Study of charmonia and charmed baryons at Belle

Yuji Kato (KMI, Nagoya University)
Contents

- Search for $\chi_{c1}(2P)$ and $X(3872)$ in $B^+ \rightarrow \chi_{c1}\pi^+\pi^- K^+$
- Search for XYZ in $\Upsilon(1S)$ decay
- Precise mass/width measurement of excited $\Xi_c$
- Excited $\Xi_c$ in $\Lambda D$ decay
- First observation of baryon DCS decay: $\Lambda_c^+ \rightarrow pK^+\pi^-$

Charmonia

Charmed baryons
Introduction: Charmonia

- The charmonium spectroscopy
  \( \rightarrow q\bar{q} \) potential = Linear + Coulomb.

- Phenomenological explanation of the confinement.
- Prove the constituent quark model.

- The discovery of so-called XYZ opened new era.
  - Not fit to constituent quark model.
  - Even states with charge (\( Z_c \)).
  - Existence established and \( J^{pc} \) measured for many states.
  - The nature not understood (molecule, tetra, hybrid??)
**X(3872): Mysterious charmonium**

\[ B^- \rightarrow K^- \, J/\psi \, \pi^+ \pi^- \]

- First observed in \( J/\psi \pi^+ \pi^- \) at Belle (Phys. Rev. Lett. 91.262001) Most sited paper!
- No prediction by quark model in this mass.
- Decay breaks isospin: \( \pi \pi = \rho \), \( I=1 \)
- Mass just above the \( D^0 D^{*0} \)
- \( J^{pc} = 1^{++} \) by LHCb.
- What is the nature of \( X(3872) \)?
B^+ \rightarrow K^+ \chi_{c1} \pi^+ \pi^- : Motivation

- One plausible interpretation of X(3872) = Admixture of DD* molecule and \chi_{c1}(2P).

\[
\begin{align*}
\text{D} & \quad \text{(C)} & \quad \pi & \quad \text{(C)} & \quad \overline{D}^* \\
\overline{u} & \quad \pi & \quad u & \quad \overline{D}^*
\end{align*}
\]

+ \quad \text{(C)} & \quad \text{(C)} \\
\chi_{c1}(2P) & \quad \chi_{c1}(2P)

- Molecular picture can explain isospin breaking.
- Large prompt X(3872) cross section in pp require \chi_{c1}(2P) component.
- Non observation of \chi_{c1}(2P).
  If \chi_{c1}(2P) exists, it should decay into \chi_{c1}\pi^+\pi^-.

- Search for \chi_{c1}(2P) and X(3872) in B \rightarrow K^+ \chi_{c1} \pi^+ \pi^-.
  - Include first observation of B \rightarrow K\chi_{c1} \pi \pi
Search for $X(3872)$ and $\chi_{c1}(2P)$ in $\chi_{c1}\pi^+\pi^-$

- First observation of three $B \to K\chi_{c1}\pi\pi$ decays. Use $B^+ \to \chi_{c1}\pi^+\pi^-$ for resonance searches.

- No events in the $X(3872)$ region.
  \[
  \text{Br}(B^+ \to X(3872)K^+) \times \text{B}(X(3872) \to \chi_{c1}\pi^+\pi^-) < 0.15 \times 10^{-6} \text{ (90\% C.L.)}.
  \]

- $\chi_{c1}(2P)$ not significant.
  Assume $\chi_{c1}(2P)$ mass and width to be 3920 MeV/c$^2$ and 20 MeV
  \[
  \text{Br}(B \to \chi_{c1}(2P)K^+) \times \text{B}(\chi_{c1}(2P) \to \chi_{c1}\pi^+\pi^-) < 1.10 \times 10^{-5} \text{ (90\% C.L.)}
  \]

- Not significant result is compatible with $X(3872)$ as $DD^*$ and $\chi_{c1}(2P)$ admixture.
Search for XYZ in the Y(1S) decay

- Almost of the XYZ are observed in the B-decay and Initial State Radiation (ISR).
- Y(1S) decays into 3 gluons ⇔ Different dynamics with B-decay or ISR.
- Comprehensive search of XYZ decaying to J/ψ or ψ' from the ~10^8 Y(1S) decay.

\[ M(\pi^+\pi^-J/\psi) \]
No X(3872) and Y(4260)

\[ M(\pi^+\pi^-\psi') \]
No Y(4360) and Y(4660)

\[ M(K^+K^-J/\psi) \]
\[ M(K^+K^-\psi') \]
No Y(4260) (~3σ evidence by CLEO)
Search for XYZ in the Y(1S) decay(2)

No XYZ states observed from the decay of Y(1S).
Input from theory is needed for interpretation.

M(\phi J/\psi)
M(\phi \psi ')
No X(4140) and X(4350)

M(\pi^+ J/\psi)
M(\pi^+ \psi ')
No Z(3900), Z(4050), and Z(4430)

M(K^+ J/\psi)
M(K^+ \psi ')
No new Z_{cs} states
Excited $\Xi_c$

- Small color spin interaction for charm ($\propto 1/m_1 m_2$).
- $u$-$s$ diquark + charm quark.

- Two excitations:
  - $\lambda$ mode: $c$ and di-quark
  - $\rho$ mode: di-quark

- $\sim 10 \Xi_c$ states observed.
  Excitation mode not identified for many states.
Precise mass, width measurements

- Mass difference of isodoublet = u-d mass difference and EM interactions
  Important input to deduce the wave function.

- Many of measurements are old and statistics not very high (errors are larger than splitting itself).
  For widths, many states have only upper limits.

- New measurements for 5 excited $\Xi_c$ isodoublets decaying into final states with $\Xi_c^+$ or $\Xi_c^0$
  $\Xi_c^+ \rightarrow \Xi_c \gamma$
  $\Xi_c(2645) \rightarrow \Xi_c \pi$
  $\Xi_c(2790) \rightarrow \Xi_c^+ \pi$
  $\Xi_c(2815) \rightarrow \Xi_c \pi\pi$ and $\Xi_c^+ \pi$
  $\Xi_c(2980) \rightarrow \Xi_c \pi\pi$ and $\Xi_c^+ \pi$

- $\Xi_c^+$ and $\Xi_c^0$ are reconstructed from 10 and 7 decay modes.
  Total yields are around $1 \times 10^5$ and $5 \times 10^4$. 
$\Xi_c \pi(\pi)$ (Preliminary)

Reduce background using decay chain $\Xi_c(2815) \rightarrow \Xi_c(2645)\pi \rightarrow \Xi_c\pi\pi$

$M(\Xi_c^0\pi^+\pi^-)$

$M(\Xi_c^{+}\pi^+\pi^-)$

$M(\Xi_c^0\pi^+)$

$M(\Xi_c^{+}\pi^-)$

$M(\Xi_c^0\pi^+\pi^-)$

$M(\Xi_c^{+}\pi^+\pi^-)$

$\Xi_c(2815)^0$

$\Xi_c(2815)^+$

$\Xi_c(2645)^0$

$\Xi_c(2645)^+$

$\Xi_c(2980)^0$

$\Xi_c(2980)^+$
First observations for
$\Xi_c^{(2815)} \rightarrow \Xi'_c \pi$
$\Xi_c^{(2980)} \rightarrow \Xi'_c \pi$

$\Xi'_c(\pi)$ (Preliminary)
## Results (Preliminary)

<table>
<thead>
<tr>
<th></th>
<th>Mass (Mev/c²)</th>
<th>Width (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi_c(2645)^+$</td>
<td>$2645.58 \pm 0.06 \pm 0.07^{+0.28}_{-0.40}$</td>
<td>$2.06 \pm 0.13 \pm 0.13$</td>
</tr>
<tr>
<td></td>
<td>($2645.9 \pm 0.5$)</td>
<td>($2.6 \pm 0.2 \pm 0.4$)</td>
</tr>
<tr>
<td>$\Xi_c(2815)^+$</td>
<td>$2816.73 \pm 0.08 \pm 0.06^{+0.28}_{-0.40}$</td>
<td>$2.43 \pm 0.20 \pm 0.17$</td>
</tr>
<tr>
<td></td>
<td>($2816.6 \pm 0.9$)</td>
<td>(&lt;3.5)</td>
</tr>
<tr>
<td>$\Xi_c(2980)^+$</td>
<td>$2966.0 \pm 0.8 \pm 0.2^{+0.3}_{-0.4}$</td>
<td>$28.1 \pm 2.4^{+1.0}_{-5.0}$</td>
</tr>
<tr>
<td></td>
<td>($2970.7 \pm 2.2$)</td>
<td>(17.9 ± 3.5)</td>
</tr>
<tr>
<td>$\Xi_c'$</td>
<td>$2578.4 \pm 0.1 \pm 0.4^{+0.3}_{-0.4}$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>($2575.6 \pm 3.1$)</td>
<td></td>
</tr>
<tr>
<td>$\Xi_c(2790)^+$</td>
<td>$2791.6 \pm 0.2 \pm 0.1 \pm 0.4^{+0.3}_{-0.4}$</td>
<td>$8.9 \pm 0.6 \pm 0.8$</td>
</tr>
<tr>
<td></td>
<td>($2789.8 \pm 3.2$)</td>
<td>(&lt;15)</td>
</tr>
</tbody>
</table>

- Significant improvement for the accuracy of masses.
  (third error is coming from ground state $\Xi_c$)

- First significant measurement for the widths for many states.
Isospin splitting (Preliminary)

- Isospin splitting also quite accurate!

- Small splitting for $\Xi_c(2645)$ and $\Xi_c'$ (spin 1 di-quark states) consistent with quark model (J. Phys. G 29, 2685 2003).

<table>
<thead>
<tr>
<th>Particle</th>
<th>$M(\Xi_c^+)-M(\Xi_c^0)$ (MeV/$c^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi_c(2645)$</td>
<td>$-0.85 \pm 0.09 \pm 0.08 \pm 0.48$</td>
</tr>
<tr>
<td>$\Xi_c(2815)$</td>
<td>$-3.47 \pm 0.12 \pm 0.05 \pm 0.48$</td>
</tr>
<tr>
<td>$\Xi_c(2980)$</td>
<td>$-4.8 \pm 0.1 \pm 0.2 \pm 0.5$</td>
</tr>
<tr>
<td>$\Xi_c'(2790)$</td>
<td>$-0.8 \pm 0.1 \pm 0.1 \pm 0.5$</td>
</tr>
<tr>
<td>$\Xi_c(2980)$</td>
<td>$-3.3 \pm 0.4 \pm 0.1 \pm 0.5$</td>
</tr>
</tbody>
</table>
Higher excited states (past studies).

Both Belle and BaBar observed
\[ \Xi_c(2980)^+, \Xi_c(3055)^+, \text{ and } \Xi_c(3080)^+ \] in \( \Sigma_c^{++}K^- \) final state.
\[ \Xi_c(3080)^+ \] in \( \Sigma_c^{*++}K^- \) final state (only BaBar observed \( \Xi_c(3123)^+ \)).

All the excited \( \Xi_c \) are observed in (heavy baryon) + (light meson) final states.
(Light baryon) + (heavy meson) decay provides complementary information \( \rightarrow \Lambda D! \).
\( \text{M(ΛD) spectra (Preliminary)} \)

- First observation of \( Ξ_c(3055), (3080) \rightarrow ΛD \)
- First discovery of isospin partner, \( Ξ_c(3055)^0 \)!
- Simultaneous fit for \( \text{M(ΛD}^0) \) with common mass/width, fixed yield ratio.

\[
\begin{align*}
\text{M(Ξ_c(3055))^0} & = 3059.0 \pm 0.5 \pm 0.6 \text{ MeV}/c^2 \\
\Gamma(Ξ_c(3055)^0) & = 6.4 \pm 2.1 \pm 1.1 \text{ MeV}
\end{align*}
\]
Combine with $\Sigma_c^{(*)}K^-$ modes (Preliminary)\(^{17}\)

**Branching fraction ratios:**
- $\Xi_c(3055)^+$
  \[
  \text{Br}(\Lambda D^+)/\text{Br}(\Sigma_c^{++}K^-) = 5.09 \pm 1.01 \pm 0.76
  \]
  Prefer $\Lambda D$
- $\Xi_c(3080)^+$
  \[
  \text{Br}(\Lambda D^+)/\text{Br}(\Sigma_c^{++}K^-) = 1.29 \pm 0.30 \pm 0.15
  \]
  Similar in 3 decays
  \[
  \text{Br}(\Sigma_c^{*++}K^-)/\text{Br}(\Sigma_c^{++}K^-) = 1.07 \pm 0.27 \pm 0.01
  \]

**In the chiral quark model,**
$\Xi_c(3055) = 2D_{\lambda\lambda}(3/2^+)$ and $\Xi_c(3080) = 2D_{\rho\rho}(3/2^+)$.  
(Phys. Rev. D 86, 034024)

They predicted $\Lambda D$ decay is suppressed.
\[\rightarrow\text{Inconsistent}\] with this measurement.

**Mass (MeV/c^2) and width (MeV)**

<table>
<thead>
<tr>
<th></th>
<th>$\Lambda D^+$</th>
<th>$\Sigma_c K^-$</th>
<th>$\Sigma_c^{*} K^-$</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M(\Xi_c(3055)^+)$</td>
<td>3055.8 ± 0.4 ± 0.2</td>
<td>3058.1 ± 1.0 ± 2.1</td>
<td>-</td>
<td>3055.9 ± 0.4</td>
</tr>
<tr>
<td>$M(\Xi_c(3080)^+)$</td>
<td>3079.6 ± 0.4 ± 0.2</td>
<td>3077.9 ± 0.4 ± 0.7</td>
<td>3076.9 ± 0.3 ± 0.2</td>
<td>3077.9 ± 0.9</td>
</tr>
<tr>
<td>$\Gamma(\Xi_c(3055)^+)$</td>
<td>7.0 ± 1.2 ± 1.5</td>
<td>9.7 ± 3.4 ± 3.3</td>
<td>-</td>
<td>7.8 ± 1.2 ± 1.5</td>
</tr>
<tr>
<td>$\Gamma(\Xi_c(3080)^+)$</td>
<td>&lt;6.3</td>
<td>2.4 ± 0.9 ± 1.6</td>
<td>3.2 ± 1.3 ± 1.3</td>
<td>3.0 ± 0.7 ± 0.4</td>
</tr>
</tbody>
</table>
In the baryon sector, Doubly Cabbibo Suppressed (DCS) decay has NEVER been observed. $\Lambda_c^+ \to pK^+\pi^-$ is expected to be sensitive.

Naively, ratio to CF decay, $pK^-\pi^+$ is expected to be

$$\frac{B(\Lambda_c^+ \to pK^+\pi^-)}{B(\Lambda_c^+ \to pK^-\pi^+)} \approx \tan^4 \theta_c$$

In the CF decay, the $W$ exchange diagram may contribute.
Observation of $\Lambda_c^+ \rightarrow pK^+\pi^-$

**CF mode:** $pK^-\pi^+$

$$\left(1.452 \pm 0.0015\right) \times 10^6$$ events

**DCS mode:** $pK^+\pi^-$

- $3587 \pm 380$ events
- $\Lambda K^+$ decay subtracted
- Significance: $9\sigma$
Branching fraction ratio

- Branching fraction ratio = (2.35 ± 0.27 (Stat) ± 0.21 (Sys)) × 10^{-3} = (0.82 ± 0.12) × tan^4 \Theta

- After subtracting contribution of Λ(1520) or Δ intermediate, which contribute only on the CF decay, the ratio is (1.10 ± 0.17) × tan^4 \Theta

- Contribution from W exchange diagram is small.
Belle is actively publishing on charmonia and charmed baryons!

$\chi_{c1}(2P)$ not observed in $\chi_{c1}\pi\pi$:
→ Comparable with $X(3872)$ as admixture picture.

No XYZ from $\Upsilon(1S)$ decay. Theoretical input needed to understand.

New results on excited $\Xi_c$ baryons.
- Precise mass/width for excited states decaying into $\Xi_c$
- $\Xi_c(3055)$ and $\Xi_c(3080)$ into $\Lambda D$ final state.
  Discovery of $\Xi_c(3055)^0$ and relative branching fraction measurements.

First observation of DCS decay of baryon: $\Lambda_c^+ \rightarrow pK^+\pi^-$

Stay tuned for more results from upcoming Belle II!
Comparison of 3 body $B \to \chi_{c1} \pi K$ and $B \to \chi_{c2} \pi K$

- First observation of two $B \to \chi_{c2} X$ exclusive decays.

- $K^* : K^*(1430)$ etc is different for $\chi_{c1}$ and $\chi_{c2}$. → Important input for decay dynamics.

- $M(\chi_{c1} \pi)$ consistent with previous Belle observation of two charged $Z$ states. No narrow structure in $M(\chi_{c2} \pi)$. 
$\Xi_c^+$ reconstruction

$\Xi_c^0$ reconstruction
B decays to $\chi_{c1}$ and $\chi_{c2}$

- The two body decay $B \to K^+ \chi_{c2}$ is suppressed relative to $\chi_{c1}$ (~2 %).
  - Due to the angular momentum conservation. Need FSI.

- In the inclusive measurement, the suppression is moderate (~25 %).
  $\rightarrow$ Multi body decays. Study of intermediate resonance clarifies decay dynamics.

- Most plausible explanation of $X(3872)$ is mixing of DD* molecule and $\chi_{c1}(2p)$, which is not observed so far.
  $\rightarrow$ Search for $X(3872)$ and $\chi_{c1}(2p)$ in $B \to K^+ \chi_{c1} \pi^+ \pi^-$. 

1. Improvement measurement of inclusive $\chi_{c12}$ with full statistics
2. Several (new) exclusive decay modes and study of intermediate states.
Inclusive measurements

**M(J/ψγ)**

Differential branching fractions

<table>
<thead>
<tr>
<th></th>
<th>New ((10^{-3}))</th>
<th>Previous ((10^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B \to χ_{c1} X)</td>
<td>3.03 ± 0.05 ± 0.24</td>
<td>2.60 ± 0.17 ± 0.23</td>
</tr>
<tr>
<td>(B \to χ_{c2} X)</td>
<td>0.70 ± 0.06 ± 0.10</td>
<td>0.97^{+0.16}_{-0.19} ± 0.13</td>
</tr>
</tbody>
</table>

- Continuum, feed down are subtracted.
- Good agreement with previous measurements with improved accuracy.
- Differential measurement shows most of \(χ_{c2}\) decay are multi-body.

Belle, PRL 89, 011803(2002)
Exclusive measurements

<table>
<thead>
<tr>
<th>Decay</th>
<th>Yield (Y)</th>
<th>$S(\sigma)$</th>
<th>$\epsilon$ (%)</th>
<th>$B$ ($10^{-4}$)</th>
<th>$\mathcal{R}_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \to \chi_{cJ}\pi^-K^+$</td>
<td>$2774 \pm 66$</td>
<td>$66.7$</td>
<td>$17.9$</td>
<td>$4.97 \pm 0.12 \pm 0.28$</td>
<td>$0.14 \pm 0.02$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$206 \pm 25$</td>
<td>$8.7$</td>
<td>$16.2$</td>
<td>$0.72 \pm 0.09 \pm 0.05$</td>
<td></td>
</tr>
<tr>
<td>$B^+ \to \chi_{cJ}\pi^+K^0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$0.20 \pm 0.04$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td>$770 \pm 35$</td>
<td>$33.7$</td>
<td>$8.6$</td>
<td>$5.75 \pm 0.26 \pm 0.32$</td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$76.4 \pm 14.7$</td>
<td>$4.6$</td>
<td>$7.5$</td>
<td>$1.16 \pm 0.22 \pm 0.12$</td>
<td></td>
</tr>
<tr>
<td>$B^+ \to \chi_{cJ}\pi^0K^+$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$&lt; 0.21$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td>$803 \pm 70$</td>
<td>$15.6$</td>
<td>$7.8$</td>
<td>$3.29 \pm 0.29 \pm 0.19$</td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$17.5 \pm 28.4$</td>
<td>$0.4$</td>
<td>$7.0$</td>
<td>$&lt; 0.62$</td>
<td></td>
</tr>
<tr>
<td>$B^+ \to \chi_{cJ}\pi^0K^+$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$0.36 \pm 0.05$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td>$1502 \pm 70$</td>
<td>$19.2$</td>
<td>$12.8$</td>
<td>$3.74 \pm 0.18 \pm 0.24$</td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$269 \pm 34$</td>
<td>$8.4$</td>
<td>$11.4$</td>
<td>$1.34 \pm 0.17 \pm 0.09$</td>
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</tr>
<tr>
<td>$B^0 \to \chi_{cJ}\pi^+\pi^-K^0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$&lt; 0.61$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td>$268 \pm 30$</td>
<td>$7.1$</td>
<td>$5.4$</td>
<td>$3.16 \pm 0.35 \pm 0.32$</td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$37.8 \pm 14.2$</td>
<td>$1.8$</td>
<td>$4.8$</td>
<td>$&lt; 1.70$</td>
<td></td>
</tr>
<tr>
<td>$B^0 \to \chi_{cJ}\pi^-\pi^0K^+$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$&lt; 0.25$</td>
</tr>
<tr>
<td>$\chi_{c1}$</td>
<td>$545 \pm 81$</td>
<td>$6.5$</td>
<td>$5.0$</td>
<td>$3.52 \pm 0.52 \pm 0.24$</td>
<td></td>
</tr>
<tr>
<td>$\chi_{c2}$</td>
<td>$76.7 \pm 42.0$</td>
<td>$4.3$</td>
<td></td>
<td>$&lt; 0.74$</td>
<td></td>
</tr>
</tbody>
</table>

- First observation of $\chi_{c2}$ exclusive decays
- First observation of $\chi_{c1}$ decays with $2\pi$.
- Improved previous measurements.
- Cover 58 (32) % of inclusive BF for $\chi_{c1}$ ($\chi_{c2}$).
Upper limit on the branching fractions

<table>
<thead>
<tr>
<th>State</th>
<th>$N_{\text{fit}}$</th>
<th>$N_{\text{up}}$</th>
<th>$\varepsilon(%)$</th>
<th>$\sigma_{\text{syst}}(%)$</th>
<th>$\Sigma(\sigma)$</th>
<th>$B_{\text{prod}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X(3872) \rightarrow \pi^+\pi^- J/\psi$</td>
<td>4.8±15.4</td>
<td>31.4</td>
<td>3.26</td>
<td>18.7</td>
<td>0.3</td>
<td>&lt; 9.5 × 10^{-6}</td>
</tr>
<tr>
<td>$Y(4260) \rightarrow \pi^+\pi^- J/\psi$</td>
<td>-31.1±88.9</td>
<td>134.6</td>
<td>3.50</td>
<td>35.6</td>
<td>-</td>
<td>&lt; 3.8 × 10^{-5}</td>
</tr>
<tr>
<td>$Y(4260) \rightarrow \pi^+\pi^- \psi(2S)$</td>
<td>6.7±29.4</td>
<td>56.9</td>
<td>0.71</td>
<td>35.0</td>
<td>0.2</td>
<td>&lt; 7.9 × 10^{-5}</td>
</tr>
<tr>
<td>$Y(4360) \rightarrow \pi^+\pi^- \psi(2S)$</td>
<td>-25.4±30.1</td>
<td>45.6</td>
<td>0.86</td>
<td>50.0</td>
<td>-</td>
<td>&lt; 5.2 × 10^{-5}</td>
</tr>
<tr>
<td>$Y(4660) \rightarrow \pi^+\pi^- \psi(2S)$</td>
<td>-55.0±26.2</td>
<td>23.1</td>
<td>1.06</td>
<td>40.7</td>
<td>-</td>
<td>&lt; 2.2 × 10^{-5}</td>
</tr>
<tr>
<td>$Y(4260) \rightarrow K^+K^- J/\psi$</td>
<td>-13.7±10.9</td>
<td>14.5</td>
<td>1.91</td>
<td>45.8</td>
<td>-</td>
<td>&lt; 7.5 × 10^{-6}</td>
</tr>
<tr>
<td>$Y(4140) \rightarrow \phi J/\psi$</td>
<td>-0.1±1.2</td>
<td>3.6</td>
<td>0.69</td>
<td>11.0</td>
<td>-</td>
<td>&lt; 5.2 × 10^{-6}</td>
</tr>
<tr>
<td>$X(4350) \rightarrow \phi J/\psi$</td>
<td>2.3±2.5</td>
<td>7.6</td>
<td>0.92</td>
<td>10.4</td>
<td>1.2</td>
<td>&lt; 8.1 × 10^{-6}</td>
</tr>
<tr>
<td>$Z_c(3900)_{\pm} \rightarrow \pi^\pm J/\psi$</td>
<td>-26.5±39.1</td>
<td>57.5</td>
<td>4.39</td>
<td>47.3</td>
<td>-</td>
<td>&lt; 1.3 × 10^{-5}</td>
</tr>
<tr>
<td>$Z_c(4200)_{\pm} \rightarrow \pi^\pm J/\psi$</td>
<td>-238.6±154.2</td>
<td>235.1</td>
<td>3.87</td>
<td>48.4</td>
<td>-</td>
<td>&lt; 6.0 × 10^{-5}</td>
</tr>
<tr>
<td>$Z_c(4430)_{\pm} \rightarrow \pi^\pm J/\psi$</td>
<td>94.2±71.4</td>
<td>195.8</td>
<td>3.97</td>
<td>34.4</td>
<td>1.2</td>
<td>&lt; 4.9 × 10^{-5}</td>
</tr>
<tr>
<td>$Z_c(4050)_{\pm} \rightarrow \pi^\pm \psi(2S)$</td>
<td>37.0±47.7</td>
<td>112.7</td>
<td>1.27</td>
<td>46.2</td>
<td>0.4</td>
<td>&lt; 8.8 × 10^{-5}</td>
</tr>
<tr>
<td>$Z_c(4430)_{\pm} \rightarrow \pi^\pm \psi(2S)$</td>
<td>23.2±42.4</td>
<td>92.0</td>
<td>1.35</td>
<td>47.1</td>
<td>0.1</td>
<td>&lt; 6.7 × 10^{-5}</td>
</tr>
<tr>
<td>$Z_{cs} \rightarrow K^\pm J/\psi$</td>
<td>-22.2±17.4</td>
<td>22.4</td>
<td>3.88</td>
<td>48.7</td>
<td>-</td>
<td>&lt; 5.7 × 10^{-6}</td>
</tr>
</tbody>
</table>