FUDAN UNIVERSITY

Recent experimental results on heavy flavors at Belle

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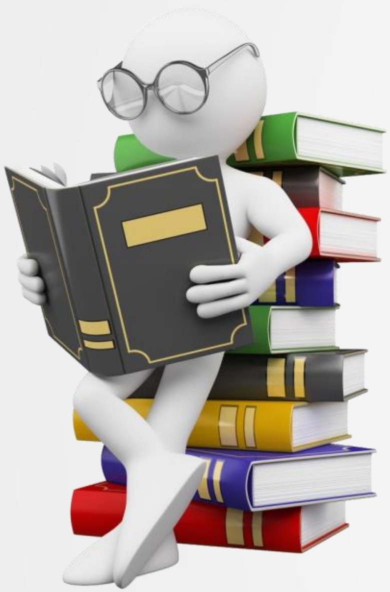
Outline



- Observation of $\Xi(1620)^0$
- Observation of an excited Ω^- baryon
- Search for $\Omega(2012) \to K\Xi(1530)$ NEW
- Ξ_c absolute branching fractions NEW
- Observation of $\Xi_c(2930)^0$ and $\Xi_c(2930)^\pm$
- Search for X(3872)$\to \pi^0\chi_{c1}$ NEW
- Observatin of a new resonance at 10.753 GeV NEW

Although Belle has stopped the data taking for more than 10 years and Belle II has started its Phase 3 data taking, Belle is still producing many exciting results.

Observation of $\Xi^0(1620)$ and evidence for $\Xi^0(1690)$

PRL 122, 072501 (2019)

List of Ξ(S=-2) particles from PDG

Particle	J^P	Overall status	Status as seen in — $\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	1/2+	****					Decays weakly
$\Xi(1530)$	3/2+	****	****				
$\Xi(1620)$	½-?	*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	3/2−	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$		**					3-body decays
$\Xi(2500)$		*		*	*		3-body decays

- NOT much is known about Ξ^*
- Not found ½-? With L =1
- **$\Xi(1620)$** and **$\Xi(1690)$** are candidates
- Ξπ is possible mode

****	Existence is certain, and properties are at least fairly well explored.
***	Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, *etc.* are not well determined.
**	Evidence of existence is only fair.
*	Evidence of existence is poor.

Status of the $\Xi(1620)$

One star:

Evidence of existence is poor

E. Briefel, PRD 16, 2706 (1977)

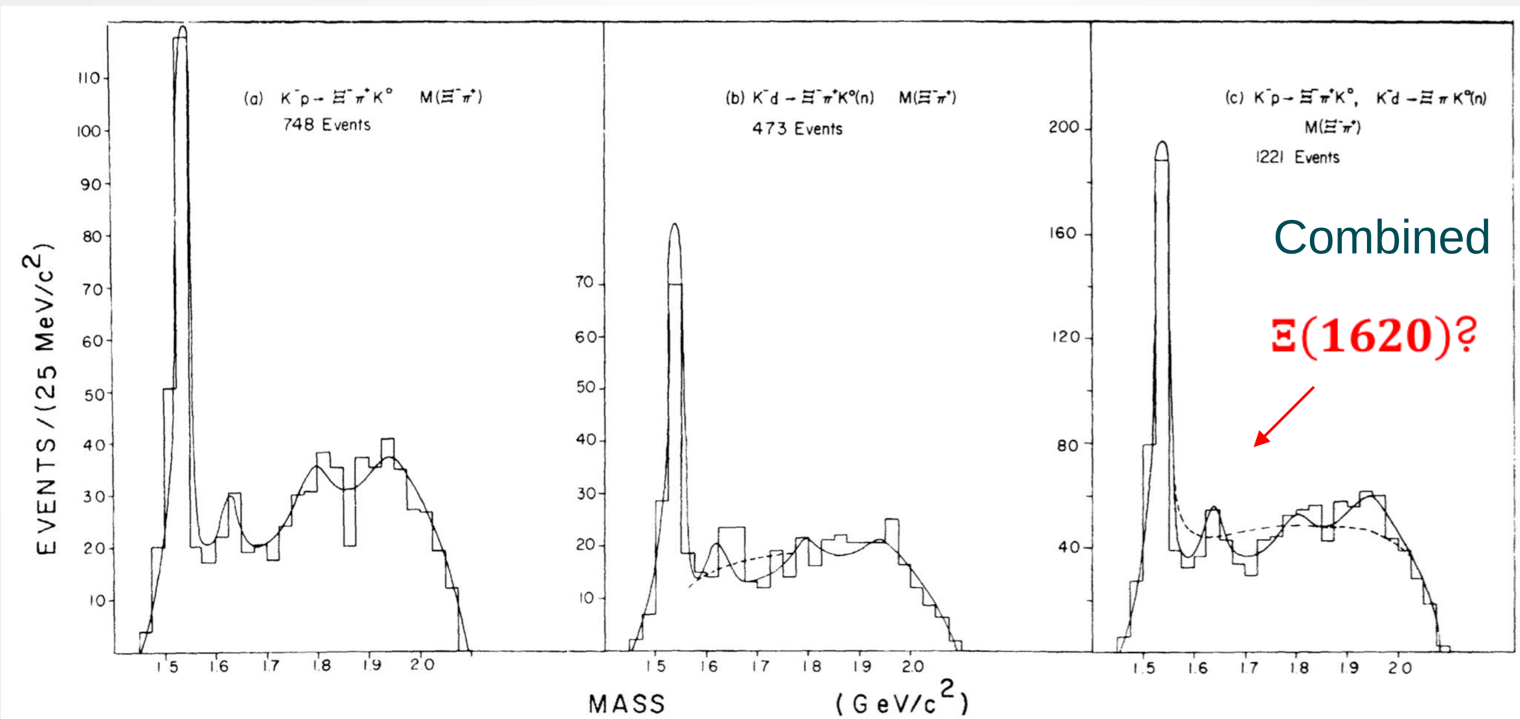
The data for this analysis came from two separate exposures, consisting of ~10^6 pictures each, of the BNL 31-in. bubble chamber to a separated beam of 2.87-GeV/c K^- mesons. During the first

But !!

J.K.Hassall says "no evidence"

In NPB189 (1981) 397

the Argonne 12 foot bubble chamber



The $\Xi^-\pi^+$ effective-mass distributions for the reaction $K^-p \to \Xi^-\pi^+K^0$

Search for $\Xi^0(1620)$ and $\Xi^0(1690)$ at Belle

PRL 122, 072501 (2019)

Search for $\Xi^0(1620)$ and $\Xi^0(1690)$ at Belle in below channel: $\Xi_c^+ \to \Xi^{*0}\pi^+$, $\Xi^{*0} \to \Xi^-\pi^+$

Data set:

Total 980fb^{-1}

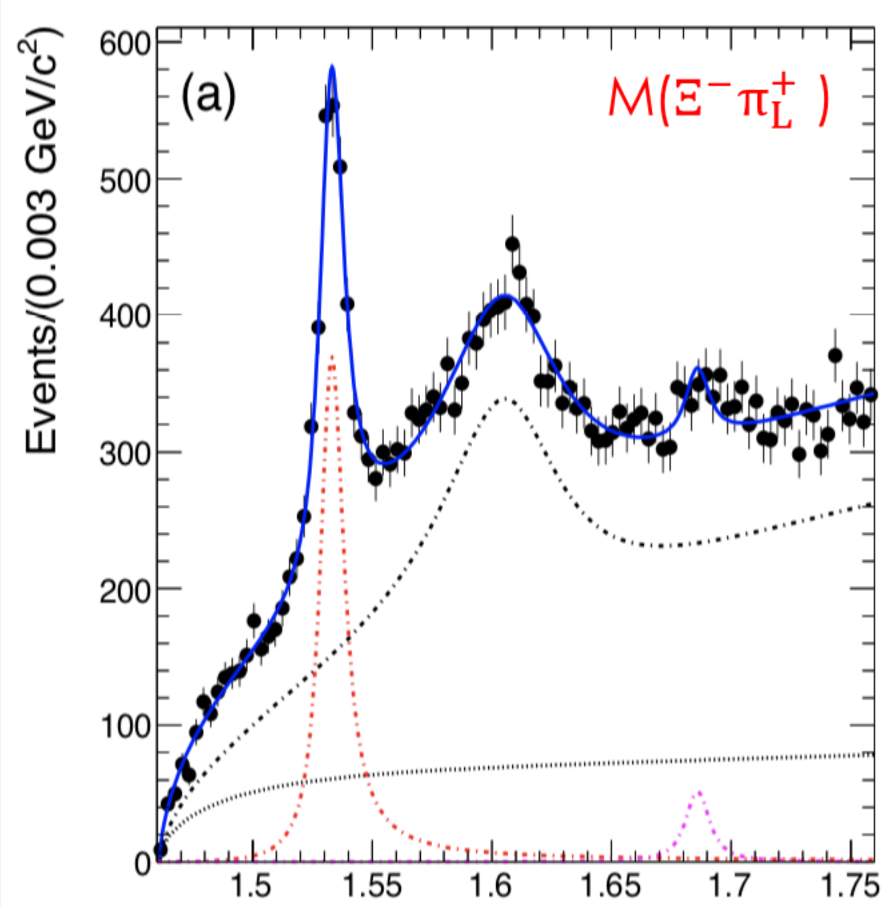
Data sample	Luminosity(fb^{-1})	Data sample	Luminosity(fb^{-1})
$\Upsilon(1S)$	5.74	$\Upsilon(2S)$	24.91
$\Upsilon(3S)$	2.9	e^+e^- at $\sqrt{s}$=10.52GeV	89.5
e^+e^- at $\sqrt{s}$=10.58GeV	711.0	e^+e^- at $\sqrt{s}$=10.867GeV	121.4

Crucial Selection criteria:

- To purify the Ξ_c^+ samples, the scaled momentum $x_p = \frac{p_{CM}}{\sqrt{\frac{1}{4}s - m(\Xi_c^+)^2}} < 0.5$
- The retained Ξ^- candidates are combined with the lower and higher momentum pions, as labeled π_L^+ and π_H^+.
- A vertex fit is applied to the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decay, and the $\chi^2 < 50$

Observation of $\Xi^0(1620)$ and evidence for $\Xi^0(1690)$

PRL 122, 072501 (2019)



In the simultaneous fit

- The $\Xi^0(1530)$ and $\Xi^0(1690)$ signals are modeled with P- and S-wave relativistic BW functions.
- The $\Xi^0(1620)$ signal is modeled with the S-wave relativistic BW function.
- The interference between $\Xi^0(1620)$ and the S-wave non-resonant process is taken into account.
- The combinatorial backgrounds are described by a threshold.

$\Xi^0(1620)$ **state**	
Mass (MeV/c^2)	$1610.4 \pm 6.0^{+5.9}_{-3.5}$
Width (MeV)	$59.9 \pm 4.8^{+2.8}_{-3.0}$

When the S-wave (P-wave) relativistic BW with fixed mass and width is used as the fitting function, the significance for $\Xi^0(1690)$ is 4.6σ (4.0σ).

Observation of an excited Ω^- baryon

PRL 121, 052003 (2018)

Ω^- = s s s (S=-3, I=0)

1. Ω^- excited states have proved difficult to find

- Only one excited Ω^- states, $\Omega(2250)$, has been confirmed until now.
- In addition, the evidence for two other states of Ω^- were reported.
- These Ω^- excited states' masses are much higher than the ground state (>600MeV).

2. $\Omega^{*-} \to \Omega^- + \pi^0$ is highly suppressed since Ω^- is isospin zero

3. Preferred modes

- $\mathbf{\Omega^{*-} \to \Xi^- + K^0_S}$ ✓
- $\mathbf{\Omega^{*-} \to \Xi^0 + K^-}$ ✓
- low-lying states
- Analogous to $\Omega_c^0 \to \Xi_c^+ K^-$

[R. Aaij et al. PRL 118, 182001 (2017)]
[J. Yelton et al. PRD 97, 051102 (2018)]

Data sample	Luminosity(fb^{-1})	Events ($\times 10^8$)
$\Upsilon(1S)$	5.7	1.02
$\Upsilon(2S)$	24.9	1.58
$\Upsilon(3S)$	2.9	-

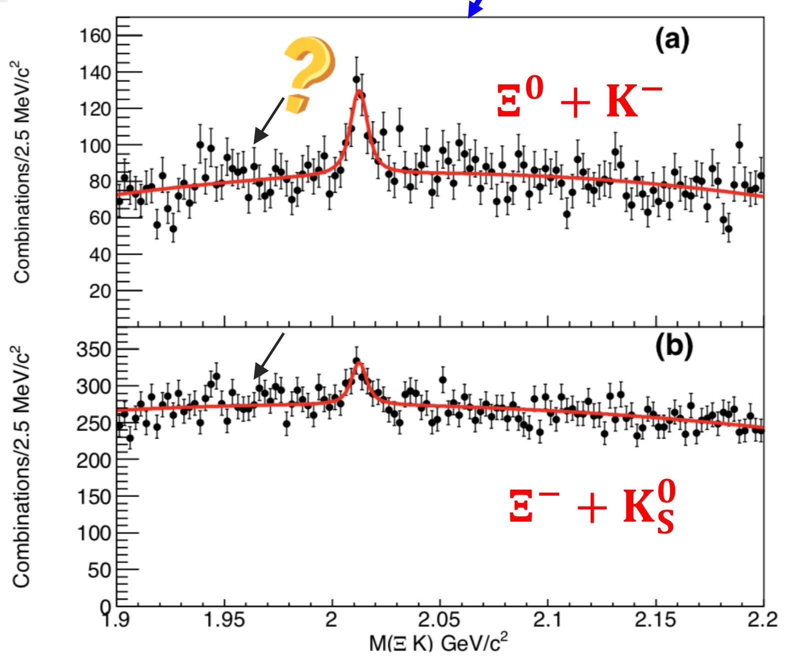
- The decays of these narrow resonances proceed via gluons.
- The production of baryon are enhanced.

Observation of an excited Ω^- baryon

Results & Summary

$$\mathcal{R} = \frac{\mathcal{B}(\Omega^{*-} \to \Xi^0 K^-)}{\mathcal{B}(\Omega^{*-} \to \Xi^- \bar{K}^0)} = 1.2 \pm 0.3$$

Data	Mode	Mass (MeV/c^2)	Yield	Γ(MeV)	χ^2/d.o.f.	n_σ
$\Upsilon(1S,2S,3S)$	$\Xi^0 K^-$, $\Xi^- K^0_S$ (simultaneous)	2012.4 ± 0.7	242 ± 48, 279 ± 71	$6.4^{+2.5}_{-2.0}$	227/230	8.3
$\Upsilon(1S,2S,3S)$	$\Xi^0 K^-$	2012.6 ± 0.8	239 ± 53	6.1 ± 2.6	115/114	6.9
$\Upsilon(1S,2S,3S)$	$\Xi^- K^0_S$	2012.0 ± 1.1	286 ± 87	6.8 ± 3.3	101/114	4.4
Other	$\Xi^0 K^-$	2012.4 (Fixed)	209 ± 63	6.4 (Fixed)	102/116	3.4
Other	$\Xi^- K^0_S$	2012.4 (Fixed)	153 ± 89	6.4 (Fixed)	133/116	1.7



PRL 121, 052003 (2018)

- The gap in the spectrum between the ground state and this excited state (~340 MeV) is smaller than other Ω^- excited states, which is more close to the negative-parity orbital excitations of many other baryons.
- The narrow width observed implies that the quantum number $J^P = \frac{3}{2}^-$ is preferable.

Theoretical interpretation for the $\Omega^*(2012)$

It is generally accepted that $\Omega^*(2012)$ is 1P orbital excitation of the ground state Ω baryon with three strange quark, whose quantum numbers are $J^P = \frac{3}{2}^-$.

Notably, the newly observed $\Omega^*(2012)$ is revealed as a KΞ(1530) hadronic molecule.
[PRD 98, 054009 (2018), PRD 98, 056013 (2018), arXiv:1807.02145, arXiv:1807.06485, arXiv:1807.06485]

The $K\Xi\pi$ three-body component is largely dominant.

From PRD 98, 056013 (2018)

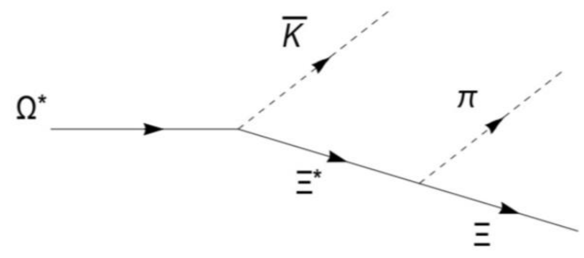


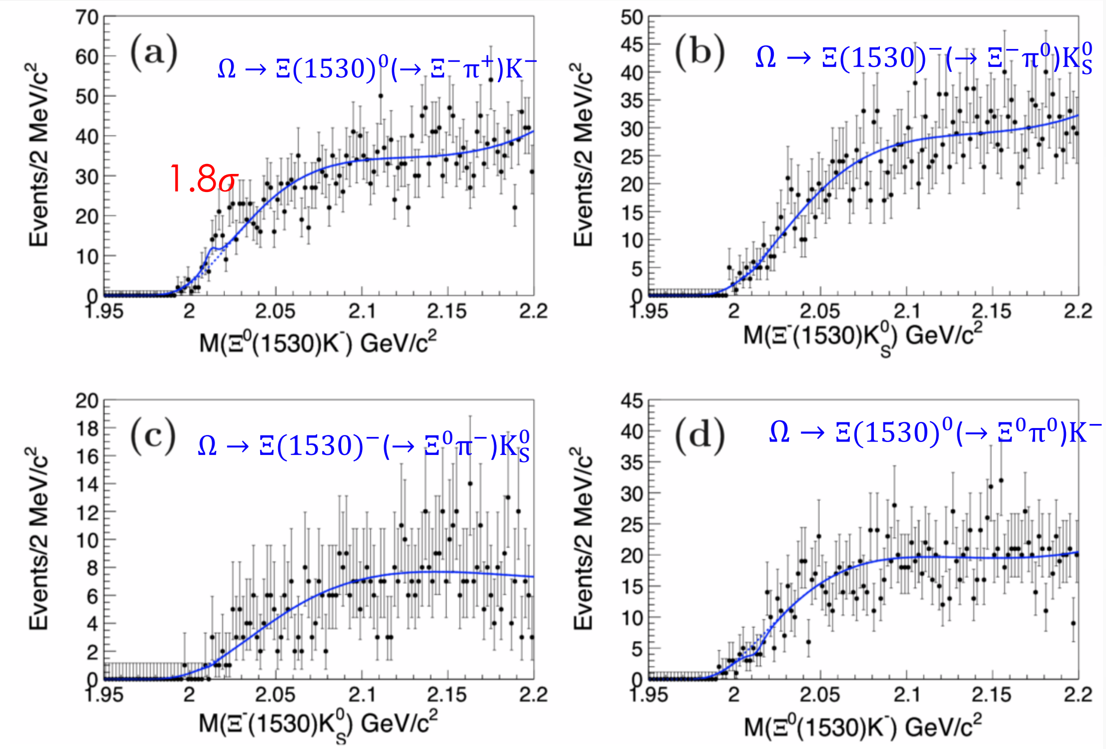
FIG. 1: The three-body decays of $\Omega(2012)$ in the $K\Xi(1530)$ molecular picture.

Mode	$J^P = \frac{3}{2}^-$ $\Omega(2012)$ $(K\Xi(1530))$ Widths (MeV)	Branch Ratio(%)
$K\Xi$	0.4	14.3
$K\pi\Xi$	2.4	85.7
Total	2.8	100.0

Search for $\Omega(2012) \to K\Xi(1530) \to K\pi\Xi$

We use the same data samples to search for $\Omega(2012) \to K\Xi(1530) \to K\pi\Xi$ in the decay of the narrow resonances $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$.

arxiv: 1906.00194



Mode	N^{Fit}	N^{UL}
$\Omega \to \Xi(1530)^0(\to \Xi^-\pi^+)K^-$	22.5±12.9	41.0
$\Omega \to \Xi(1530)^-(\to \Xi^-\pi^0)K^0_S$	-3.5±11.6	16.6
$\Omega \to \Xi(1530)^-(\to \Xi^0\pi^-)K^0_S$	-1.0±3.6	7.2
$\Omega \to \Xi(1530)^0(\to \Xi^0\pi^0)K^-$	-12.0±9.8	13.2

No clear $\Omega(2012)$ signals are observed.
We give the upper limits on the ratios of the branching fractions at 90% C.L. as below.

$$R^{\Xi^-\pi^+K^-}_{\Xi^-\bar{K}^0} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^0(\to \Xi^-\pi^+)K^-)}{\mathcal{B}(\Omega \to \Xi^-\bar{K}^0)} < 9.3\%$$

$$R^{\Xi^-\pi^0\bar{K}^0}_{\Xi^-\bar{K}^0} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^-(\to \Xi^-\pi^0)\bar{K}^0)}{\mathcal{B}(\Omega \to \Xi^-\bar{K}^0)} < 81.1\%$$

$$R^{\Xi^0\pi^-\bar{K}^0}_{\Xi^0K^-} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^-(\to \Xi^0\pi^-)\bar{K}^0)}{\mathcal{B}(\Omega \to \Xi^0K^-)} < 21.3\%$$

$$R^{\Xi^0\pi^0K^-}_{\Xi^0K^-} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^0(\to \Xi^0\pi^0)K^-)}{\mathcal{B}(\Omega \to \Xi^0K^-)} < 30.4\%$$

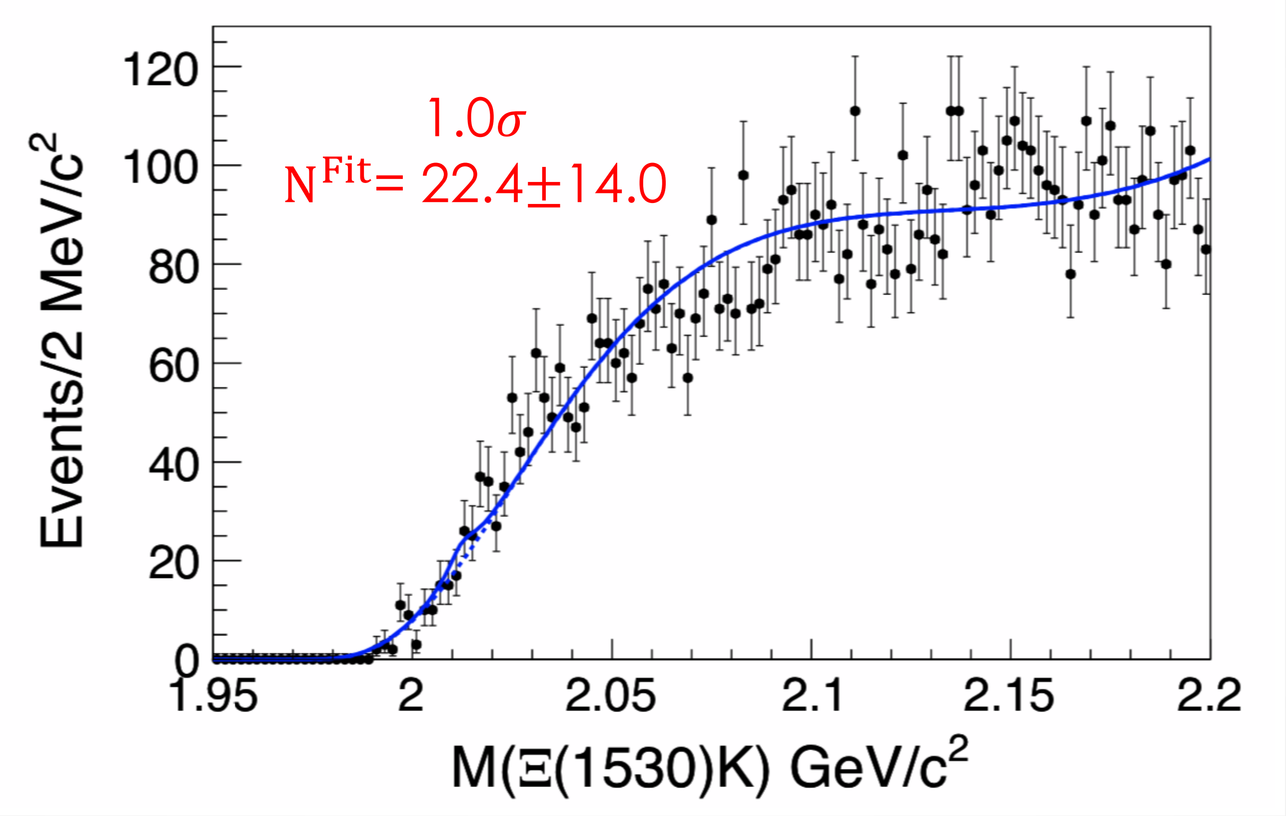
$$R^{\Xi^-\pi^+K^-}_{\Xi^0K^-} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^0(\to \Xi^-\pi^+)K^-)}{\mathcal{B}(\Omega \to \Xi^0K^-)} < 7.8\%$$

$$R^{\Xi^0\pi^-\bar{K}^0}_{\Xi^-\bar{K}^0} = \frac{\mathcal{B}(\Omega \to \Xi(1530)^-(\to \Xi^-\pi^0)\bar{K}^0)}{\mathcal{B}(\Omega \to \Xi^-\bar{K}^0)} < 25.6\%$$

Search for Ω(2012) → KΞ(1530) → KπΞ

NEW

A simultaneous fit to all three-body decay modes is performed.

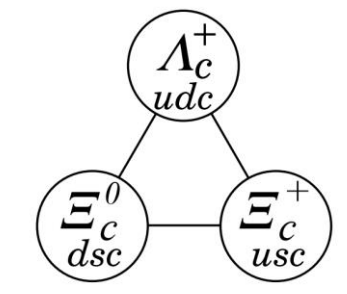


$$R^{\Xi\pi K}_{\Xi K} = \frac{\mathcal{B}(\Omega\to\Xi(1530)(\to\Xi\pi)K)}{\mathcal{B}(\Omega\to\Xi K)} = (6.0\pm3.7(\text{stat.})\pm1.3(\text{syst.}))\%$$

$$R^{\Xi\pi K}_{\Xi K} = \frac{\mathcal{B}(\Omega\to\Xi(1530)(\to\Xi\pi)K)}{\mathcal{B}(\Omega\to\Xi K)} < 11.9\% \text{ at } 90\% \text{ C.L.}$$

Measurements of absolute Brs of Ξ_c^0

- Weak decays of charmed hadrons play an unique role in the study of strong interaction； the charmed-baryon sector also offers an unique and excellent laboratory for testing heavy-quark symmetry and light-quark chiral symmetry.
- For the charmed baryons of the SU(3) anti-triplet, only Λ_c absolute Brs were measured by Belle [PRL113,042002(2014), first time] and BESIII [PRL116,052001(2016)]
- Since Ξ_c^0 [PRL62,863(1989)] and Ξ_c^+[PLB122,455 (1983)] were discovered ~30 years ago, no absolute Brs could be measured.



- For Ξ_c^0, the Brs are all measured with ratios to the $\Xi^-\pi^+$, the so called reference mode.

Measurements of absolute Brs of Ξ_c^0

- Theory: $B(\Xi_c^0 \to \Xi^-\pi^+)$~1.12% or 0.74% [PRD48, 4188 (1993)], (2.24±0.34)% [JHEP03, 66(2018)], (1.91±0.17)% [1811.07265]
- The $B(\Xi_c^0 \to \Lambda K^-\pi^+)$/ $B(\Xi_c^0 \to \Xi^-\pi^+)$ = 1.07 ± 0.12± 0.07 and

$B(\Xi_c^0 \to pK^-K^-\pi^+)$/ $B(\Xi_c^0 \to \Xi^-\pi^+)$= 0.33 ± 0.03±0.03 [PLB 605,237]

- $\Xi_c^0 \to pK^-K^-\pi^+$ plays a fundamental role in lots of bottom baryons study at LHCb .
- How to measure Ξ_c^0 absolute Brs ? Model Independent !

$$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)},$$

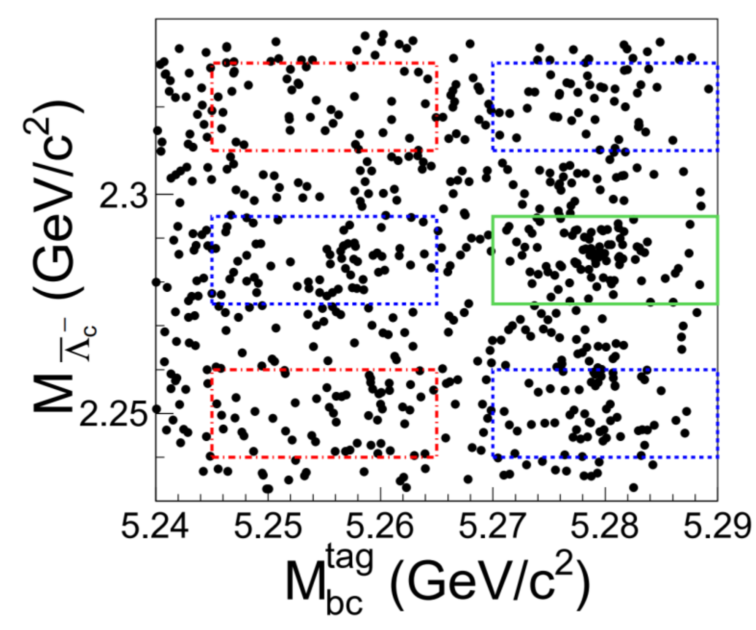
$$\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)}.$$

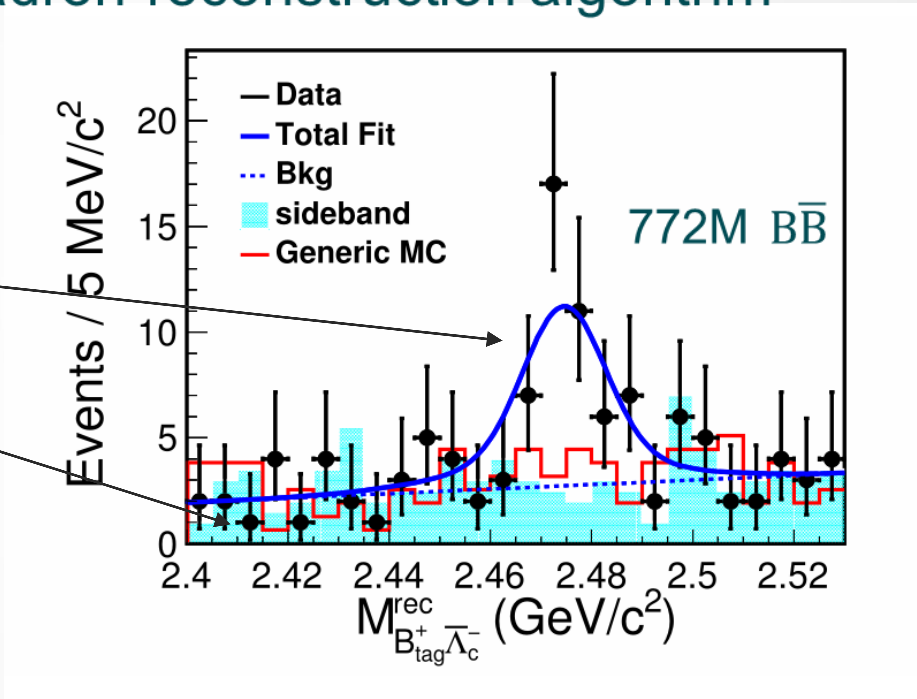
$$\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)}.$$

- For inclusive $\boldsymbol{B^-} \to \boldsymbol{\bar{\Lambda}_c^-}\Xi_c^0$, Ξ_c^0 →anything, never measured before.
- For exclusive $B(\boldsymbol{B^-} \to \boldsymbol{\bar{\Lambda}_c^-}\Xi_c^0)$ $B(\Xi_c^0 \to \Xi^-\pi^+)$; $B(\boldsymbol{B^-} \to \boldsymbol{\bar{\Lambda}_c^-}\Xi_c^0)$ $B(\Xi_c^0 \to \Lambda K^-\pi^+)$, measured by Belle and BaBar with large errors.

Measurements of Br of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, $\Xi_c^0 \to$anything

- The $\bar{\Lambda}_c^-$ reconstructed via its $\bar{p}K^+\pi^-$ and $\bar{p}K_S^0$ decays
- A tagged B meson candidate, B_{tag}^+, is reconstructed using a neural network based on the full hadron-reconstruction algorithm





- An unbinned maximum likelihood fit: N(Ξ_c^0)=40.9 ±9.0, 5.5σ(stat.)
- B($B^- \to \bar{\Lambda}_c^- \Xi_c^0$, $\Xi_c^0 \to$anything)= $(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$ for the first time

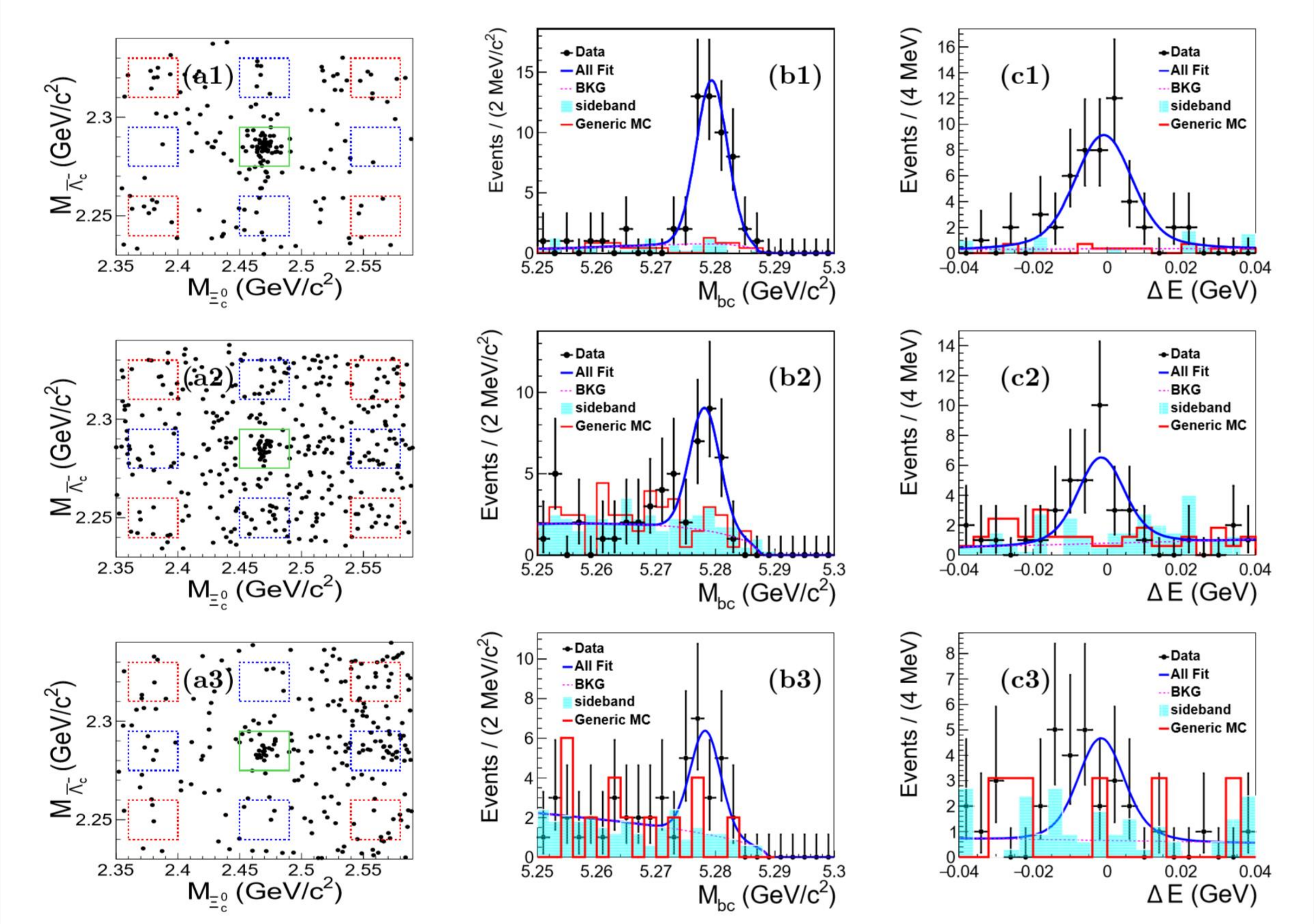
PRL122, 082001 (2019)

Measurements of Brs of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, with $\Xi_c^0 \to \Xi^-\pi^+; \Xi_c^0 \to \Lambda K^-\pi^+; \Xi_c^0 \to pK^-K^-\pi^+$

$\Xi^-\pi^+$
44.8 ± 7.3
9.5σ

$\Lambda K^-\pi^+$
24.1 ±5.5
6.8σ

$pK^-K^-\pi^+$
16.6 ± 5.4
4.6σ



PRL122, 082001 (2019)

Measurements of absolute Brs of Ξ_c^0

Summary of the measured branching fractions and the ratios of Ξ_c^0 decays

PRL122, 082001 (2019)

Channel	Br/Ratio
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$	$(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.71 \pm 0.28 \pm 0.15) \times 10^{-5}$
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.11 \pm 0.26 \pm 0.10) \times 10^{-5}$
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to p K^- K^- \pi^+)$	$(5.47 \pm 1.78 \pm 0.57) \times 10^{-6}$
$B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.80 \pm 0.50 \pm 0.14)\%$
$B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.17 \pm 0.37 \pm 0.09)\%$
$B(\Xi_c^0 \to p K^- K^- \pi^+)$	$(0.58 \pm 0.23 \pm 0.05)\%$
$B(\Xi_c^0 \to \Lambda K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.65 \pm 0.18 \pm 0.04$
$B(\Xi_c^0 \to p K^- K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.32 \pm 0.12 \pm 0.07$

$(2.4 \pm 0.9) \times 10^{-5}$

$(2.1 \pm 0.9) \times 10^{-5}$

PDG

1.07 ± 0.14

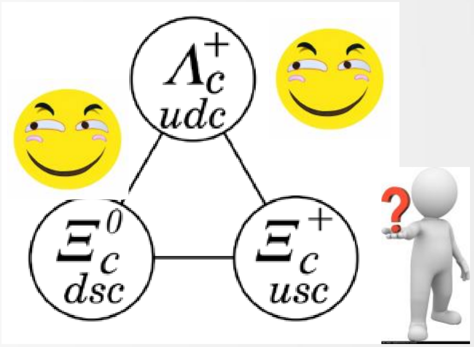
0.34 ± 0.04

- We have performed an analysis of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$ inclusively and exclusively
- First model-independent measurement of absolute Brs of Ξ_c^0 decays
- The branching fraction $B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$ is measured for the first time
- The $B(\Xi_c^0 \to \Xi^- \pi^+)$ can be used to determine the BR of other Ξ_c^0 decays.

Measurements of absolute Brs of Ξ_c^+

- The decays of charmed baryons in experiment are needed to extract the non-perturbative contribution thus important to constrain phenomenological models of strong interaction.

- For the SU(3) anti-triplet charmed baryons the branching fractions of $\boldsymbol{\Lambda_c^+}$ [PRL 113,042003(2014); PRL 116,052001(2016)] and Ξ_c^0 [PRL 122,082001(2019)] has been measured.



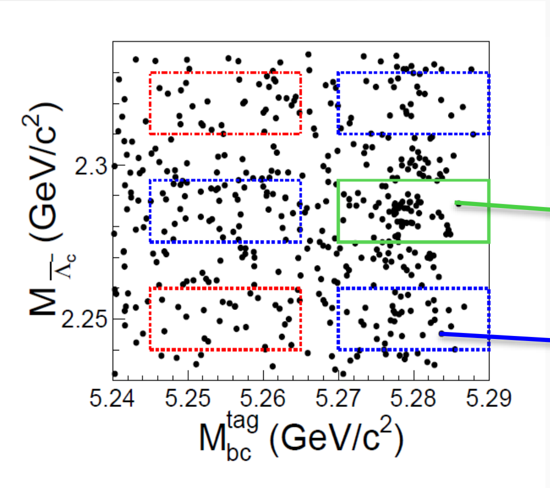
- The Brs of remaining Ξ_c^+ are all measured with ratio to the $\Xi_c^+ \to \boldsymbol{\Xi^-\pi^+\pi^+}$

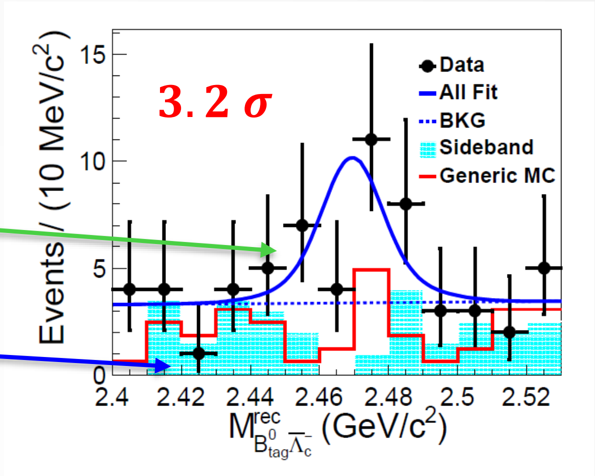
- The comparison of Ξ_c^+ decays with those of Λ_c^+ and and Ξ_c^0 can also provide an important test of SU(3) flavor symmetry.

$\Xi_c^+ \to p\, K^- \pi^+$ is a particularly important decay mode as it is the one most often used to reconstruct Ξ_c^+ candidates at hadron collider experiments, such as LHCb. Theory predicts the B($\Xi_c^+ \to p\, K^- \pi^+$)=(2.2$\pm$0.8)% [EPJC 78, 224 (2018); Chin. Phys. C 42, 051001 (2018)].

Measurement of Ξ_c^+ absolute BRs

Measurement $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$ with $\Xi_c^+ \to anythings$





- reconstruct $\bar{\Lambda}_c^-$ via $\bar{p}K^+\pi^-$ decay mode
- tag a B^0 with neural network based Full-Reconstruction algorithm.
- An unbinned maximum likelihood fit: $N(\Xi_c^+) = 18.8 \pm 6.8$
- $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+) = [1.16 \pm 0.42(stat.) \pm 0.15(syst.)] \times 10^{-3}$

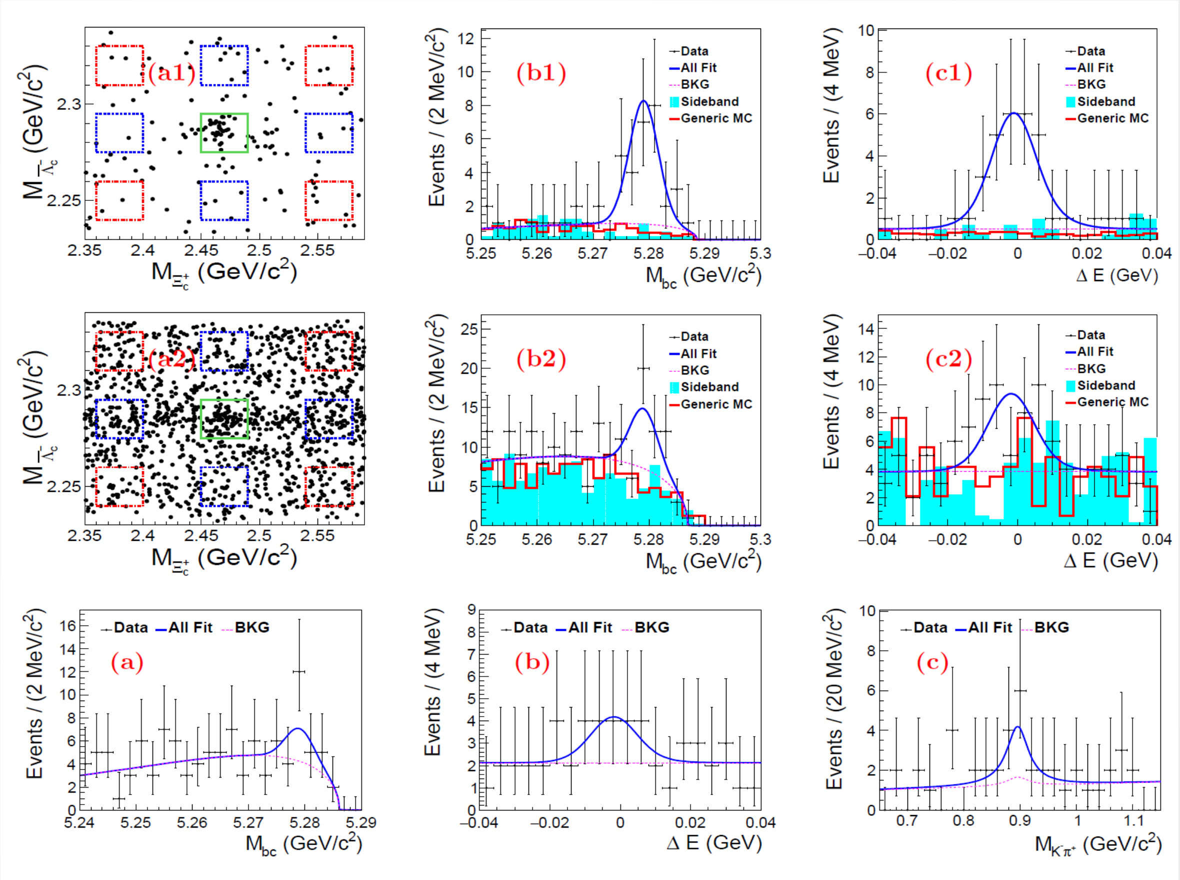
Measurement of Ξ_c^+ absolute BRs

Measurement $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$ with $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$ or $\mathrm{p}[\bar{\mathrm{K}}^*(892) \to \mathrm{K}^- \pi^+]$

$\Xi_c^+ \to \Xi^- \pi^+ \pi^+$
$N = 24.2 \pm 5.4$ **6.9σ**

$\Xi_c^+ \to p K^- \pi^+$
$N = 24.0 \pm 6.9$ **4.5σ**

$\Xi_c^+ \to \mathrm{p}\bar{\mathrm{K}}^*(892)$
$N = 8.9 \pm 3.9$ **3.3σ**



Measurement of Ξ_c^+ absolute BRs

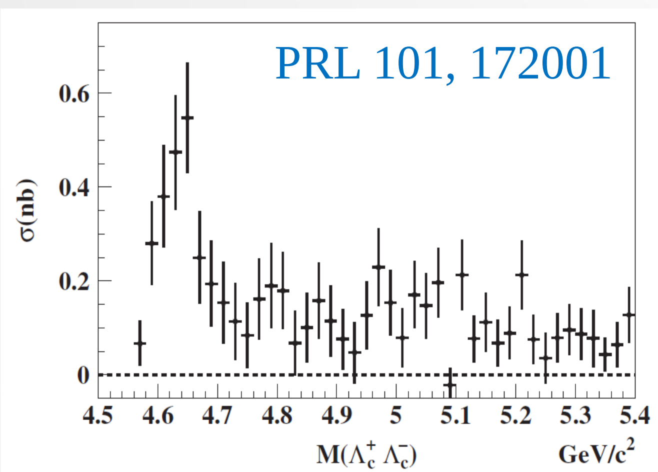
Summary of the measured BRs

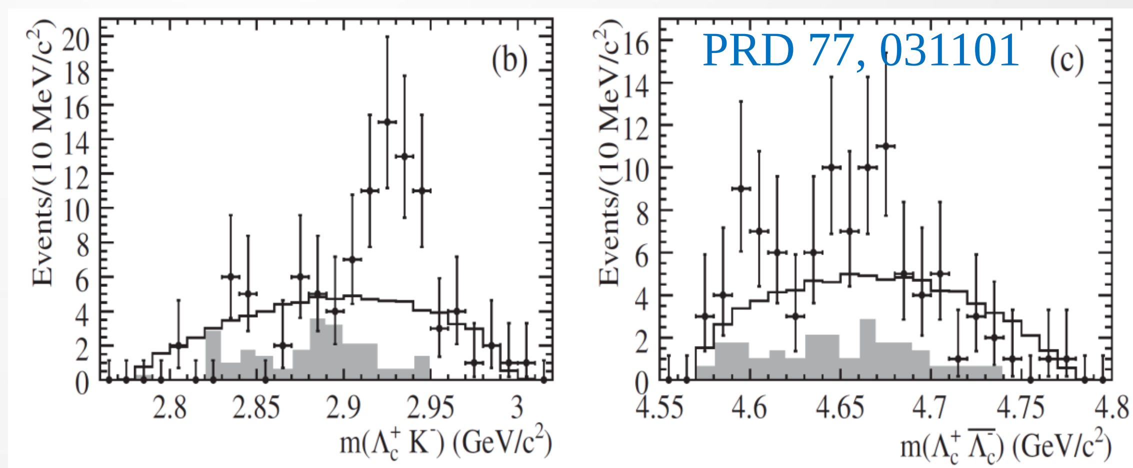
Decay mode	Br/ Ratio	PDG value
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$	$[1.16 \pm 0.42 \pm 0.15] \times 10^{-3}$	
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$[3.32 \pm 0.74 \pm 0.33] \times 10^{-5}$	$(1.8 \pm 1.8) \times 10^{-5}$
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$[5.27 \pm 1.51 \pm 0.69] \times 10^{-5}$	
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to \mathrm{p}\bar{\mathrm{K}}^*(892))$	$[2.97 \pm 1.31 \pm 0.44] \times 10^{-5}$	
$\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$[2.86 \pm 1.21 \pm 0.38]\%$	
$\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$[0.45 \pm 0.21 \pm 0.07]\%$	
$\mathcal{B}(\Xi_c^+ \to \mathrm{p}\bar{\mathrm{K}}^*(892))$	$[0.25 \pm 0.16 \pm 0.04]\%$	
$\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)/\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$0.16 \pm 0.06 \pm 0.02$	0.21 ± 0.04
$\mathcal{B}(\Xi_c^+ \to \mathrm{p}\bar{\mathrm{K}}^*(892))/\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$0.09 \pm 0.04 \pm 0.01$	0.116 ± 0.030
$\mathcal{B}(\Xi_c^+ \to \mathrm{p}\bar{\mathrm{K}}^*(892))/\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$0.56 \pm 0.30 \pm 0.08$	$0.54 \pm 0.09 \pm 0.05$

- First model –independent $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$ measurement
- $\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$ can be used to determine the BR of other Ξ_c^+ decay

$\Xi_c(2930)^0$ in $B^+ \to K^+\Lambda_c^+\bar{\Lambda}_c^-$

- Belle reported a structure, called X(4630), in the $\Lambda_c^+\bar{\Lambda}_c^-$ invariant mass distribution in $e^+e^- \to \gamma_{ISR}\Lambda_c^+\bar{\Lambda}_c^-$ PRL 101, 172001
- BarBar once studied $B^+ \to K^+\Lambda_c^+\bar{\Lambda}_c^-$ and found two small peaks in $M_{\Lambda_c^+\bar{\Lambda}_c^-}$ spectrum and a vague structure named $\Xi_c(2930)$ is seen in the distribution of $M_{K\,\Lambda_c}$. Larger data is needed to verify them. PRD 77, 031101
- Also, some theory explained that Y(4660) has a large partial decay width to $\Lambda_c^+\bar{\Lambda}_c^-$ and it's isospin partner Y(4616) is predicted. PRD 82, 094008; PRL102, 242004





$\Xi_c(2930)^0$ in $B^+ \to K^+ \Lambda_c^+ \overline{\Lambda}_c^-$

$\Xi_c(2930)$ *

CHARMED BARYONS

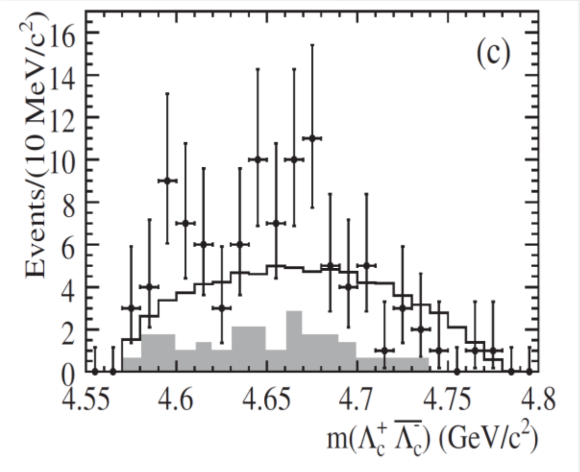
($C = +1$)

$\Lambda_c^+ = udc$, $\Sigma_c^{++} = uuc$, $\Sigma_c^+ = udc$, $\Sigma_c^0 = ddc$,$\Xi_c^+ = usc$, $\Xi_c^0 = dsc$, $\Omega_c^0 = ssc$

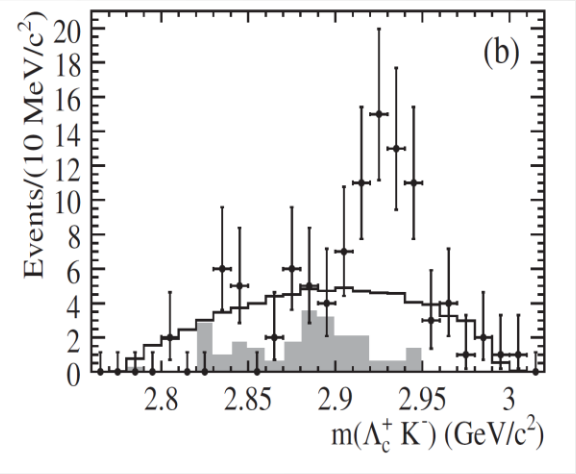
$\Xi_c(2930)$ $\quad$ $I(J^P) = ?(?^?)$

A peak seen in the $\Lambda_c^+ K^-$ mass projection of $B^- \to \Lambda_c^+ \overline{\Lambda}_c K^-$ events.

$\Xi_c(2930)$ MASS	2931 ± 6 MeV
$\Xi_c(2930)$ WIDTH	36 ± 13 MeV

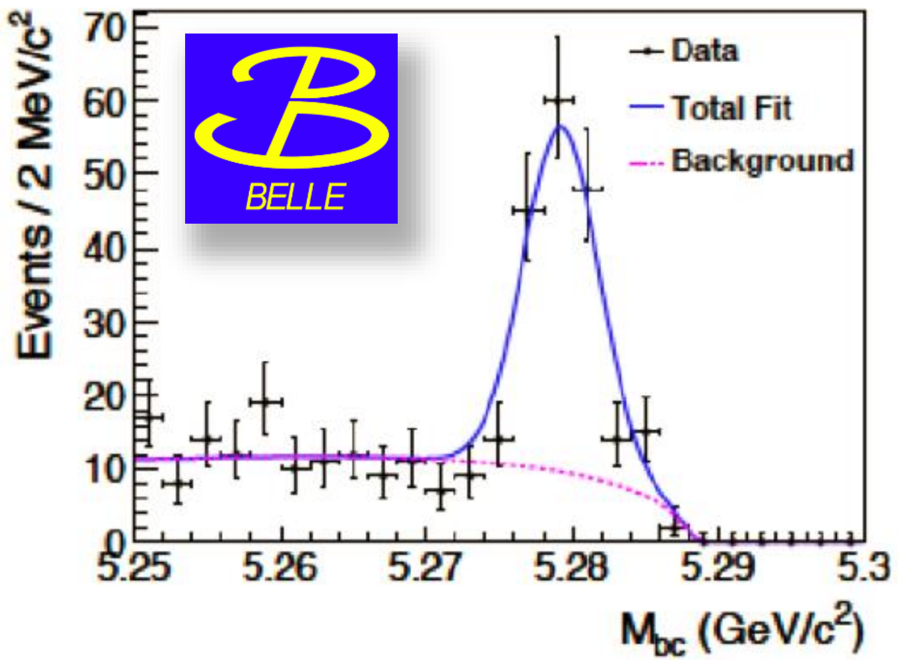


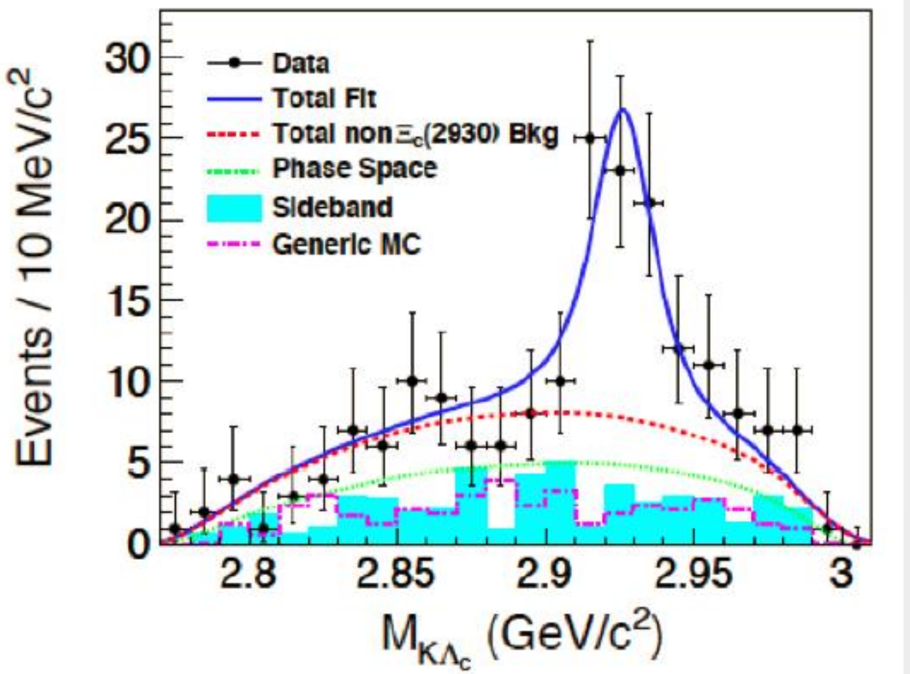
tion for experimental resolution, we obtain $m = 2931 \pm 3(\text{stat}) \pm 5(\text{syst})\ \text{MeV}/c^2$ and $\Gamma = 36 \pm 7(\text{stat}) \pm 11(\text{syst})$ MeV. We do not see any such structure in the m_{ES} sideband region. This description is in good agreement with the data (χ^2 probability of 22%) and could be interpreted as a single Ξ_c^0 resonance with those parameters, though a more complicated explanation (e.g. two narrow resonances in close proximity) cannot be excluded.



Observation of $\Xi_c(2930)^0$ in $B^+ \to K^+ \Lambda_c^+ \overline{\Lambda}_c^-$ at Belle

Eur. Phys. J. C78, 252 (2018)





153±14 B decay signal events.
$Br(B^+ \to \Lambda_c^+ \Lambda_c^- K^+) = (4.80 \pm 0.43 \pm 0.68) \times 10^{-4}$

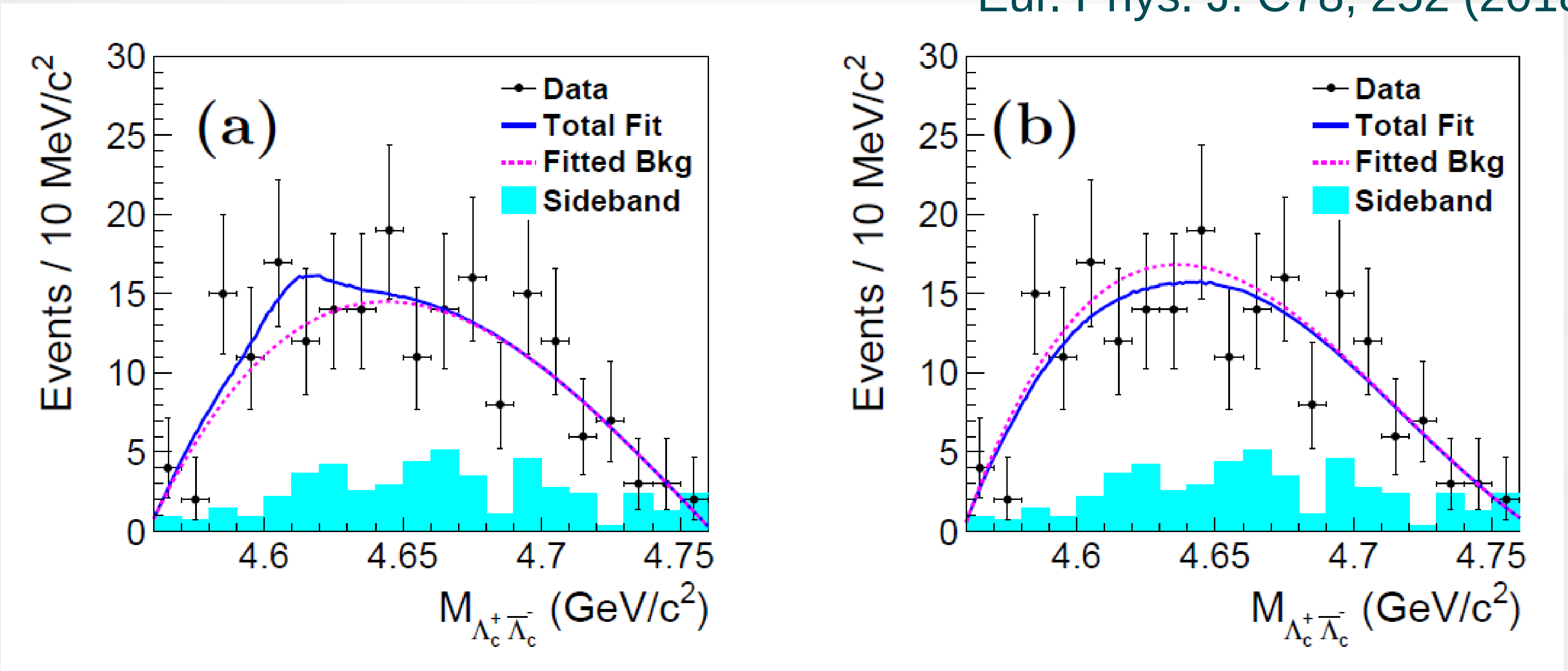
$\Xi_c(2930)^0 \to \Lambda_c^+ K^-$ 61±16 events
5.1σ significance

Clear confirmation for the BaBar claim, PRD77,031101(2008) and much more precise M=2928.9±3.0 +0.8/-12.0 MeV, Γ=19.5±8.4 +5.4/-7.9 MeV

- $\Xi_c(2930)^0 = csd$ is the first charmed-strange baryon established in B decay.

Search for Y(4660) and its spin part in $B^+ \to K^+\Lambda_c^+\overline{\Lambda}_c^-$ at Belle

Eur. Phys. J. C78, 252 (2018)



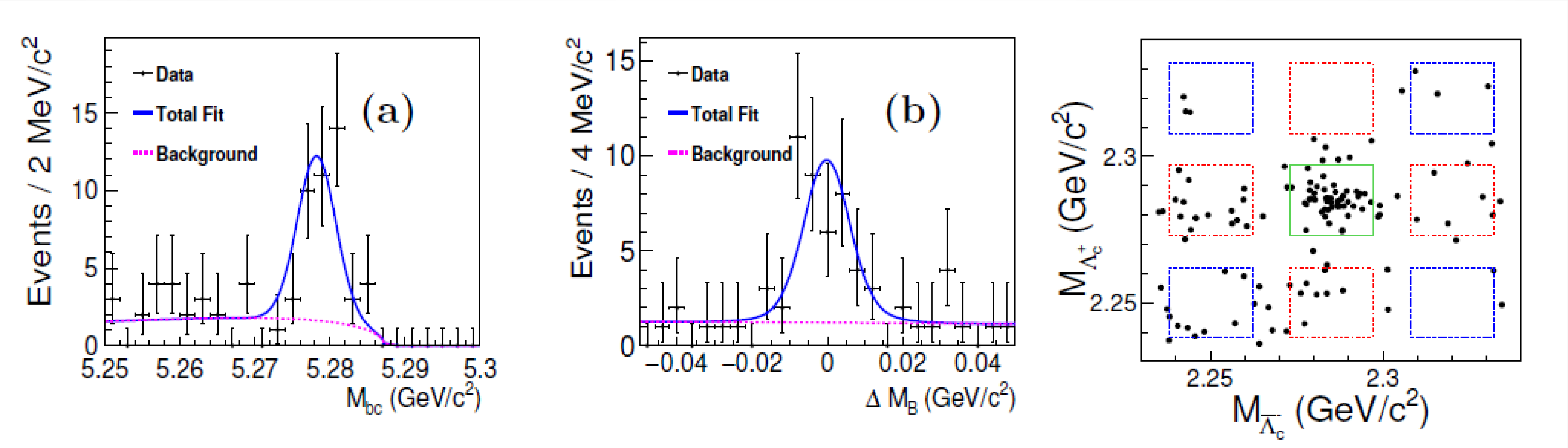
- No Y(4660) and its spin partner Y_η were observed in the $\Lambda_c^+\overline{\Lambda}_c^-$ invariant mass distribution
- 90% C.L. upper limits of $B^+ \to K^+Y(4660) \to K^+\Lambda_c^+\overline{\Lambda}_c^-$ and $B^+ \to K^+Y_\eta \to K^+\Lambda_c^+\overline{\Lambda}_c^-$ are 1.2×10^{-4} and 2.0×10^{-4}.

Evidence of charged $\Xi_c(2930)$ in $B^0 \to K^0 \Lambda_c^+ \bar{\Lambda}_c^-$

Eur. Phys. J. C 78, 928 (2018)

BELLE

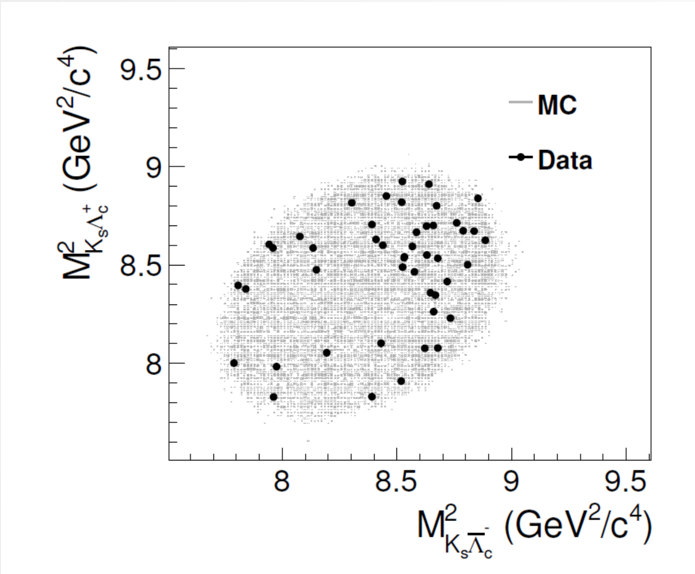
- Based on full $\Upsilon(4S)$ data set (772 M $B\bar{B}$ pairs) at Belle
- Three Λ_c decay channels:
  $\Lambda_c^+ \to pK^-\pi^+$, $\Lambda_c^+ \to pK_s(\pi^+\pi^-)$ and $\Lambda_c^+ \to \Lambda(p\pi^-)\pi^+$.
- B candidates extracted via 2D fit to M_{bc} and ΔM_B

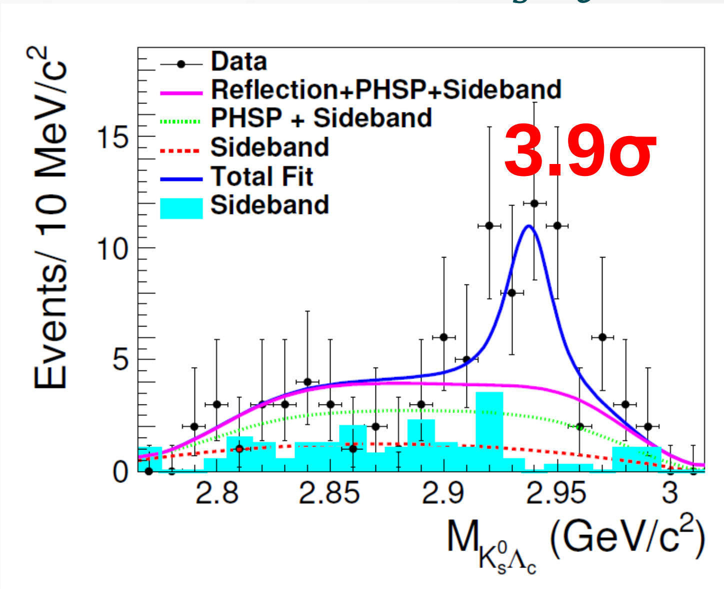


- Quite clear $\Lambda_c^+\bar{\Lambda}_c^-$ signals and B^0 signals.
  - $N^{sig} = 34.9 \pm 6.6$ with a statistical signal significance above 8.3σ
  - $\mathcal{B}(\bar{B}^0 \to \bar{K}^0\Lambda_c^+\bar{\Lambda}_c^-) = [3.99 \pm 0.76(\text{stat.}) \pm 0.51(\text{syst.})] \times 10^{-4}$

Evidence of charged $\Xi_c(2930)$ in $B^0 \to K^0 \Lambda_c^+ \bar{\Lambda}_c^-$

- Charged $\Xi_c(2930)$ extracted by fitting $M_{K_S^0 \Lambda_c}$





- $N(\Xi_c^{\pm}(2930))=21.2 \pm 4.6$, stat. significance 4.1σ
- $M(\Xi_c^{\pm}(2930))=2942.3 \pm 4.4 \pm 1.5$ MeV/c^2
- $\Gamma\ (\Xi_c^{\pm}(2930))=14.8 \pm 8.8 \pm 2.5$ MeV

After this measurement, * → **

$\Xi_c(2930)$ $I(J^P) = ?(?^?)$ Status: **

Search for $X(3872) \to \pi^0\chi_{c1}(1P)$

- Although the $X(3872)$ has been found in several modes, the nature of the $X(3872)$ remains unclear.
- If the $X(3872)$ were a conventional $c\bar{c}$ state, pionic transitions to the χ_{cJ} should be very small ($\Gamma(X(3872) \to \pi^0\chi_{c1})$ ~ 0.06keV [PRD77, 014013 (2018)]).
- If the $X(3872)$ were a tetraquark or molecular state, the ratios of the pionic transitions are excepted to be sizeable [PRD77, 014013 (2018)], PRD92, 034019 (2015)].
- The study of $X(3872) \to \pi^0\chi_{c1}(1P)$ can help to figure out the $X(3872)$ is conventional $c\bar{c}$ state or tetraquark/molecular.

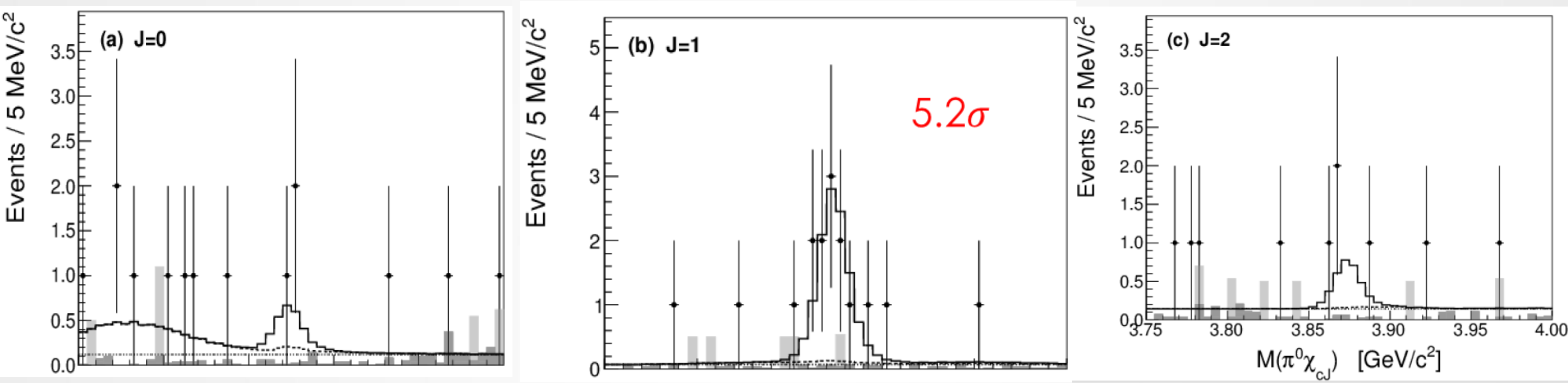
The study for $X(3872) \to \pi^0\chi_{c1}(1P)$ at BESIII and Belle:

Collaboration	Studied mode	Dataset
BESIII	$e^+e^- \to \gamma X(3872)$ $X(3872) \to \pi^0\chi_{c1}(1P)$	$9fb^{-1}$ E_{CM} between 4.15 and 4.30 GeV
Belle	$B^+ \to X(3872)K^+$ $X(3872) \to \pi^0\chi_{c1}(1P)$	772× 10^6 $B\bar{B}$ events collected at the $\Upsilon(4S)$ resonance

Observation of the decay $X(3872) \to \pi^0 \chi_{c1}(1P)$ at BESIII

The distributions of the invariant mass of the $\pi^0 \chi_{cJ}(1P)$

Phys.Rev.Lett. 122 (2019) 202001



	$\pi^+\pi^- J/\psi$	$\pi^0\chi_{c0}$	$\pi^0\chi_{c1}$	$\pi^0\chi_{c2}$
Event yield	$84.1^{+10.1}_{-9.4}$	$1.9^{+1.9}_{-1.3}$	$10.8^{+3.8}_{-3.1}$	$2.5^{+2.3}_{-1.7}$
Signal significance (σ)	16.1	1.6	5.2	1.6
Efficiency (no ISR) (%)	32.3	8.8	14.1	12.8
Efficiency ratio (with ISR)	...	0.272	0.435	0.392
$\mathcal{B}(\chi_{cJ} \to \gamma J/\psi) \times \mathcal{B}(\pi^0 \to \gamma\gamma)$ (%)	...	1.3	33.5	19.0
Total systematic error (%)	...	17.0	11.9	9.4
$\mathcal{B}(X \to \pi^0\chi_{cJ})/\mathcal{B}(X \to \pi^+\pi^- J/\psi)$	...	$6.6^{+6.5}_{-4.5} \pm 1.1$ (19)	$0.88^{+0.33}_{-0.27} \pm 0.10$	$0.40^{+0.37}_{-0.27} \pm 0.04$ (1.1)

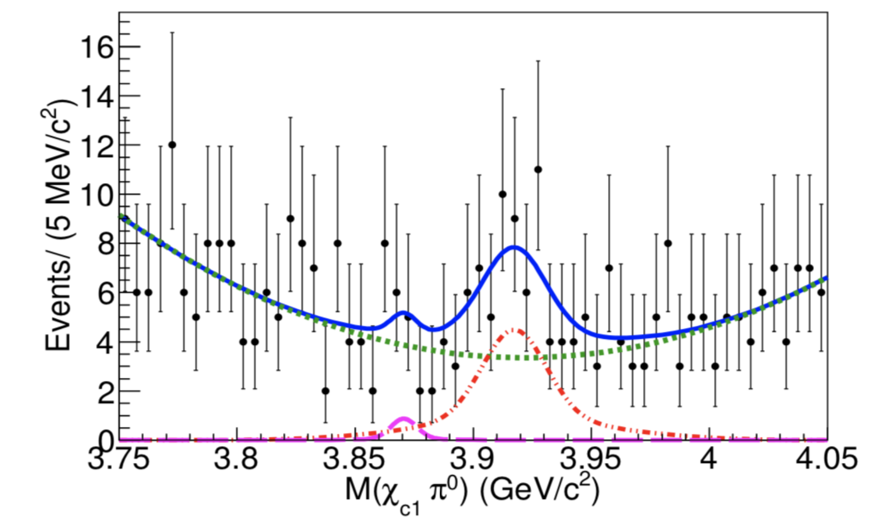
- This is the first time the $\mathbf{X(3872)}$ was observed in mode $\boldsymbol{\pi^0\chi_{c1}(1P)}$.
- BESIII results disfavors the $c\bar{c}$ interpretation for X(3872).

Search for $X(3872) \to \pi^0 \chi_{c1}(1P)$ at Belle

NEW

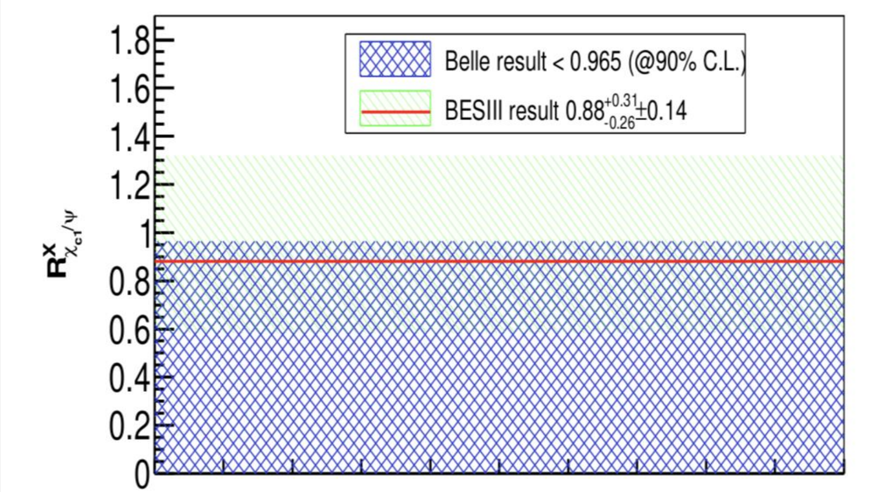
1D unbinned extended maximum likelihood fit to the $M(\pi^0 \chi_{c1}(1P))$

PRD 99, 111101 (R) (2019)



- The magenta dashed curve shows the $B^+ \to X(3872)(\to \pi^0 \chi_{c1}(1P))K^+$ signal
- The red dashed curve shows the $B^+ \to X(3915)(\to \pi^0 \chi_{c1}(1P))K^+$ signal
- The fit yields (2.7±5.5) events for the $B^+ \to X(3872)(\to \pi^0 \chi_{c1}(1P))K^+$ with the significance of 0.3σ
- $R^X_{\chi_{c1}/\psi} = \frac{\mathcal{B}(X \to \pi^0 \chi_{c1}(1P))}{\mathcal{B}(X \to \pi^+\pi^- J/\psi)} < 0.97$ at 90% C.L.

Comparison of Belle and BESIII result.



- The $R^X_{\chi_{c1}/\psi}$ at 90% C.L from Belle does not contradict the BESIII result.
- But more data samples are needed to confirm the BESIII result.

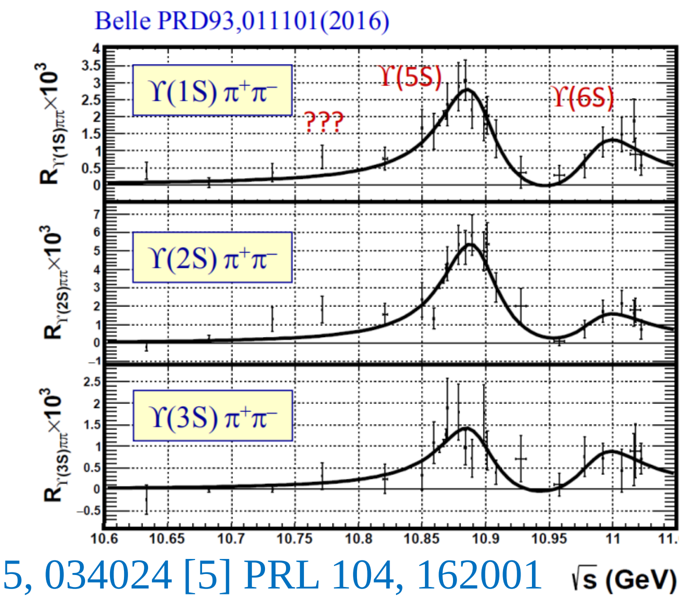
Motivation

(A. Bondar, R. Mizuk *et al.* (to be submitted to JHEP))

- Above the $B\bar{B}$ threshold, $\Upsilon(4S)$, $\Upsilon(10860)$ and $\Upsilon(11020)$ have properties that are unexpected for pure $b\bar{b}$ bound states [1]. Possible explanations:
  - Contribution of hadron loops (equivalently, presence of a $B^{(*)}_{(s)}\bar{B}^{(*)}_{(s)}$ admixture) [2-4].
  - Presence of other exotic states (e.g. compact tetraquarks [5] or hadrobottomonia [6]).
- $\Upsilon(3,4D)$ states are predicted in the region of the $\Upsilon(4,5,6S)$ levels [7,8].
- Recent study of $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ in Belle show a small hint of new structure at $\sqrt{s} = 10.77$ GeV [9].

Analysis features

- $\Upsilon(nS) \to \ell^+\ell^-(\ell \in \{\mu, e\})$.
- Signal yields are extracted via fitting to $M_{\text{recoil}}(\pi^+\pi^-)$ instead of counting.
- Using ISR process with the high stat. $\Upsilon(10860)$ on-resonance data to obtain additional information about the cross section shapes.
- Energy balance requirement: $|M_{\text{recoil}}(\pi^+\pi^-) - M(\ell^+\ell^-)| < 150$ MeV.



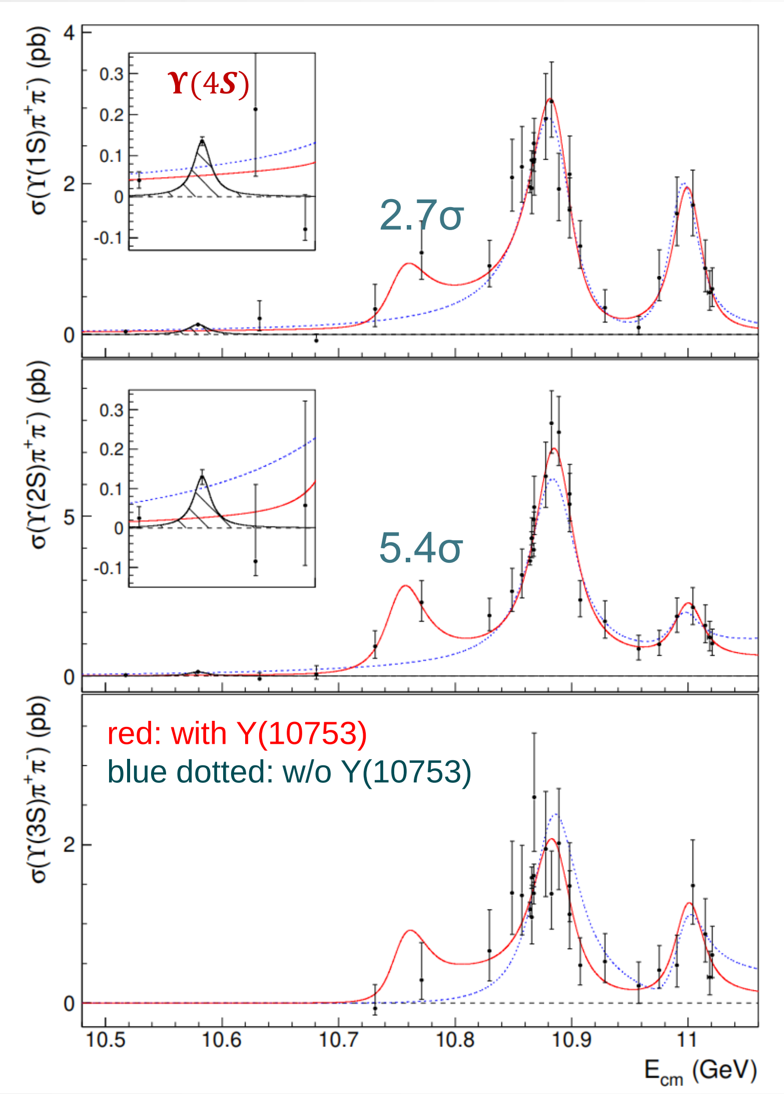
[1] MPLA32,1750025 [2] PRD77,074003 [3] PLB 671, 55 [4] PRD85, 034024 [5] PRL 104, 162001 [6] PLB 666, 344 [7] EPJC 71, 1825 [8] PRD 92, 054034 [9] PRD 93, 011101

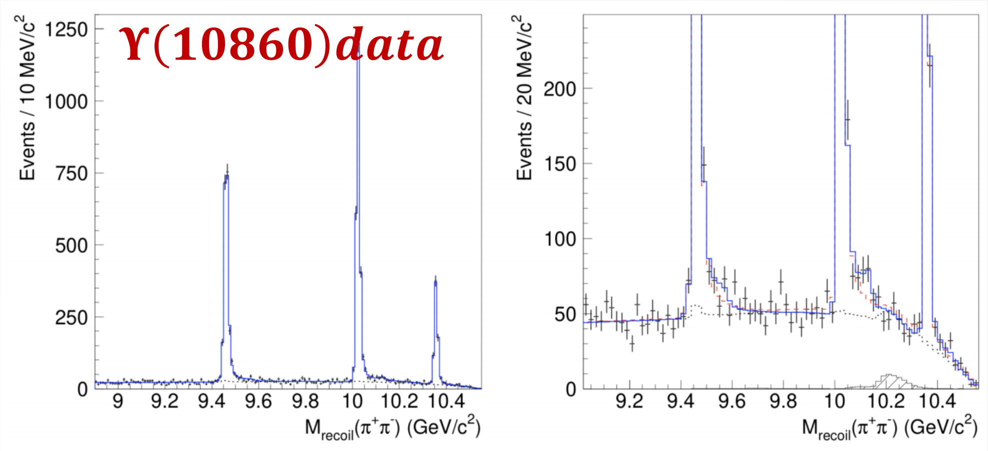
$e^+e^- \to \Upsilon(nS)\pi^+\pi^-$

Scan data: 22 points, each point 1fb^{-1}

$\Upsilon(10860)$ on-resonance data: 121 fb^{-1}, between 10.864 and 10.868 GeV

Continuum data at 10.52 GeV, 60 fb^{-1}





	$\Upsilon(10860)$	$\Upsilon(11020)$	New structure
M (MeV/c^2)	$10885.3 \pm 1.5^{+2.2}_{-0.9}$	$11000.0^{+4.0}_{-4.5}{}^{+1.0}_{-1.3}$	$10752.7 \pm 5.9^{+0.7}_{-1.1}$
Γ (MeV)	$36.6^{+4.5}_{-3.9}{}^{+0.5}_{-1.1}$	$23.8^{+8.0}_{-6.8}{}^{+0.7}_{-1.8}$	$35.5^{+17.6}_{-11.3}{}^{+3.9}_{-3.3}$

$\Gamma_{ee} \times \mathcal{B}$ (in eV)

	$\Upsilon(10860)$	$\Upsilon(11020)$	new
$\Upsilon(1S)\pi^+\pi^-$	$0.75 - 1.43$	$0.38 - 0.54$	$0.12 - 0.47$
$\Upsilon(2S)\pi^+\pi^-$	$1.35 - 3.80$	$0.13 - 1.16$	$0.53 - 1.22$
$\Upsilon(3S)\pi^+\pi^-$	$0.43 - 1.03$	$0.17 - 0.49$	$0.21 - 0.26$

a range due to multi-solutions

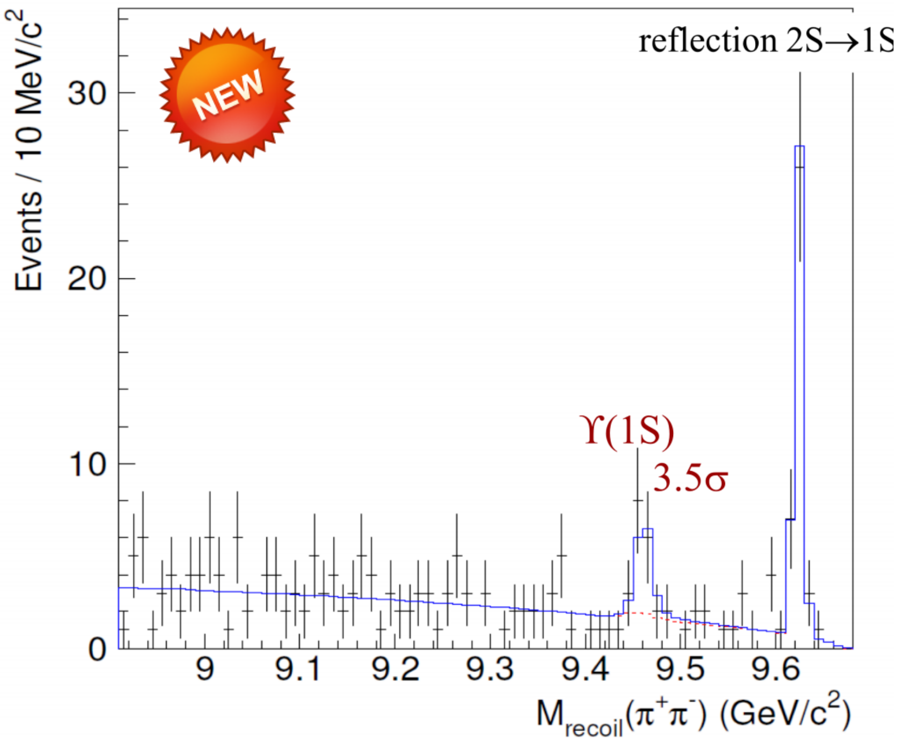
Global significance: 6.7σ

Possible explanations: resonance $\Upsilon(3D)$, exotic state, complicated rescattering, ….

$e^+e^- \to \Upsilon(nS)\pi^+\pi^-$

Continuum below $\Upsilon(4S)$

- $E_{c.m.} = 10.52$ GeV.
- Required $M(\pi^+\pi^-) > 0.85$ GeV.
- A clear signal for the $\Upsilon(1S)\pi^+\pi^-$ process is evident.
- $\sigma[e^+e^- \to \Upsilon(1S)\pi^+\pi^-] = 42^{+17}_{-15}$ fb.
- Significance including systematics: $> 3.5\sigma$.
  $\to$ Evidence for $e^+e^- \to \Upsilon(1S)\pi^+\pi^-$ in continuum at $E_{c.m.} = 10.52$ GeV!



It is an indication of the presence of a non-resonant contribution in the energy dependence of the $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ cross sections.

Summary

- **Although Belle has stopped data taking for ~10 years, we are still producing exciting results in (light) hadron spectrum, charmed baryon, exotic states, and bottomonium spectrum.**
- **Belle II has started to take data on 25 March with full its detector.**
- **Belle II will reach 50 ab^{-1} by 2027, which will provide greater sensitivity and precise measurements in hadron physics**

Belle II physics book (arXiv:1808.10567):
https://confluence.desy.de/display/BI/B2TiP+ReportStatus

復旦大學
FUDAN UNIVERSITY

Thanks for your attention

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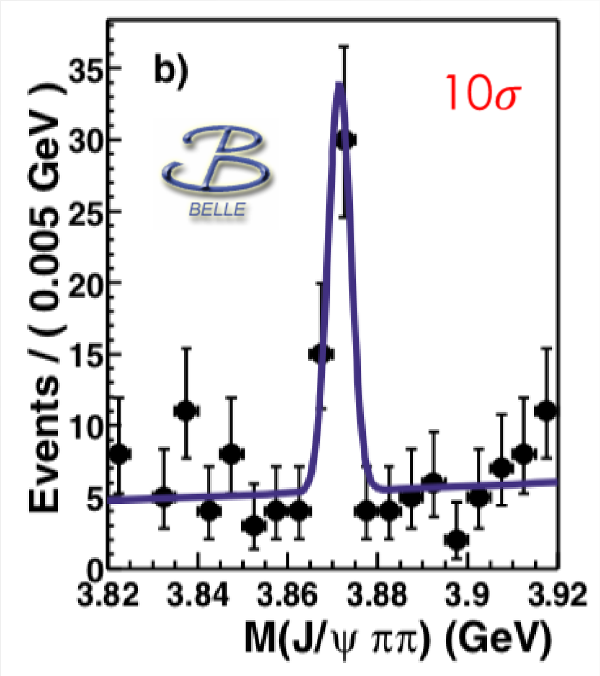
Short summary on the X(3872)

The X(3872) was first observed in 2003 by Belle in the process of $B \to KX(3872)(\to \pi^+\pi^- J/\psi)$. Then, it was confirmed by BESIII, BABAR, CDF, DØ, CMS, LHCb, …

PRL91, 262001 (2003)

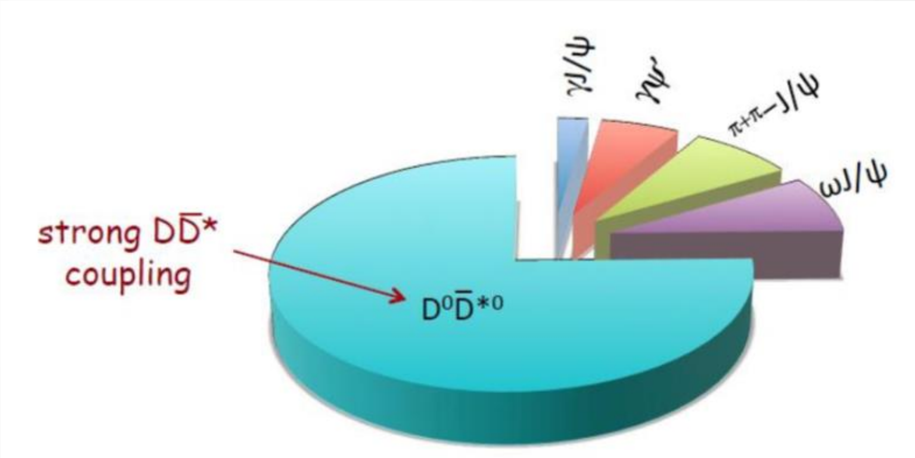


The remarkable features:

- M_X closes to $D^0\bar{D}^{*0}$ threshold (ΔM=0.18 MeV/c²)
- Surprisingly narrow: Γ_{tot}<1.2 MeV at 90% C.L.
- It has quantum numbers $J^{PC} = 1^{++}$
- No isospin partners are recently knows
- No nearby neutral $X(3872)$ partners
- It has isospin-violating decays $\rho J/\psi$ and $\omega J/\psi$
- It also decays to $D^0\bar{D}^{*0}$, $\gamma J/\psi$, $\gamma\psi(2S)$, and $\omega J/\psi$.

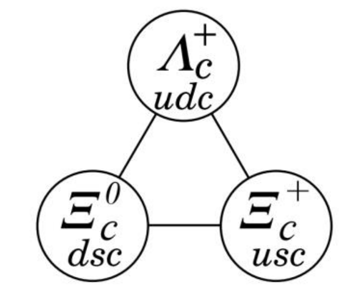
Γ_{tot}=15× $\Gamma(X(3872) \to \pi^+\pi^- J/\psi)$

$\Gamma(X(3872) \to \pi^+\pi^- J/\psi)$ < 80keV



Measurements of absolute Brs of Ξ_c^0

- Weak decays of charmed hadrons play an unique role in the study of strong interaction； the charmed-baryon sector also offers an unique and excellent laboratory for testing heavy-quark symmetry and light-quark chiral symmetry.
- For the charmed baryons of the SU(3) anti-triplet, only Λ_c absolute Brs were measured by Belle [PRL113,042002(2014), first time] and BESIII [PRL116,052001(2016)]
- Since Ξ_c^0 [PRL62,863(1989)] and Ξ_c^+[PLB122,455 (1983)] were discovered ~30 years ago, no absolute Brs could be measured.
- For Ξ_c^0, the Brs are all measured with ratios to the $\Xi^-\pi^+$, the so called reference mode.



Measurements of absolute Brs of Ξ_c^0

- Theory: $B(\Xi_c^0 \to \Xi^-\pi^+)$~1.12% or 0.74% [PRD48, 4188 (1993)], (2.24±0.34)% [JHEP03, 66(2018)], (1.91±0.17)% [1811.07265]
- The $B(\Xi_c^0 \to \Lambda K^-\pi^+)$/ $B(\Xi_c^0 \to \Xi^-\pi^+)$ = 1.07 ± 0.12± 0.07 and $B(\Xi_c^0 \to pK^-K^-\pi^+)$/ $B(\Xi_c^0 \to \Xi^-\pi^+)$= 0.33 ± 0.03±0.03 [PLB 605,237]
- $\Xi_c^0 \to pK^-K^-\pi^+$ plays a fundamental role in lots of bottom baryons study at LHCb .
- How to measure Ξ_c^0 absolute Brs ? Model Independent !

$$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)},$$

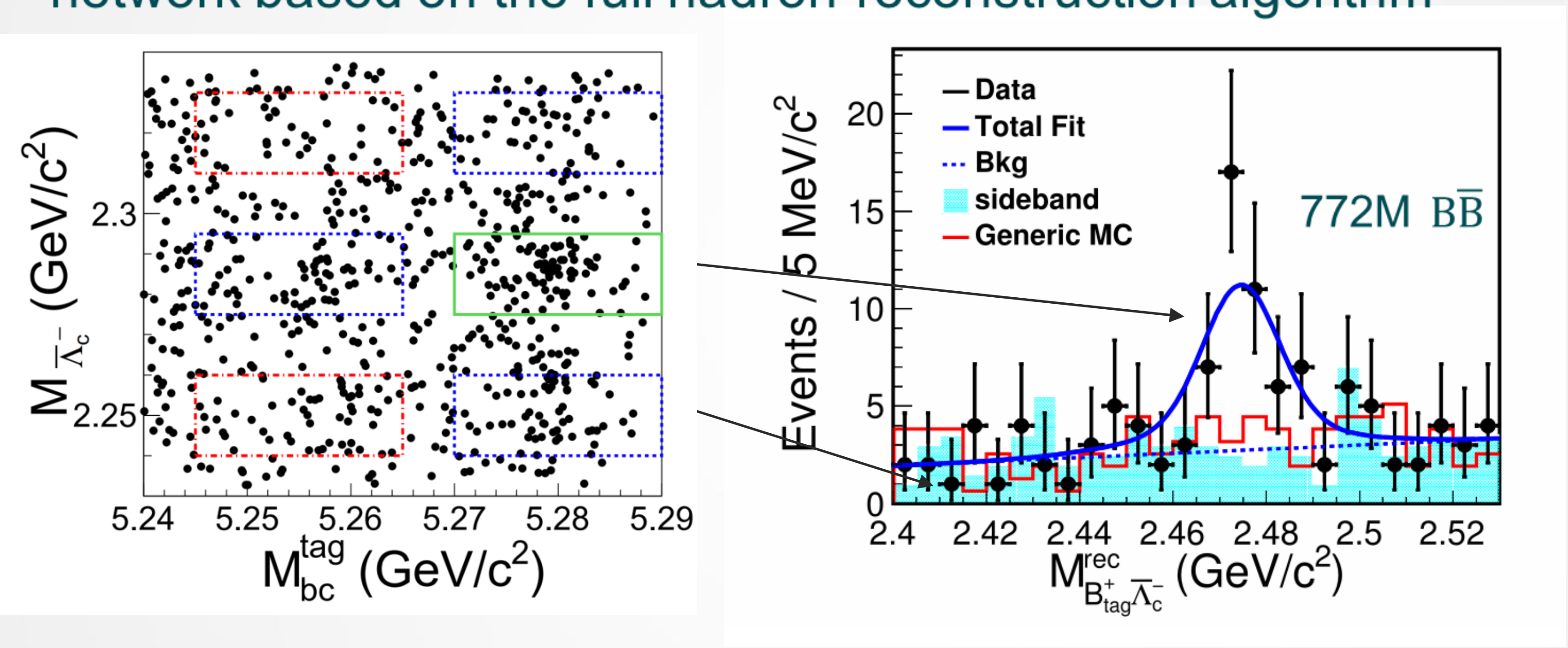
$$\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)}.$$

$$\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to pK^-K^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)}.$$

- For inclusive $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, Ξ_c^0 →anything, never measured before.
- For exclusive $B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$ $B(\Xi_c^0 \to \Xi^-\pi^+)$; $B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$ $B(\Xi_c^0 \to \Lambda K^-\pi^+)$, measured by Belle and BaBar with large errors.

Measurements of Br of $B^{-} \to \bar{\Lambda}_c^{-} \Xi_c^0$, $\Xi_c^0 \to$anything

- The $\bar{\Lambda}_c^-$ reconstructed via its $\bar{p}K^{+}\pi^{-}$ and $\bar{p}K_S^0$ decays
- A tagged B meson candidate, B_{tag}^{+}, is reconstructed using a neural network based on the full hadron-reconstruction algorithm



- An unbinned maximum likelihood fit: N(Ξ_c^0)=40.9 $\pm$9.0, 5.5σ(stat.)
- B($B^{-} \to \bar{\Lambda}_c^{-} \Xi_c^0$, Ξ_c^0 →anything)= $(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$ for the first time

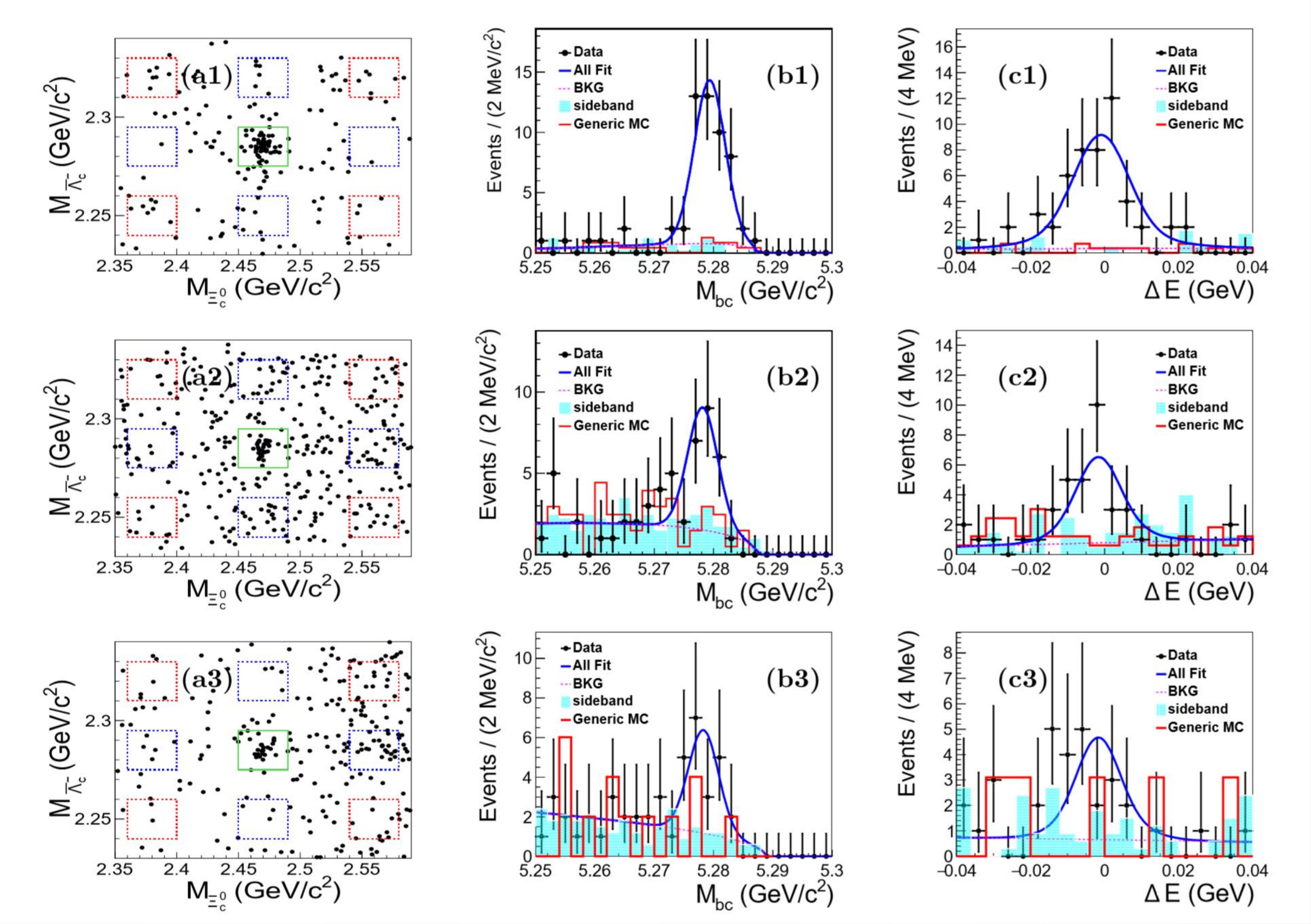
PRL122, 082001 (2019)

Measurements of Brs of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, with $\Xi_c^0 \to \Xi^-\pi^+; \Xi_c^0 \to \Lambda K^-\pi^+; \Xi_c^0 \to pK^-K^-\pi^+$

$\Xi^-\pi^+$
44.8 ± 7.3
9.5σ

$\Lambda K^-\pi^+$
24.1 ±5.5
6.8σ

$pK^-K^-\pi^+$
16.6 ± 5.4
4.6σ



PRL122, 082001 (2019)

Measurements of absolute Brs of Ξ_c^0

Summary of the measured branching fractions and the ratios of Ξ_c^0 decays

PRL122, 082001 (2019)

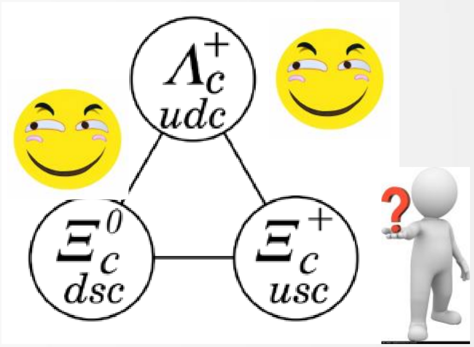
Channel	Br/Ratio	PDG
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$	$(9.51\pm2.10\pm0.88)\times10^{-4}$	
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.71\pm0.28\pm0.15)\times10^{-5}$	$(2.4\pm0.9)\times10^{-5}$
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.11\pm0.26\pm0.10)\times10^{-5}$	$(2.1\pm0.9)\times10^{-5}$
$B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\, B(\Xi_c^0 \to p K^- K^- \pi^+)$	$(5.47\pm1.78\pm0.57)\times10^{-6}$	
$B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.80\pm0.50\pm0.14)\%$	
$B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.17\pm0.37\pm0.09)\%$	
$B(\Xi_c^0 \to p K^- K^- \pi^+)$	$(0.58\pm0.23\pm0.05)\%$	
$B(\Xi_c^0 \to \Lambda K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.65\pm0.18\pm0.04$	1.07 ± 0.14
$B(\Xi_c^0 \to p K^- K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.32\pm0.12\pm0.07$	0.34 ± 0.04

- We have performed an analysis of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$ inclusively and exclusively
- First model-independent measurement of absolute Brs of Ξ_c^0 decays
- The branching fraction $B(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$ is measured for the first time
- The $B(\Xi_c^0 \to \Xi^- \pi^+)$ can be used to determine the BR of other Ξ_c^0 decays.

Measurements of absolute Brs of Ξ_c^+

- The decays of charmed baryons in experiment are needed to extract the non-perturbative contribution thus important to constrain phenomenological models of strong interaction.

- For the SU(3) anti-triplet charmed baryons the branching fractions of Λ_c^+ [PRL 113,042003(2014); PRL 116,052001(2016)] and Ξ_c^0 [PRL 122,082001(2019)] has been measured.



- The Brs of remaining Ξ_c^+ are all measured with ratio to the $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$

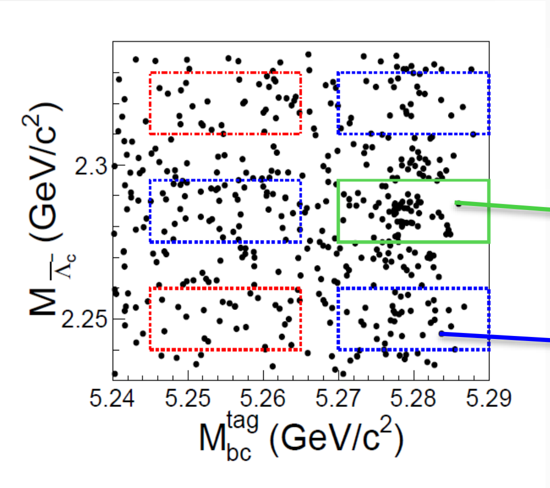
- The comparison of Ξ_c^+ decays with those of Λ_c^+ and and Ξ_c^0 can also provide an important test of SU(3) flavor symmetry.

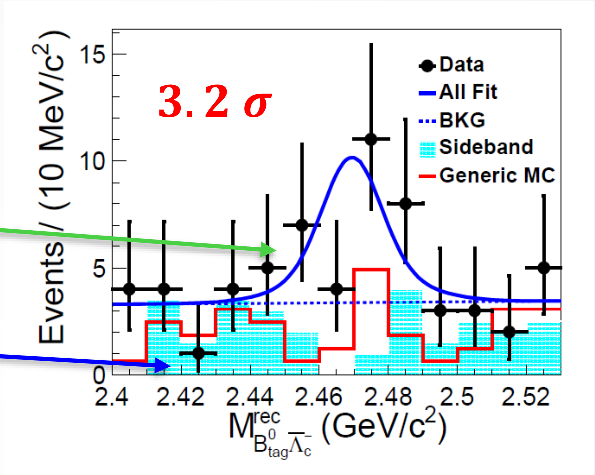
$\Xi_c^+ \to p K^- \pi^+$ is a particularly important decay mode as it is the one most often used to reconstruct Ξ_c^+ candidates at hadron collider experiments, such as LHCb. Theory predicts the $B(\Xi_c^+ \to p K^- \pi^+)=(2.2\pm0.8)\%$ [EPJC 78, 224 (2018); Chin. Phys. C 42, 051001 (2018)].

Measurement of Ξ_c^+ absolute BRs

arXiv:1904.12093

Measurement $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$ with $\Xi_c^+ \to anythings$





- reconstruct $\bar{\Lambda}_c^-$ via $\bar{p}K^+\pi^-$ decay mode
- tag a B^0 with neural network based Full-Reconstruction algorithm.
- An unbinned maximum likelihood fit: $N(\Xi_c^+) = 18.8 \pm 6.8$
- $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+) = [1.16 \pm 0.42(stat.) \pm 0.15(syst.)] \times 10^{-3}$

Measurement of Ξ_c^+ absolute BRs

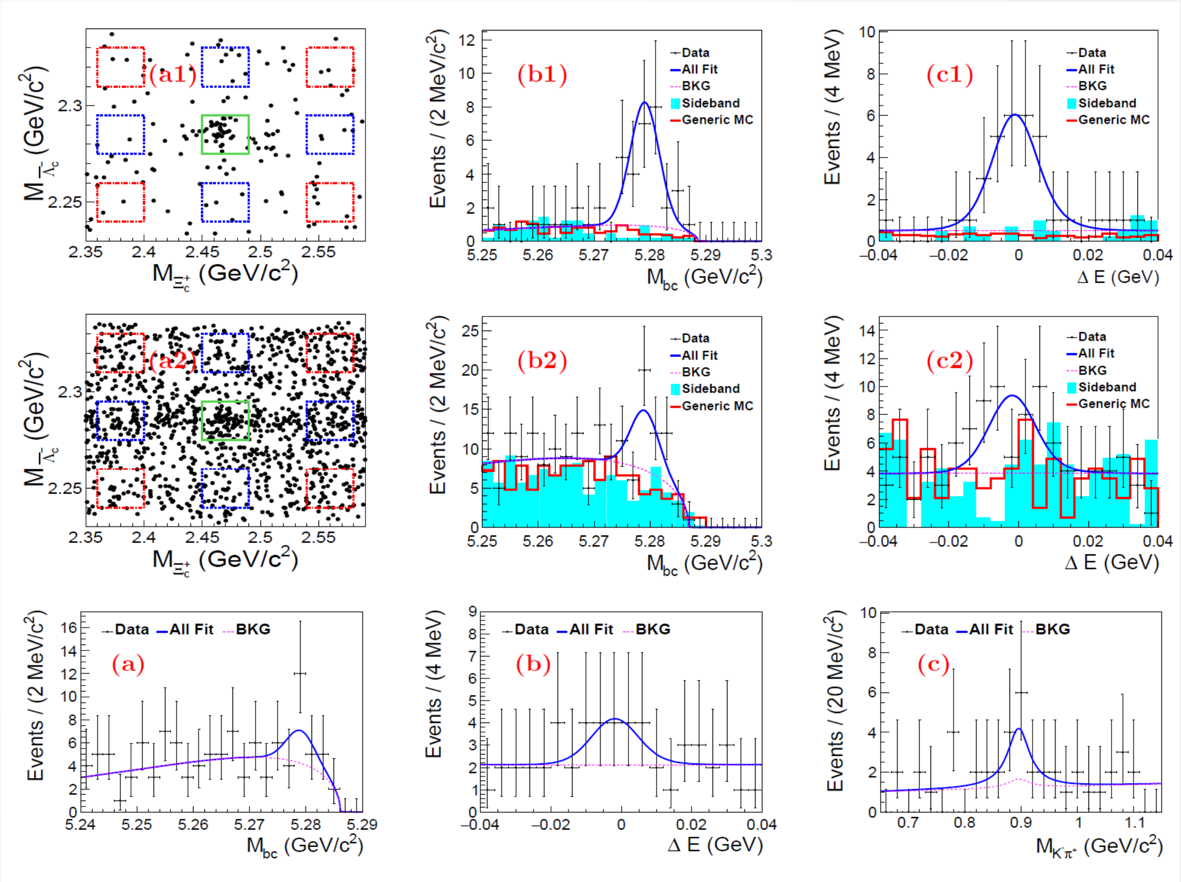
arXiv:1904.12093

Measurement $\mathcal{B}\left(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+\right)$ with $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$ or $p[\bar{K}^*(892) \to K^- \pi^+]$

$\Xi_c^+ \to \Xi^- \pi^+ \pi^+$
$N = 24.2 \pm 5.4$ **6.9σ**

$\Xi_c^+ \to p K^- \pi^+$
$N = 24.0 \pm 6.9$ **4.5σ**

$\Xi_c^+ \to p\bar{K}^*(892)$
$N = 8.9 \pm 3.9$ **3.3σ**



Measurement of Ξ_c^+ absolute BRs

Summary of the measured BRs

arXiv:1904.12093

Decay mode	Br/ Ratio	PDG value
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$	$[1.16 \pm 0.42 \pm 0.15] \times 10^{-3}$	
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$[3.32 \pm 0.74 \pm 0.33] \times 10^{-5}$	$(1.8 \pm 1.8) \times 10^{-5}$
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$[5.27 \pm 1.51 \pm 0.69] \times 10^{-5}$	
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to p\bar{K}^*(892))$	$[2.97 \pm 1.31 \pm 0.44] \times 10^{-5}$	
$\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$[2.86 \pm 1.21 \pm 0.38]\%$	
$\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$[0.45 \pm 0.21 \pm 0.07]\%$	
$\mathcal{B}(\Xi_c^+ \to p\bar{K}^*(892))$	$[0.25 \pm 0.16 \pm 0.04]\%$	
$\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)/\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$0.16 \pm 0.06 \pm 0.02$	0.21 ± 0.04
$\mathcal{B}(\Xi_c^+ \to p\bar{K}^*(892))/\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$0.09 \pm 0.04 \pm 0.01$	0.116 ± 0.030
$\mathcal{B}(\Xi_c^+ \to p\bar{K}^*(892))/\mathcal{B}(\Xi_c^+ \to p K^- \pi^+)$	$0.56 \pm 0.30 \pm 0.08$	$0.54 \pm 0.09 \pm 0.05$

- First model –independent $\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$ measurement
- $\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$ can be used to determine the BR of other Ξ_c^+ decay