New Results on Charmonium like states at Belle

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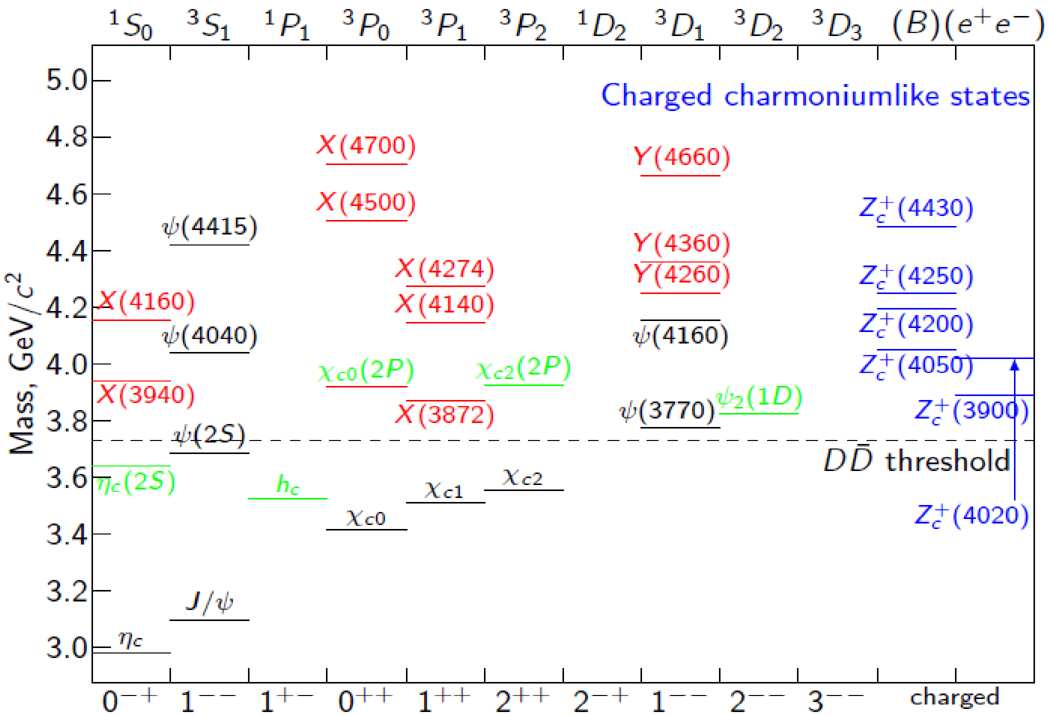
Outline

- Introduction
- Experimental Facility: Belle at KEKB
- New Results on Charmonium Like States

• Search for $\Upsilon(1S, 2S) \rightarrow Z_c^+ Z_c^-$ and $e^+ e^- \rightarrow Z_c^+ Z_c^-$ at $\sqrt{s}$ = 10.52, 10.58 and 10.867 GeV	**arXiv:1805.02308v1 [hep-ex] Accepted by PRD**
• Measurements of the absolute branching fractions of $B^+ \rightarrow X_{c\bar{c}} K^+$ at Belle	**PRD 97, 012005 (2018)**
• Observation of $\Xi_c(2930)^0$ and Updated Measurements of $B^- \rightarrow K^- \Lambda_c^+ \bar{\Lambda}_c^-$ at Belle	**EPJ C 78, 252 (2018)**
• Angular Analysis of the $e^+e^- \rightarrow D^{(*)\pm} D^{(*)\mp}$ process near open charm threshold using initial-state radiation	**PRD 97, 012002 (2018)**

Introduction: Charmonium & Charmonium like States

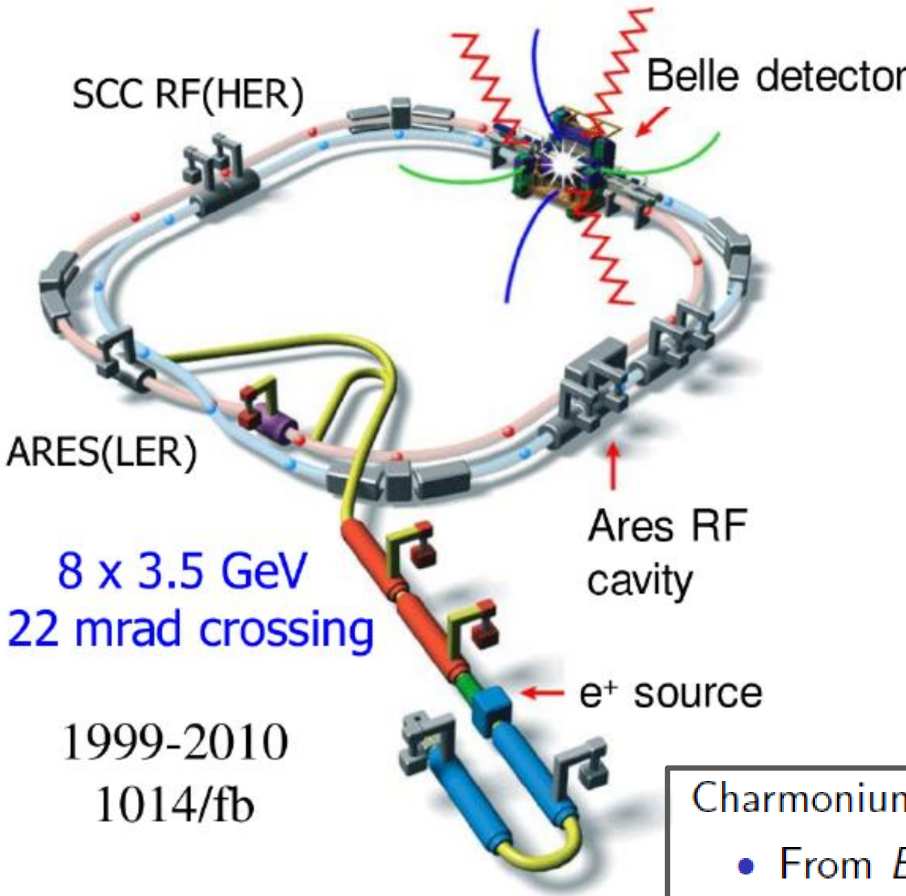
- $c\bar{c}$ bound states can be described using potential models.
- All predicted states below the $D\bar{D}$ threshold have been found.
  - Properties are in agreement with predictions.
- Several unpredicted states have been reported above $D\bar{D}$ threshold.
- To understand their nature, it is necessary to study their production processes along with their decay channels.

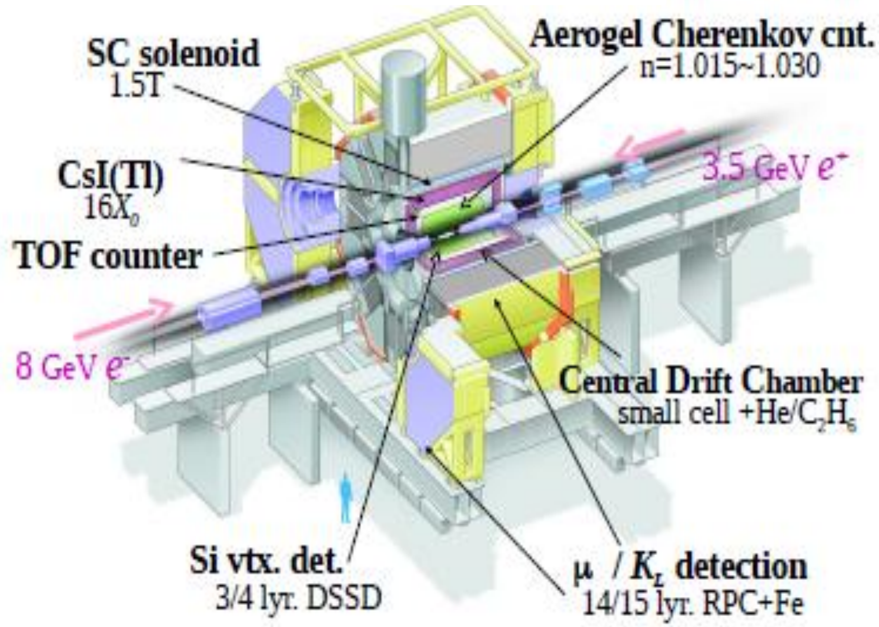


K. Chilikin (LPI RAS), Charm-2018

Belle Experiment at KEKB

L = 2.1 x 10^{34}/cm^2/sec





Charmonium production:

- From B decays - 711 fb^{-1} (at Υ(4S))
- Double charmonium production (all energies): 980 fb^{-1}.

Search for $\Upsilon(1S,2S) \rightarrow Z_c^+ Z_c^-$ and $e^+ e^- \rightarrow Z_c^+ Z_c^-$ at $\sqrt{s}$ = 10.52, 10.58 and 10.867 GeV at Belle

(arXiv:1805.02308v1 [hep-ex] Accepted by PRD)

Analysis of $\Upsilon(1S,2S) \to Z_c^+ Z_c^-$ and $e^+ e^- \to Z_c^+ Z_c^-$

Previous Experiments

Experiments	Publications
Belle observed charged charmonium-like states $Z_c^+(4430)$ in $\pi^+\psi(2S)$ decay mode	**PRL 498 100, 142001 (2008)**
Belle observed $Z_{c1}^+(4050)$ and $Z_{c2}^+(4250)$ ($\to\pi^+\chi_{c1}(1P)$)	**PRD 78, 072004 (2008)**
BESIII and Belle experiments confirmed state $Z_c^+(3900)$	**PRL 110, 252001 (2013)** **PRL 110, 252002 (2013)**
Belle confirmed $Z_c^+(4200)$ in π^+J/ψ through PWA analysis	**PRD 90, 112009 (2014)**
LHCb confirmed the existence of a $Z^+(4430)$	**P R L 112, 222002 (2014)**
Belle observed $Z_c^+(4050)$ in $\pi^+\psi(2S)$	**PRD 91, 508 112007 (2015)**

$J^P = 1^+$ for $Z_c^+(4430)$, $Z_c^+(3900)$, $Z_c^+(4200)$
PR D 90, 112009 (2014)
PRL 112, 222002 (2014)
PRL 119, 072001 (2017)

Non-conventional $q\bar{q}$ states

- **Theory:** tetraquarks, molecules, hybrid etc.

  ➡ More experimental information is needed.

  For $e^+ e^- \to Z_c^+ Z_c^-$, electromagnetic form factor (F) **(PLB 764, 174 (2017) PRD 91, 114025 (2015))**

  $F_{Z_c^+ Z_c^-} \sim 1/s^3$ (Z_c state is tetraquark structure)

  $F_{Z_c^+ Z_c^-} \sim 1/s$ (Z_c is a system of two tightly bound diquarks)

  s is center of mass energy

- Aim is to observe Z_c signals and determine the cross section dependence on the s, it will help to understand the nature of Z_c.

Analysis of $\Upsilon(1S,2S) \to Z_c^+ Z_c^-$ and $e^+ e^- \to Z_c^+ Z_c^-$

arXiv:1805.02308v1 [hep-ex] Accepted by PRD

Data Sample

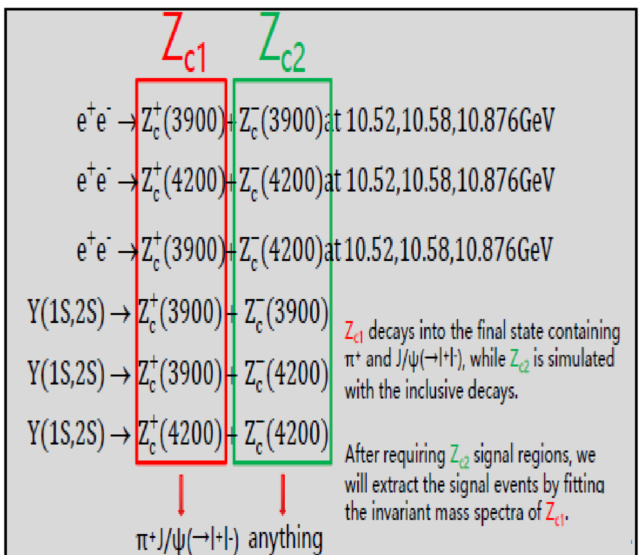
5.74 fb^{-1} at ϒ(1S) peak
24.91 fb^{-1} at ϒ (2S) peak
89.5 fb^{-1} at $\sqrt{s}$ = 10.52 GeV,
711fb^{-1}at $\sqrt{s}$ = 10.58 GeV (ϒ (4S) peak)
121.4 fb^{-1} at $\sqrt{s}$ = 10.867GeV (ϒ (5S) peak)

Analysis Method

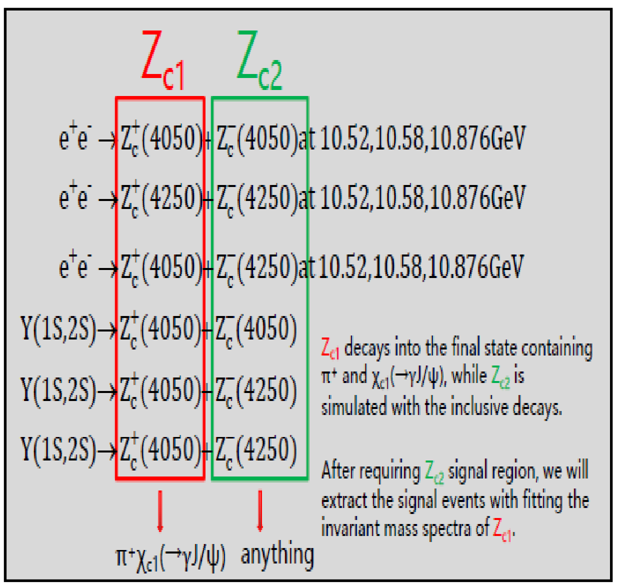
- Z_{c1} decays into $\pi^+ J/\psi$, $\pi^+\chi_{c1}$, $\pi^+\psi(2S)$.
  Z_{c2} is simulated with inclusive decays.
  ($e^+ e^- \to u\bar{u}/d\bar{d}/s\bar{s}/c\bar{c}$)
- After requiring Z_{c2} signal regions, we will extract the signal events by fitting the invariant mass spectra of Z_{c1}.

Decay Modes

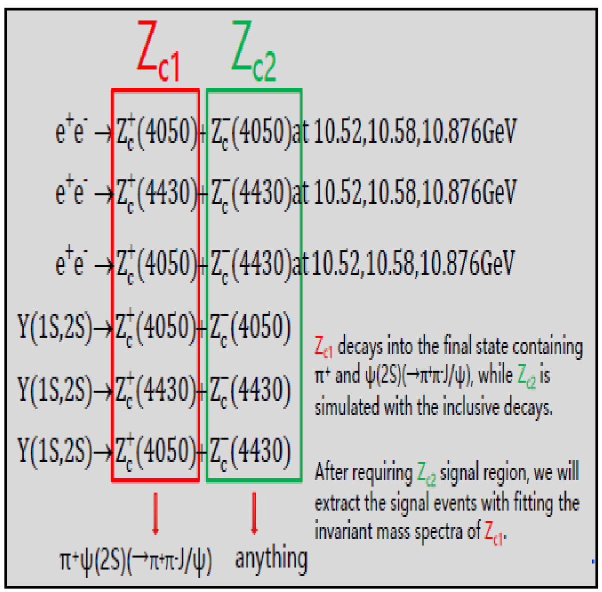
$Z_{c1} \to \pi^+ J/\psi$



$Z_{c1} \to \pi^+ \chi_{c1}$



$Z_{c1} \to \pi^+ \psi$ (2S)



Analysis of $\Upsilon(1S,2S) \to Z_c^+ Z_c^-$ and $e^+ e^- \to Z_c^+ Z_c^-$

arXiv:1805.02308v1 [hep-ex] Accepted by PRD

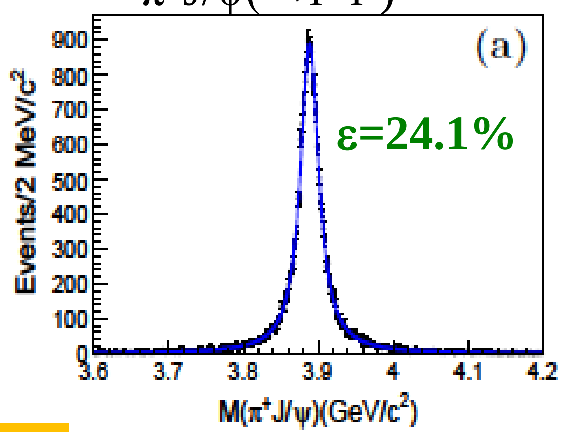
MC Simulation

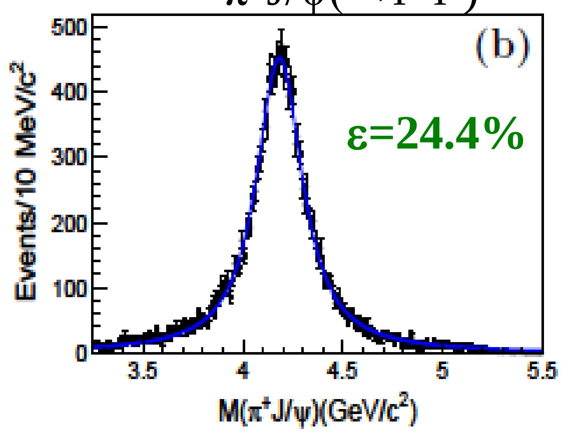
Invariant Mass of Z_c ($\to \pi^+ J/\psi$)

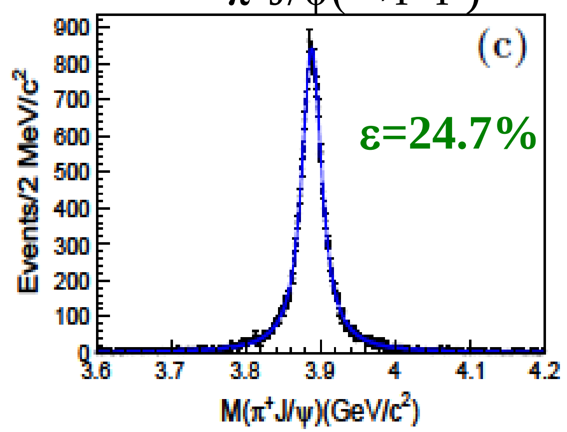
$\Upsilon(1S) \to Z_c(3900) + Z_c(3900)$ ↓ $\pi^+ J/\psi(\to l^+ l^-)$

$\Upsilon(1S) \to Z_c(4200) + Z_c(4200)$ ↓ $\pi^+ J/\psi(\to l^+ l^-)$

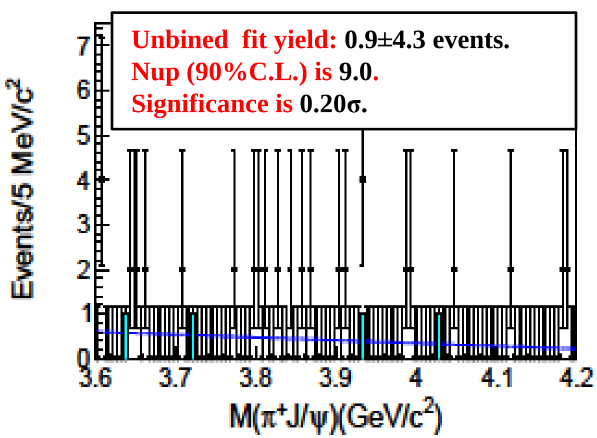
$\Upsilon(1S) \to Z_c(3900) + Z_c(4200)$ ↓ $\pi^+ J/\psi(\to l^+ l^-)$

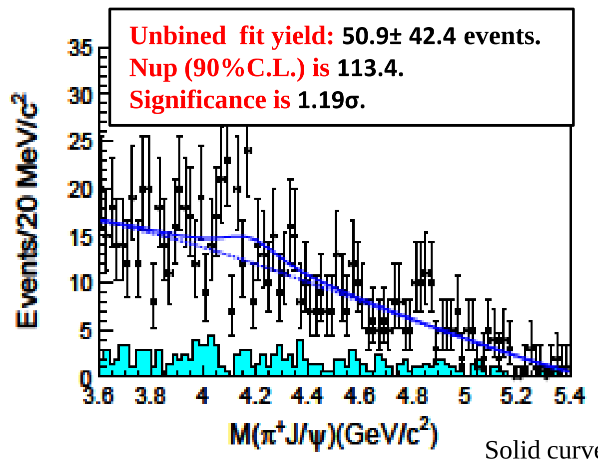


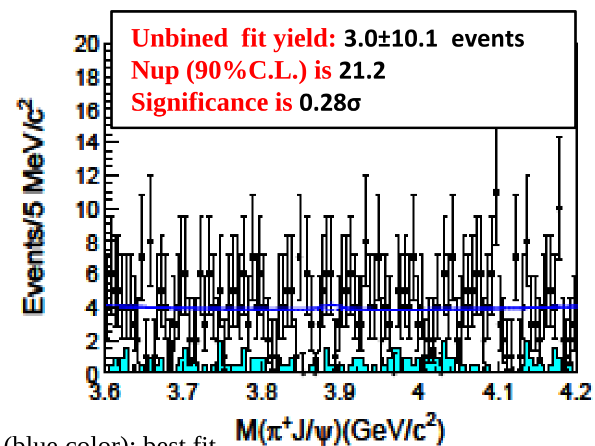




data







Solid curve (blue color): best fit
Dotted lines: background
Shaded area: normalized J/ψ mass side band events

➡ **No evident signal for Z_c states is observed.**

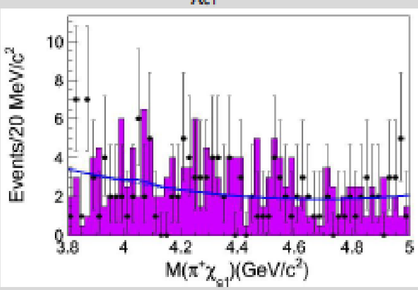
Analysis of $\Upsilon(1S,2S) \rightarrow Z_c^+ Z_c^-$ and $e^+ e^- \rightarrow Z_c^+ Z_c^-$

arXiv:1805.02308v1 [hep-ex] Accepted by PRD

Invariant Mass of $Z_c \rightarrow \pi^+ \chi_{c1}$

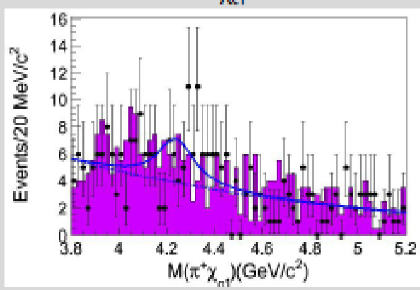
$\sqrt{s}$ = 10.52 Data sample

$e^+e^- \rightarrow Zc(4050)+Zc(4050)$, $Zc \rightarrow \pi^+\chi_{c1}$



The unbined fit yields 1.2±6.5 signal events. N^{up} (90%C.L.) is 12.7. The significance is 0.2σ.

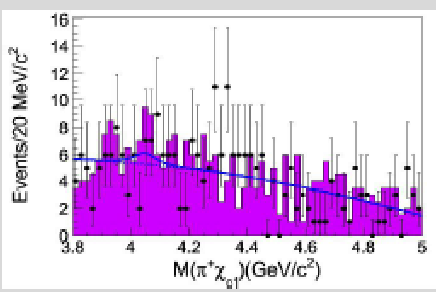
$e^+e^- \rightarrow Zc(4250)+Zc(4250)$, $Zc \rightarrow \pi^+\chi_{c1}$



The unbined fit yields 40.9±16.8 signal events. N^{up} (90%C.L.) is 64.3. The significance is 2.6σ.

$e^+e^- \rightarrow Zc(4050)+Zc(4250)$, $Zc \rightarrow \pi^+\chi_{c1}$

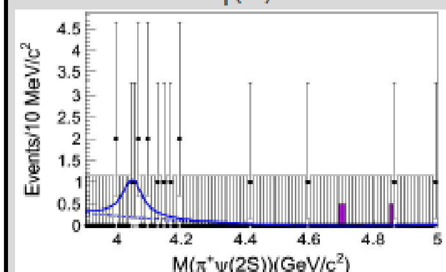
The unbined fit yields 5.2±10.4 signal events. N^{up} (90%C.L.) is 21.1. The significance is 0.5σ.



Invariant Mass of $Z_c \rightarrow \pi^+ \psi(2S)$

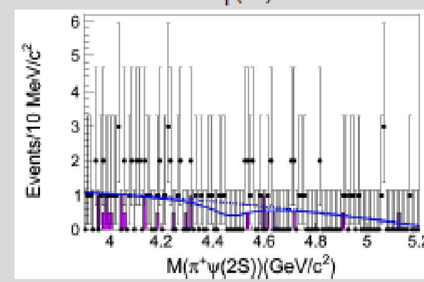
$\sqrt{s}$ = 10.52 Data sample

$e^+e^- \rightarrow Zc(4050)+Zc(4050)$, $Zc \rightarrow \pi^+\psi(2S)$



The unbined fit yields 9.4±15.5 signal events. N^{up} (90%C.L.) is 17.9.

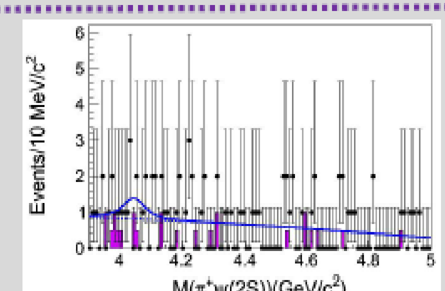
$e^+e^- \rightarrow Zc(4430)+Zc(4430)$, $Zc \rightarrow \pi^+\psi(2S)$



The unbined fit yields -9.7±8.4 signal events. N^{up} (90%C.L.) is 11.3.

$e^+e^- \rightarrow Zc(4050)+Zc(4430)$, $Zc \rightarrow \pi^+\psi(2S)$

The unbined fit yields 6.5±7.2 signal events. N^{up} (90%C.L.) is 18.2. The significance is 0.9.



➡ **No evident signal for Z_c states is observed.**

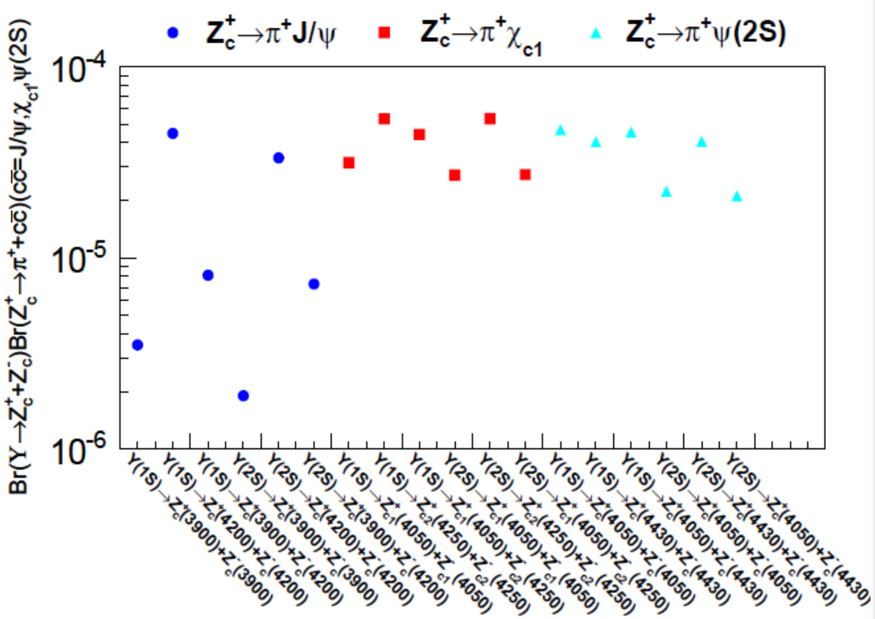
Solid curve (blue color): best fit
Dotted lines: background, Shaded area (Magenta color): normalized $\pi^+\chi_{c1}$, $\pi^+\psi(2S)$ mass side band events

Measurement of the Branching Fraction and Cross section

arXiv:1805.02308v1 [hep-ex] Accepted by PRD

B.F. $(\Upsilon\,(1S,2S) \rightarrow Z_c^+ Z_c^-) \times$ B.F. $(Z_c^+ \rightarrow \pi^+ c\bar{c})$

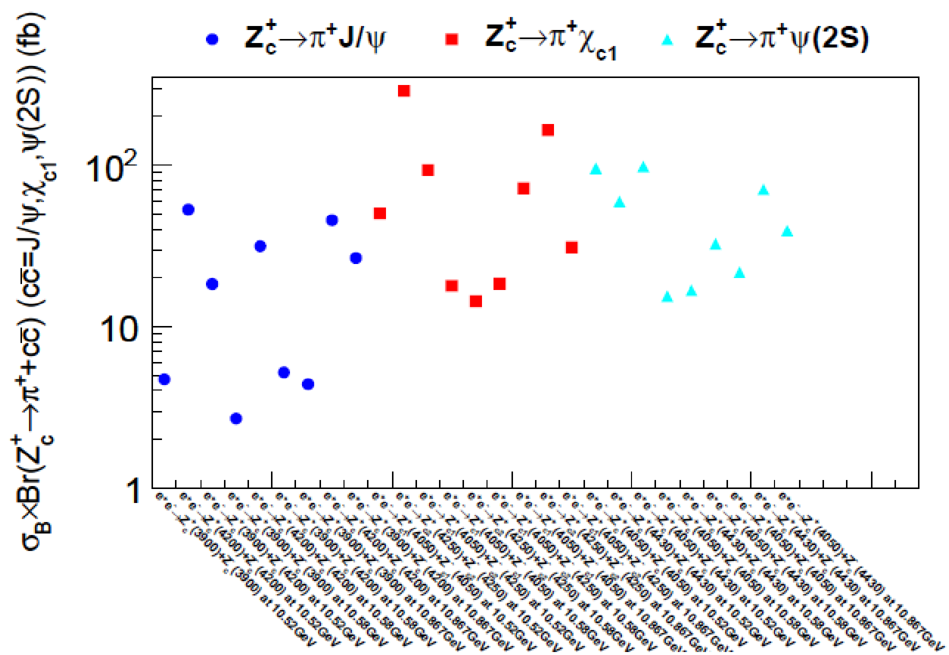
$$= \frac{N_{fit}}{N_{\Upsilon\,(1S,2S)} \times \varepsilon \times B_{decay}}$$



$\sigma\,(e^+ e^- \rightarrow Z_c^+ Z_c^-) \times$ B.F. $(Z_c^+ \rightarrow \pi^+ c\bar{c})$

$$= \frac{N_{fit} \times |1-\Pi|^2}{L \times \varepsilon \times (1+\delta)_{ISR} \times B_{decay}}$$

N_{fit} : number of fitted Z_c^+ signal yields
$N_{\Upsilon\,(1S,2S)}$: total number of Υ (1S, 2S) events
ε is the corresponding selection Efficiency
L is the integrated luminosity
Bdecay = B(J/ψ → ℓ+ℓ−)
$(1+\delta)_{ISR}$ radiative correction factor
$|1-\Pi|^2$ is the vacuum polarization factor.



- No clear signals are observed in the studied modes.
- Determined 90% C.L. upper limits on the B.F. & cross section.

Measurements of the absolute branching fractions of $B^+ \to X_{c\bar{c}} K^+$ at Belle

PRD 97, 012005 (2018)

Analysis of $B^+ \rightarrow X_{c\bar{c}} K^+$

- The X(3872) is not explained by the Quark Model.
  Int. J. Mod. Phys. A 20, 240 (2005)

- As its mass is very close to combined mass of charmed mesons D^0 and $\bar{D}^{*0}$.
  $J^{PC} = 1^{++}$ is determined by LHCb **PRL 110, 222001 (2013)**
  X(3872) seems to be $D^0 \bar{D}^{*0}$ molecular state.

- The large cross section observed by CDF experiment contradicts to pure molecular interpretation. **PRL 98, 132002 (2007)**

- X (3872) seems to be an admixture of $D^0 \bar{D}^{*0}$ molecular state and a pure χ_{c1}(2P) state.
  Phys. 2013, 903D01 (2013)

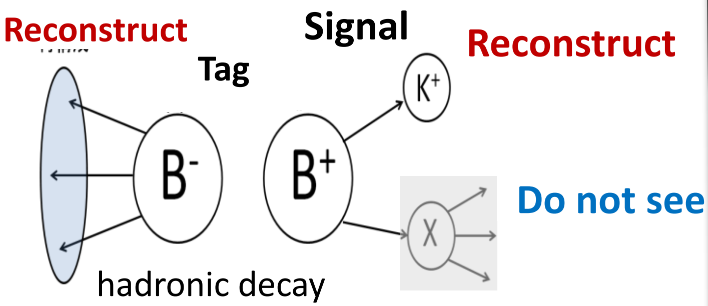
- To understand the nature of X(3872), a measurement of the absolute branching fraction B.F. ($B^+ \rightarrow X$ (3872) K^+) is required.

Missing Mass Distributions of K^+ in $B^+ \to X_{c\bar{c}} K^+$

Data Sample:

772×10^6 $B\bar{B}$ pairs at Υ (4S) resonance

Reconstruction Method

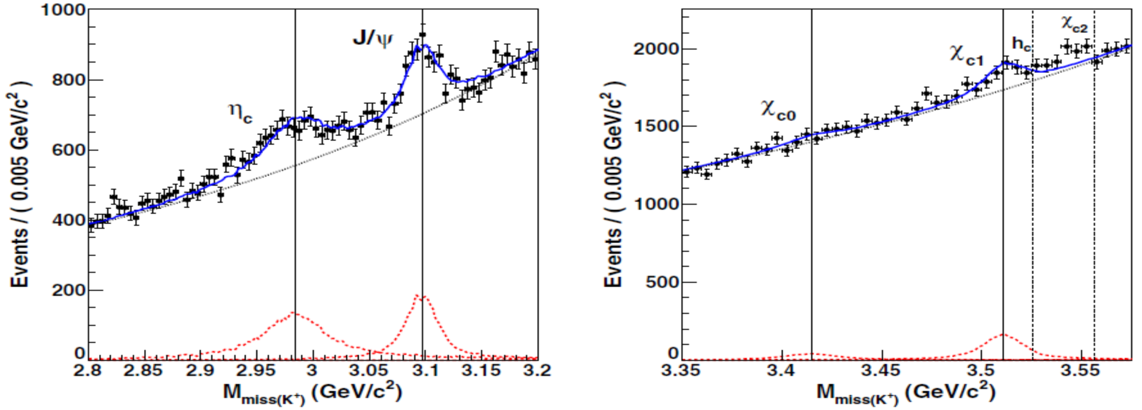


Missing mass is used to reconstruct the $X_{c\bar{c}}$ mass

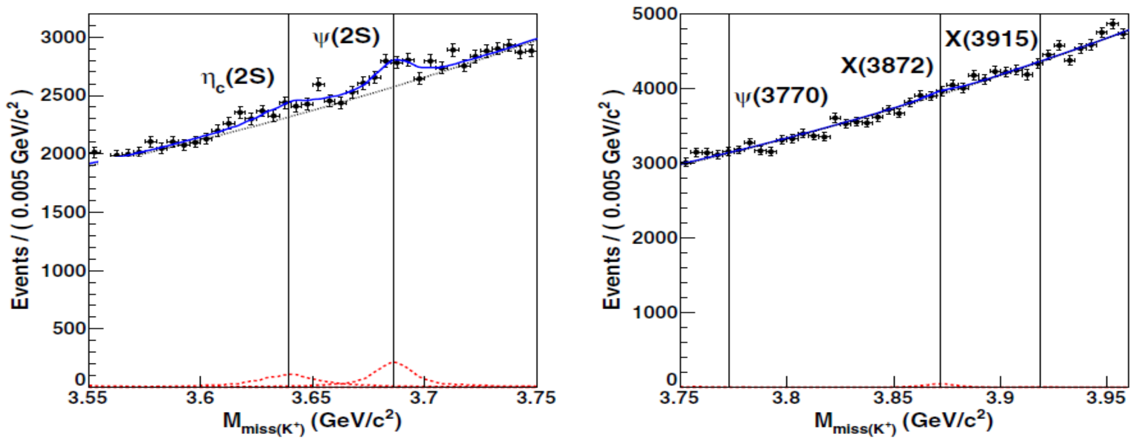
$$M_{miss\,(h)} = \sqrt{(p^*_{e^+e^-} - p^*_{tag} - p^*_h)^2}\,/c$$

$p^*_{e^+e^-}$, p^*_{tag} and p^*_h are four momenta of electron -positron initial state, B_{tag} and kaon, respectively.

PRD 97, 012005 (2018)



Enhancement near 3545MeV/c^2 is not significant.



Vertical solid lines: nominal mass of X_{cc} included in the fit.
Vertical dashed lines: nominal mass of X_{cc} not included in fit.
Solid line (blue color): total fit results.
Dashed and dotted lines are X_{cc} contributions and background contributions, respectively

$X_{c\bar{c}}$: η_c, J/ψ, χ_{c0}, χ_{c1}, η_c (2S), ψ (2S), ψ (3770), X(3872), X(3915)

➡ We do not observe significant signal for X(3872)

Measurement of Branching Fraction of $B^+ \to X_{c\bar{c}} K^+$

$$\text{B.F.} = \frac{N_{sig}}{2\, N_{B^\pm}\, \varepsilon}$$

$N_{B^\pm} = N_{\Upsilon(4S)}$ B.F. (Υ (4S)$\to B^+B^-$)

$X_{c\bar{c}}$: η_c, J/ψ, χ_{c0}, χ_{c1}, η_c (2S), ψ (2S), ψ (3770), X(3872), X(3915)

Belle results

PRD 97, 012005 (2018)

Mode	Yield	Significance (σ)	$\mathcal{B}$ (10^{-4})
η_c	2590 ± 180	14.2	$12.0 \pm 0.8 \pm 0.7$
J/ψ	1860 ± 140	13.7	$8.9 \pm 0.6 \pm 0.5$
χ_{c0}	430 ± 190	2.2	$2.0 \pm 0.9 \pm 0.1$ (<3.3)
χ_{c1}	1230 ± 180	6.8	$5.8 \pm 0.9 \pm 0.5$
$\eta_c(2S)$	1050 ± 240	4.1	$4.8 \pm 1.1 \pm 0.3$
$\psi(2S)$	1410 ± 210	6.6	$6.4 \pm 1.0 \pm 0.4$
$\psi(3770)$	-40 ± 310	-	$-0.2 \pm 1.4 \pm 0.0$ (<2.3)
$X(3872)$	260 ± 230	1.1	$1.2 \pm 1.1 \pm 0.1$ (<2.6)
$X(3915)$	80 ± 350	0.3	$0.4 \pm 1.6 \pm 0.0$ (<2.8)

BaBar results

PRL 96, 052002 (2006)

Particle	Yield	$\mathcal{B}(10^{-4})$	σ
η_c	273 ± 43	$8.4\pm1.3\pm0.8$	7.3
η_c relative		$10.6\pm2.3\pm0.4\pm0.4$	
η_c combined		8.7 ± 1.5	
J/ψ	259 ± 41	$8.1\pm1.3\pm0.7$	6.9
χ_{c0}	9 ± 21	<1.8	-
χ_{c1}	227 ± 40	$8.0\pm1.4\pm0.7$	6.0
χ_{c2}	0 ± 36	<2.0	-
η_c'	98 ± 52	$3.4\pm1.8\pm0.3$	1.8
ψ'	139 ± 44	$4.9\pm1.6\pm0.4$	3.2
ψ''	99 ± 69	$3.5\pm2.5\pm0.3$	1.4
$X(3872)$	15 ± 39	< 3.2	-

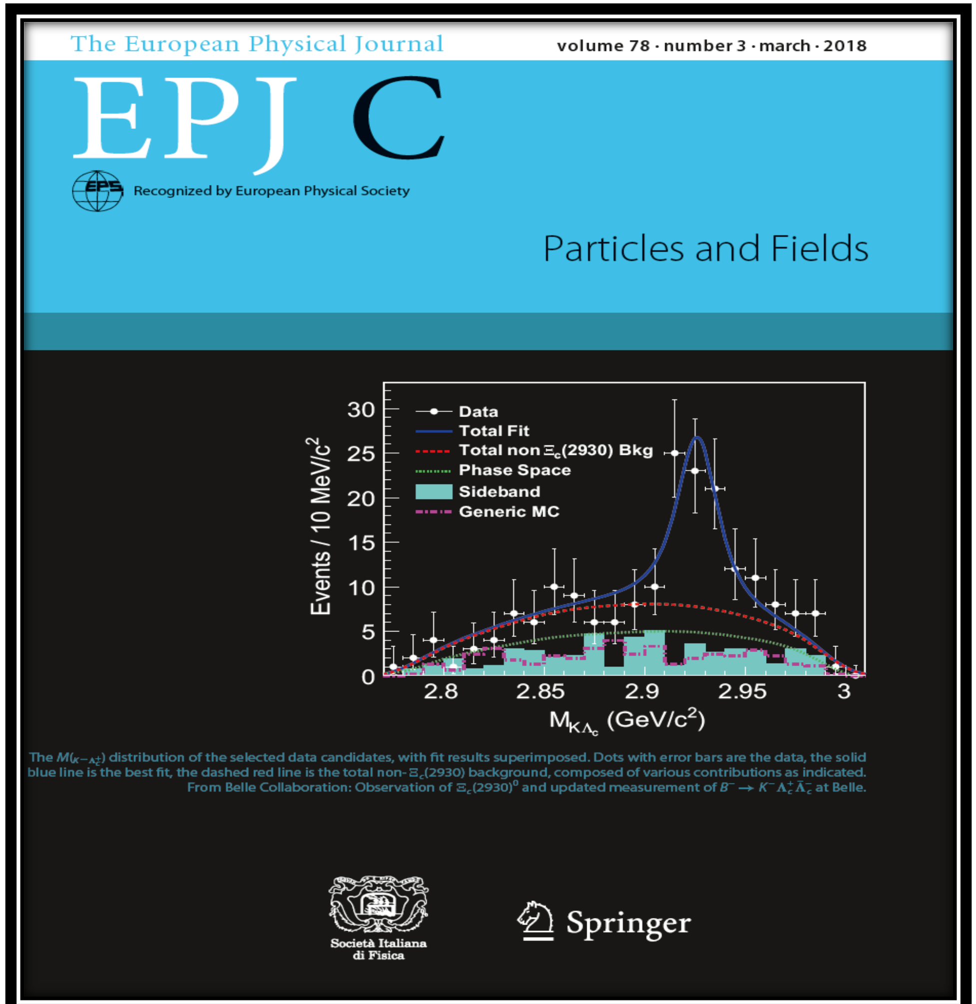
- B.F. ($B^+ \to X(3872)\, K^+$) < 2.6×10^{-4} is more stringent than determined by BABAR (3.2×10^{-4}).
- B.F. ($B^+ \to X(3915)\, K^+$) < 2.8×10^{-4} for the first time. (upper limit with 90 % CL)
- B.F. ($B^+ \to \eta_c K^+$) = $(12.0\pm0.8 \pm0.7)\times10^{-4}$

  B.F.($B^+ \to \eta_c$ (2S) K^+) = $(4.8\pm1.1 \pm0.3)\times10^{-4}$ **(First Significant Measurement)**

Observation of $\Xi_c(2930)^0$ and Updated Measurements of $B^- \to K^- \Lambda_c^+ \bar{\Lambda}_c^-$ at Belle

Eur. Phys. J. C 78, 252 (2018)

Selected as a cover paper of the journal



Observation of $\Xi_c(2930)^0$

Search for charmed strange baryons and charmonium-like states

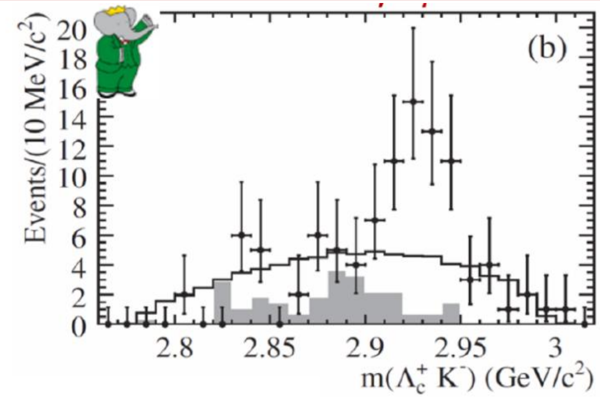
- BaBar performed a study using $B^- \to K^- \Lambda_c^+ \bar{\Lambda}_c^-$
  - A structure named $\Xi_c(2930)$ in the distribution of $M_{K\bar{\Lambda}_c}$
  - Two small peaks in $M_{\Lambda_c^+ \bar{\Lambda}_c^-}$ spectrum

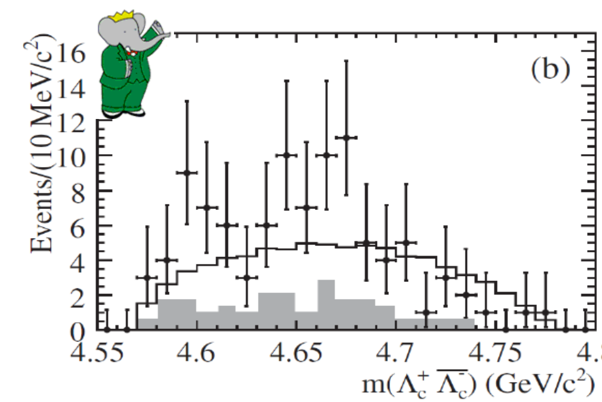
  PRD 77, 031101 (2008)

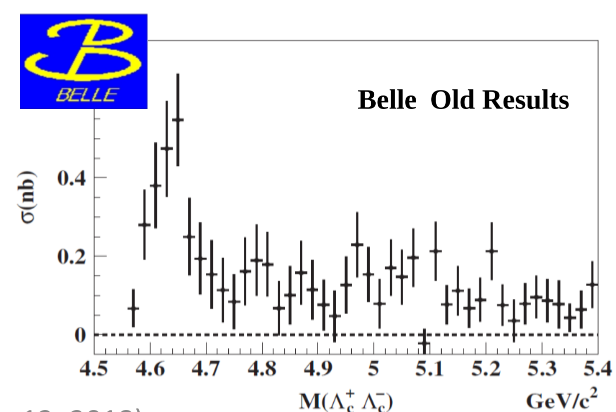
- Belle also performed study using $B^- \to K^- \Lambda_c^+ \bar{\Lambda}_c^-$
  Data sample used: $386 \times 10^6 B\bar{B}$ pairs.
  Distribution of intermediate $K\Lambda_c$ system has not been reported.
  PRL 97, 202003 (2006)

- Large statistics is needed to verify them.

- In papers **PRD 82, 094008 (2010)**
  PRL 102, 242004 (2009)
  Y(4660) has large partial decay width into $\Lambda_c^+ \bar{\Lambda}_c^-$
  Its isospin partner Y(4616) is predicted.







Observation of $\Xi_c(2930)^0$ in $B^- \to K^- \Lambda_c^+ \bar{\Lambda}_c^-$ (Updated Measurement by Belle)

Eur. Phys. J. C 78, 252 (2018)

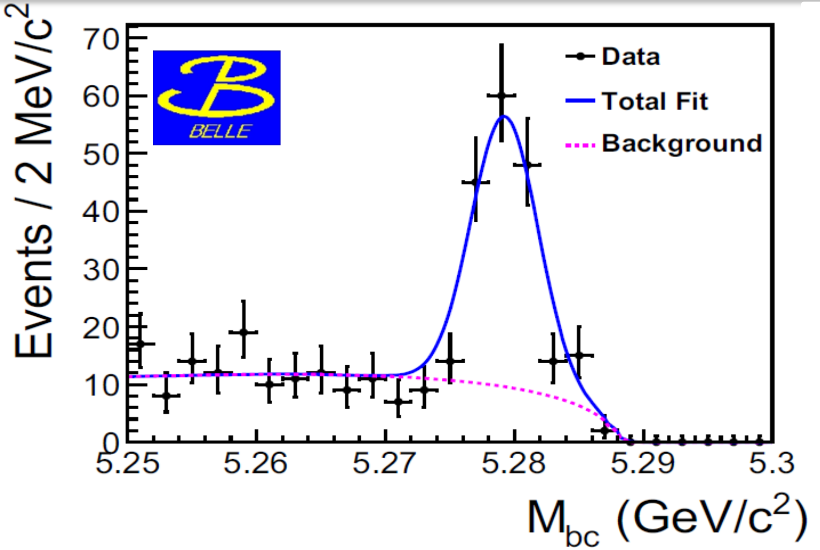
Data Sample: 772×10^6 $B\bar{B}$ pairs at Υ (4S) resonance

(3 times larger statistics than BaBar,
2 times larger than previous Belle study)

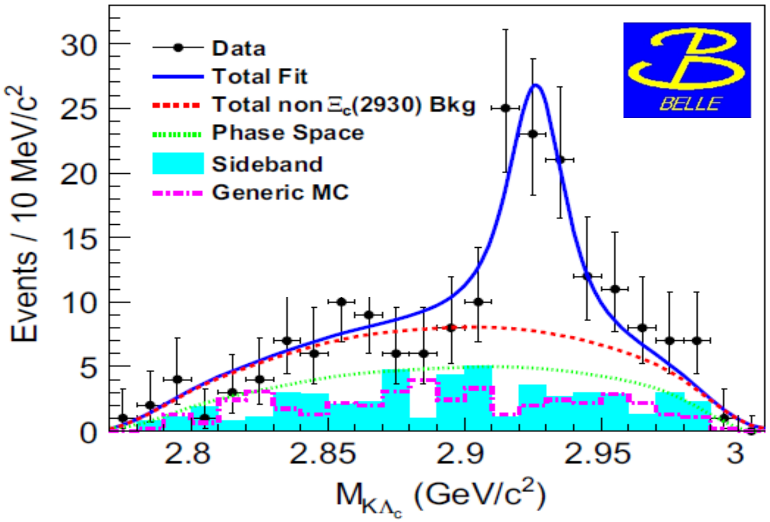
Decay Modes

$K_S^0 \to \pi^+\pi^-$
$\Lambda \to p\pi^-$

Λ_c decay modes
$\Lambda_c^+ \to pK^-\pi^+, \bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$
$\Lambda_c^+ \to pK_S^0, \bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$
$\Lambda_c^+ \to \Lambda\pi^+, \bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$
$\Lambda_c^+ \to pK_S^0\pi^+\pi^-, \bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$
$\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-, \bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$



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

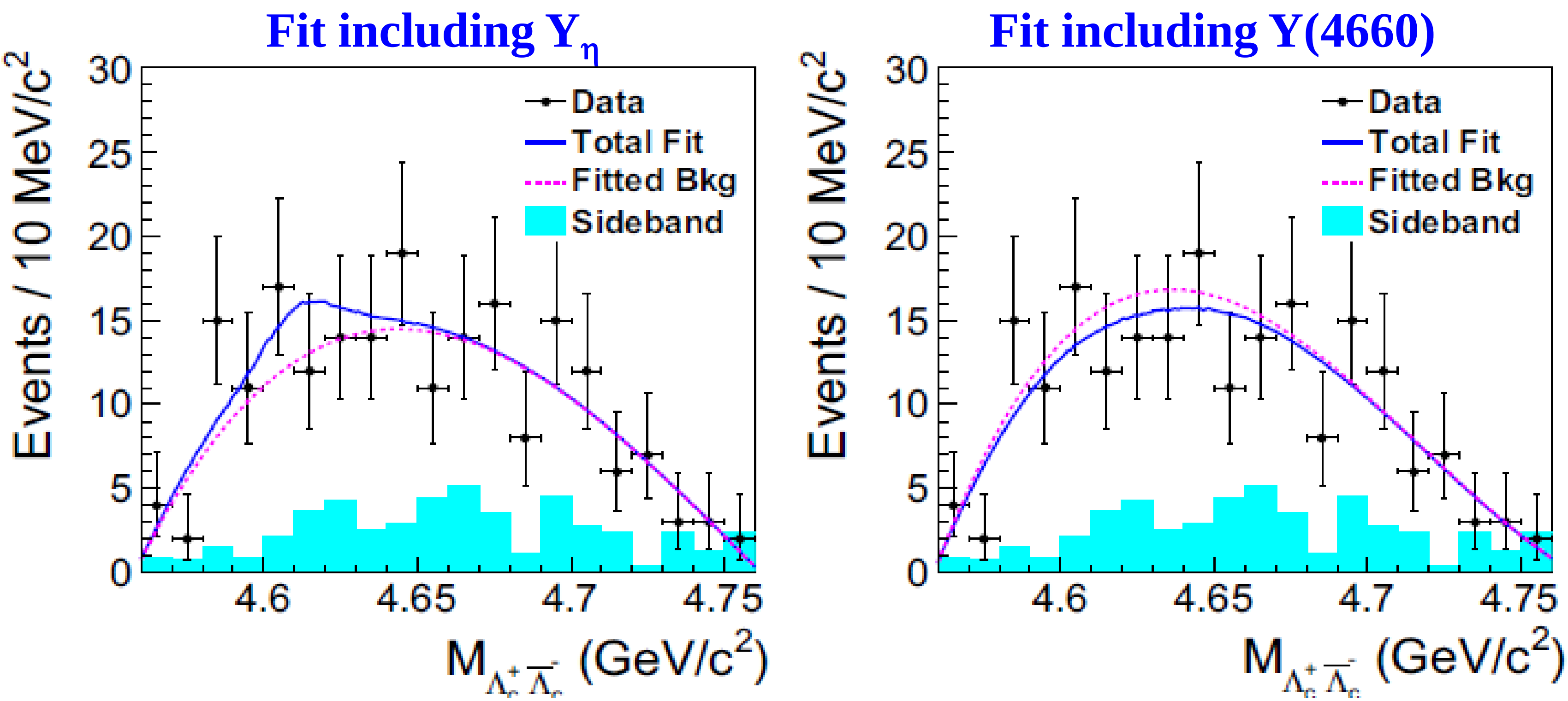


$\Xi_c(2930)^0 \to \Lambda_c^+ K^-$ 61±16 events
5.1σ significance

- First observation of $\Xi_c(2930)^0$ by the Belle Collaboration.
- Mass (M) = 2928.9±3.0 +0.8/-12.0 MeV/c² Width (Γ)=19.5±8.4+5.4/-7.9 MeV

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

Eur. Phys. J. C 78, 252 (2018)



No significant signals seen in the $\Lambda_c^+ \bar{\Lambda}_c^-$ mass spectrum.

$\mathcal{B}(B^- \to K^- Y(4660))\mathcal{B}(Y(4660) \to \Lambda_c^+ \bar{\Lambda}_c^-) < 1.2 \times 10^{-4}$ at 90% C.L.

$\mathcal{B}(B^- \to K^- Y_\eta)\mathcal{B}(Y_\eta \to \Lambda_c^+ \bar{\Lambda}_c^-) < 2.0 \times 10^{-4}$ at 90% C.L.

Angular Analysis of the $e^+e^- \to D^{(*)\pm} D^{*\mp}$ process near open charm threshold using initial-state radiation

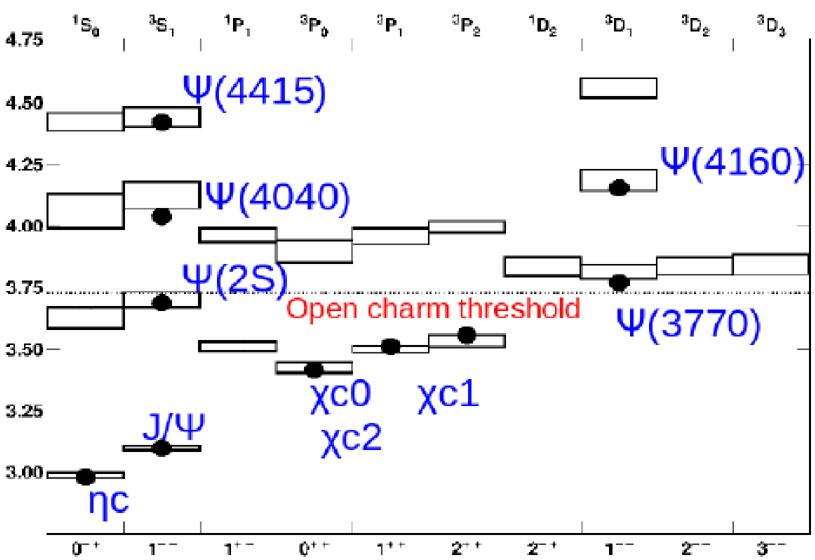
PRD 97, 012002 (2018)

Analysis of the $e^+e^- \rightarrow D^{*+}D^{*-}$

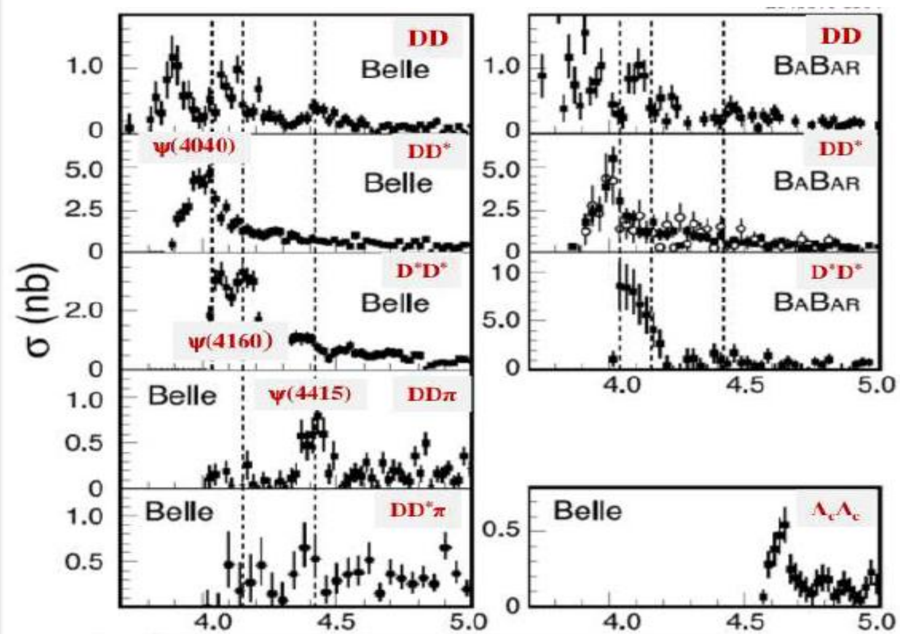
Charmonium Spectrum

- Vector Charmonium state (ψ's) above open charm threshold are not fully understood.

- Parameters of ψ states obtained from σ_{tot} ($e^+e^- \rightarrow$ hadrons)
  - ➢are model-dependent
  - ➢have large uncertainties



Results from Previous Experiments



V. Zhukova, Charm-2018

- Belle and BaBar results are agree with each other.

- Statistics of data sample is too low to study the structure of the cross sections.

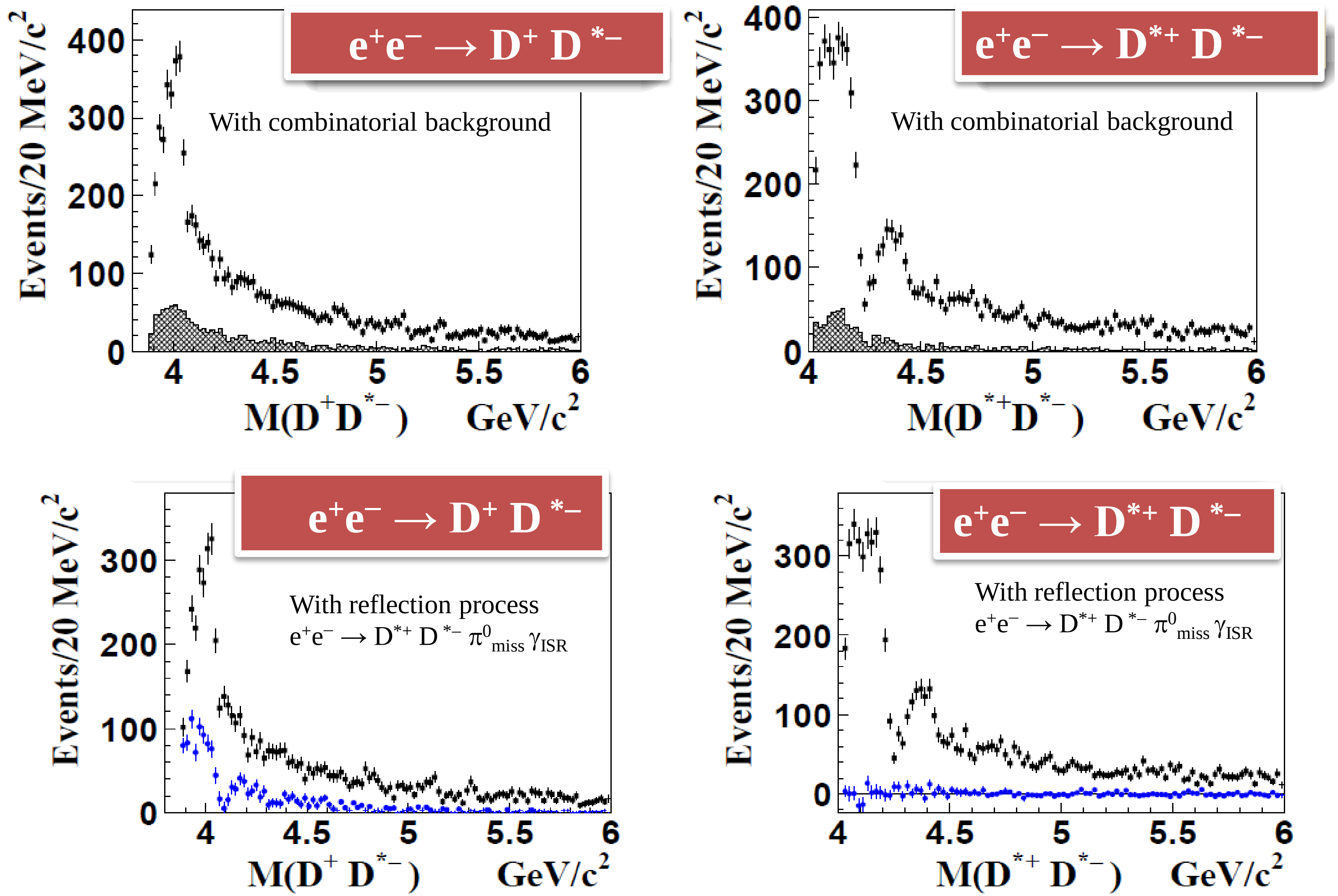
➡ **Goal:** Improve the accuracy of cross section measurements.
Measure separately cross sections for all 3 possible helicity combinations (TT, LT, LL) for the $D^*\overline{D}^*$ final state.

Mass Spectrum

$M(D^{+} D^{*-})$ $M(D^{*+} D^{*-})$

Data Sample: 951 fb^{-1}

PRD 97, 012002 (2018)



Updated mass spectra are consistent with the previous published results.

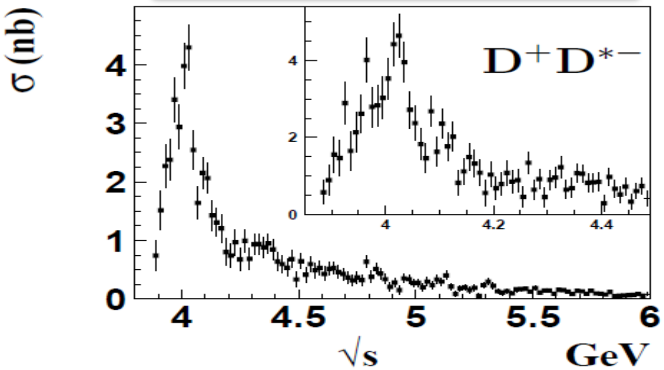
Measurement of Cross sections

PRD 97, 012002 (2018)

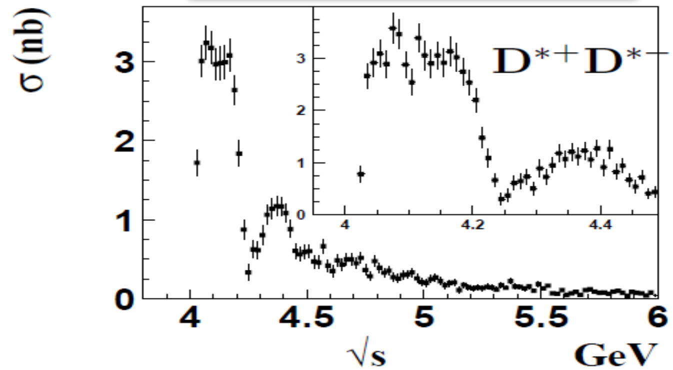
$$\sigma_{e^+e^-\to D^{(*)+}D^{*-}} = \frac{dN/dM}{\eta_{\mathrm{tot}}(M)\cdot dL/dM}$$

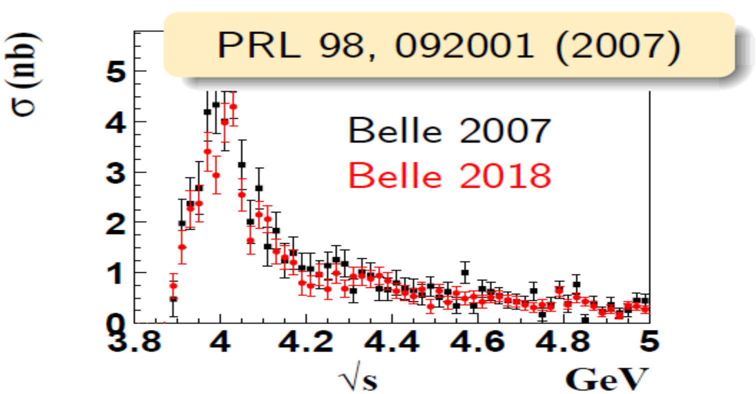
dL/dM includes the second order QED corrections **E. A. Kuraev and V. S. Fadin, Sov. J. Nucl. Phys. 41, 466 (1985).**

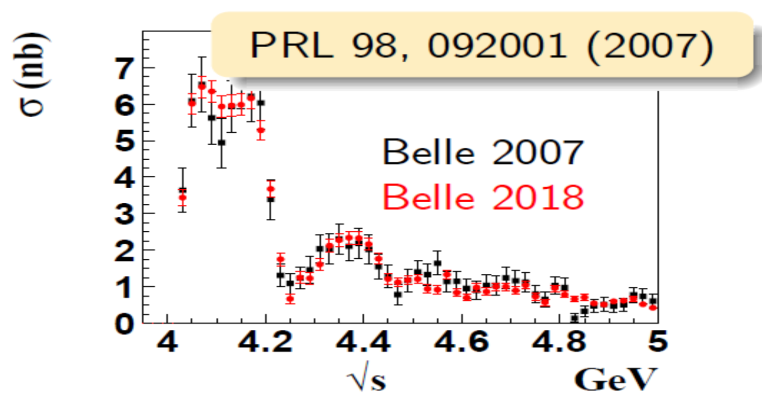
$e^+e^- \to D^+ D^{*-}$



$e^+e^- \to D^{*+} D^{*-}$



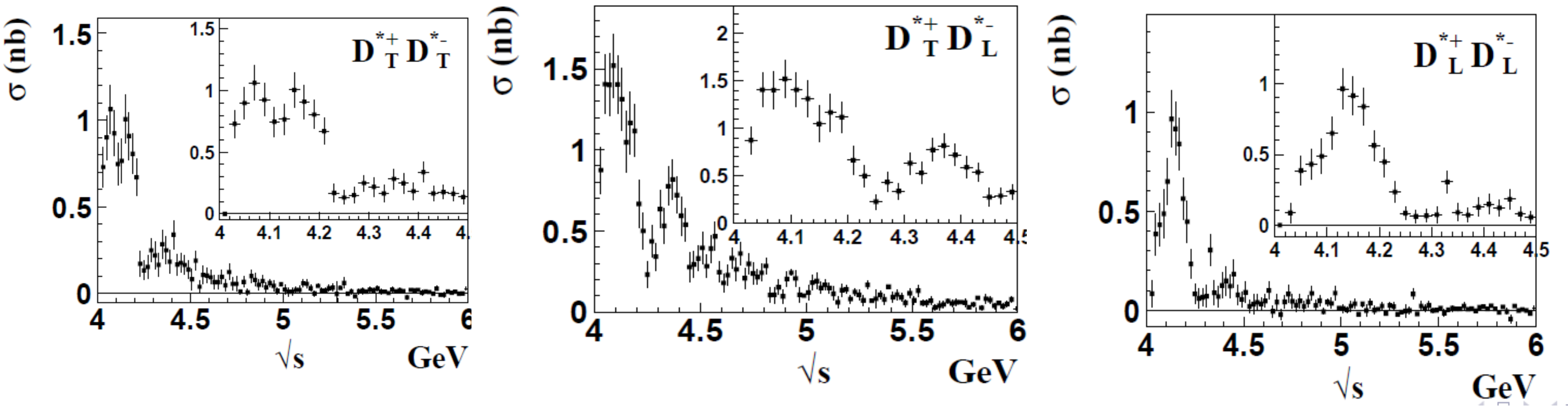




Updated cross sections are consistent with the previous published results with improved precision.

Angular Analysis of Process $e^+e^- \to D^{*+}D^{*-}$

PRD 97, 012002 (2018)



- For $e^+e^- \to D^{*+} D^{*-}$ process, we measured separately the cross sections for all three possible helicity final states (TT, LT and LL).

Summary

Search for $\Upsilon(1S,2S) \rightarrow Z_c^+ Z_c^-$ and $e^+ e^- \rightarrow Z_c^+ Z_c^-$ at $\sqrt{s}$ = 10.52, 10.58 and 10.867 GeV

- No clear signals are observed in the studied modes.
- Determined upper limits on product of branching fraction and cross section (90 % C.L.).

Measurements of the absolute branching fraction of $B^+ \rightarrow X_{c\bar{c}} K^+$

- B.F. $(B^+ \rightarrow X(3872) K^+) < 2.6 \times 10^{-4}$ (90 % CL) ➡More stringent results than BaBar (3.2×10^{-4})

  PRL 96, 052002 (2006)

- B.F. $(B^+ \rightarrow \eta_c K^+) = (12.0 \pm 0.8 \pm 0.7) \times 10^{-4}$
  B.F.$(B^+ \rightarrow \eta_c (2S)\ K^+) = (4.8 \pm 1.1 \pm 0.3) \times 10^{-4}$
  (First Significant Measurement)

Observation of $\Xi_c(2930)^0$ and Updated Measurements of $B^- \rightarrow K^- \Lambda_c^+ \bar{\Lambda}_c^-$

- Ξ_c $(2930)^0$is observed with a statistical significance greater than 5σ.
- Precise Results M = 2928.9±3.0 +0.8/-12.0 MeV, Γ=19.5±8.4+5.4/-7.9 MeV
  B.F. $(B^- \rightarrow K^- \Lambda_c^+ \bar{\Lambda}_c) = (4.80 \pm 0.43 \pm 0.60) \times 10^{-4}$ (consistent with **PDG 2016, 2017)**.
- B.F. $(B^- \rightarrow K^-$ Y(4660)) × B.F. (Y(4660) $\rightarrow \Lambda_c^+ \bar{\Lambda}_c^-) < 1.2 \times 10^{-4}$ (90% C. L).
  B.F. $(B^- \rightarrow K^- Y_\eta) \times$ B.F. $(Y_\eta \rightarrow \Lambda_c^+ \bar{\Lambda}_c^-) < 2.0 \times 10^{-4}$ (90% C. L).

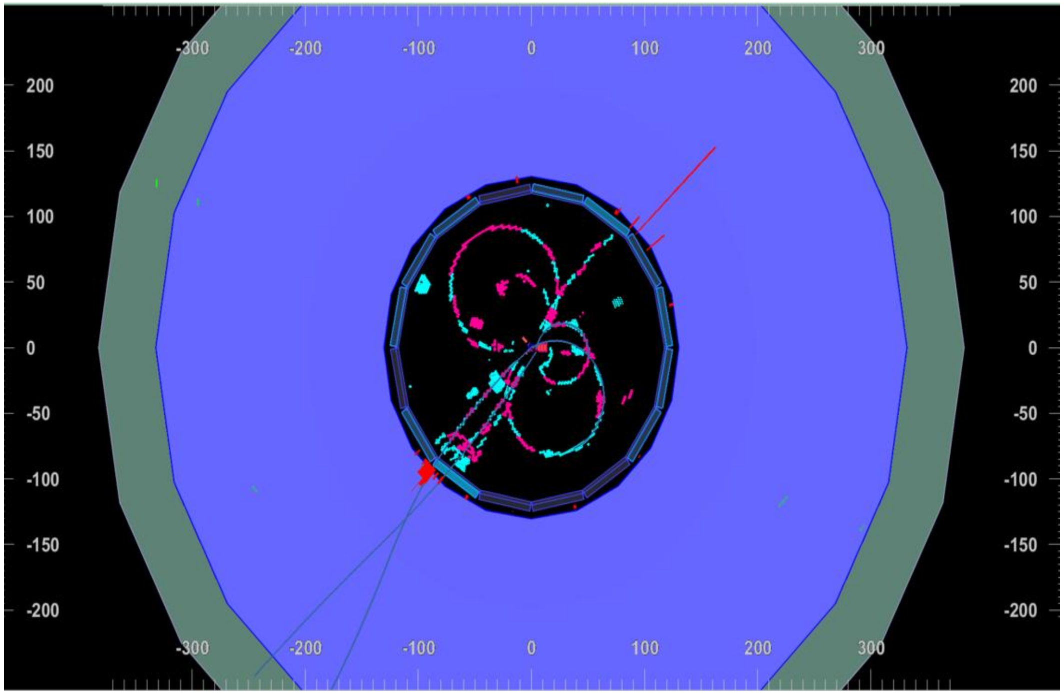
Measured exclusive cross sections of the $e^+e^- \rightarrow D^+ D^{*-}$ and $e^+e^- \rightarrow D^{*+} D^{*-}$ processes

- The accuracy of the cross section measurements is increased.
- For $e^+e^- \rightarrow D^{*+} D^{*-}$ process we measured separately the cross sections for all three possible helicity final states (TT, LT and LL).

Thank You

More Exciting Results are expected with Belle II

First Collisions at Belle II



April 25, 2018

Back Up Slides

Results: Branching Fraction of $B^+ \to \bar{D}^{(*)0}\pi^+$

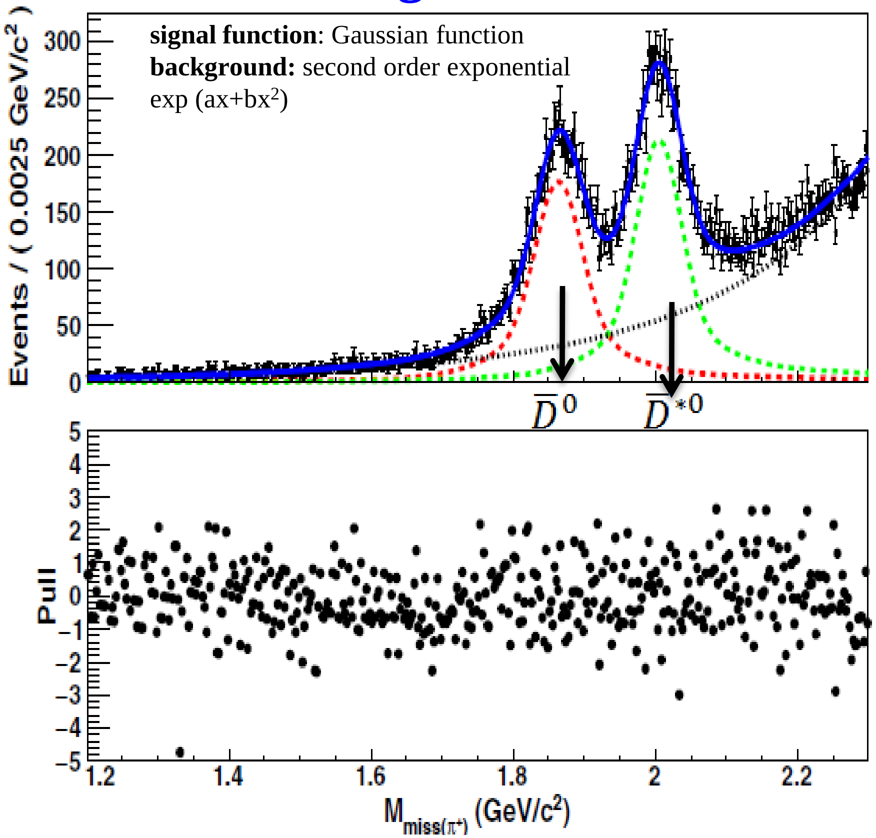
PRD 97, 012005 (2018)

Data Sample:

772×10^6 $B\,\bar{B}$ pairs at Υ (4S) resonance

Decay Modes: $B^+ \to \bar{D}^{(*)0} K^+$

Missing Mass of π^+



Mode	N_{sig}	$(\mu_{data} - \mu_{MC})$ (MeV/c^2)	$(\sigma_{data}/\sigma_{MC})$	ϵ (10^{-3})	$\mathcal{B}$ (10^{-3})	World average for $\mathcal{B}$ (10^{-3}) *
$B^+ \to \pi^+\bar{D}^0$	8550 ± 190	-0.5 ± 0.8	0.994 ± 0.025	2.48 ± 0.02	$4.34 \pm 0.10 \pm 0.25$	4.80 ± 0.15
$B^+ \to \pi^+\bar{D}^{*0}$	9980 ± 250	-0.8 ± 0.8	1.035 ± 0.029	2.61 ± 0.02	$4.82 \pm 0.12 \pm 0.35$	5.18 ± 0.26

→ MC describes the signal shape well.
Branching fraction measurements are consistent with world average.

*Phys. C 40, 100001 (2016)