Recent Belle results and Belle II status

Chengping Shen shencp@fudan.edu.cn

Outline

- – Recent results on charmed baryons at Belle
- – Recent results on exotic states at Belle
- – Belle II status and prospects

- Summary

Measurements of Branching Fractions of $\Lambda_c^+ \to p\pi^0$ and $\Lambda_c^+ \to p\eta$ decays at Belle

Motivation:

- **The weak decay of charmed baryons is very useful for testing many contradictory theoretical models and methods**. However, the cognition and exploration of charmed baryon goes pretty slowly.
- The precision of measurement of the decay branching fraction remains poor for many Cabibbo-favored (CF) decays and even worse for some decays dominated by Cabibbo-suppressed even though many different experiments like Belle and BESIII have hard work on improving the measurement results of charmed baryons.
- In theory, the singly Cabibbo-suppressed (SCS) decays $\Lambda_c^+ \to p\pi^0$ and $\Lambda_c^+ \to p\eta$ proceed dominantly through internal W-emission and W-exchange. The measurement of these two decay branching fractions may **be interesting to study the underlying dynamic of charmed baryon decays.**
- In experiment, BESIII report the branching fractions of these two SCS decays, which are $B(\Lambda_c^+ \to p\pi^0) < 2.7 \times 10^{-4}$ at 90% confidence level and $B(\Lambda_c^+ \to p\eta) = (1.24 \pm 0.30) \times 10^{-3}$.
- In this analysis, we utilize the much higher statistic sample of Λ_c^+ collected by Belle detector to improve the measurement precision.

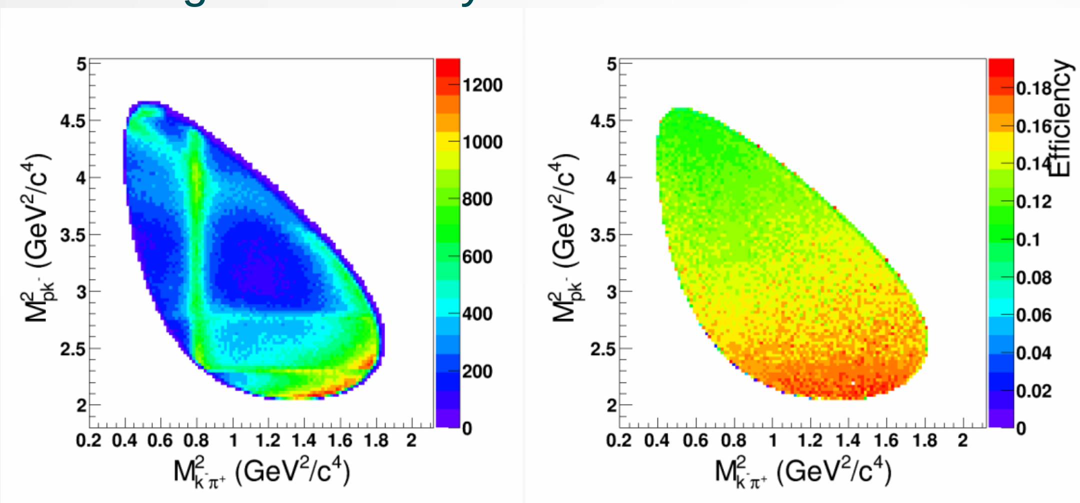
Measurement of $\Lambda_c^+ \to pK^-\pi^+$ decay

preliminary

A method of branching ratio with respect to CF decay $\Lambda_c^+ \to pK^-\pi^+$ (reference mode) is applied to measure the branching fractions of two SCS decays.

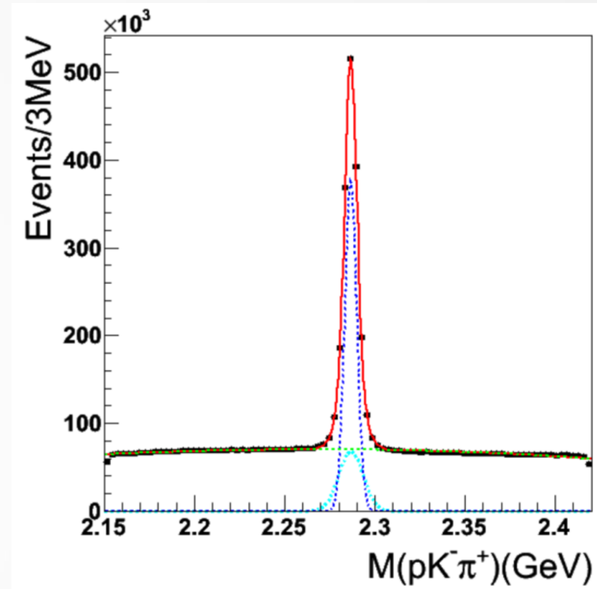
$$\frac{B(SCS)}{B(CF)} = \frac{N^{obs}(SCS)}{\epsilon^{MC}(SCS)} \times \frac{\epsilon^{MC}(CF)}{N^{obs}(CF)}$$

Signal efficiency estimation: Dalitz method.



Left: Dalitz plot from data; Right: Dalitz plot of efficiency from signal MC.

$$\varepsilon = \sum s_i / \sum_j (s_j/\varepsilon_j) = (14.06 \pm 0.01)\ \%.$$



Fit to M($pK^-\pi^+$) from data.

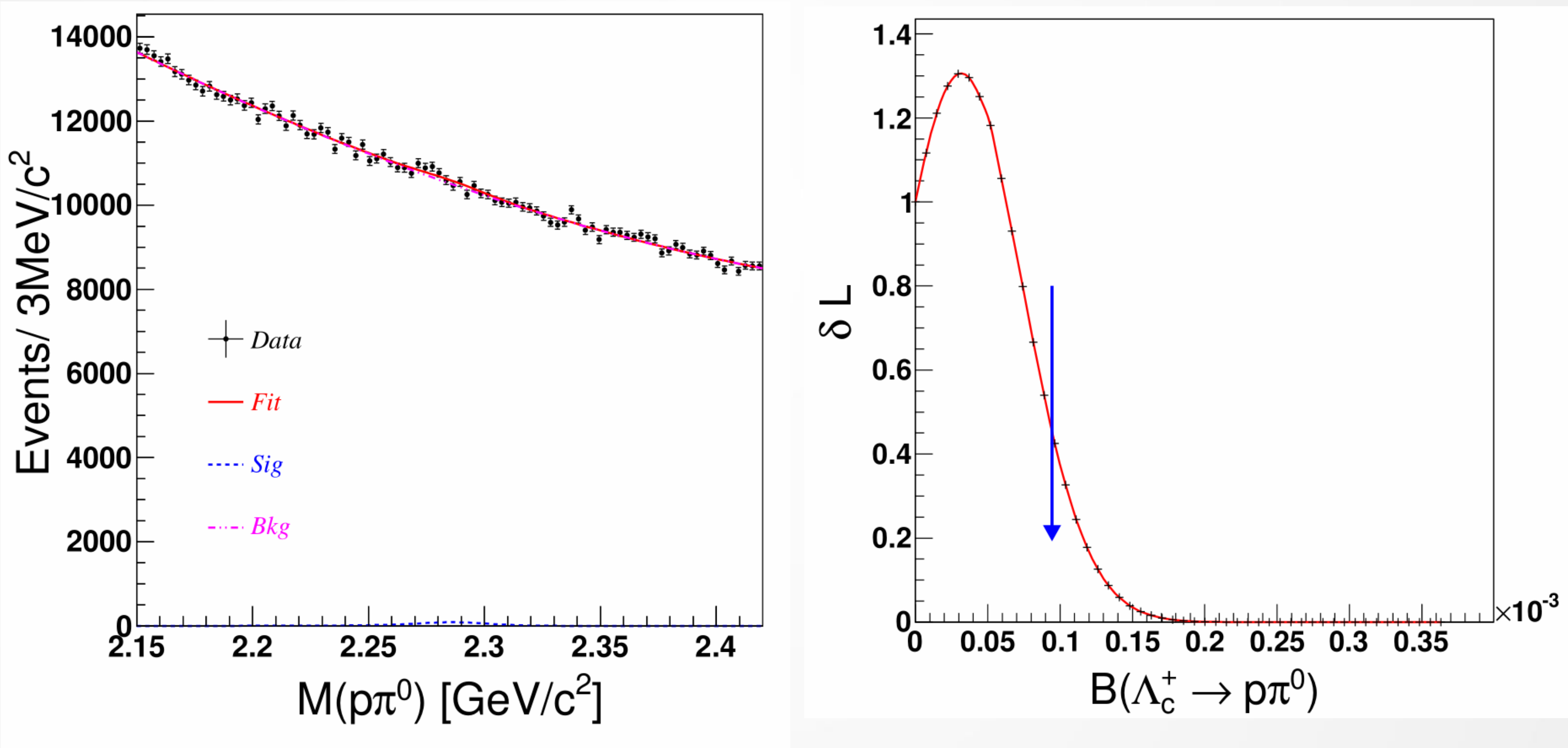
double Gaussian + second-order polynomial

Yield: **1476200 ± 1560**
χ^2/ndf=1.06

Measurement of $\Lambda_c^+ \to p\pi^0\ (\to \gamma\gamma)$ decay

preliminary

- The efficiency estimated from signal MC sample is $(8.891 \pm 0.030)\%$.
- There is no obvious signal excess in M($p\pi^0$) from data. We set an upper limit on branching fraction of $B(\Lambda_c^+ \to p\pi^0) < 9.44 \times 10^{-5}$ at 90% C.L., reducing the value to more than half of the current best upper limit of 2.7×10^{-4}.

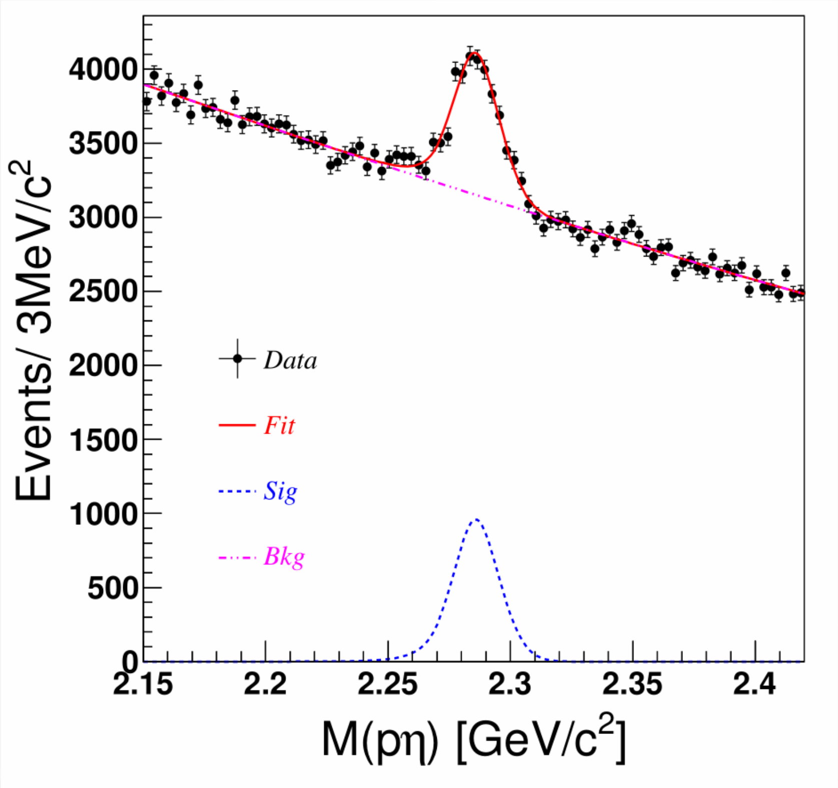


Left: fit to the invariant mass distribution of $p\pi^0$ with a fixed signal yield of **1269**. Right: The likelihood distribution changing with the branching fraction with the systematic uncertainty involved.

Measurement of $\Lambda_c^+ \to p\eta(\to \gamma\gamma)$decay

preliminary

- The efficiency estimated from signal MC sample is $(\mathbf{8.279} \pm \mathbf{0.030})\%$.



Fit to M($p\eta$) from data.

Gaussian + CB for signal. Second-order polynomial for background.

Yield: **7734 ± 263**
χ^2/ndf=1.23

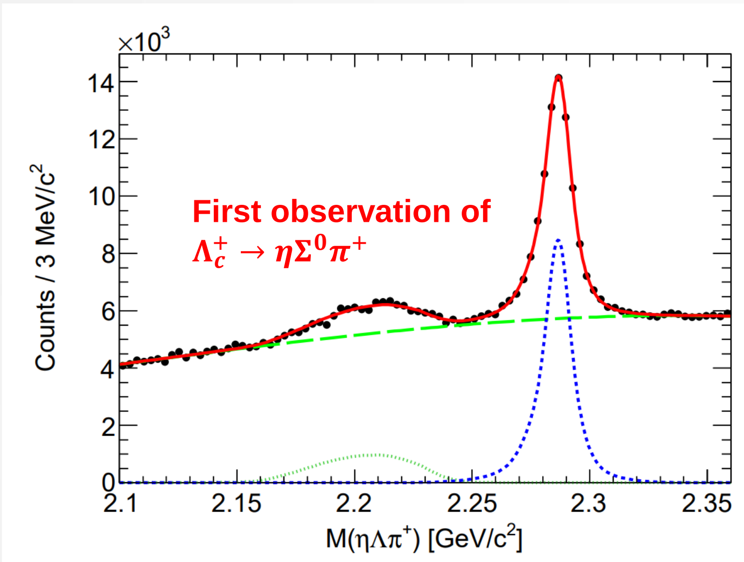
- A significant Λ_c^+ signal is observed in M($p\eta$) distribution from data. The branching fraction is $\boldsymbol{B(\Lambda_c^+ \to p\eta) = (1.54 \pm 0.06 \pm 0.10) \times 10^{-3}}$, which is consistent with the latest BESIII measured result of $(1.24 \pm 0.30) \times 10^{-3}$ with much improved precision.

Measurements of $\Lambda_c^+ \to \eta\Lambda\pi^+$ and $\Lambda_c^+ \to \eta\Sigma^0\pi^+$

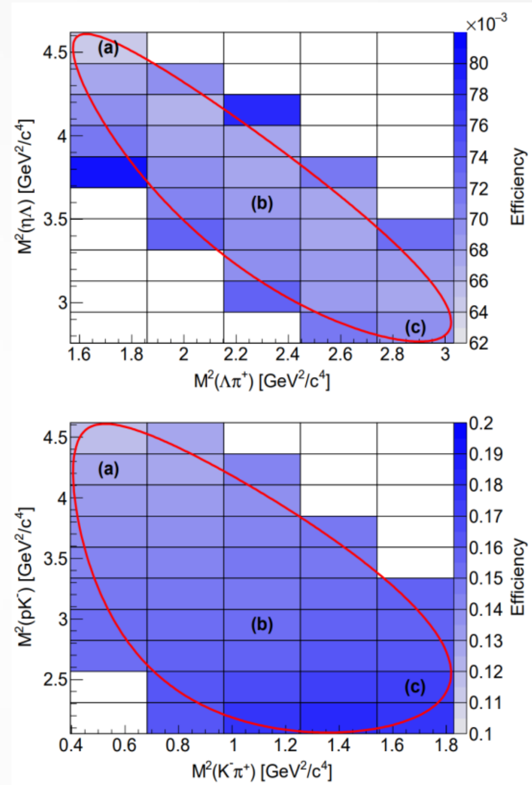
- A method to measure the branching fractions of above two decays is:

arXiv:2008.11575

$$\frac{B(\text{Decay mode})}{B(\Lambda_c^+ \to pK^-\pi^+)} = \frac{y\,(\text{Decay mode})}{B_{\text{PDG}} \times y(\Lambda_c^+ \to pK^-\pi^+)}$$ (y is the efficiency-corrected yield).



Fit to the M($\eta\Lambda\pi^+$) distribution. The structure near 2.286 GeV/c^2 is from $\Lambda_c^+ \to \eta\Lambda\pi^+$; The other one is from $\Lambda_c^+ \to \eta\Sigma^0\pi^+$ with a missing photon from the Σ^0 decay.



Dalitz plots for decay and reference mode.

The extracted yields are efficiency-corrected in each bin and summed up over the Dalitz plots.

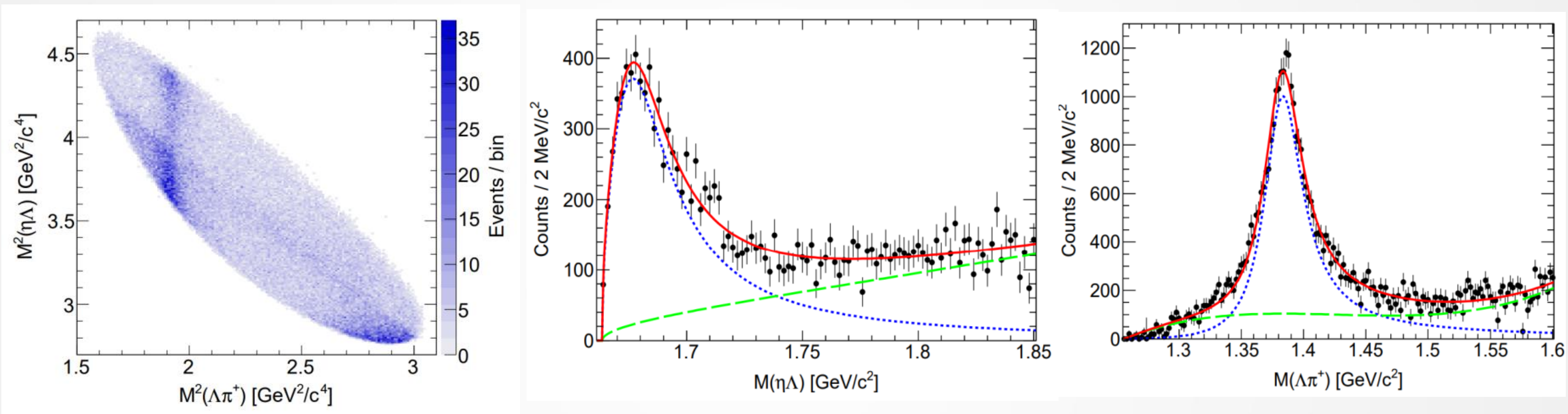
Decay mode	$y(\times 10^5)$	Branching Fraction	Reference mode	$y(\times 10^5)$
$\Lambda_c^+ \to \eta\Lambda\pi^+$	(7.41 ± 0.07)	$(1.84 \pm 0.02 \pm 0.09)\%$	$\Lambda_c^+ \to pK^-\pi^+$	(100.47 ± 0.10)
$\Lambda_c^+ \to \eta\Sigma^0\pi^+$	(3.05 ± 0.16)	$(7.56 \pm 0.39 \pm 0.37) \times 10^{-3}$		

Measurements of $\Lambda_c^+ \to \Lambda(1670)\pi^+$ and $\Lambda_c^+ \to \eta\Sigma(1385)^+$

arXiv:2008.11575

- $\Lambda_c^+ \to \Lambda(1670)\pi^+$ and $\Lambda_c^+ \to \eta\Sigma(1385)^+$ are visible in Dalitz plot.
- Fit to the M($\eta\Lambda\pi^+$) distributions in every 2 MeV/c^2 bin of the M($\eta\Lambda$) and M($\Lambda\pi^+$) distributions to extract the signal yields.
- Clear $\Lambda(1670)$ and $\Sigma(1385)^+$ signals show up.

(First observation of the $\Lambda(1670)$ in $\Lambda_c^+ \to \Lambda(1670)\pi^+$.)



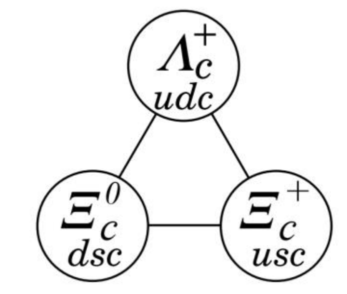
Left: Dalitz plot for $\Lambda_c^+ \to \eta\Lambda\pi^+$ from data. Middle: fit to the M($\eta\Lambda\pi^+$) distributions in each M($\eta\Lambda$) bin. Right: fit to the M($\eta\Lambda\pi^+$) distributions in each M($\Lambda\pi^+$) bin.

Decay mode	Yield	$y(\times 10^5)$	Branching Fraction
$\Lambda_c^+ \to \Lambda(1670)\pi^+$	9760 ± 519	(1.40 ± 0.07)	$(3.48 \pm 0.19 \pm 0.46) \times 10^{-3}$ *
$\Lambda_c^+ \to \eta\Sigma(1385)^+$	29372 ± 875	(4.23 ± 0.13)	$(1.21 \pm 0.04 \pm 0.16)\%$

*$B(\Lambda_c^+ \to \Lambda(1670)\pi^+) \times B(\Lambda(1670) \to \eta\Lambda)$

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 !

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

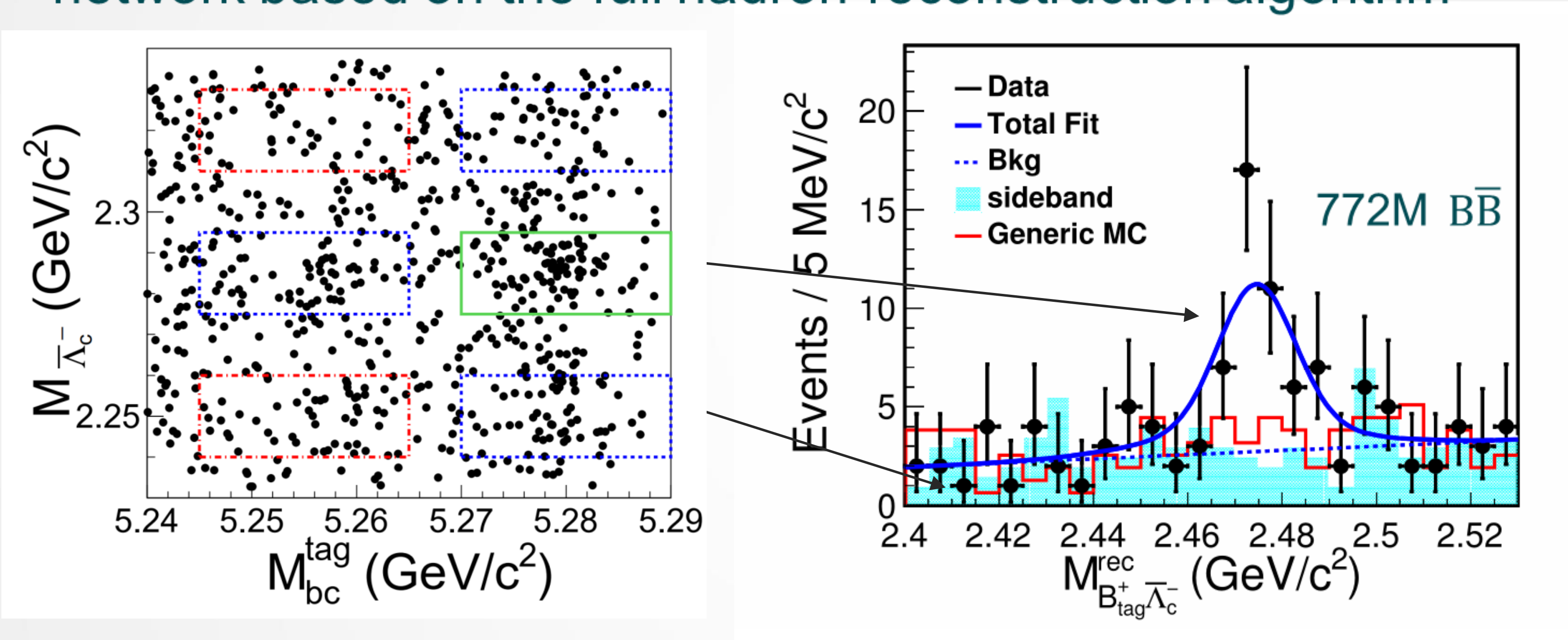
$$\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+) \equiv \frac{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Lambda K^-\pi^+)}{\mathcal{B}(B^- \to \bar{\Lambda}_c^-\Xi_c^0)}.$$

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

- 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 $\pm$9.0, 5.5σ(stat.)
- B($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

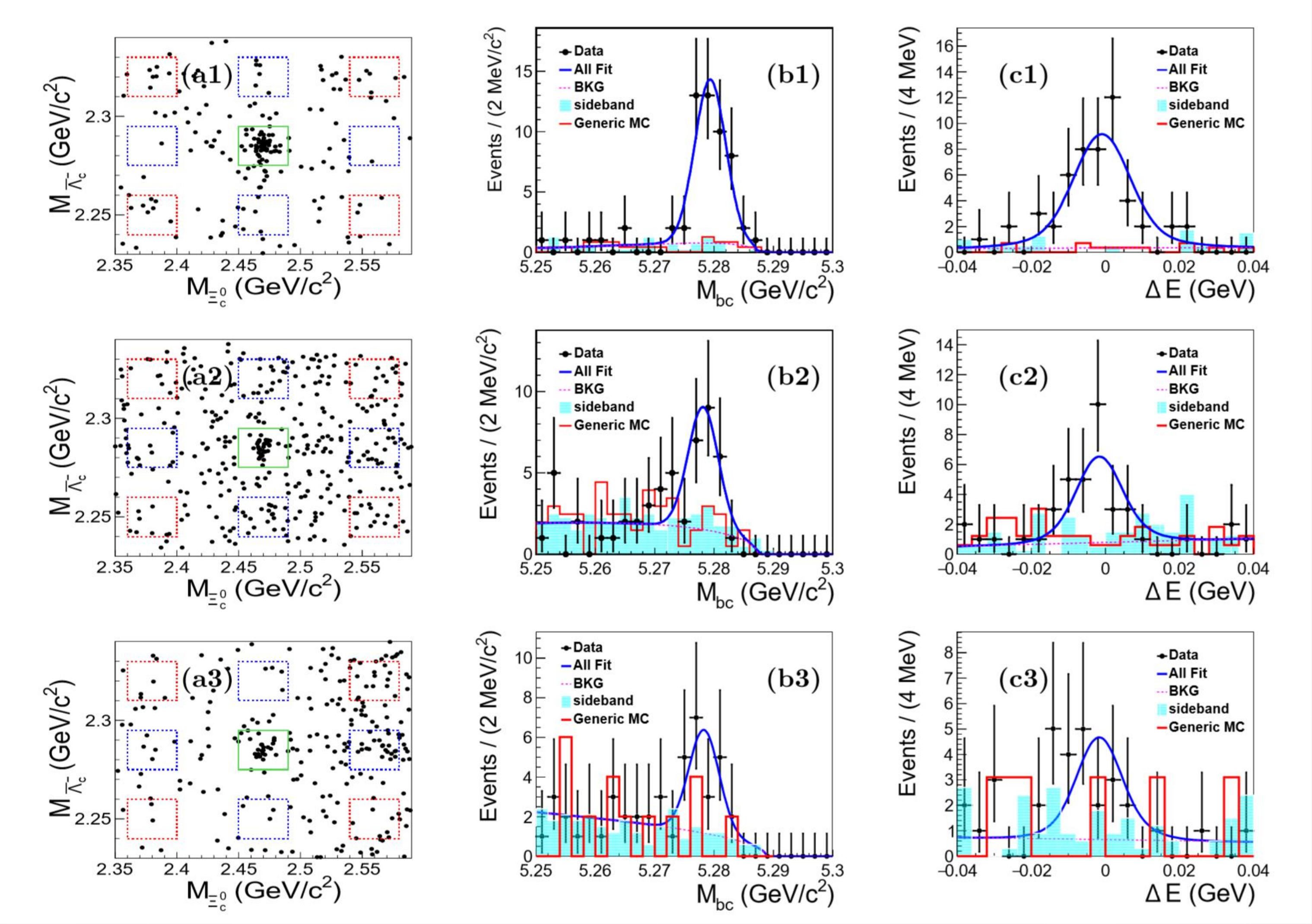
Y.B.Li, C.P.Shen et al. (Belle)
PRL122, 082001 (2019)

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



Y.B.Li, C.P.Shen et al (Belle) 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

Y.B.Li, C.P.Shen et al (Belle) PRL122, 082001 (2019)

BF	Result	Theory	PDG
$\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)$	$(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$	$\sim 10^{-3}$	
$\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.71 \pm 0.28 \pm 0.15) \times 10^{-5}$		$(2.4 \pm 0.9) \times 10^{-5}$
$\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.11 \pm 0.26 \pm 0.10) \times 10^{-5}$		$(2.1 \pm 0.9) \times 10^{-5}$
$\mathcal{B}(B^- \to \bar{\Lambda}_c^- \Xi_c^0)\mathcal{B}(\Xi_c^0 \to p K^- K^- \pi^+)$	$(5.47 \pm 1.78 \pm 0.57) \times 10^{-6}$		
$\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.80 \pm 0.50 \pm 0.14)\%$	1.12% or 0.74%	
$\mathcal{B}(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.17 \pm 0.37 \pm 0.09)\%$		
$\mathcal{B}(\Xi_c^0 \to p K^- K^- \pi^+)$	$(0.58 \pm 0.23 \pm 0.05)\%$		
$\mathcal{B}(\Xi_c^0 \to \Lambda K^- \pi^+)/\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)$	$0.65 \pm 0.18 \pm 0.04$		1.07 ± 0.14
$\mathcal{B}(\Xi_c^0 \to p K^- K^- \pi^+)/\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)$	$0.32 \pm 0.12 \pm 0.07$		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.

Measurement of Ξ_c^+ absolute BRs

Y. B. Li. C. P. Shen et al (Belle) PRD 100, 031101 (2019)

BF	Result	Theory	PDG
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)$	$(1.16 \pm 0.42 \pm 0.15) \times 10^{-3}$	$\sim 10^{-3}$	
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+))\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$(3.32 \pm 0.74 \pm 0.33) \times 10^{-5}$		$(1.8 \pm 1.8) \times 10^{-5}$
$\mathcal{B}(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+)\mathcal{B}(\Xi_c^+ \to pK^- \pi^+)$	$(5.27 \pm 1.51 \pm 0.69) \times 10^{-5}$		
$\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$(2.86 \pm 1.21 \pm 0.38)\%$	$(1.47 \pm 0.84)\%$	
$\mathcal{B}(\Xi_c^+ \to pK^- \pi^+)$	$(0.45 \pm 0.21 \pm 0.07)\%$	$(2.2 \pm 0.8)\%$	
$\mathcal{B}(\Xi_c^+ \to pK^- \pi^+)/\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$	$0.16 \pm 0.06 \pm 0.02$		0.21 ± 0.04

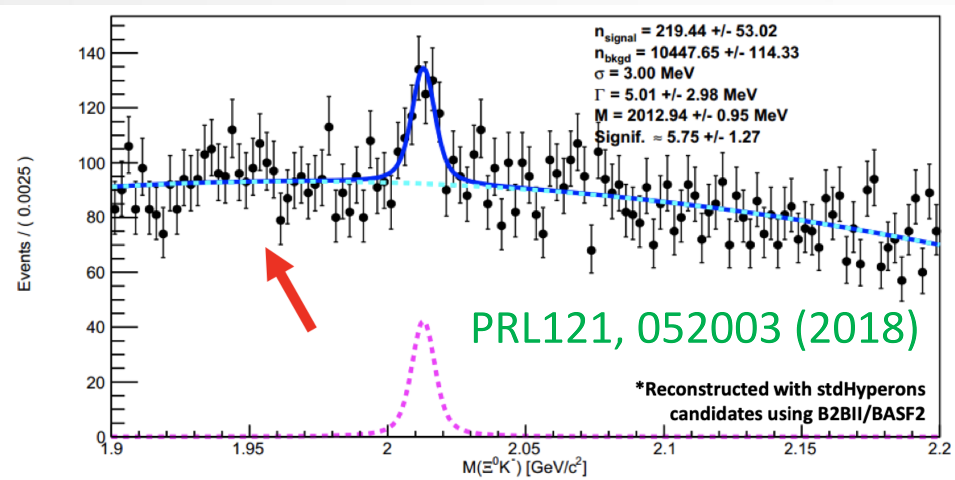
- First model –independent $\mathcal{B}\left(\bar{B}^0 \to \bar{\Lambda}_c^- \Xi_c^+\right)$ measurement
- $\mathcal{B}(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)$ can be used to determine the BR of other Ξ_c^+ decay

Measurement of the Resonant and Non-Resonant Branching Ratios in $\Xi_c^0 \rightarrow \Xi^0 K^+ K^-$

arXiv: 2012.05607 (2020)

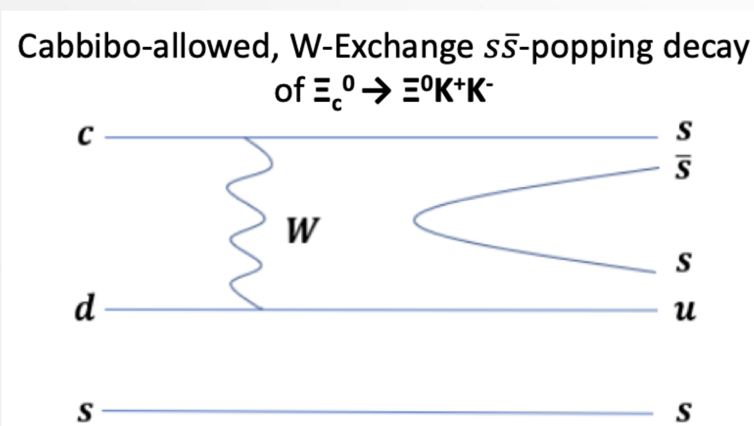
Motivation:

- Background Motivation in Excited Ω Searches



From quark model predictions, it can be expected that Ω(2012) could have a partner near 1.95 GeV/c² [PRD 101, 016002 (2020)] and low-statistics evidence of an excess in $M(\Xi^0 K^-)$ has been noticed.

- Spin-Polarized $\Xi_c^0 \rightarrow \Xi^0 \phi(\rightarrow K^+ K^-)$ Substructure



A resonant $\phi(\rightarrow K^+ K^-)$ in the decay channel $\Xi_c^0 \rightarrow \Xi^0 \phi(\rightarrow K^+ K^-)$ is known to be polarized due to the spin helicities of the parent baryon decay (1/2 → 1/2 1).

Dalitz Plot

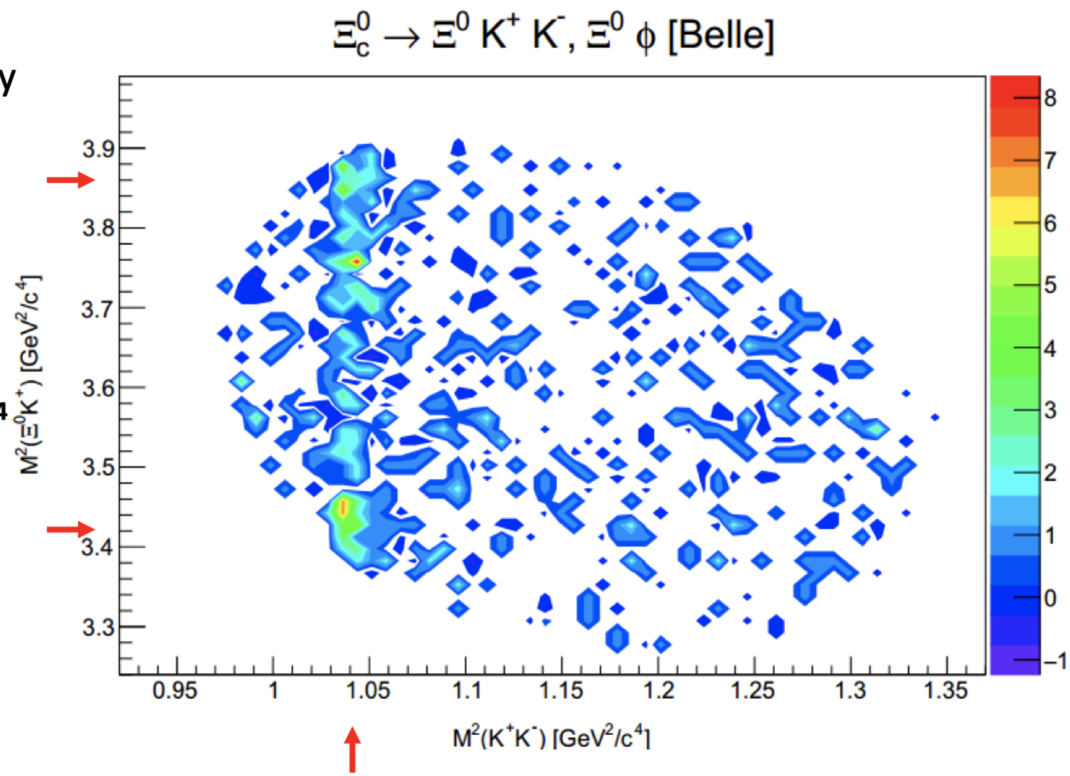
arXiv: 2012.05607 (2020)

(Ξ^0 Mass-Constrained, Sideband Subtracted)

Across the entire $M(\Xi^0 K^+ K^-)$ phasespace only a single resonance ($\phi \rightarrow K^+K^-$) at $M^2(K^+K^-)$ = **1.04 GeV²/c⁴** is observed

Along the resonant ϕ band, two non-uniform substructure peaks in the $M(\Xi^0 K^\pm)$ projections are indeed observed near $M^2(\Xi^0 K^-)$ = **3.85 GeV²/c⁴** and **3.425 GeV²/c⁴** due to the ½ → ½ 1 polarization of the ϕ

To study these resonant substructures, we ideally proceed with an amplitude analysis of the $M(\Xi^0 K^+ K^-)$ phasespace using AmpTools (v.10.2)



Amplitude Model to Analyze the Dalitz Plot:

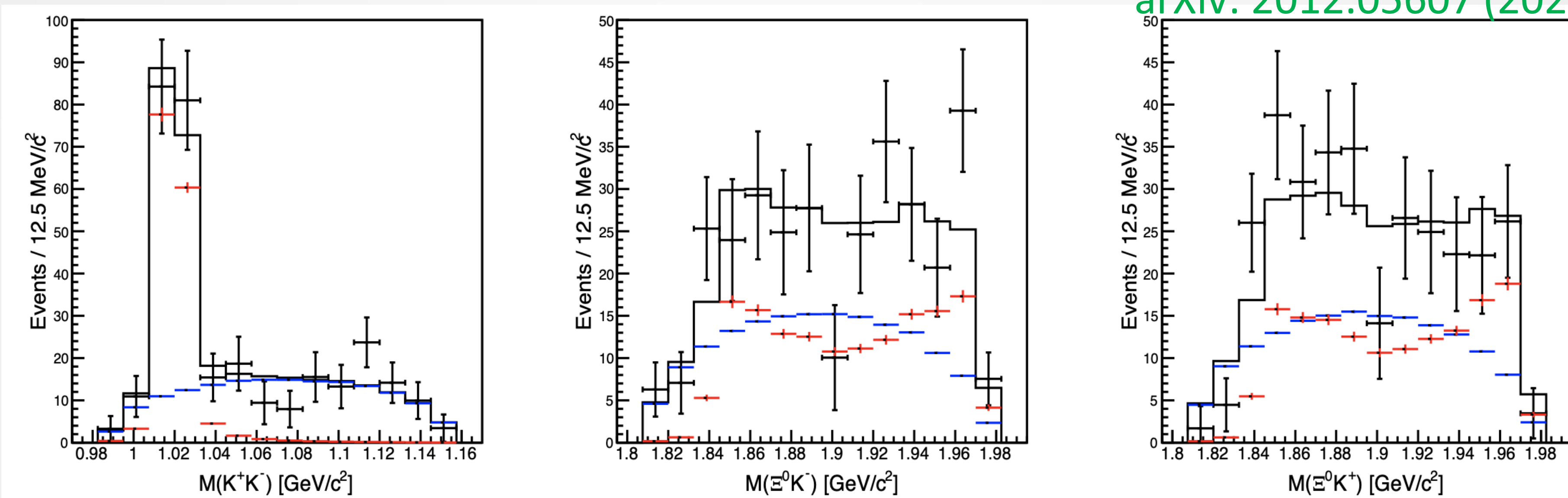
$$< \Xi_c^0 | H | \Xi^0 K^+ K^- > = < \Xi_c^0 | H | \Xi^0 K^+ K^- > + < \Xi_c^0 | H | \Xi^0 \phi >$$

Direct process, phase space decays are modelled with a constant, phase space amplitude (A_{phsp})

Polarized resonances are modelled with a Breit-Wigner and Spin-Polarization amplitude

Amplitude Fit over the Belle Data Sample

arXiv: 2012.05607 (2020)



$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^0 \phi(\to K^+K^-))}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	**0.036±0.004(stat.)±0.002(syst.)**
$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^0 K^+K^-)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)}$	**0.039±0.004(stat.)±0.002(syst.)**

Resonant Amplitude

Non-Resonant Amplitude

Amplitude Sum (Resonant and Non-Resonant)

- The measurements of these Ξ_c^0 decay modes, which can only proceed via W-exchange together with $s\bar{s}$ production, add to our knowledge of the weak decay of charmed baryons.
- It is unlikely that contributions from these resonant $\Xi^0\phi(\to K^+K^-)$ decays will correlate to significant event excesses in the Ξ^0K^- reconstruction near 1.95 GeV.

Ξ_c worklist:

1. Measurement of absolute decay branching fractions

$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = (1.80 \pm 0.52)\%$ PRL 122 082001

$\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (2.86 \pm 1.27)\%$ PRD 100 031101

μ? $\mathcal{B}(\Xi_c^0 \to \Xi^- e^+ \nu_e) = (1.8 \pm 1.2)\%$ PDG

$\mathcal{B}(\Xi_c^+ \to \Xi^0 e^+ \nu_e) = (1.8^{+0.7}_{-0.8})\%$ PDG, ratios to $\Xi^- 2\pi^+$

Need updated

2. Find more decay modes:

PRD 101, 053002

CF (%)

$\Xi_c^+ \to \Sigma^+ \bar{K}^{*0}$	1.40 ± 0.69[a]
$\Xi_c^+ \to \Xi^0 \rho^+$	14.48 ± 2.44[a]
$\Xi_c^0 \to \Lambda^0 \bar{K}^{*0}$	1.37 ± 0.26
$\Xi_c^0 \to \Sigma^0 \bar{K}^{*0}$	0.42 ± 0.23
$\Xi_c^0 \to \Sigma^+ K^{*-}$	0.24 ± 0.17
$\Xi_c^0 \to \Xi^0 \rho^0$	0.88 ± 0.22
$\Xi_c^0 \to \Xi^0 \omega$	2.78 ± 0.45
$\Xi_c^0 \to \Xi^0 \phi$	0.14 ± 0.13
$\Xi_c^0 \to \Xi^- \rho^+$	8.98 ± 0.55

SCS (10^{-3})

$\Xi_c^+ \to \Lambda^0 \rho^+$	1.52 ± 0.57
$\Xi_c^+ \to p \bar{K}^{*0}$	4.71 ± 1.22[a]
$\Xi_c^+ \to \Sigma^0 \rho^+$	11.45 ± 1.52
$\Xi_c^+ \to \Sigma^+ \rho^0$	2.85 ± 0.81
$\Xi_c^+ \to \Sigma^+ \omega$	4.11 ± 0.77
$\Xi_c^+ \to \Sigma^+ \phi$	1.82 ± 0.40[a]
$\Xi_c^+ \to \Xi^0 K^{*+}$	4.28 ± 1.64
$\Xi_c^0 \to \Lambda^0 \rho^0$	0.13 ± 0.11
$\Xi_c^0 \to \Lambda^0 \omega$	1.51 ± 0.20
$\Xi_c^0 \to \Lambda^0 \phi$	0.44 ± 0.08[a]
$\Xi_c^0 \to p K^{*-}$	0.19 ± 0.14
$\Xi_c^0 \to n \bar{K}^{*0}$	2.52 ± 0.79
$\Xi_c^0 \to \Sigma^0 \rho^0$	0.11 ± 0.10
$\Xi_c^0 \to \Sigma^0 \omega$	0.70 ± 0.13
$\Xi_c^0 \to \Sigma^0 \phi$	0.30 ± 0.07
$\Xi_c^0 \to \Sigma^+ \rho^-$	0.19 ± 0.13
$\Xi_c^0 \to \Sigma^- \rho^+$	5.56 ± 0.34
$\Xi_c^0 \to \Xi^0 K^{*0}$	0.79 ± 0.23
$\Xi_c^0 \to \Xi^- K^{*+}$	3.36 ± 0.23

DCS (10^{-4})

$\Xi_c^+ \to \Lambda^0 K^{*+}$	$0.34^{+0.37}_{-0.34}$
$\Xi_c^+ \to p \rho^0$	0.22 ± 0.17
$\Xi_c^+ \to p \omega$	1.66 ± 0.70
$\Xi_c^+ \to p \phi$	2.29 ± 0.39
$\Xi_c^+ \to n \rho^+$	0.43 ± 0.33
$\Xi_c^+ \to \Sigma^0 K^{*+}$	3.08 ± 0.20
$\Xi_c^+ \to \Sigma^+ K^{*0}$	0.40 ± 0.08
$\Xi_c^0 \to \Lambda^0 K^{*0}$	0.28 ± 0.13
$\Xi_c^0 \to p \rho^-$	0.15 ± 0.11
$\Xi_c^0 \to n \rho^0$	0.07 ± 0.06
$\Xi_c^0 \to n \omega$	0.56 ± 0.24
$\Xi_c^0 \to n \phi$	0.77 ± 0.13
$\Xi_c^0 \to \Sigma^0 K^{*0}$	0.07 ± 0.01
$\Xi_c^0 \to \Sigma^- K^{*+}$	2.08 ± 0.14

Semileptonic — PLB792, 214

$10^3\mathcal{B}(\Xi_c^+ \to \Sigma^0 e^+ \nu_e)$	3.1 ± 0.4
$10^4\mathcal{B}(\Xi_c^+ \to \Lambda e^+ \nu_e)$	10.3 ± 1.5
$10^4\mathcal{B}(\Xi_c^0 \to \Sigma^- e^+ \nu_e)$	15.7 ± 2.2

3.Decay parameter measurement:

Ξ_c^0 DECAY PARAMETERS

α FOR $\Xi_c^0 \to \Xi^- \pi^+$ $\quad -0.6 \pm 0.4$

The only measurement with large error

4. Form factors

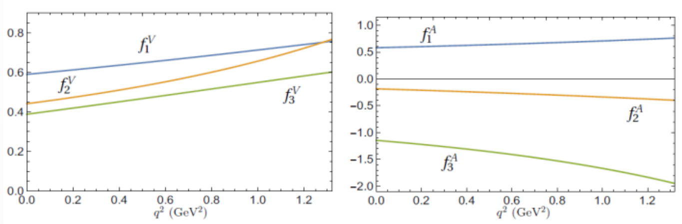
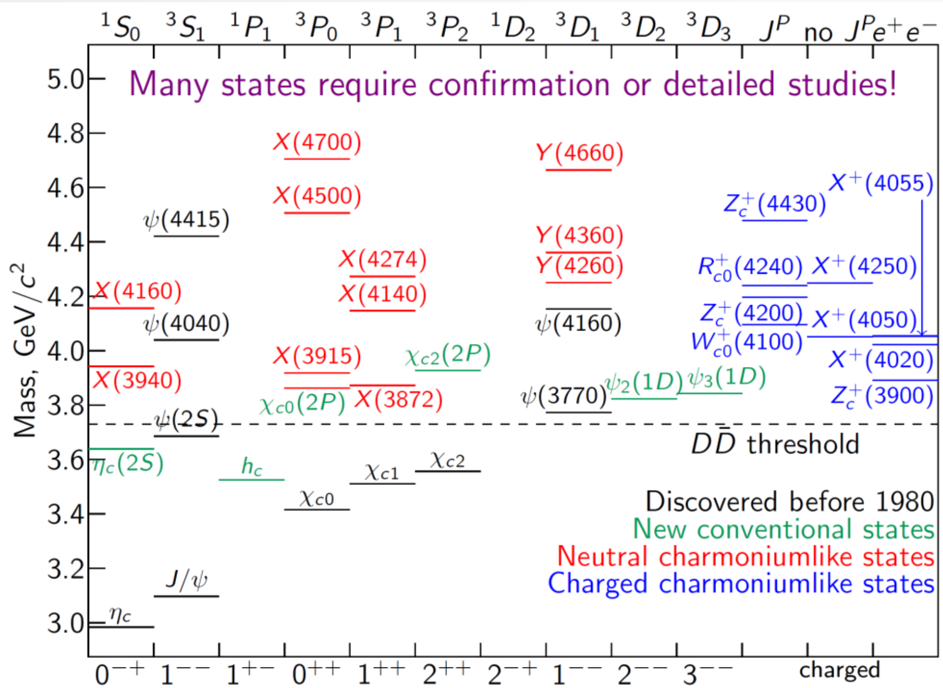


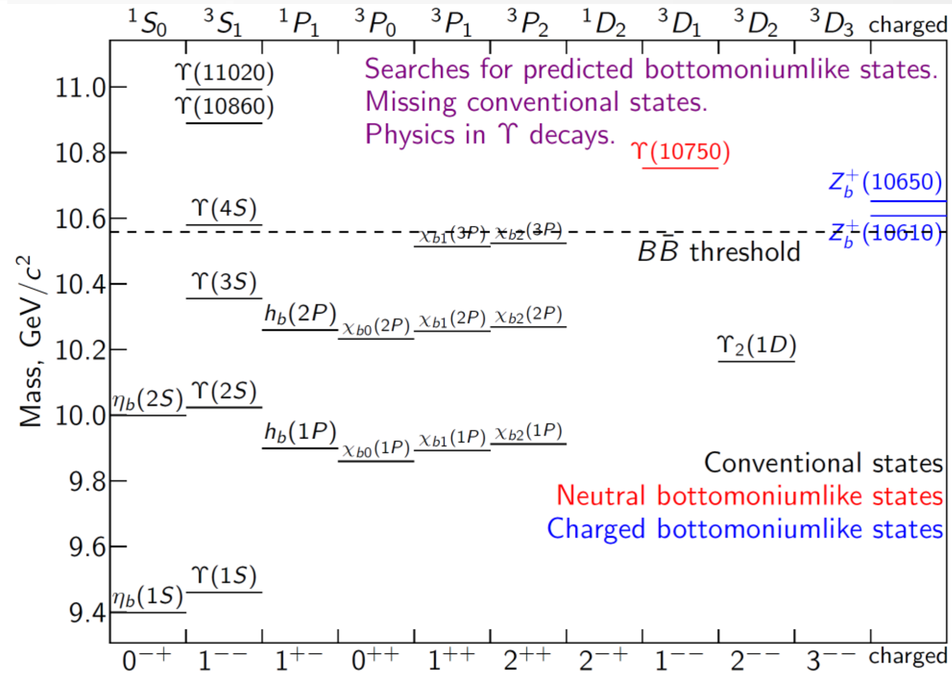
FIG. 1: Form factors of the weak $\Xi_c \to \Xi$ transitions.

EPJC 79 695

Plentiful physics parameters need to be measured ！

Quarknium and Quarkonium-like exotic hadrons





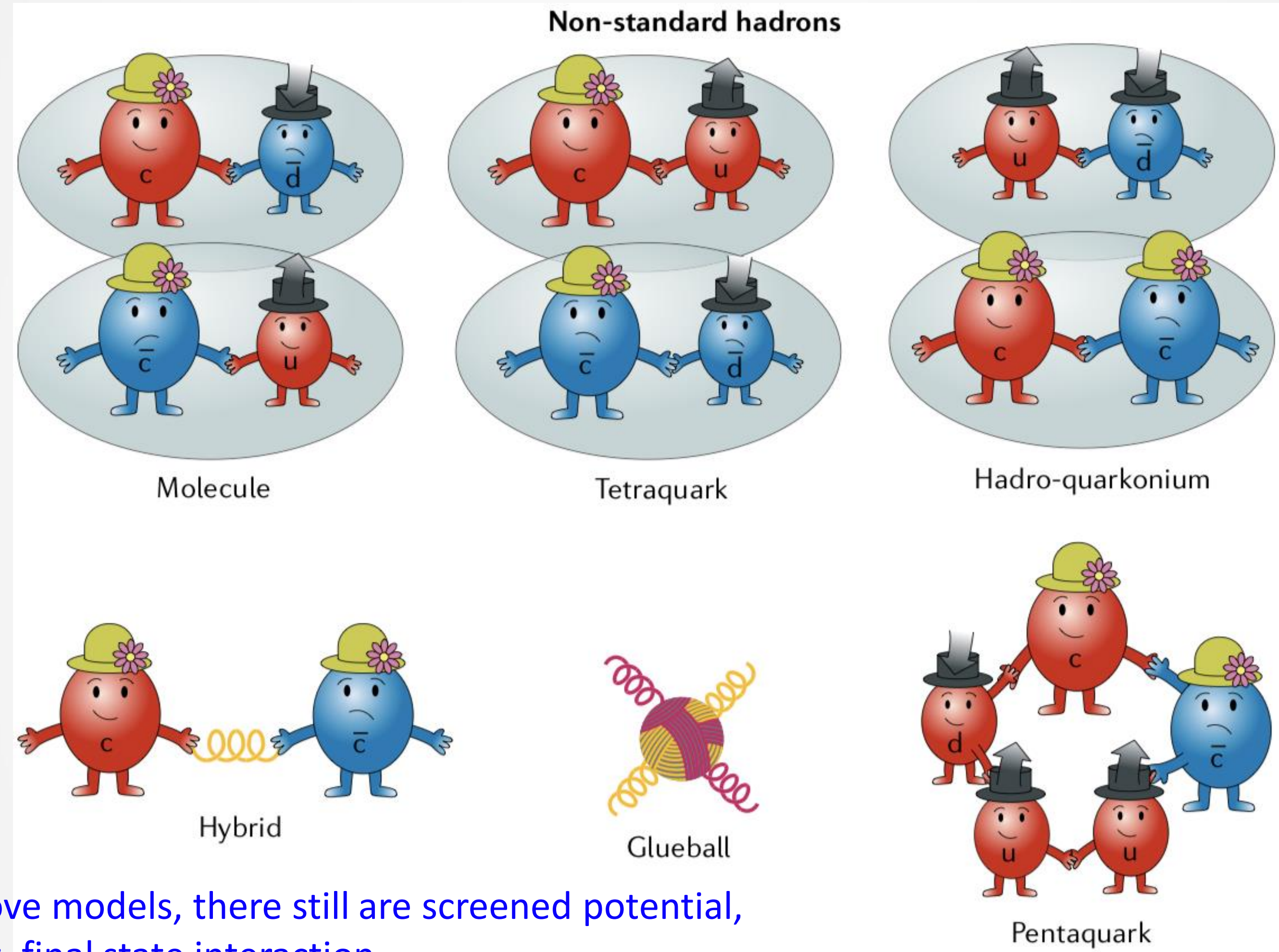
Classification:

- $Q\bar{Q}q\bar{q}$
- $Q\bar{Q}qqq$: P_c^+

X: Neutral, $J^{PC} \neq 1^{--}$; Y: Neutral, $J^{PC} = 1^{--}$; Z: Charged

- Quarkonium: $q\bar{q}$, the simplest system of a hadron.
- Below $D\bar{D}/B\bar{B}$ thresholds – both charmonium and bottomonium are successful stories of QCD.
- But there are many exotic states observed in the past decade, and they are hard to fit in the two families.

Too many models !



Besides above models, there still are screened potential, cusps effect, final state interaction …

Nature Reviews Physics 1, 480 (2019)

<u>High Priority:</u>

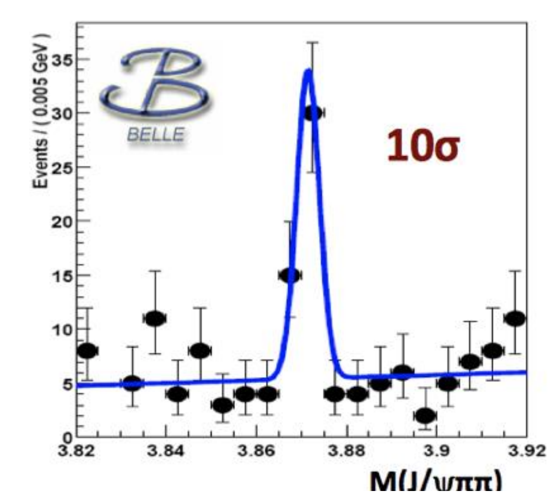
- Identify most prominent component in wave function
- Seek unique picture describing all XYZ states, not state-by-state

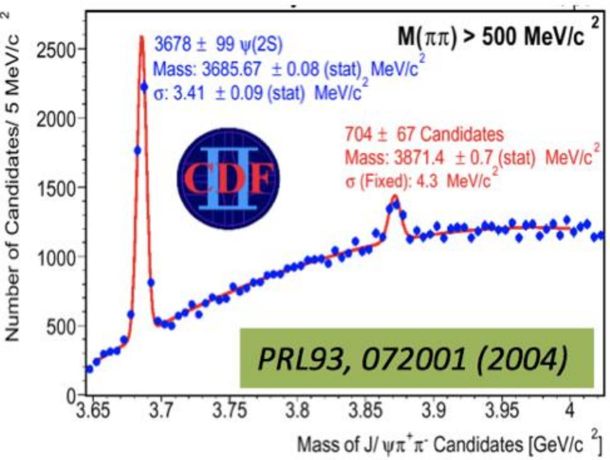
X(3872)→J/ψπ⁺π⁻

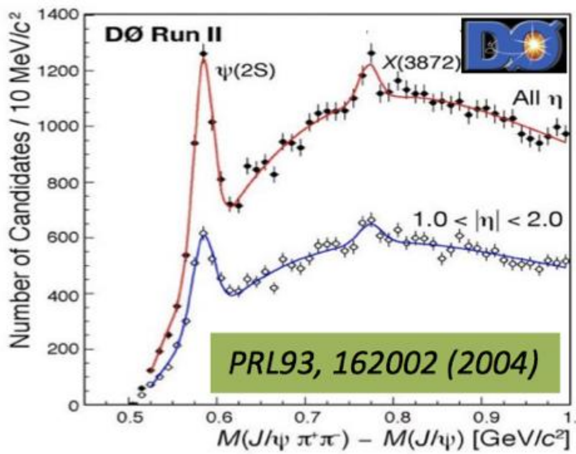
The most-cited article at Belle: 1800+

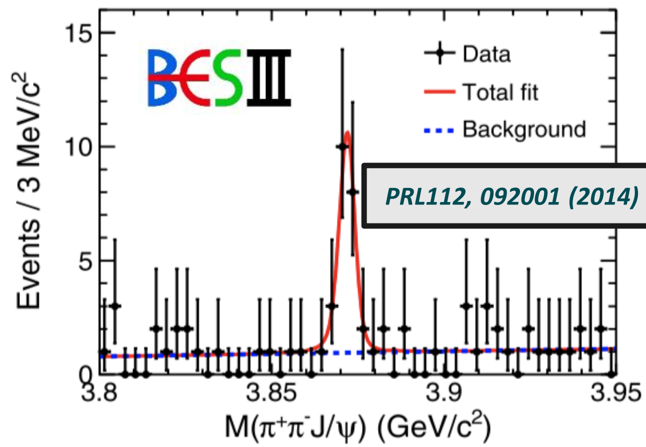
First observed by Belle in $B \to K\,J/\psi\pi^+\pi^-$ ***PRL91, 262001 (2003)***

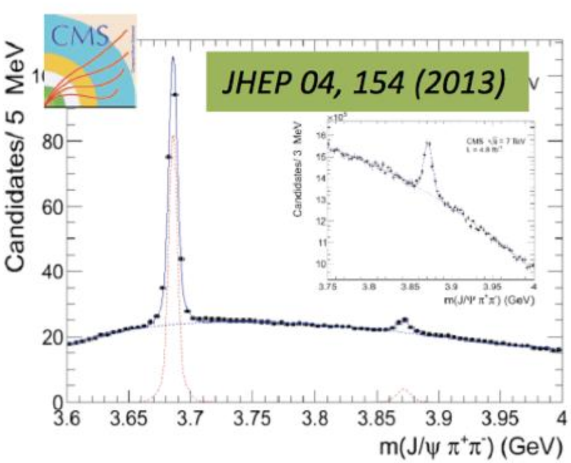
- M_X close to $D^0\bar{D}^{*0}$ threshold M = (3871.68±0.17) MeV
- Surprisingly narrow: $\Gamma_{tot} < 1.2$ MeV at 90% C.L.

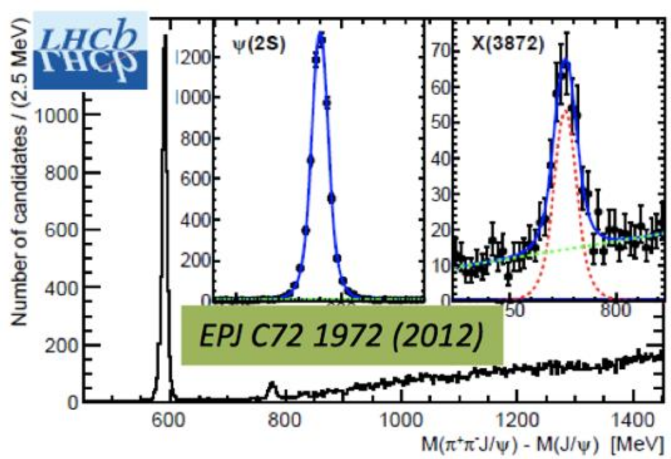












X(3872)→J/ψγ: C-even

Angular analysis:

Belle 2006: $J^{PC} = 1^{++}$ or ≥2

CDF 2008: $J^{PC} = 1^{++}$ or 2^{-+}

Belle 2011: $J^{PC} = 1^{++}$ or 2^{-+}

LHCb 2013: $J^{PC} = 1^{++}$

Evidence for X(3872)→ $\pi^+\pi^-J/\psi$ produced in single-tag two-photon interactions

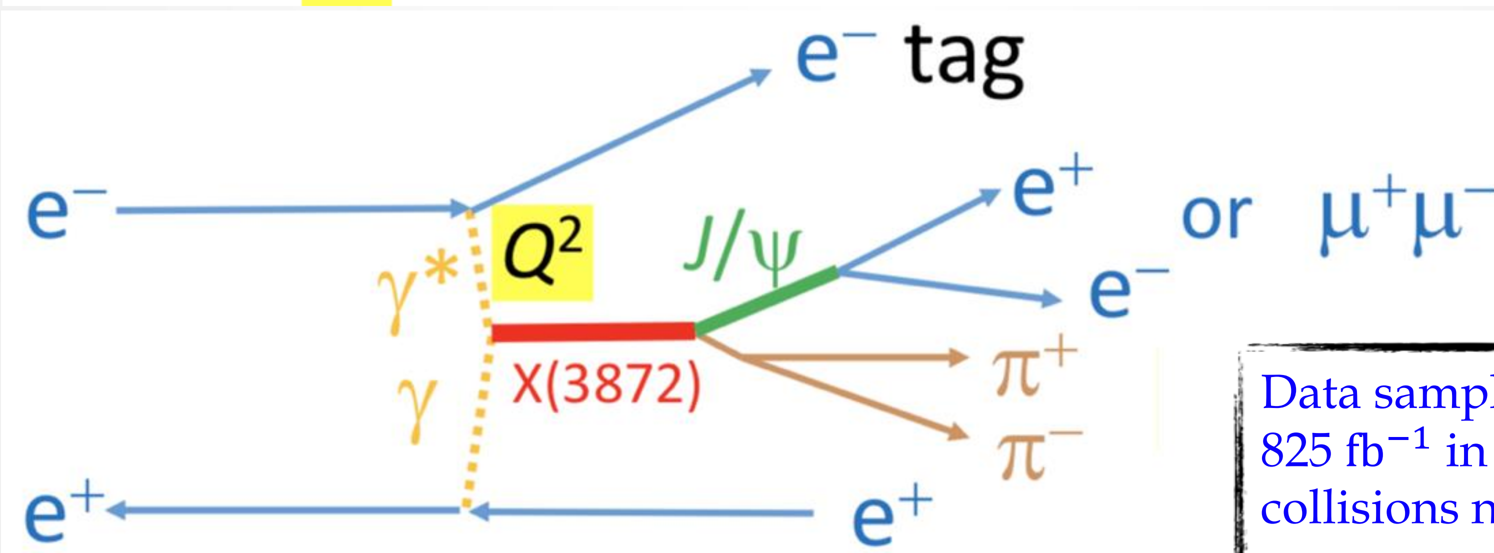
arXiv: 2007.05696 (2020), submitted to PRL

- X(3872) with $J^{PC} = 1^{++}$ could be produced if one or both photons are highly virtual [Nucl. Phys. B 523, 423 (1998)].
- The measurement of X(3872) in two-photon reactions help to understand its internal structure.

X(3872): $J^{PC} = 1^{++}$

$\gamma\gamma \to X(3872)$ ⟶ Not allowed

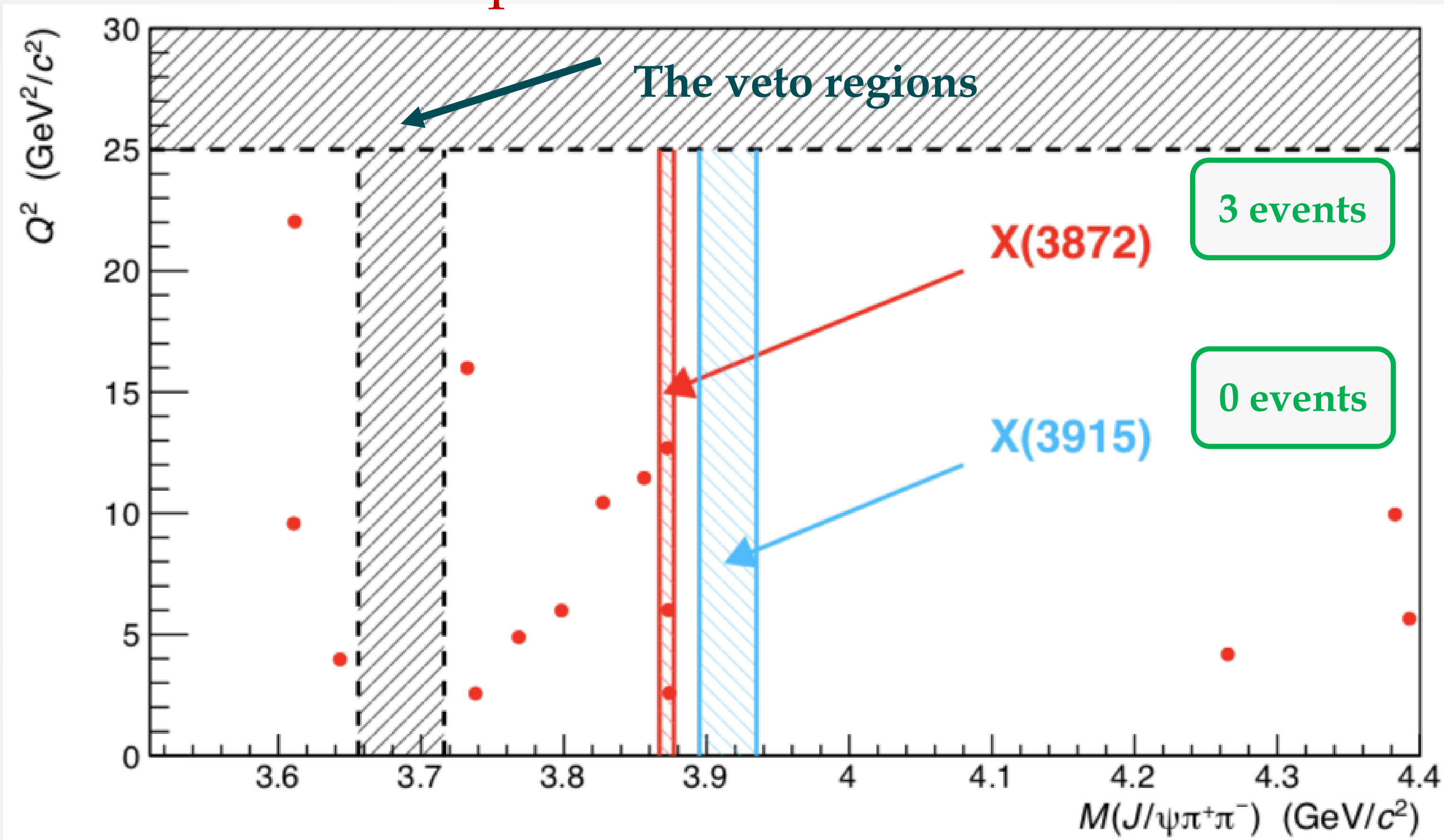
But, $\gamma^*\gamma \to X(3872)$ ⟶ Allowed



Data sample:
825 fb^{-1} in e^+e^- collisions near 10.6 GeV

$-Q^2$ is the invariant mass-squared of the virtual photon.

Evidence for X(3872)→ $\pi^+\pi^- J/\psi$ produced in single-tag two-photon interactions

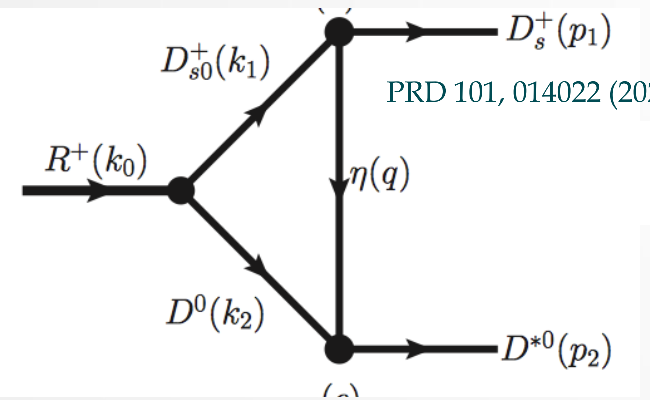


- M(X(3872)) = (3.8723±0.0012) GeV/c^2
- With 0.11±0.10 background events, **the number of signal events is N_{sig} = $2.9^{+2.2}_{-2.0}(\text{stat.}) \pm 0.1(\text{syst.})$ with a significance of 3.2σ** (Feldman-Cousins method applied [Phys. Rev. D 57, 3873 (1998)]).
- **$\tilde{\Gamma}_{\gamma\gamma}\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi) = 5.5^{+4.1}_{-3.8}(\text{stat.}) \pm 0.7(\text{syst.})$ eV** using the Q^2 dependence expected from a $c\bar{c}$ meson model.

Search for $R^{++} \to D^+ D_s^{*+}$

Phys. Rev. D 102, 112001 (2020)

- A doubly-charged and doubly-charmed molecule $\boldsymbol{R^{++}}$ decays to $D^+ D_s^{*+}$ with modest rates according to Refs. [PRD 99, 076017 (2019), PRD 101, 014022 (2020)].
- The mass of R++ is predicted to be in the range of 4.13 to 4.17 GeV/c^2; the width is (2.30−2.49) MeV.
- A state decaying to $D^+ D_s^{*+}$ is also a good candidate for a doubly-charged tetraquark according to Ref. [PRL 119, 202001 (2017)].

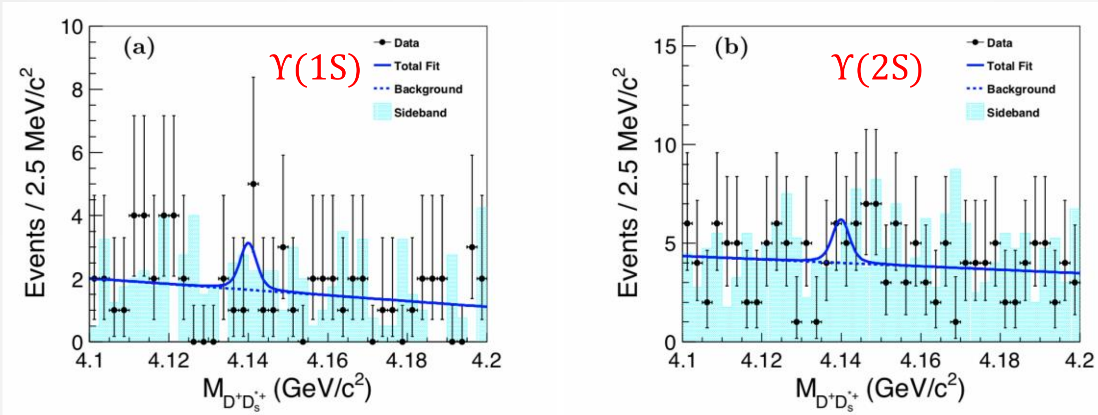


- $D^+ \to K^-\pi^+\pi^- / K_S^0(\to \pi^+\pi^-)\pi^+$
- $D_s^{*-} \to D_s^- \gamma$
- $D_s^- \to \phi\pi^- / \bar{K}^{*0} K^+$

Data samples:

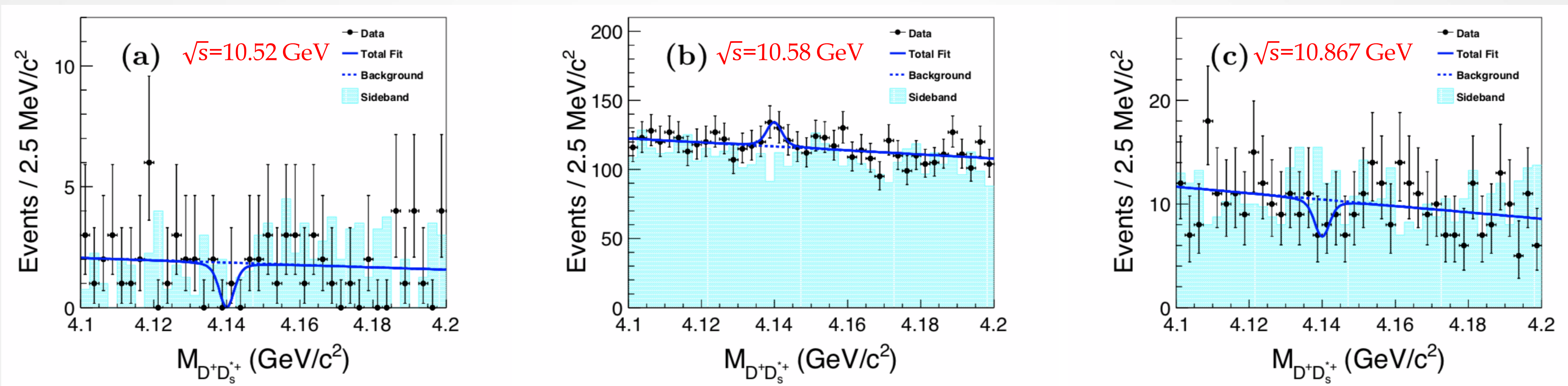
$\sqrt{s}$ (GeV)	Luminosity (fb^{-1})	Events
9.46 [Υ(1S)]	5.74±0.09	(102±3) million
10.023 [Υ(2S)]	24.91±0.35	(158±4) million
10.52	89.5±1.3	-
10.58 [Υ(4S)]	711±10	-
10.867 [Υ(5S)]	121.4±1.7	-

The Punzi parameter S/(3/2+$\sqrt{B}$) [arXiv:physics/0308063] is applied to optimize the mass windows of intermediate states.



The fitted results with the R^{++} mass fixed at 4.14 GeV/c^2 and width fixed at 2 MeV.

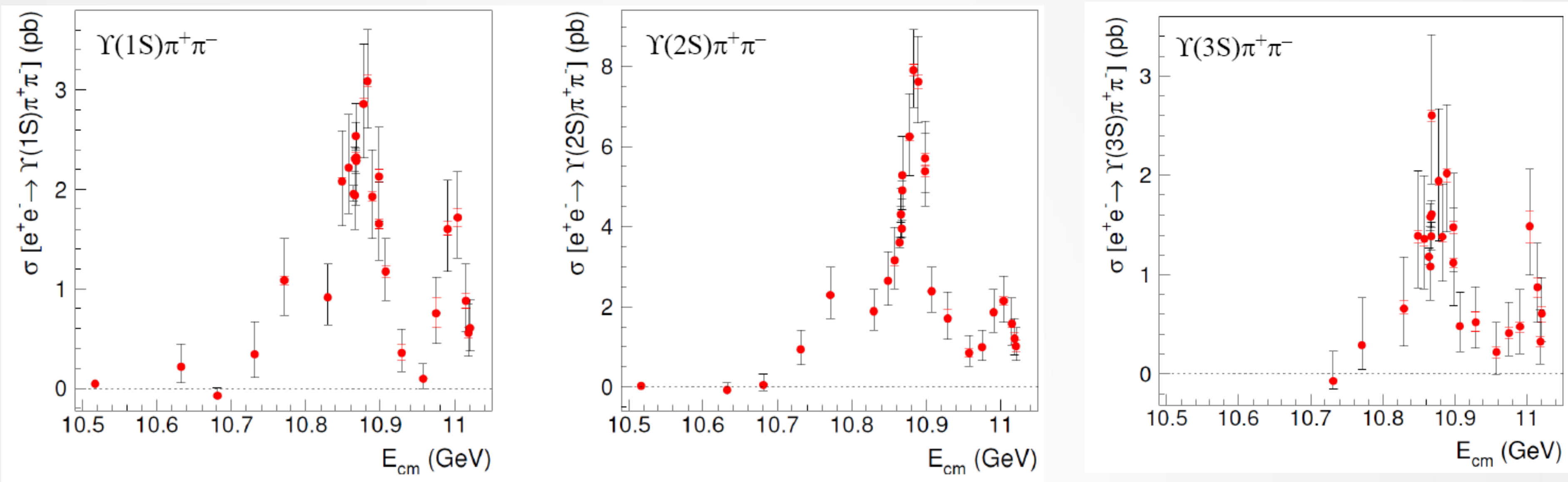
No R^{++} signals are observed.



90% C. L. Upper limits [M(R^{++}) varying from 4.13 to 4.17 GeV/c^2, Γ(R^{++}) varying from 0 to 5 MeV]
$\mathcal{B}(\Upsilon(1S) \to R^{++} + \text{anything})\mathcal{B}(R^{++} \to D^+D_s^{*+})$=(11.8 - 54.5)× 10^{-5}
$\mathcal{B}(\Upsilon(2S) \to R^{++} + \text{anything})\mathcal{B}(R^{++} \to D^+D_s^{*+})$=(16.3 - 68.6)× 10^{-5}
$\sigma(e^+e^- \to R^{++} + \text{anything})\mathcal{B}(R^{++} \to D^+D_s^{*+})$ = (202.8 – 880.4) fb at $\sqrt{s}$ = 10.52 GeV
$\sigma(e^+e^- \to R^{++} + \text{anything})\mathcal{B}(R^{++} \to D^+D_s^{*+})$ = (218.9 – 1054.0) fb at $\sqrt{s}$ = 10.58 GeV
$\sigma(e^+e^- \to R^{++} + \text{anything})\mathcal{B}(R^{++} \to D^+D_s^{*+})$ = (346.6 – 1517.6) fb at $\sqrt{s}$ = 10.867 GeV

Update cross sections of $e^+e^- \to \pi^+\pi^-\Upsilon(nS)$

Belle, JHEP 1910, 220 (2019)



Black error bars: statistical

Red error bars: uncorrelated systematic errors

Structure at 10.75 GeV is more significant

Fits to energy dependent cross sections

$$|\mathrm{BW}^{(n)}_{\Upsilon(5S)} + e^{i\alpha_n}\,\mathrm{BW}^{(n)}_{\Upsilon(6S)} + e^{i\beta_n}\,\mathrm{BW}^{(n)}_{\mathrm{new}} + e^{i\gamma_n}\,\mathrm{BW}^{(n)}_{\Upsilon((n+1)S)}|^2 \otimes \mathrm{Gaussian}$$

$$F_{BW}(s, M, \Gamma, \Gamma^0_{ee} \times \mathcal{B}_f) = \frac{\sqrt{12\pi\,\Gamma\,\Gamma^0_{ee} \times \mathcal{B}_f}}{s - M^2 + iM\Gamma}\sqrt{\frac{\Gamma_f(s)}{\Gamma_f(M^2)}},$$

Simultaneous fit to three channels with some common parameters.

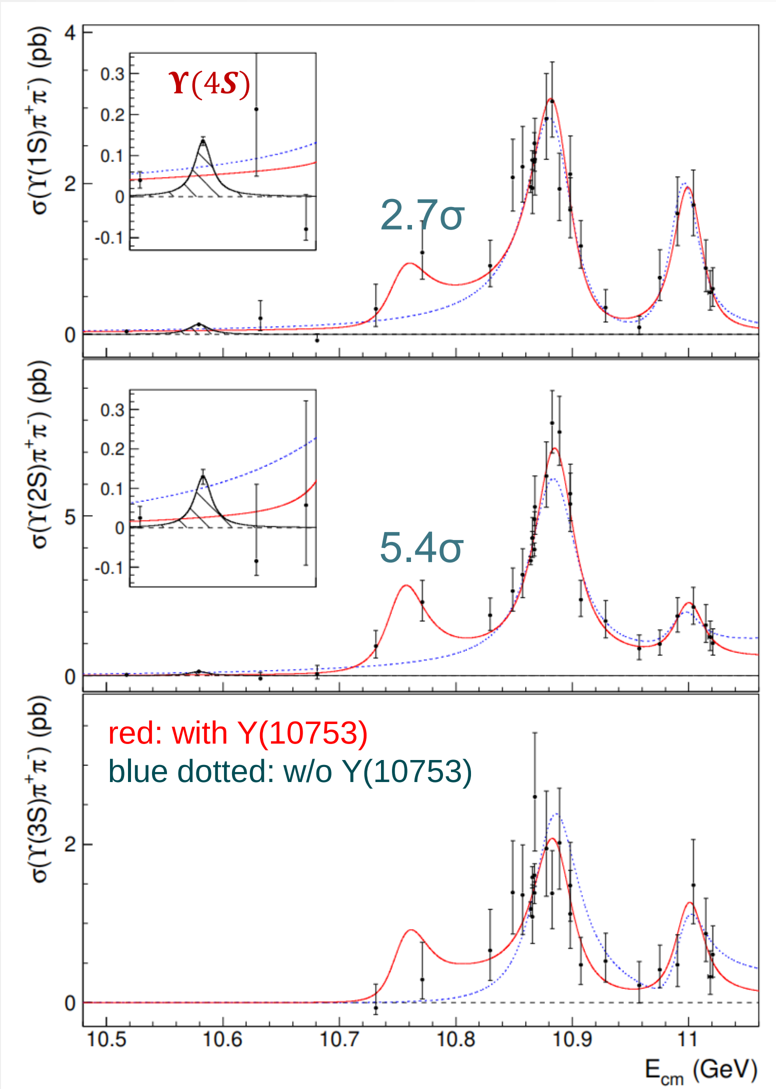
Free parameters: Mass M, width Γ, product of partial width and branching fraction $\Gamma_{ee}B(\pi\pi\Upsilon)$, relative phase ϕ.

Fit results to $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ cross sections

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

$\boldsymbol{\Upsilon(10860)}$ 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

- Could there be a Z_b enhancement?
- Could it be Υ(3D) bottomonium or a tetraquark?
- Near $B^{(*)}B^*\pi$ threshold regions

Interpretation of the Y(10750)

- D-wave bottomonium
  - B. Chen, A.L. Zhang, J. He, arXiv:1910.06065, Bottomonium spectrum in the relativistic flux tube model (3D)
  - Q. Li, M.S. Liu, Q.F. Lü, L.C. Gui, X.H. Zhong, arXiv:1905.10344, Canonical interpretation of Y(10750) and Y(10860) in the Y family (4D)
- $\bar{B}^{(*)}B^{(*)}$ dynamically generated pole
  - P. Bicudo, M. Cardoso, N. Cardoso, M. Wagner, arXiv:1910.04827, Bottomonium resonances with I=0 from lattice QCD correlation functions with static and light quarks
- Hybrid
  - J. T. Castellà, arXiv:1908.05179, Spin Structure of heavy-quark hybrids
- Tetraquark state
  - A. Ali, L. Maiani, A. Y. Parkhomenko, W. Wang, arXiv:1910.07671, Interpretation of Yb (10753) as a tetraquark and its production mechanism
  - Z.G. Wang, arXiv:1905.06610, Vector hidden-bottom tetraquark candidate: Y(10750)

Belle II at SuperKEKB

Plan to collect **50 ab^{-1}** of collisions at and near $\Upsilon(4S)$

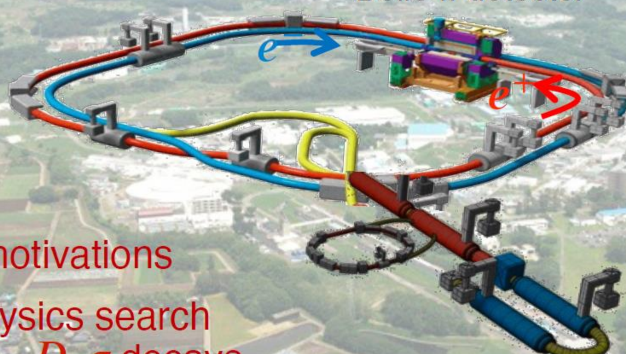
Successor to Belle at KEKB (1.05 ab^{-1})

At $\Upsilon(4S)$, E_{CM} = 10.58 GeV

7 GeV e^- (HER; High Energy Ring)

4 GeV e^+ (LER; Low Energy Ring)

Belle II detector

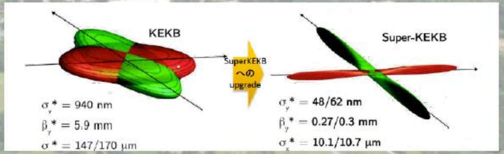


Nano beam scheme

$$\mathscr{L} = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

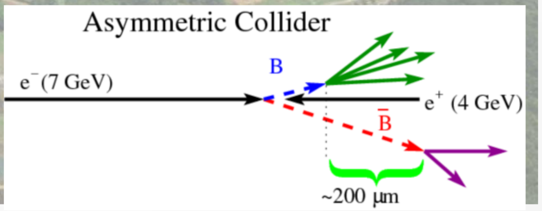
5.9 → 0.3 mm

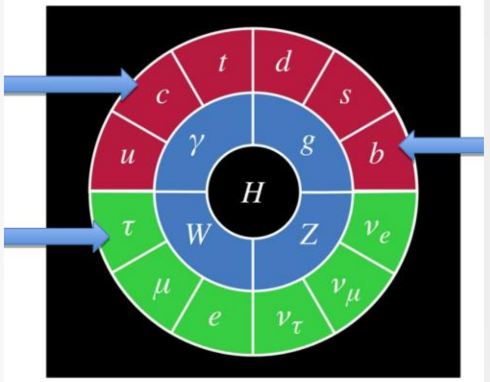
KEKB SuperKEKB



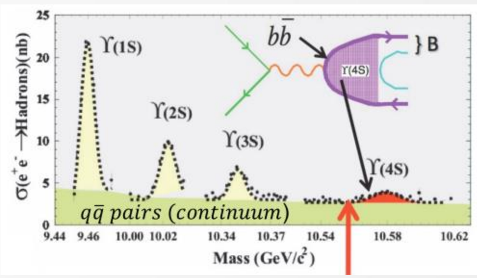
Physics motivations

- New physics search in B, B_s, D, τ decays
- Direct search for light new particles
- Precise measurement of Standard Model
- Hadron physics

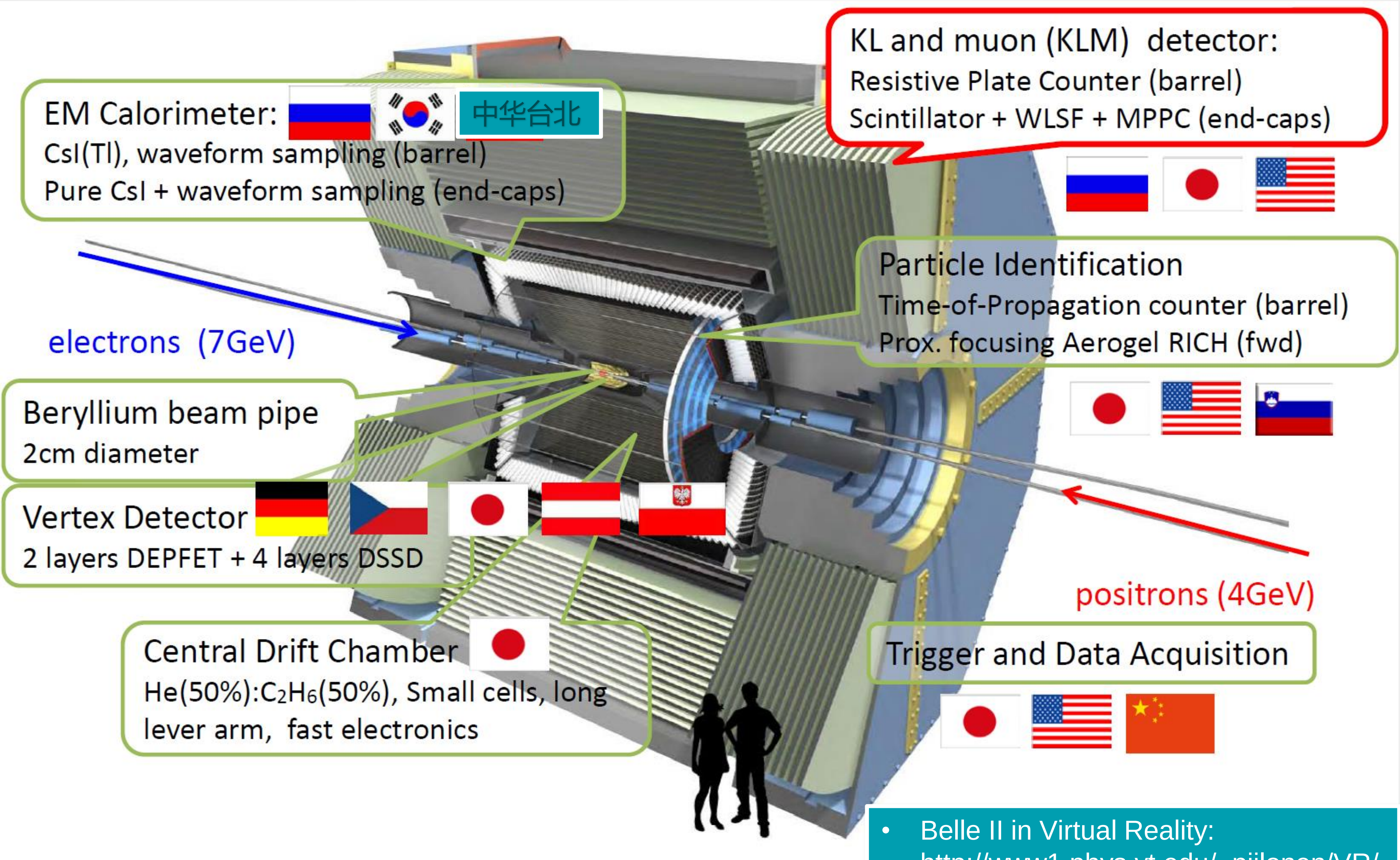




Physics process	Cross section [nb]
$\Upsilon(4S)$	1.110 ± 0.008
$u\bar{u}(\gamma)$	1.61
$d\bar{d}(\gamma)$	0.40
$s\bar{s}(\gamma)$	0.38
$c\bar{c}(\gamma)$	1.30

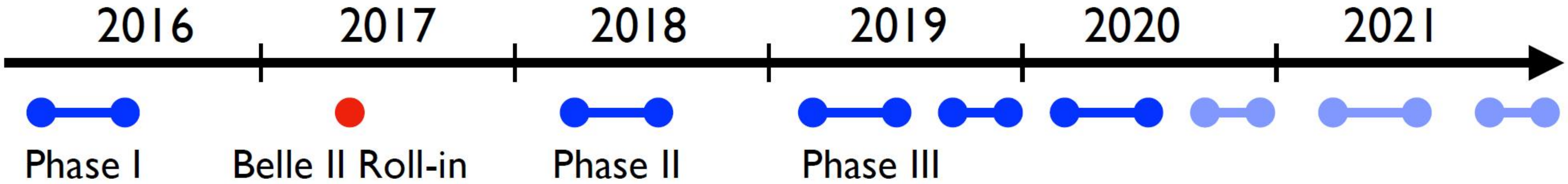


Belle II探测器



- Belle II in Virtual Reality: http://www1.phys.vt.edu/~piilonen/VR/

SuperKEKB/Belle II Operation History



Phase 1 (w/o QCS/Belle II)

- Accelerator tuning w/ single beams

Phase 2 (w/ QCS/Belle II but w/o VXD)

- Verification of nano-beam scheme
- Understand beam background
- Collision data w/o VXD

Phase 3 (w/ full detector)

- Production of physics data

Belle II roll-in (2017.4.17)

1st collision (2018.4.26)

Installation of VXD

Phase 3 physics run (2019.3.25~)

Achievements in 2020 a/b

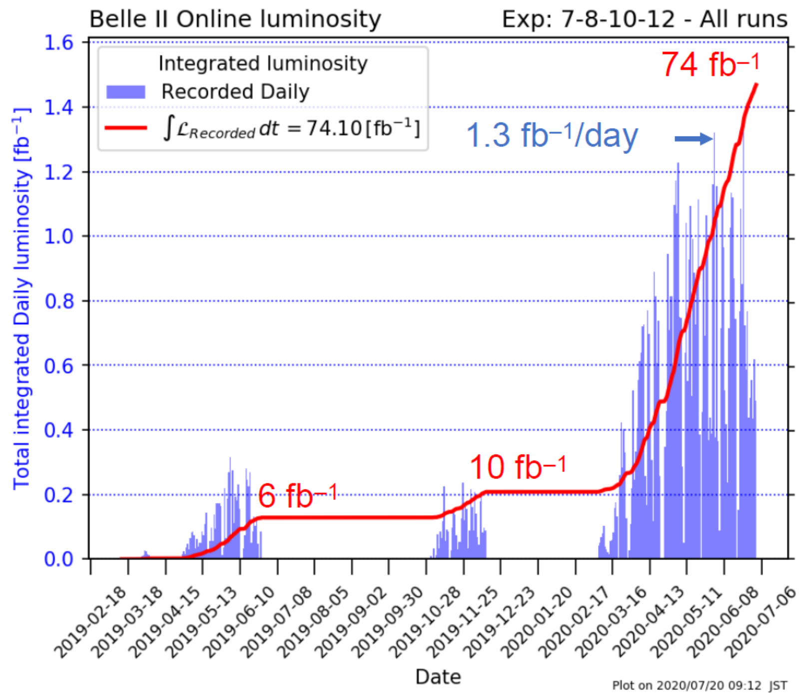
- Recorded 64 fb^{-1}
  - L_{int} =74 fb^{-1} by adding 2019 data set
- ★ L_{day}^{max} = 1.34 fb^{-1} (June 22)
- ★ L_{peak} = 2.4 x $10^{34}cm^{-2}s^{-1}$ w/ Belle II ON
  - on-resonance
  - HER: 607mA, LER: 712mA, N_b: 978

a factor 2-3 lower currents than KEK

KEKB record
- L_{day}^{max} = 1.48 fb^{-1} (2009.6.14)
- Lpeak = 2.11 x $10^{34}cm^{-2}s^{-1}$

Luminosity world record !
Belle II background (TOP, CDC, PXD) lower than the limit, thanks to many many efforts

Belle II data taking efficiency was improved to 84%.
- less DAQ errors
- Error analysis (ELK)
- Well experienced shifters
- Better controlled injection veto

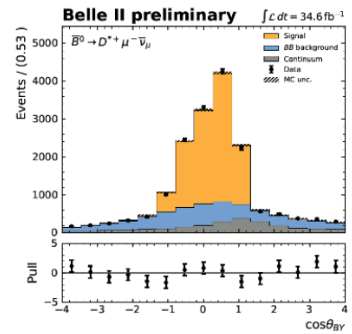


Belle II Summer Results

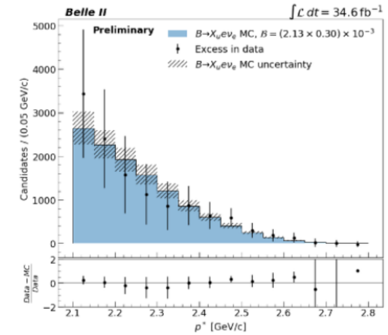
We presented a nice set of results at (virtual) ICHEP 2020:

- 9 conference papers uploaded to the arXiv;
- 13 public documents of rediscoveries and performance on data;
- 3 sensitivity studies based on the simulation;

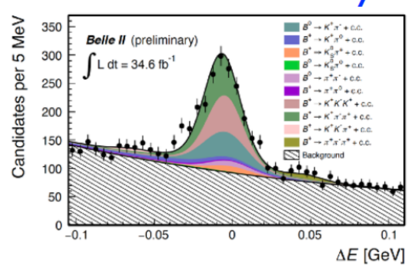
Exclusive B→D*lν



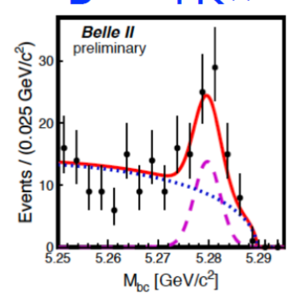
Inclusive b→u



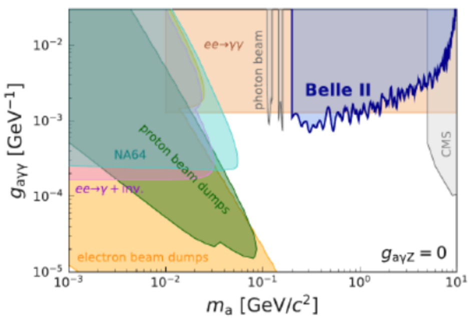
Charmless B decays



B → ΦK(*)

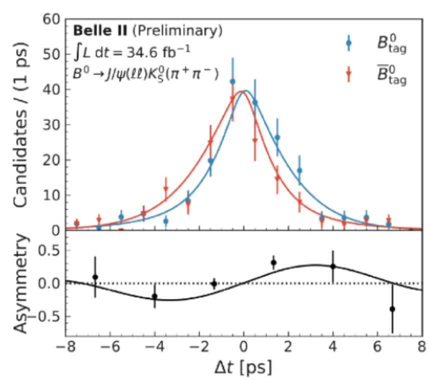


Search for Axion Like Particle (ALP)



2nd physics paper by Belle II
PRL 125 (2020) 16, 161806

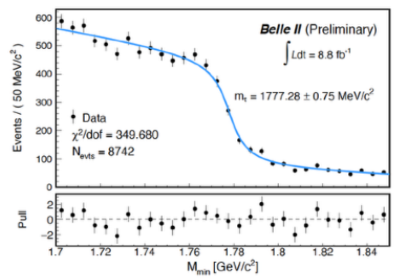
TDCPV (B→J/ψKs⁰)



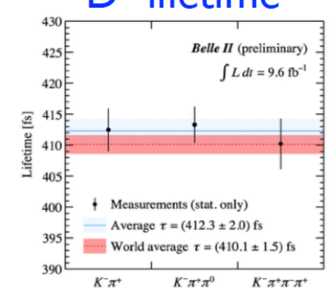
$S_{CP} = 0.55 \pm 0.21(\text{stat.}) \pm 0.04(\text{syst.})$

$S_{\text{PDG}} = 0.701 \pm 0.017$

τ mass measurement



D⁰ lifetime



Belle II Physics results

2 Dark Sector PRL publications on Phase2 data:

- Search for an Invisibly Decaying Z′ Boson at Belle II in $e^+e^- \to \mu^+\mu^-(e^\pm\mu^\mp)$ Plus Missing Energy Final States, PRL 124, 141801 (2020);
- Search for Axionlike Particles Produced in e^+e^- Collisions at Belle II, PRL 125, 161806 (2020);

12 conference papers posted on arXiv:

Spring

- Charmless B decay reconstruction, arXiv:2005.13559 [hep-ex];
- Measurement of the branching fraction B(anti-$B^0 \to D^{*+} l^- \nu_l$), arXiv:2004.09066 [hep-ex];
- Measurement of the B^0 lifetime using fully reconstructed hadronic decays, arXiv:2005.07507 [hep-ex];

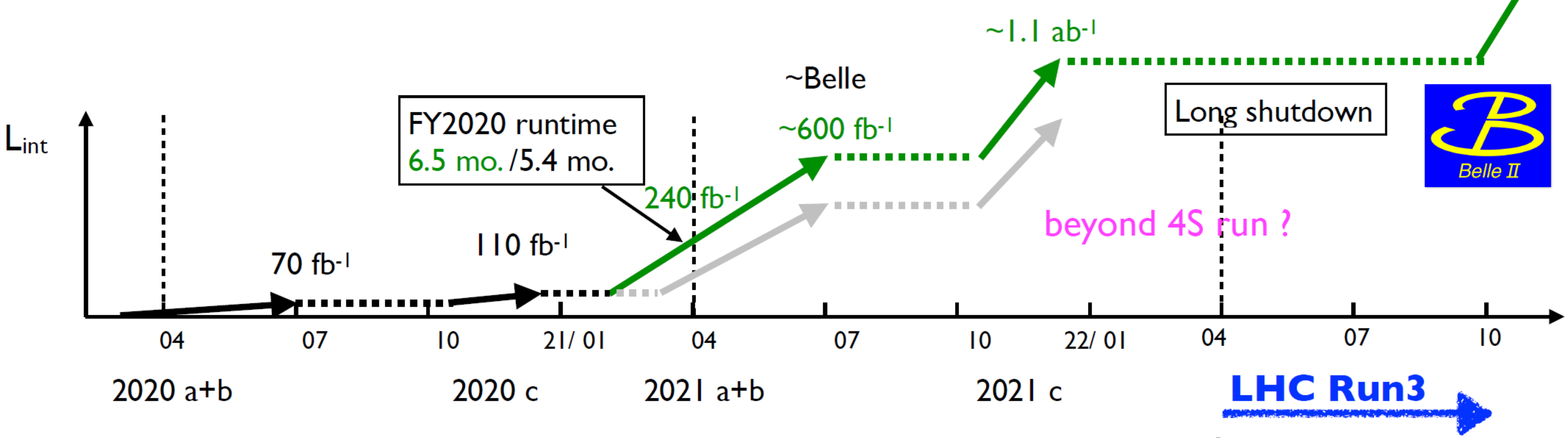
- Measurement of the branching ratios of $B^0 \to D^{(*)-} l^+ \nu$ (untagged analysis), arXiv:2008.07198 [hep-ex];
- Calibration of the Belle II hadronic Full Event Interpretation (FEI), arXiv:2008.06096 [hep-ex];
- Measurement of the hadronic mass moments of $B \to X_c l^+ \nu$ decays, arXiv:2009.04493 [hep-ex];
- Measurement of the branching ratios of $B^0 \to D^{*-} l^+ \nu$ (using the hadronic FEI), arXiv:2008.10299 [hep-ex];
- Rediscovery of $B^0 \to \pi^- l^+ \nu$ (using the hadronic FEI), arXiv:2008.08819 [hep-ex];
- Calibration of the Belle II B FlavorTagger, arXiv:2008.02707 [hep-ex];
- Rediscovery of $B \to \phi K^{(*)}$ decays, and measurement of the longitudinal polarization fraction of $B \to \phi K^*$, arXiv:2008.03873 [hep-ex];
- Branching ratios and direct CP asymmetries of B → Charmless decays, arXiv:2009.09452 [hep-ex];
- Measurement of the τ lepton mass, arXiv:2008.04665 [hep-ex];

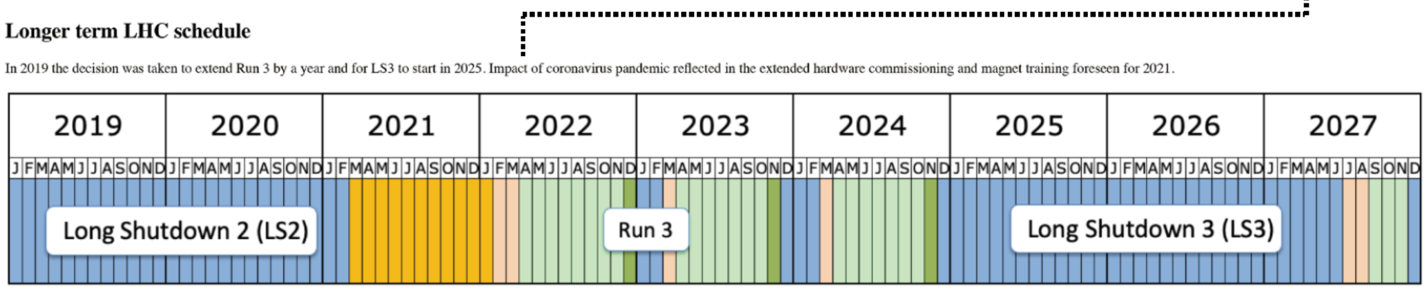
Summer

What we are hoping …

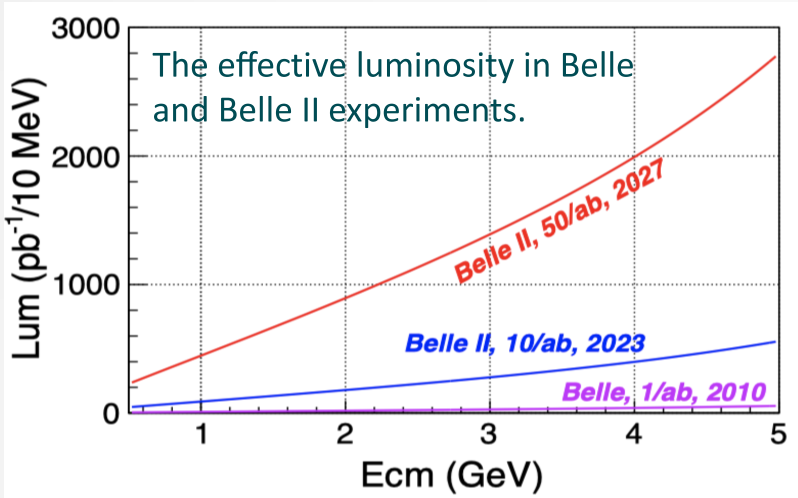
- Belle II is ready to accumulate more data (as endorsed by the BPAC review)
  - Good prospect for 6.5mo. operation in JFY2020
  - Comparable to Belle by 2021 summer
  - $>1ab^{-1}$ target before the long shutdown.

*Many many results with "world-leading **precision**" !*





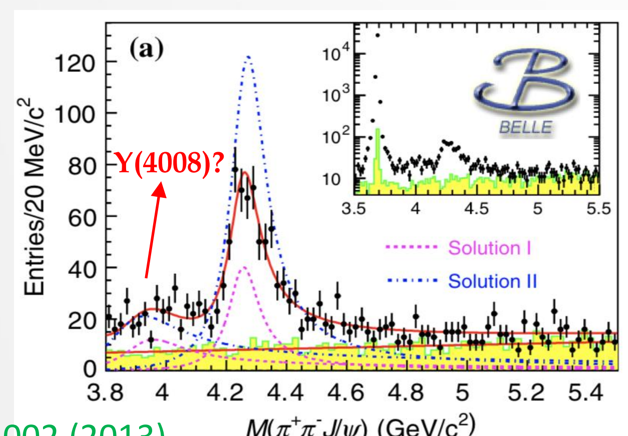
$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ via initial-state radiation at Belle II



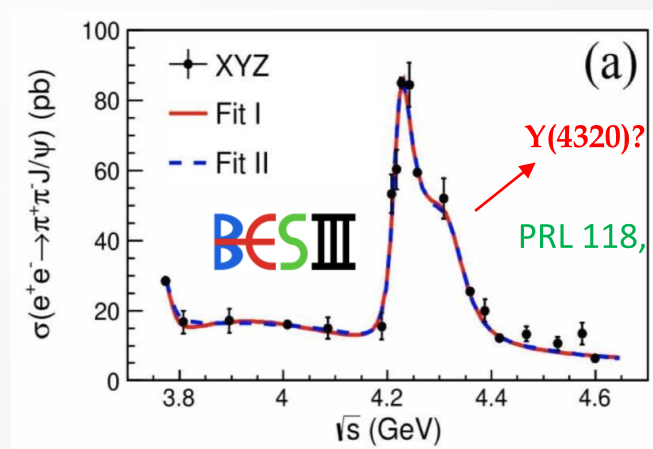
- ISR technique can explore $J^{PC} = 1^{--}$ states far away from e^+e^- collision energy.
- The whole hadron spectrum is visible.
- The effective luminosity and detection efficiency are relatively low.

For $e^+e^- \rightarrow \pi^+\pi^- J/\psi(\rightarrow \mu^+\mu^-)$ via ISR at Belle II

- Rediscover the first Y state at Belle II
- Identify existences of the Y(4008) and Y(4320) in $M(\pi^+\pi^- J/\psi)$
- Minimize the statistical errors.
- Study the properties of charged charmonium-like state $Z_c(3900)$.



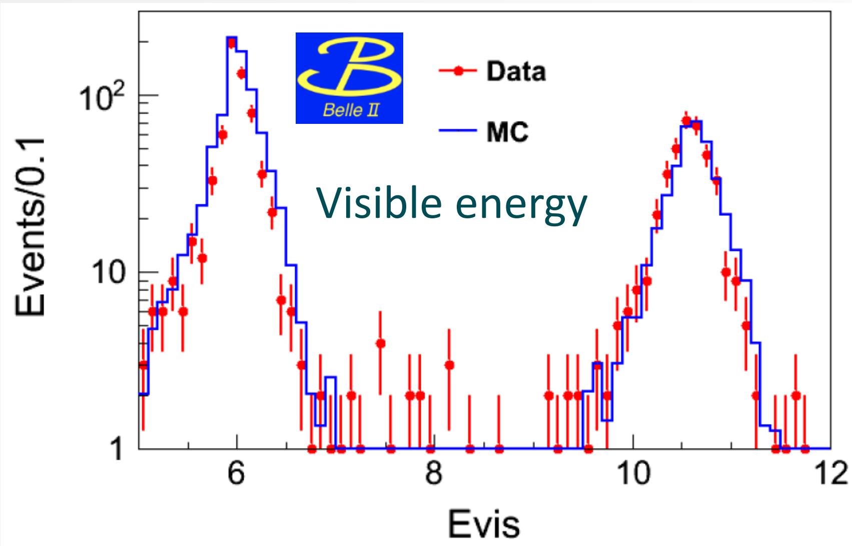
PRL 110, 252002 (2013)

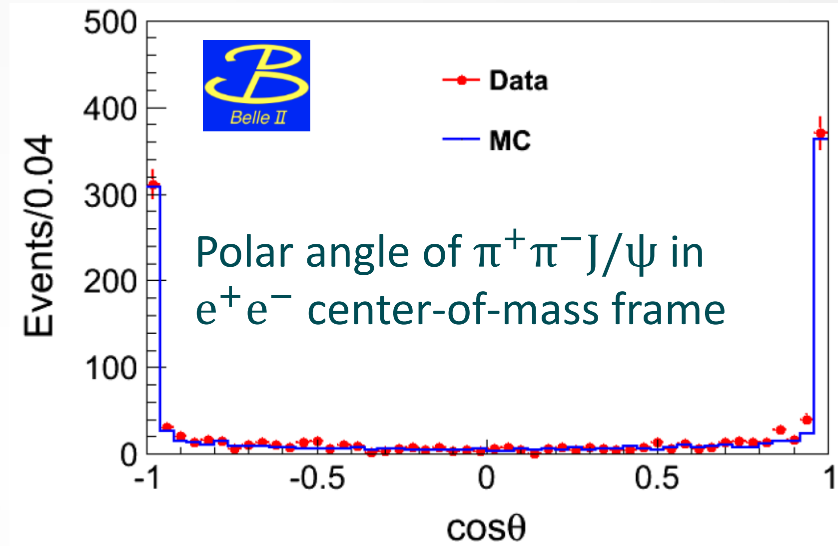


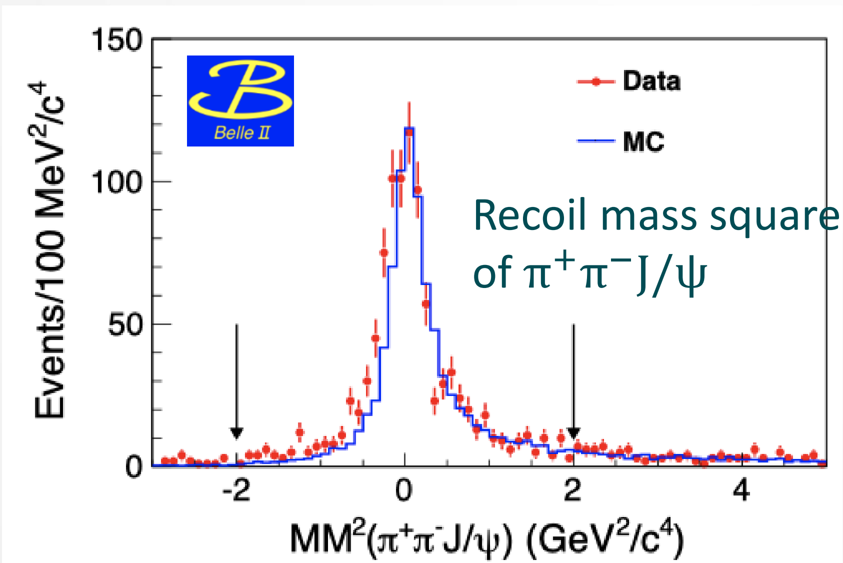
PRL 118, 092001 (2017)

ISR characteristics

The distributions from data and signal MC are compatible, which are all consistent with ISR characteristics.







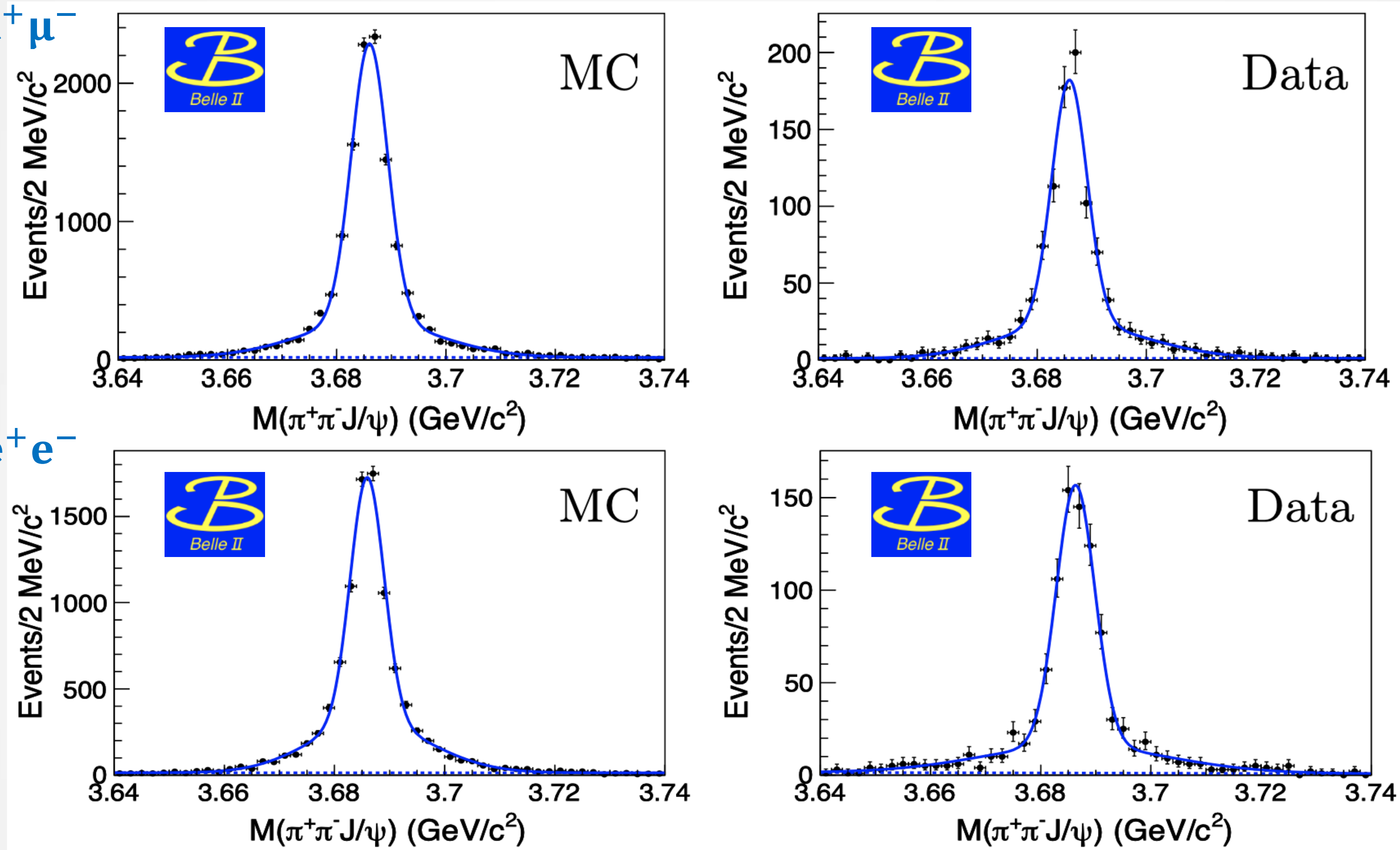
Data sample:
37.8 fb^{-1} in e^+e^- collisions at $\sqrt{s}$ = 10.58 GeV

MC samples:
MC signal samples are generated with Phokhara generator with NLO corrections.

Control samples of $\psi(2S) \to \pi^+\pi^- J/\psi$ via ISR

$J/\psi \to \mu^+\mu^-$

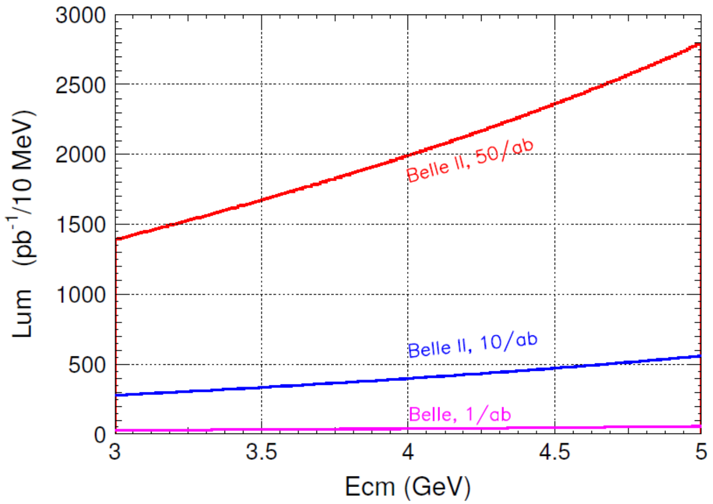
$J/\psi \to e^+e^-$



Mode	Our measurements	Theoretical calculation [Yad. Fiz. 41, 733 (1985)]
$J/\psi \to \mu^+\mu^-$	(12.0 ± 1.2) pb	(14.1 ± 0.3) pb
$J/\psi \to e^+e^-$	(13.0 ± 1.2) pb	

- Further PID and tracking corrections at Belle II are needed.
- The numbers of the expected Y(4260) signal events in data are (12.5 ± 2.3) and (10.6 ± 1.8) for $J/\psi \to \mu^+\mu^-$ and $J/\psi \to e^+e^-$.

Charmonium in ISR: can be done



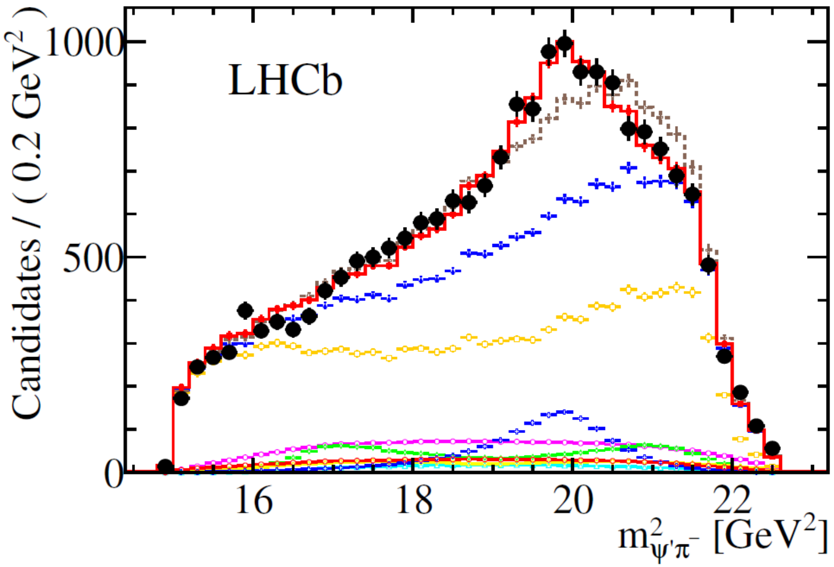
- Comparable samples for e.g. $e^+e^- \to J/\psi\pi^+\pi^-$.
- Access for high-energy region (current limit for BESIII is 4.6 GeV).
- Data are accumulated at the same time for all energies - simplifies lineshape analysis.

1. Improved measurements and fits of $e^+e^- \to \gamma_{\rm ISR}(c\bar{c})(X)$ cross sections.
2. Improved measurements and fits of the open-charm cross-sections, for example $e^+e^- \to \gamma_{\rm ISR}D^{(*)}\bar{D}^{(*)}(X)$
3. Measurements of higher mass open-charm channels, for example $e^+e^- \to \gamma_{\rm ISR}\Sigma_c^+\overline{\Sigma}_c^-$.
4. Analyses of the channels that are currently studied at BESIII only, for example $e^+e^- \to h_c\pi^+\pi^-$ with confirmation of the $Z_c(4020)^+$.

Can be done at Belle II and BESIII with direct production.

Charged charmoniumlike states: current status

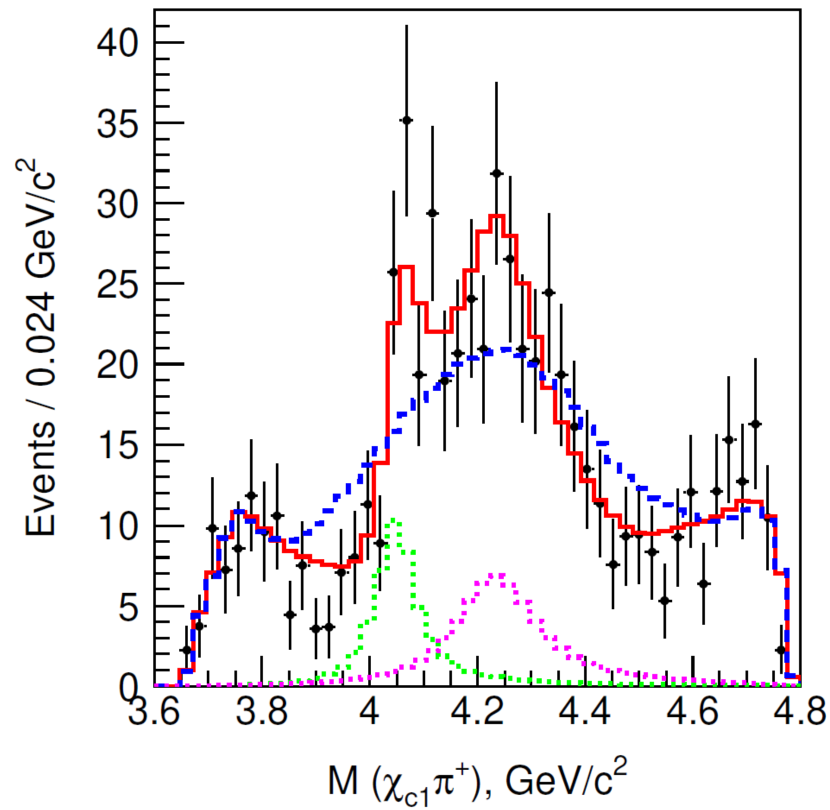
$Z_c(4430)^+$ $(B^0 \to \psi(2S)\pi^- K^+)$
LHCb PRL **112**, 222002 (2014)



Belle (first J^P): PRD **88**, 074026 (2013)

(These analyses are the latest ones; observed by Belle in PRL **100**, 142001 (2008).)

$Z_c(4050)^+$, $Z_c(4250)^+$
$(B^0 \to \chi_{c1}\pi^- K^+)$
Belle PRD **78**, 072004 (2008)



Only the $Z_c(4430)^+$ is confirmed (seen by Belle and LHCb), it is studied relatively well now. Other charged charmoniumlike states observed in B decays are not confirmed; the analyses were performed either only at Belle or only at LHCb.

Charged charmoniumlike states: can be done

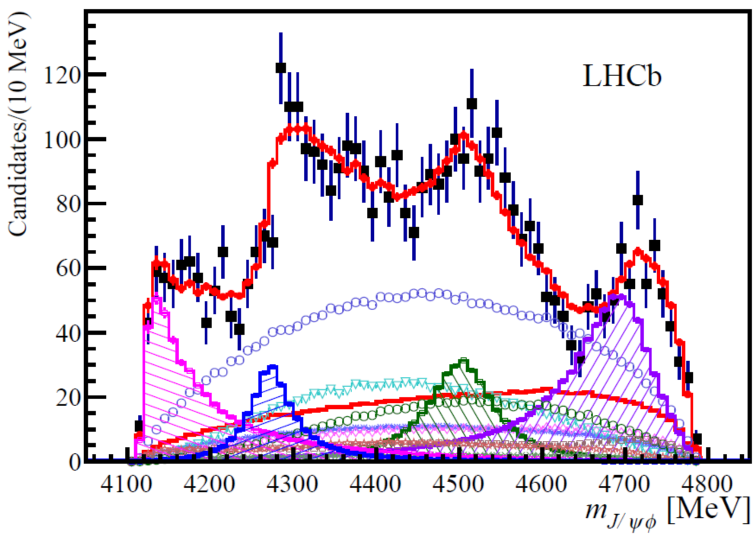
1. Updated amplitude analysis of $\bar{B}^0 \to \psi(2S)\pi^+K^-$: confirmation of the LHCb observation of the resonant character of the $Z_c(4430)^+$, confirmation of the $Z_c(4240)^+$ / $R_{c0}(4240)^+$.
2. Confirmation of the $W_{c0}(4100)^+$ in $\bar{B}^0 \to \eta_c\pi^+K^-$
3. Amplitude analysis of $\bar{B}^0 \to \chi_{c1}\pi^+K^-$, measurement of the $Z_c(4050)^+$ and $Z_c(4250)^+$ quantum numbers.
4. Search for the neutral partners of all charged charmoniumlike states observed in B decays.
5. Amplitude analyses of unexplored channels, for example $\bar{B}^0 \to X(3872)\pi^+K^-$.
6. Search for the $Z_c(3900)^+$ in $\bar{B}^0 \to J/\psi\pi^+\pi^-K^+$.
7. Search for decays of charged charmoniumlike states to $D^{(*)}\bar{D}^{(*)}$ in $B \to D^{(*)}\bar{D}^{(*)}K$.

Can be done at Belle II and LHCb.

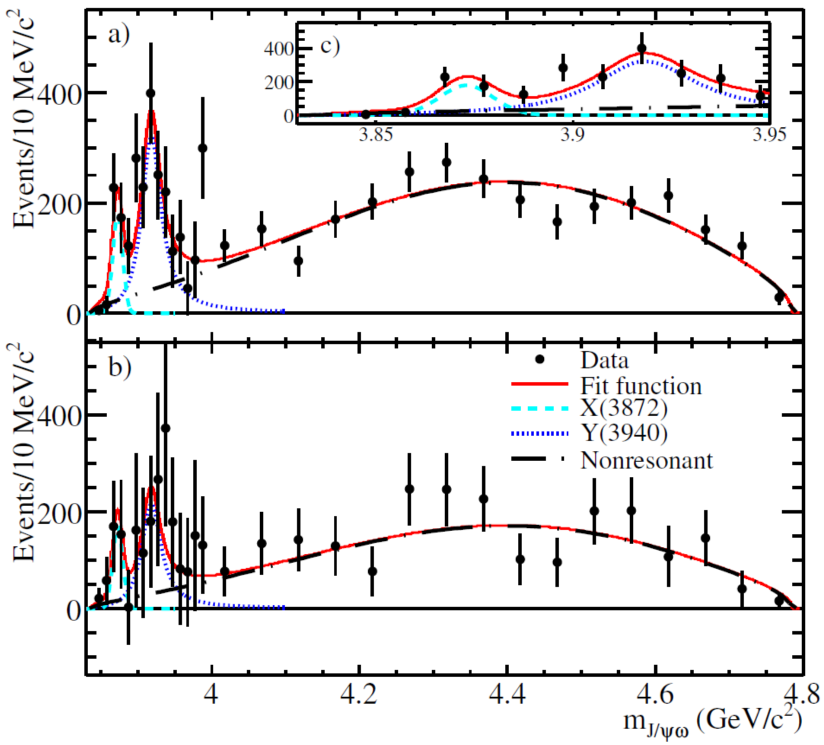
Belle II has a good sensitivity for neutral partners.

Neutral charmoniumlike states: current status

$B^+ \to J/\psi\phi K^+$
LHCb PRL **118**, 022003 (2017)
(amplitude analysis)



$B \to J/\psi\omega K$
BaBar PRD **82**, 011101 (2010)



While the $X(4140)$ and $X(4274)$ are seen by many experiments, the only amplitude analysis (and observation of two other states), has been performed by LHCb. The $X(3915)$ is also seen by Belle and BaBar, but the amplitude analysis of the decay $B \to J/\psi\omega K$ has never been performed.

Neutral charmoniumlike states: can be done

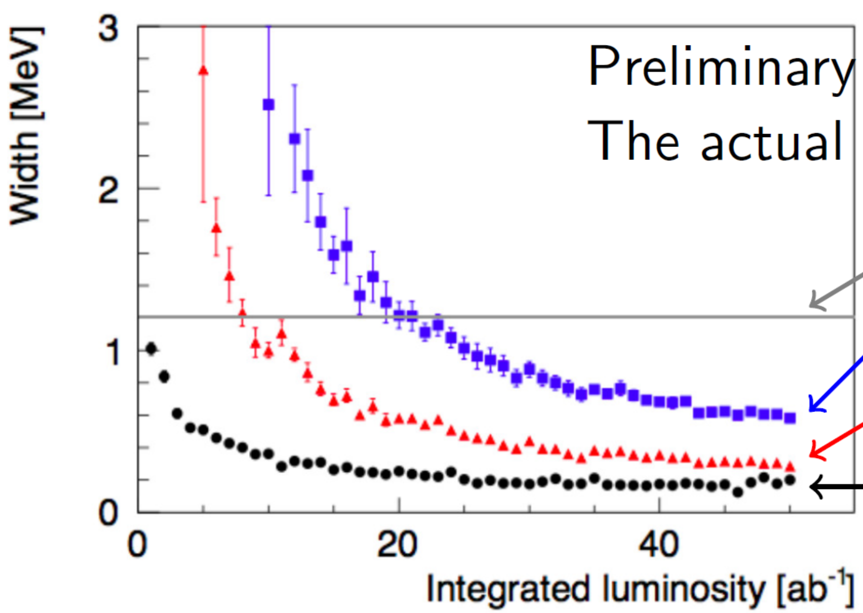
1. Amplitude analysis of $B \to J/\psi\phi K$, confirmation of 4 states observed by LHCb.
2. Amplitude analysis of $B \to J/\psi\omega K$, measurement of the $X(3915)$ quantum numbers in B decays.
3. Updated search for $B \to Y(4260)(\to J/\psi\pi^+\pi^-)K$ and other $J^{PC} = 1^{--}$ charmoniumlike states.
4. Amplitude analyses of unexplored channels with a J/ψ such as $B \to J/\psi\eta K$ or $B \to J/\psi\eta' K$.
5. Analyses of the above channels with K_S^0.
6. Search for decays of known charmoniumlike states to other final states, for example, $X(3915) \to \eta_c\eta$ ($X(3915)$ should decay to this channel if it is a $c\bar{c}s\bar{s}$ state).
7. Absolute branching fractions for $B \to X(3872)K$, $B \to X(3915)K$.

Can be done at Belle II and LHCb.

Absolute branching fractions are unique for Belle II!

The $X(3872)$ width: sensitivity

- The current upper limit on the $X(3872)$ width is 1.2 MeV at 90% C. L (Belle PRD **84**, 052004 (2011), from $B \to J/\psi\pi^+\pi^- K$ data).
- Using the $B \to (D^0\bar{D}^0\pi^0)K$ data can significantly improve the mass resolution (near-threshold decay), and, consequently, the total-width sensitivity.
- The sensitivity has been estimated on MC (H. Hirata, master thesis, 2019), the expectation is shown below.



Preliminary and the error is statistical only.
The actual limit should be larger.

Current limit: 1.2 MeV at 90% C. L.

Measureable width (5σ)

Measureable width (3σ)

Limit (90%C.L.) if $\Gamma = 0$ MeV
About 180 keV for full data sample

Bottomonium: $\Upsilon(3S)$ data

Current samples in fb^{-1} (millions of events)

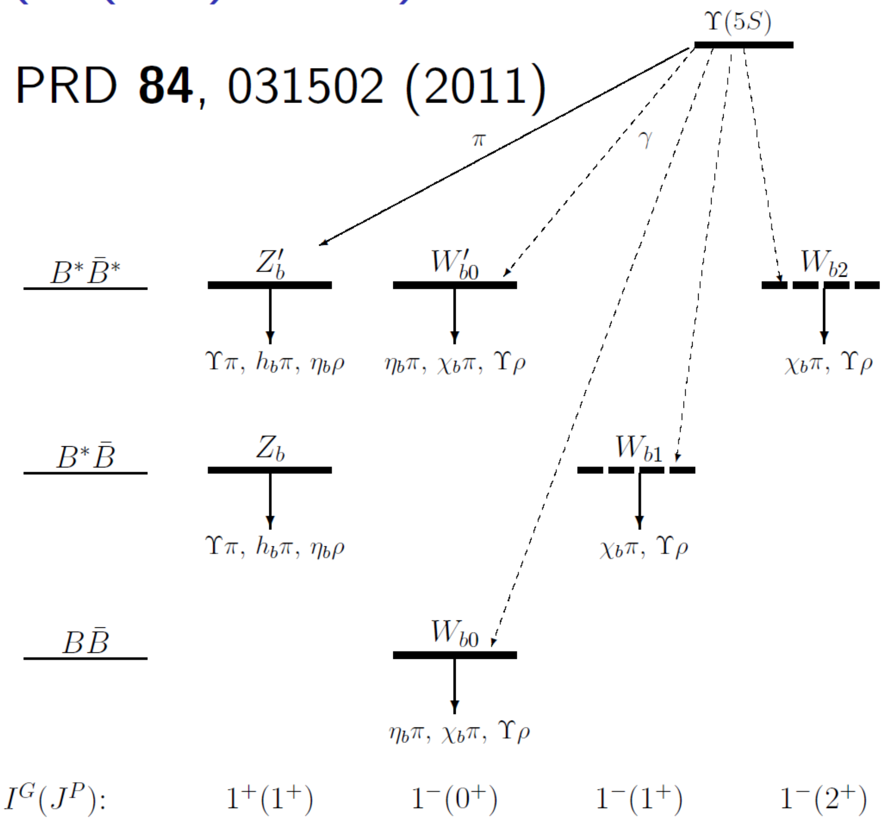
Experiment	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$	$\Upsilon(4S)$	$\Upsilon(5S)$	$\Upsilon(6S)$	$\frac{\Upsilon(nS)}{\Upsilon(4S)}$
CLEO	1.2 (21)	1.2 (10)	1.2 (5)	16 (17.1)	0.1 (0.4)	-	23%
BaBar	-	14 (99)	30 (122)	433 (471)	R_b scan	R_b scan	11%
Belle	6 (102)	25 (158)	3 (12)	711 (772)	121 (36)	5.5	23%
BelleII	-	-	300 (1200)	5×10^4 (5.4×10^4)	1000 (300)	100+400(scan)	3.6%

1. Inclusive production of charmonium(-like) states in $\Upsilon(nS)$ decays.
2. Double production of charmonium(-like) states in $\Upsilon(nS)$ decays.
3. Amplitude analyses of $\Upsilon(3S) \to \Upsilon(1S, 2S)\pi^+\pi^-$ (possible contribution from bottomonium states).
4. Search for missing $\pi\pi$ and η transitions to lower-mass bottomonium states, suppressed radiative transitions.
5. Study of baryons in bottomonia decays.
6. Correlation in $D\bar{D}^*$ production.
7. Study of deutron production.

Can be done at Belle and (some topics) LHC experiments.

Bottomonium ($\Upsilon(5S)$ data): can be done

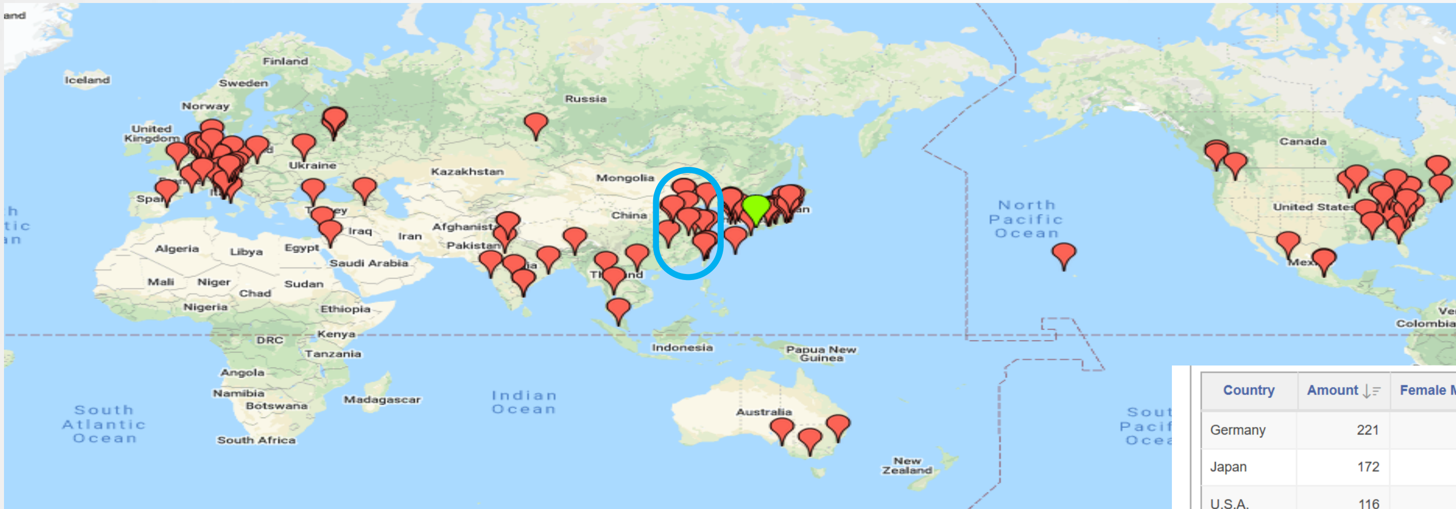
M. Voloshin PRD **84**, 031502 (2011)



Molecular states with quantum numbers other than $I^G = 1^+$, $J^P = 1^+$ are expected to exist. The transitions to such states are radiative and they are consequently suppressed by $\sim \alpha$. However, using the high statistics their observation might be possible.

Unique for Belle II!

Belle II国际合作组与中国组



- 规模排第五，但是竞争很激烈。
- 需要考虑更多的研究内容！
- 需要更多的国内支持！

Country	Amount ↓	Female Members	Male Members	Other Members	No Gender Set
Germany	221	41	175		
Japan	172	31	141		
U.S.A.	116	8	108		
Italy	90	14	75		
China	61	15	46	-	-
India	49	18	31	-	-
Russia	47	8	39	-	-
France	47	5	42	-	-

61名成员！

- 合作组规模: 26个国家和地区，>120个研究单位, >1000名成员。
  - 50%为博士后及以上。
  - 众多实验室：KEK, IHEP(Beijing), BNL, SLAC, TRIUMF, DESY, LAL, INFN, BINP, …
- 中国组： 复旦，高能所，中科大等12个单位。
- 技术支持：
  - 网页: https://napp.fudan.edu.cn/belle2/ （复旦）
  - Indico: https://indico.ihep.ac.cn/category/109/ （高能所），https://napp.fudan.edu.cn/indico/ （复旦）

- 参与内容:
  - 物理分析：传统强项，但需要拓展研究领域
  - 硬件：高能所，复旦
  - 计算：高能所，复旦，北航；+科大，山大，南师
  - DAQ和触发：高能所，辽师，+山大
  - 探测器刻度：复旦，高能所，
  - 数据检查：中科大，北航

Summary

- We are still producing interesting results using Belle data
- The expected Belle II data sample of 50 ab^{-1} will provide a lot of new opportunities for physics analyses
- Some of them, for example, double charmonium production, charmonium in two-photon processes, or bottomonium physics, are unique for Belle II.
- Several quarkonium states and exclusive B decays to charmonium and other particles were “rediscovered" using the currently available data.

Thanks a lot!

Thanks for your attention

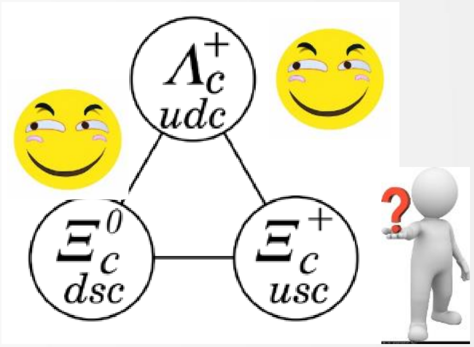
沈成平　　shencp@buaa.edu.cn

Measurements of absolute Brs of Ξ_c^+

复旦、北大

- 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.



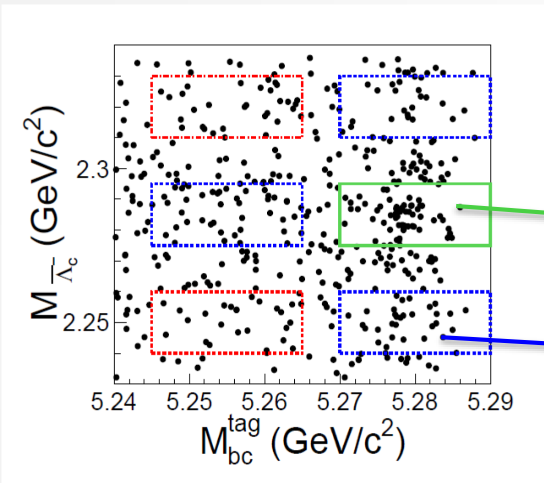
- The Brs of remaining Ξ_c^+ are all measured with ratio to the $\Xi_c^+ \to \Xi^- \pi^+ \pi^+$

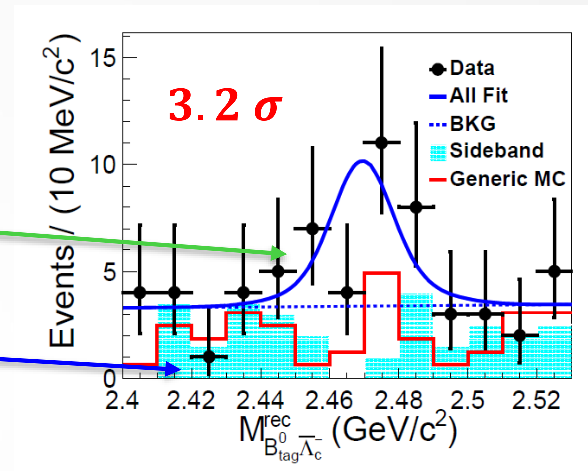
- The comparison of Ξ_c^+ decays with those of Λ_c^+ and and Ξ_c^0 can also provide an important test of SU(3) flavor symmetry.

$\Xi_c^+ \to p K^- \pi^+$ 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

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





- reconstruct $\overline{\Lambda}_c^-$ via $\bar{p}K^+\pi^-$ decay mode

Y.B.Li, C.P.Shen et al (Belle)
PRD 100, 031101 (2019)

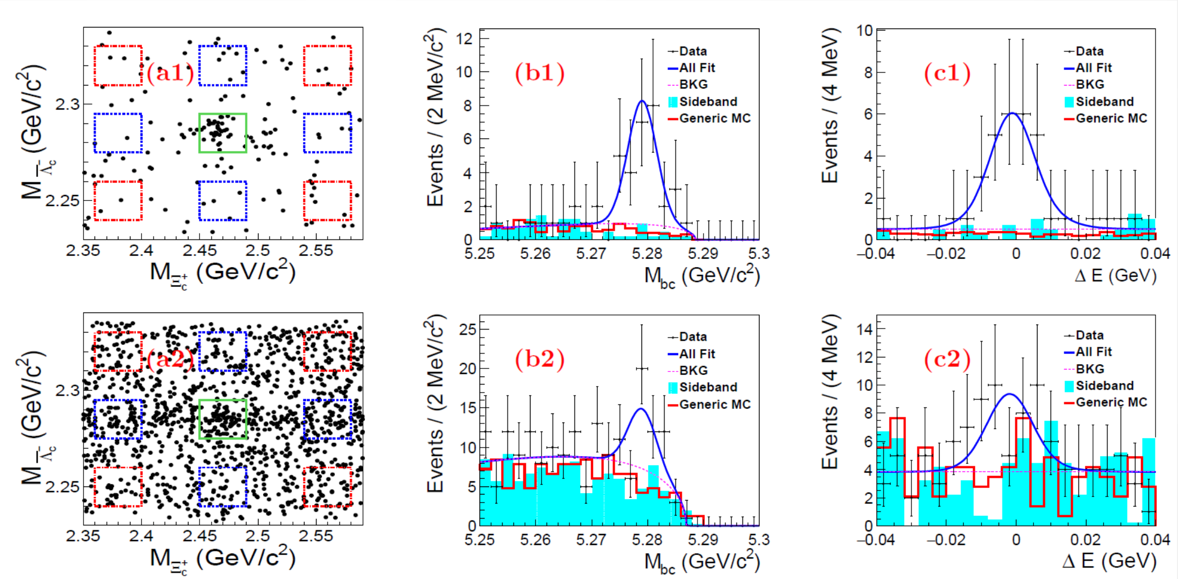
- tag a B^0 with neural network based Full-Reconstruction algorithm.
- An unbinned maximum likelihood fit: $N(\Xi_c^+) = 18.8 \pm 6.8$
- $\mathcal{B}(\bar{B}^0 \to \overline{\Lambda}_c^- \Xi_c^+) = [1.16 \pm 0.42(stat.) \pm 0.15(syst.)] \times 10^{-3}$

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 $pK^- \pi^+$

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

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



Y. B. Li. C. P. Shen et al (Belle) PRD 100, 031101 (2019)