

Hadronic Physics at Belle

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Outline

1. Hadron production at B factories
2. Study of charmonium(-like) states
3. States of light quarks
4. Summary of $\Upsilon(5S)$ results
5. Conclusions

Introductory Remarks

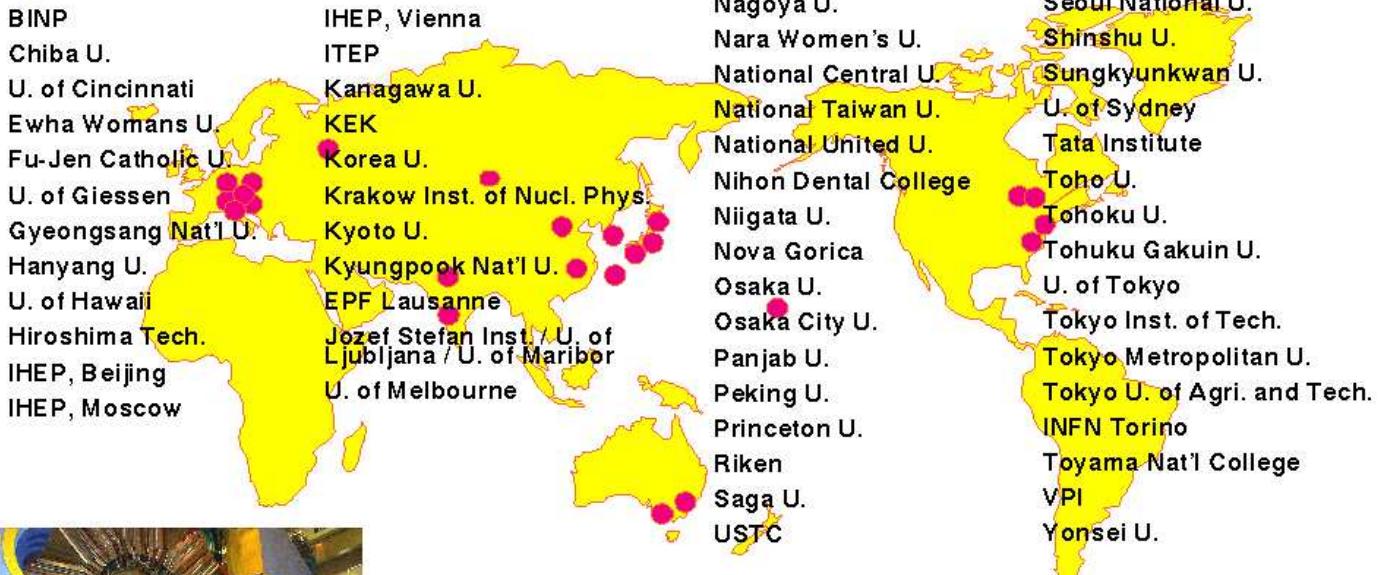
If in doubt, tell the truth
Mark Twain

- Very recent results were selected,
mostly on production and decays of unstable mesons
- Many topics mentioned/covered in talks by W.-S. Hou, E. Klempert, L. Maiani,
R. Mussa, A. Palano and A. Reis
- A lot of interesting results on D_{sJ} , D^{**} mesons and baryons, but . . .
- Very rich B and D meson physics discussed at numerous conferences
- Thanks are due to many Belle colleagues

Belle Geography

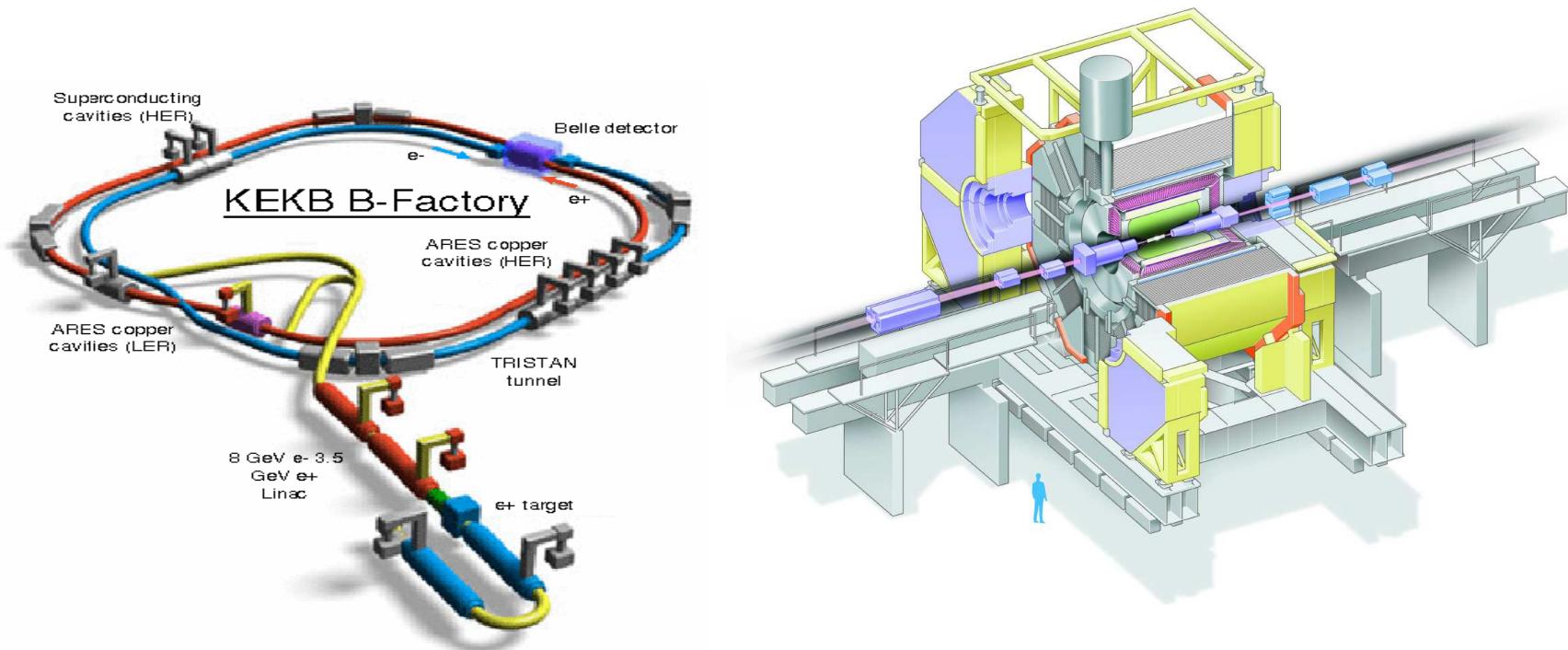


International Collaboration: Belle



14 countries, 55 institutes, ~400 collaborators

KEKB, Belle Detector



$$3.5 \text{ GeV } e^+ \times 8.0 \text{ GeV } e^- \quad \mathcal{L}_{\max} = 1.71 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}$$

$$\text{Continuous injection} \Rightarrow 1.2 \text{ fb}^{-1}/\text{day} \quad \int \mathcal{L} dt \approx 715 \text{ fb}^{-1}$$

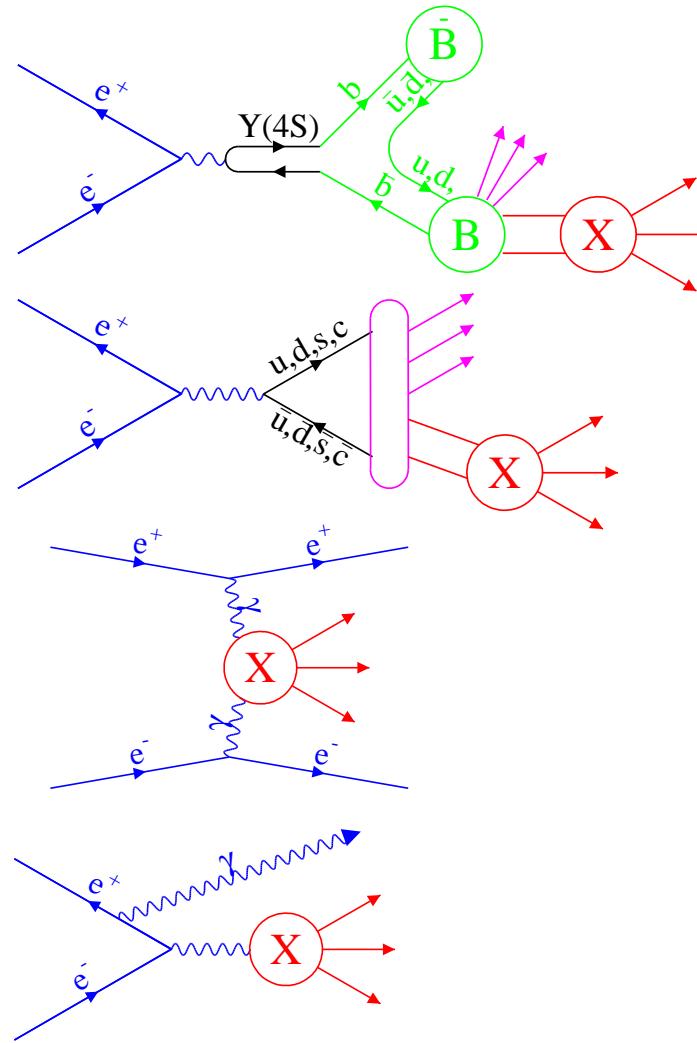
Particle Production at B Factories

Production from B-decay
 (broad D^{**} , D_{sJ} , $X(3872)$, $Y(3940)$)

Production from continuum
 $(D_{sJ}, \eta_c(2S), X(3940), \Sigma(2800))$

Two-photon production
 $(\eta_c(2S), \chi_{c2}(2P))$

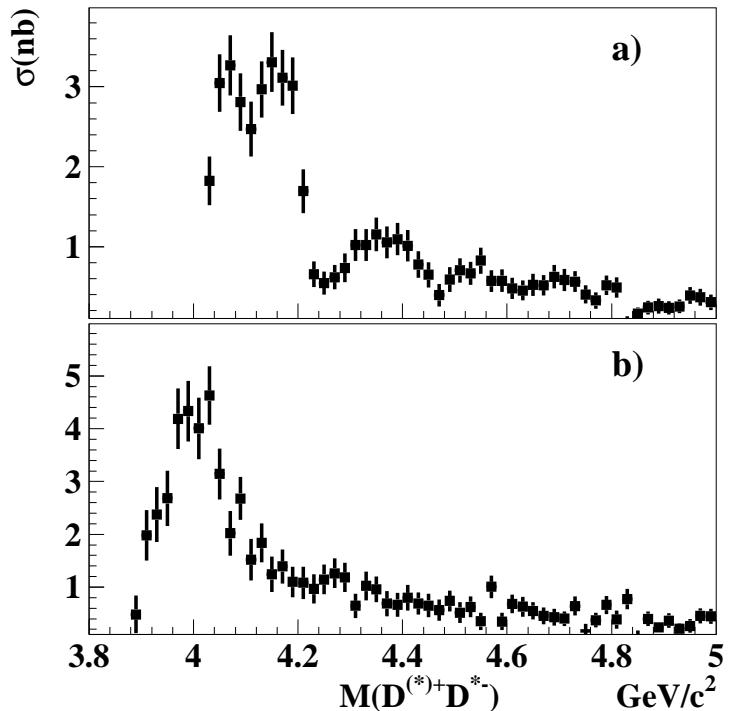
Initial state radiation
 $(Y(4260), Y(4360), Y(4660))$



What Do We Know about J/ψ Excitations?

- Four broad ψ -like structures known since 25 years –
 $\psi(3770)$, $\psi(4040)$, $\psi(4160)$, $\psi(4415)$
- Even main properties (M , Γ , Γ_{ee}) from DASP/MARK I data known badly
- From Crystal Ball/BES data serious revision needed
K.K. Seth, PRD 72, 017501 (2005)
- Difficulties are due to opening thresholds, common decay channels ($D^{(*)}\bar{D}_{(s)}^{(*)}$)
- Recently BES made a model-dependent coupled-channel analysis
M. Ablikim et al., arXiv:0705.4500
- Exclusive studies and determination of decay mechanisms will be helpful

$$e^+ e^- \rightarrow D^{(*)\pm} D^{*\mp}$$



548 fb^{-1} , $3.9 < \sqrt{s} < 5 \text{ GeV}$

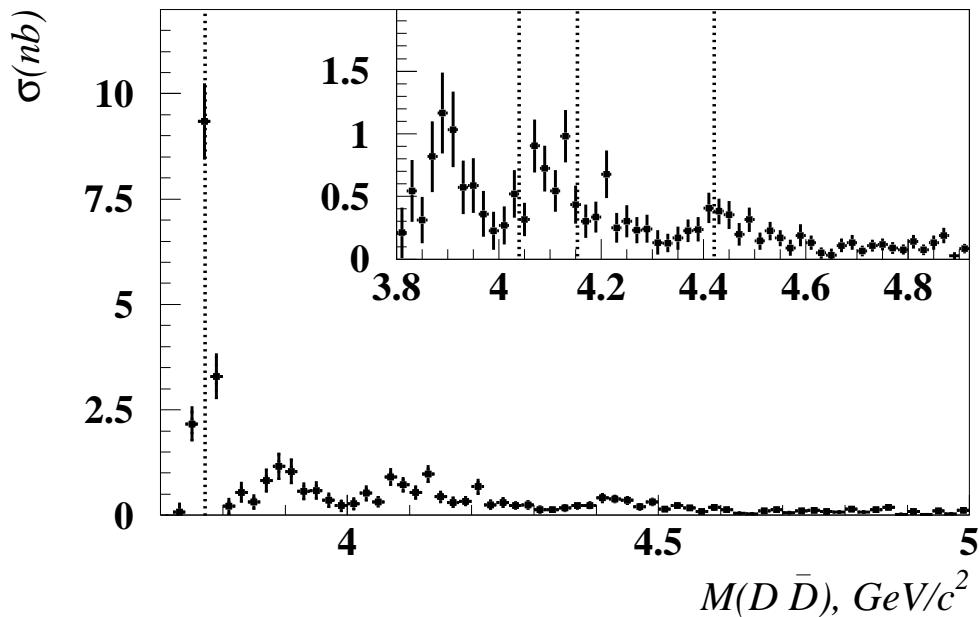
$D^{*+}D^{*-}$ (a) – rich,
minimum at 4.25 GeV

due to $D_s^*D_s^*(DD^{**})$ or
interference with $\psi(nS)$

D^+D^{*-} (b) – excess at $\psi(4040)$

G. Pakhlova et al., PRL 98, 092001 (2007)
Partial reconstruction: one $D^{(*)+}$, γ_{ISR} , π_{slow}^-

$e^+e^- \rightarrow D\bar{D}$ via ISR

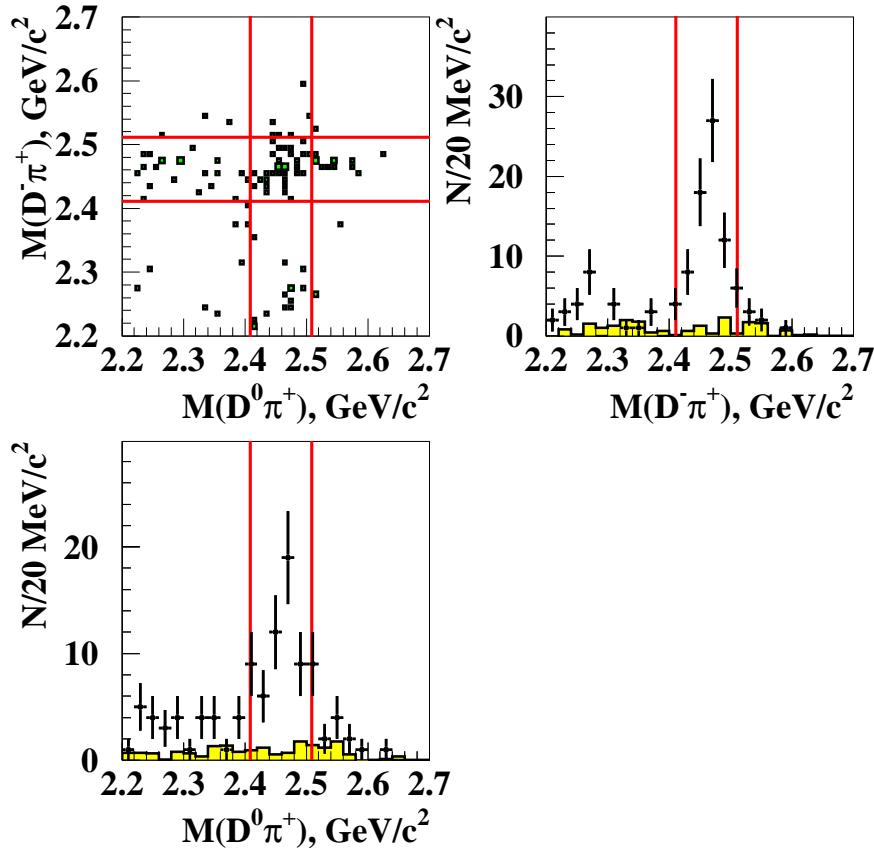
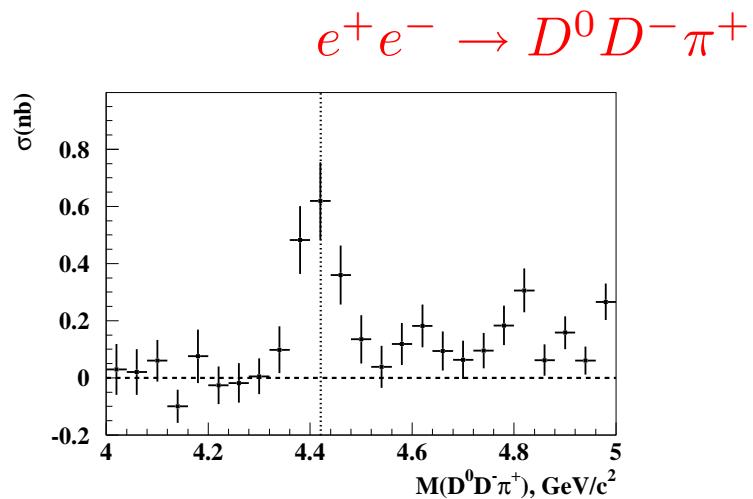


G. Pakhlova et al., arXiv:0708.0082; 673 fb^{-1}

Peak at 3.9 GeV as in BES, BaBar

Above 4 GeV the shape of $\sigma(D\bar{D})$ is similar to $\sigma(D^{*+}D^{*-})$

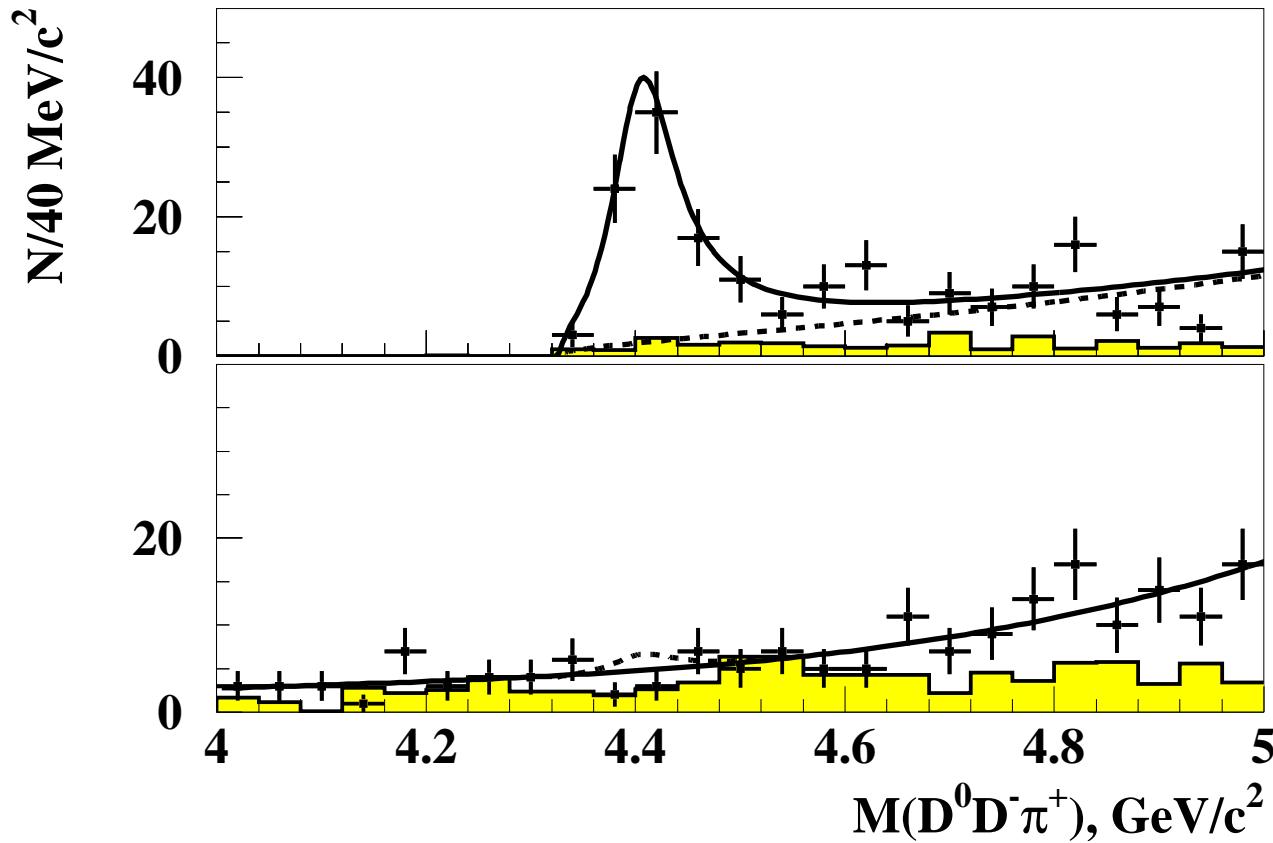
$\psi(4415) \rightarrow D\bar{D}_2^*(2460)$ via ISR – I



G. Pakhlova et al., arXiv:0708.3313, PRL; 673 fb^{-1}

Clear signals of $D^0 \bar{D}_2^*(2460)^0$ and $D^- \bar{D}_2^*(2460)^+$ seen

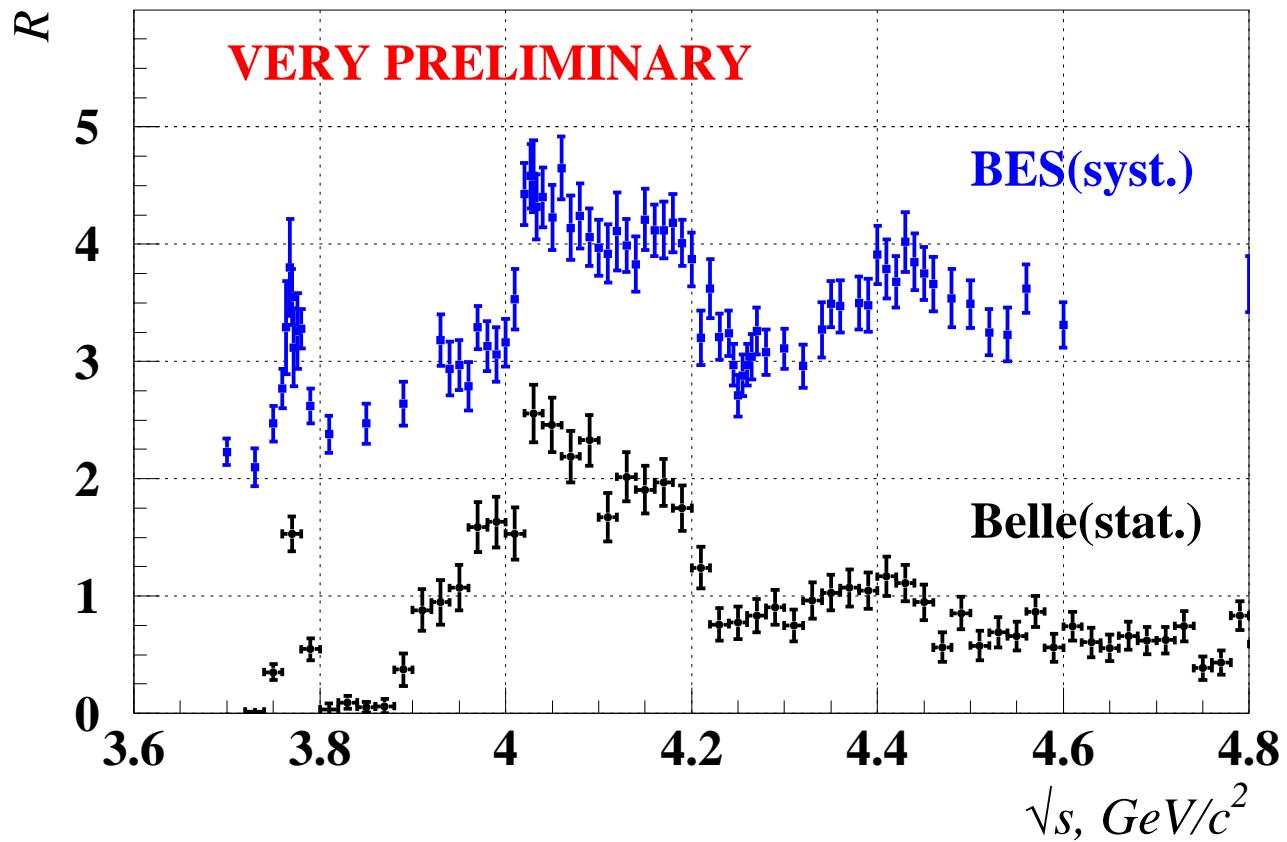
$\psi(4415) \rightarrow D\bar{D}_2^*(2460)$ via ISR – II



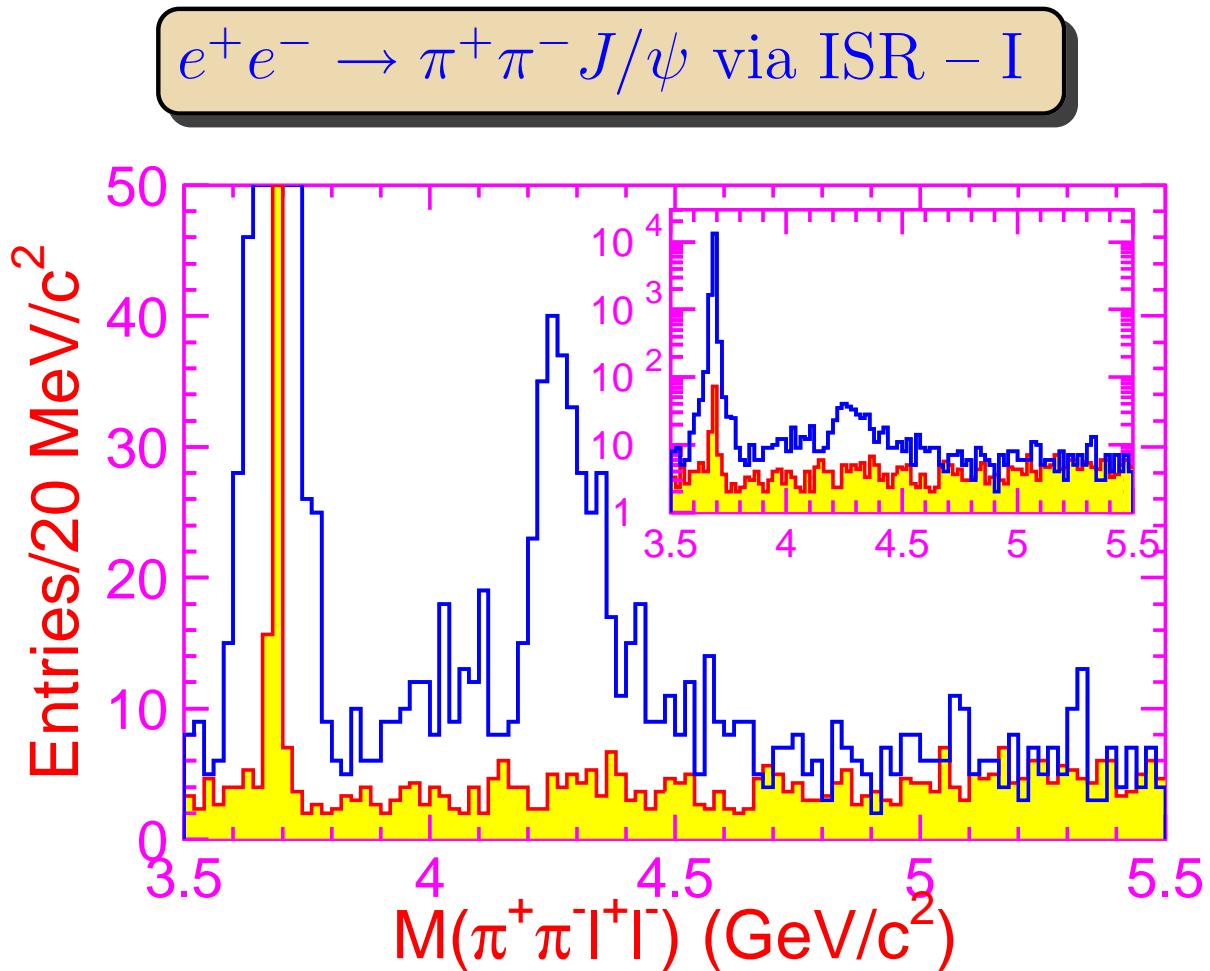
109 ± 25 events ($\sim 10\sigma$) $M = 4411 \pm 7 \text{ MeV}$ $\Gamma = 77 \pm 20 \text{ MeV}$

$\mathcal{B}(D^0 D^- \pi^+)_{\text{non-res}} / \mathcal{B}(D\bar{D}_2^*(2460) \rightarrow D^0 D^- \pi^+) < 0.22$

Total Exclusive Cross Section via ISR

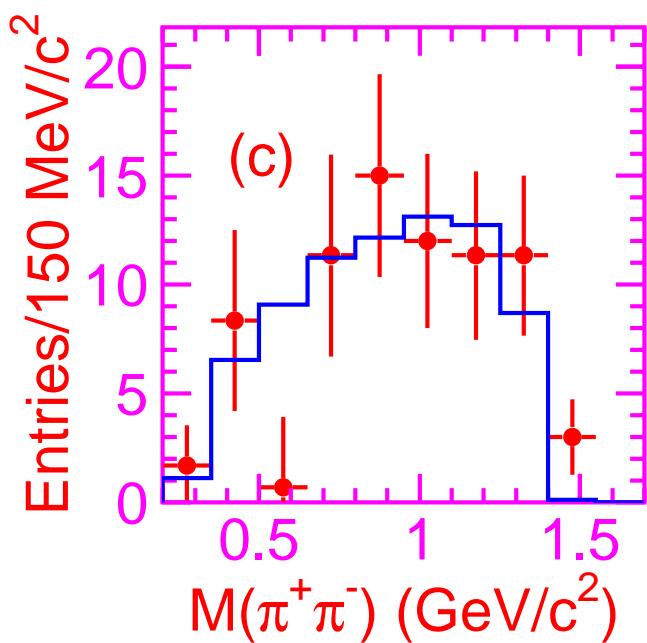
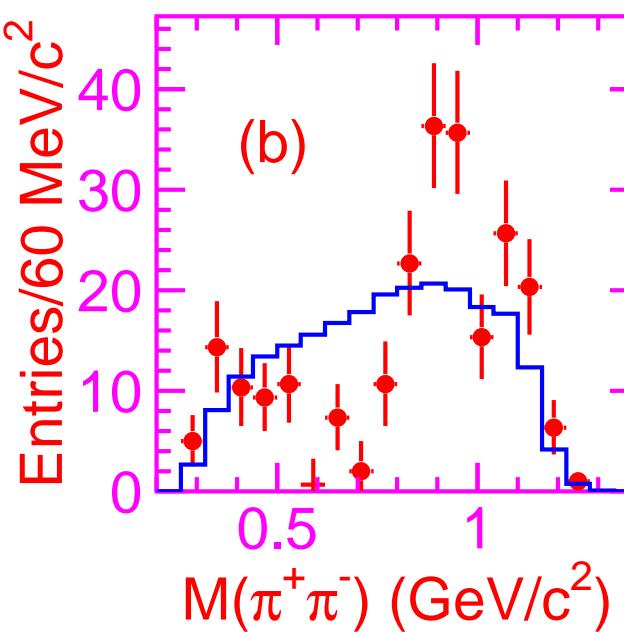
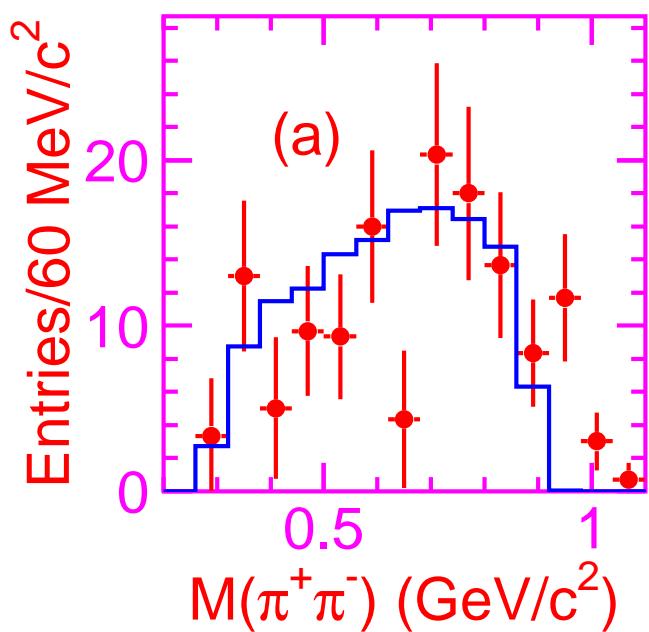


More exclusive modes needed to saturate R above 4.2 GeV
after subtracting the contribution of light (u, d, s) quarks



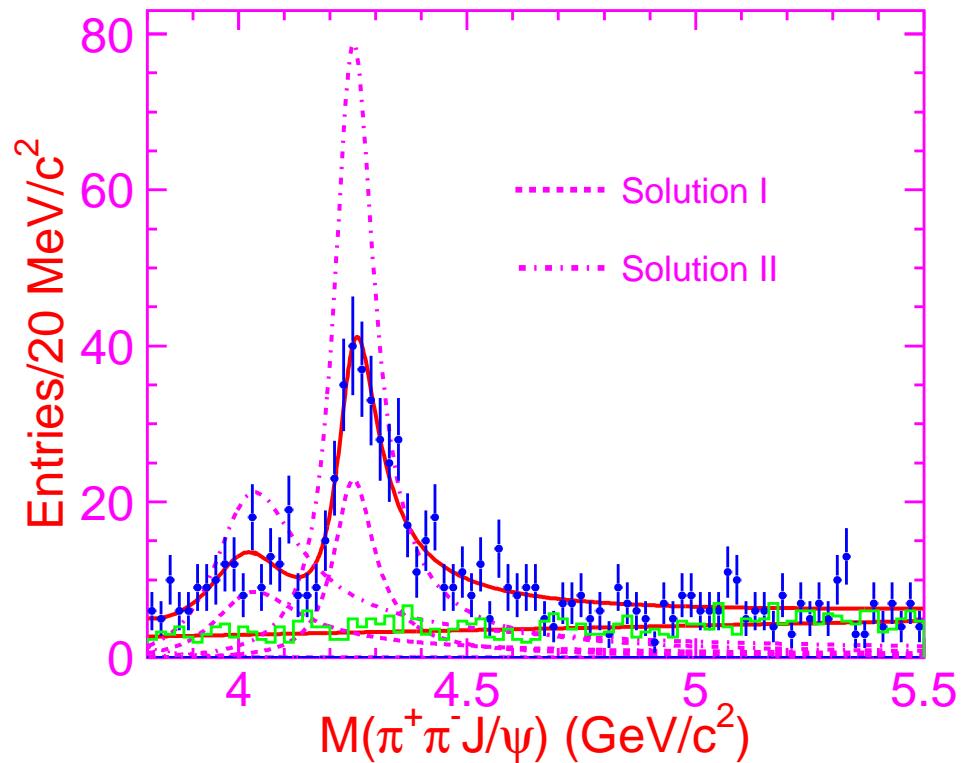
C.-Z. Yuan et al., arXiv:0707.2541, PRL; 548 fb^{-1} , $3.8 < \sqrt{s} < 5.5 \text{ GeV}$,
Clear peak at 4.25 GeV and cluster of events at 4.05 GeV

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



The $M_{\pi^+\pi^-}$ spectrum differs from phase space

$$e^+ e^- \rightarrow \pi^+ \pi^- J/\psi \text{ via ISR - III}$$

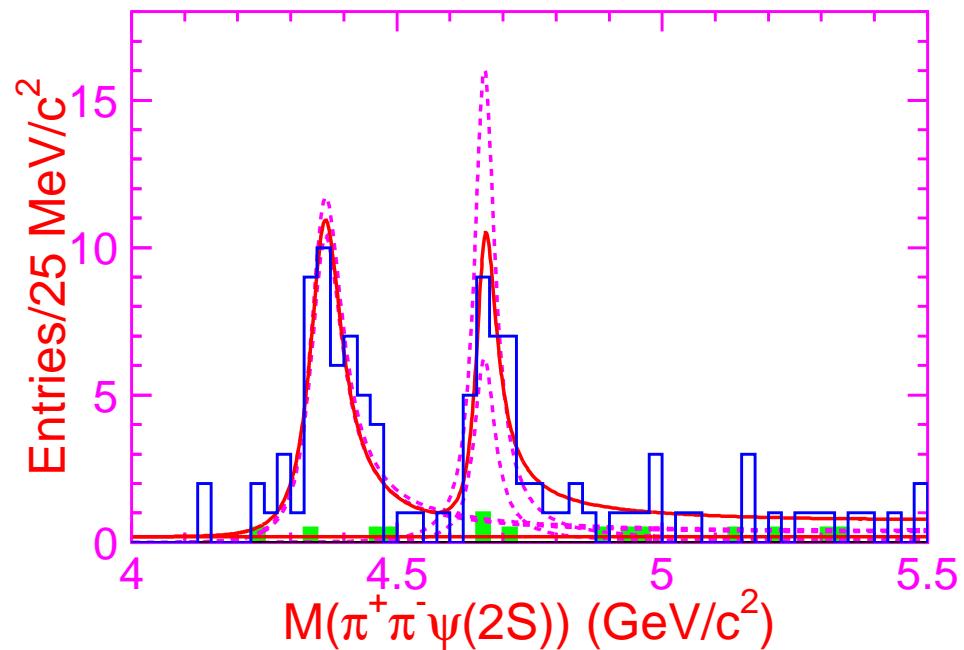


The structure at 4.25 GeV is consistent with that of BaBar and CLEO
The structure at 4.05 GeV is observed for the first time

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

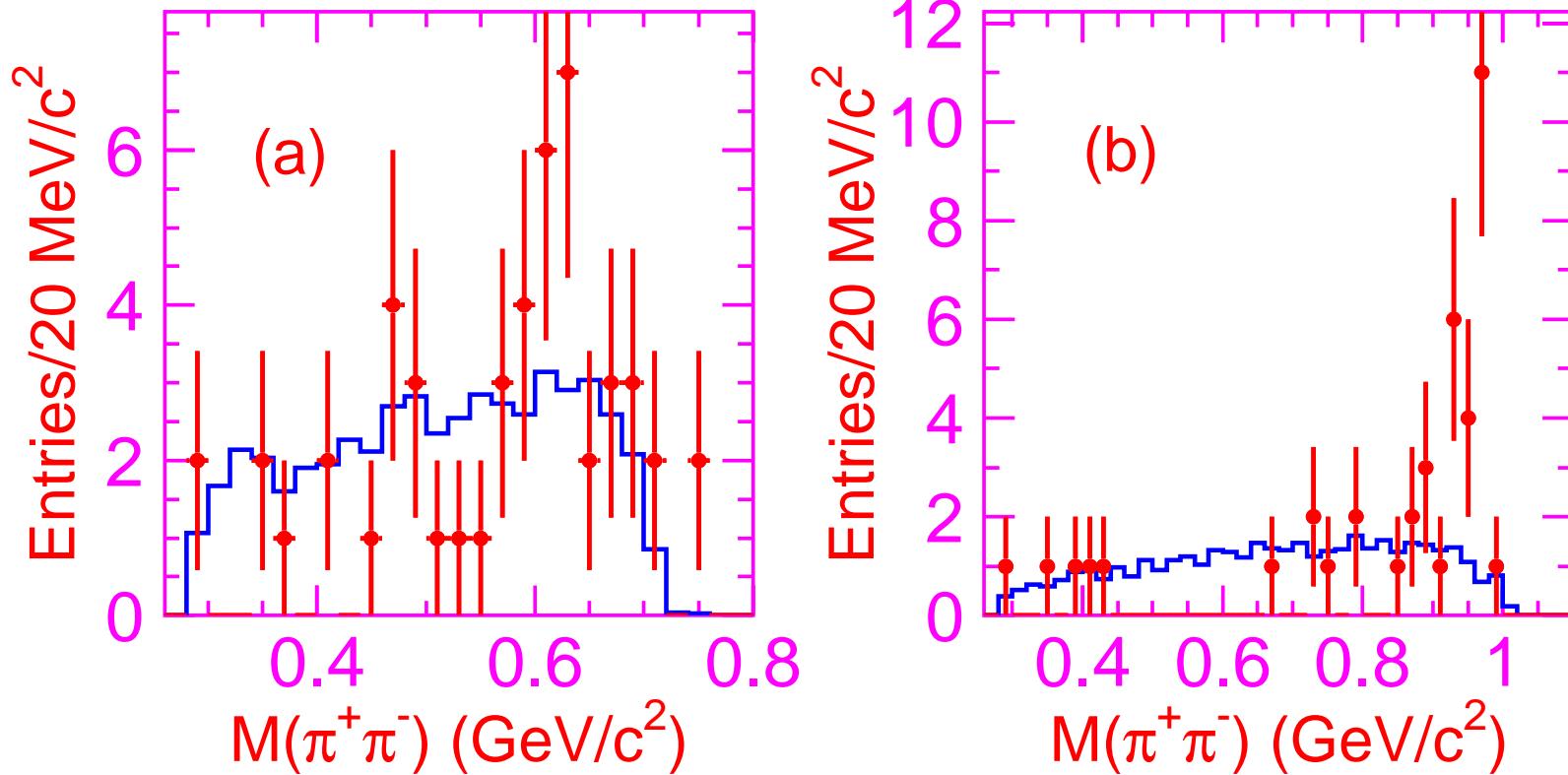
Parameters	Solution I	Solution II
$M(R1)$	$4008 \pm 40^{+114}_{-28}$	
$\Gamma_{\text{tot}}(R1)$	$226 \pm 44 \pm 87$	
$\mathcal{B} \cdot \Gamma_{ee}(R1)$	$5.0 \pm 1.4^{+6.1}_{-0.9}$	$12.4 \pm 2.4^{+14.8}_{-1.1}$
$M(R2)$	$4247 \pm 12^{+17}_{-32}$	
$\Gamma_{\text{tot}}(R2)$	$108 \pm 19 \pm 10$	
$\mathcal{B}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

Coupled-channel and rescattering ($D^{(*)}\bar{D}^{(*)}$) effects
may affect the interpretation

$$e^+ e^- \rightarrow \pi^+ \pi^- \psi(2S) \text{ via ISR - I}$$


X.-L. Wang et al., PRL 99, 142002 (2007); 673 fb^{-1} , $4.0 < \sqrt{s} < 5.5 \text{ GeV}$,
Distinct peaks at 4.36 GeV and 4.66 GeV

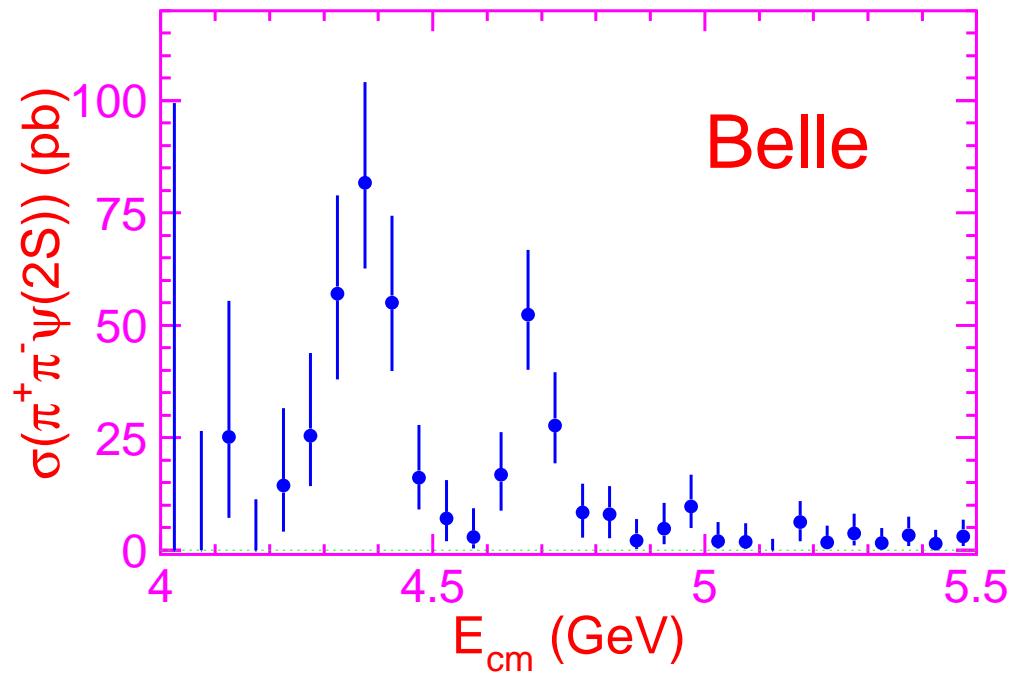
$e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$ via ISR – II



$M_{\pi^+\pi^-}$ spectra differ from phase space

At $4.5 \text{ GeV} < \sqrt{s} < 4.9 \text{ GeV}$ $M_{\pi^+\pi^-} \approx M_{f_0(980)}$

$$e^+e^- \rightarrow \pi^+\pi^-\psi(2S) \text{ via ISR - III}$$



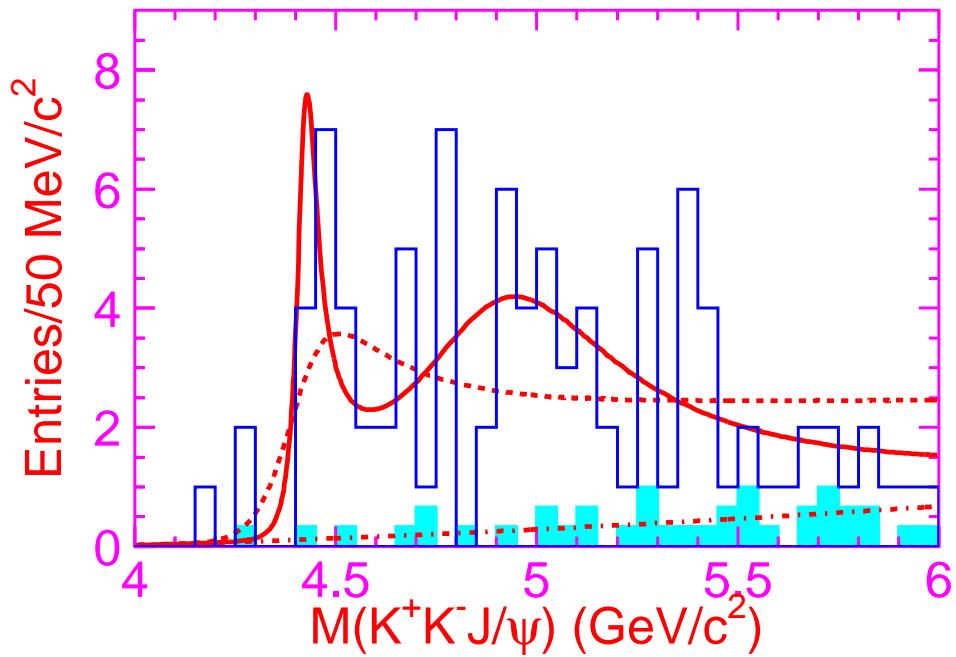
The cross sections are consistent with those of BaBar
The first structure is much narrower than that of BaBar
The second structure is observed for the first time

$$e^+e^- \rightarrow \pi^+\pi^-\psi(2S) \text{ via ISR - IV}$$

Parameters	Solution I	Solution II
$M(Y(4360))$	$4361 \pm 9 \pm 9$	
$\Gamma_{\text{tot}}(Y(4360))$	$74 \pm 15 \pm 10$	
$\mathcal{B} \cdot \Gamma_{ee}(Y(4360))$	$10.4 \pm 1.7 \pm 1.5$	$11.8 \pm 1.8 \pm 1.4$
$M(Y(4660))$	$4664 \pm 11 \pm 5$	
$\Gamma_{\text{tot}}(Y(4660))$	$48 \pm 15 \pm 3$	
$\mathcal{B} \cdot \Gamma_{ee}(Y(4660))$	$3.0 \pm 0.9 \pm 0.3$	$7.6 \pm 1.8 \pm 0.8$
ϕ	$39 \pm 30 \pm 22$	$-79 \pm 17 \pm 20$

These structures differ from those in $J/\psi\pi^+\pi^-$
 Coupled-channel and rescattering ($D^{(*)}\bar{D}^{(*)}$, $D_s^{(*)}\bar{D}_s^{(*)}$) effects
 may affect the interpretation

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



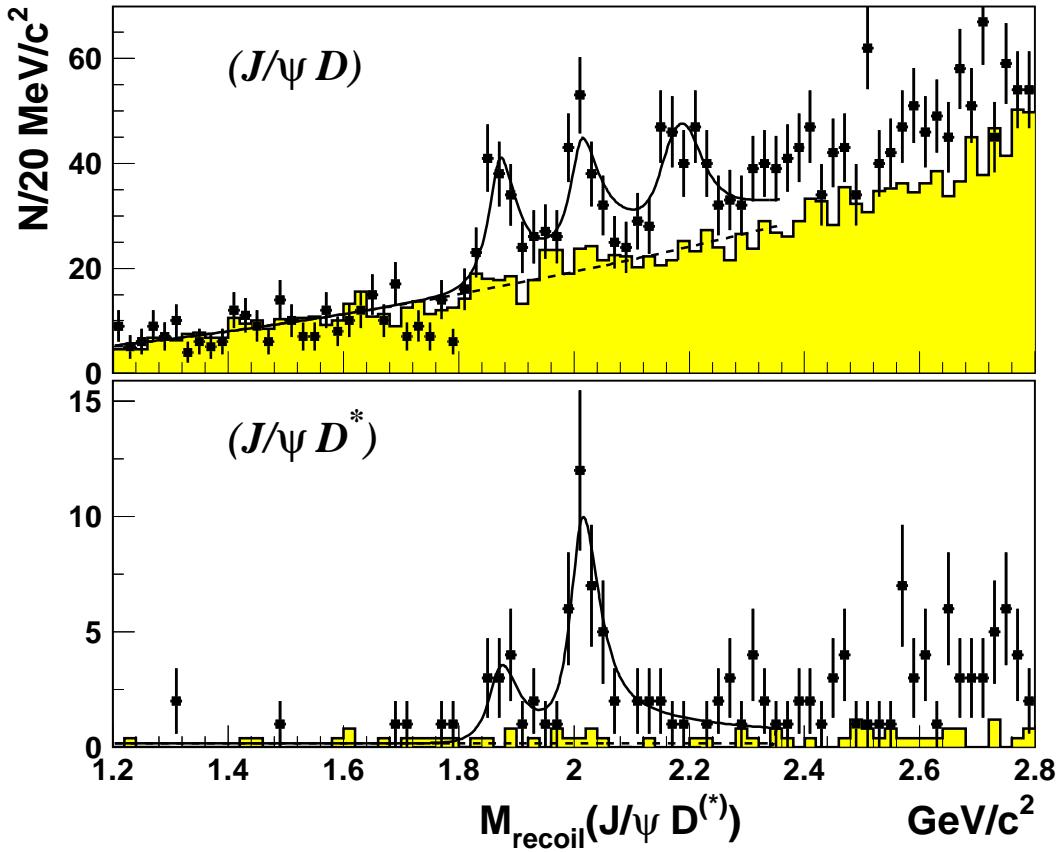
$673 \text{ fb}^{-1}, \quad 4.1 < \sqrt{s} < 6 \text{ GeV}$

C.-Z. Yuan et al., arXiv:0709.2565

A broad structure not described by existing ψ' 's

Two events near $Y(4260)$, three $K_S^0K_S^0$ events from 4.4 to 5.2 GeV

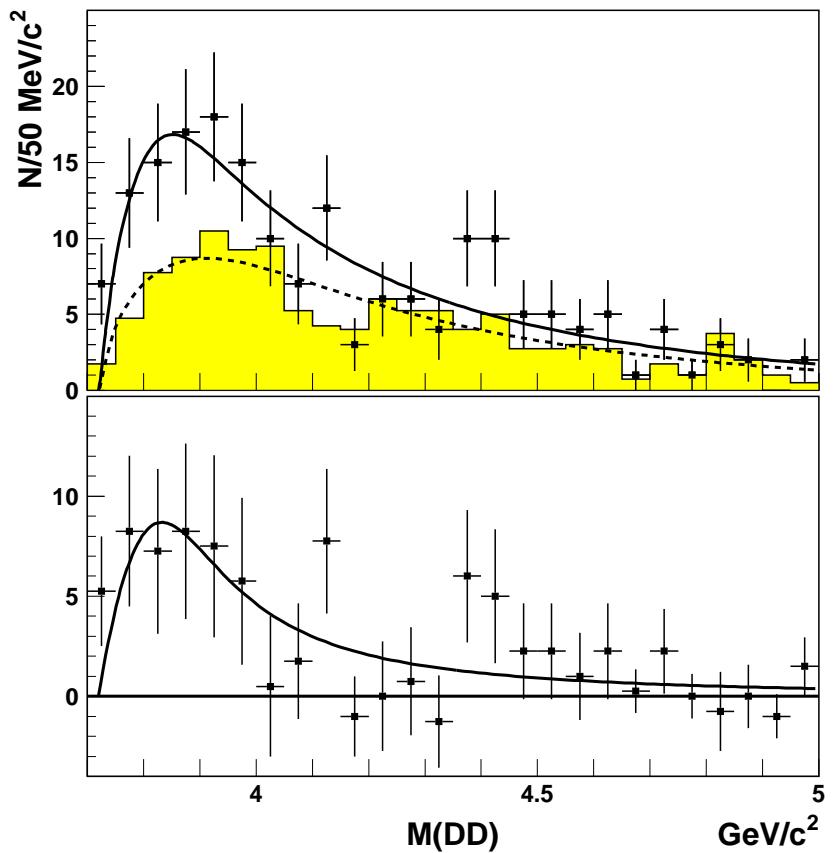
$$e^+ e^- \rightarrow J/\psi D^{(*)} \bar{D}^{(*)} - I$$



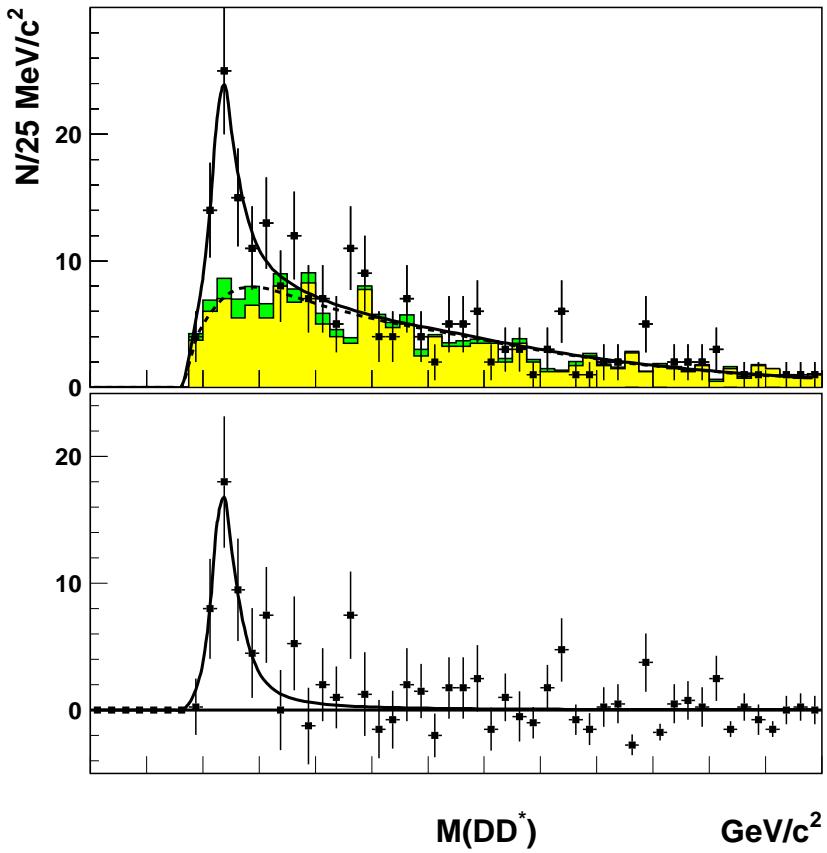
P. Pakhlov et al., arXiv:0708.3812, PRL; 693 fb^{-1}

$D^{*+} \rightarrow D^0 \pi^+$ Only one $D^{(*)}$ is fully reconstructed

$$e^+e^- \rightarrow J/\psi D^{(*)}\bar{D}^{(*)} - \text{II}$$

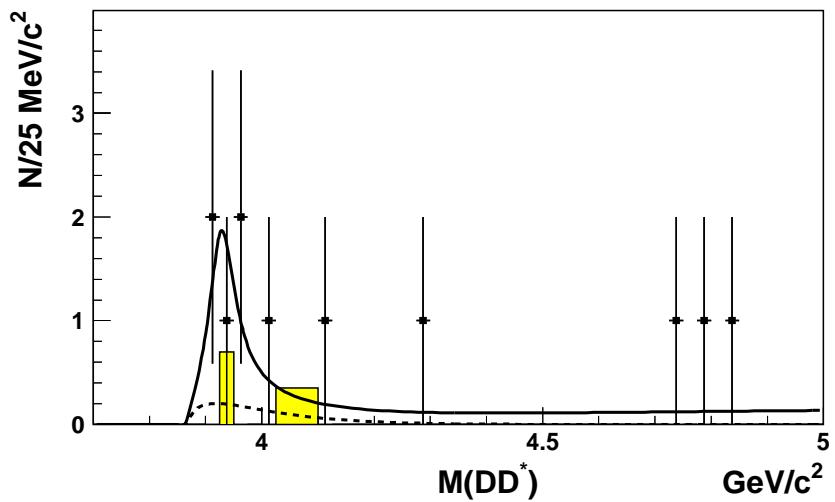


$D_{\text{rec}}\bar{D}_{\text{assoc}}$

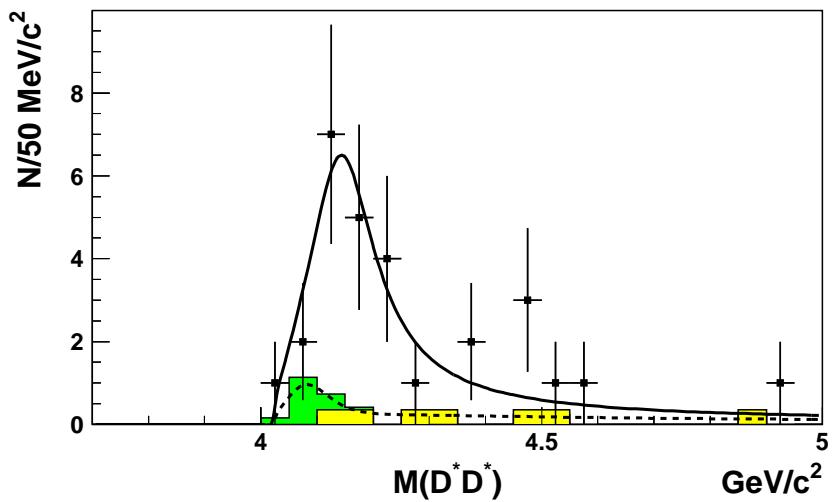


$D_{\text{rec}}\bar{D}_{\text{assoc}}^*$

$$e^+e^- \rightarrow J/\psi D^{(*)}\bar{D}^{(*)} - \text{III}$$



$D_{\text{rec}}^* \bar{D}_{\text{assoc}}$



$D_{\text{rec}}^* \bar{D}_{\text{assoc}}^*$

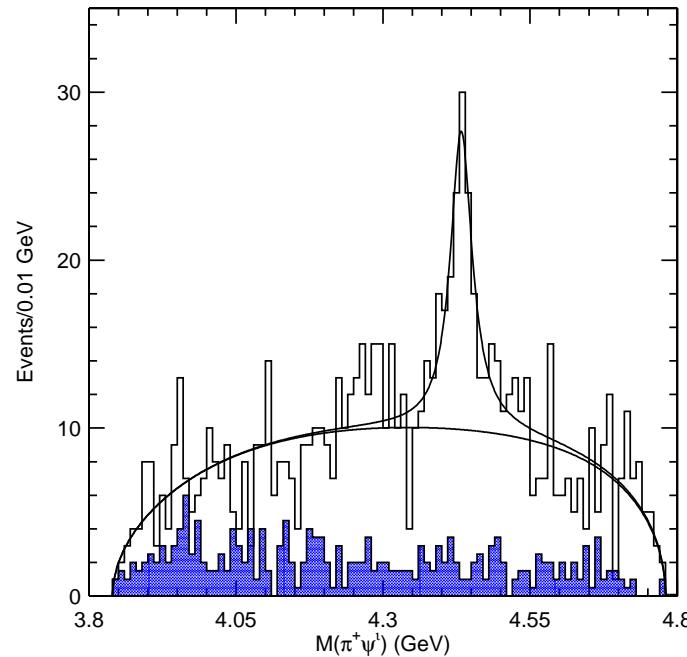
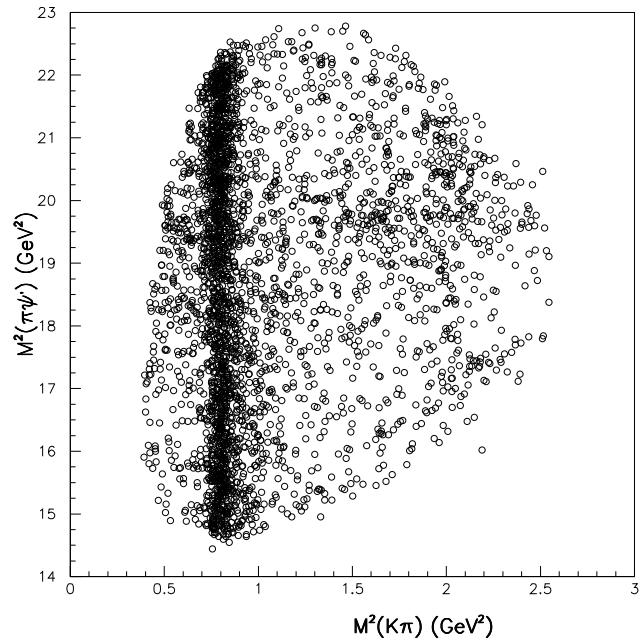
$$e^+e^- \rightarrow J/\psi D^{(*)}\bar{D}^{(*)} - \text{IV}$$

State	N_{ev}	$M, \text{ MeV}$	$\Gamma, \text{ MeV}$	N_σ
$X(3880)(D_{\text{rec}}\bar{D}_{\text{tag}})$	63^{+31}_{-25}	3878 ± 48	347^{+316}_{-143}	3.8
$X(3940)(D_{\text{rec}}\bar{D}_{\text{tag}}^*)$	52^{+24}_{-16}	3942^{+7}_{-6}	37^{+26}_{-15}	6.0
$X(3940)(D_{\text{rec}}^*\bar{D}_{\text{tag}}^*)$	$5.2^{+3.4}_{-2.7}$	3934^{+23}_{-17}	57^{+62}_{-34}	2.8
$X(4160)(D_{\text{rec}}^*\bar{D}_{\text{tag}}^*)$	$23.8^{+12.3}_{-8.0}$	4156^{+25}_{-20}	139^{+111}_{-61}	5.5

$X(3940)$ confirmed, $X(4160)$ observed for the first time

The inclusive peak in $M_{\text{rec}}(J/\psi)$ may consist of several states

A $\pi^\pm\psi'$ Structure in $B \rightarrow K\pi^\pm\psi'$ Decays



S.-K. Choi et al., arXiv:0708.1790; 605 fb^{-1} ($657 \cdot 10^6 B\bar{B}$)

$$M = (4433 \pm 4 \pm 2) \text{ MeV} \quad \Gamma = (45_{-13}^{+18} {}^{+30}_{-13}) \text{ MeV}$$

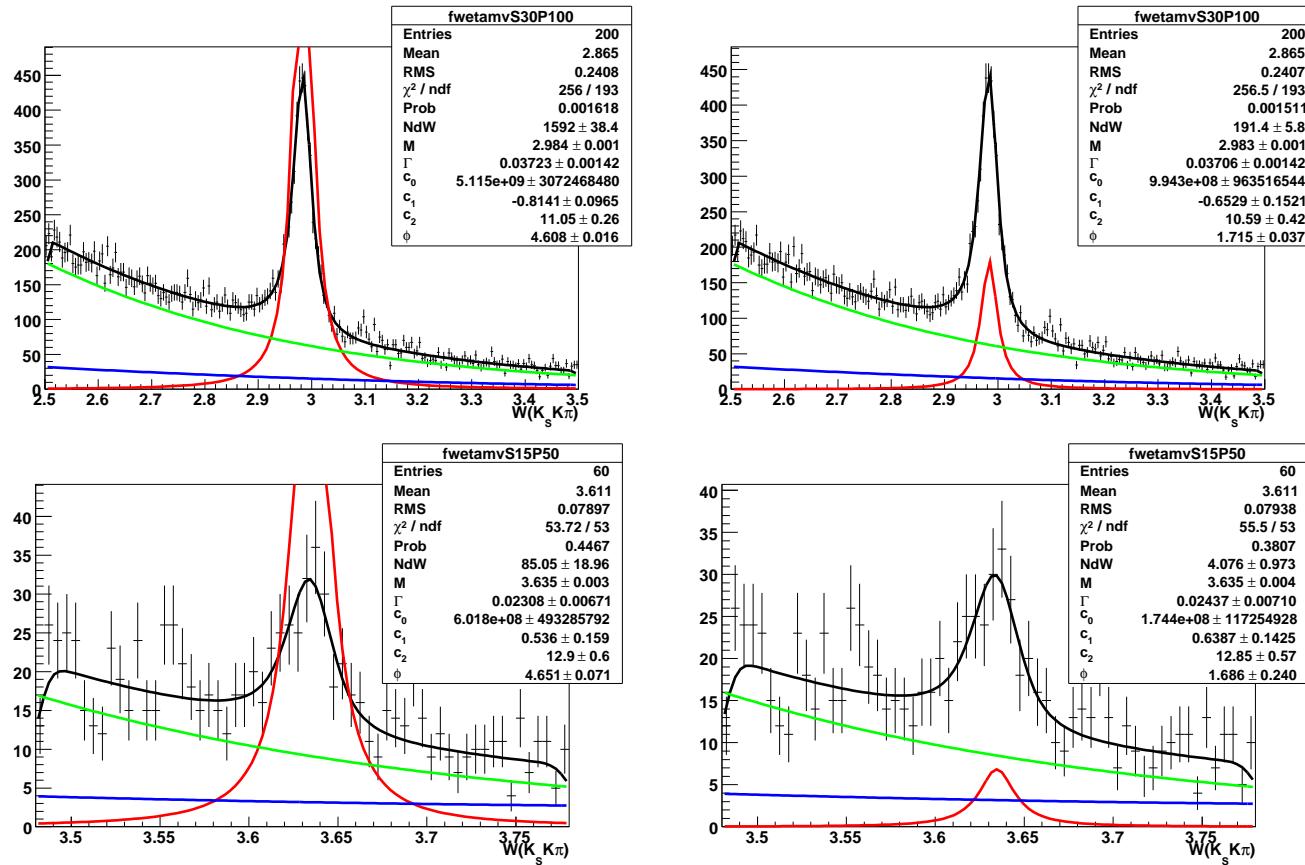
$$\mathcal{B}(B^0 \rightarrow K^\mp Z^\pm(4430)) \cdot \mathcal{B}(Z^\pm(4430) \rightarrow \pi^\pm\psi') = (4.1 \pm 1.0 \pm 1.4) \cdot 10^{-5}$$

The 1st charmonium-like meson with non-zero electric charge! Exotic ($4q$)?

Learning Charmonia Better From $\gamma\gamma$ Collisions

- $\chi_{c2}(2P)$ (former $Z(3930)$) discovered in $D\bar{D}$ with 395 fb^{-1} :
 $M = 3929 \pm 5 \pm 2 \text{ MeV}$, $\Gamma = 29 \pm 10 \pm 2 \text{ MeV}$
S. Uehara et al., PRL 96, 082003 (2006)
- $\chi_{c0(2)} \rightarrow \pi^+\pi^-$, K^+K^- , $K_S^0K_S^0$ studied:
 $\Gamma_{\gamma\gamma} \cdot \mathcal{B}$ determined, \mathcal{B} improved, QCD tests
 $\pi^+\pi^-$, K^+K^- – H. Nakazawa et al., PLB 615, 39 (2005)
 $K_S^0K_S^0$ – W.-T. Chen et al., PLB 651, 15 (2007)
- $\eta_c \rightarrow p\bar{p}$, $\Lambda\bar{\Lambda}$, $\Sigma^0\bar{\Sigma}^0$ studied:
 $\Gamma_{\gamma\gamma} \cdot \mathcal{B}$ determined, \mathcal{B} improved, QCD tests
 $p\bar{p}$ – C.-C. Kuo et al., PLB 621, 41 (2005)
 $\Lambda\bar{\Lambda}$, $\Sigma^0\bar{\Sigma}^0$ – C.-C. Kuo et al., hep-ex/0609.048

η_c and $\eta_c(2S)$ in $\gamma\gamma \rightarrow K_S^0 K\pi - I$

 483fb^{-1}

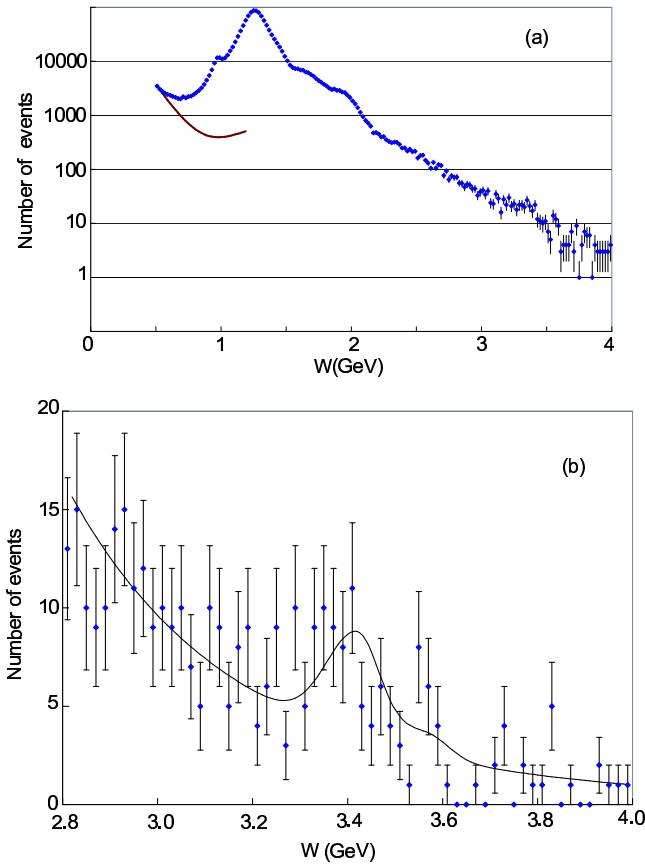
Interference effects extremely important

H. Nakazawa, talk at PHOTON 07

η_c and $\eta_c(2S)$ in $\gamma\gamma \rightarrow K_S^0 K\pi$ – II

M , MeV	Group	η_c	$\eta_c(2S)$
	Belle	$2981.4 \pm 0.5 \pm 0.4$	$3633.7 \pm 2.3 \pm 1.9$
	PDG-07	2979.8 ± 1.2	3637.0 ± 4.0
	CLEO	$2981.8 \pm 1.3 \pm 1.5$	$3642.9 \pm 3.1 \pm 1.5$
	BaBar	$2982.5 \pm 1.1 \pm 0.9$	$3630.8 \pm 3.4 \pm 1.0$
Γ , MeV	Group	η_c	$\eta_c(2S)$
	Belle	$36.6 \pm 1.5 \pm 2.0$	$19.1 \pm 6.9 \pm 6.0$
	PDG-07	25.5 ± 3.4	14.0 ± 7.0
	CLEO	$24.8 \pm 3.4 \pm 3.5$	$6.3 \pm 12.4 \pm 4.0 (< 31)$
	BaBar	$34.3 \pm 2.3 \pm 0.9$	$17.0 \pm 8.3 \pm 2.5$
$\Gamma_{\gamma\gamma}\mathcal{B}$, eV	Group	η_c	$\eta_c(2S)$
	Belle	$142 \pm 4 \pm 14$	$11.2 \pm 2.4 \pm 2.7$

$$\gamma\gamma \rightarrow \pi^0\pi^0$$



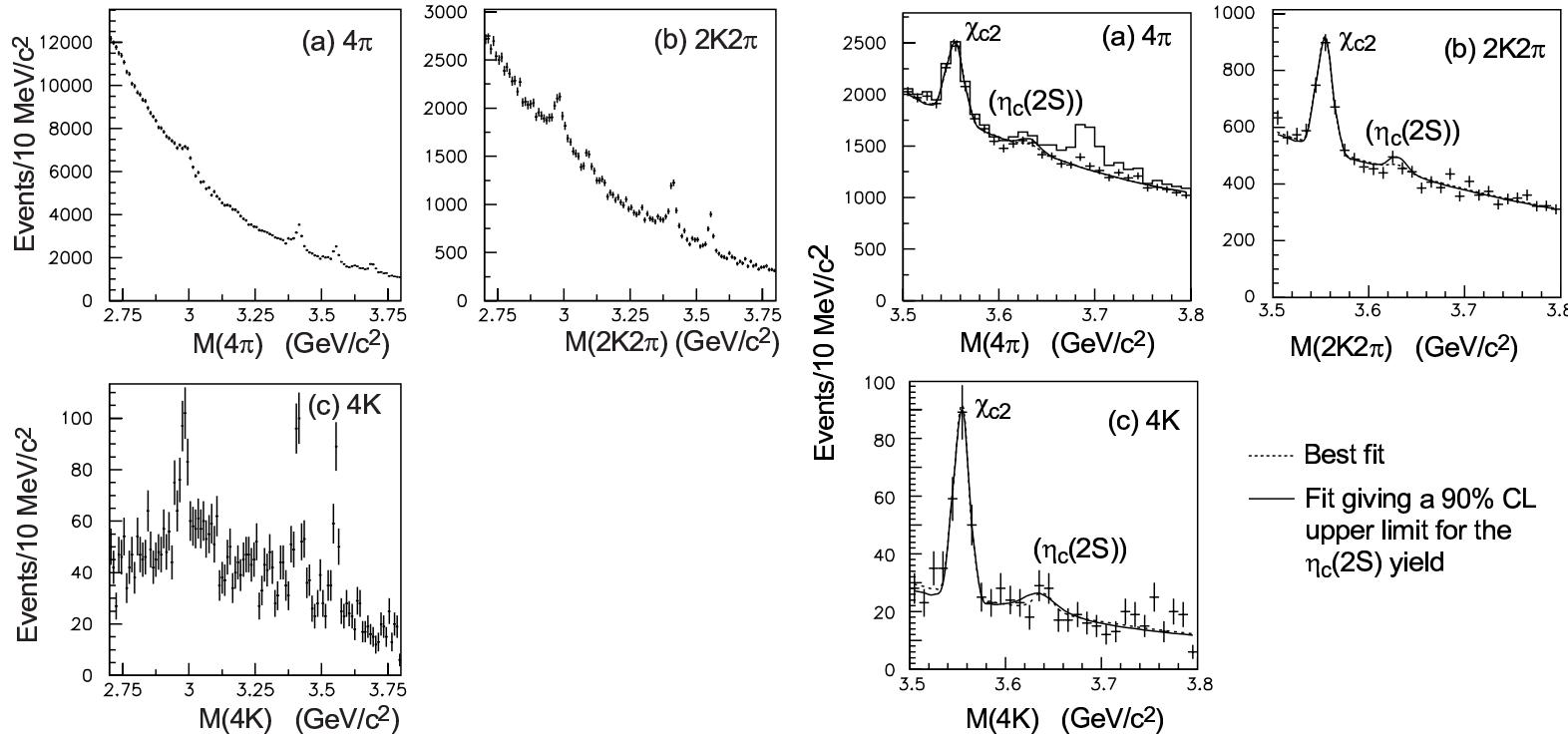
$95 \text{ fb}^{-1}, 0.6 \text{ GeV} < W < 4.0 \text{ GeV}$

R	N_{ev}	$\Gamma_{\gamma\gamma}\mathcal{B}, \text{ eV}$
χ_{c0}	35.3 ± 9.2	$8.4 \pm 2.2 \pm 0.8$
χ_{c2}	8.2 ± 6.4	$0.29 \pm 0.23 \pm 0.03$

$$\Gamma_{\gamma\gamma}\mathcal{B}(\pi^0\pi^0) \approx 0.5\Gamma_{\gamma\gamma}\mathcal{B}(\pi^+\pi^-)$$

S. Uehara, talk at PHOTON 07

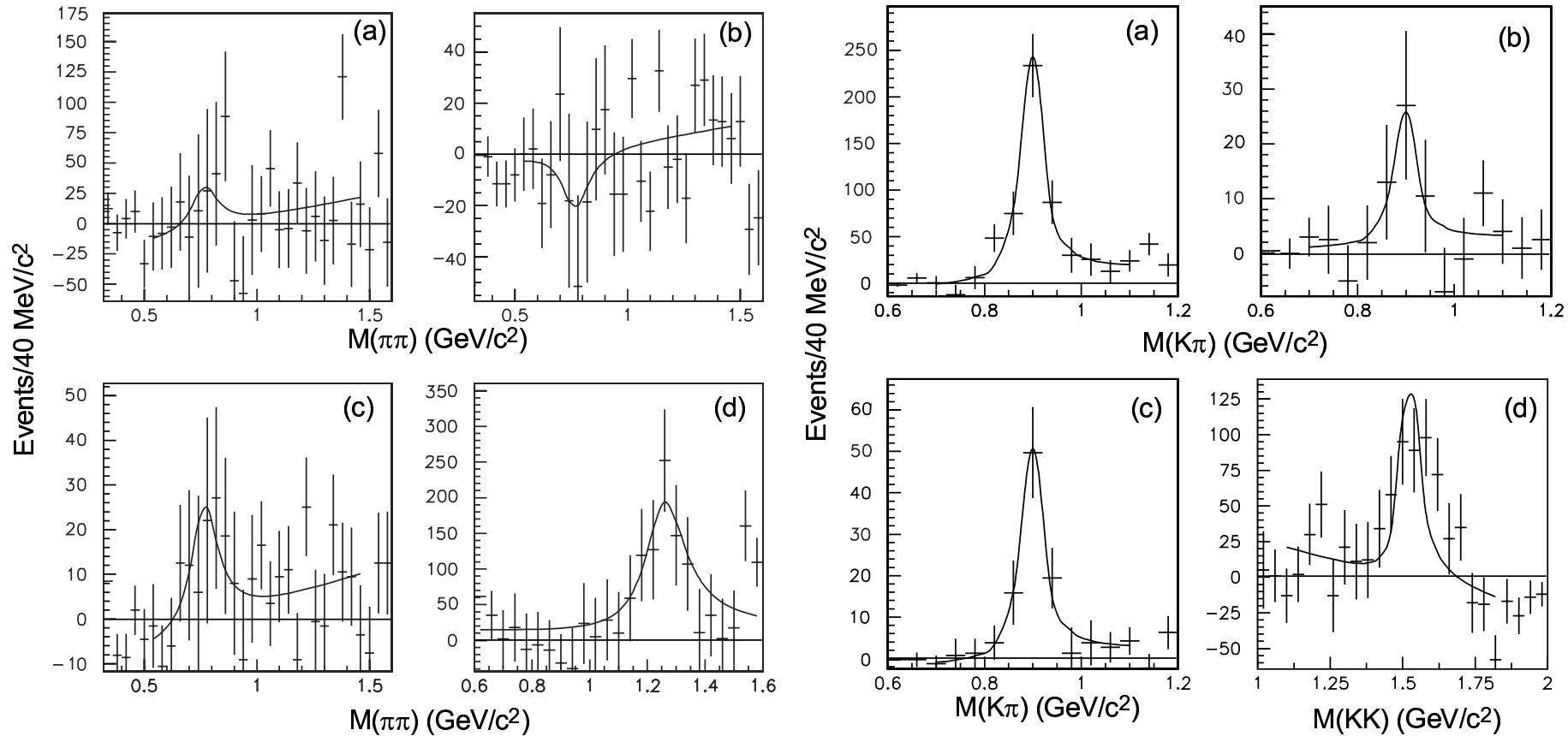
$\gamma\gamma \rightarrow 2\pi^+2\pi^- , \pi^+\pi^-K^+K^- , 2K^+2K^- - I$



S. Uehara et al., arXiv:0706.3955, EPJC; 395 fb^{-1}

For the $\eta_c(2S)$ UL's on $\Gamma_{\gamma\gamma}\mathcal{B}$ are 2–5 times smaller compared to the $\eta_c(1S)$
For the $\eta_c(1S)$ new values of $\Gamma_{\gamma\gamma}\mathcal{B}$ are a few times smaller than previously

$\gamma\gamma \rightarrow 2\pi^+ 2\pi^- , \pi^+ \pi^- K^+ K^- , 2K^+ 2K^- - \text{II}$

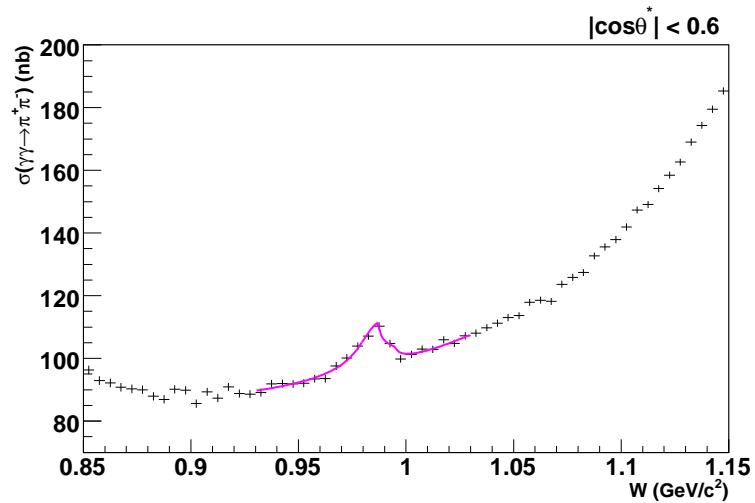
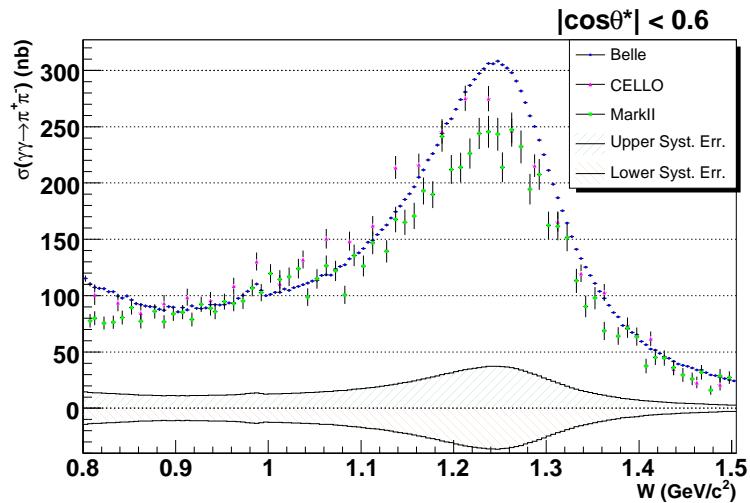


$\eta_c, \chi_{c0} \rightarrow \rho^0 \rho^0$ not observed, $\chi_{c2} \rightarrow \rho^0 \rho^0$ seen

$\eta_c, \chi_{c0}, \chi_{c2} \rightarrow K^{*0} \bar{K}^{*0}$, $\eta_c \rightarrow f_2 f_2, f_2 f'_2$ seen

Studies of Light Quark States

- Two sources – $\gamma\gamma$ production and τ decays
- Clean conditions – hadrons in the final state only,
for two-body states no final state interaction
- QCD studies from $\gamma\gamma \rightarrow \pi^+\pi^-$, K^+K^- , $K_S^0K_S^0$, $p\bar{p}$
- Resonance studies in $\gamma\gamma \rightarrow K^+K^-$, $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi^+\pi^-\pi^0$
- Resonance production in $\tau^- \rightarrow \pi^-\pi^0\nu_\tau$, $K_S^0\pi^-\nu_\tau$

$\gamma\gamma \rightarrow \pi^+\pi^-$


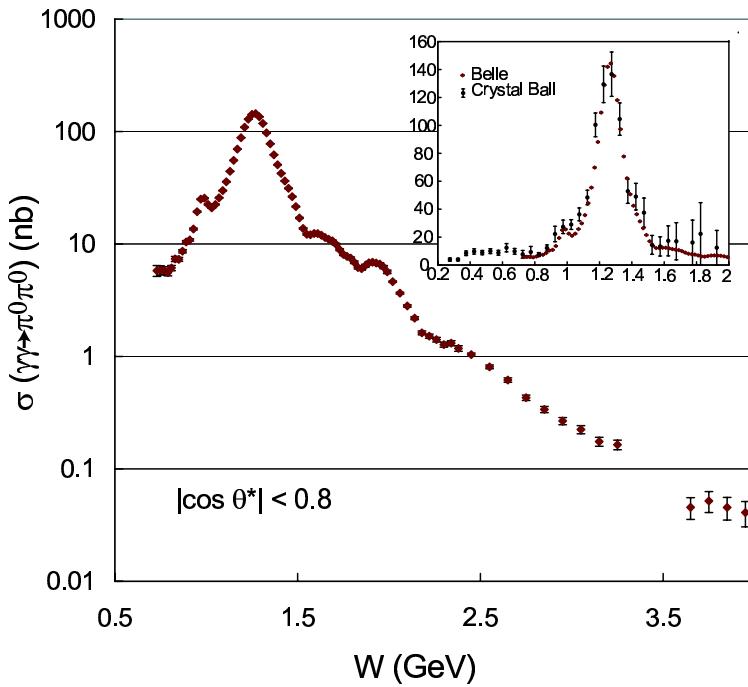
T. Mori et al., PRD 75, 051101 (2007), JPSJ 76, 074102 (2007); 85.9 fb^{-1}

$$f_0(980): \quad M = 985.6^{+1.2}_{-1.5} {}^{+1.1}_{-1.6} \text{ MeV}$$

$$\Gamma_{\pi^+\pi^-} = 34.2^{+13.9}_{-11.8} {}^{+8.8}_{-2.5} \text{ MeV}$$

$$\Gamma_{\gamma\gamma} = 205^{+95}_{-83} {}^{+147}_{-117} \text{ eV}$$

$$\gamma\gamma \rightarrow \pi^0\pi^0$$

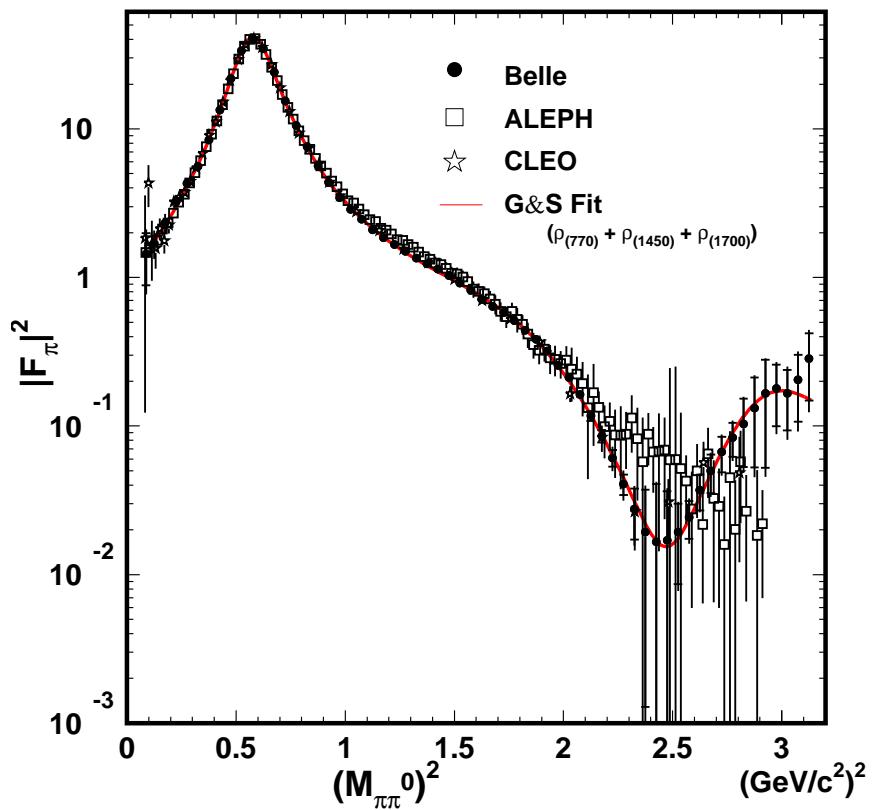


Prominent structures at 0.98, 1.27, 1.65 and 1.95 GeV

Analysis of angular distributions is in progress

S. Uehara, talk at PHOTON 07

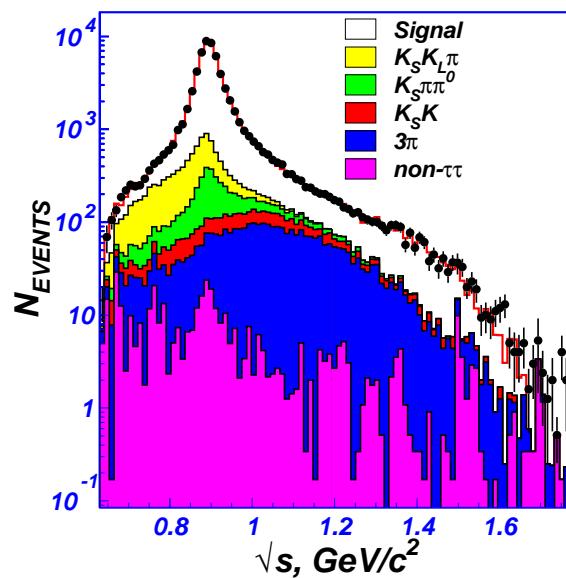
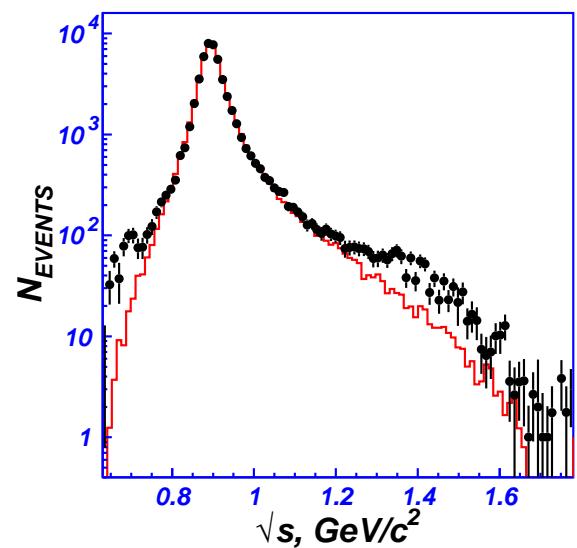
ρ Excitations from $\tau^- \rightarrow \pi^-\pi^0\nu_\tau$



M. Fujikawa et al., Nucl. Phys. B (Proc. Suppl.) 169, 36 (2007)

72 fb^{-1} , $5.5 \cdot 10^6$ events, ρ , $\rho(1450)$, $\rho(1700)$ clearly seen

$K_S^0\pi$ Mass Spectrum in $\tau^- \rightarrow K_S^0\pi^-\nu_\tau$

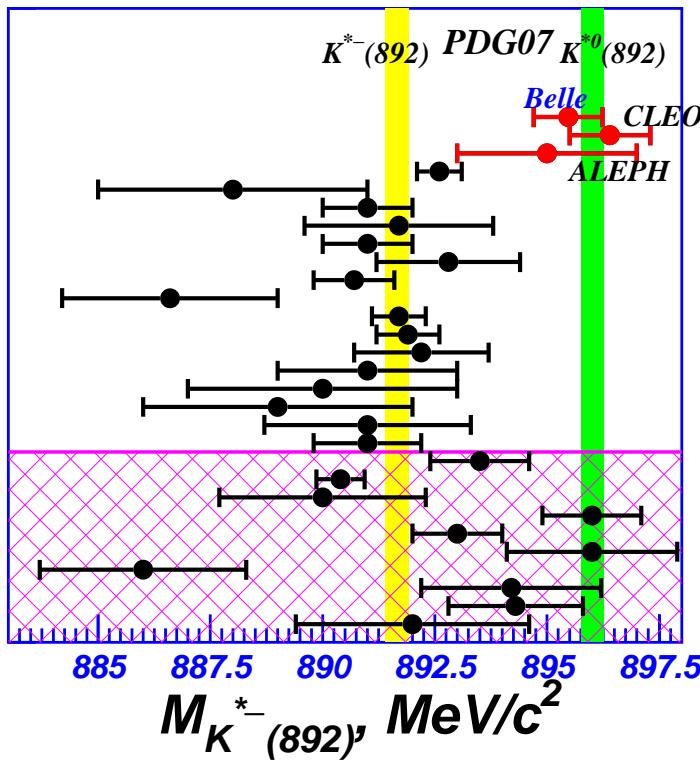


D. Epifanov et al., PLB 654, 65 (2007); 351 fb^{-1} or $313 \cdot 10^6 \tau^+\tau^-$ pairs

The $M_{K\pi}$ spectrum is well described by

the $K^*(892)$, $K^*(800)$ (κ) and $K_0^*(1430)$ (or $K^*(1410)$).

$K^*(892)$ Mass and Width Measurement



$$M(K^*(892)^-) = (895.47 \pm 0.20 \pm 0.44 \pm 0.59) \text{ MeV}$$

$$\Gamma(K^*(892)^-) = (46.2 \pm 0.6 \pm 1.0 \pm 0.7) \text{ MeV}$$

Summary of Results at the $\Upsilon(5S)$, talk of W.-S. Hou

1. $\Upsilon(5S)$ decays from 21.7 fb^{-1}

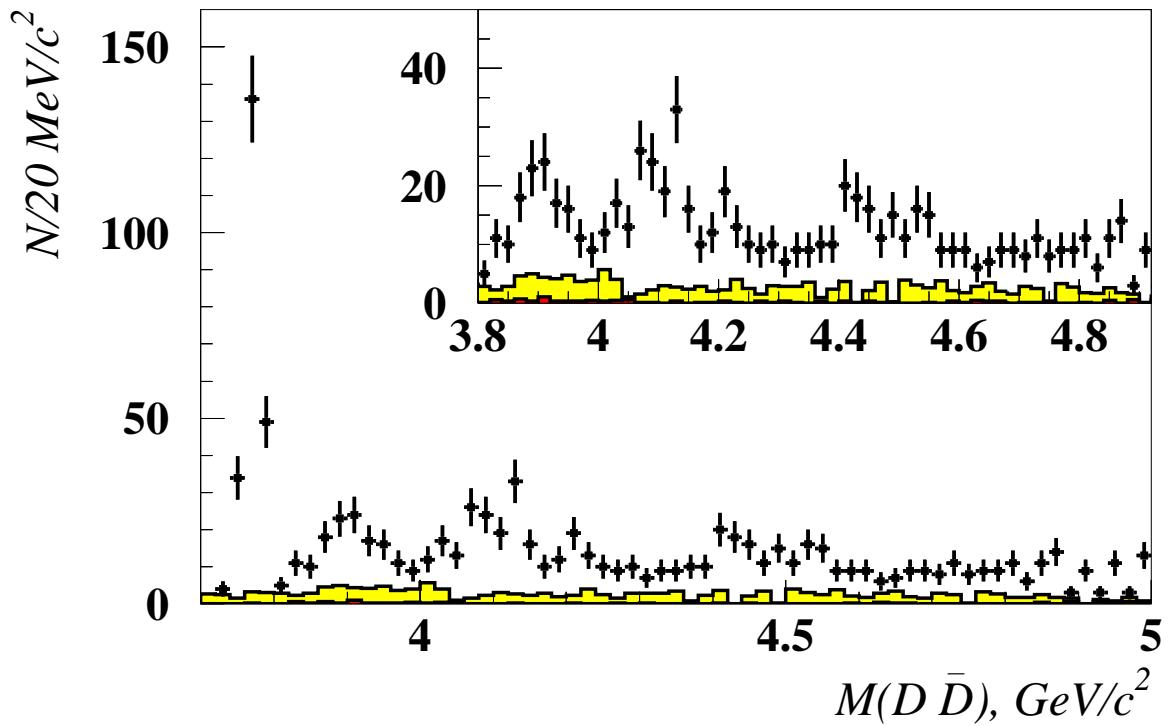
- $\mathcal{B}(\Upsilon(5S) \rightarrow \Upsilon(1S)\pi^+\pi^-) = (0.53 \pm 0.03 \pm 0.05)\% \text{ (20}\sigma\text{)}$
- $\mathcal{B}(\Upsilon(5S) \rightarrow \Upsilon(2S)\pi^+\pi^-) = (0.78 \pm 0.06 \pm 0.11)\% \text{ (14}\sigma\text{)}$
- $\mathcal{B}(\Upsilon(5S) \rightarrow \Upsilon(3S)\pi^+\pi^-) = (0.48_{-0.15}^{+0.18} \pm 0.07)\% \text{ (3.2}\sigma\text{)}$
- $\mathcal{B}(\Upsilon(5S) \rightarrow \Upsilon(1S)K^+K^-) = (0.061_{-0.014}^{+0.016} \pm 0.010)\% \text{ (4.9}\sigma\text{)}$
- Unexpectedly large partial widths

2. B_s^0 decays from 23.6 fb^{-1}

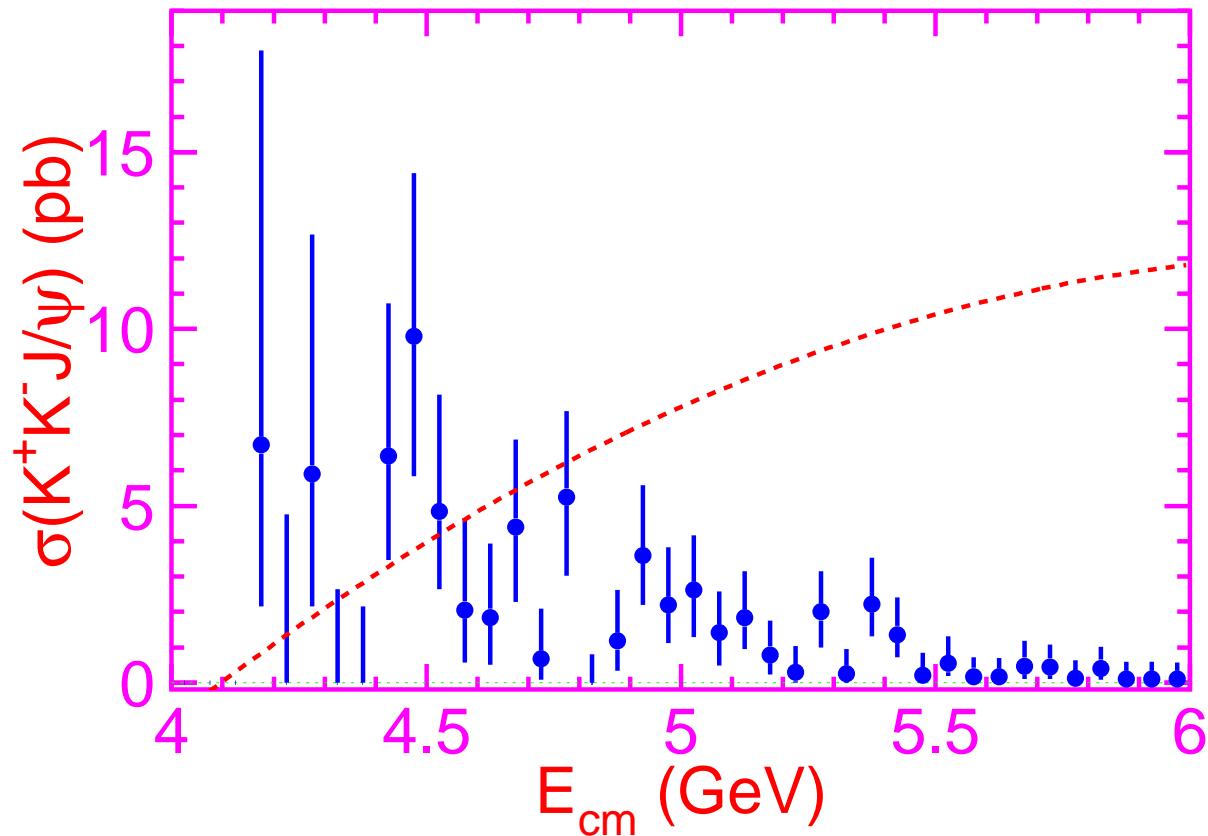
- $\mathcal{B}(B_s^0 \rightarrow X^+l^-\nu) = (10.2 \pm 0.8 \pm 0.9)\%$
- $\mathcal{B}(B_s^0 \rightarrow \phi\gamma) = (5.7_{-1.5}^{+1.8} {}^{+1.2}) \times 10^{-5}$
First observation of the radiative penguin
- $\mathcal{B}(B_s^0 \rightarrow \gamma\gamma) < 8.7 \times 10^{-6}$ at 90% CL
($\mathcal{B}_{\text{Belle}} < 0.53 \times 10^{-4}$)

Conclusions

- Four well-known excitations of the J/ψ are confirmed; first steps to disentangle decay mechanisms made. Still far from complete picture
- New vector states observed ($Y(4005)$, $Y(4660)$) or confirmed ($Y(4260)$, $Y(4330)$). Interpretation is not straightforward
- New states with other J^{PC} discovered ($X(4160)$, $Z(4430)$)
- Better understanding of the $\eta_c(1S)$, $\eta_c(2S)$, χ_{c0} , χ_{c2} from $\gamma\gamma$
- First promising results on $\gamma\gamma \rightarrow \pi^0\pi^0$
- τ is ideal to study various non-strange mesons and K^* states
- A zoo of particles, C. Linnaeus classification?
- Questions/puzzles coming faster than answers!

$$e^+e^- \rightarrow D^0\bar{D}^0, D^+D^- \text{ via ISR}$$


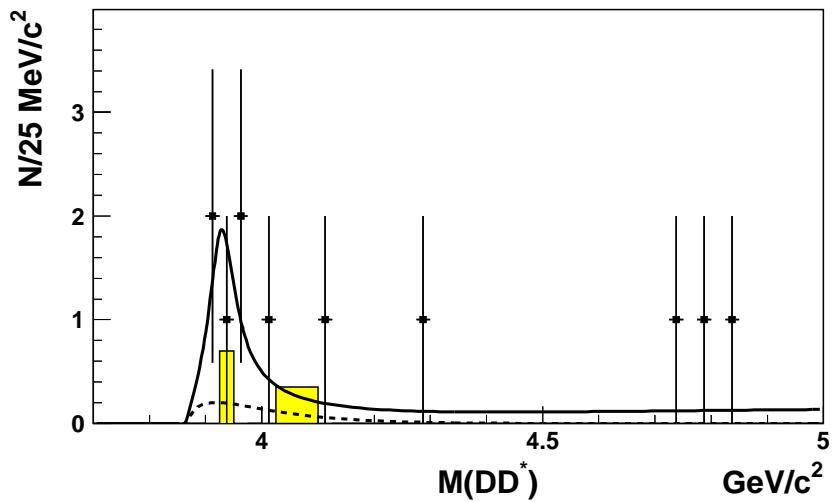
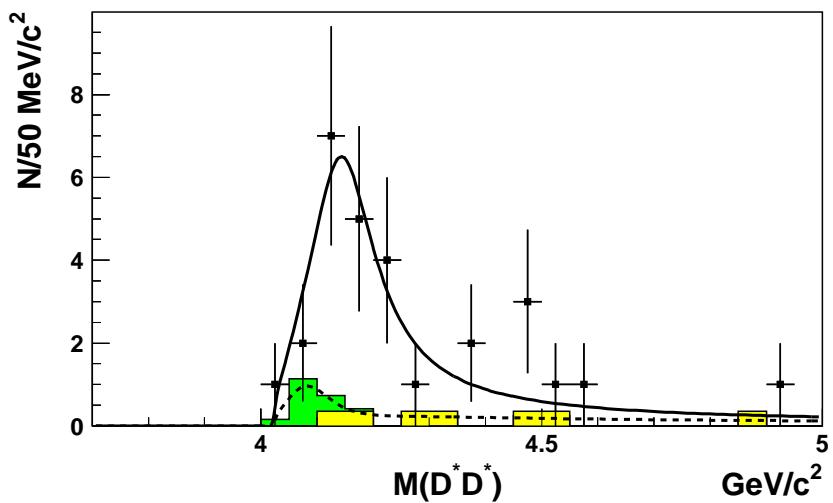
$e^+e^- \rightarrow K^+K^-J/\psi$ via ISR – II



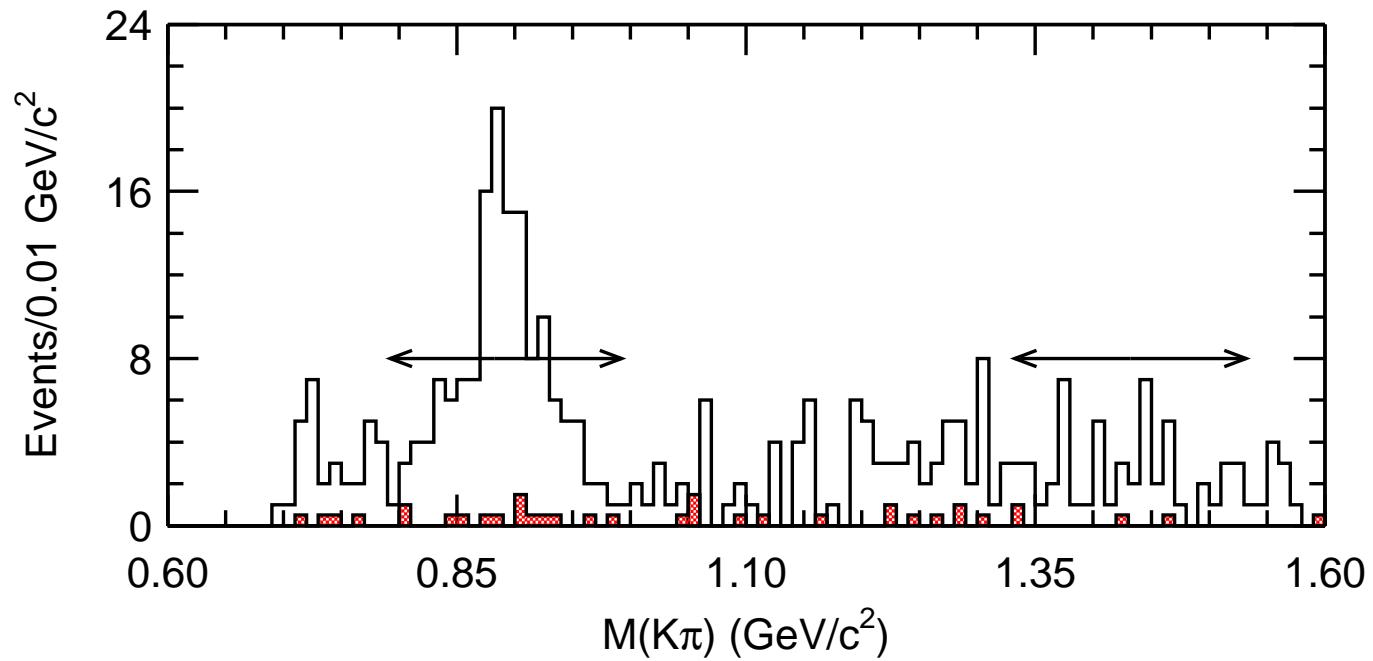
A broad structure not described by existing ψ' 's

Three $K_S^0K_S^0$ events observed between 4.4 and 5.2 GeV

$$e^+ e^- \rightarrow J/\psi D^{(*)} \bar{D}^{(*)} - \text{III}$$


 $D_{\text{rec}}^* \bar{D}_{\text{tag}}$

 $D_{\text{rec}}^* \bar{D}_{\text{tag}}^*$

A $\pi^\pm\psi'$ Structure in $B \rightarrow K\pi^\pm\psi'$ Decays

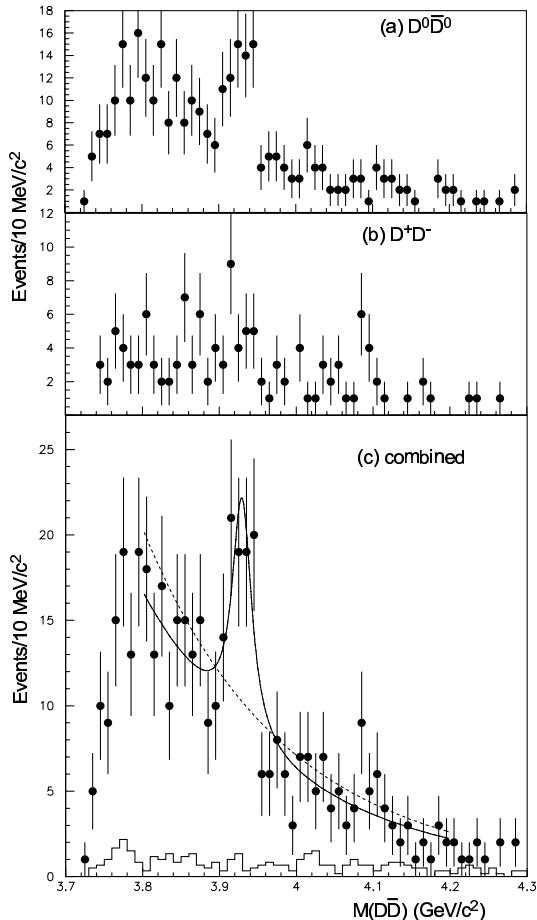


Only $K^*(890)$ seen in $M(K\pi)$ if the K^* veto is removed

η_c and $\eta_c(2S)$ in $\gamma\gamma \rightarrow K_S^0 K\pi$ – Interference

		η_c	$\eta_c(2S)$
M , MeV	no int.	2981.4 ± 0.5	3633.7 ± 2.3
	$\phi > \pi$	2983.6 ± 0.7	3634.8 ± 3.2
	$\phi < \pi$	2983.5 ± 0.7	3634.8 ± 3.2
Γ , MeV	no int.	36.6 ± 1.5	19.1 ± 6.9
	$\phi > \pi$	37.2 ± 1.4	23.0 ± 6.7
	$\phi < \pi$	37.1 ± 1.4	23.0 ± 7.1
$\Gamma_{\gamma\gamma}$, keV	no int.	7.48 ± 0.20	0.59 ± 0.13
	$\phi > \pi$	16.5 ± 0.4	2.16 ± 0.49
	$\phi < \pi$	1.99 ± 0.06	0.22 ± 0.05
ϕ	$\phi > \pi$	4.61 ± 0.02	4.65 ± 0.07
	$\phi < \pi$	1.71 ± 0.04	1.67 ± 0.22

Observation of $\chi_{c2}(2P)$



395 fb^{-1}

$64 \pm 18 \text{ ev. } (5.3\sigma)$

$M = 3929 \pm 5 \pm 2 \text{ MeV}$

$\Gamma = 29 \pm 10 \pm 2 \text{ MeV}$

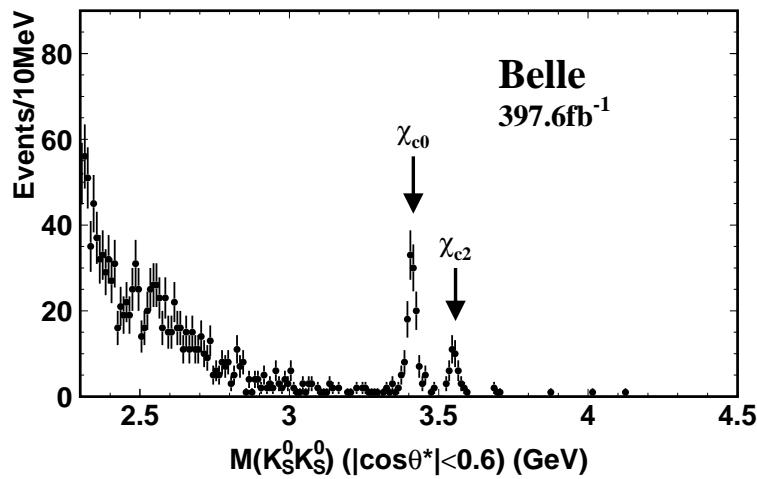
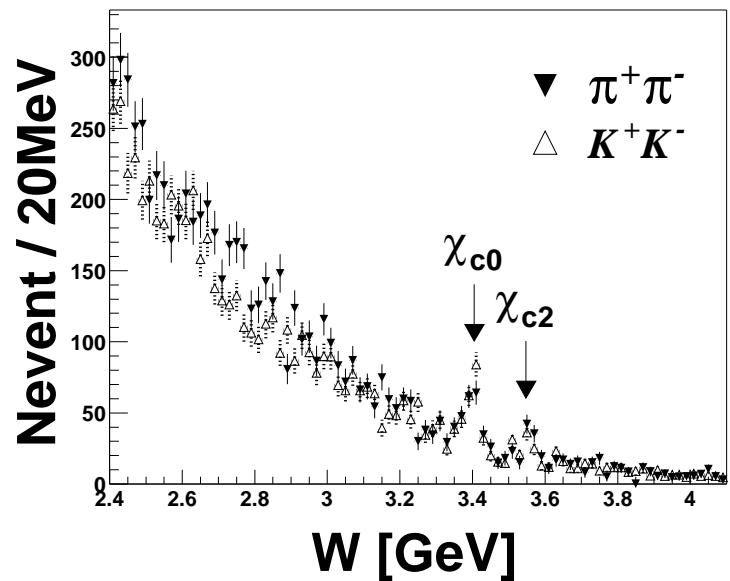
$\Gamma_{\gamma\gamma}\mathcal{B}(D\bar{D}) = 0.18 \pm 0.05 \pm 0.03 \text{ keV}$

$\mathcal{B}(D^+D^-)/\mathcal{B}(D^0\bar{D}^0) = 0.74 \pm 0.43 \pm 0.16$

Angular analysis \Rightarrow spin=2

S. Uehara et al., PRL 96, 082003 (2006)

$$\gamma\gamma \rightarrow \chi_{c0(2)} \rightarrow \pi^+\pi^-, K^+K^-, K_S^0K_S^0$$

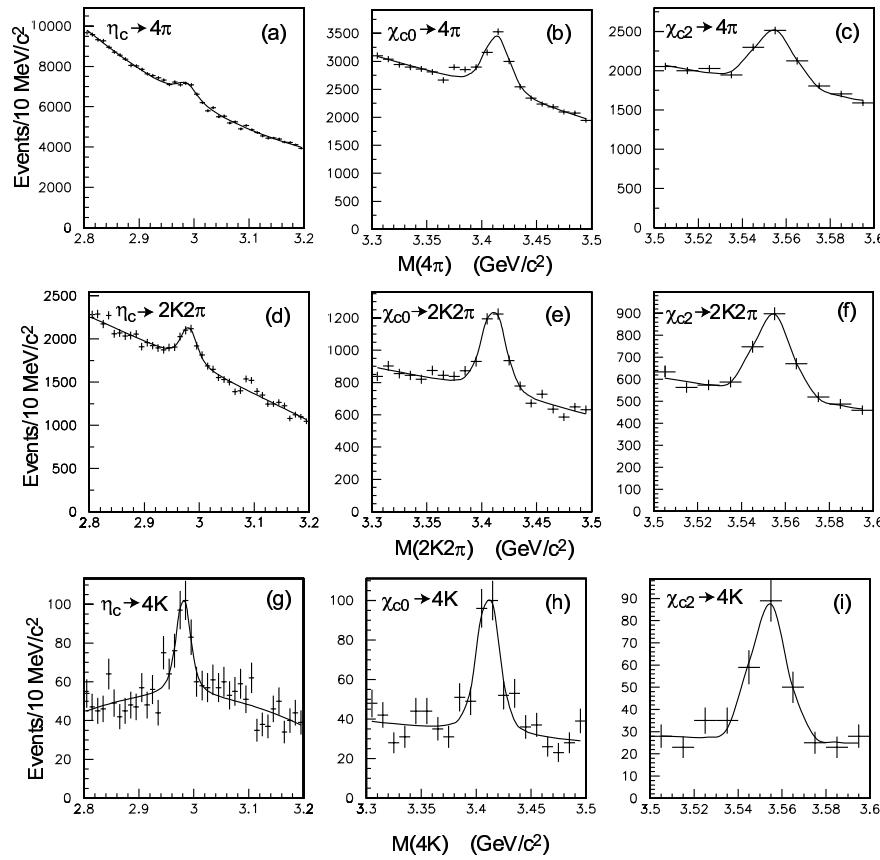


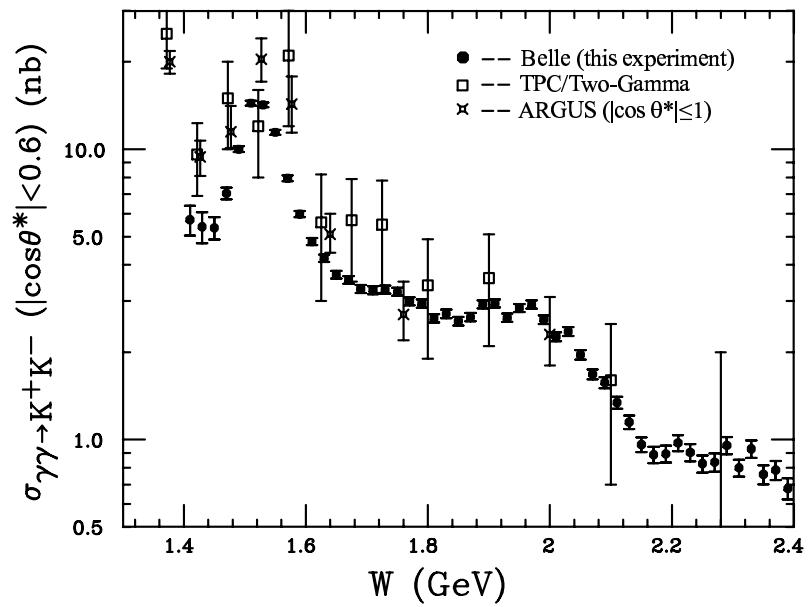
H. Nakazawa et al., PLB 615, 39 (2005) W.-T. Chen et al., PLB 651, 15 (2007)

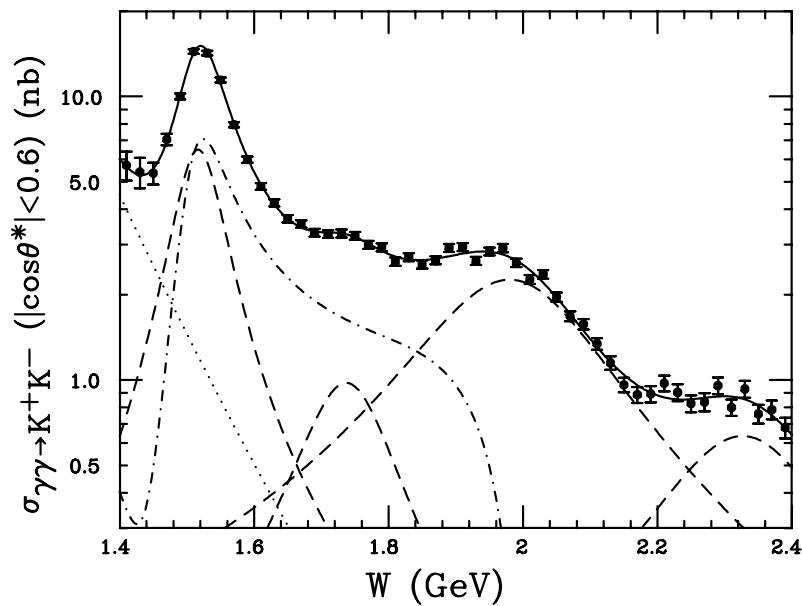
For χ_{c0} and χ_{c2} $\Gamma_{\gamma\gamma} \cdot \mathcal{B}$ determined

Corresponding branching fractions of χ_{c0} and χ_{c2} improved

$$\gamma\gamma \rightarrow 2\pi^+ 2\pi^-, \pi^+ \pi^- K^+ K^-, 2K^+ 2K^-$$



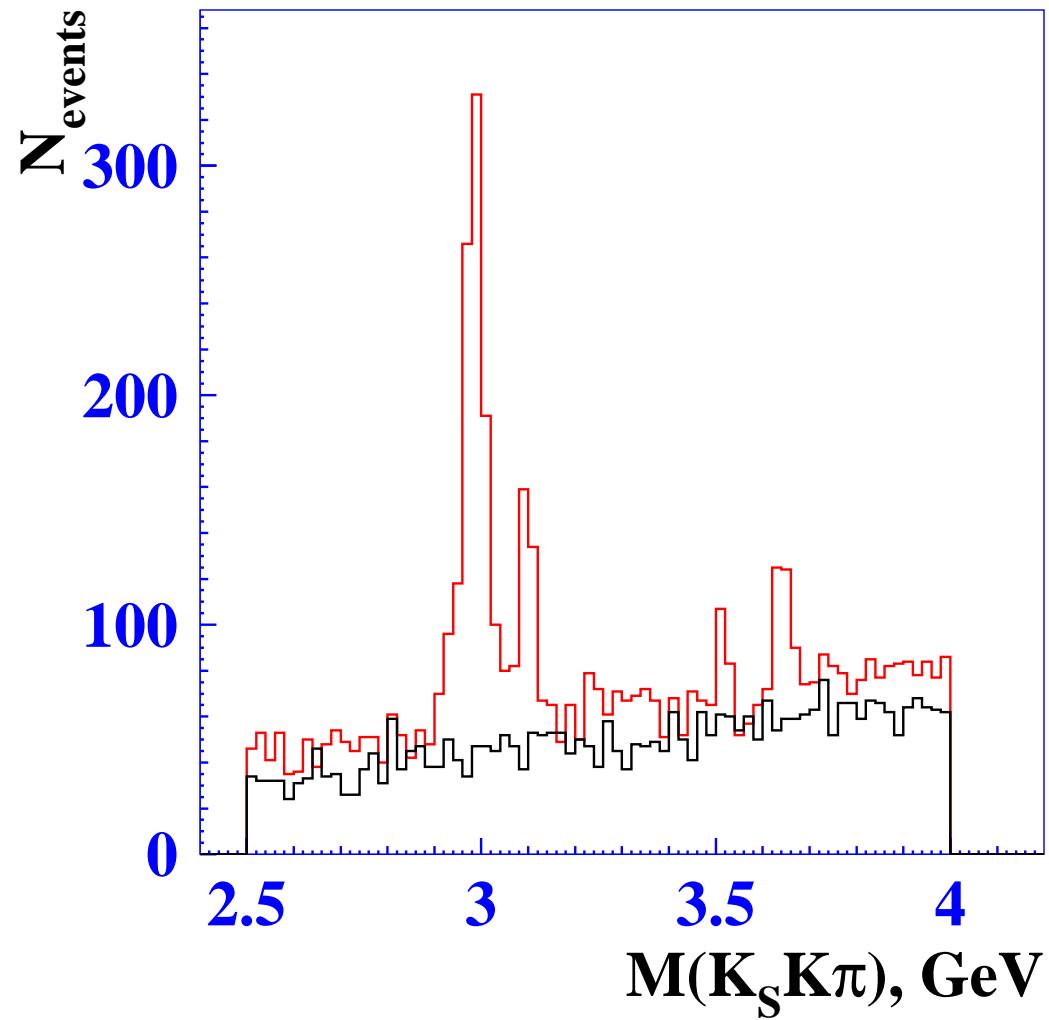
$\gamma\gamma \rightarrow K^+K^- - I$ 

$\gamma\gamma \rightarrow K^+K^- - \text{II}$ 

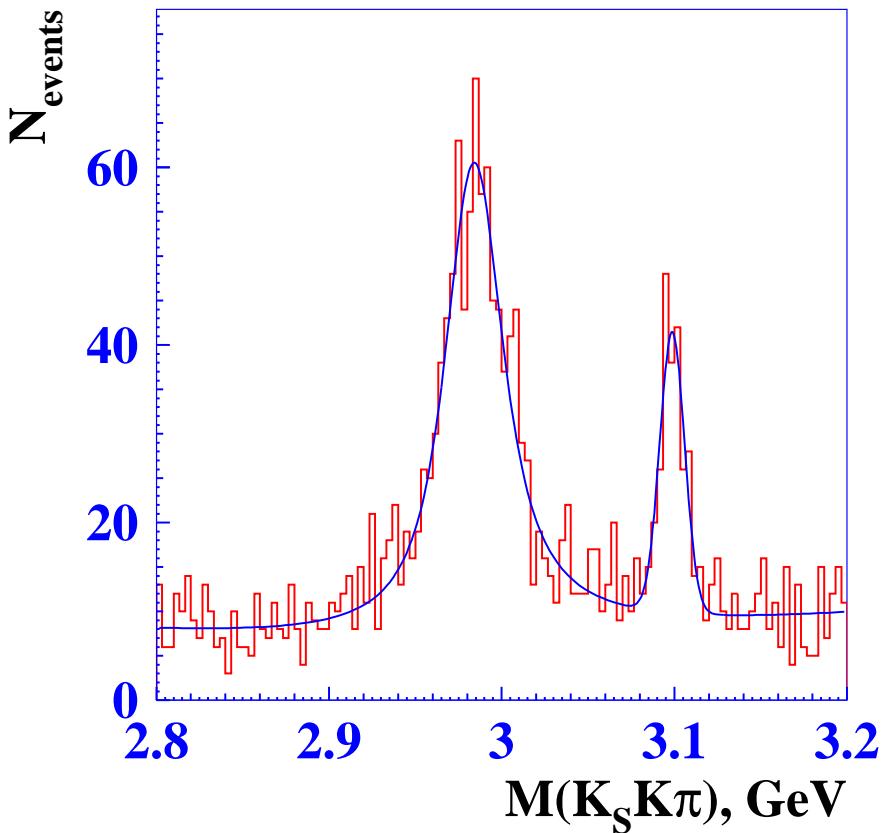
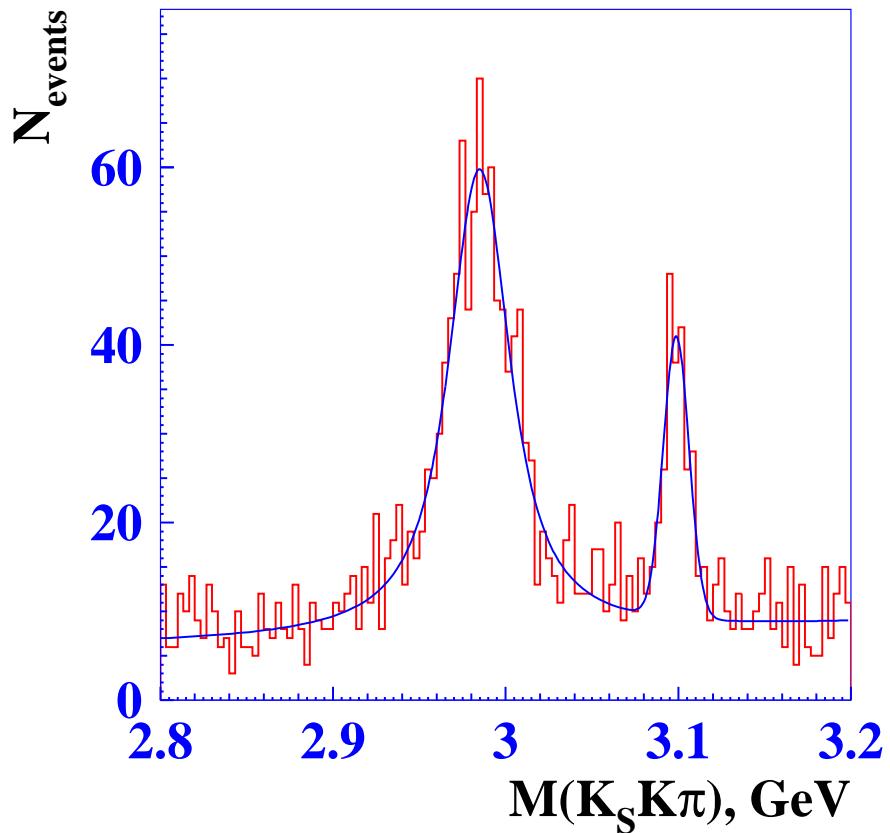
A High-Statistics Study of $\tau^- \rightarrow K_S \pi^- \nu_\tau$

- Analysis of 351 fb^{-1} or $313 \cdot 10^6 \tau^+ \tau^-$ pairs
- Normalized to $\sim 4 \cdot 10^6 e^+ \mu^-$ and $e^- \mu^+$ events
- Background and efficiencies from $1.5 \cdot 10^9$ MC $\tau^+ \tau^-$
- \mathcal{B} from $(e^+, K_S \pi^-)$, $(e^-, K_S \pi^+)$, $(\mu^+, K_S \pi^-)$, $(\mu^-, K_S \pi^+)$
- Thorough analysis of systematics
- 53110 lepton tagged events selected

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