Charmless B decay measurements at Belle

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on behalf of the Belle collaboration

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Introduction

• Charmless B decays:
  - Suppressed in Standard Model with small BF (usually < $10^{-5}$).
  - Sensitive to non-SM physics within the penguin loop in many decays.
  - Some SM sensitivity tests with precision measurement in the flavor sector.
  - Discrepency in measurement: indicate non-SM physics.

• Main challenge in experimental measurement: Small BF and large $ee \to q\bar{q}$ ($q=u,d,s,c$) background.
  - Combinatorial background in reconstruction with the same final state.
  - PID & continuum suppression.

Results of these six decay modes will be reported.

• $B \to p\bar{p}\pi\pi$ PRD 101, 052012 (2020)
• $B^+ \to K^+K^0\pi^+$
• $B^+ \to \pi^+\pi^0\pi^0$
• $B^0_s \to \eta'X_{s\bar{s}}$ PRD 104, 012007 (2021)
• $B^0_s \to \eta'\eta$ PRD 104, L031101 (2021)
• $B^0_s \to \eta'K^0_s$
KEKB collider

- An asymmetric energy $e^+e^-$ collider at KEK.
  - LER($e^+$) 3.5 GeV.
  - HER($e^-$) 8 GeV.
  - Crossing angle: $\pm 11$ mrad.

- Target:
  - $e^+e^- \rightarrow Y(4S) \rightarrow B\bar{B}$ for $B$ decay: 711 fb$^{-1}$.
  - $e^+e^- \rightarrow Y(5S) \rightarrow B_0^{(*)0}\bar{B}_0^{(*)0}$ for $B_0$ decay: 121 fb$^{-1}$.

- Main background: $e^+e^- \rightarrow q\bar{q}$ ($q=u,d,s,c$) with 3 times larger cross section.

Analysis overview

- **Blind analysis:**
  - Use Monte Carlo (MC) samples for signal and backgrounds study.
  - Signal is scaled with an assumed BF.

- **Backgrounds:**
  - Continuum $e^+e^- \rightarrow q\bar{q}$ (q=u,d,s,c):
    Based on the decay shape difference, use multivariate tools (Fisher, Neuro-Network) with various event topology variables.

  - $B\bar{B}$ background: Looking for peaking background (usually from charmed) and apply proper veto on invariant mass.
    "Generic" B background: $b \rightarrow c$.
    "Rare" B background: $b \rightarrow u,d,s$.

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PRL 41, 1581 (1978)
Ann. Human Genet. 7, 179 (1936)
PRL 91, 261801 (2003)
Analysis overview (cont'd)

- Major variables for signal B identification:
  - Energy difference: \( \Delta E \equiv E_B - E_{\text{beam}} \) in C.M. frame
  - Beam-energy constrained mass: \( M_{bc} \equiv \sqrt{E_{\text{beam}}^2/c^4 - |\vec{p}_B/c|^2} \) in C.M. frame
  - Discriminant for continuum suppression.

- Signal extraction:
  Extended unbinned maximum likelihood fit on data with above variables.

- Branching fraction determination:
  - \( N_{BB} = 772M \) for \( Y(4S) \) data of 771 fb\(^{-1}\).
  - \( Y(5S): 121 \text{ fb}^{-1} \) with 3 branches:
    \( B^{*0}_s \bar{B}^{*0}_s \) 87.0\%, \( B^{*0}_s \bar{B}^0_s \) 7.3\%, \( B^0_s \bar{B}^0_s \) 5.7\%.

  ▶ Fraction containing \( B^0_s \):
    \( f_s = 0.201 \pm 0.031 \) (world average)
  ▶ \( N_{B0s} = (16.60 \pm 2.68) \times 10^6 \)

\[
\begin{align*}
\beta &= \frac{N_{\text{sig}}}{\epsilon \times \eta \times N_{\overline{B}B}} \\
\end{align*}
\]

Fitted signal yield

Signal reconstruction eff. & calibration due to systematic effects.

Total number of \( B_{(s)} \) events in Belle.
• Charmless B decays: good field to search for CP violation due to interference between $b \to s$ penguin and $b \to u$ tree.
  - Evidence of direct CP violation in $B^+ \to p\bar{p}K^+$ by LHCb.  \textit{PRL 113, 141801 (2014)}
  - $M_{p\bar{p}}$ peaks near threshold.  \textit{PRL 88, 181803 (2002)}
  - In $p\bar{p}$ reset frame, $K$ is produced preferably in the $\bar{p}$ direction.  
    Opposite to that of $B^+ \to p\bar{p}\pi^+$, in which $b \to u$ dominates.  \textit{PLB 659, 80 (2008)}

• Most of baryonic B decays presumably proceed predominantly via $b \to s$.
  - Measurement of $b \to u$ modes is important for theoretical investigation based on a generalized factorization approach.  \textit{PRD 96, 051103 (2017)}

• $B^0 \to p\bar{p}\pi^+\pi^-$: Measured by LHCb.
• $B^+ \to p\bar{p}\pi^+\pi^0$: First measurement by this study.
B → p¯pππ: Data result

- 2D fit with ΔE, M_{bc}.
- Signal + continuum bkg.

<table>
<thead>
<tr>
<th></th>
<th>B^0 → p¯pπ^+π^-</th>
<th>B^+ → p¯pπ^+π^0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal yield</td>
<td>73.8^{+15.4}_{-14.9}</td>
<td>151 ± 39</td>
</tr>
<tr>
<td>Significance (σ)</td>
<td>5.5</td>
<td>5.4</td>
</tr>
<tr>
<td>BF (10^{-6})</td>
<td>0.83 ± 0.17 ± 0.17</td>
<td>4.58 ± 1.17 ± 0.67</td>
</tr>
</tbody>
</table>

M_{bc} > 5.27 GeV/c^2

Signal-enhanced projection plot of data fit result

|ΔE| < 0.03 GeV
• Measure the signal yields in different bins with the same 2D fit method.

• \(B^+\) mode: a \(\chi^2\) fit to separate \(B^+ \to p\bar{p}\rho^+\) and nonresonant.
  
  – \(B^+ \to p\bar{p}\rho^+\): Breit-Widner convolved with a Gaussian resolution function. Signal yield = \(86 \pm 41\).
  Measured \(B(B^+ \to p\bar{p}\pi^+\pi^0)\): \(~10X\) smaller than predicted \(B(B^+ \to p\bar{p}\rho^+)\).

\[\text{PRD 75, 094013 (2007)}\]
B → p̅pππ: $M_{pp}$ distribution

- Measure the signal yields in different bins with the same 2D fit method.
- Dibaryon mass system tends to peak near the low mass threshold.
- 2.85 - 3.128 GeV/c²: charmonium-enhanced region. e.g. J/ψ.

<table>
<thead>
<tr>
<th>$M_{pp}$ (GeV/c²)</th>
<th>$N_s$</th>
<th>$\sigma$</th>
<th>$\varepsilon_{eff}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{pp} &lt; 2.85$</td>
<td>$26.1_{-9.1}^{+10.0}$</td>
<td>4.0</td>
<td>9.8</td>
</tr>
<tr>
<td>$2.85 &lt; M_{pp} &lt; 3.128$</td>
<td>$19.6_{-9.3}^{+10.2}$</td>
<td>2.9</td>
<td>9.9</td>
</tr>
<tr>
<td>$3.128 &lt; M_{pp}$</td>
<td>$29.1_{-13.1}^{+16.2}$</td>
<td>3.5</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Equally distributed below and above the charmonium-enhanced region

BF in threshold enhancement region is consistent with LHCb result.

<table>
<thead>
<tr>
<th>$M_{pp}$ (GeV/c²)</th>
<th>$N_s$</th>
<th>$\sigma$</th>
<th>$\varepsilon_{eff}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{pp} &lt; 2.85$</td>
<td>$133.5_{-25.2}^{+26.6}$</td>
<td>5.1</td>
<td>4.8</td>
</tr>
<tr>
<td>$2.85 &lt; M_{pp} &lt; 3.128$</td>
<td>$12.3_{-9.7}^{+10.3}$</td>
<td>1.4</td>
<td>4.0</td>
</tr>
<tr>
<td>$3.128 &lt; M_{pp}$</td>
<td>$-3.8_{-13.8}^{+15.1}$</td>
<td>...</td>
<td>3.4</td>
</tr>
</tbody>
</table>

The lowest bin dominates.
Possible contributions in SM:

- Tree, W-exchange ($KK^*$), strong penguin, electroweak penguin ($\phi\pi$), where experimental limit of $B(B^+ \to \phi\pi^+)$: $1.5 \times 10^{-7}$

An unidentified structure observed Babar and LHCb.

- LHCb reported large CP asymmetry in low $M_{KK}$ as well.

Theoretical explanation:

- Final-state state interactions may enhance CP violation.
- LHCb also suggests the large CP asymmetry in low $M_{KK}$ originates from $\pi\pi \leftrightarrow KK$ rescattering.

Previous report by full Belle data: Inclusive BF and $A_{CP}$.

This study will update the following with a re-optimized binning:

- Angular distribution of KK at low mass.
- $dBF$ along $M_{K\pi}$. 

References:

- PRL 123, 231802 (2019)
- PRL 112, 011801 (2014)
- PRD 96, 031101(R) (2017)
- PRD 90, 112004 (2014)
- PLB 726, 337 (2013)
- PLB 728, 85 (2014)
- PRD 89, 094013 (2014)
\( \text{B}^+ \rightarrow \text{K}^+ \text{K}^- \pi^+ \): \( M_{\text{KK}} \) distribution & \( \cos \theta_{\text{hel}} \)

- 2D fit with \( \Delta E, M_{bc} \) within each bin.

\begin{itemize}
  \item \( \text{B}^+ \rightarrow \text{K}^+ \text{K}^- \pi^+ \): \( M_{\text{KK}} \) distribution & \( \cos \theta_{\text{hel}} \)\n  \item \( \text{LHCb model: from PRL 123, 231802 (2019)} \)
  \item \( M_{\text{KK}} < 1.1 \text{ GeV/c}^2 \): \( A_{\text{CP}} = -0.90 \pm 0.17 \pm 0.03 \) with 4.8σ significance
  \item Events within \( M_{\text{KK}} < 1.1 \text{ GeV/c}^2 \)
  \item Angle between \( \text{B}^+ \) and \( \text{K}^+ \) in KK rest frame.
  \item Consistent with a coherent sum of spin-0 and spin-1.
  \item P-wave and S-wave fraction: \( r = A_P/A_S = 0.31 \pm 1.21 \)
  \item Forward-backward asymmetry: \( A_{\text{FB}} = 0.21 \pm 1.09 \)
\end{itemize}

\begin{table}
\begin{tabular}{l|cccc|}
\hline
                & \( X_{J=0} \) & \( X_{J=1} \) & \( X_{J=2} \) & coherent sum & LHCb model \\
\hline
\( \chi^2/ndf \) & 1.9/4        & 14.4/4       & 1.6/3        & 0.5/2        & 7.0/4        \\
p-value         & 0.750        & 0.006        & 0.815        & 0.792        & 0.136        \\
\hline
\end{tabular}
\end{table}
2D fit with $\Delta E$, $M_{bc}$ within each bin.

LHCb model: from PRL 123, 231802 (2019)
  
  - Consistent with our data.

Model 1: 10% of $X_{KK}\pi$ with spin-0.

Model 2: Expected resonances $K^{*0}K^+$ and $K^{*0}_0K^+$.
Charmless three-body B decays are useful to study the properties of the weak interaction in the quark sector.

Dalitz plot analysis: search for intermediate resonances and localized $A_{CP}$. Also to constrain magnitudes and phases of the CKM matrix elements. For instance, $B \rightarrow \rho \pi$ for $\phi_2 (\alpha)$ and also $B^+ \rightarrow \chi_{c0} \pi^+$ for $\phi_3 (\gamma)$.

Similar measurement on $B^+ \rightarrow \pi^+ \pi^- \pi^+$ by Babar and LHCb.
- $BF = (15.2 \pm 0.6 \pm 1.2 \pm 0.4) \times 10^{-6}$
- Full amplitude analysis.

Upper limit of $B^+ \rightarrow \pi^+ \pi^0 \pi^0$ was reported: $8.9 \times 10^{-4}$ at 90 C.L. by CLEO.

$B^+ \rightarrow \rho(770)^+ \pi^0$: $(10.9 \pm 1.4) \times 10^{-6}$, by Belle and Babar.
- Majority of the $B^+ \rightarrow \pi^+ \pi^0 \pi^0$ decays.
B^+ \rightarrow \pi^+\pi^0\pi^0: Data result

- Major challenge: Shower leakage due to 2 $\pi^0$ and correlation between energy and other variables.
  - A $\pi^0$ momentum threshold 0.5 GeV/c is adopted.

- 3D fit with $\Delta E$, $M_{bc}$, $C'_{NN}$ (Continuum suppression with Neuro-Network).

- Signal yield = 1062.8 $^{+86.8}_{-85.4}$
  - Inclusive BF = $(19.0 \pm 1.5 \pm 1.4) \times 10^{-6}$

- $A_{CP} = (9.2 \pm 6.8)\%$

Signal-enhanced projection plot of data fit result
B^+ \to \pi^+\pi^0\pi^0: Structure in Dalitz plot

- Signal isolation on Dalitz plot (M_{\pi\pi}): sPlot technique.
  - 2D binned fit on sWeights M_{\pi\pi} histogram: Incoherent sum of PDFs.

- Small contribution from non-resonant: < 6x10^{-7} @ 90% C.L.

- B(B^+ \to \rho(770)^+\pi^-) = (11.2 \pm 1.1 \pm 0.9 \pm 1.4)x10^{-6}

- New structure at low M_{\pi^0\pi^0} region from multiple resonances with a significance of 9.2\sigma.
  - Combined BF = (6.4 \pm 0.9 \pm 0.6)x10^{-6}

1st uncertainty: stat.
2nd uncertainty: syst.
3rd uncertainty (if any): interference effect.

sWeighted Dalitz plot

2D fit result
**B^+ → π^+π^0π^0: Localized A_{CP}**

- 2D fit on the charge-separated sWeights M_{ππ} histograms.
- An asymmetry is found at M_{π0π0} ~ 1.4 GeV/c^2.
  - Corresponding to f_2(1270)^0π^+.
  - Also seen in B^+ → π^+π^-π^+ by Babar and LHCb.

\[
A_{CP} = (92 \pm 28)\% \\
3.2\sigma \text{ confirmed by 3D fit within selected region.}
\]

PRD 79, 072006 (2009)  
PRD 101, 012006 (2020)
Introduction on $\eta'$ modes study

• $\eta'$: anomalous production in B decays.
  - First observed at CLEO. \[ \text{PRL 81, 1786–1790 (1998)} \]
  \[ \text{PRD 68, 011101 (2003)} \]
  - $\eta'$ mass is higher than is expected from symmetry considerations. \[ \text{PRD 97, 054508 (2018)} \]
  - Unexpected BF enhancement seen in some inclusive measurements e.g. $B \to \eta'X_s$.
  - Large rate of exclusive modes (e.g. $B^+ \to \eta' K^+$) could be accounted for SM factorization. \[ \text{hep-ph/9707354} \]
  - New observation on decay with $\eta'$ could provide information for better understanding on it.
• First measurement based on semi-inclusive method.
  - To have better understanding on \( \eta' \) mass and BF issues by models such as glueball coupling.  

\[ \eta' \rightarrow \pi^+\pi^-\eta, \quad \eta \rightarrow \gamma\gamma. \]

- \( X_{ss} \): Use PYTHIA6 for MC.
  - \( X_{ss} \): Use PYTHIA6 for MC.
  - Reconstruct \( K^+K^- + n\pi \) and \( K^+K^0_S + n\pi \): sum-of-exclusive

\[ B^0_s \rightarrow \eta'X_{ss}^- \text{ : Data result} \]

\[ 1 \text{D fit with } M_{bc} \text{ in bins of } M(X_{ss}): \text{ with } -0.12 < \Delta E < 0.05 \text{ GeV.} \]

\[ \eta' \rightarrow \pi^+\pi^-\eta, \quad \eta \rightarrow \gamma\gamma. \]

\[ X_{ss}: \text{ Use PYTHIA6 for MC.} \]

Reconstruct \( K^+K^- + n\pi \) and \( K^+K^0_S + n\pi \): sum-of-exclusive

**Sum of fits to all \( M(X_{ss}) \) bins**

Multiple peaks in signal:
- Energy shift due to missing \( \gamma \) in \( B^0_s \rightarrow B^0 \gamma \) decay.

\[ Y(5S) \rightarrow B^0 \bar{B}^0 \]

\[ Y(5S) \rightarrow B^{*0} \bar{B}^0 \]

\[ Y(5S) \rightarrow B^{0*} \bar{B}^0 \]
B^0_s → η'X_{sS} : Data result (cont'd)

- \( B(B^0_s → η'X_{sS}) = (-0.7 ± 8.1 ± 0.7 \pm 0.1) \times 10^{-4} \)
  - UL: 1.4x10^{-3} @ 90 C.L.

- \( R(η') = B(B^0_s → η'X_{sS})/B(B → η'X_s) = -0.2 ± 2.1 ± 0.2 \pm 0.03 \)
  - UL: 3.5 @ 90% C.L.
  - ~1 assuming naive SU(3) symmetry.

<table>
<thead>
<tr>
<th>(M(X_{sS}))</th>
<th>(\epsilon' (%))</th>
<th>(N_{\text{sig}})</th>
<th>(B(B^0_s → η'X_{sS}) \times 10^{-4})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0–1.2</td>
<td>3.60 ± 0.08</td>
<td>0.4+2.6−1.9</td>
<td>0.05+0.30−0.22 (stat) +0.004−0.005 (syst)</td>
</tr>
<tr>
<td>1.2–1.4</td>
<td>2.82 ± 0.08</td>
<td>0.08+2.4−1.7</td>
<td>0.01+0.36−0.28 (stat) +0.001−0.001 (syst)</td>
</tr>
<tr>
<td>1.4–1.6</td>
<td>0.90 ± 0.04</td>
<td>0.7+2.5−1.8</td>
<td>0.3+1.1−0.8 (stat) +0.04−0.05 (syst)</td>
</tr>
<tr>
<td>1.6–1.8</td>
<td>0.54 ± 0.03</td>
<td>0.4+2.1−1.4</td>
<td>0.3+1.6−1.1 (stat) +0.05−0.01 (syst)</td>
</tr>
<tr>
<td>1.8–2.0</td>
<td>0.34 ± 0.03</td>
<td>1.4+2.6−2.0</td>
<td>1.7+3.3−2.5 (stat) +0.4−0.6 (syst)</td>
</tr>
<tr>
<td>2.0–2.2</td>
<td>0.22 ± 0.02</td>
<td>0.3+3.7−3.4</td>
<td>0.6+7.1−6.4 (stat) +0.2−0.2 (syst)</td>
</tr>
<tr>
<td>2.2–2.4</td>
<td>0.14 ± 0.02</td>
<td>−2.3+3.8−3.4</td>
<td>−7.0+11.6−10.4 (stat) +1.7−4.1 (syst)</td>
</tr>
</tbody>
</table>

\(X_{sS} : K^+K^- + n\pi\)

\(X_{sS} : K^+K^0_s + n\pi\)

Uncertainty:
1\(^{st}\): stat.
2\(^{nd}\): syst.
3\(^{rd}\): X_{sS} fragmentation in PYTHIA6
4\(^{th}\): \(N(B^{(*)0}_s B^{(*)0}_s)\)
$B^0_s \rightarrow \eta'\eta$: Data result

- Only through transitions sensitive to BSM physics.
  - SM prediction: $(2 - 4) \times 10^{-5}$.
  - BF of $B^0_{d,s} \rightarrow \eta(')\eta(')$: extract CPV parameters from SU(3)/U(3) symmetry.

- 3D fit with $\Delta E$, $M_{bc}$, $M_{\eta'}$.
  - $\eta' \rightarrow \pi^+\pi^-\eta$, $\eta \rightarrow \gamma\gamma$.

- Signal yield = $2.7 \pm 2.5$.

$$f_s \times \mathcal{B}(B^0_s \rightarrow \eta'\eta) \quad (0.51 \pm 0.44 \pm 0.09) \times 10^{-5}$$
$$< 1.3 \times 10^{-5} \text{ @ 90\% CL}$$

$$\mathcal{B}(B^0_s \rightarrow \eta'\eta) \quad (2.5 \pm 2.2 \pm 0.6) \times 10^{-5}$$
$$< 6.5 \times 10^{-5} \text{ @ 90\% CL}$$

Signal-enhanced projection plot of data fit result

1\(^{st}\) uncertainty: stat.
2\(^{nd}\) uncertainty: syst.
**B^0_s → η'K_S:** Data result

- Contributions from gluonic and electroweak penguin amplitudes.
  - Sensitive to BSM physics which could affect decay rates and CPV.
  - SM prediction: \((0.72 - 4.5) \times 10^{-6}\)

- 3D fit with \(\Delta E, M_{bc}, M_{η'}\).
  - \(η' \rightarrow π^+π^-η, η \rightarrow γγ\).

- Signal yield = \(-3.21 \pm 1.85\).
  - UL @ 90% C.L.: 
    \[ f_s \times B(B^0_s \rightarrow η'K^0_S) \] 
    \[ B(B^0_s \rightarrow η'K^0_S) \] 
    \(< 1.64 \times 10^{-6}\) 
    \(< 8.16 \times 10^{-6}\)

**Signal-enhanced projection plot of data fit result**
Summary

- $B \rightarrow p\bar{p}\pi\pi$:
  - First measurement for $B^+ \rightarrow p\bar{p}\pi^+\pi^0$. Search for $\rho$ modes.

- $B^+ \rightarrow K^+K^-\pi^+$:
  - Angular study on KK system at low mass with large $A_{CP}$.

- $B^+ \rightarrow \pi^+\pi^0\pi^0$:
  - New $\pi^0\pi^0$ structure with multiple resonances, and large $A_{CP}$ at $M_{\pi^0\pi^0} \sim 1.4$ GeV/c$^2$.

- $B^0_s \rightarrow \eta'X_{s\bar{s}}$, $B^0_s \rightarrow \eta\eta$, $B^0_s \rightarrow \eta'K^0_S$:
  - UL on BF is set.

- Looking forward to larger data from Belle II to improve these studies and to have more new results.
Backup
B^+ \to \pi^+\pi^0\pi^0: Summary of results

- Inclusive BF: Efficiency is determined by the signal model from 2D fit.
- BF(B^+ \to \rho(770)^+\pi^0): We consider the interference effect with B^+ \to \rho(1450)^+\pi^0.
- BF of the \pi^0\pi^0 structure can't be reported separated due to lack of information: highly overlapping PDFs, large variations of masses and widths, interference.

<table>
<thead>
<tr>
<th>Decay mode</th>
<th>Mass</th>
<th>Width</th>
<th>(\epsilon) (%)</th>
<th>Fitted yield</th>
<th>(\mathcal{B}) ((10^{-6}))</th>
<th>(\mathcal{A}_{CP}) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\pi^+\pi^0\pi^0) (inclusive)</td>
<td>8.1</td>
<td>1063 ± 86</td>
<td></td>
<td>19.0 ± 1.5 ± 1.4</td>
<td>9.2 ± 6.8 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>Non-resonant</td>
<td></td>
<td></td>
<td></td>
<td>(\rho(770)^+\pi^0), (\rho(770)^+ \to \pi^+\pi^0)</td>
<td>775.5</td>
<td>150.3</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(\rho(1450)^+\pi^0), (\rho(1450)^+ \to \pi^+\pi^0)</td>
<td>1465</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(f_0(980)^+\pi^0), (f_0(980)^+ \to \pi^0\pi^0)</td>
<td>980</td>
<td>50</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>(f_2(1270)^+\pi^0), (f_2(1270)^0 \to \pi^0\pi^0)</td>
<td>1275.4</td>
<td>185.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(f_0(600)^+\pi^0), (f_0(600)^0 \to \pi^0\pi^0)</td>
<td>600</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(X\pi^+, X \to \pi^0\pi^0)</td>
<td>–</td>
<td>–</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(f_0(1370)^+\pi^0), (f_0(1370)^0 \to \pi^0\pi^0)</td>
<td>1400</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(\chi_c\pi^+\pi^0), (\chi_c \to \pi^0\pi^0)</td>
<td>3415.2</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>(\chi_{c2}\pi^+\pi^0), (\chi_{c2} \to \pi^0\pi^0)</td>
<td>3556.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

1st uncertainty: stat.
2nd uncertainty: syst.
3rd uncertainty (if any): interference effect.