An Improved Limit for Γ_{ee} of $X(3872)$ and Γ_{ee} Measurement of $\psi(3686)$

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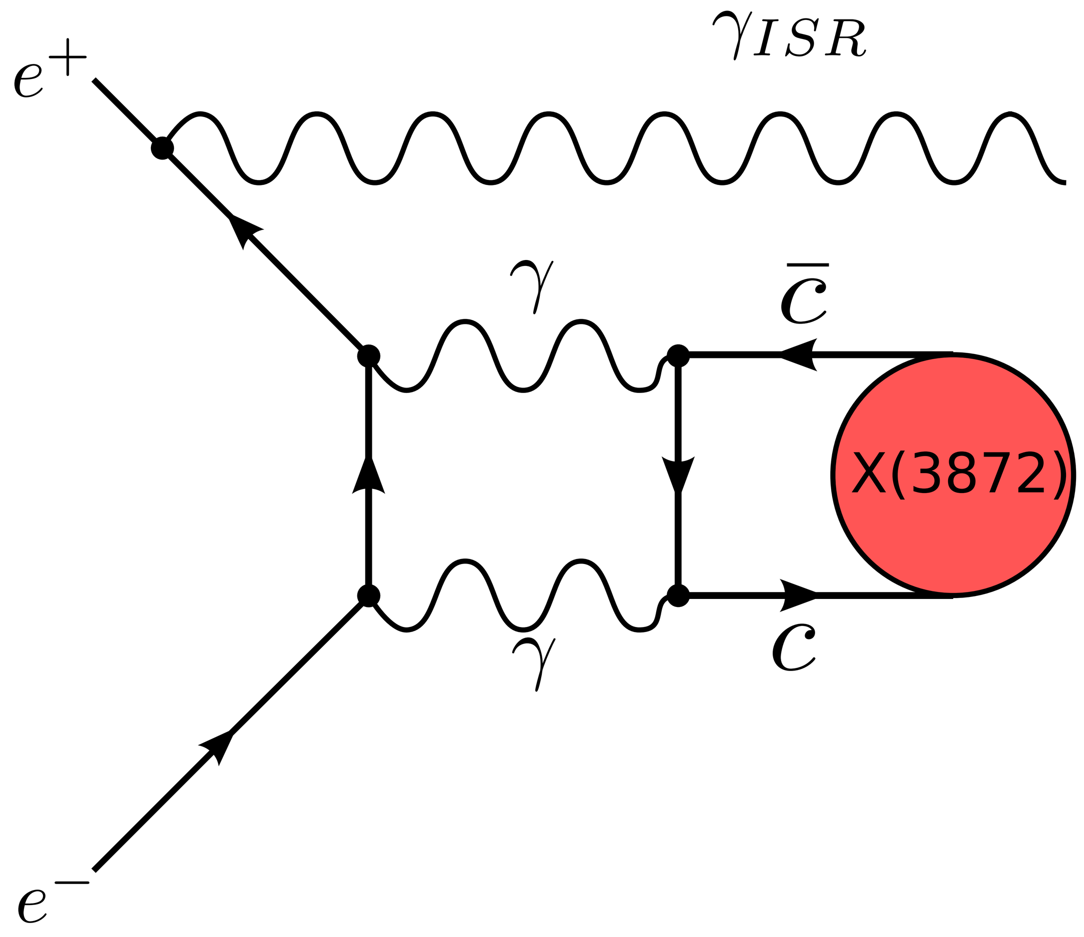
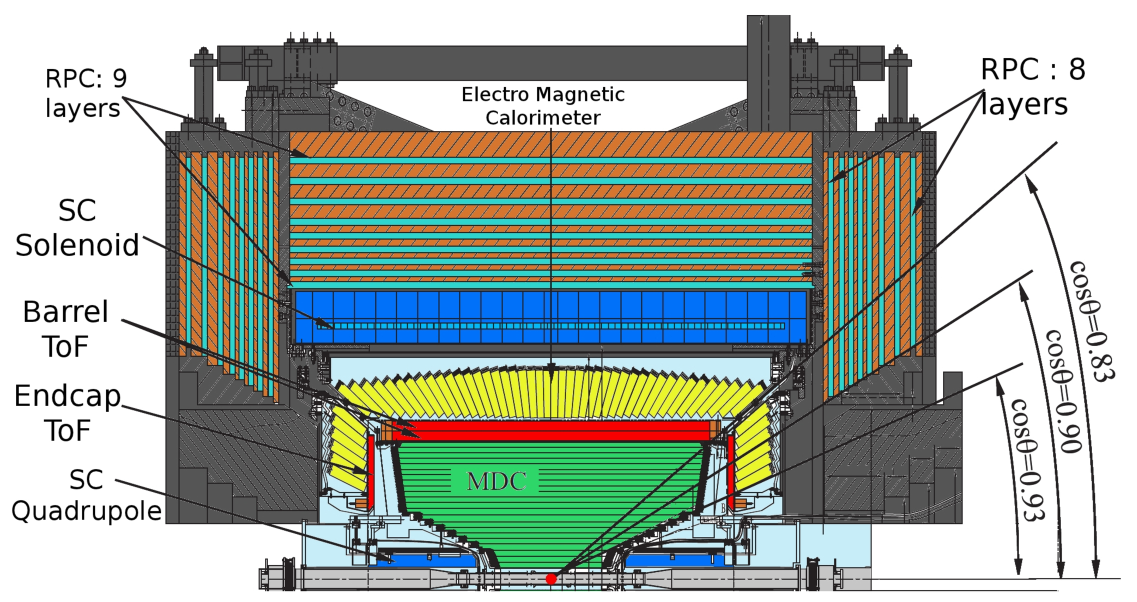
Introduction

- $X(3872)$ First observed in 2003 by Belle [PRL **91**, 262001 (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 $X(3872) \to \gamma\psi(3686)$ compared to $X(3872) \to \gamma J/\psi$
  → tetraquark? [Nucl.Ph. B **886**, 665 (2014)] [PRL **112**, 092001 (2014)]



- Decay $Y(4260) \to \gamma X(3872)$ recently observed at BESIII [PRL **112**, 092001 (2014)]
- Theoretical calculation predicts $\Gamma_{ee}^{X(3872)} \approx 0.03$ eV [PLB **736**, 221 (2014)]
- The current upper limit for $\Gamma_{ee}^{X(3872)}$ is at the $\mathcal{O}(10^2)$ 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



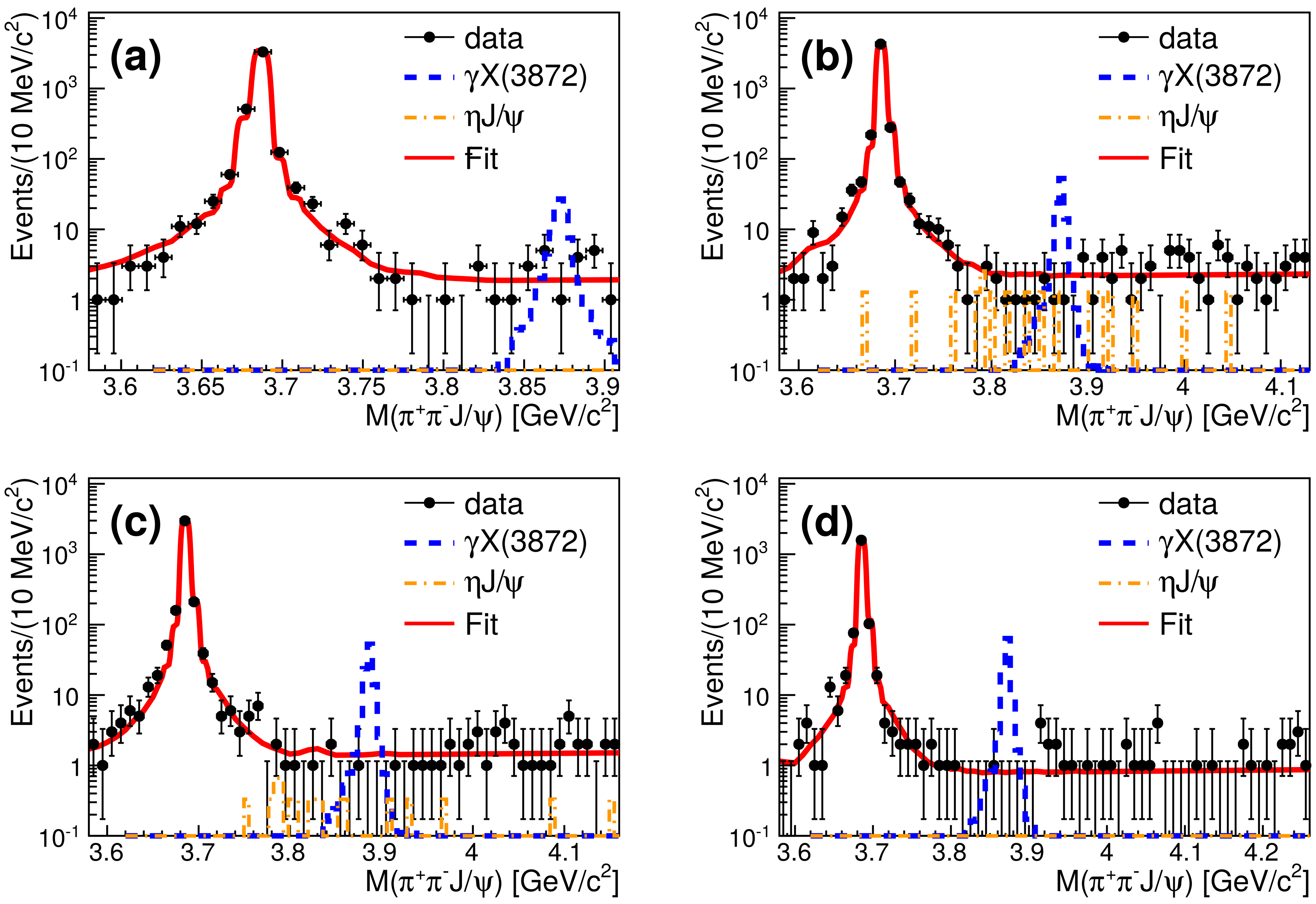
- Operating at BEPC II in Beijing/China
- Symmetric e^+e^- collider [2-4.6 GeV/c^2]

482 pb^{-1} @ 4.009 GeV, 1092 pb^{-1} @ 4.230 GeV, 826 pb^{-1} @ 4.260 GeV, 540 pb^{-1} @ 4.360 GeV

Analysis Strategy

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

$\pi^+\pi^- J/\psi$ Mass Spectrum



- **(a)** 4.009 GeV, **(b)** 4.230 GeV, **(c)** 4.260 GeV and **(d)** 4.360 GeV
- No significant $X(3872)$ peak observed at any of the four c.m. energies

Calculation of Γ_{ee}

- Event count rate $\frac{dN_A}{dx}$ $(A = \psi(3686), X(3872))$ obtained by unbinned maximum likelihood fits
- Fit PDF: $\psi(3686)$-MC-shape⊗Gaussian + Polynomial + $X(3872)$-MC-shape
- Relation to non-radiative cross section: $\frac{dN_A}{dx} = W(s,x)\varepsilon_A \mathcal{L}\,\sigma(e^+e^- \to A)\mathcal{B}(A \to \pi^+\pi^- J/\psi)$

$$\Gamma_{ee}^A \mathcal{B}(A \to \pi^+\pi^- J/\psi) = \frac{N_A}{\varepsilon_A \mathcal{L}\, I_A \mathcal{B}(J/\psi \to \ell^+\ell^-)}$$

- with $I_A = 12\pi\Gamma_{\rm tot}\int_{x_1}^{x_2} dx \frac{W(s,x)}{(s'-M_A^2)^2+\Gamma_{\rm tot}^2 M_A^2}$ and $x = \sqrt{1 - M(\pi^+\pi^- J/\psi)^2/s}$
- Set an upper limit at the 90% confidence level (C.L.)
- Four likelihood curves from fit: $L_i(\gamma)$, $i = 1\ldots4$, and $\gamma = \Gamma_{ee}^{X(3872)}\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$
- Look for $\gamma_i^{\rm up}$ in $\int_0^{\gamma_i^{\rm up}} d\gamma L_i(\gamma) = 0.9\int_0^\infty d\gamma L_i(\gamma)$
- Combining the four measurements: Look for $\gamma_{\rm tot}^{\rm up}$ in the product of the single likelihood curves

$$\int_0^{\gamma_{tot}^{\rm up}} d\gamma \prod_{i=1}^{4} L_i(\gamma) = 0.9\int_0^\infty d\gamma \prod_{i=1}^{4} L_i(\gamma)$$

Results

- $\Gamma_{ee}^{X(3872)}\mathcal{B}(X(3872) \to \pi\pi J/\psi) < 0.13$ eV at 90% C.L. , improves recent results ≈ 60
- $\Gamma_{ee}^{\psi(3686)} = (2213 \pm 18_{\rm stat} \pm 99_{\rm sys})$ eV

Systematic Uncertainties

Source	$\sigma_{\rm sys}^{X(3872)}$ [%]	$\sigma_{\rm sys}^{\psi(3686)}$ [%]
Luminosity	1.0	1.0
Tracking	4.0	4.0
J/ψ selection	0.2	0.2
Kinematic Fit	0.4	0.4
Integrals I_A	0.7	0.7
Branching ratio	0.5	1.4
$X(3872)$ width	2.7	-
ISR simulation	3.4	-
$\psi(3686)$ fit model	-	1.0
Total	6.1	4.5