**INTRODUCTION**

- $X(3872)$ First observed in 2003 by Belle [PRL 91, 202001 (2003)]
- $J^{PC} = 1^{++}$ [PRL 110, 222001 (2013)]
- Close to $D^0 \bar{D}^{*0}$ threshold → meson molecule? [PLB 725, 127 (2013)]
- Large decay rate $X(3872) \rightarrow \gamma\psi(3686)$ compared to $X(3872) \rightarrow \gamma J/\psi \rightarrow$ tetraquark? [Nucl. Phys. B 886, 665 (2014)] [PRL 112, 092001 (2014)]
- Decay $Y(4260) \rightarrow \gamma X(3872)$ recently observed at BESIII [PRL 112, 092001 (2014)]
- Theoretical calculation predicts $\Gamma_X^{(3872)} \approx 0.03$ eV [PLB 736, 221 (2014)]
- The current upper limit for $\Gamma_X^{(3872)}$ is at the $\mathcal{O}(10^{-6})$ eV level [PDG (2014)]
- $1^{+}$ state never observed directly in $e^+e^-$ annihilation
- Process may occur via a two-photon box diagram

**BESIII DETECTOR, DATA, MC**

- Operating at BEPC II in Beijing/China
- Symmetric $e^+e^-$ collider [2-4.6 GeV/c$^2$]
- $482 \text{pb}^{-1}$ @ 4.099 GeV, $1092 \text{pb}^{-1}$ @ 4.230 GeV, $826 \text{pb}^{-1}$ @ 4.260 GeV, $540 \text{pb}^{-1}$ @ 4.360 GeV

**ANALYSIS STRATEGY**

- Using Initial State Radiation (ISR) technique to access $X(3872)$ resonantly
- $e^+e^- \rightarrow \gamma_{\text{ISR}} X(3872)$
- $X(3872) \rightarrow \pi^+\pi^- J/\psi$ ($B > 3.8\%$)
- $J/\psi \rightarrow \ell^+\ell^-$, $\ell = \mu, e$ ($B = 11.96\%$)
- Untagged ISR photon: $|\cos \theta_{\text{ISR}}| > 0.95$

**CALCULATION OF $\Gamma_{ee}$**

- Event count rate $\frac{dN}{dx}$ ($A = \psi(3686)$, $X(3872)$) obtained by unbinned maximum likelihood fits
- Fit PDF: $\psi(3686)$-MC-shape + Gaussian + Polynomial + $X(3872)$-MC-shape
- Relation to non-radiative cross section: $\frac{dN}{dx} = W(s, x) \epsilon_A \mathcal{L} \sigma(e^+e^- \rightarrow A) B(A \rightarrow \pi^+\pi^- J/\psi)$
- $\Gamma_{\text{ee}} B(A \rightarrow \pi^+\pi^- J/\psi) = \frac{N_A}{\epsilon_A \mathcal{L} \mathcal{I}_A B(J/\psi \rightarrow \ell^+\ell^-)}$
- Set an upper limit at the 90% confidence level (C.L.)
- Four likelihood curves from fit: $L_i(\gamma)$, $i = 1 \ldots 4$, and $\gamma = \Gamma_{\text{ee}} B(X(3872) \rightarrow \pi^+\pi^- J/\psi)$
- Look for $\gamma_{\text{ee}}^{\text{up}}$ in $\int_{0}^{\infty} d\gamma L_i(\gamma) = 0.9 \int_{0}^{\infty} d\gamma L_i(\gamma)$
- Combining the four measurements: Look for $\gamma_{\text{ee}}^{\text{up}}$ in the product of the single likelihood curves

**RESULTS**

- $\Gamma_X^{(3872)} B(X(3872) \rightarrow \pi^+\pi^- J/\psi) < 0.13$ eV at 90% C.L., improves recent results $\approx 60$
- $\Gamma_{\text{ee}}^{(3872)} = (2213 \pm 18_{\text{stat}} \pm 99_{\text{sys}}) \text{ eV}$

**SYSTEMATIC UNCERTAINTIES**

<table>
<thead>
<tr>
<th>Source</th>
<th>$\sigma_{\text{ee}}^{X(3872)}$ [%]</th>
<th>$\sigma_{\text{ee}}^{(3872)}$ [%]</th>
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<tbody>
<tr>
<td>Luminosity</td>
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<td>Branching ratio</td>
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<td>$X(3872)$ width</td>
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<td>ISR simulation $\psi(3686)$ fit model</td>
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<tr>
<td>Total</td>
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