

Study of $e^+e^- \rightarrow \pi^+\pi^- J/\psi$ & $e^+e^- \rightarrow K^+K^- J/\psi$ via ISR at Belle

C. P. Shen (沈成平)

IHEP, Beijing

文章发表在:

Phys. Rev. Lett. 99, 182004 (2007)

Phys. Rev. D 77, 011105 (R) (2008)

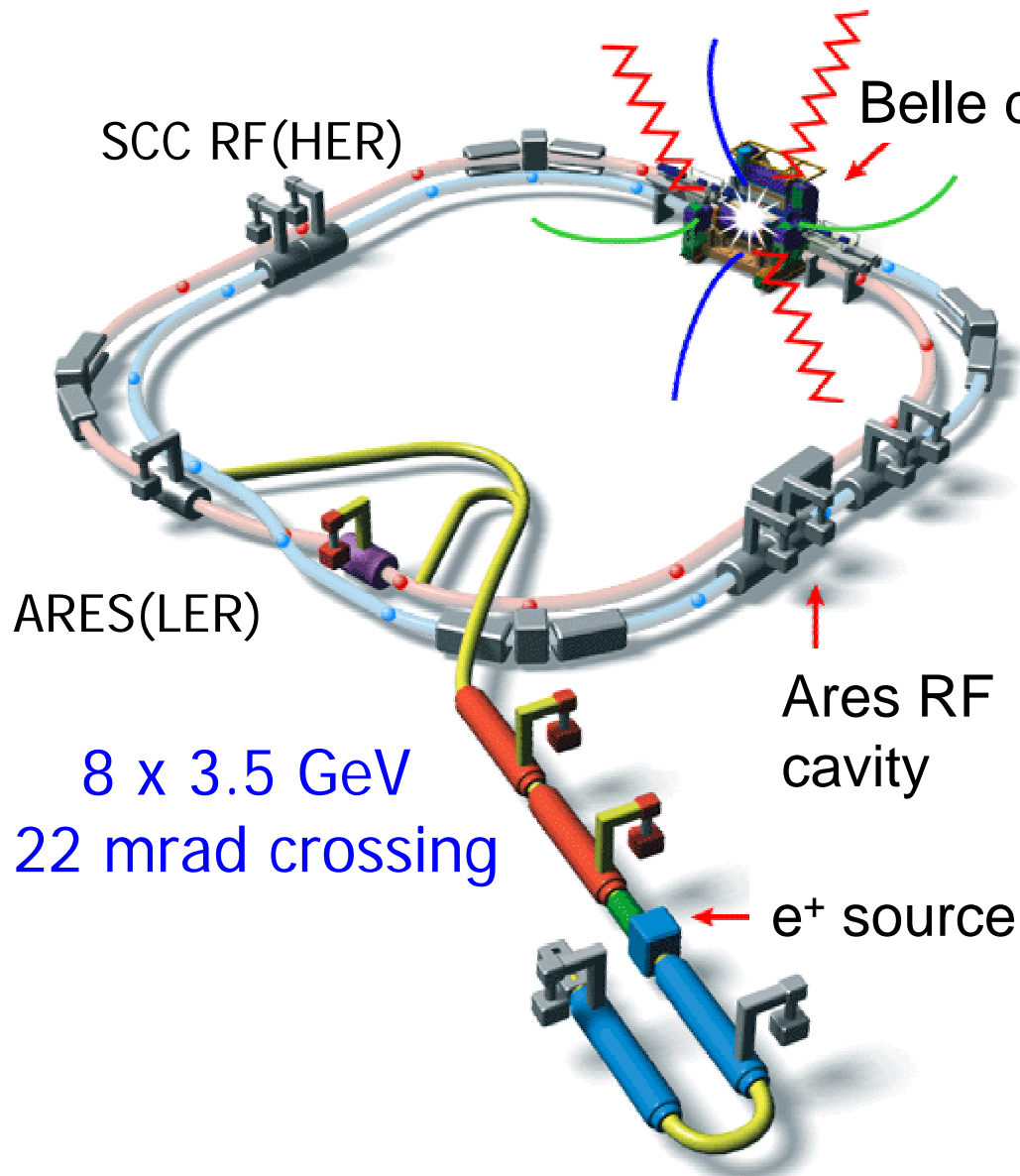
April 27, 2008, Nanjing

Outline

- Introduction
- $e^+e^- \rightarrow \pi^+\pi^- J/\psi$
- $e^+e^- \rightarrow K^+K^- J/\psi$
- Summary

The KEKB Collider

since 1999



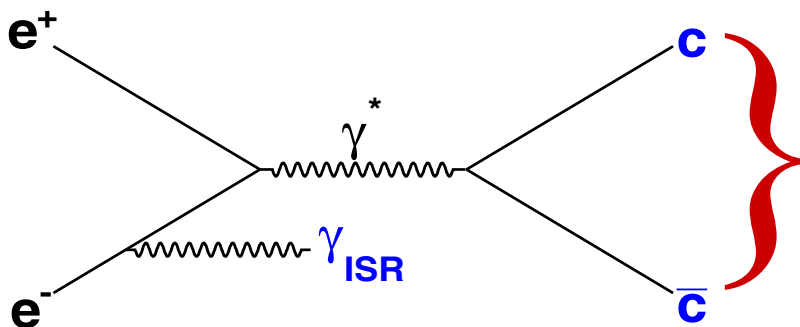
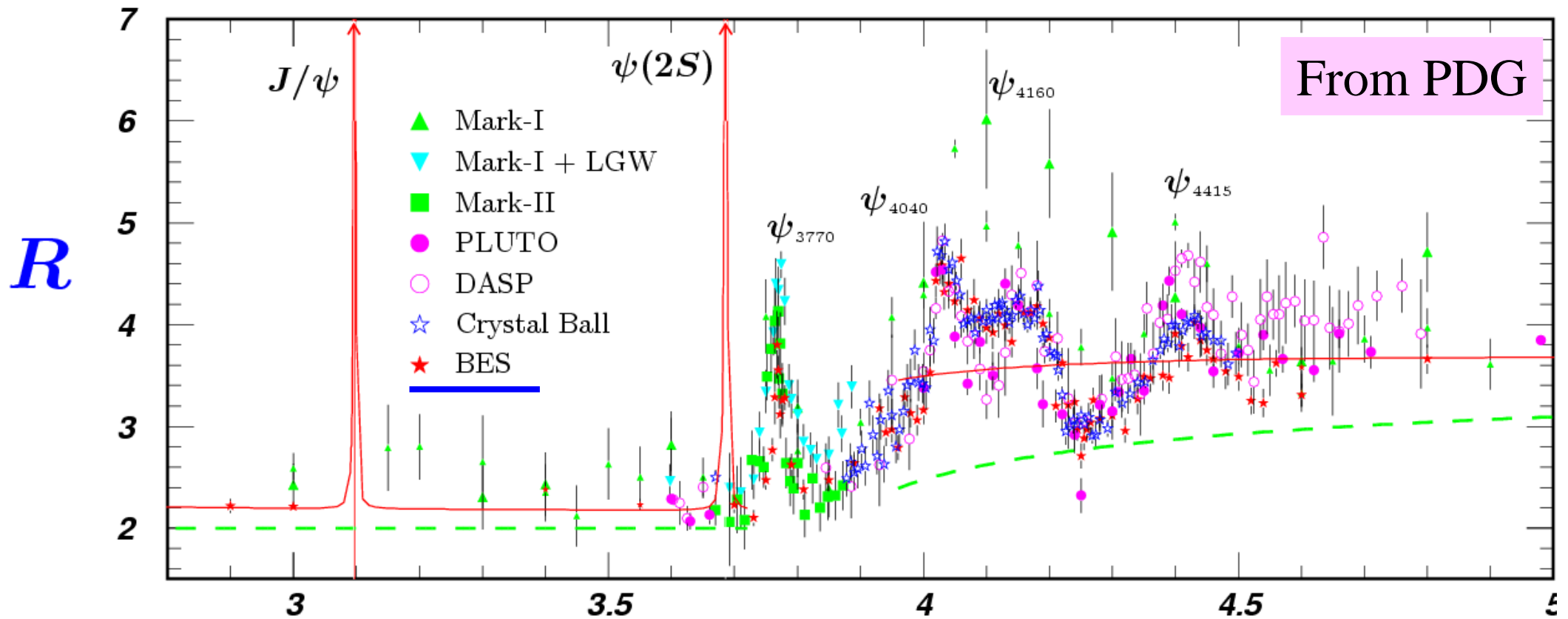
8 x 3.5 GeV
22 mrad crossing

Lum=492 fb⁻¹ on resonance
= 55 fb⁻¹ off resonance

World record:
 $L = 1.7 \times 10^{34}/\text{cm}^2/\text{sec}$

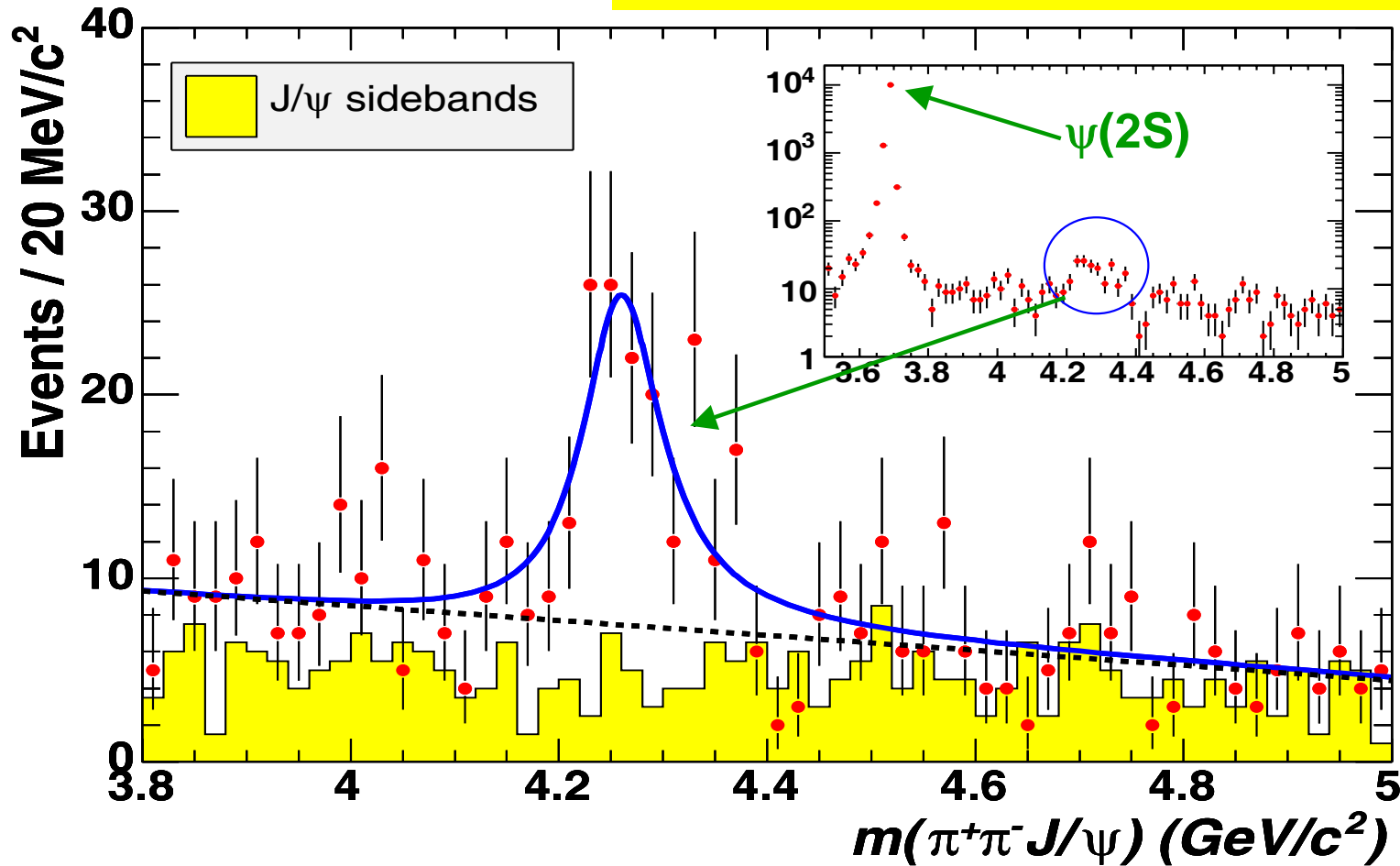


R values/ ψ states/ Y states



$J^{PC} = 1^{--}$
 $\psi', \psi'', Y \dots$

The Y states should also appear in this plot (between 4.0 and 4.7 GeV!)



BaBar:
232 fb⁻¹

>8 σ significance
structure called
Y(4260)

$M(J/\psi\pi\pi)$ of $\psi(2S)$
with J/ψ constraint
is well described by
Cauchy shape funct.

- fit with Rel-BW \times PhaseSpace \otimes Reso + 2nd polynomial (BKGD)
- fit-probability (χ^2) is about 2.6%, $N_{\text{events}} = 125 \pm 23$

$$m = 4259 \pm 8_{-6}^{+2} \text{ MeV}$$

$$\Gamma = 88 \pm 23_{-4}^{+6} \text{ MeV}$$

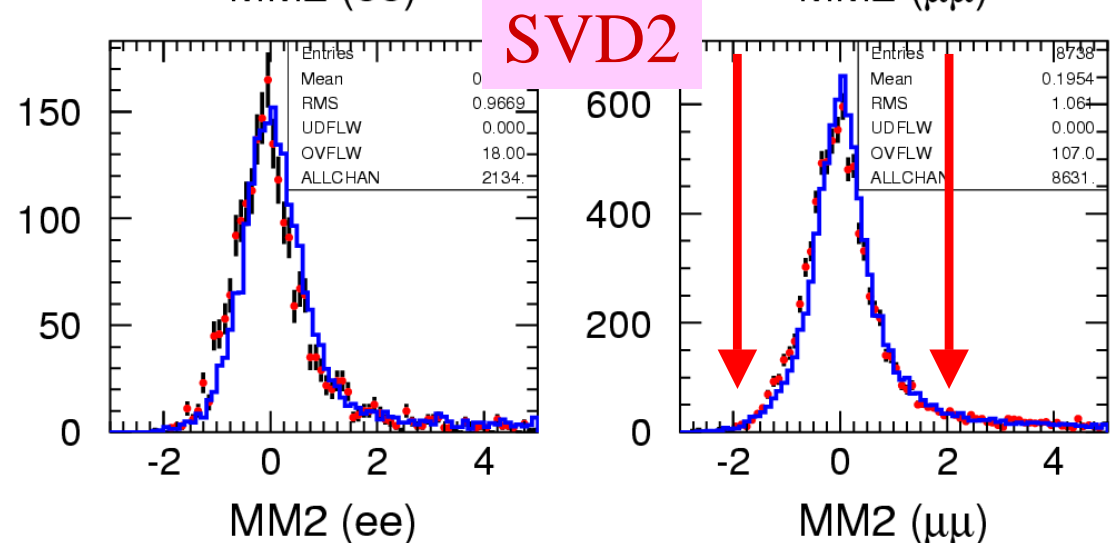
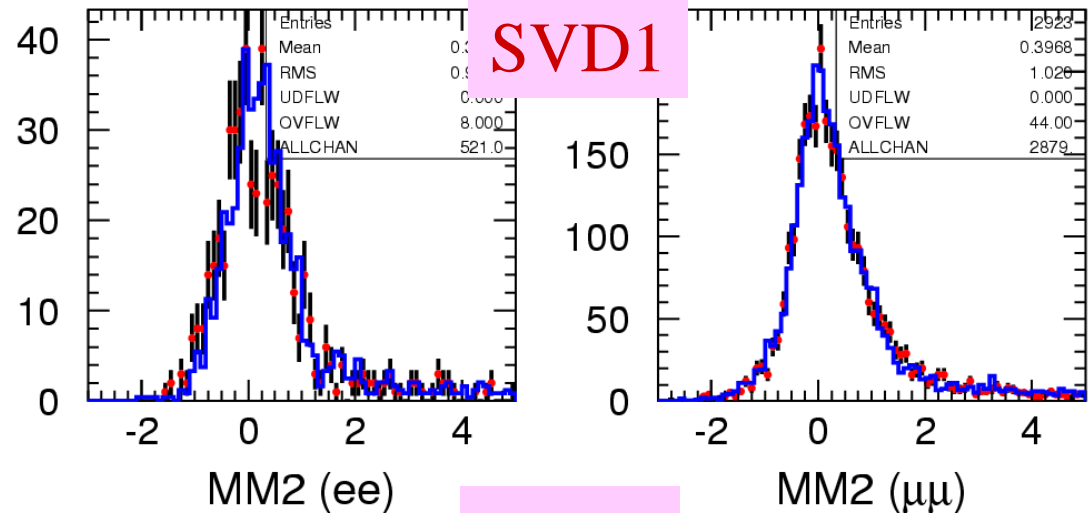
$$\Gamma(Y \rightarrow e^+e^-) \cdot B(Y \rightarrow \pi^+\pi^-J/\psi) = 5.5 \pm 1.0_{-0.7}^{+0.8} \text{ eV}$$



Selection Criteria

- $N_{\text{trk}}=4, \text{Net_chrg}=0$
- $|\text{dr}| < 0.5 \text{ cm}$
- $|\text{dz}| < 4 \text{ cm}$
- $-2 < \text{MM}^2 < 2 \text{ GeV}^2$
- Lepton ID
- Pion ID
- Remove gamma conversion

Evts in ψ' mass region

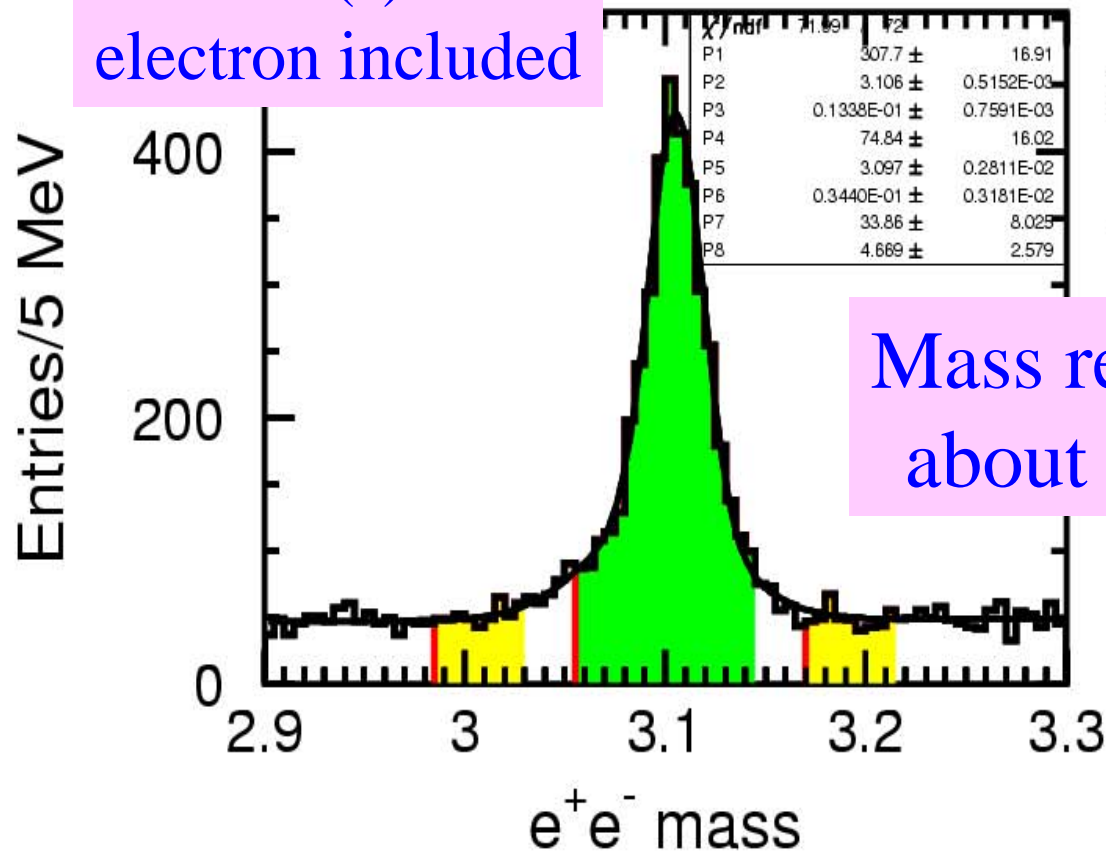




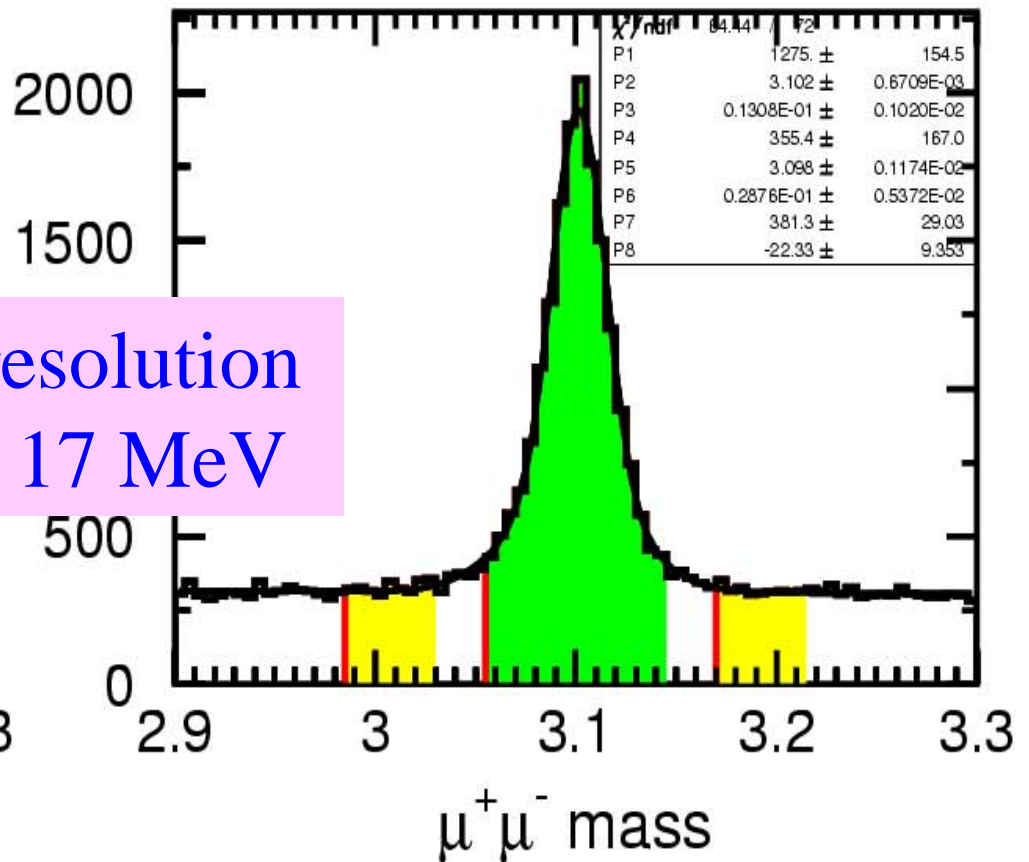
J/ ψ signals

- Signal region: 3.06 – 3.14 GeV
- Sidebands: 2.99-3.03, 3.17-3.21 GeV

Photon(s) near electron included



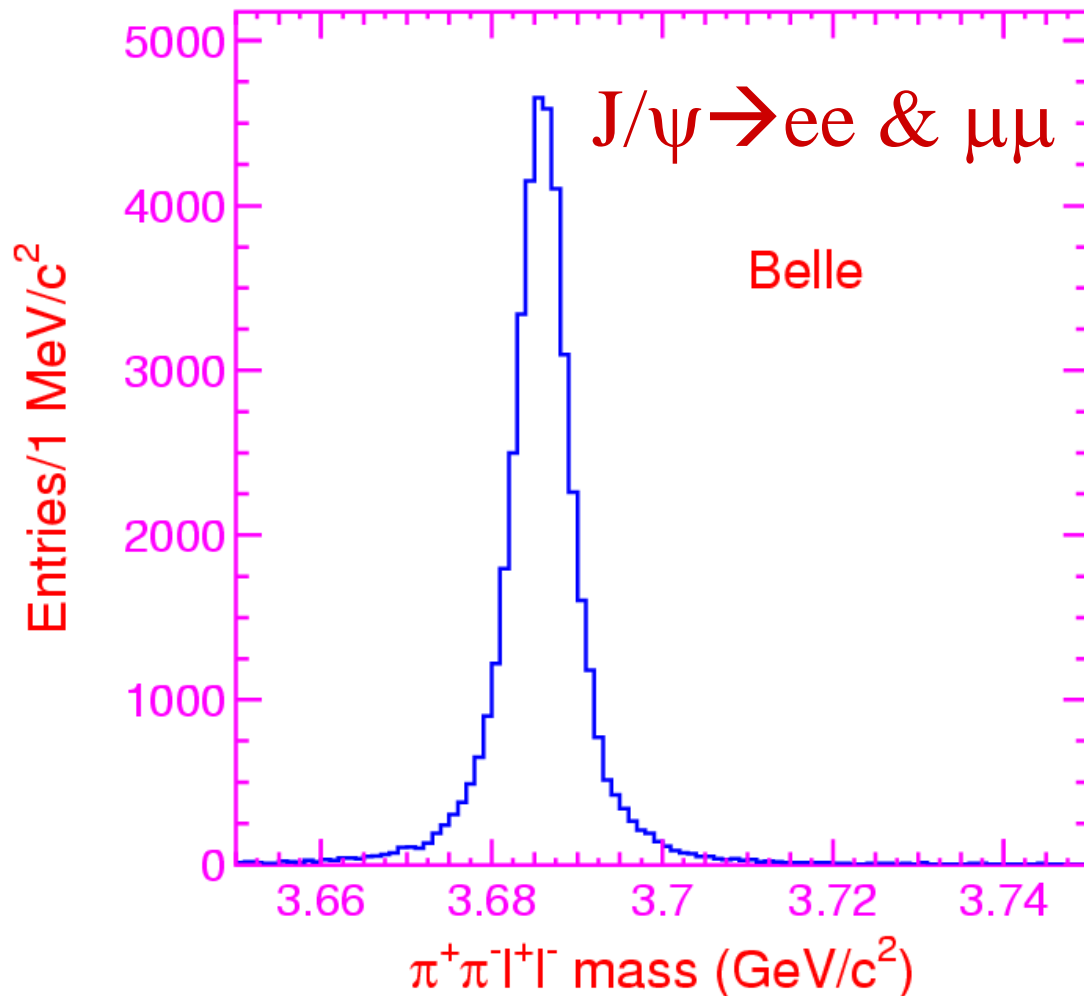
Mass resolution about 17 MeV





$e^+e^- \rightarrow \psi'$ as reference signal

N^{obs}	Lum (/fb)	Cross section (pb)
15,444	547.8	$15.42 \pm 0.12 \pm 0.89$



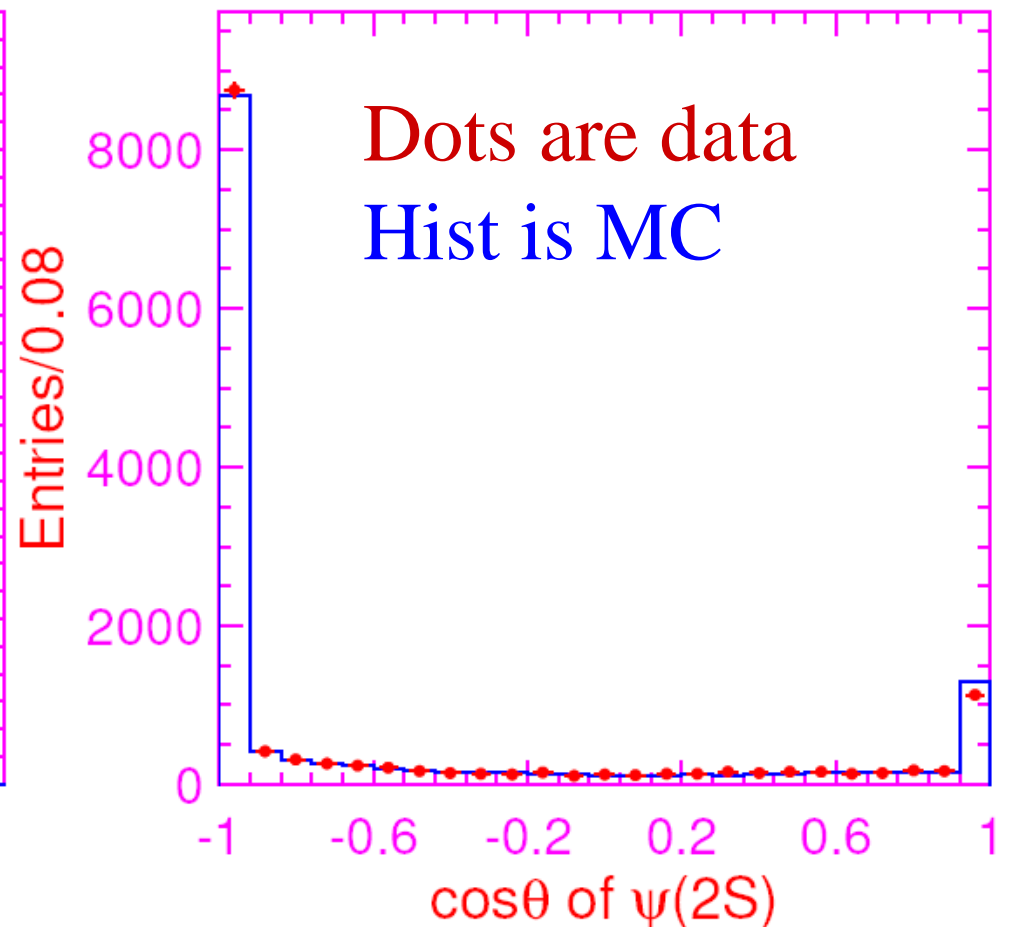
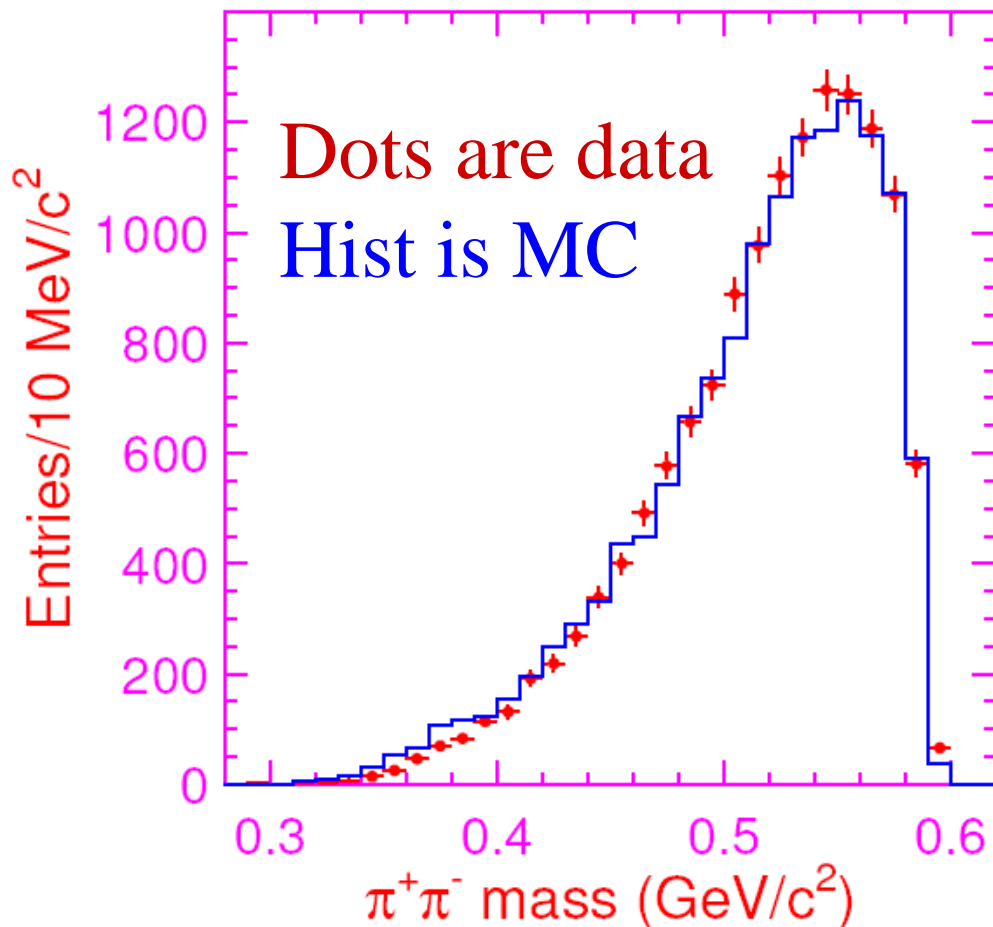
- From cross section, one gets partial width to e^+e^- .
- $\Gamma_{ee} = 2.54 \pm 0.02 \pm 0.15$ keV
- PDG'06
 - $\Gamma_{ee} = 2.48 \pm 0.06$ keV
- Belle agrees with other experiments well.

Belle: PRL99, 182004 (2007)



ψ' sample: Data vs MC

We used Phokhara



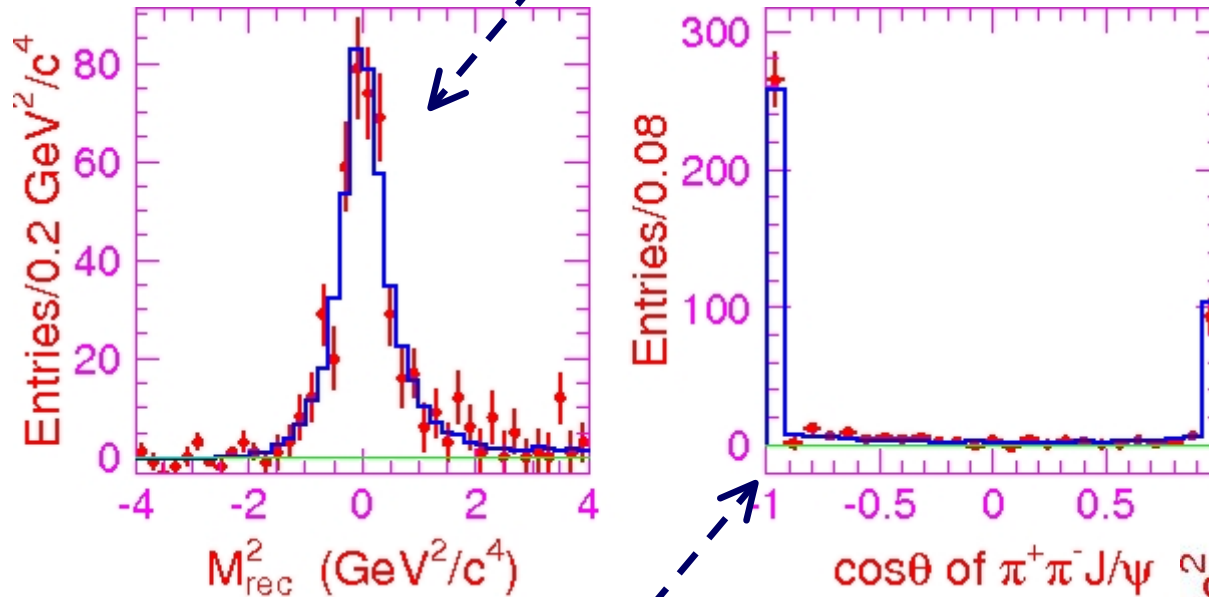
Good agreement between data and MC simulation.
→ (ISR events & background low & MC reliable)



$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ via ISR

Clear signal of missed massless particle (γ_{ISR})

Lum=548 fb⁻¹

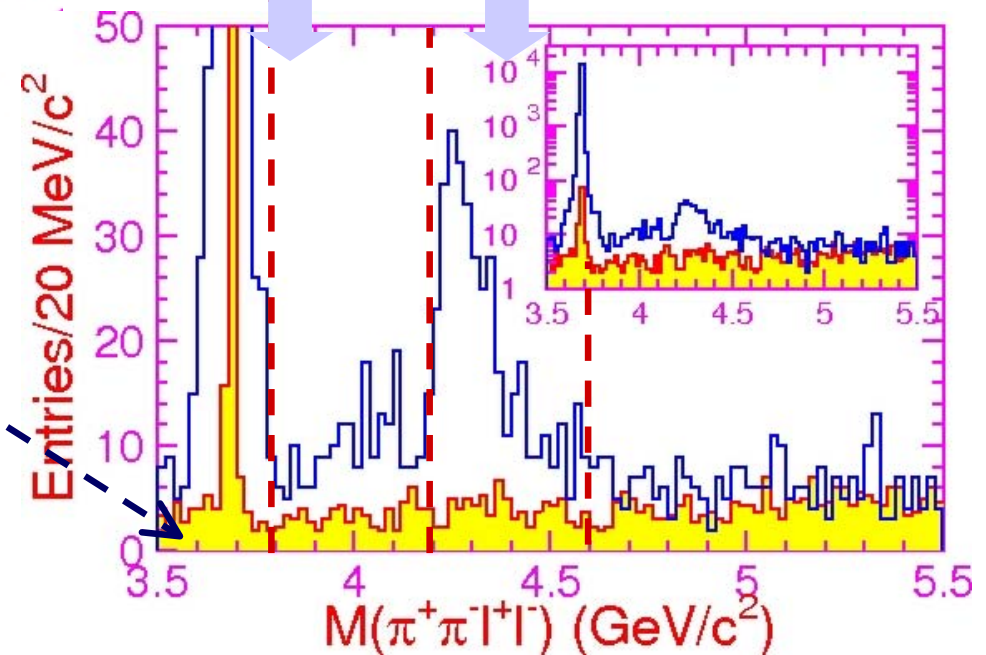


$J/\psi(\rightarrow l^+l^-) + \pi\pi$ + no extra tracks
detection of γ_{ISR} is not required

120±14 evts

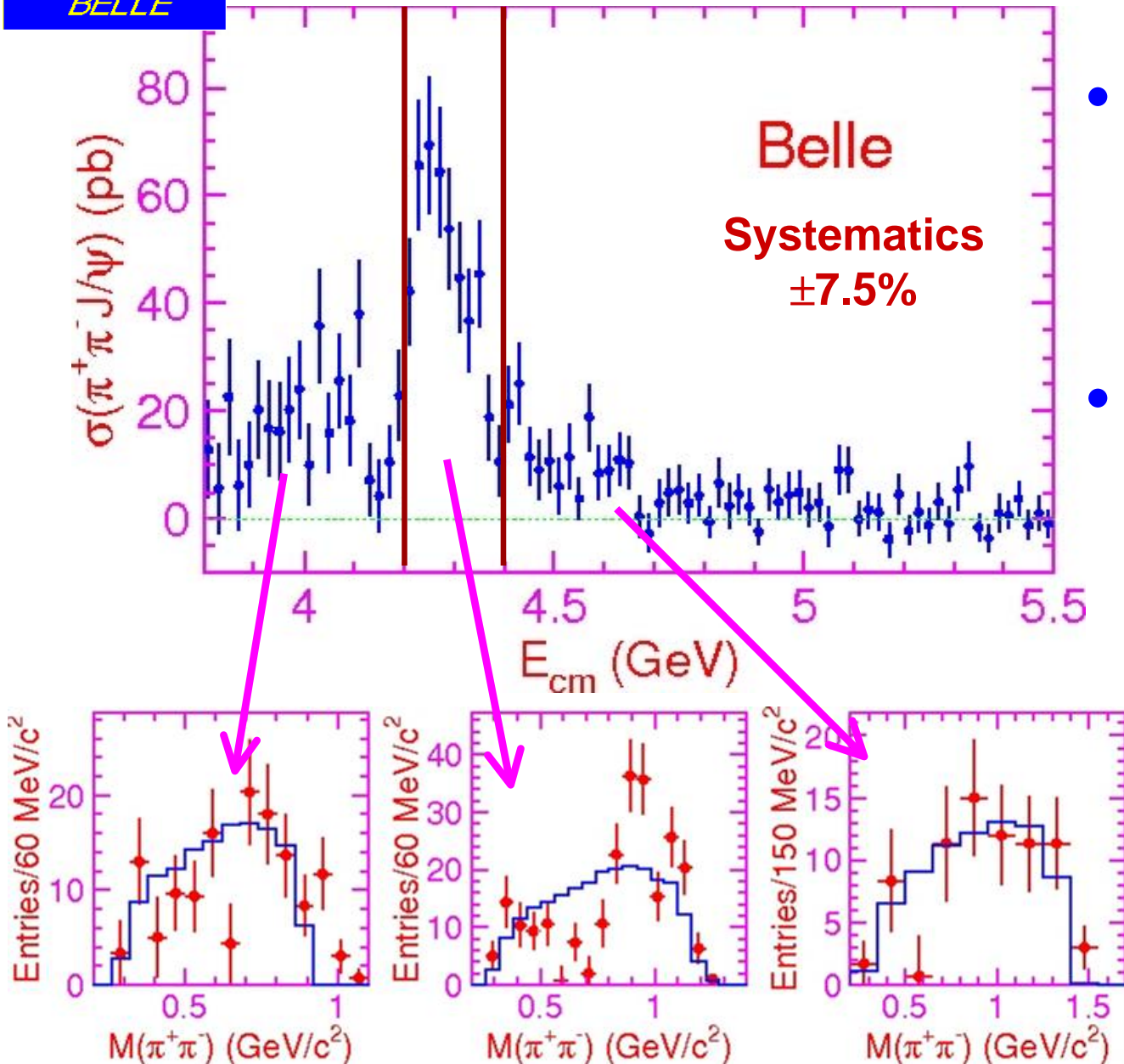
324±21 evts

- Polar angle distribution agrees well with ISR expectation
- Combinatorial background estimated by J/ψ sidebands
- Backgrounds from real $(J/\psi \pi\pi)_{\text{non ISR}}$ or $J/\psi X_{\text{non } \pi\pi}$ are negligibly small





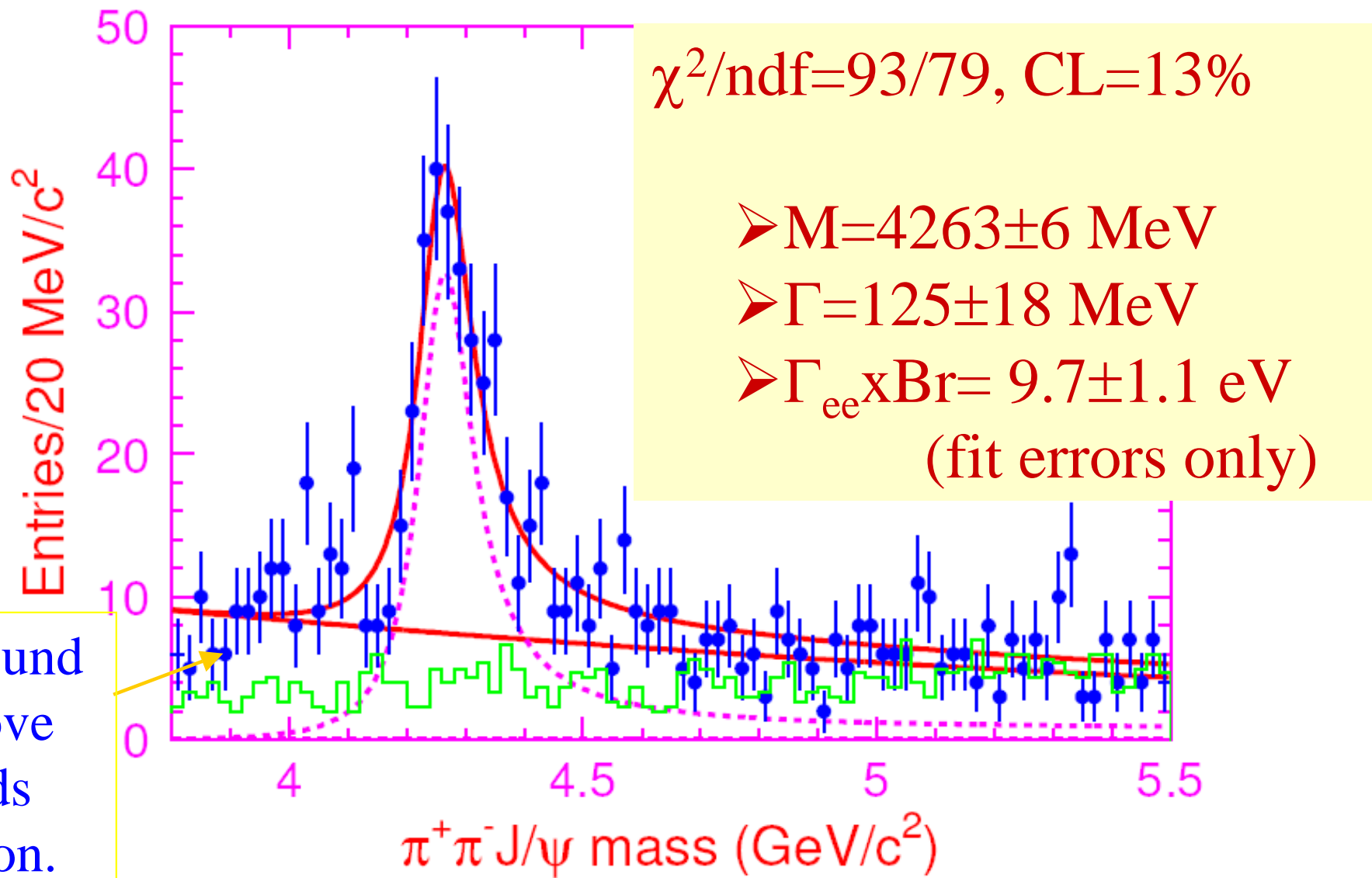
$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ via ISR



- **Background subtracted $M(J/\psi\pi\pi)$ corrected for efficiency and differential luminosity**
- **$M_{\pi\pi}$ spectra in different \sqrt{s} regions:**
 - $\sqrt{s} = 3.8 - 4.2$ & $4.4 - 4.6$ GeV in agreement with 3-body phase space
 - **Y(4260) region**
 - $\sqrt{s} = 3.8 - 4.15$ GeV: two clusters at low and high masses (scalars?)



$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ via ISR

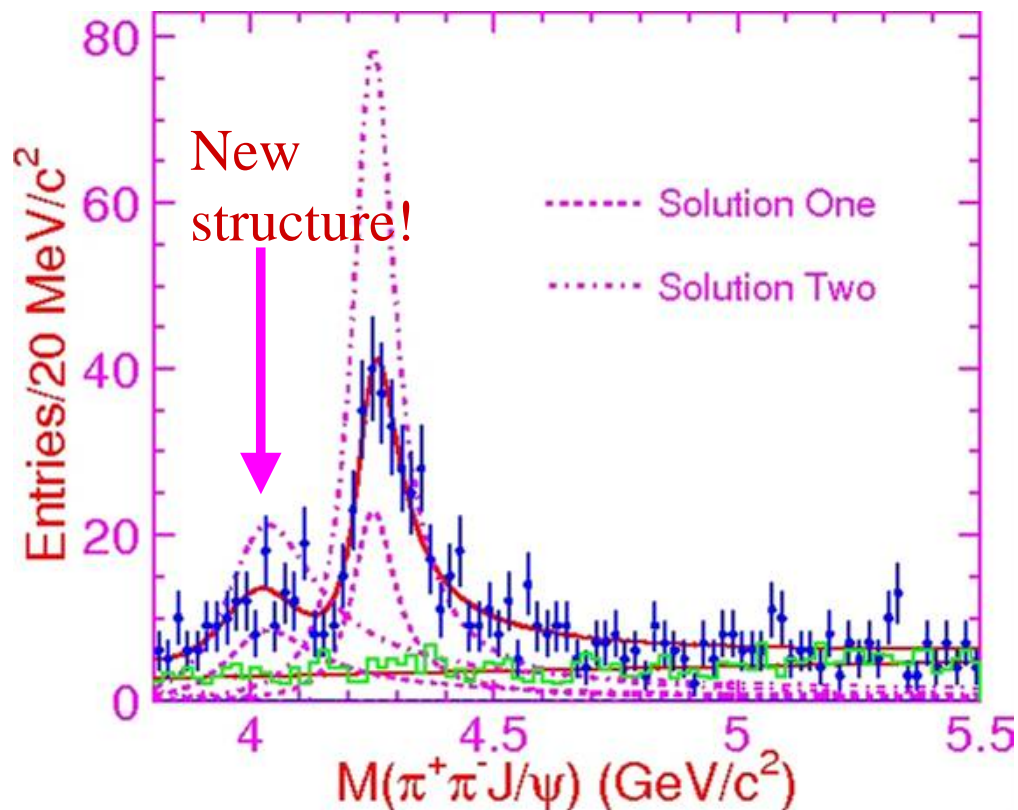


Fit with function Babar used. Similar results are got.



$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ via ISR

- **Non resonant $J/\psi\pi\pi$?**
- **Re-scattering $ee \rightarrow D^{(*)}D^{(*)} \rightarrow J/\psi\pi\pi$?**
- **Another broad state ?**



2-BW fit with interference better describes the data: $Y(4260)$ parameters are different (especially peak cross section – large uncertainty)

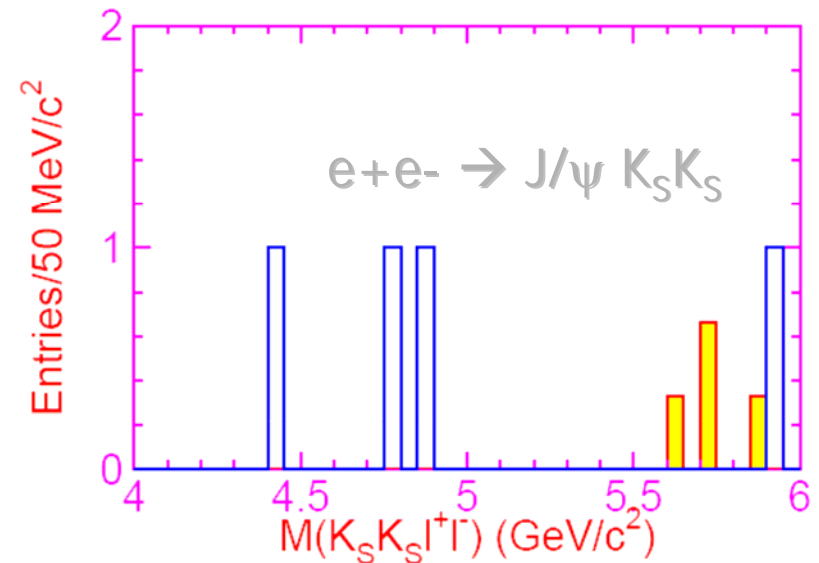
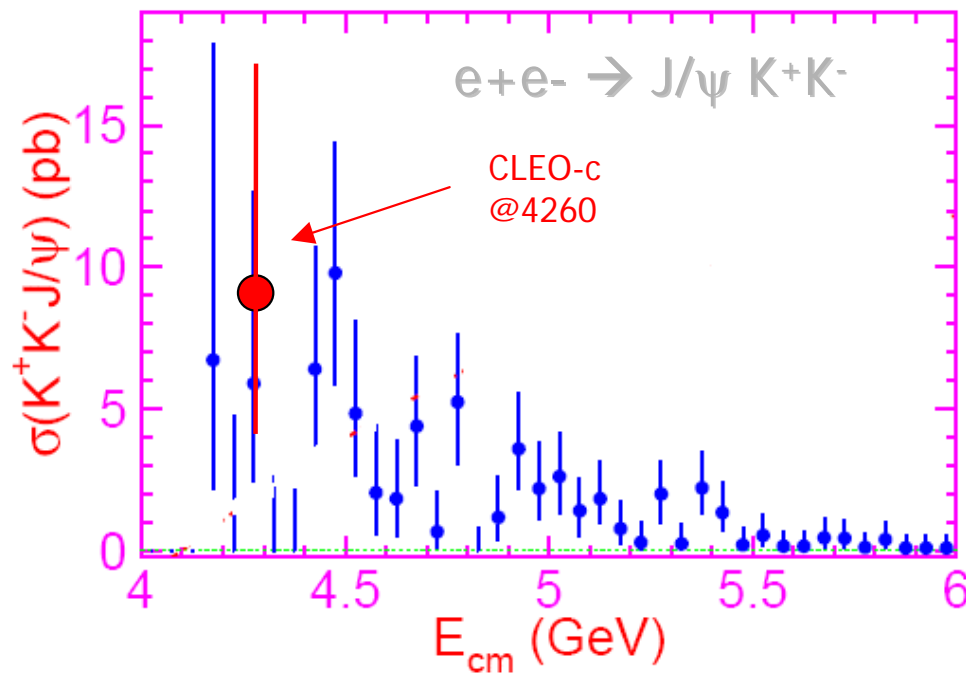
- **Check the latter hypothesis and influence of interference of $Y(4260)$ with non- Y contribution:**
- **Fit with 2 coherent BWs**
- **Two-fold ambiguity in amplitude (constructive-destructive interference) + model uncertainty due to ψ' tail**

Parameters	Solution I	Solution II
$M(R1)$	$4008 \pm 40_{-28}^{+114}$	
$\Gamma_{\text{tot}}(R1)$	$226 \pm 44 \pm 87$	
$\mathcal{B} \cdot \Gamma_{e^+e^-}(R1)$	$5.0 \pm 1.4_{-0.9}^{+6.1}$	$12.4 \pm 2.4_{-1.1}^{+14.8}$
$M(R2)$	$4247 \pm 12_{-32}^{+17}$	
$\Gamma_{\text{tot}}(R2)$	$108 \pm 19 \pm 10$	
$\mathcal{B} \cdot \Gamma_{e^+e^-}(R2)$	$6.0 \pm 1.2_{-0.5}^{+4.7}$	$20.6 \pm 2.3_{-1.7}^{+9.1}$
ϕ	$12 \pm 29_{-98}^{+7}$	$-111 \pm 7_{-31}^{+28}$



$e^+e^- \rightarrow K^+K^-J/\psi$ via ISR

- CLEO-c observed 3 K^+K^-J/ψ at $E_{cm}=4.26$ GeV and assumed from $Y(4260)$
- Belle : first observation of $e^+e^- \rightarrow J/\psi K^+K^-$ and evidence for $e^+e^- \rightarrow J/\psi K_S K_S$

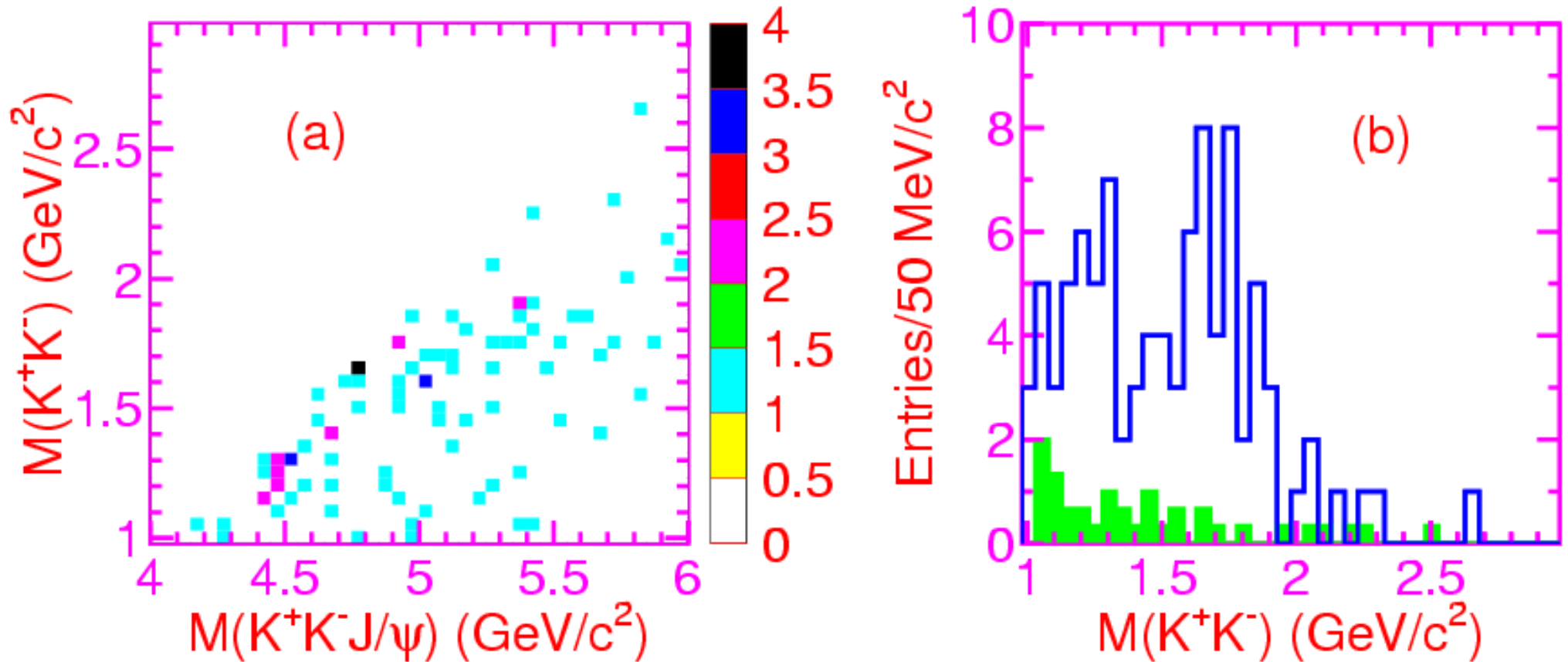


$$\sigma(e^+e^- \rightarrow J/\psi K_S K_S) / \sigma(e^+e^- \rightarrow J/\psi K^+ K^-) = 0.6^{+0.5}_{-0.4}$$

Consistent with isospin (0.5)



$e^+e^- \rightarrow K^+K^-J/\psi$ via ISR



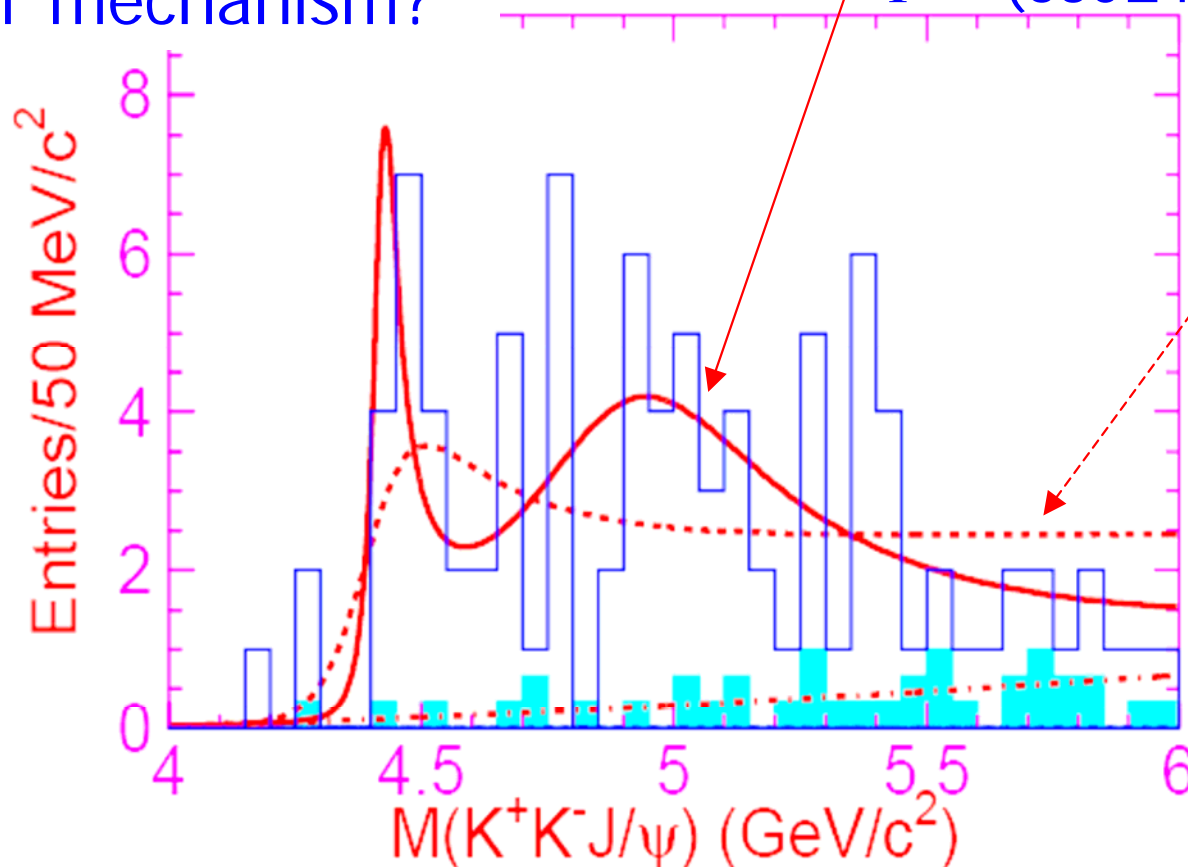
KK invariant mass tends to be large!



$e^+e^- \rightarrow K^+K^-J/\psi$ via ISR

New resonance or just continuum production, or other mechanism?

PDG $\psi(4415)$ + 1 BW:
 $M = (4875 \pm 132)$ MeV
 $\Gamma = (630 \pm 126)$ MeV



single BW:
 $M = (4430 \pm 38)$ MeV
 $\Gamma = (254 \pm 49)$ MeV

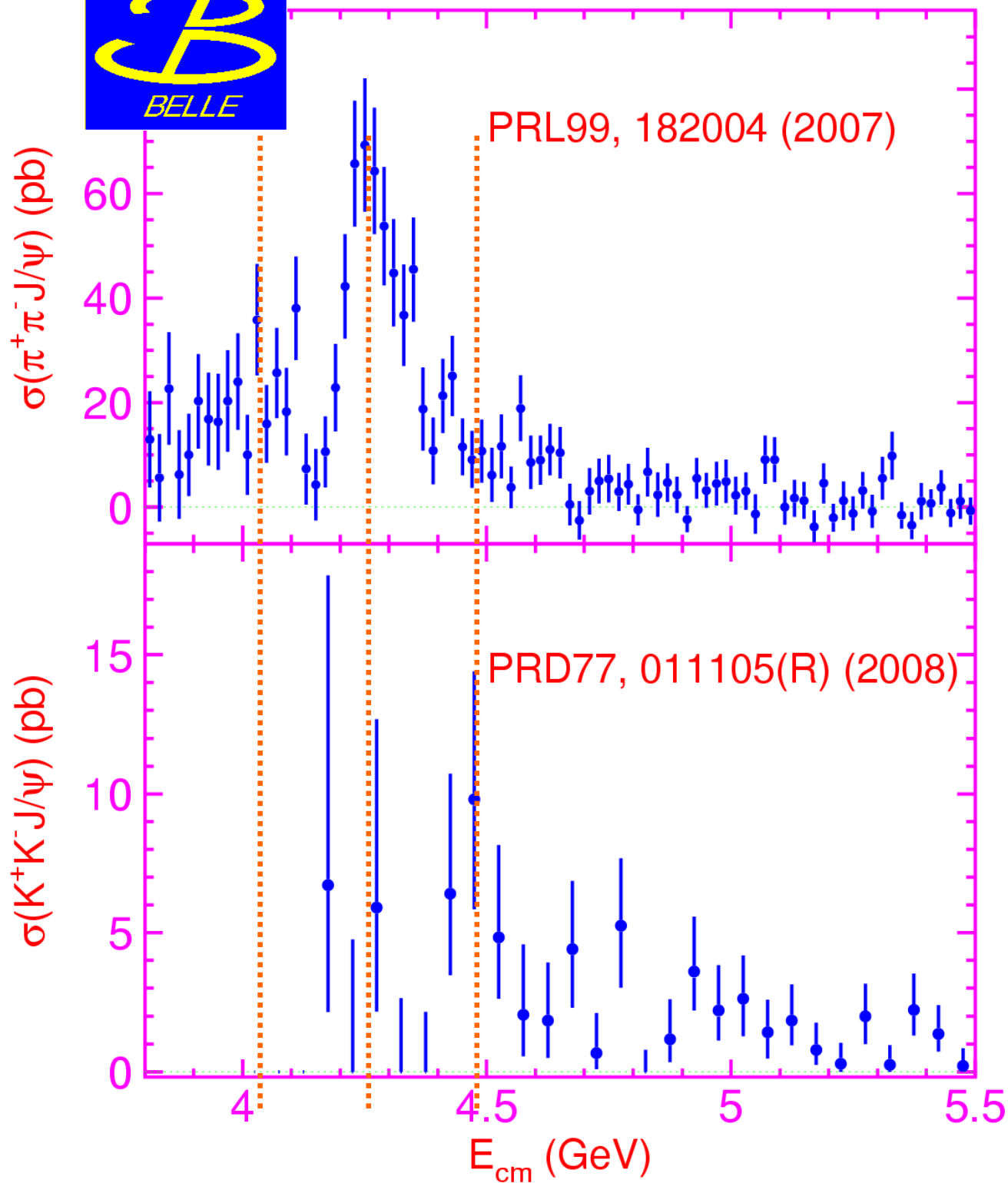
$$\Gamma(Y(4260) \rightarrow e^+e^-) \cdot B(Y \rightarrow K^+K^-J/\psi) < 1.2 \text{ eV @ 90\% C.L.}$$

$\pi^+\pi^-J/\psi$ and K^+K^-J/ψ



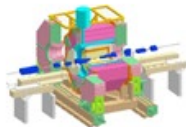
确认了Y(4260), 发现了未知性质的新结构Y(4008)。

KKJ/ ψ 中未观察到Y(4260)与用 $D_s^*D_s^*$ 散射解释截面增长不一致。





Belle Collaboration



Belle is an experiment at the KEK B-factory. Its goal is to study the origin of CP violation.

Introduction [English | Japanese]

- Hot !



Belle members only



KEK [English]



KEKB



Super-B

3rd International Workshop on "B Factories and New Measurements" (BNM 2008) (January 24-26, 2008, Atami, Japan)

BES-Belle-CLEO-BaBar Joint Workshop on Charm Physics (November 26-27, 2007, IHEP, Beijing)

First successful operation of crab cavities [English] [Japanese] [CERN courier article]

Another Breakthrough in "Missing Energy" Decays: Belle Reports the First Observation of $B^0 \rightarrow D^{*+} \tau^- \nu_\tau$

A. Matyja et al., PRL 99, 191807 (2007) (arXiv:0706.4429)

Belle Discovers More "New Particles"

A Y_b state?: Observation of an anomalously large rate for

"Upsilon(5S)" \rightarrow Upsilon(1,2S) $\pi^+ \pi^-$

K. Abe et al., arXiv:0710.2577 (submitted to PRL)

Z(4430): A charged charmonium-like resonant structure

S.K. Choi, S.L. Olsen et al., arXiv:0708.1790 (submitted to PRL)

Press release (English, Japanese)

Y(4660): X. L. Wang et al, PRL 99, 142002 (2007) (arXiv:0707.3699)

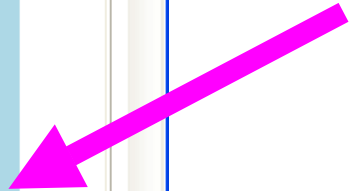
Y(4008): C.Z. Yuan et al, PRL 99, 182004 (2007) (arXiv:0707.2541)

X(4160): P. Pakhlov et al., arXiv:0708.3812 (submitted to PRL)

psi(4415) \rightarrow DD₂: G.Pakhlova et al, arXiv:0708.3313 (to appear in PRL)

D_{sJ}(2700): J. Brodzicka et al., arXiv:0707.3491 (submitted to PRL)

Belle合作组报道发现了更多新粒子!



X(4260)

$$I^G(J^{PC}) = ?^?(1^{--})$$

Seen in radiative return from e^+e^- collisions at $\sqrt{s} = 9.54\text{--}10.58$ GeV by AUBERT,B 05I, HE 06B, and YUAN 07, and in e^+e^- collisions at $\sqrt{s} \approx 4.26$ GeV by COAN 06. Possibly seen by AUBERT 06 in $B^- \rightarrow K^- \pi^+ \pi^- J/\psi$. See also the mini-review of the X(3872). (See the index for the page number.)

PDG'08

X(4260) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
4263⁺⁸₋₉ OUR AVERAGE Error includes scale factor of 1.1.				
YOUR DATA				
4247 ⁺¹² ₋₃₂		¹ YUAN	07 BELL	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
4284 ⁺¹⁷ ₋₁₆ ± 4	13.6	HE	06B CLEO	9.4–10.6 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
4259 ± 8 ⁺² ₋₆	125	² AUBERT,B	05I BABR	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
¹ From a two-resonance fit. ² From a single-resonance fit. Two interfering resonances are not excluded.				

X(4260) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
95 ± 14 OUR AVERAGE				
YOUR DATA				
108 ± 19 ± 10		³ YUAN	07 BELL	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
73 ⁺³⁹ ₋₂₅ ± 5	13.6	HE	06B CLEO	9.4–10.6 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
88 ± 23 ⁺⁶ ₋₄	125	⁴ AUBERT,B	05I BABR	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$
³ From a two-resonance fit. ⁴ From a single-resonance fit. Two interfering resonances are not excluded.				

X(4260) $\Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(J/\psi \pi^+ \pi^-) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					$\Gamma_2 \Gamma_1 / \Gamma$
VALUE (eV)	EVTS	DOCUMENT ID	TECN	COMMENT	
5.9^{+1.2}_{-0.9} OUR AVERAGE					
YOUR DATA					
6.0 ± 1.2 ^{+4.7} _{-0.5}		⁵ YUAN	07 BELL	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$	
8.9 ^{+3.9} _{-3.1} ± 1.8	8.1	HE	06B CLEO	9.4–10.6 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$	
5.5 ± 1.0 ^{+0.8} _{-0.7}	125	⁶ AUBERT,B	05I BABR	10.58 $e^+e^- \rightarrow \gamma \pi^+ \pi^- J/\psi$	

X(4260) $\Gamma(l)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(J/\psi K^+ K^-) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					$\Gamma_4 \Gamma_1 / \Gamma$
VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
YOUR DATA					
<1.2	90	⁸ YUAN	08 BELL	$e^+e^- \rightarrow \gamma K^+ K^- J/\psi$	
⁸ From a fit of the broad $K^+ K^- J/\psi$ enhancement including a coherent X(4260) amplitude with mass and width from YUAN 07.					

结果的引用

SLAC-spires: 23+3

会议广泛引用:

Lepton-Photon'07

Hadron'07

QWG'07

EPS-HEP'07

...

XYZ粒子研究是目前强子谱研究热点之一。



Summary

- Y and ψ are studied via ISR at $\sqrt{s}=10.58$ GeV at Belle
- Observation of Y(4008), Y(4260)
- Observation of $e^+e^- \rightarrow J/\psi K^+K^-$ & $J/\psi K_S K_S$

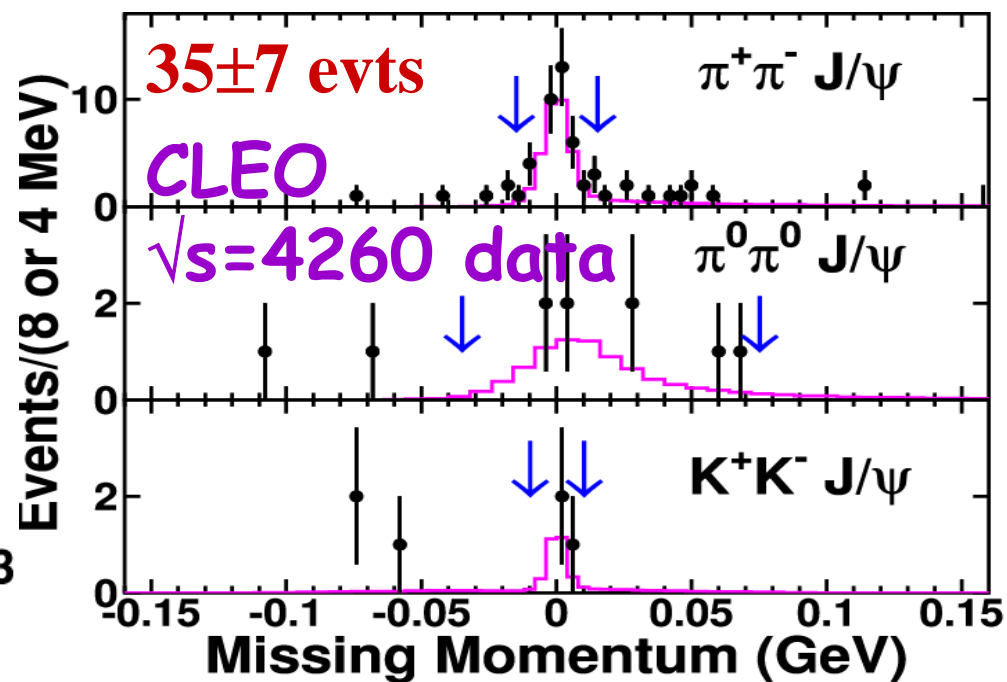
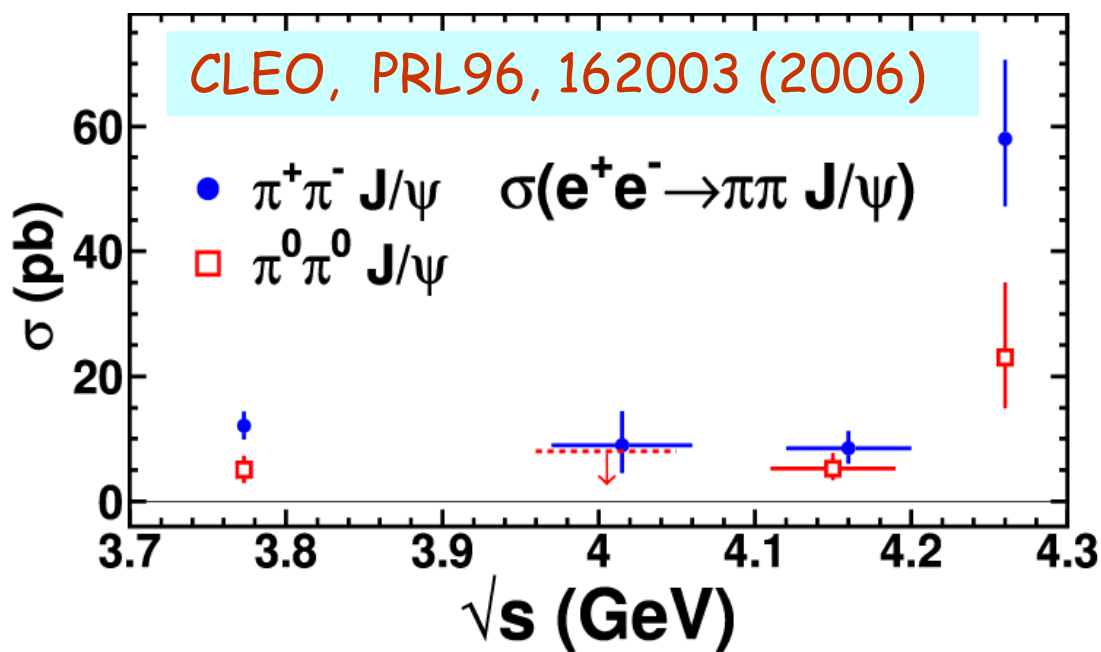
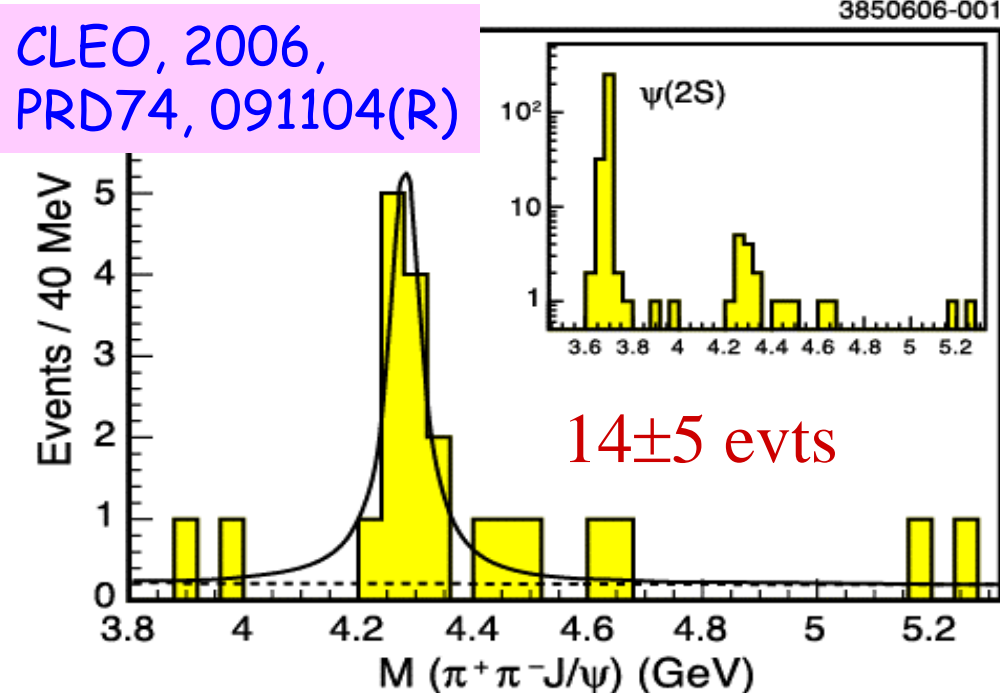
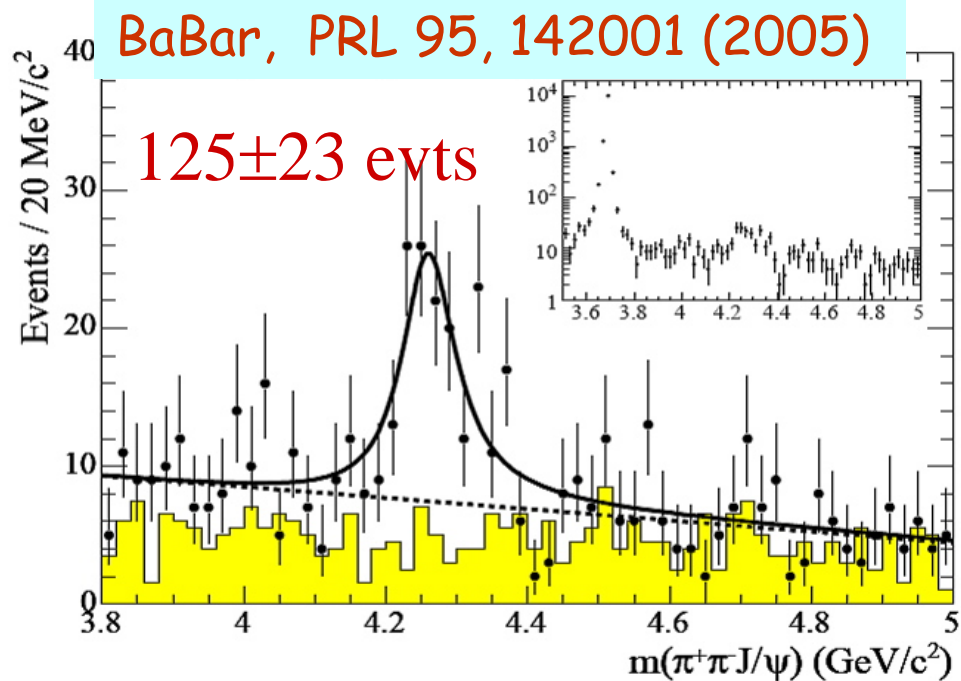
• Nature of the Y states (charmonium, hybrid, molecular, hadro-charmonium, baryonium, ...)?

• $Y(\text{xxxx}) = \psi(\text{xxxx})$?

Thanks a lot!

More information

Y(4260) in other experiments



Y(4260) in other experiments

X.H. Mo et al, PLB **640**, 182 (2006)
Using R-values from BES experiment.

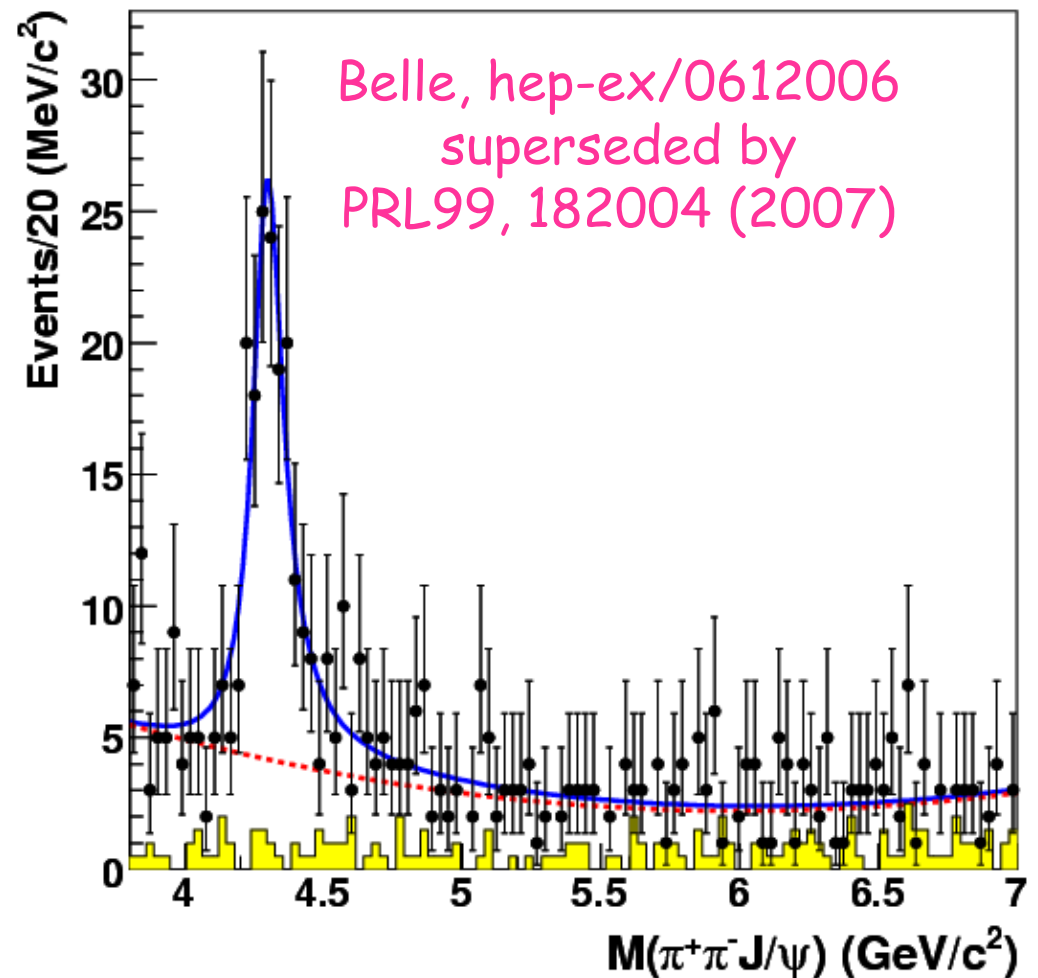
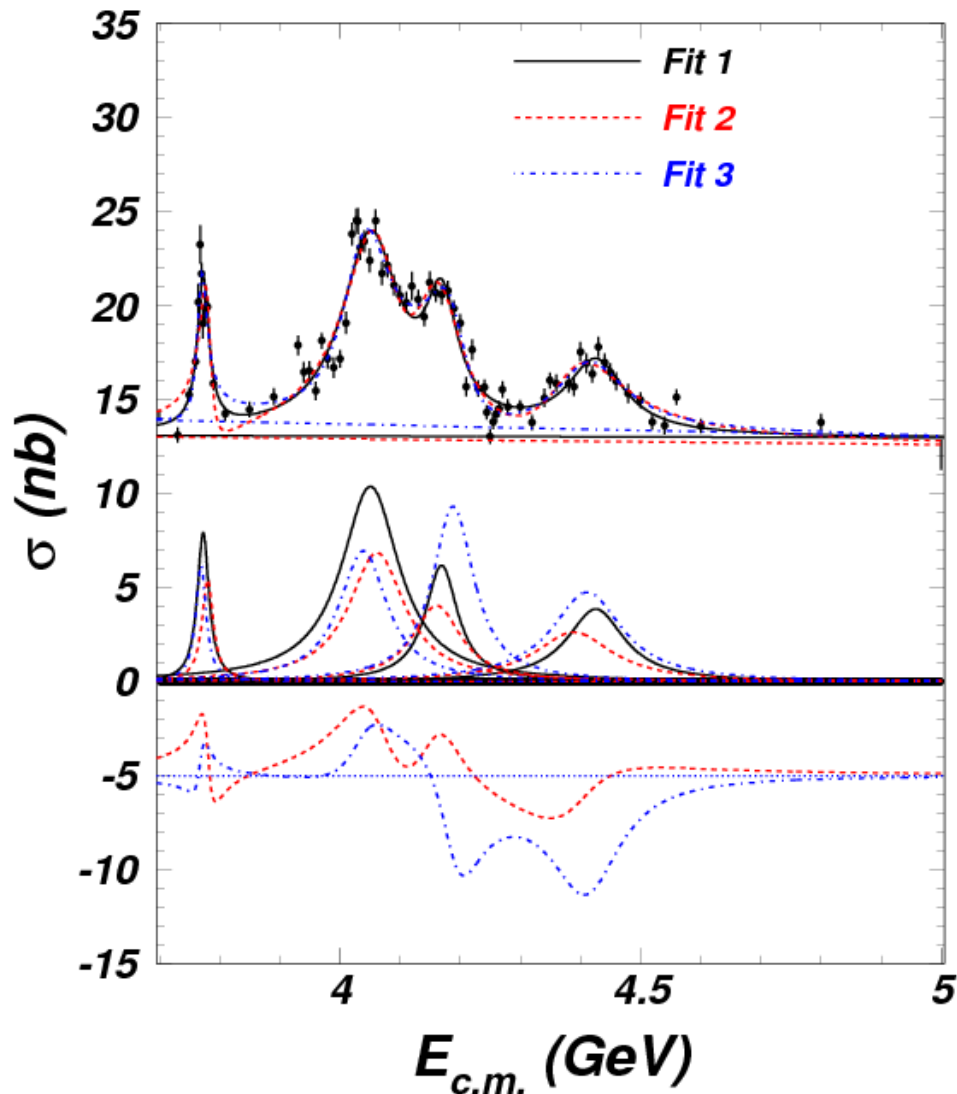
$$\Gamma_{ee} < 580 \text{ eV @ 90\% C.L.}$$

$$N = 165 \pm 24$$

$$M = 4295 \pm 10_{-5}^{+10} \text{ MeV}$$

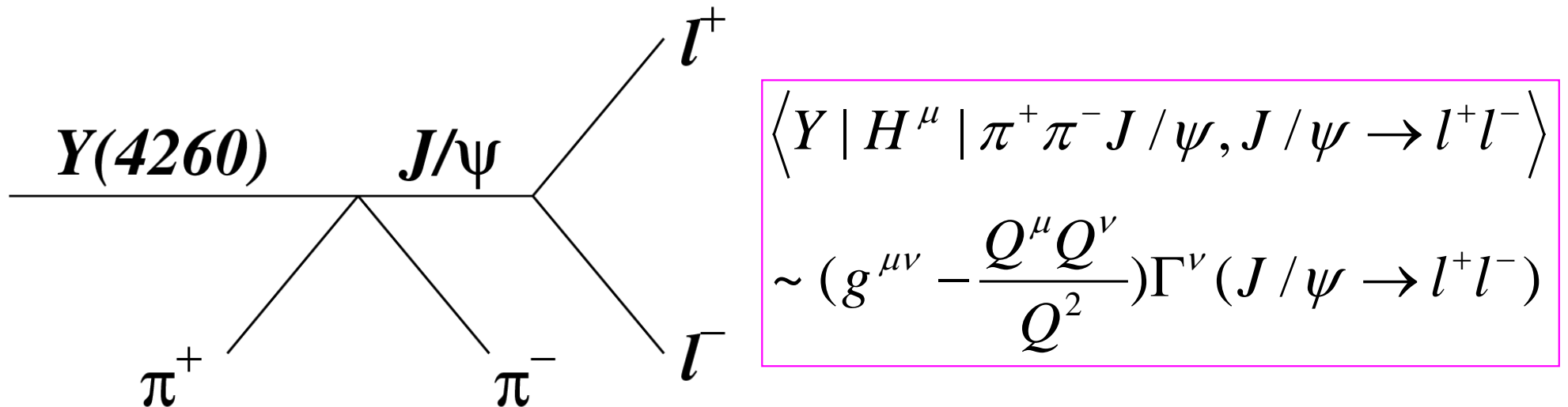
$$\Gamma = 133 \pm 26_{-6}^{+13} \text{ MeV}$$

$$\Gamma_{ee} \cdot B(Y \rightarrow \pi^+ \pi^- J/\psi) = 8.7 \pm 1.1_{-0.9}^{+0.3} \text{ eV}$$



MC generator

- Phokhara
 - <http://www.lnf.infn.it/wg/sighad/>
- Matrix element [R. Decker et al., Z. Phys. C 70, 247 (1996)]



$$\langle Y | H^\mu | \pi^+ \pi^- J / \psi, J / \psi \rightarrow l^+ l^- \rangle$$
$$\sim (g^{\mu\nu} - \frac{Q^\mu Q^\nu}{Q^2}) \Gamma^\nu (J / \psi \rightarrow l^+ l^-)$$

- ψ' generated with correct resonance parameters, $\pi\pi$ mass distribution, angular distribution; other states generated according to phase space at fixed mass