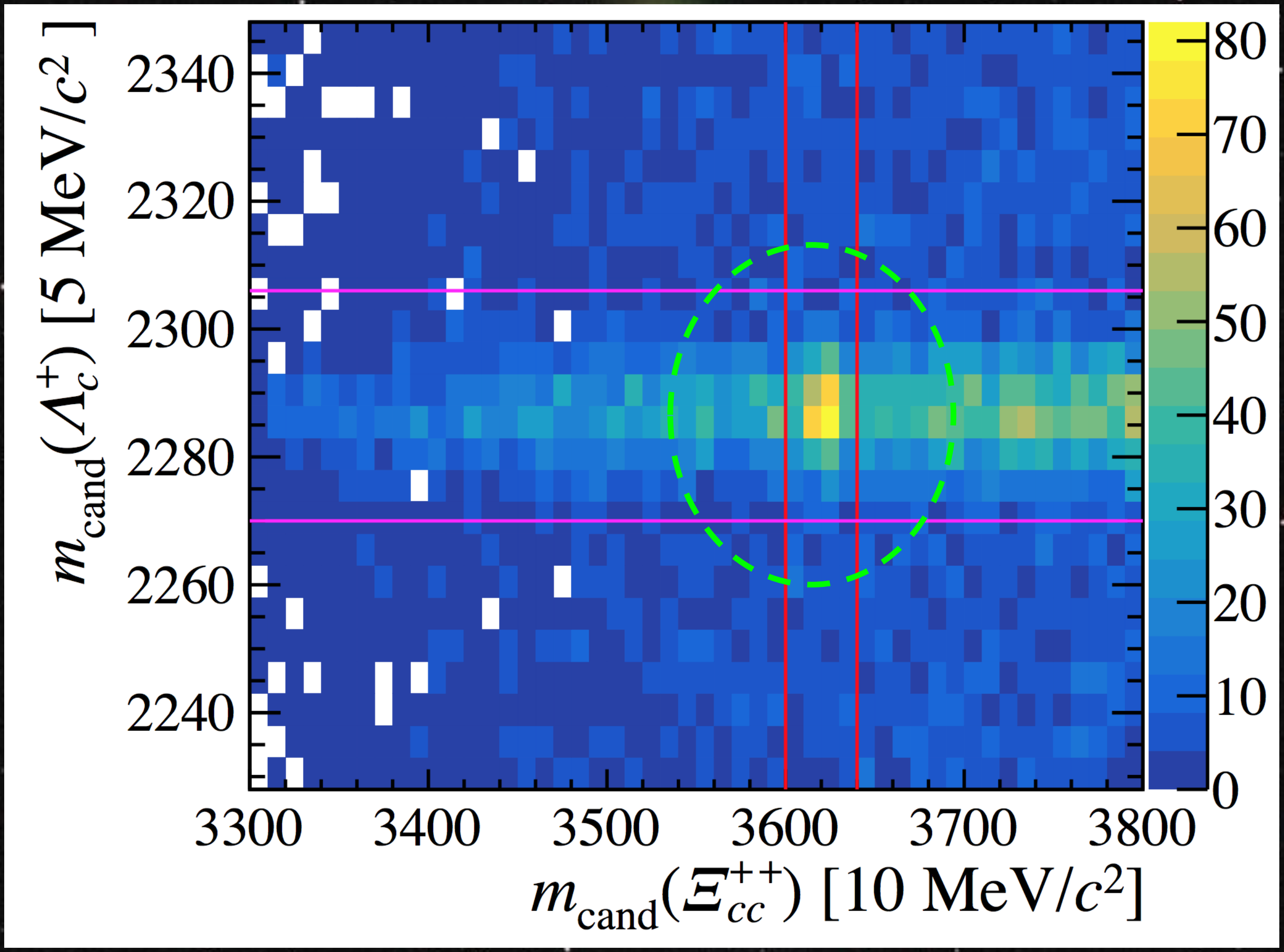
- Peaking structure remains significant $(> 12\sigma)$ after requiring minimum decay time $t > 5\sigma_t$
- **Indeed a weak decay!**



More checks: 2D mass distribution

PRL119(2017)112001

- Signal candidates only present in Λ_c^+ signal region



More tests: Run-I data

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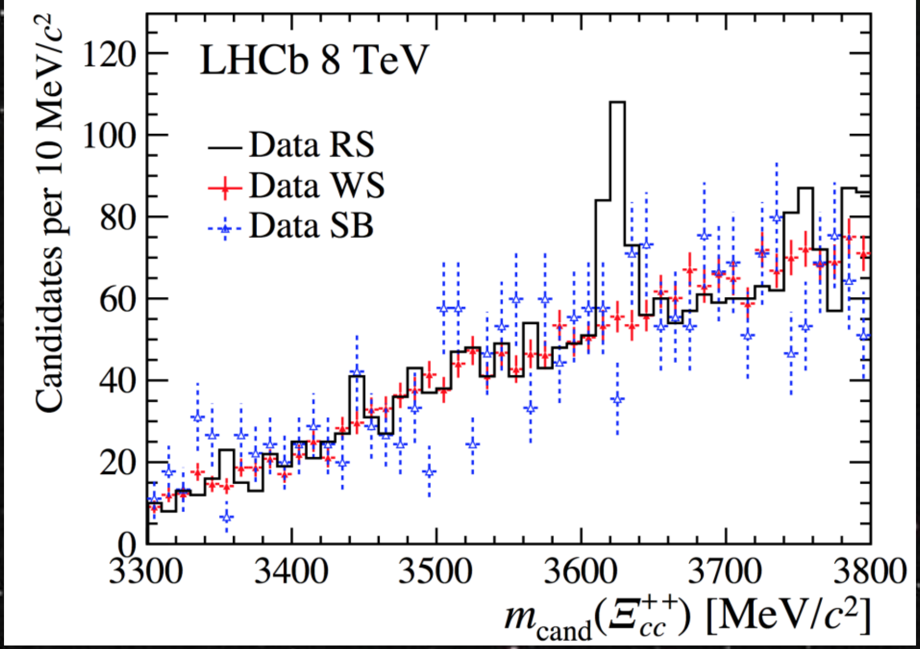
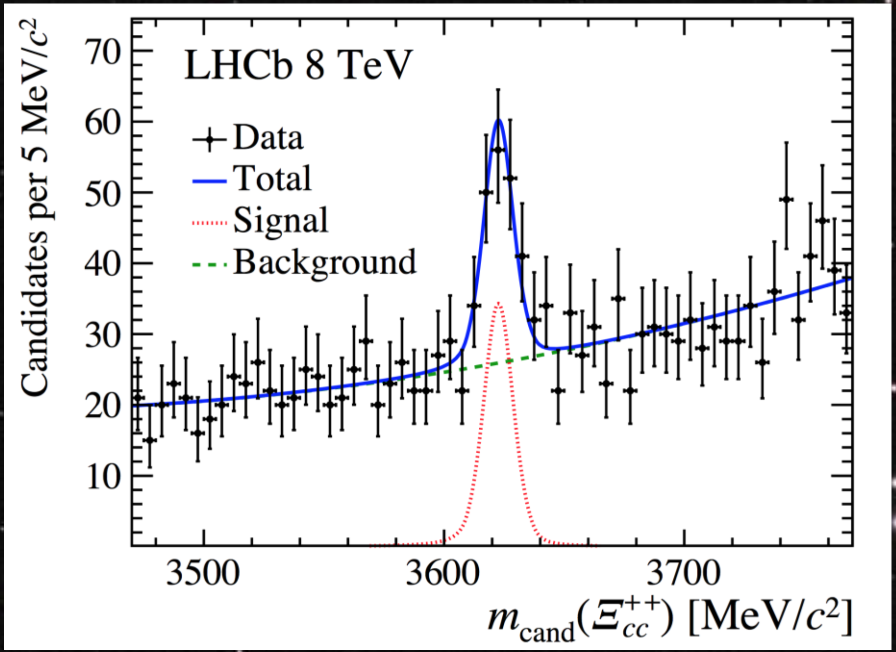
- Signal peak presents in Run-I data sample with significance above 7σ





$N(\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+) = 113 \pm 21$

Resolution: 6.6 ± 1.4 MeV

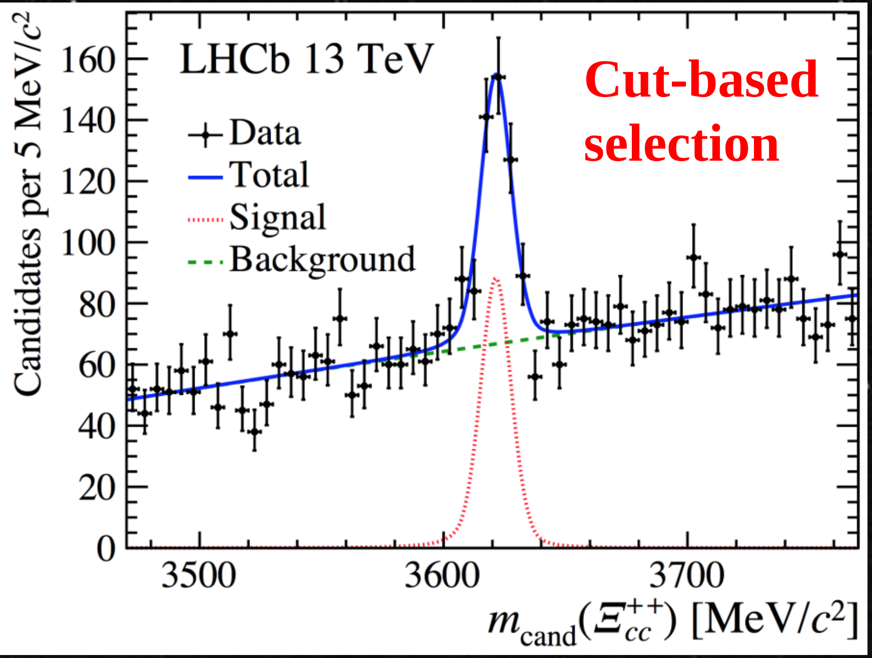
$\delta M(\text{run I}, \text{run II}) = 0.8 \pm 1.4$ MeV

Consistent between two samples

More checks: others

PRL119(2017)112001

1. Multiple candidates: not creating fake narrow structure
2. Checking combinations of tracks from Λ_c^+ and Ξ_{cc}^{++}: not peaking
3. MVA efficiency as a function of mass: very smooth
4. Varying MVA selector cut: structure stays significant
5. Varying particle ID selections: no peaking structure emerging in WS combinations, structure stays in RS sample
6. Using a cut based selection instead of using MVA, requiring good vertex fit quality, Ξ_{cc}^{++} vertex displaced and tracks are not produced from PV: peak significance $> 12\sigma$



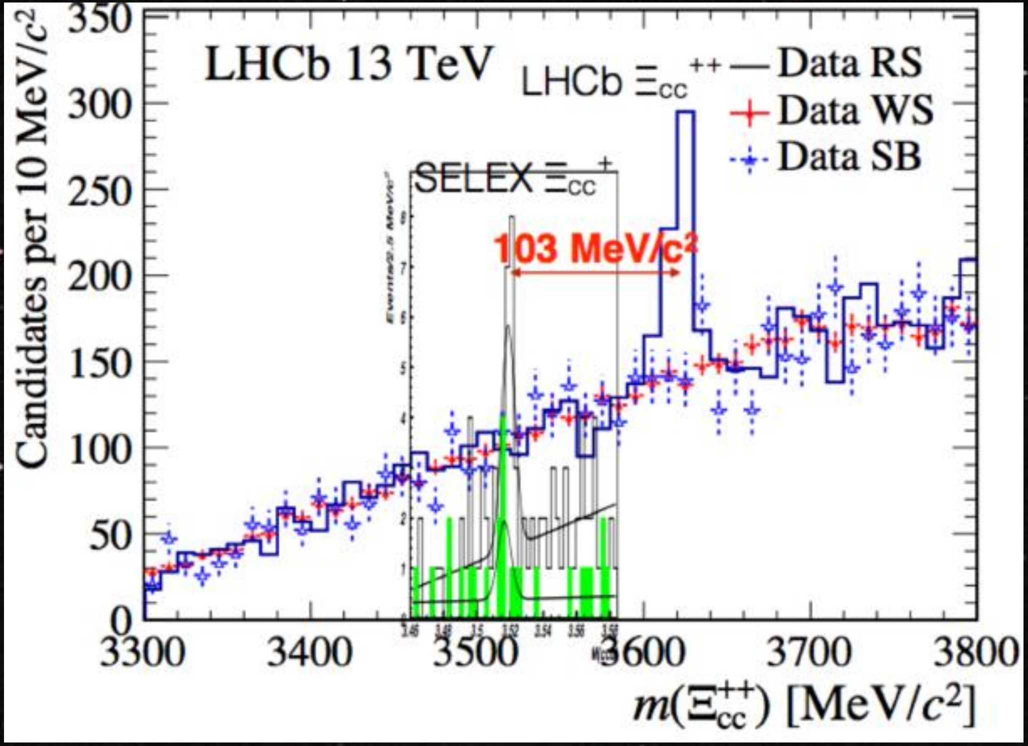
Comparion with SELEX

PRL119(2017)112001

- Large mass difference, inconsistent with being isospin partners

$$m(\Xi_{cc}^{++})_{\mathrm{LHCb}} - m(\Xi_{cc}^{+})_{\mathrm{SELEX}} = 103 \pm 2\ \mathrm{MeV/c^2}$$

- Production: $N(\Xi_{cc})/N(\Lambda_c^+)$ much smaller in the LHCb result



- **Giovanni Passaleva, LHCb发言人**

  *"The LHCb Chinese scientists played a crucial role in the observation of the new particle. They are being rewarded for a long standing and highly recognized experimental effort. A group of **Chinese theorists** provided also **fundamental inputs** to drive the analysis to the right direction and gave **key suggestions** to achieve this result."*

- **Vincenzo Vagnoni, LHCb物理协调人**

  *"Our Chinese colleagues have been very active in the LHCb physics analysis. They ever played a **leading role** in the **discovery of pentaquark states** in 2015 and this time in the **discovery of** Ξ_{cc}^{++}. I am looking forward to their continuous efforts on this exciting topic in the future."*

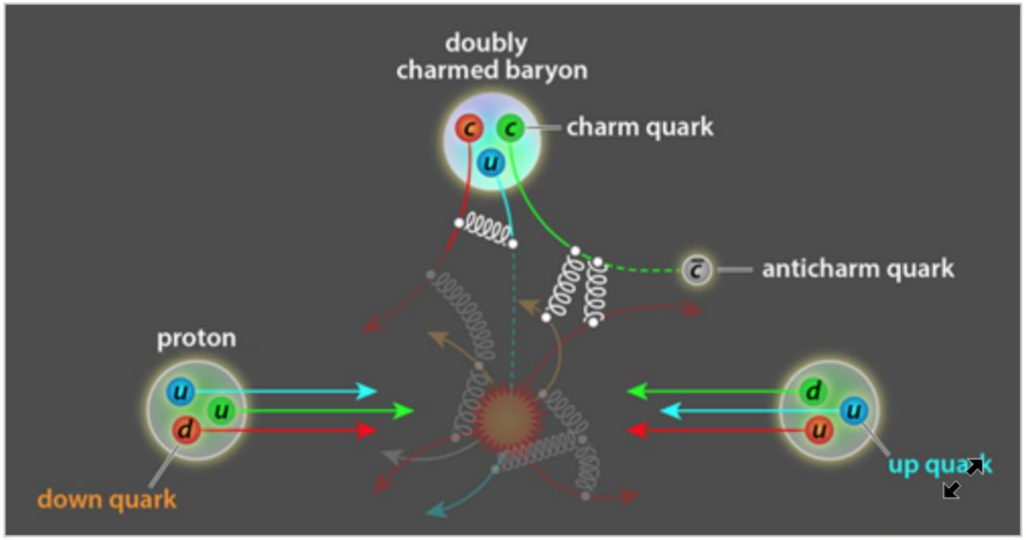
Highlighted by PRL editors as "*Editors' Suggestion*"

Viewpoint: A Doubly Charming Particle

Raúl A. Briceño, Department of Physics, Old Dominion University, Norfolk, VA 23529, USA and Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

September 11, 2017 • *Physics* 10, 100

High-precision experiments at CERN find a new baryon containing two charm quarks.



APS/Alan Stonebraker

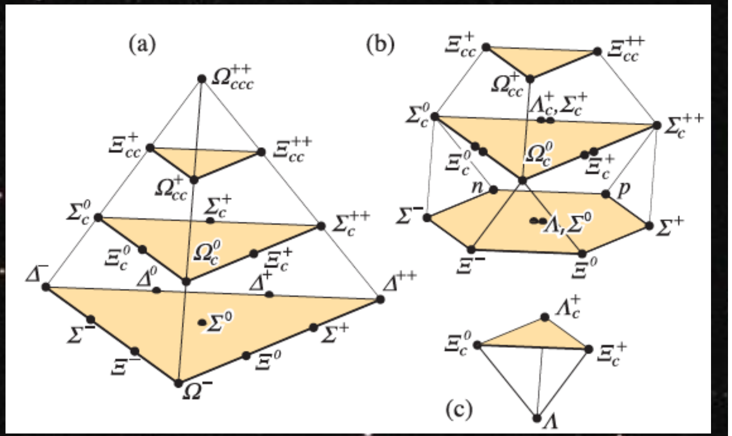
Figure 1: The LHCb Collaboration has provided evidence for a doubly charmed baryon called Ξ_{cc}^{++} [1]. The baryon is formed when two charm quarks, produced in high-energy proton-proton collisions, join a light quark.

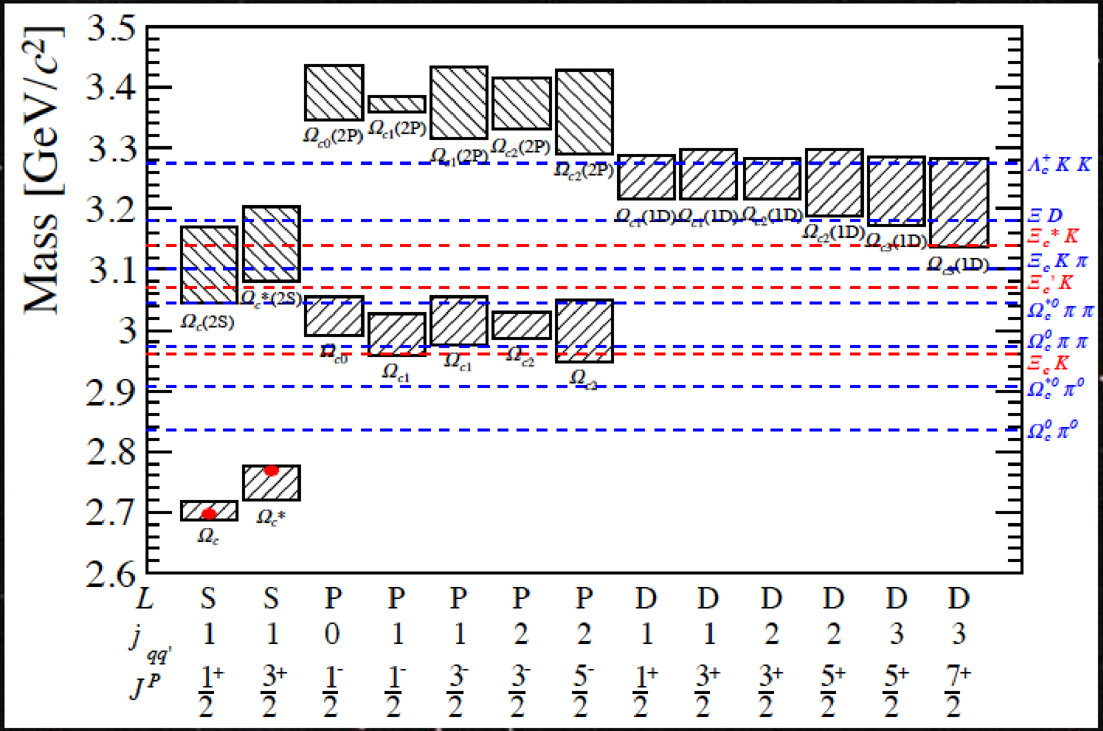
Observation of excited Ω_c^0 states

[PRL 118 (2017) 182001]

Ω_c baryons

- Experimental knowledge of charmed baryons is limited
- Only two $\Omega_c(css)$ states observed, many others to be filled in the table
- LHCb has great potential to study excited states of Ω_c

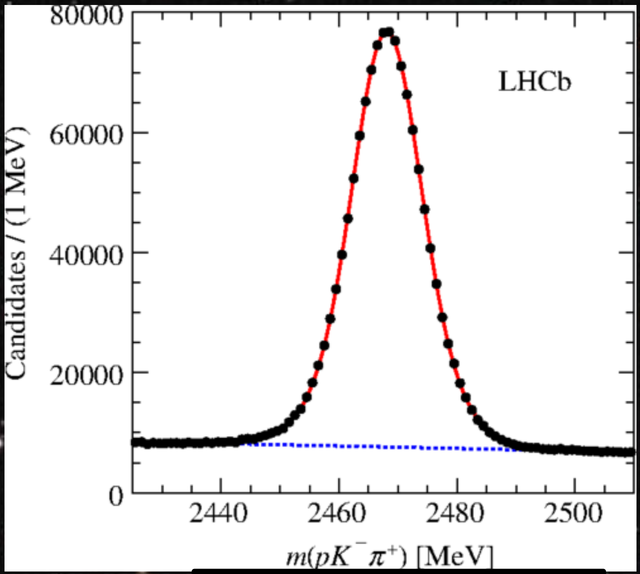




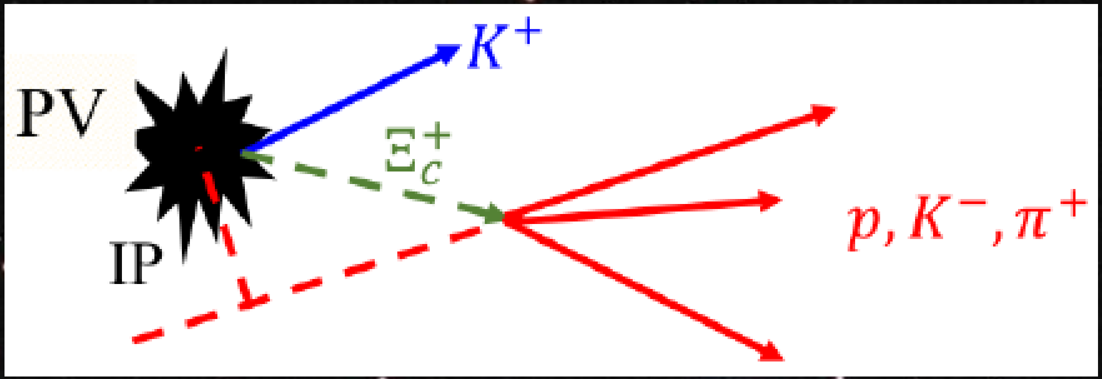
Observation of excited Ω_c^0 resonances

LHCb, PRL118 (2017) 182001

- Data sample $3.3\ \mathrm{fb}^{-1}$ of LHCb data at 7, 8 and 13 TeV
- Decay chain: $\Omega_c^{**0} \to \Xi_c^+ K^-$
  $\hookrightarrow pK^-\pi^+$
  - Mass spectrum studied up to 3450 MeV
- Clean $\Xi_c^+ \to pK^-\pi^+$ signals
  - Cabibbo suppressed, but high selection efficiency at LHCb



$\sigma(m) = 7$ MeV
Purity: 83%



Five new Ω_c^0 resonances in $\Xi_c^+ K^-$

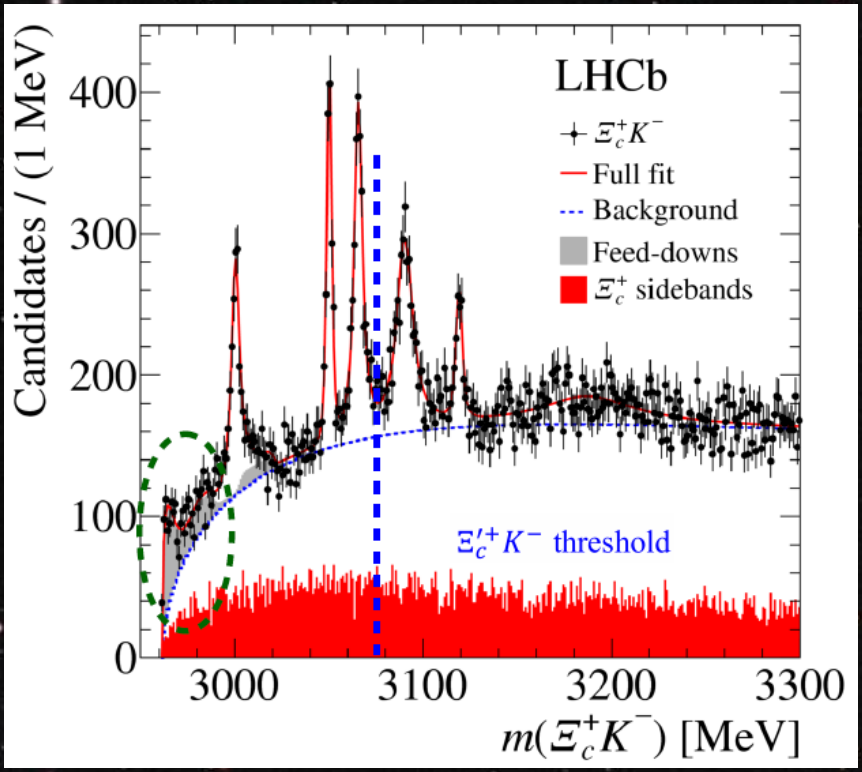
LHCb, PRL118 (2017) 182001

- **Five clear peaks observed!**
  - No peaks in Ξ_c^+ sideband with K^- combination, nor wrong-sign combination $\Xi_c^+ K^+$
  - A possible 6[th] wider state, feed-down contribution,

$\Omega_c^{**0} \to \Xi_c'^+ K^-$

$\hookrightarrow \Xi_c^+ \gamma$ *(missing)*

Fit quality improved when including a broad structure or multiple states around 3200 MeV.

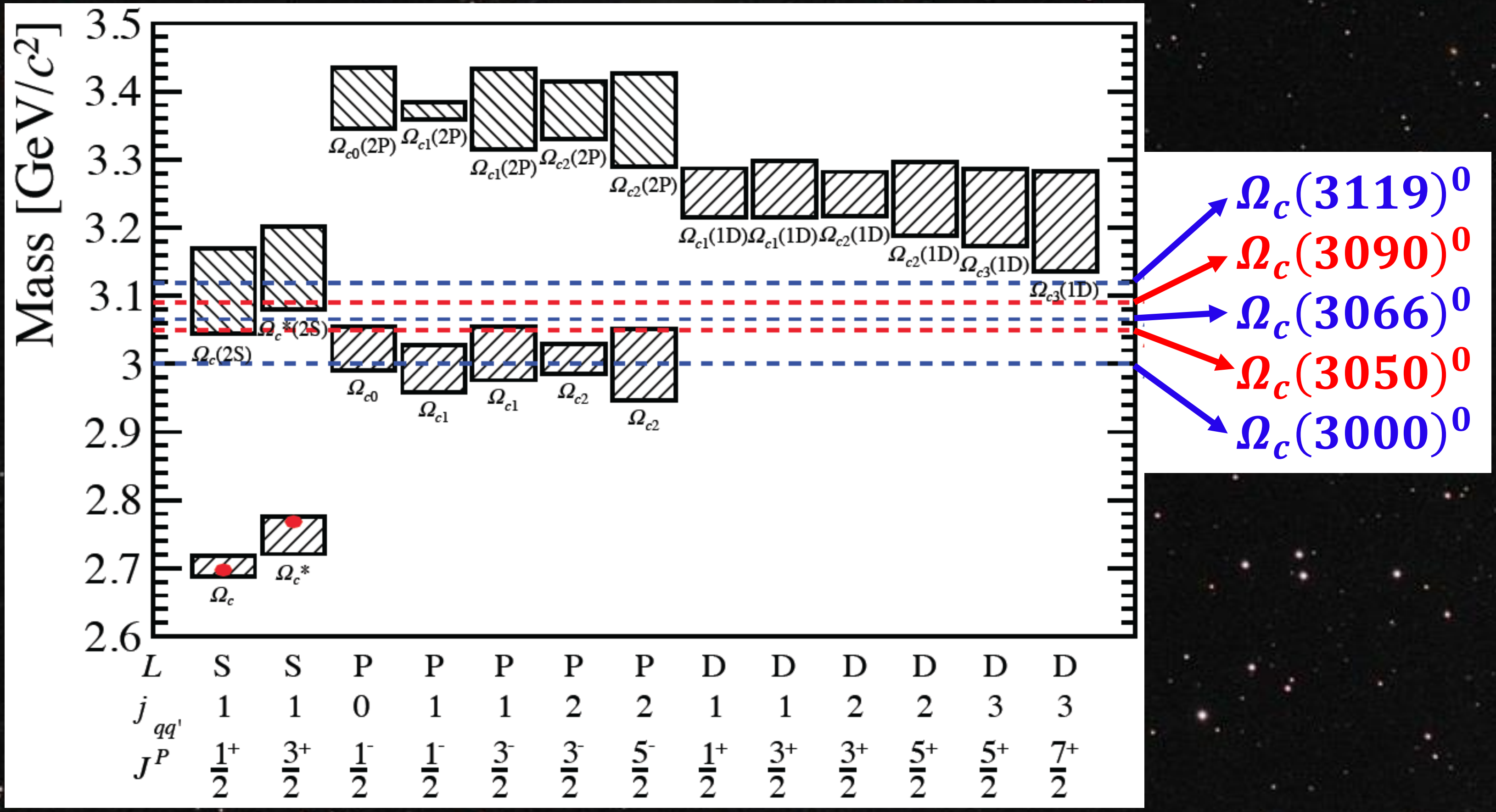


A demonstration of the power of precision!

Five new Ω_c^0 resonances in $\Xi_c^+ K^-$

LHCb, PRL118 (2017) 182001

- Not clear who is who
- Spin and parity need to be determined via 3-body decays or decays from heavier baryons



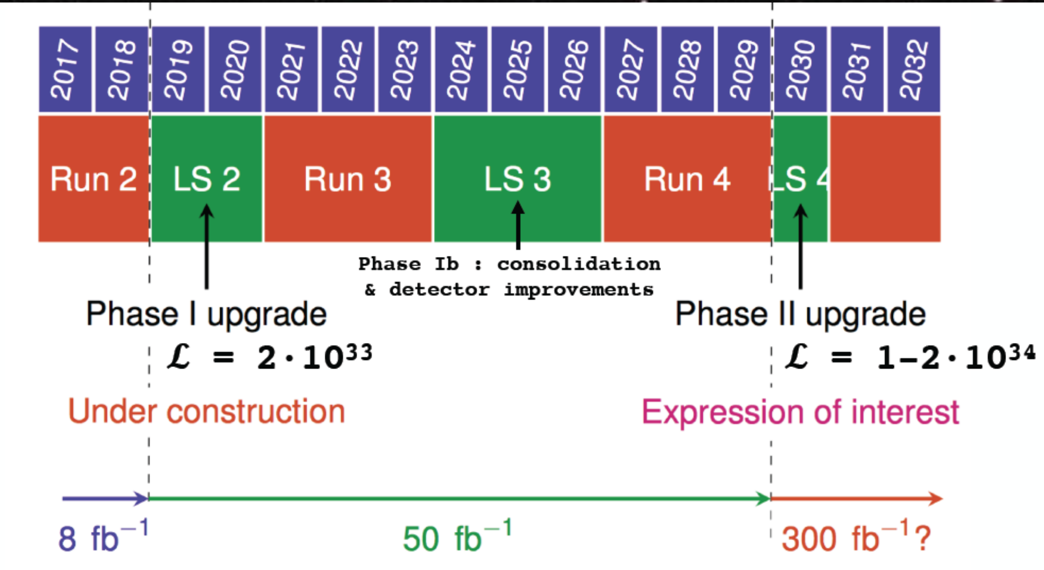
Prospects

Full of opportunities and challenges in charm spectroscopy

- Determine the Ξ_{cc}^{++} lifetime, cross-section, and J^P
  - Difficult to determine efficiencies, possible biases
  - How to determine the J^P?
- Other decays of Ξ_{cc}^{++}: $\Xi_c^+\pi^+$, $\Lambda_c^+\pi^+$, $pD^+K^-\pi^+$, ……
  - BF's and/or efficiencies smaller, and more data needed
- The isospin partner Ξ_{cc}^{+} and the Ω_{cc}^{+}
  - Lower efficiencies due to shorter lifetime
  - Smaller production ratio for Ω_{cc}^{+}
  - More data and more clever triggers/selections awaited
- The excited states (singly or doubly charmed)?
  - Detection power of low p_{T} hadrons/photons to be improved

Prospects

- $8\ \mathrm{fb}^{-1}$ expected by end of 2018 (including $3\ \mathrm{fb}^{-1}$ Run1)
  - Huge amount of open charms produced (and recorded?)
- Detector fully replaced in 2019-2020 to achieve $50\ \mathrm{fb}^{-1}$
  - More efficient and powerful
- Phase II upgrade for $300\ \mathrm{fb}^{-1}$ is on the way
  - To make the impossible be possible



Inputs from you are needed.

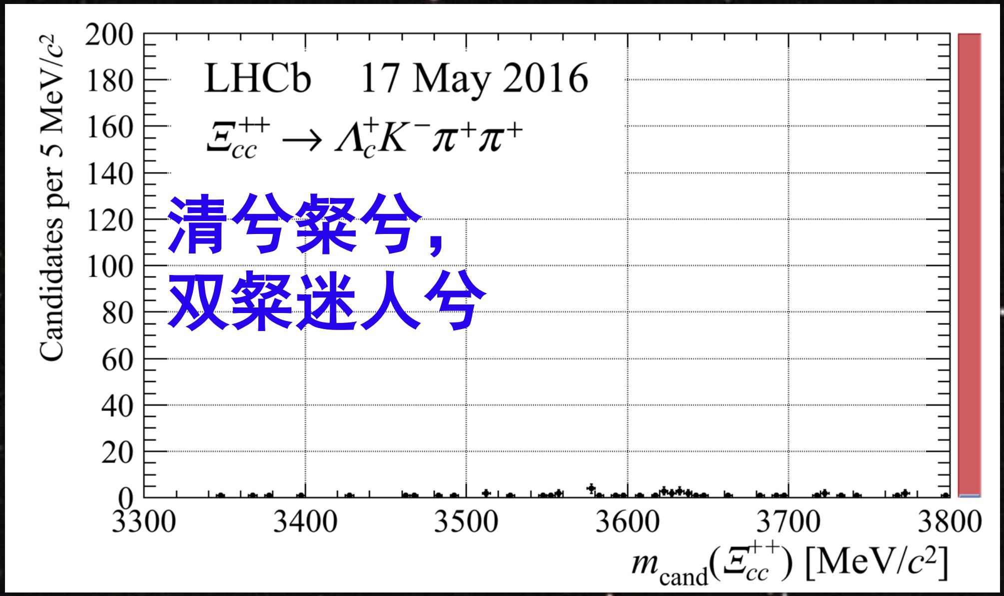
When?——Now!

Summary

- “*The LHCb experiment is charmed to announce observation of a new particle with two heavy quarks*” (LHCb实验粲然宣布发现双粲重子) ——CERN press release
  - Mass $m = 3621.40 \pm 0.78\ \mathrm{MeV}/c^2$, inconsistent with the Ξ_{cc}^{+} reported by SELEX being its isospin partner
  - New window opened for charm hadron spectroscopy studies
- Observation of five new excited Ω_c^{**0} resonances

“人类首次破天荒地同时发现了5个粒子”
——国内媒体报道

Thank you ~



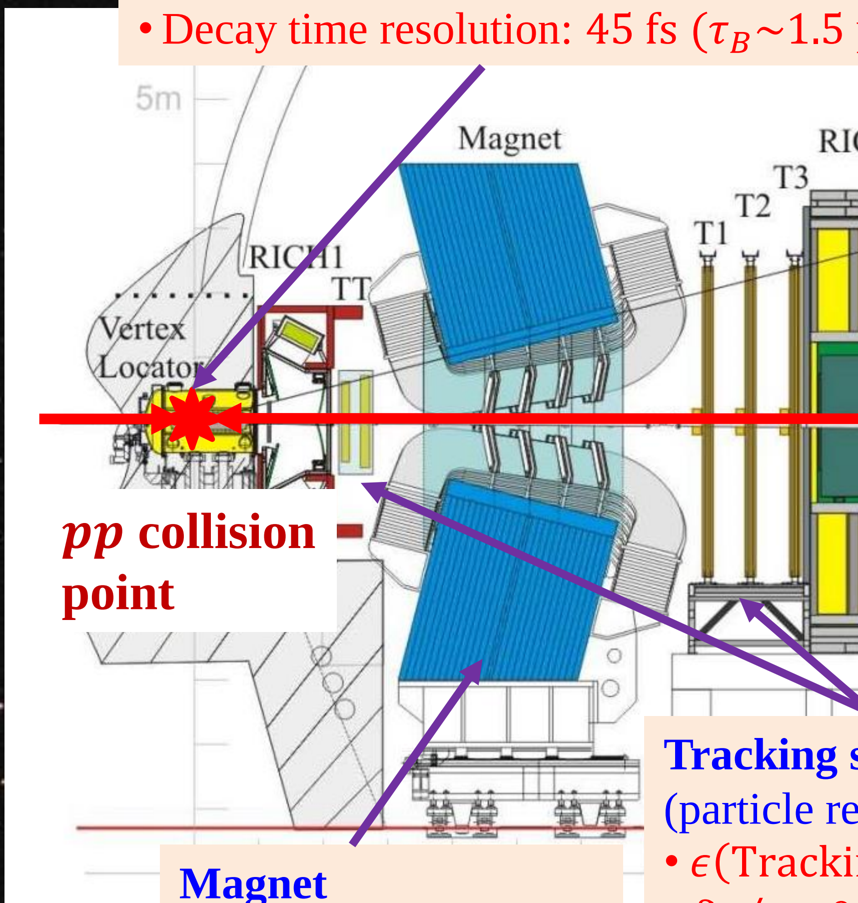
Backup slides

The LHCb detector

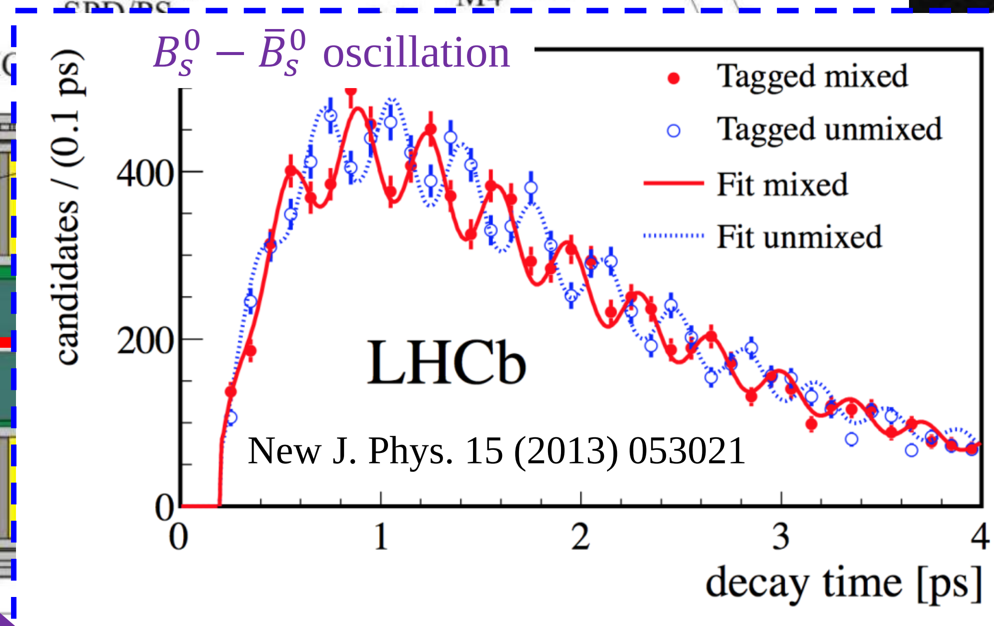
JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

Vertex Locator (vertex reconstruction)

- Impact parameter resolution: 20μm
- Decay time resolution: 45 fs (τ_B~1.5 ps)



pp collision point



Magnet
Bending power: 4 Tm

Tracking system
(particle reconstruction)

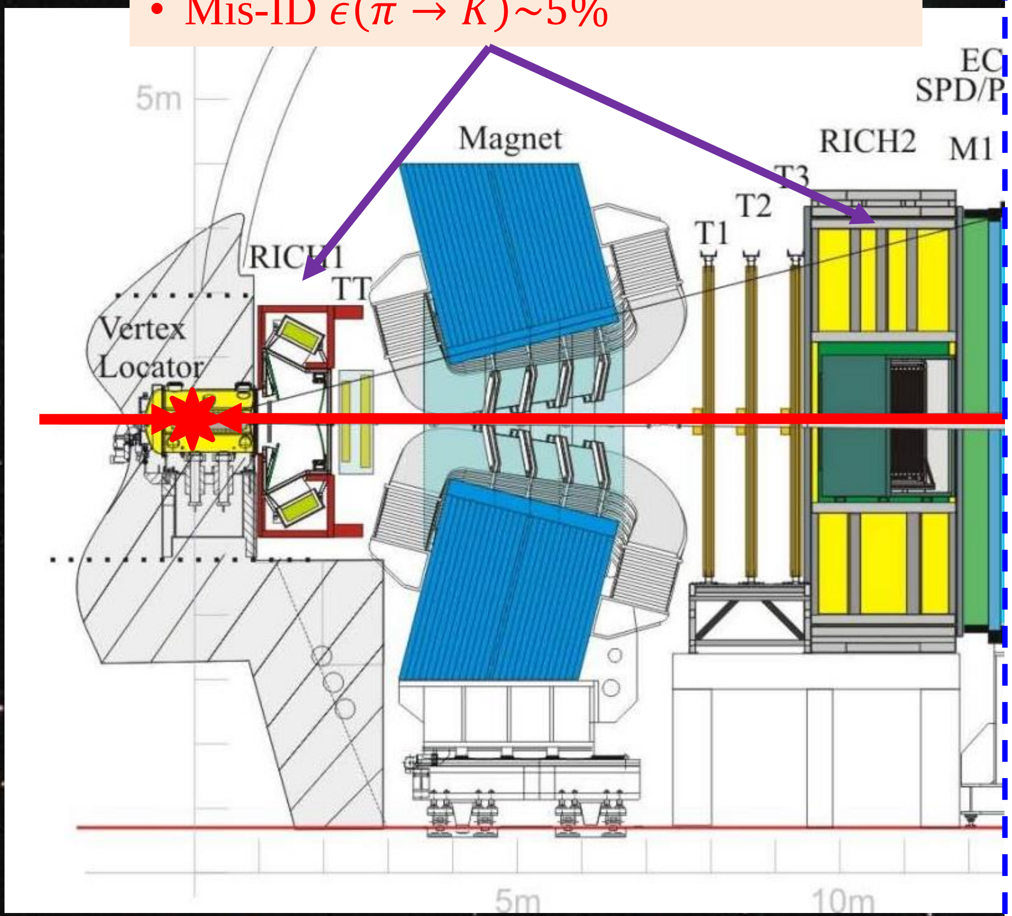
- ϵ(Tracking)~96%
- $\delta p/p$ ~0.5%-1% (5-200 GeV)
- $\sigma(m_{B\rightarrow hh}) \approx 22$ MeV

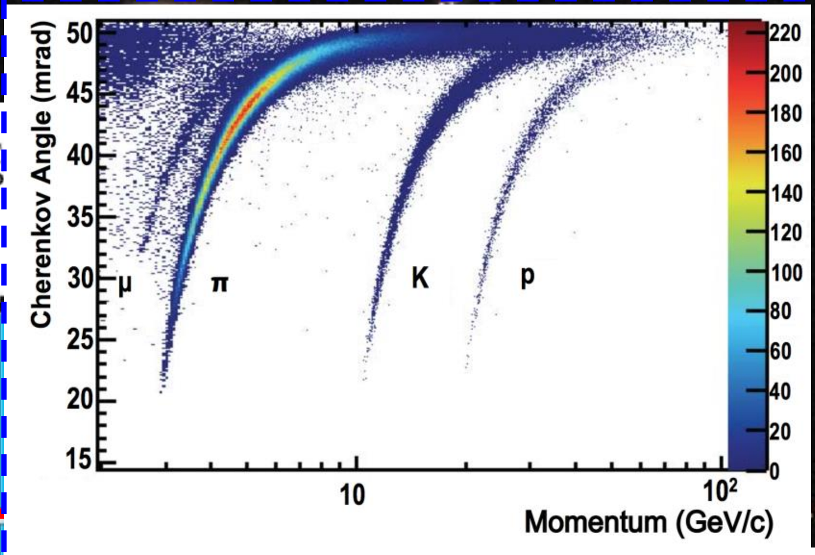
The LHCb detector

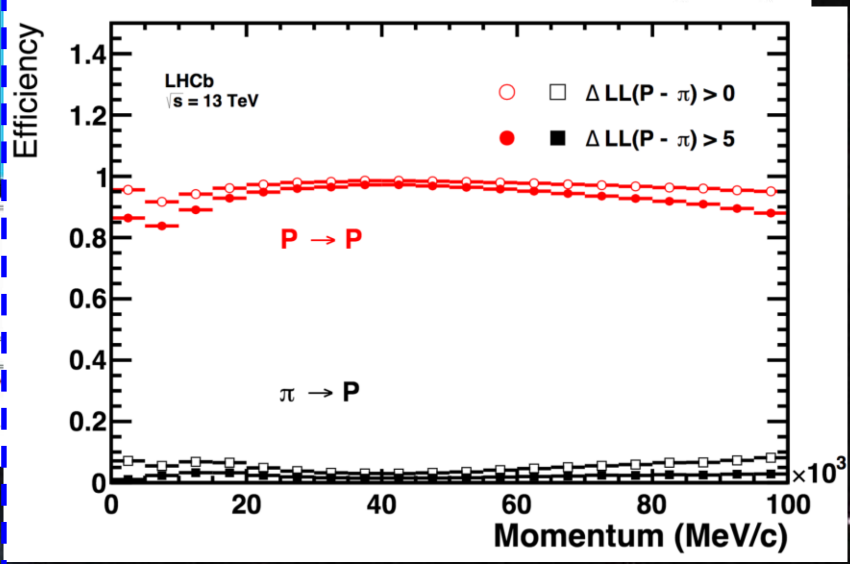
JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

RICH detectors ($K/\pi/p$ separation)

- $\epsilon(K \to K) \sim 95\%$
- Mis-ID $\epsilon(\pi \to K) \sim 5\%$

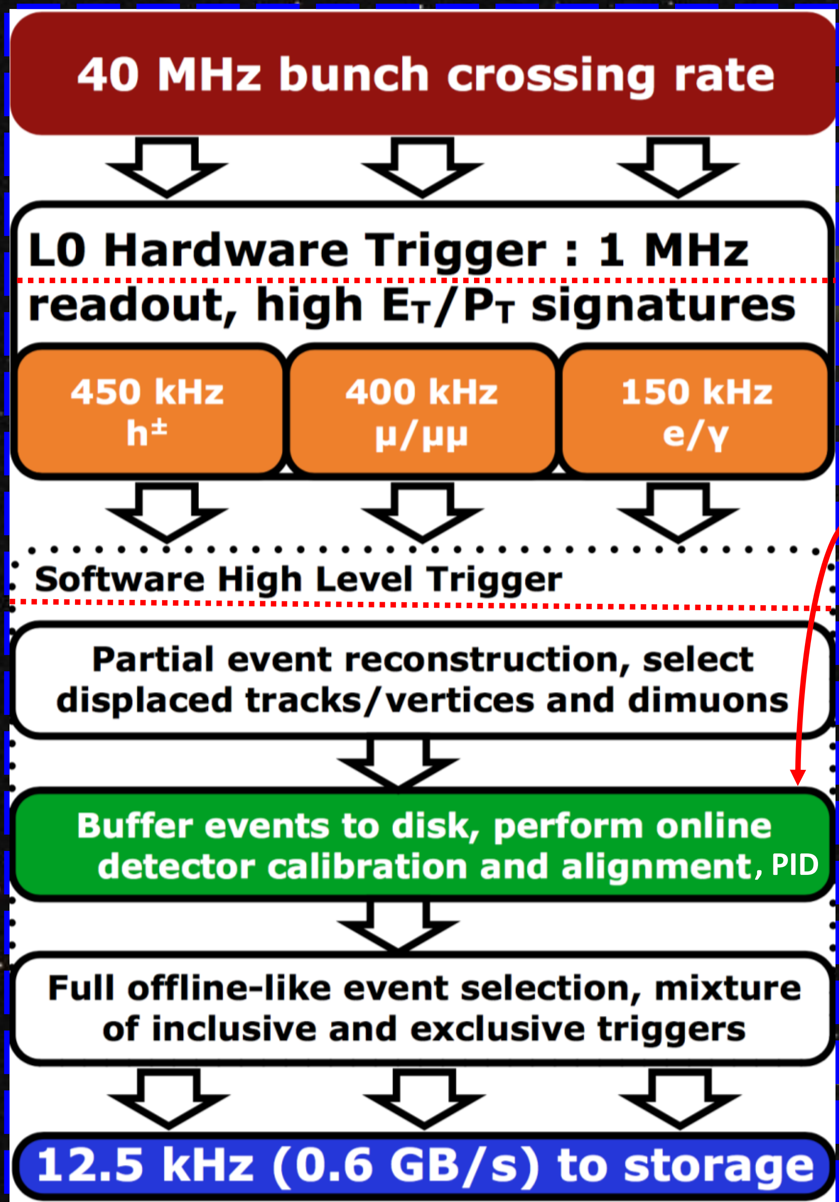






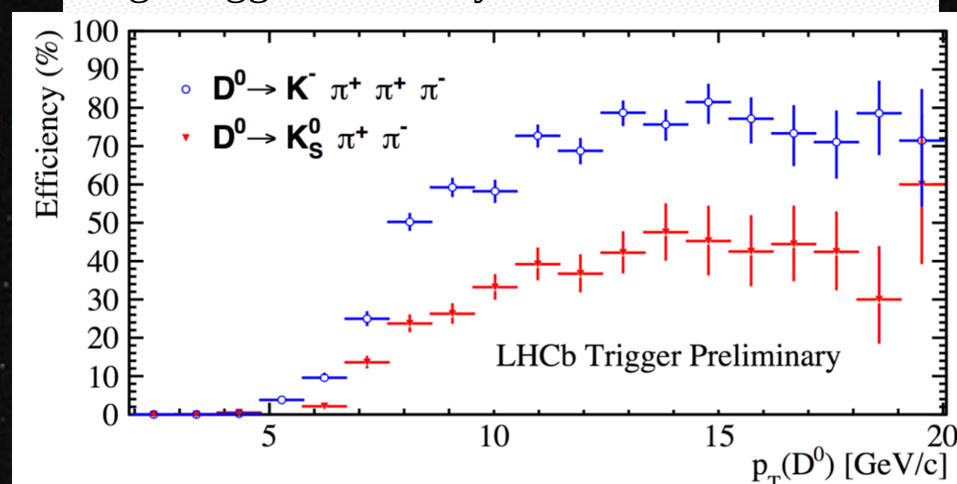
Trigger

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



Run II Turbo stream:
Candidates reconstructed at trigger level saved for offline analyses directly

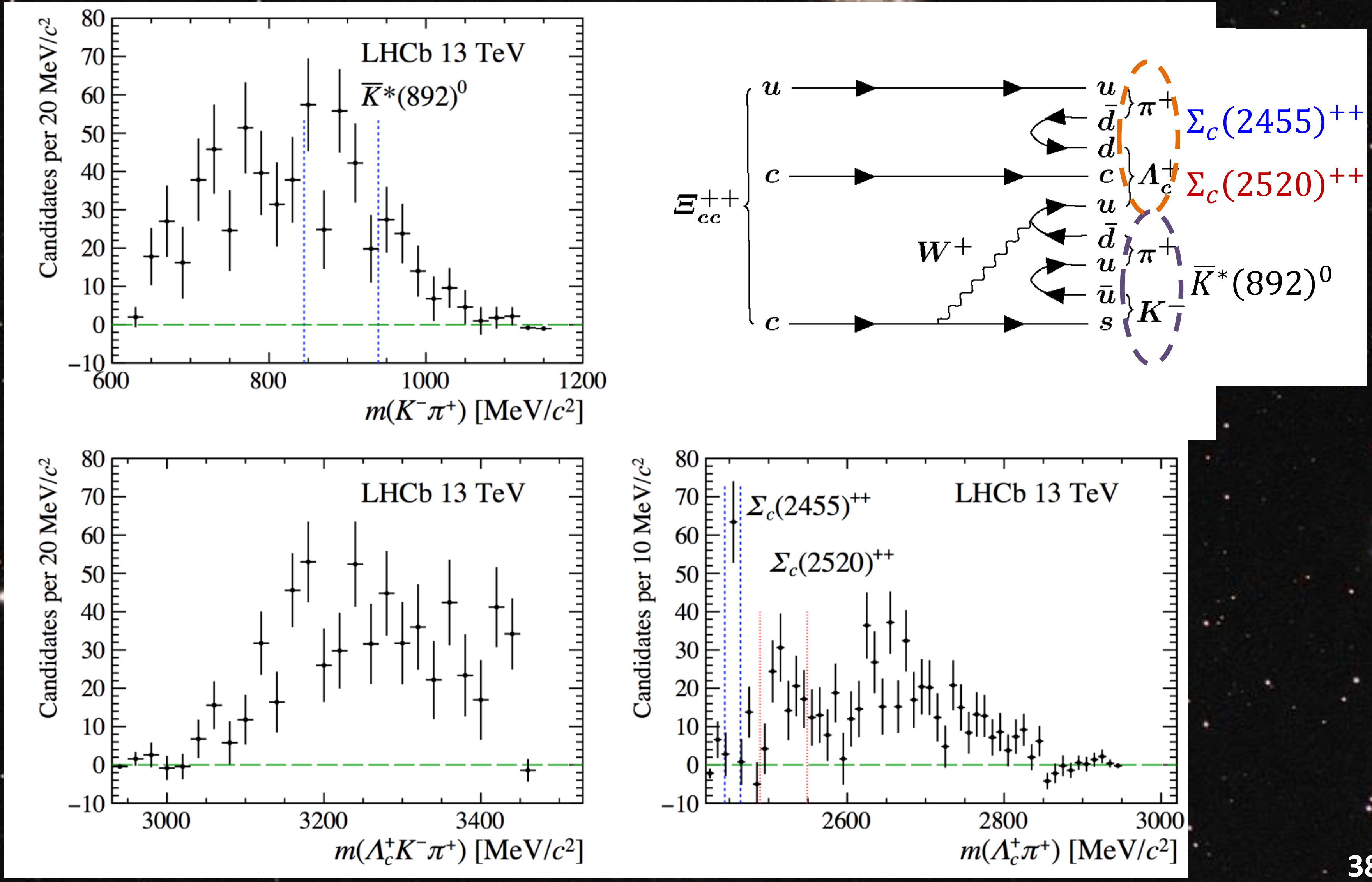
High trigger efficiency for hadronic channels



Signal properties: intermediate resonances

➢ $\overline{K}^{*}(892)^{0}$, $\Sigma_c(2455)^{++}$, $\Sigma_c(2520)^{++}$

PRL119(2017)112001



Lifetimes of ½⁺ states

- Spectator model predicts almost equal lifetimes
  - True for bottom hadrons: 1.5 ps $\pm$ 10%
  - True for charm semi-leptonic decay width:

    $\Gamma(H_c \to l\nu_l X) = \frac{\mathrm{Br}(H_c \to l\nu_l X)}{\tau_{H_c}} \approx 0.3\ \mathrm{ps}^{-1}$

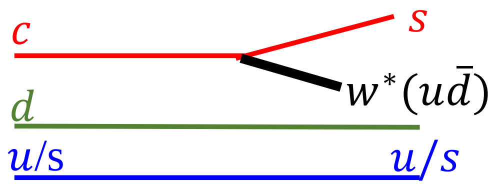
- But charm hadron lifetimes known to vary a lot

	PDG
D^0	0.410 ± 0.002
D_s^+	0.500 ± 0.007
D^+	1.040 ± 0.007
$D_b^+(B_c^+)$	0.507 ± 0.009
$\Lambda_c^+(cud)$	0.200 ± 0.006
$\Xi_c^0\,(csd)$	0.112 ± 0.012
$\Xi_c^+(csu)$	0.442 ± 0.026
$\Omega_c^0\,(css)$	0.069 ± 0.012

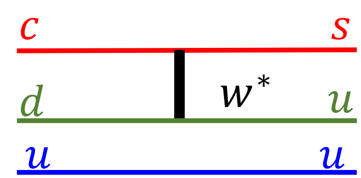
ps

- Explained by non-spectator decays and Pauli interference, qualitatively

Spectator (Γ_s)



W-exchange (W)



  - Destructive/constructive interference ($\Gamma_s^{-/+}$): $cuq/csq \to suq/ssq(u\bar{d})$
  - W-exchange process (enhancement): $cdq \to suq$
  - $\Gamma(\Xi_c^0: W + \Gamma_s^+) > \Gamma(\Lambda_c^+: W + \Gamma_s^-) > \Gamma(\Xi_c^+: \Gamma_s^{+-})$

- Expectation: $\tau(\Xi_{cc}^{++}(ccu)) \gg \tau(\Xi_{cc}^{+}(ccd))$
- Calculations give $\tau(\Xi_{cc}^{++}) \in [\,200 - 700]$ fs Refs.[5, 6, 12 49-52]

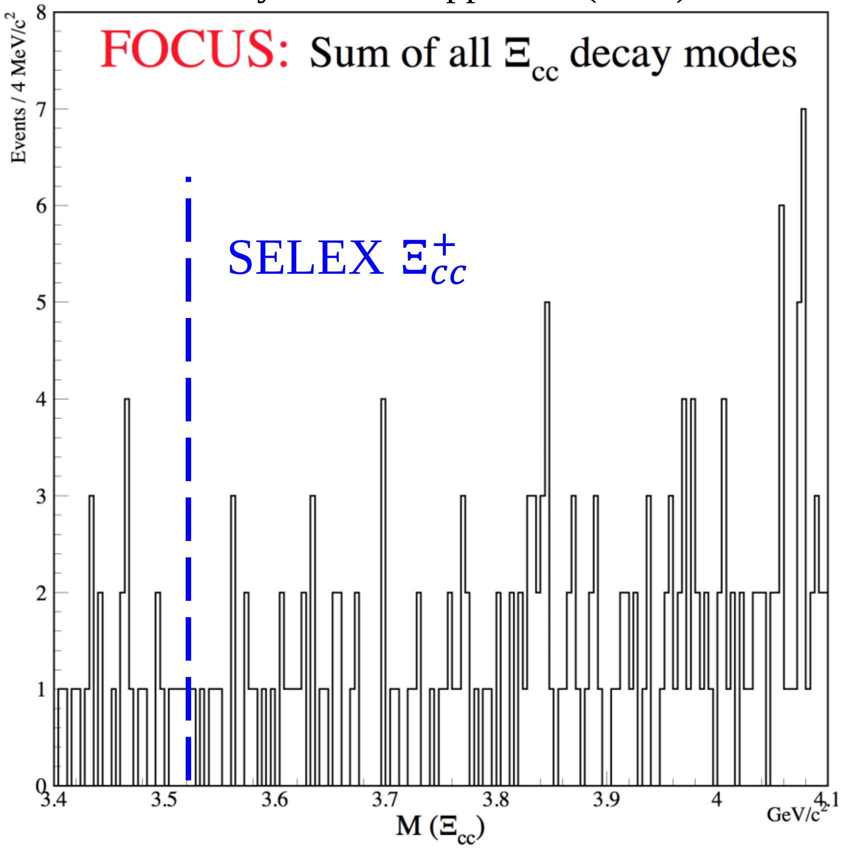
Studies of Ξ_{cc} by FOCUS

- FOCUS (Fermilab E831) studies charm hadrons produced in photon-nuclear fixed target collisions
- FOCUS didn't confirm Ξ_{cc}^{+} observed by SELEX in $\Lambda_c^+ K^- \pi^+$ decay

Decay Mode	$\Xi_{cc}^{+} \to \Lambda_c^+ K^- \pi^+$	
Experiment	FOCUS	SELEX
Ξ_{cc} Events	<2.21 @ 90%	15.8
Reconstructed Λ_c	$19,444 \pm 262$	1650
Relative Efficiency	5%	10%
Ξ_{cc}/Λ_c^+	<0.23% @ 90%	9.6%
$\frac{\text{SELEX}}{\text{FOCUS}}$ Rel $\frac{\Xi_{cc}}{\Lambda_c}$ Prod	>42 @ 90%	

- Other modes also studied: $\Xi_{cc}^{+} \to \Lambda_c^+ X$, $D^0 X$ $D^+ X$, no SELEX-like signal peak observed

Nucl. Phys. Proc. Suppl. 115 (2003) 33

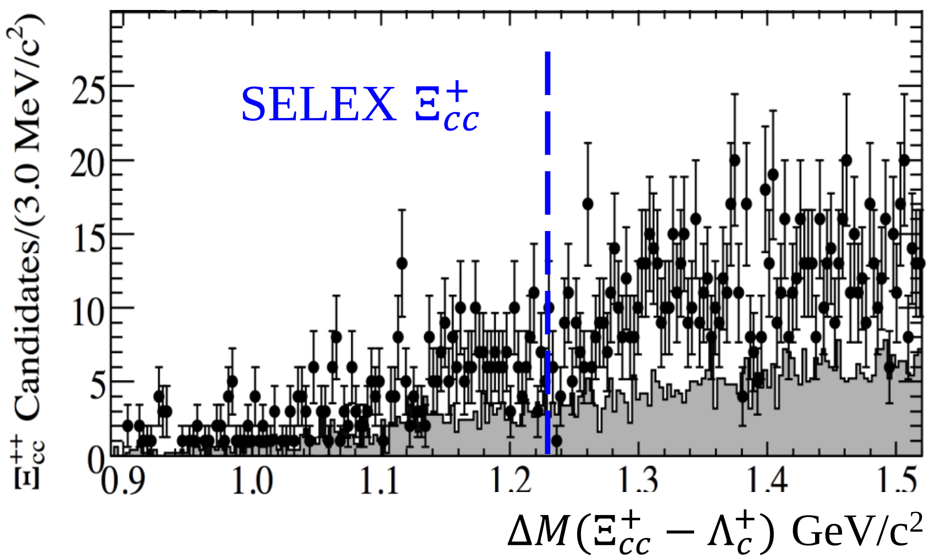


Studies of Ξ_{cc} by BaBar and Belle

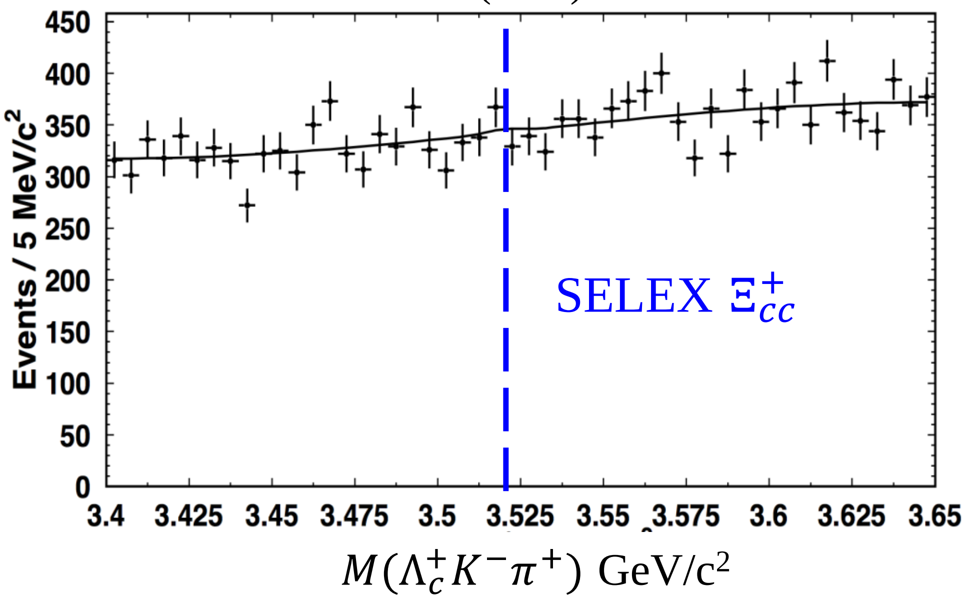
- e^+e^- colliders working at $\Upsilon(4S)$ mass $\sqrt{s} = 10.58$ GeV
- Large Λ_c^+ yields: $\approx$ 0.6 M at BaBar, $\approx$ 0.8 M at Belle
- SELEX-like Ξ_{cc}^+ signal not confirmed in $\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ decays

$$R = \frac{\sigma(\Xi_{cc}^+) \times \mathrm{BF}(\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+)}{\sigma(\Lambda_c^+)} < 2.7 \times 10^{-4} \text{ (BaBar)} \quad 1.5 \times 10^{-4} \text{ (Belle)} \quad @ \text{ 95\% CL}$$

BaBar: PRD 74 (2006) 011103



Belle: PRL 97 (2006) 162001



Ω_c^{**0} results

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.		
$\Omega_c(3188)^0$	$3188 \pm 5 \pm 13$	$60 \pm 15 \pm 11$	$1670 \pm 450 \pm 360$	
$\Omega_c(3066)^0_{\rm fd}$			$700 \pm 40 \pm 140$	
$\Omega_c(3090)^0_{\rm fd}$			$220 \pm 60 \pm 90$	
$\Omega_c(3119)^0_{\rm fd}$			$190 \pm 70 \pm 20$	

More results from SELEX (unpublished)

Summary I

- Double charm is here to stay
  - Selex has seen 3 double charmed baryon states in 3, 1 and 2 decay modes.
  - $\Xi_{cc}^{+}(3520)$ seen decaying into three different single charm states.
  - $\Xi_{cc}^{++}(3780)$ excited state shows chain decay via pion emission.
  - $\Xi_{cc}^{++}(3452)$ ground state observed in two different decay modes. Splitting is too large (67 MeV) for this state to sensibly be the isospin partner of the $\Xi_{cc}^{++}(3519)$. Radiative decays are suppressed?
  - This logic requires at least two more weakly decaying states, the isospin partners of the $\Xi_{cc}^{++}(3452)$ ground state and the partner of the EM decay suppressed $\Xi_{cc}^{++}(3519)$.
  - Selex has some hints of these but makes no claims now.
  - No report yet on the third double charm baryon, the Ω_{cc}^{+}(ccs)