Search for X(3872) in $\gamma\gamma$ Fusion and ISR at CLEO

hep-ex/0410038, submitted to PRL

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For the CLEO Collaboration

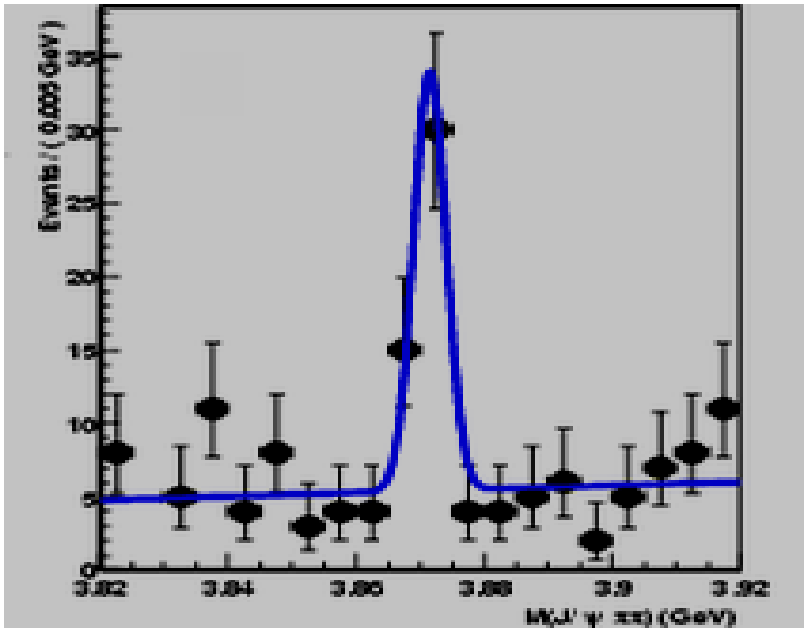
First APS Topical Group Meeting on Hadron Physics

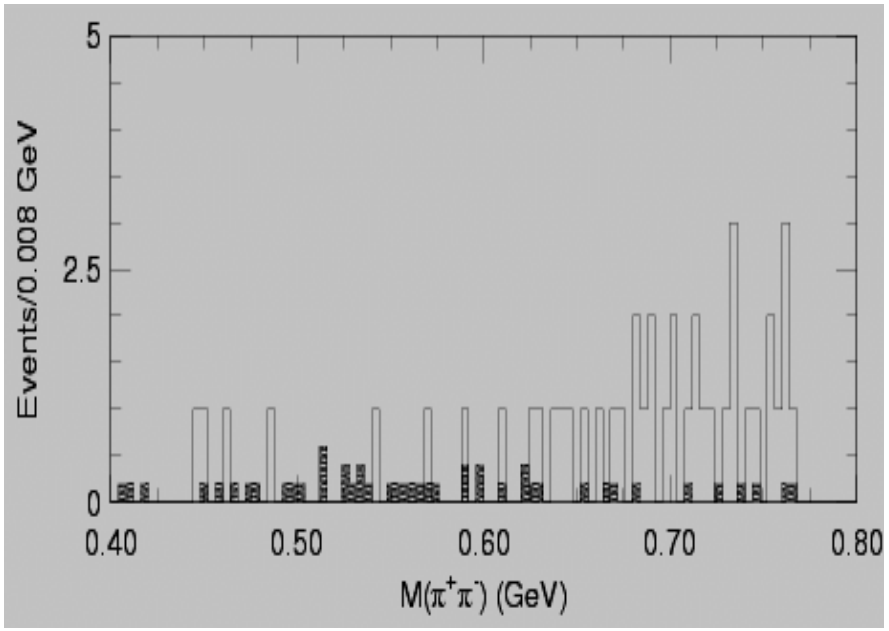
- Experimental & Theoretical Status of X(3872)
- $\gamma\gamma$ Fusion and ISR Resonance Production
- Search for X(3872) with CLEO III Data

X(3872) Discovery

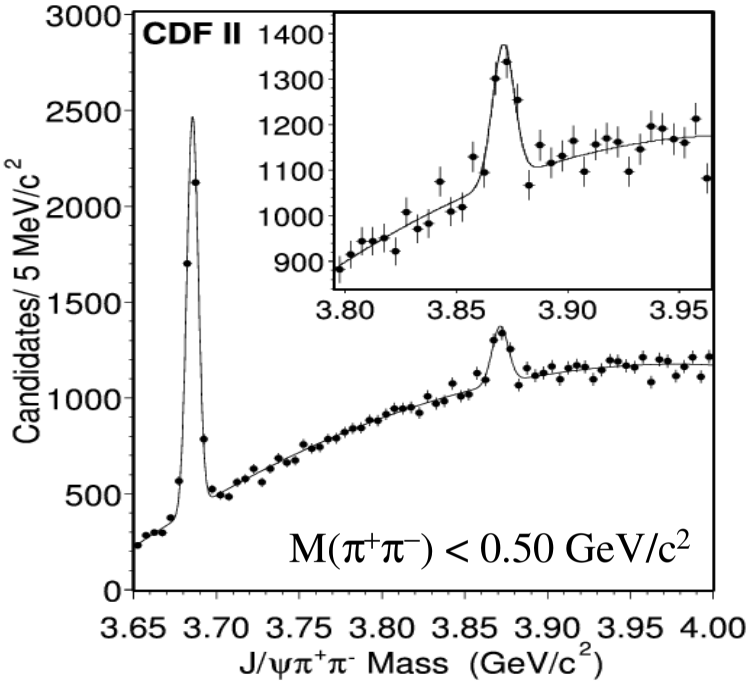
X(3872) was discovered by the Belle Collaboration in $B^{\pm} \to K^{\pm} X$, $X \to \pi^+ \pi^- J/\psi$, $J/\psi \to \ell^+ \ell^-$ [$\ell = e, \mu$] from a sample of 153 million $B\bar{B}$ pairs (PRL **91**, 262001 (2003))

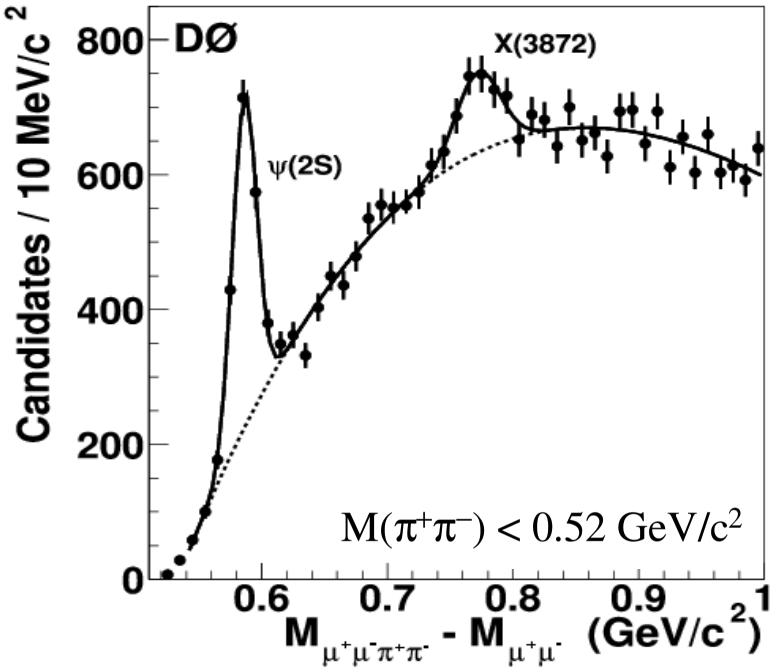
$M = 3872.0 \pm 0.6 \pm 0.5$ MeV/c^2 $\quad\quad$ $\Gamma < 2.3$ MeV/c^2 (90% CL)





Confirmation of X(3872)





Experiment	Mass (MeV/c^2)	
Belle	3872.0 ± 0.6 ± 0.5	PRL **91**, 262001 (2003)
CDF	3871.3 ± 0.7 ± 0.4	PRL **93**, 072001 (2004)
DØ	3871.8 ± 3.1 ± 3.0	PRL **93**, 162002 (2004)
BABAR	3873.4 ± 1.4	hep-ex/0406022

Other Searches for X(3872)

All observations of X(3872) have been made in $\pi^+\pi^- J/\psi$

Belle: $\gamma\,\chi_{c1}$ (PRL **91**, 262001 (2003))

Belle: $\gamma\,\chi_{c2}$, $\gamma\,J/\psi$ (hep-ex/0408116)

BABAR: $\eta J/\psi$ (PRL **93**, 041801 (2004))

Belle: D^+D^-, $D^0\bar{D}^0$, $D^0\bar{D}^0\pi^0$ (PRL **93**, 051803 (2004))

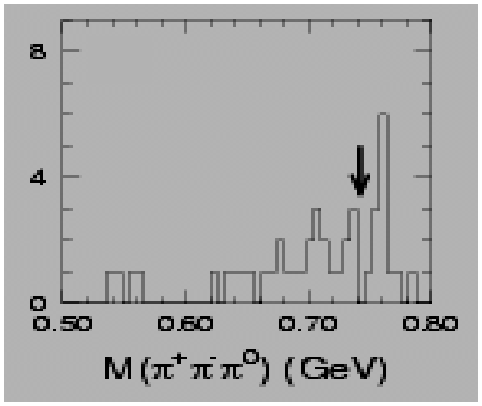
Belle: $$\frac{\Gamma(X \to \pi^0\pi^0 J/\psi)}{\Gamma(X \to \pi^+\pi^- J/\psi)} < 1.3\,\frac{\Gamma(\psi' \to \pi^0\pi^0 J/\psi)}{\Gamma(\psi' \to \pi^+\pi^- J/\psi)}$$ (hep-ex/0408116)

BABAR: $X^\pm \to \pi^\pm\pi^0\,J/\psi$ (hep-ex/0408083)

BES: $\Gamma_{ee}(X(3872))B(X \to \pi^+\pi^-\,J/\psi) < 10$ eV (90% CL)

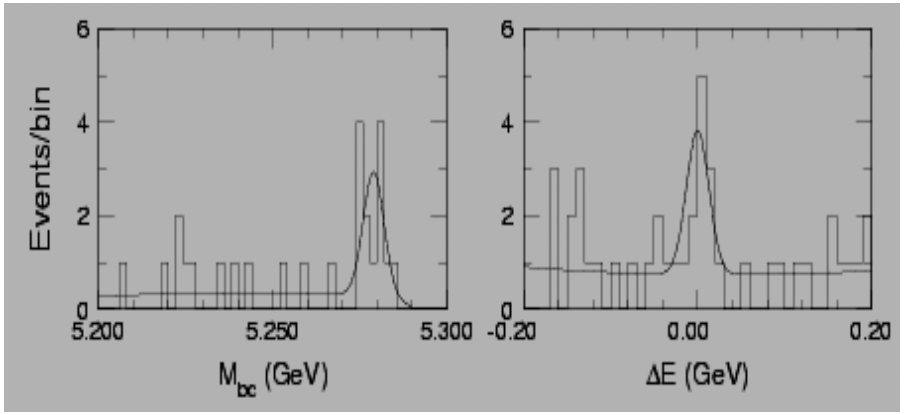
(PL **B579**, 74 (2004))

Exception: $\pi^+\pi^-\pi^0$ J/ψ near X(3872)



Belle studied $B^\pm \to K^\pm (\pi^+\pi^-\pi^0 J/\psi)$ with $M(\pi^+\pi^-\pi^0 J/\psi) = 3872 \pm 12$ MeV/c^2 using a sample of 274 million $B\bar{B}$ pairs (hep-ex/0408116)

$M(\pi^+\pi^-\pi^0) > 0.75$ GeV/c^2



PDG 2004

$M(\omega\, J/\psi) = 3879.5 \pm 0.1$ MeV/c^2

$\Gamma(\omega) = 8.49 \pm 0.08$ MeV/c^2

$N = 10.0 \pm 3.6$ events

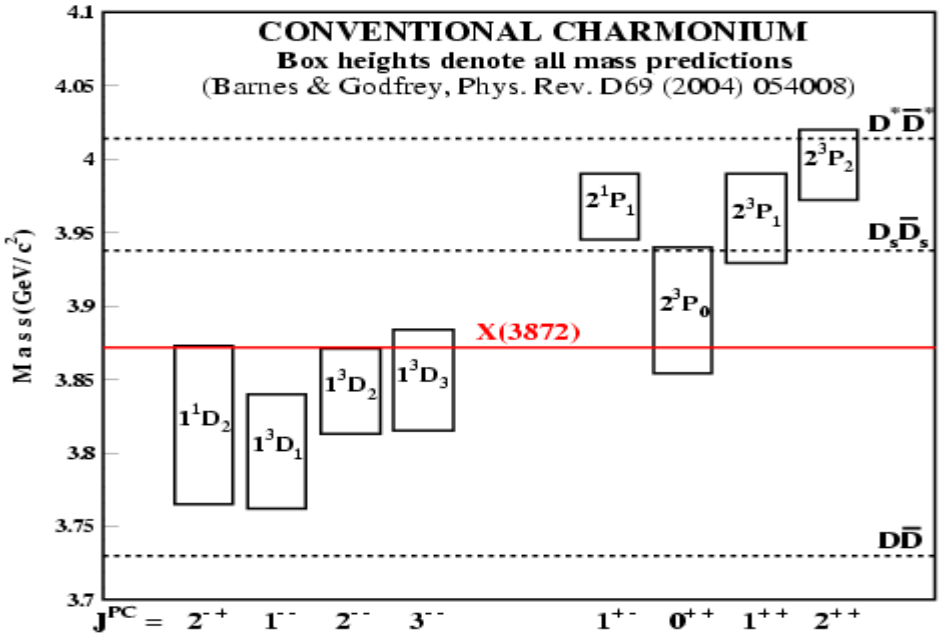
$S/B = 5.0$

5.8σ Significance

Theoretical Interpretation of X(3872)

Theoretical review was given by Eichten at QWG (Beijing, Oct 2004)

- Conventional Charmonium

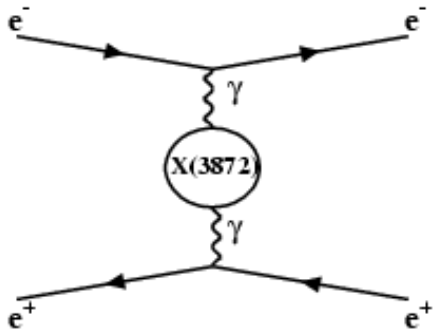


- $D^0 \bar{D}^{*0}$ Molecule: $M(D^0) + M(\bar{D}^{*0}) = 3871.3 \pm 0.5$ MeV/c^2 (PDG 04)
  – $J^{PC} = 1^{++}$ (S-wave), 0^{-+} (P-wave)
- Exotic State

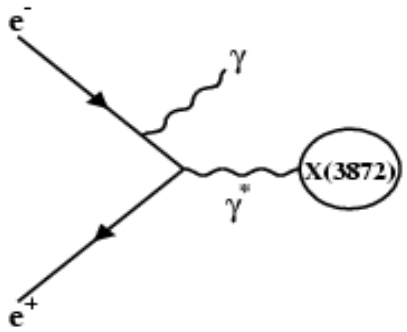
Important to determine J^{PC} of X(3872) !

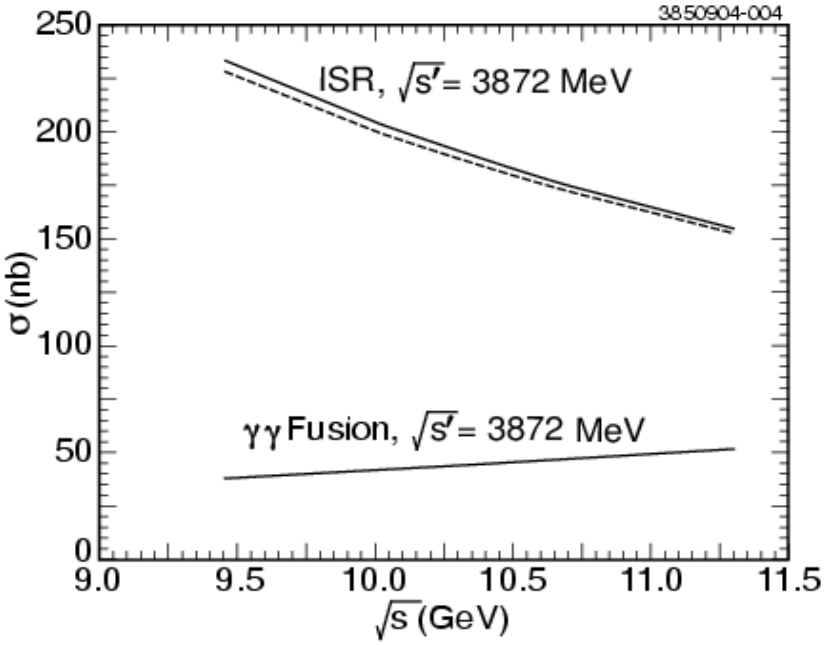
Resonance Production by γγ Fusion and ISR

Untagged γγ Fusion: + C; $J^{PC} = 0^{\pm+}, 2^{\pm+}, \ldots$



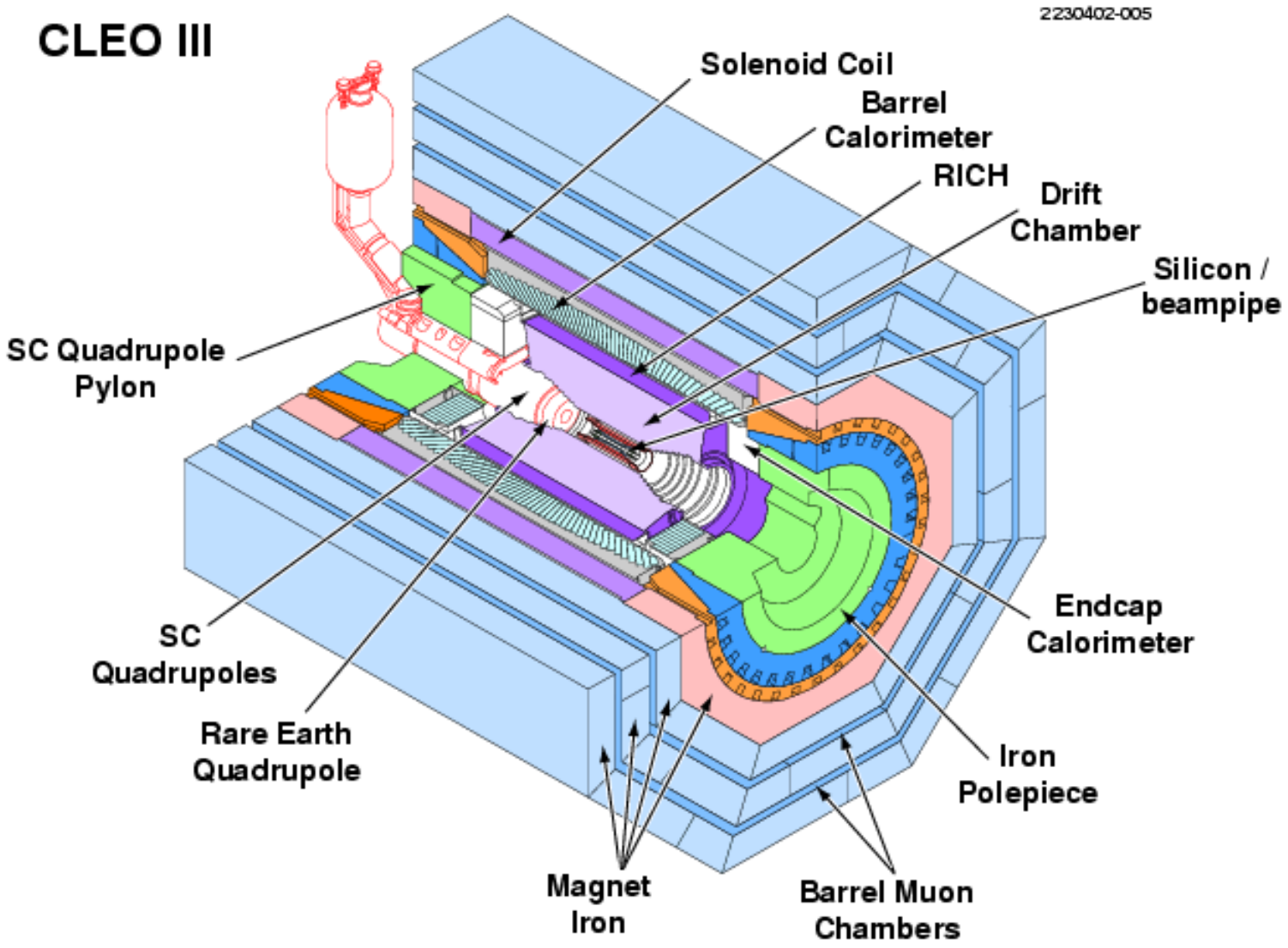
ISR: $J^{PC} = 1^{--}$





Cross sections for e^+e^- collisions at CM energy √s to produce reduced CM energy √s' = 3872 MeV for γγ fusion and ISR

CLEO III Detector



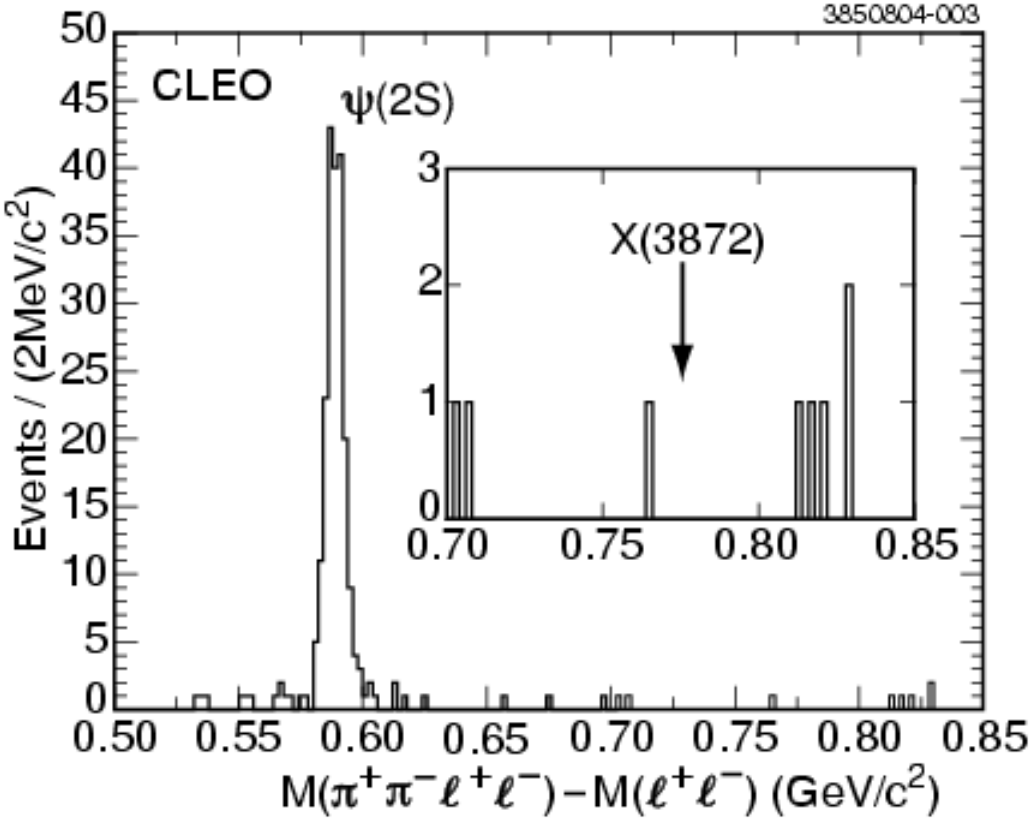
CLEO III Data Sample

Total $\mathcal{L}(e^+e^-) = 15.10\ fb^{-1}$

	$\langle\sqrt{s}\rangle$ (GeV)	$\mathcal{L}(e^+e^-)$ (fb^{-1})
Y(1S)	9.468	1.47
Y(2S)	10.018	1.84
Y(3S)	10.356	1.67
Y(4S)	10.566	8.97
Y(5S)	10.868	0.43
$\Lambda_b \bar{\Lambda}_b$ threshold	11.296	0.72

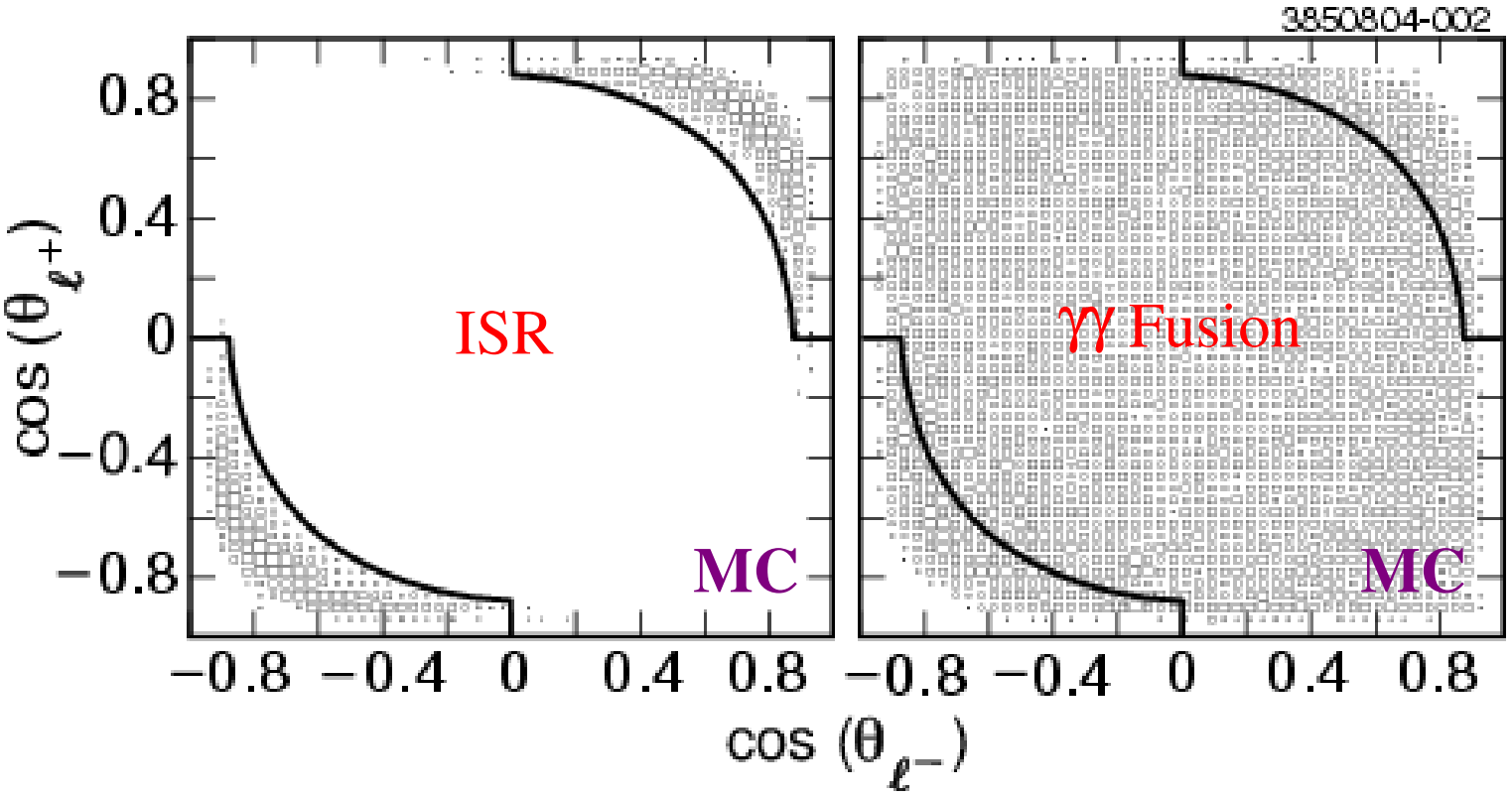
Event Selection

Exclusive Channel: $\pi^+ \pi^- J/\psi \rightarrow \pi^+ \pi^- (\ell^+ \ell^-)$ [$\ell = e, \mu$]



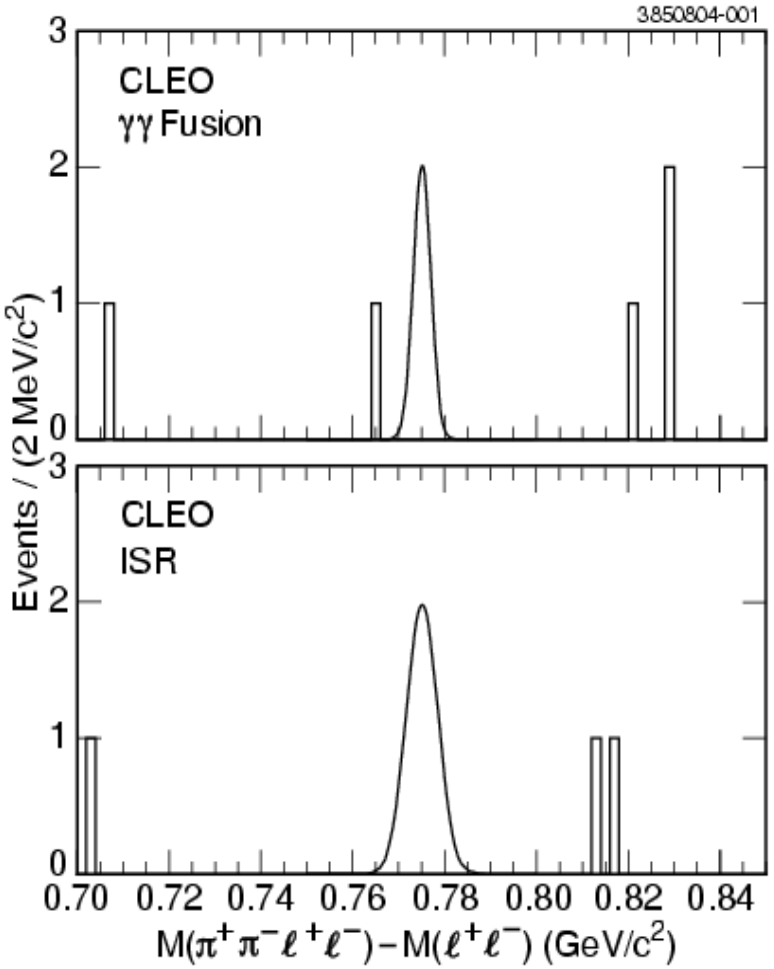
- Number of tracks = 4
  - Each track comes from IP
  - Satisfies respective PID
- Net Charge = 0
- Observed $E_{tot} < 6$ GeV
- Net $p_{tr} < 0.3$ GeV/c
- $E_{neu} < 0.4$ GeV
- $M(\ell^+ \ell^-)$ [GeV/c^2]
  - $2.96 < M(e^+e^-) < 3.125$
  - $3.05 < M(\mu^+\mu^-) < 3.125$

Separation of $\gamma\gamma$ Fusion and ISR Production



$\gamma\gamma$ fusion sample: 86% of $\gamma\gamma$ events and < 0.5% of ISR events
ISR sample: 14% of $\gamma\gamma$ events and > 99.5% of ISR events

CLEO X(3872) Results



$N_{obs} < 2.36$ (90% CL)

$(2J+1)\Gamma_{\gamma\gamma}(X)B(X \rightarrow \pi^+ \pi^- J/\psi)$
< 12.9 eV (90% CL)

$N_{obs} < 2.36$ (90% CL)

$\Gamma_{ee}(X)B(X \rightarrow \pi^+ \pi^- J/\psi)$
< 8.3 eV (90% CL)

Systematic uncertainties have been included in the results above

Summary

With a $\mathcal{L}(e^+e^-) \sim 15$ fb^{-1} data sample taken with the CLEO III detector:

$$(2J+1)\Gamma_{\gamma\gamma}(X(3872))B(X \to \pi^+\pi^- J/\psi) < 12.9 \text{ eV (90\% CL)}$$

$$\Gamma_{ee}(X(3872))B(X \to \pi^+\pi^- J/\psi) < 8.3 \text{ eV (90\% CL)}$$

Assuming $B(B^\pm \to K^\pm X) \approx B(B^\pm \to K^\pm \psi') \to B(X \to \pi^+\pi^- J/\psi) \approx 0.02$

$(2J+1)\Gamma_{\gamma\gamma}(X(3872)) < 0.65$ keV

- ¼ that for χ_{c0} and χ_{c2}
- Ackleh &Barnes prediction for 1^1D_2 state: $(2J+1)\Gamma_{\gamma\gamma}(1^1D_2) = 0.1$ keV (PR **D45**, 232 (1992))

$\Gamma_{ee}(X(3872)) < 0.42$ keV

- comparable to $\psi(3770)$
- ½ that of $\psi(4040)$