

# *Nouveaux Etats mésoniques découverts avec les usines à B*

Réunion du GDR "Physique subatomique et calculs sur réseau"  
LAL, Orsay  
15-17 juin 2007

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# New Resonances

- Tentatively assigned to Charmonium states :

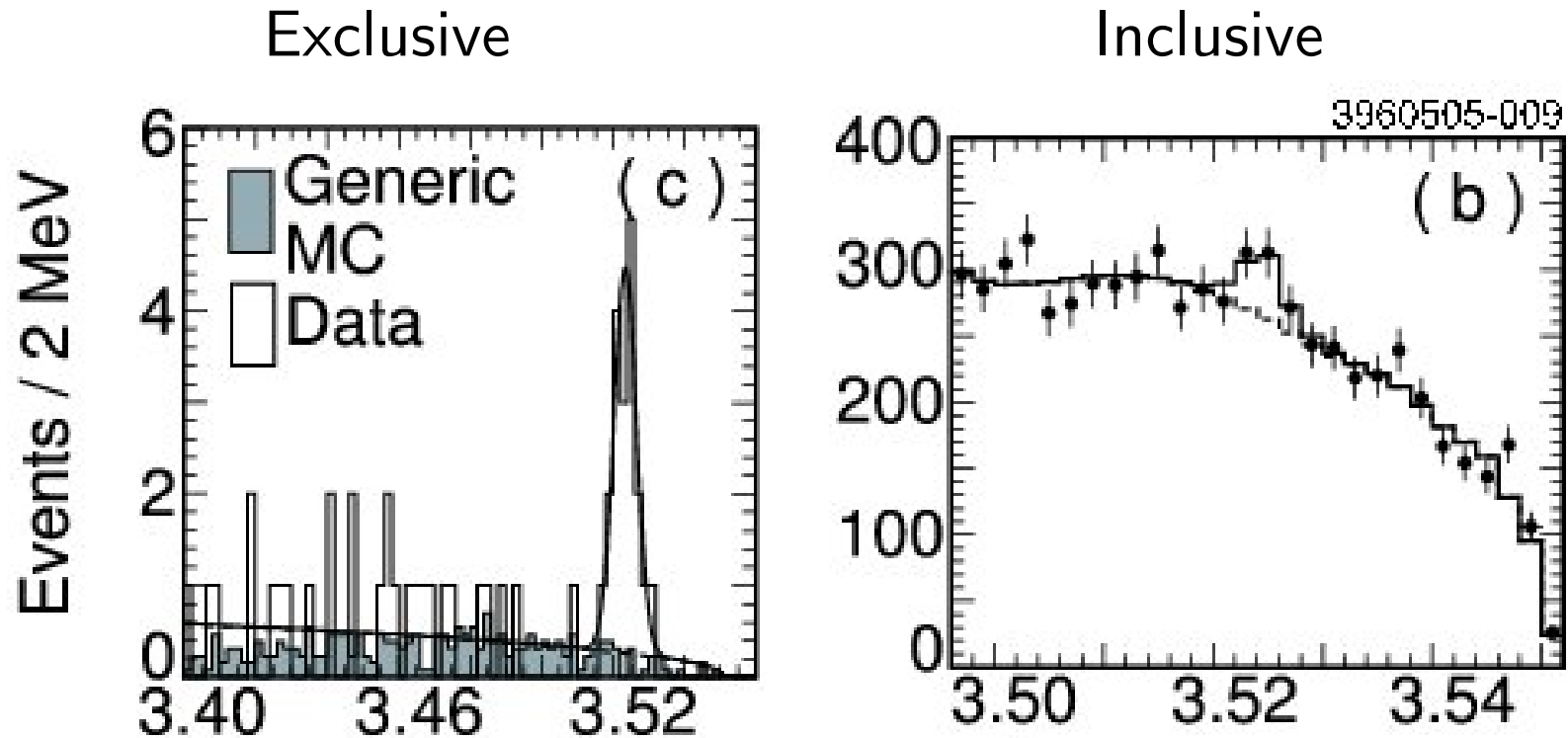
$h_c$	$1^1P_1$	(CLEO)	$\psi(2S) \rightarrow \pi^0 h_c(\gamma \eta_c)$
$X(3943)$	$\eta_c''(3^1S_0(c\bar{c}))?$	(Belle)	recoil on $J/\psi$ in $e^+e^-$
$Y(3940)$	$\chi'_{c1}(2^3P_1(c\bar{c}))?$	(Belle)	$B \rightarrow (J/\psi \omega)K$
$Z(3930)$	$\chi'_{c2}(2^3P_2(c\bar{c}))?$	(Belle)	$\gamma\gamma \rightarrow D\bar{D}$

- Certainly not Charmonium states (What are they ?) :

$X(3872)$	(Belle)
$Y(4260)$	(BaBar)

$$\psi(2S) \rightarrow \pi^0 h_c(\gamma \eta_c)$$

$3.08 \times 10^6$   $\psi(2S)$  decays.



- $M(h_c) = 3524.4 \pm 0.6(stat) \pm 0.4(syst)$  MeV
- $M(^3P_J) - M(^1P_1) = 1.0 \pm 0.6(stat) \pm 0.4(syst)$  MeV

CLEOc

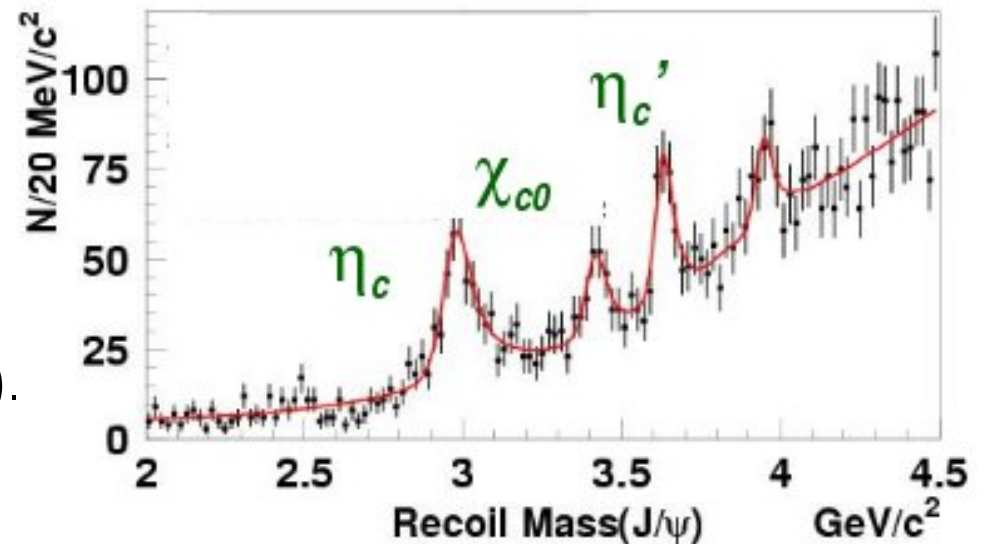
PRL 95, 102003 (2005)

$$X(3943) : e^+e^- \rightarrow J/\psi X$$



Double charmonium production  $350 \text{ fb}^{-1}$  hep-ex/0507019 (LP 2005)

- $M = 3943 \pm 6 \pm 6 \text{ MeV}$
- $\Gamma = 15.4 \pm 10.1 \text{ MeV}$ .
- $BR(X \rightarrow D\bar{D}^*) = 96_{-32}^{+45} \pm 22\%$ ,
- $BR(X \rightarrow D\bar{D}) < 41\%$  (90% CL),
- and  $BR(X \rightarrow \omega J/\psi) < 26\%$  (90% CL).



Possibly  $3^1S_0(c\bar{c}) \eta_c''$  state

Test  $\gamma\gamma \rightarrow D\bar{D}^*$

(S. Godfrey FPCP 2006, hep-ph/0605152)

$$B \rightarrow Y(3940)K, Y(3940) \rightarrow J/\psi \pi \pi \pi^0$$

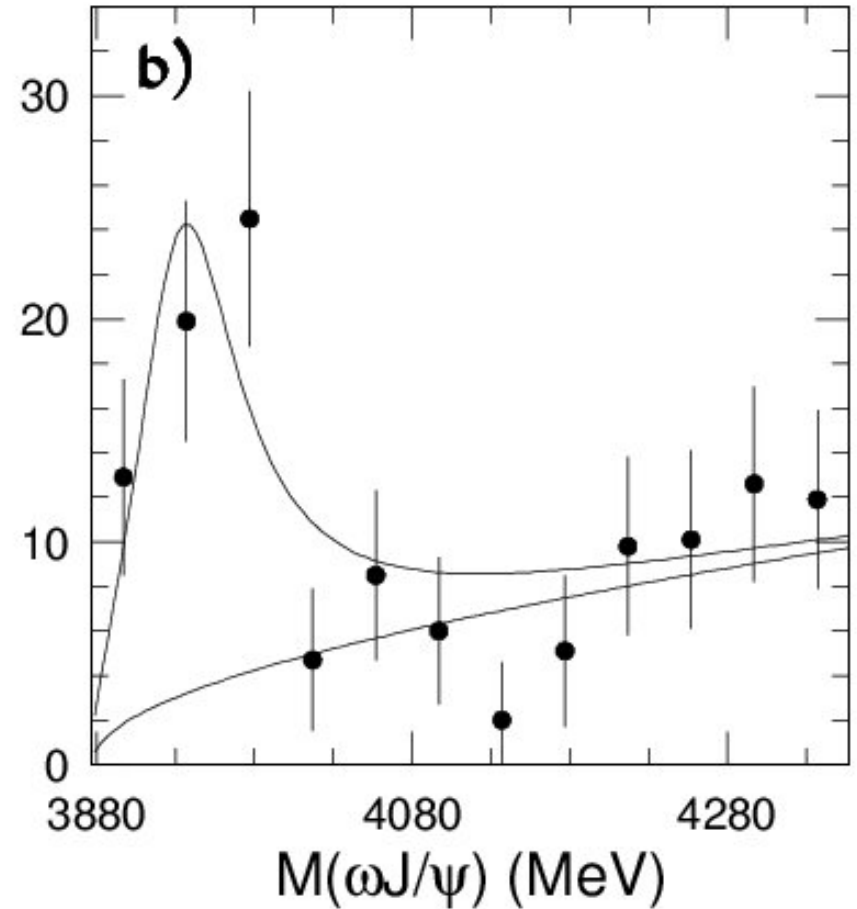


$> 8\sigma$

253 fb<sup>-1</sup>

PRL 94, 182002 (2005)

- $M = 3943 \pm 11 \pm 13$  MeV
- $\Gamma = 87 \pm 22 \pm 26$  MeV.
- not yet seen in  $Y \rightarrow D\bar{D}$  or  $D\bar{D}^*$ .



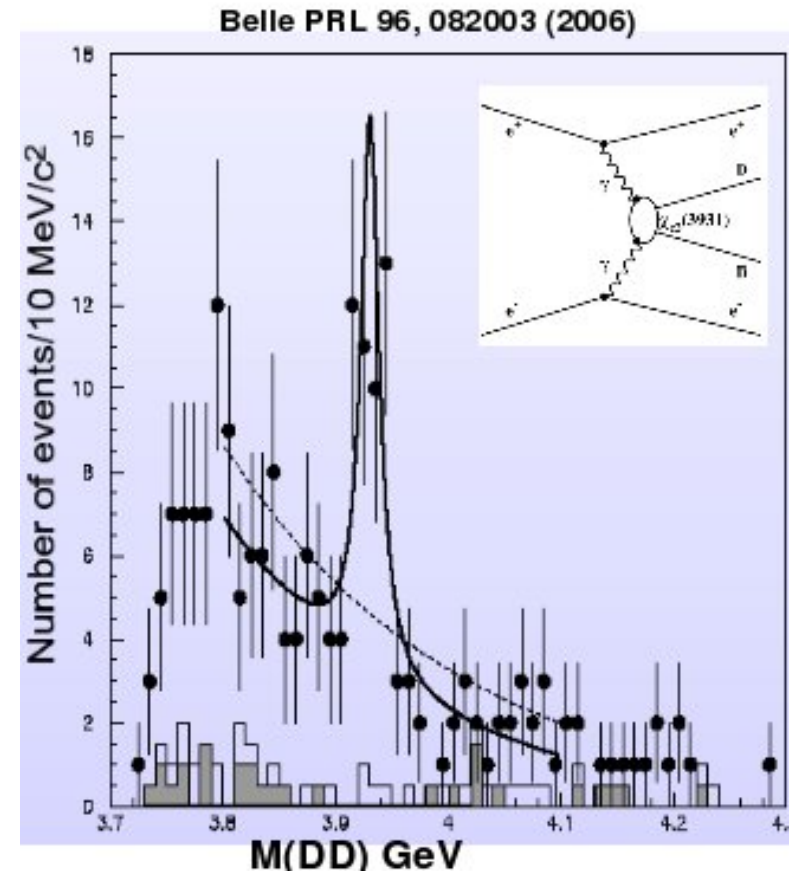
$\chi'_{c1}$  state ( $2^3P_1(c\bar{c})$ )

Test : see  $D\bar{D}^*$ , don't see  $D\bar{D}$  .. (Godfrey).

but  $\mathcal{B}$ 's ...

# $\gamma\gamma \rightarrow Z(3930) \rightarrow D\bar{D}$

- $\gamma\gamma \rightarrow D\bar{D} : J^{PC} = 0^{++}, 2^{++}$
- $M = 3929 \pm 5 \pm 2 \text{ MeV}$
- $\Gamma = 29 \pm 10 \pm 2 \text{ MeV}$
- $\Gamma_{\gamma\gamma} \cdot \mathcal{B}_{D\bar{D}} = 0.18 \pm 0.05 \pm 0.03 \text{ keV}$ .
- $D\bar{D}$  angular distrib. consistent with  $J = 2$ .



Probably  $\chi'_{c2}$  state ( $2^3P_2(c\bar{c})$ )

Test : exclude  $\chi'_{c0}$  by observing  $D\bar{D}^*$  ( $D\bar{D}^*/D\bar{D} \approx 1/3$  for  $\chi'_{c2}$ ) (Godfrey)



395 fb<sup>-1</sup>

PRL 96, 082003 (2006)

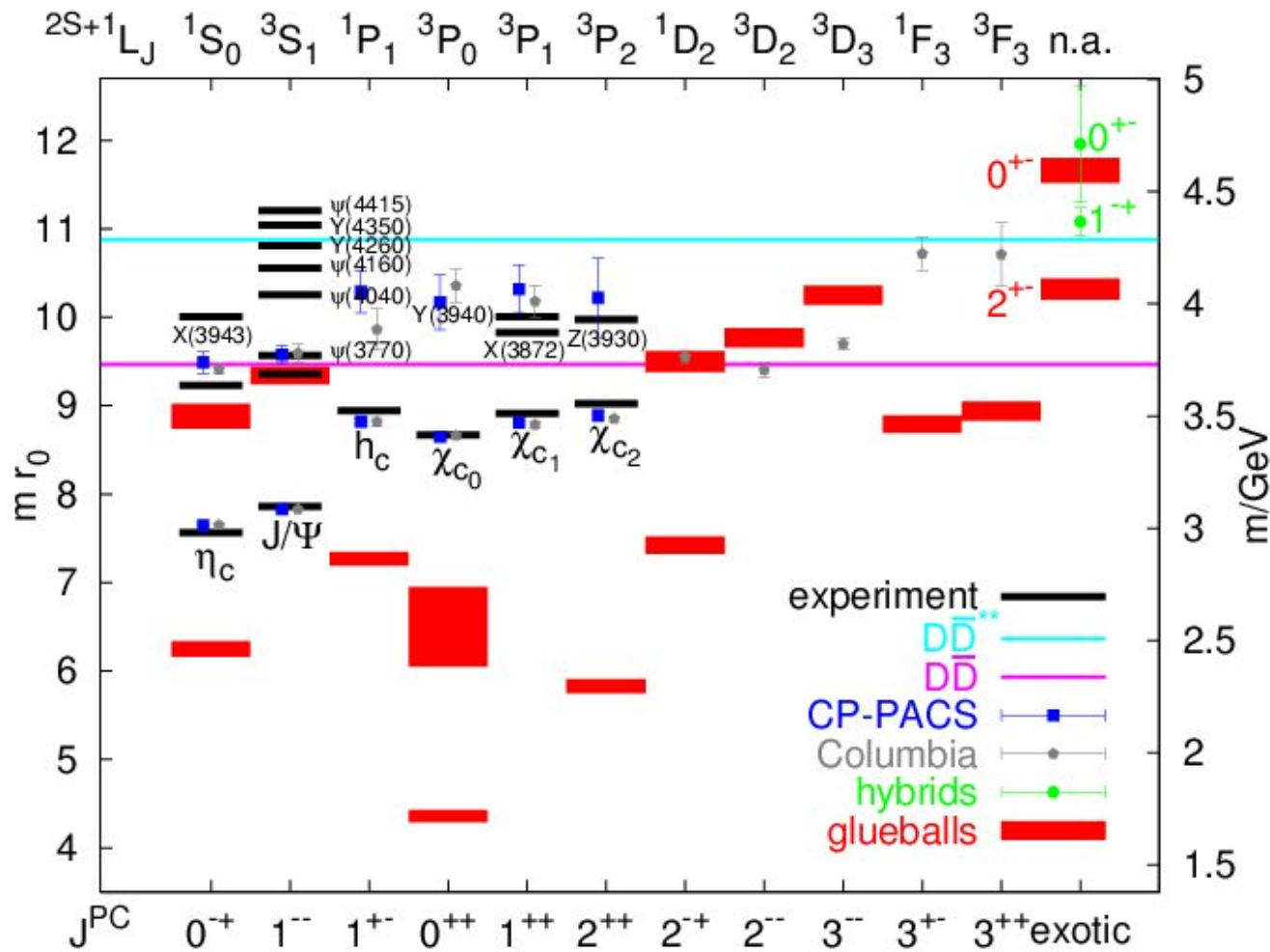


Fig. 2. The quenched charmonium spectrum (Columbia<sup>2</sup>, CP-PACS<sup>3</sup>), glueballs<sup>4</sup> and spin-exotic  $c\bar{c}$ -glue hybrids<sup>2</sup>, overlaid with the experimental spectrum.

“Charmonia from lattice QCD”

G. Bali hep-lat/0608004

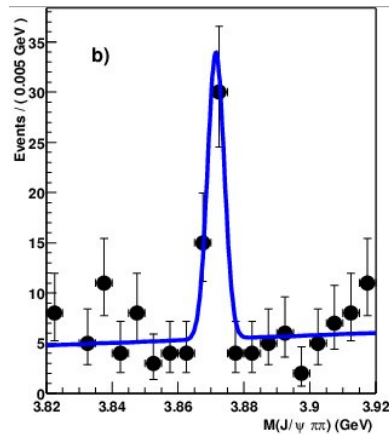
$X(3872)$



# $X(3872)$ Observation

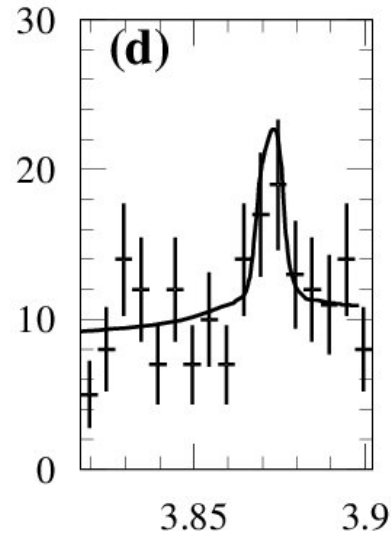
- Discovered by Belle in  $B \rightarrow K X(3872)$ ,  $X(3872) \rightarrow J/\psi \pi^+ \pi^-$
- Confirmed by BaBar,
- Also seen in inclusive production in  $\bar{p}p$  by D0, CDF.

Belle



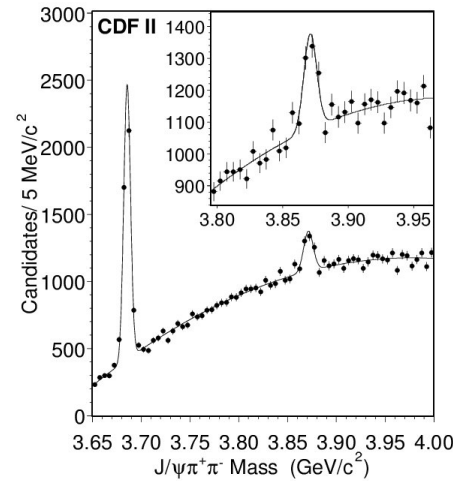
PRL91 :262001,2003

BaBar



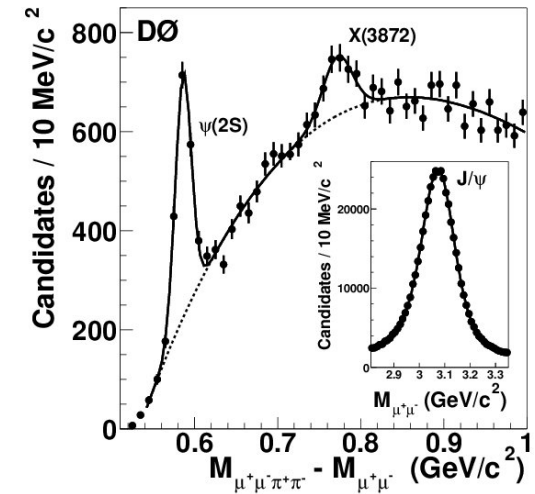
PR.D71 :071103,2005

CDF



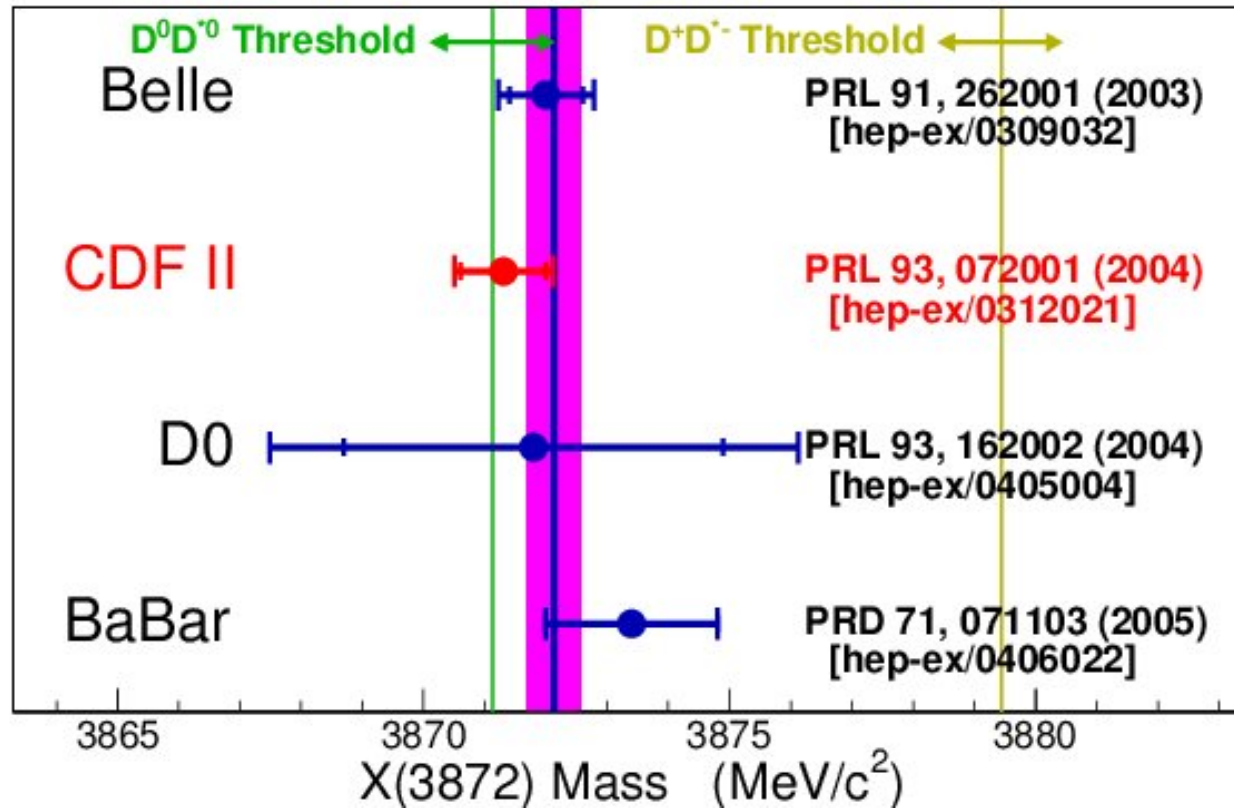
PRL93 :072001,2004

D0



PRL93 :162002,2004

# $X(3872)$ Mass : 2005

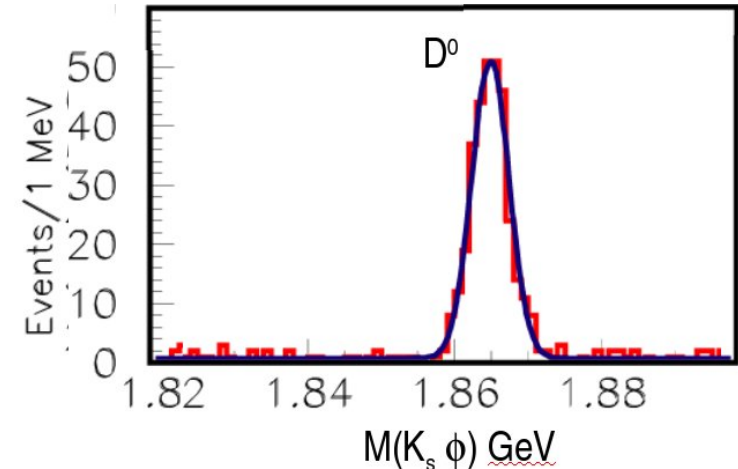


- $m = 3871.9 \pm 0.5 \text{ MeV}/c^2$  ( $D^0 \bar{D}^{*0}$  threshold is at  $3871.3 \pm 1.0 \text{ MeV}/c^2$ ) PDG04
- $M_{X(3872)} - M_{D^0 \bar{D}^{*0}} = 0.6 \pm 1.1 \text{ MeV}/c^2$
- Narrow  $\Gamma < 2.3 \text{ MeV}$  @ 90 % CL. (Belle)  $< 4.1 \text{ MeV}$  (BaBar)

# $X(3872)$ Mass and CLEO's $D^0$ Mass

$$\Psi(3770) \rightarrow D^0 \bar{D}^0, D^0 \rightarrow K_S^0 \phi, (\pi^+ \pi^-)(K^+ K^-)$$

- Very small background
- $D^0$ ,  $K_S^0$ ,  $\phi$ , have small momenta
- $D^0$  mass calibrated by  $K_S^0$ ,  $\phi$  mass.



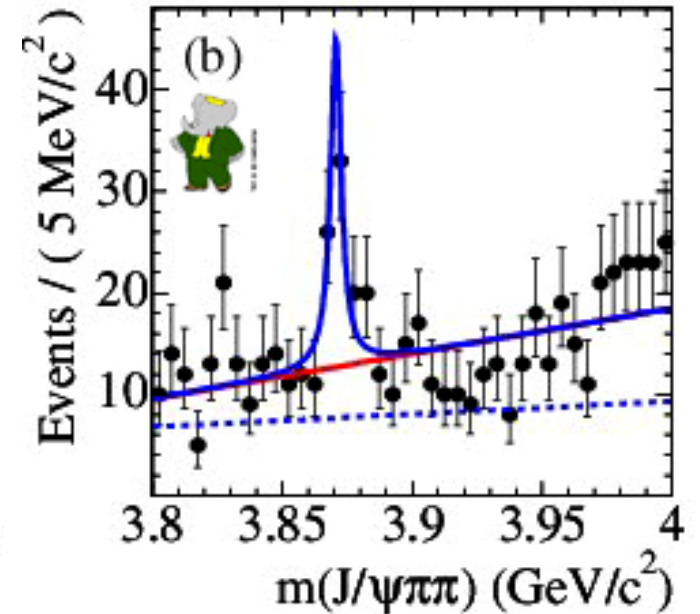
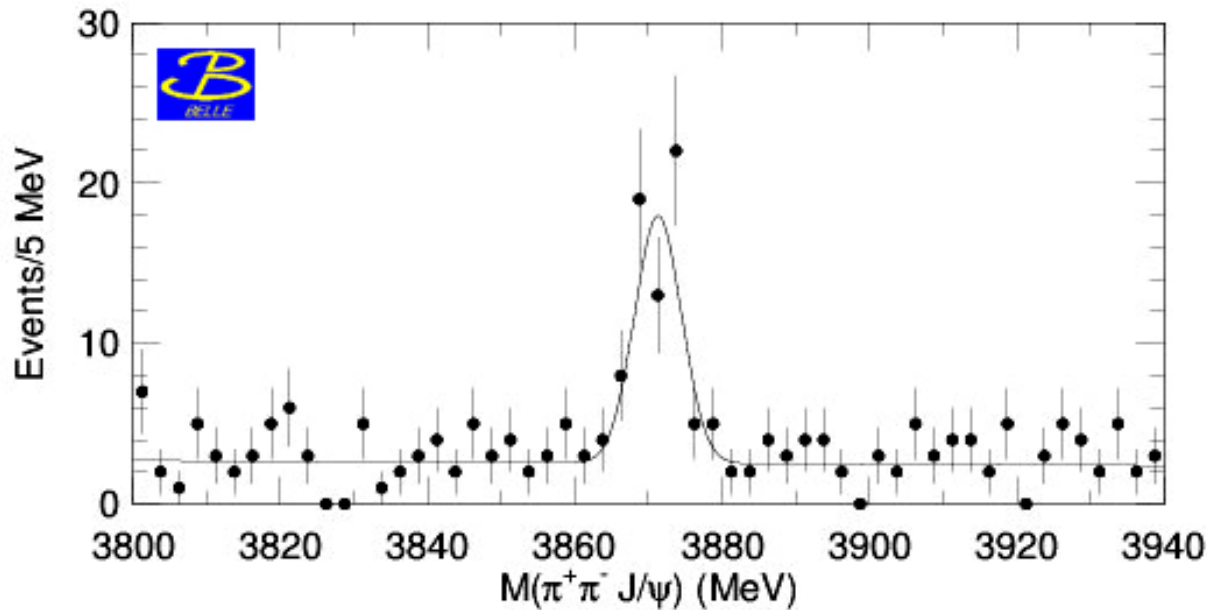
T. Skwarnicki © ICHEP 06.

## CLEO PRELIMINARY

- $1864.85 \pm 0.15 \pm 0.20 \text{ MeV}/c^2$
- $1864.5 \pm 0.40 \text{ MeV}/c^2$  PDG'06 fit
- $1864.1 \pm 1.00 \text{ MeV}/c^2$  PDG'06 average

- $M_{X(3872)} = 3871.2 \pm 0.5 \text{ MeV}/c^2$  PDG'06
- $M_{X(3872)} - M_{D^0 D^{*0}} = 0.1 \pm 1.0 \text{ MeV}/c^2$  PDG'06
- $-0.4 \pm 0.7 \text{ MeV}/c^2$  PDG'06+CLEO

# $X(3872)$ : Branching Fraction



256 fb<sup>-1</sup> hep-ex/0505038 (LP 2005)  $(13.1 \pm 2.4 \pm 1.3) \times 10^{-6}$ .

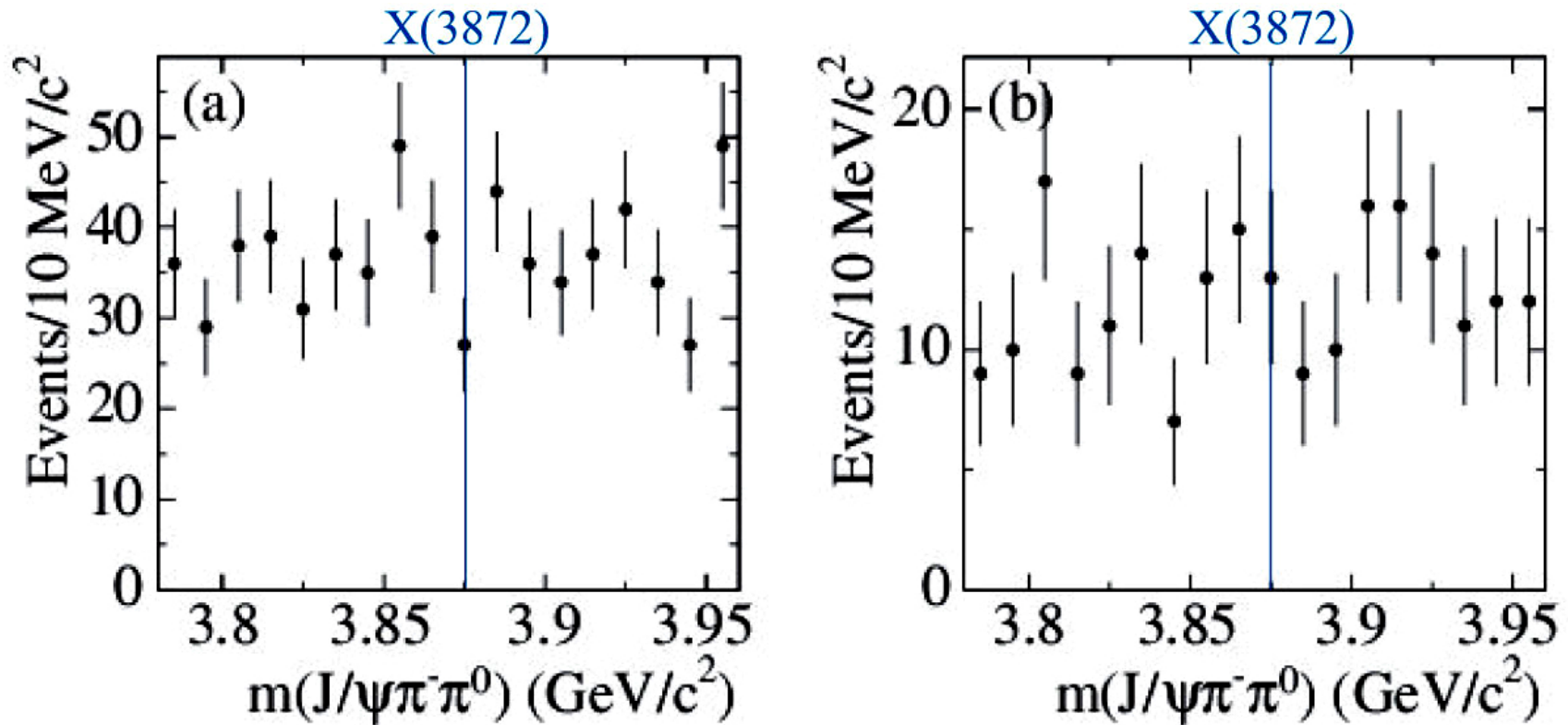


211 fb<sup>-1</sup> PRD 73 011101(R) 2006  $(8.5 \pm 2.3 \pm 0.8) \times 10^{-6}$

- $\mathcal{B}(B \rightarrow KX) \times \mathcal{B}(X \rightarrow \pi^+ \pi^- J/\psi) = (10.5 \pm 1.8) \times 10^{-6}$ .

# $X(3872)$ : Search for a Charged Partner

If  $X(3872)$  is isospin 1, then  $\mathcal{B}(B \rightarrow K X^\pm) \approx 2\mathcal{B}(B \rightarrow K X^0)$



$$\mathcal{B}(B^0 \rightarrow X^- K^+, X^- \rightarrow J/\psi \pi^- \pi^0) < 5.4 \times 10^{-6} \quad @ 90\% \text{ C.L.}$$

$$\mathcal{B}(B^- \rightarrow X^- \bar{K}^0, X^- \rightarrow J/\psi \pi^- \pi^0) < 22 \times 10^{-6}$$



212 fb<sup>-1</sup>

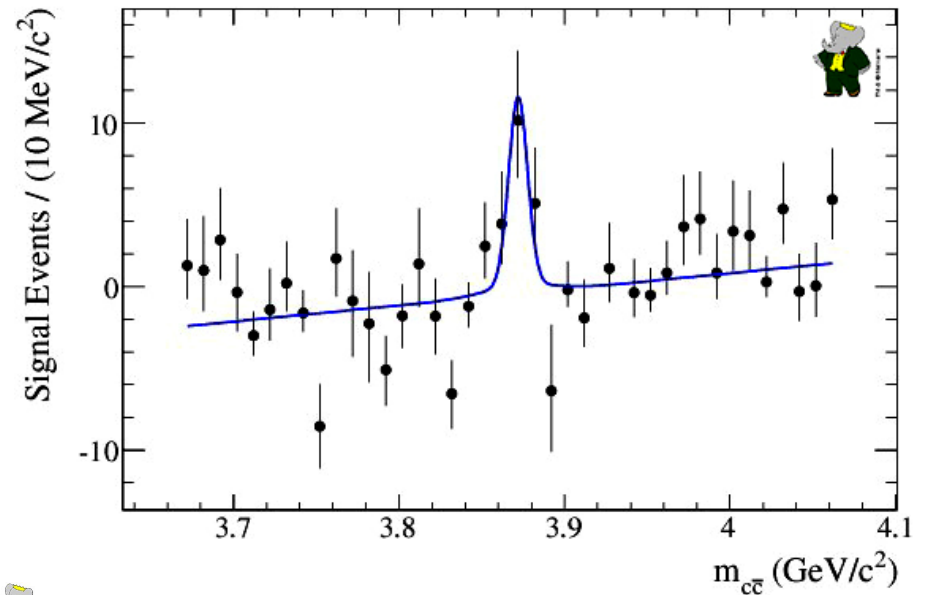
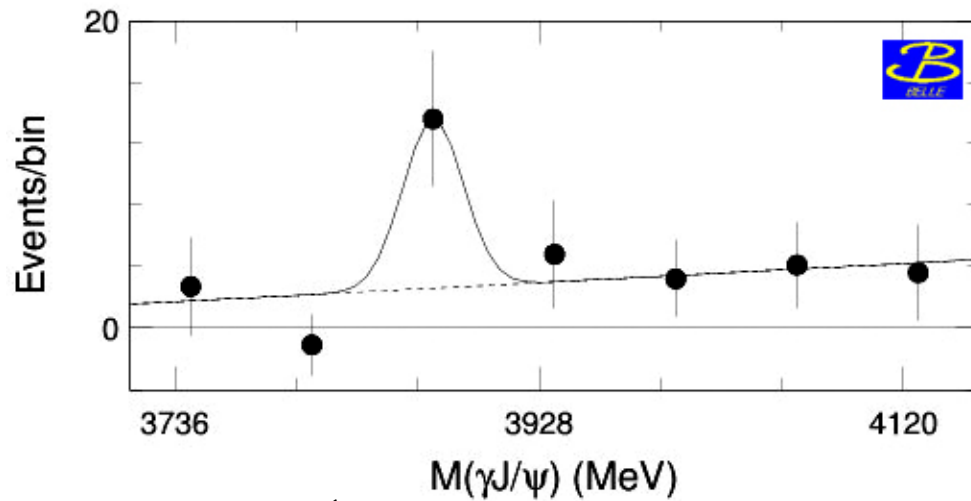
No signal observed

$I \neq 1$

Phys.Rev.D71 :031501,2005

# Observation of $X(3872) \rightarrow J/\psi \gamma$

$B \rightarrow X(3872)K, X(3872) \rightarrow J/\psi \gamma$



-   $256 \text{ fb}^{-1}$   $4.0 \sigma$  hep-ex/0505037 ,   $260 \text{ fb}^{-1}$   $3.4 \sigma$  PRD 74 :071101,2006

- Implies  $C_{X(3872)} = +1$

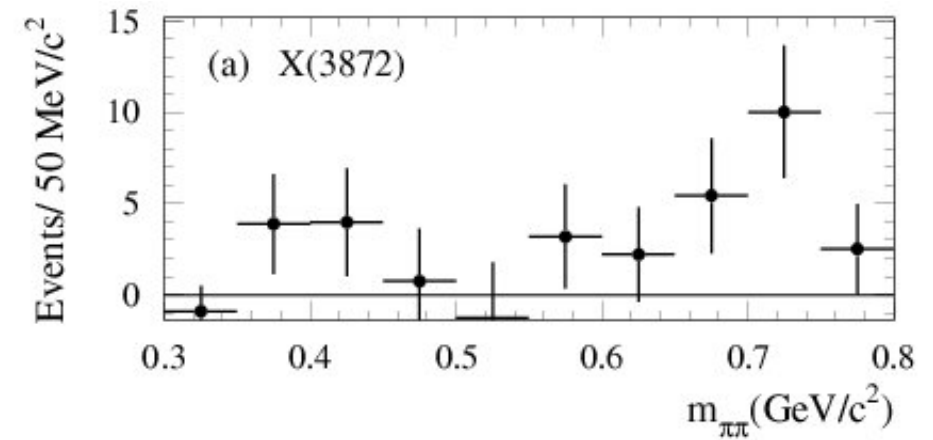
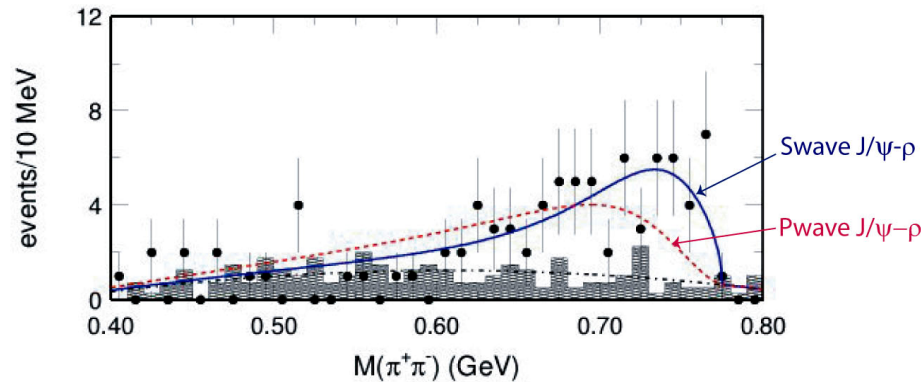
- No  $X^-$  seen  $\Rightarrow I_{X(3872)} \neq 1$

- $C_{(\pi^+\pi^-)} = -1 \Rightarrow l^{(\pi^+\pi^-)} \text{ odd} \Rightarrow I_{(\pi^+\pi^-)} = 1, P_{(\pi^+\pi^-)} = -1$

- $l^{(\pi^+\pi^-)}$  odd indicates P-wave, i.e.  $\rho$

Check :  $X \rightarrow J/\psi \pi^0 \pi^0$  forbidden.

# $X(3872) : \pi^+\pi^-$ Invariant Mass Distribution



 hep-ex/0505038



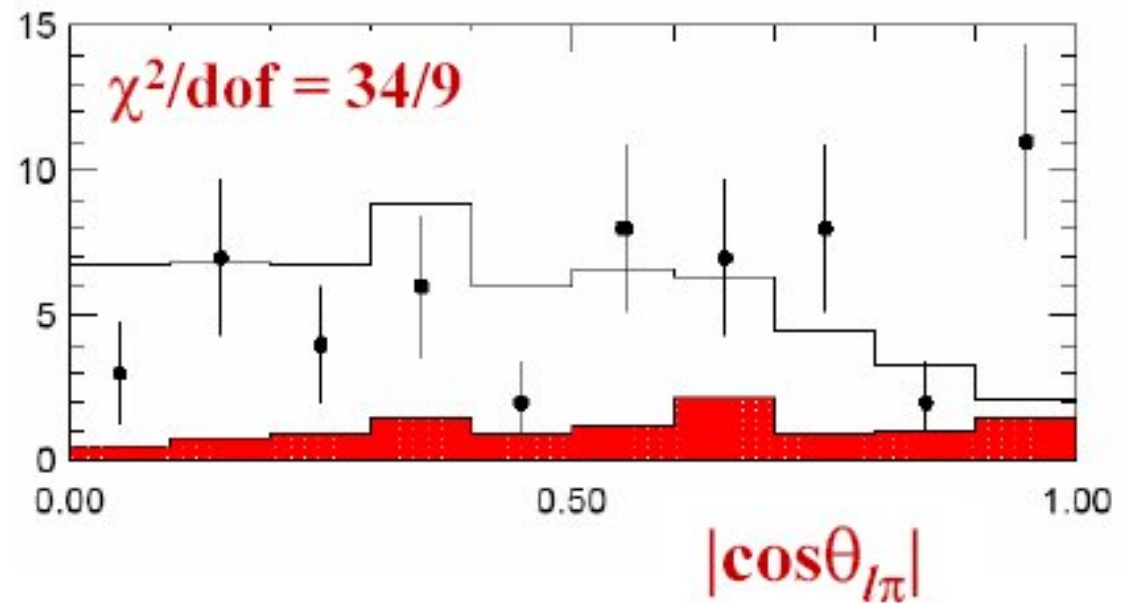
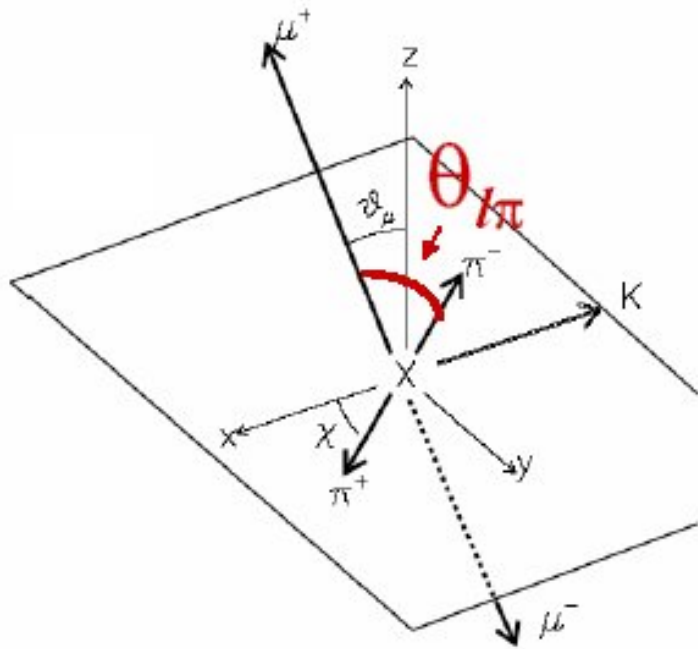
Phys. Rev. D 73, 011101(R) (2006)

- Dipion mass consistent with  $\rho^0 \rightarrow \pi^+\pi^-$  : again  $C_{X(3872)} = +1$
- (Isospin violating again)
- S-wave  $J/\psi - \rho$  favored :  $J^{++}$  favored over  $J^{-+}$
- C.L. of  $\chi^2 = 28\%$  vs  $0.1\%$

$$P_{X(3872)} = +1$$

# Angular Analysis of $X(3872) \rightarrow J/\psi \pi^+ \pi^-$

In the limit where the  $X(3872)$ ,  $J/\psi$  and  $\rho$  rest frames coincide  $dN/d(\cos \theta_{l\pi}) \propto \sin^2 \theta_{l\pi}$ .



$0^{++}$  disfavored.



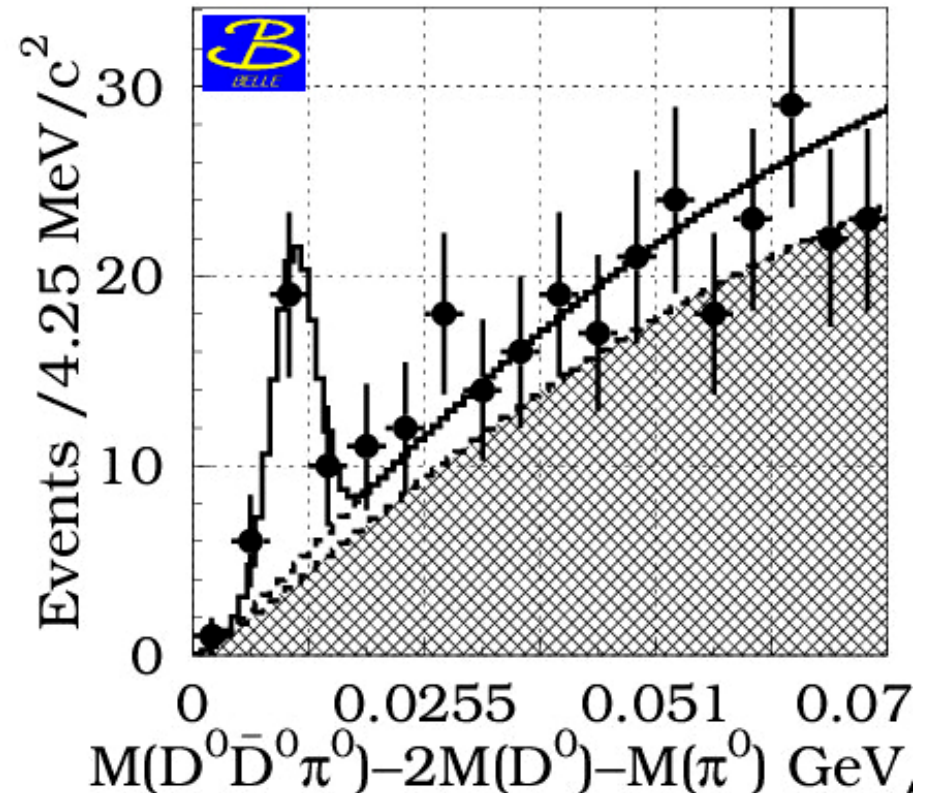
hep-ex/0505038



# Search for $B \rightarrow X(3872)K$ , $X(3872) \rightarrow D^0\bar{D}^0\pi^0$

- $1^{++}$  :  $DD^*$  in an S-wave  $\propto q^*$
- $2^{++}$  :  $DD\pi$  in a D-wave  $\propto q^{*5}$   
 $q$  momentum of  $D$  in  $X(3872)$  frame
- $M = 3875.4 \pm 0.7_{-2.0}^{+1.2} \text{ MeV}/c^2$

$$m - m_{D^0+D^{*0}} = 4.3 \pm 0.7 \text{ MeV}/c^2$$



$$\mathcal{B}(B \rightarrow D\bar{D}\pi^0 K) = (1.27 \pm 0.31_{-0.39}^{+0.22}) \times 10^{-4}.$$



6.4  $\sigma$

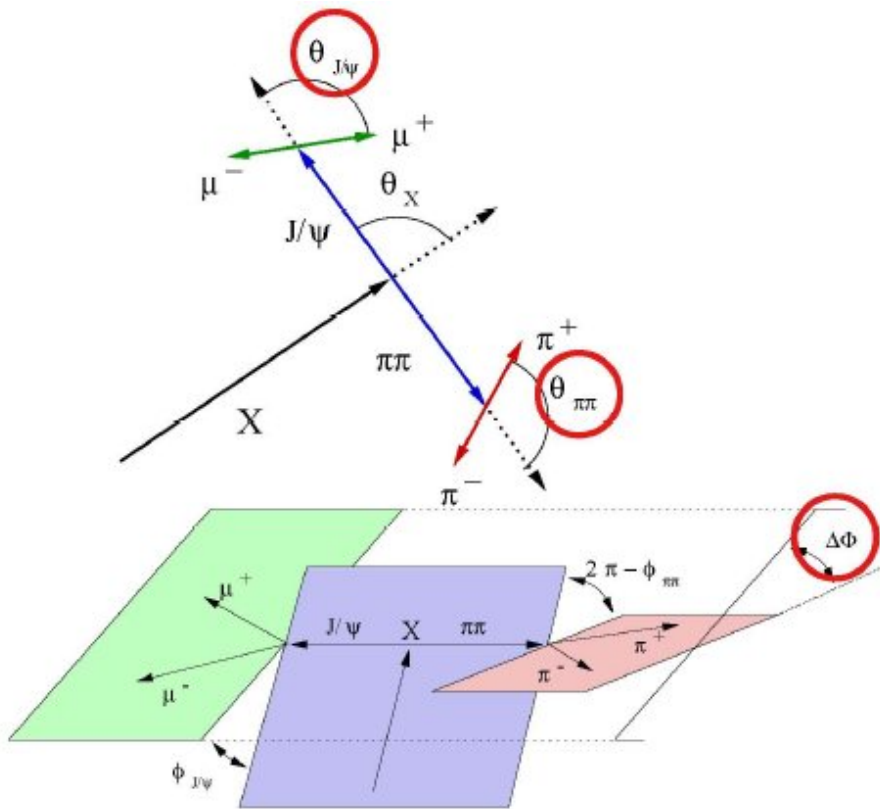
414 fb<sup>-1</sup>

Preliminary

$2^{++}$  disfavored

hep-ex/0606055

# CDF 3D Angular Analysis



$J^{PC}$	$\chi^2$ prob.
$1^{++}$	27.8%
$2^{-+}$	25.8%
$1^{--}$	0.02%
$2^{+-}$	$5.5 \cdot 10^{-5}$
$1^{+-}$	$3.8 \cdot 10^{-5}$
$2^{--}$	$3.8 \cdot 10^{-5}$
$3^{+-}$	$3.8 \cdot 10^{-5}$
$3^{--}$	$2.4 \cdot 10^{-5}$
$2^{++}$	$1.1 \cdot 10^{-5}$
$1^{-+}$	$4.1 \cdot 10^{-6}$
$0^{-+}$	$3.5 \cdot 10^{-17}$
$0^{+-}$	$< 1 \cdot 10^{-20}$
$0^{++}$	$< 1 \cdot 10^{-20}$

- Method checked on  $\psi(2S)$   $J^{PC} = 1^{--}$
- X(3872) : Only  $J^{PC} = 1^{++}$  and  $2^{-+}$  compatible with data !
- (Belle had “strongly disfavored  $2^{-+}$  assignment” (hep-ex/0505038))

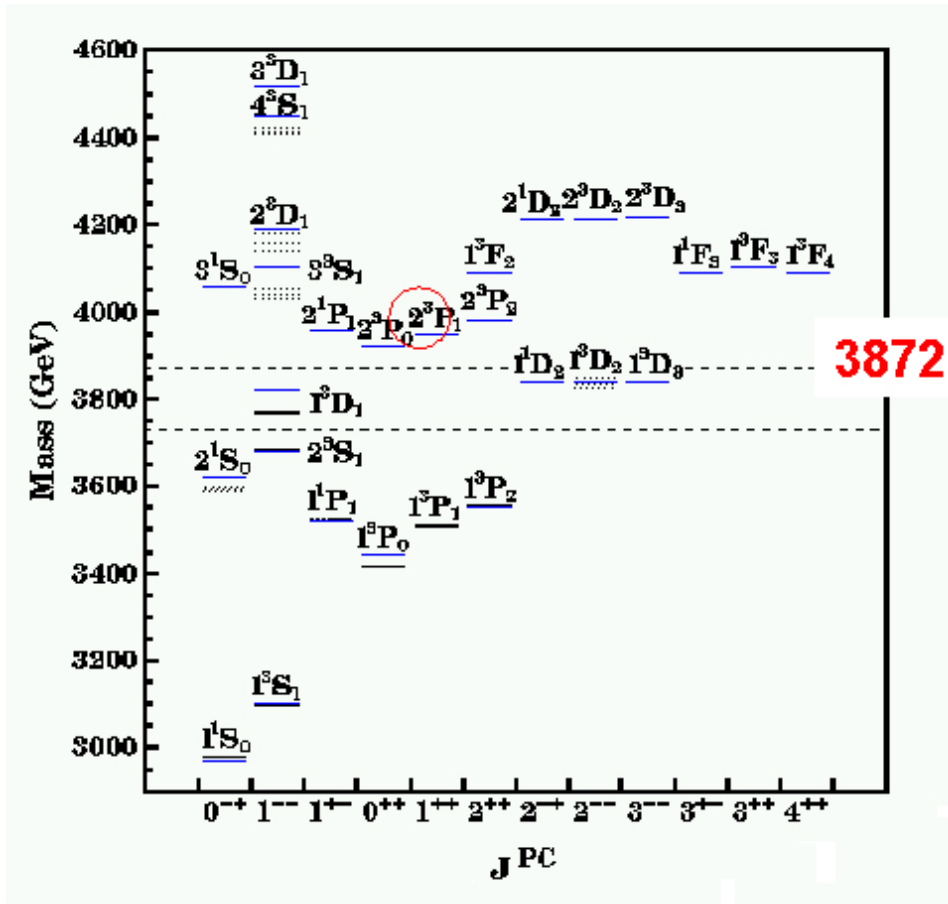
$1^{++}$  left  780 pb<sup>-1</sup> CDF Run II Preliminary M. Kreps @ ICHEP 2006.

Test :  $1^{++}(^3P_1) \rightarrow \psi\gamma$  vs  $2^{-+}(^1D_2) \rightarrow h_c\gamma$  (Barnes, Godfrey PRD69 054008)

# $X(3872)$ : Not a Charmonium Meson

- 1 :  $1^{++}$  is  $\chi_{c1}'$  (predicted at  $\approx 3950 \text{ MeV}/c^2$ )

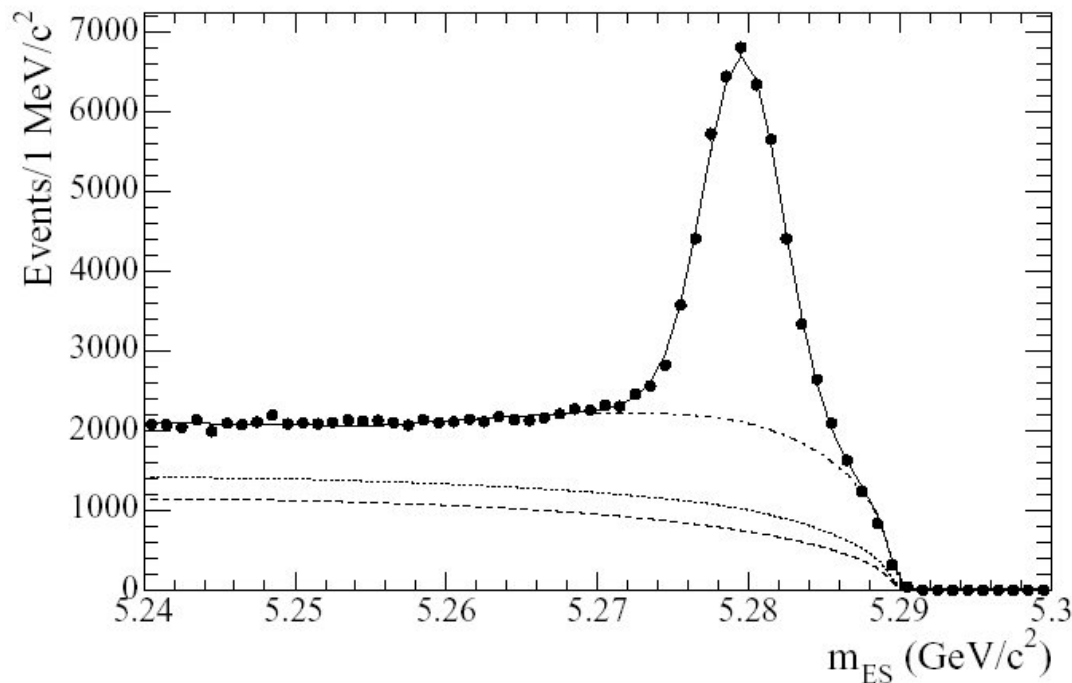
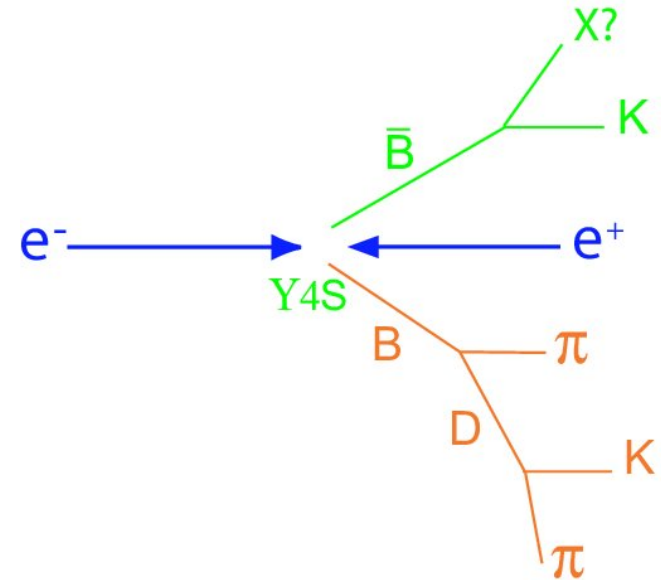
$X(3872)$  is too light !



# Direct Measurement of $\mathcal{B}(B \rightarrow XK^+)$

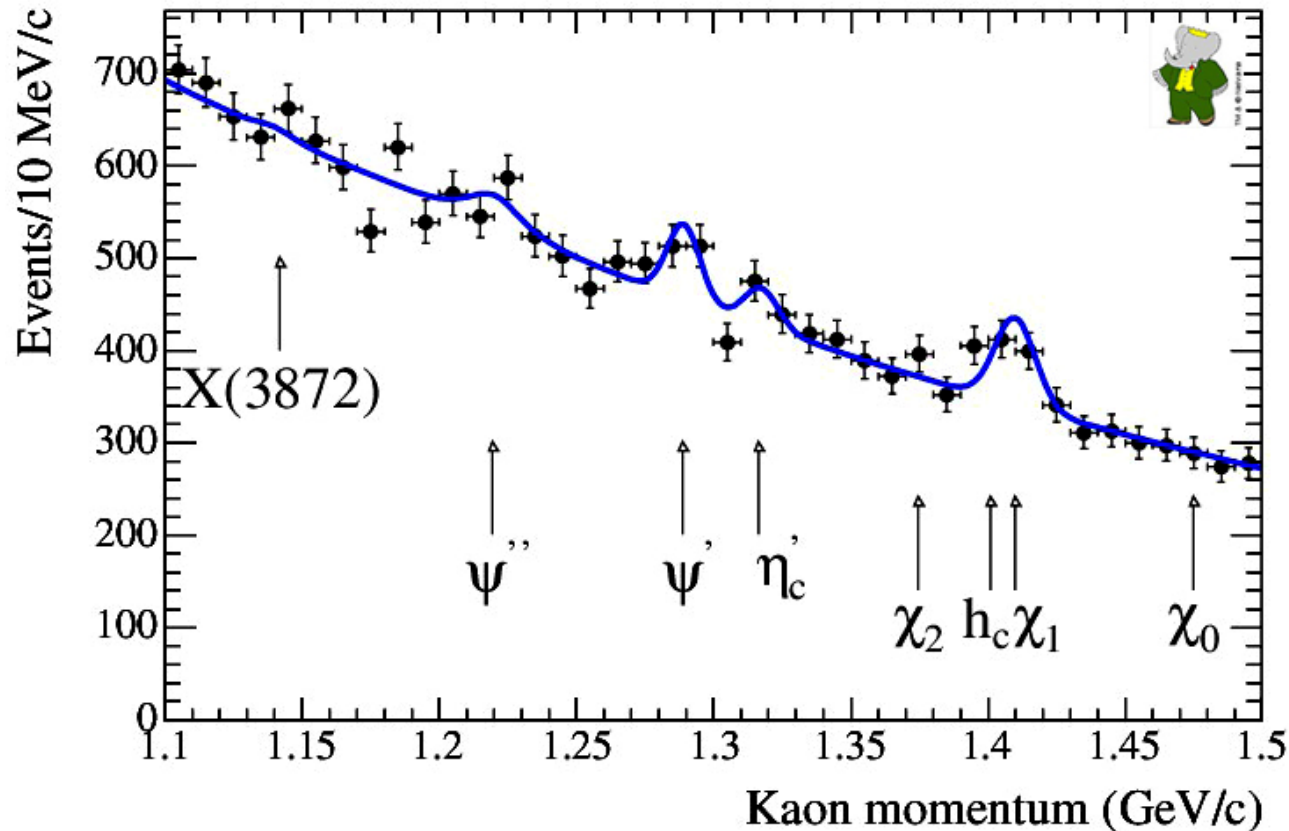
Inclusive Search on the Recoil :  $B \rightarrow XK$

- One reconstructed  $B$  (NN1)
- One selected  $K$  (NN2)
- $K$  momentum computed in recoil  $\bar{B}$  rest frame



$\approx 4 \cdot 10^5 B's.$

# Inclusive Searches : $B \rightarrow XK^+$



- $\mathcal{B}(B \rightarrow X(3872)K) = (0.5 \pm 1.4)10^{-4} < 3.2 \times 10^{-4}$
- $\mathcal{B}(X(3872) \rightarrow J/\psi \pi^+ \pi^-) > 4.3\%$  at 90% CL.
- 2 : Too large for an isospin violating decay (e.g.  $\mathcal{B}(\psi(2S) \rightarrow J/\psi \pi^0) = 0.10 \pm 0.02\%$ )



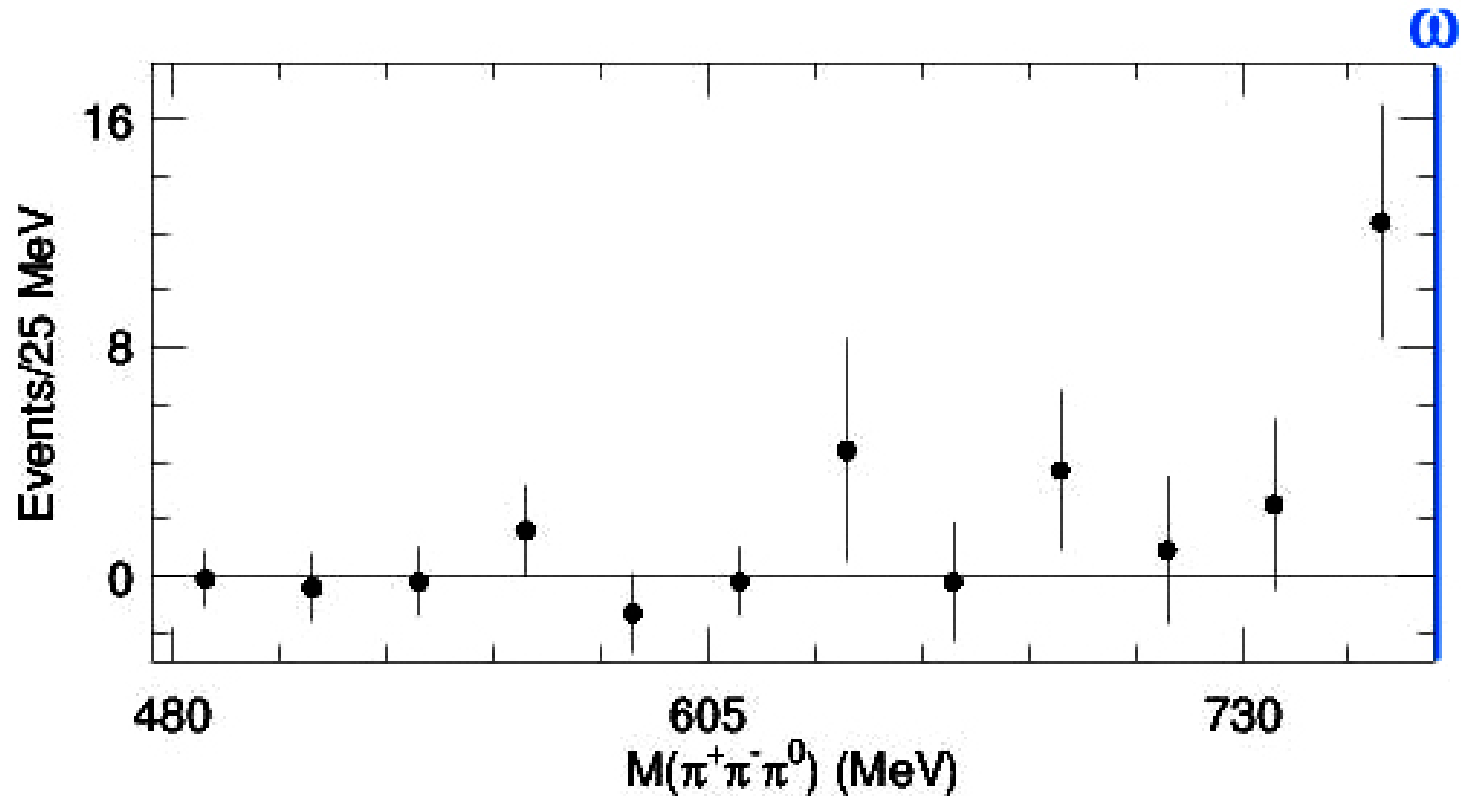
210 fb<sup>-1</sup>

Phys.Rev.Lett.96 :052002,2006

# Measuring Isospin Violation in $X(3872)$ Decay

Observation of  $B \rightarrow X(3872)(J/\psi \pi^+ \pi^- \pi^0)K$ , consistent with  
Isospin-conserving  $X(3872) \rightarrow J/\psi \omega$

4.3  $\sigma$



$$\frac{\mathcal{B}(X(3872) \rightarrow J/\psi \omega)}{\mathcal{B}(X(3872) \rightarrow J/\psi \rho)} \approx \frac{\mathcal{B}(X(3872) \rightarrow J/\psi \pi^+ \pi^- \pi^0)}{\mathcal{B}(X(3872) \rightarrow J/\psi \pi^+ \pi^-)} = 1.0 \pm 0.4 \pm 0.3$$



256 fb<sup>-1</sup>

hep-ex/0505037

# $X(3872)$ : Interpretation ?

$1^{++}$  .. 4-quark models      Predictions :

- Diquark-antidiquark ; Maiani et al., PRD71 014028 (2005)

- 2 neutral states

$$X_u = [cu] [\bar{c}\bar{u}],$$

$$X_d = [cd] [\bar{c}\bar{d}],$$

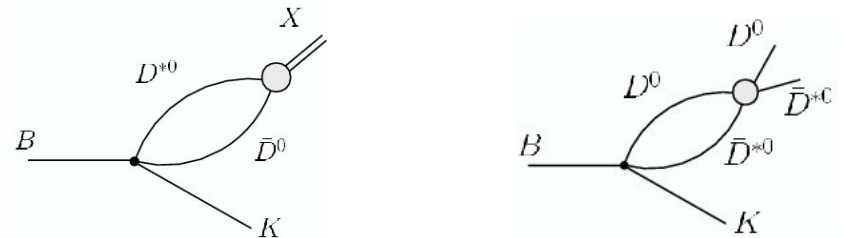
- 2 charged states

$$X^+ = [cu] [\bar{c}\bar{d}],$$

$$X^- = [cd] [\bar{c}\bar{u}]$$

- Neutral states produced in  $B^0$  and  $B^+$  decays,  $m(X_d) - m(X_u) \approx (7 \pm 2) \text{ MeV}/c^2$ .

- S-wave  $D^0 \bar{D}^{*0}$  molecule ;



Braaten & Kusunoki, PRD 71 (2005) 074005

- using  $B \rightarrow D^{(*)} D^{(*)} K$  BF's, factorization, heavy quark and isospin symmetry.

- $B^0 \rightarrow X(3872)K^0$  Suppressed by 1 order of magn. wrt  $B^+ \rightarrow X(3872)K^+$

They need the Dalitz plot analysis of  $B \rightarrow D^{(*)} D^{(*)} K$  !

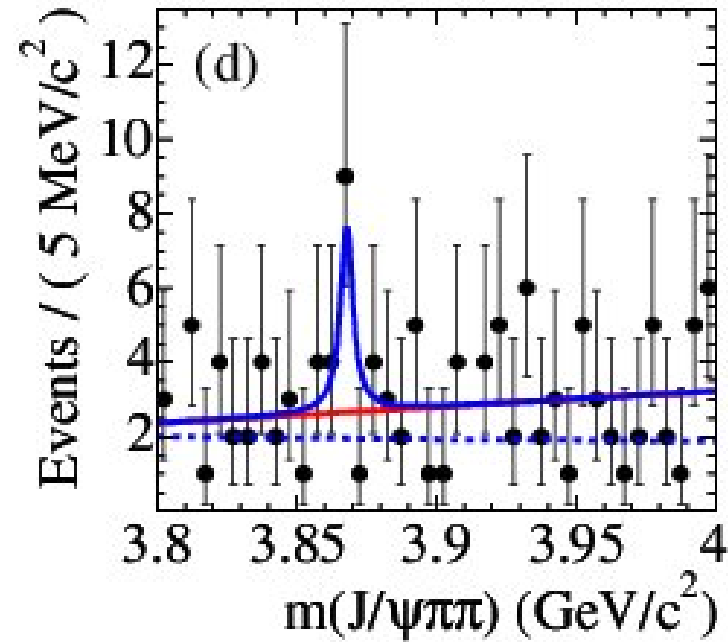
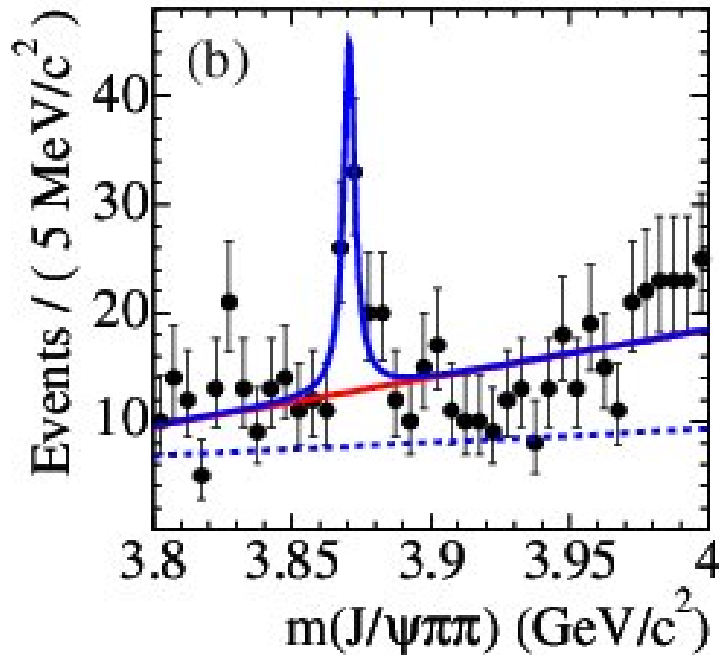
Swanson predicts  $R \approx 0.06 - 0.29$ .

Phys.Rept.429 :243-305,2006

# $X(3872)$ in Exclusive $B^+$ and $B^0$ Decays

$$B^+ \rightarrow X(3872)K^+ \quad 5.7 \sigma$$

$$B^0 \rightarrow X(3872)K^0 \quad 2.5 \sigma$$



- $R = \mathcal{B}^0/\mathcal{B}^+ = 0.50 \pm 0.30 \pm 0.05$ ,  $0.15 < R < 1.34$  at 90% CL
- $\Delta m = 2.7 \pm 1.3 \pm 0.2 \text{ MeV}/c^2$  (mass resolution  $\Gamma = 5.4 \text{ MeV}/c^2$ )
- $R$ : Molecule model in trouble?
- $\Delta m$ : Di-Diquark model in trouble?

Need more statistics!  $\sigma_{\Delta m} \approx 0.6 \text{ MeV}/c^2 / \sqrt{\mathcal{L}(\text{ab}^{-1})}$   $\sigma_R \approx 0.17 / \sqrt{\mathcal{L}(\text{ab}^{-1})}$



211  $\text{fb}^{-1}$

PRD 73 011101(R) 2006



# $R = 0/+$ , $\Delta m$ , in Belle's $B \rightarrow K X(3872) (D^0 \bar{D}^0 \pi^0)$ ?



414 fb<sup>-1</sup>

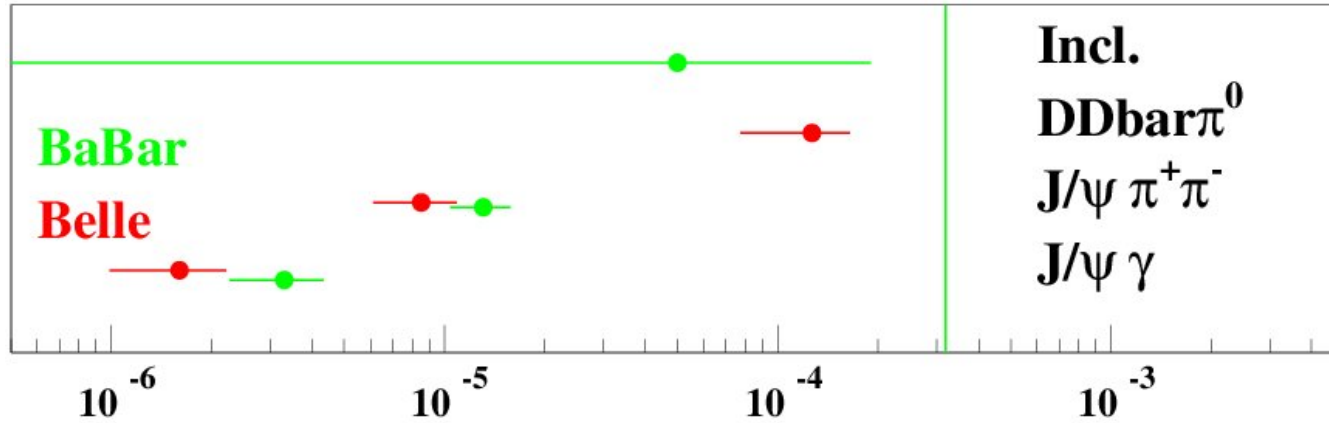
Preliminary

hep-ex/0606055

Signal	$\epsilon \mathcal{B} \times 10^4$	$N_{obs}$	sig, $\sigma$	$\mathcal{B} \times 10^4$
$B \rightarrow D^0 \bar{D}^0 \pi^0 K$	$2.12 \pm 0.10$	$24.1 \pm 6.1$	6.4	$1.27 \pm 0.31^{+0.22}_{-0.39}$
$B^+ \rightarrow D^0 \bar{D}^0 \pi^0 K^+$	$3.62 \pm 0.14$	$17.4 \pm 5.2$	5.0	$1.07 \pm 0.31^{+0.19}_{-0.33}$
$B^0 \rightarrow D^0 \bar{D}^0 \pi^0 K^0$	$0.84 \pm 0.04$	$6.5 \pm 2.6$	4.6	$1.73 \pm 0.70^{+0.31}_{-0.53}$

- $R$  compatible with 1?!?!?
- $\Delta m$ ?

# $X(3872)$ $\mathcal{B}$ 's : Let's Go Inclusive Again!



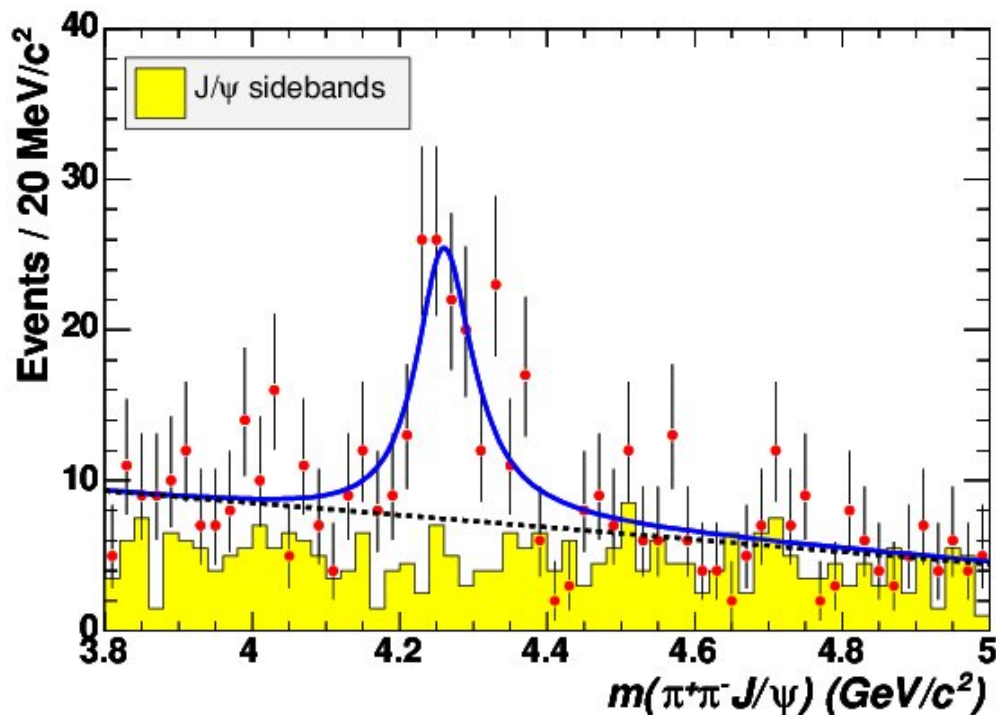
- $\mathcal{B}(B \rightarrow X(3872)K) = (0.5 \pm 1.4) \times 10^{-4} < 3.2 \times 10^{-4}$  (BaBar)
- $\mathcal{B}(B \rightarrow X(3872)K) \times \mathcal{B}(X(3872) \rightarrow \pi^+\pi^-J/\psi) = (10.5 \pm 1.8) \times 10^{-6}$ . (av)
- $\mathcal{B}(B \rightarrow X(3872)K)\mathcal{B}(X(3872) \rightarrow D\bar{D}\pi^0) = (1.27 \pm 0.31^{+0.22}_{-0.39}) \times 10^{-4}$  (Belle)
- ⇒
- $\mathcal{B}(B \rightarrow X(3872)K) \approx 2. \times 10^{-4}$  (similar to factorization suppressed  $B \rightarrow \chi_{c0}K$ )
- $X(3872) \rightarrow D\bar{D}\pi^0$  dominant?
- $4.3\% < \mathcal{B}(X(3872) \rightarrow J/\psi\pi^+\pi^-) < 7.6\%$
- Inclusive  $\mathcal{B}(B \rightarrow X(3872)K)$  should be detectable  $\sigma_{\mathcal{B}} = 0.64 \times 10^{-4} / \sqrt{\mathcal{L}(\text{ab}^{-1})}$

Due to  $D\bar{D}\pi^0$  possibly saturating the width, a  $D^0$  tag would help lower the BKG!

$Y(4260)$

# A New $1^{--}$ Resonance Decaying to $J/\psi \pi^+ \pi^-$ in Initial State Radiation Production

- Was searching for  $e^+e^- \rightarrow X(3872)\gamma$ ,  $X(3872) \rightarrow J/\psi \pi^+ \pi^-$
- Found a new resonance  $m = 4259 \pm 8 \text{ MeV}/c^2$ ,  $\Gamma = 88 \pm 23 \text{ MeV}$ ,  $> 8\sigma$
- $\Gamma(Y \rightarrow e^-e^-) \cdot \mathcal{B}(Y \rightarrow J/\psi \pi^+ \pi^-) = 5.5 \pm 1.0_{-0.7}^{+0.8} \text{ eV}$ .



Detection of ISR  $\gamma$  not required

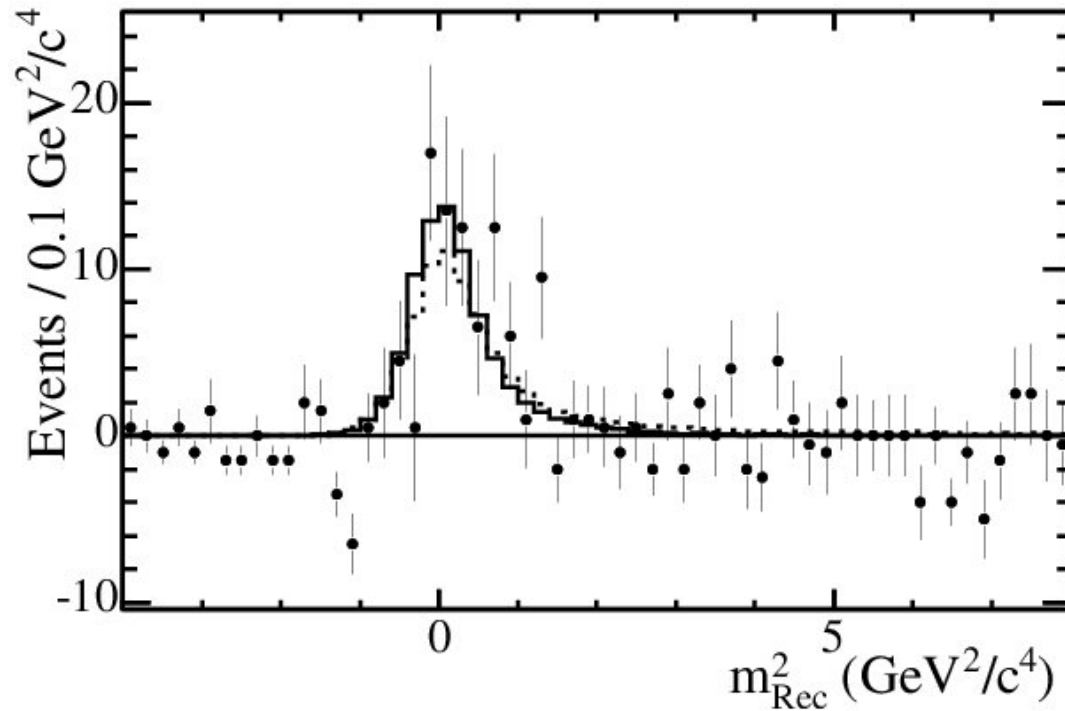


$211 \text{ fb}^{-1}$

Phys. Rev. Lett. 95, 142001 (2005)

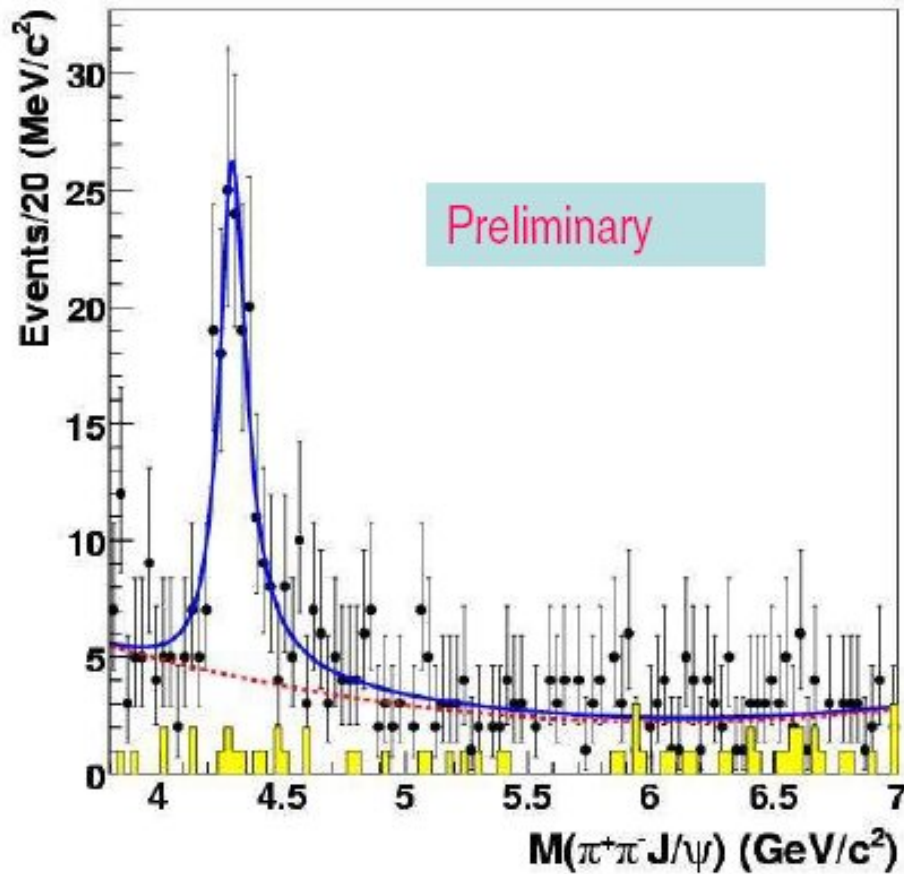
# ISR Checks

- All events :  $J/\psi \pi^+ \pi^-$  system recoiling against  $m_{Rec}$



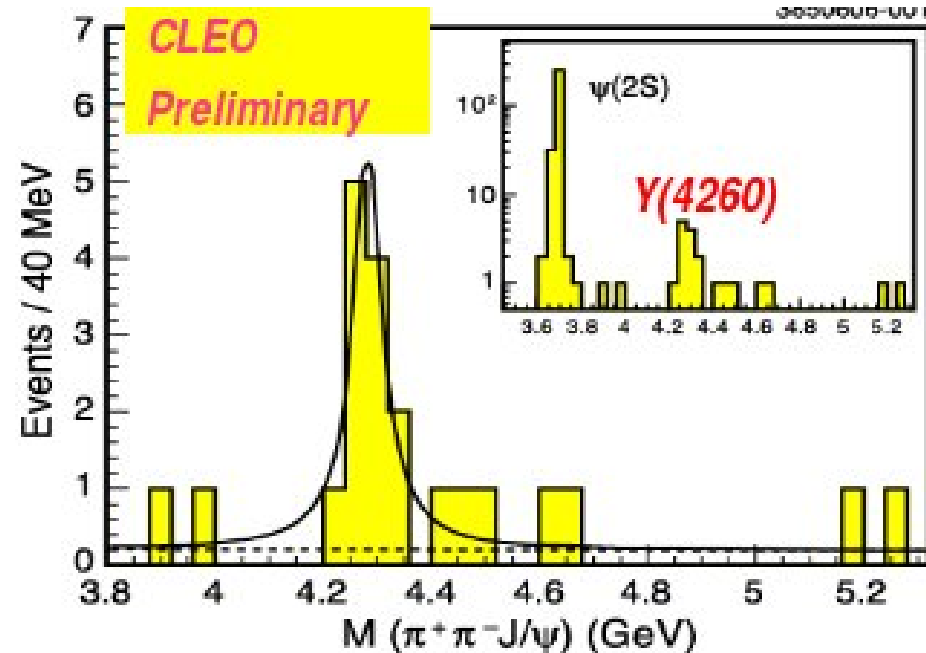
- Events with  $\gamma$  reco'ed ( $\approx 25\%$ ) : extensive checks.

# Confirmed by Belle, CLEO



553 fb<sup>-1</sup>

G. Majumber @ ICHEP 06.



13 fb<sup>-1</sup>

I. Shipsey @ ICHEP 06 and  
PRL 96 :162003,2006

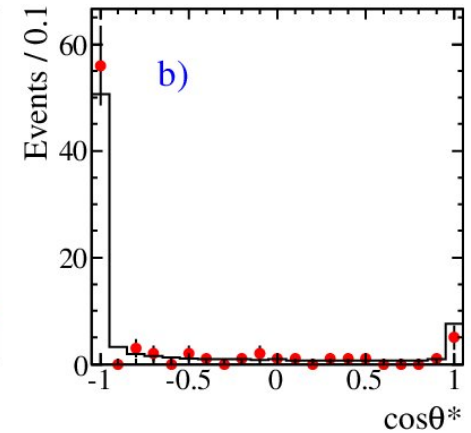
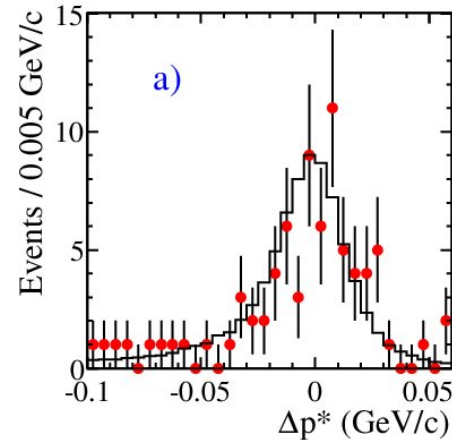
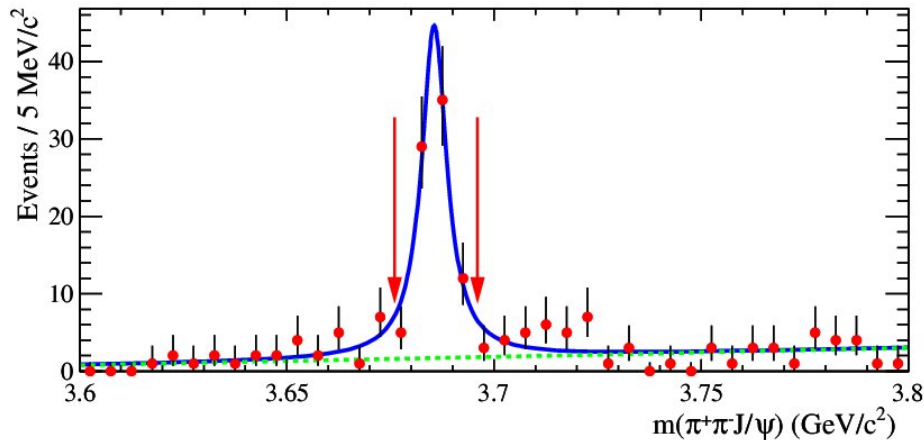
# Search for $Y(4260) \rightarrow \psi(2S)\pi^+\pi^-$ in ISR Production

$$e^+e^- \rightarrow Y(4260)\gamma_{ISR}$$

$$Y(4260) \rightarrow \psi(2S)\pi^+\pi^-$$

$$\psi(2S) \rightarrow J/\psi\pi^+\pi^-$$

Detection of ISR  $\gamma$  not required

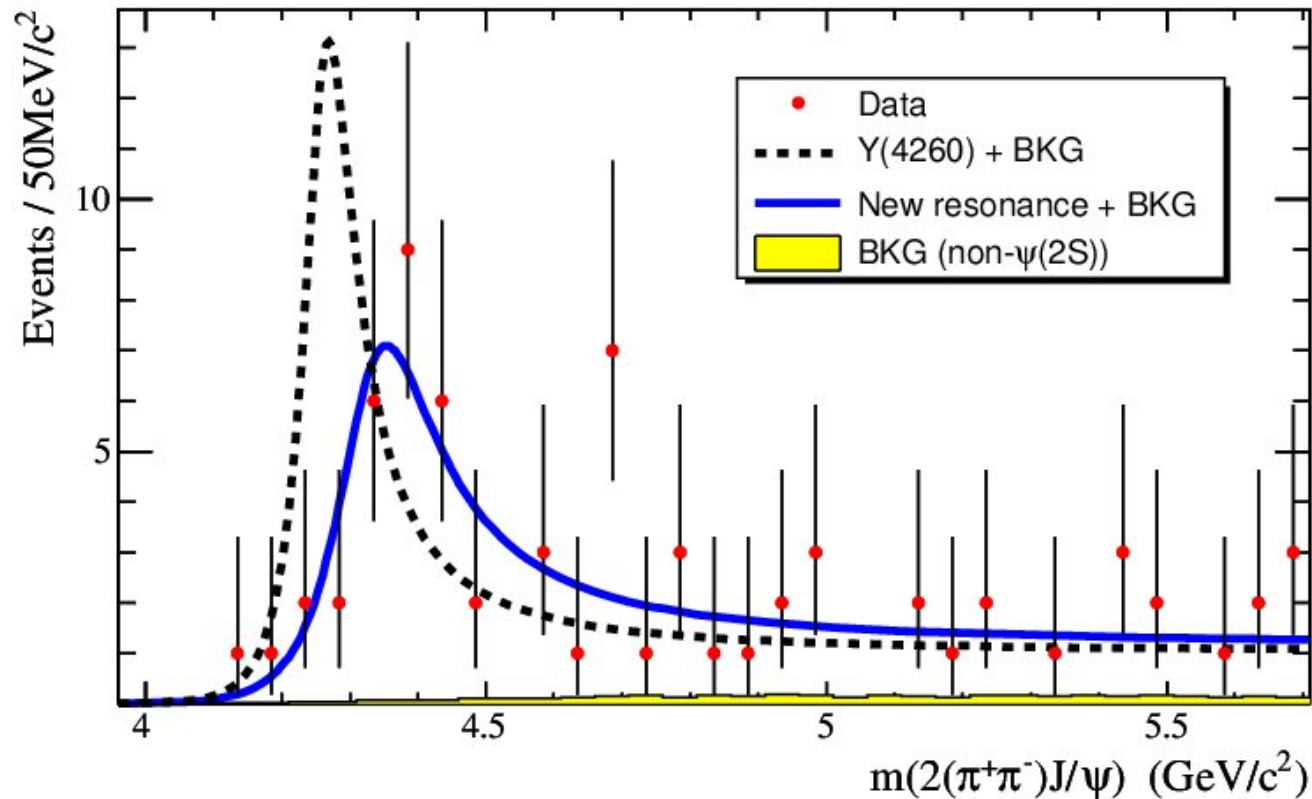


Preliminary

298  $\text{fb}^{-1}$

X. Lou @ ICHEP 06. (hep-ex/0610057)

# $Y(4260) \rightarrow \psi(2S)\pi^+\pi^-$ in ISR Production



$$m = (4324 \pm 24) \text{ MeV}/c^2, \Gamma = (172 \pm 33) \text{ MeV} \quad (\text{statistical errors only})$$



Preliminary

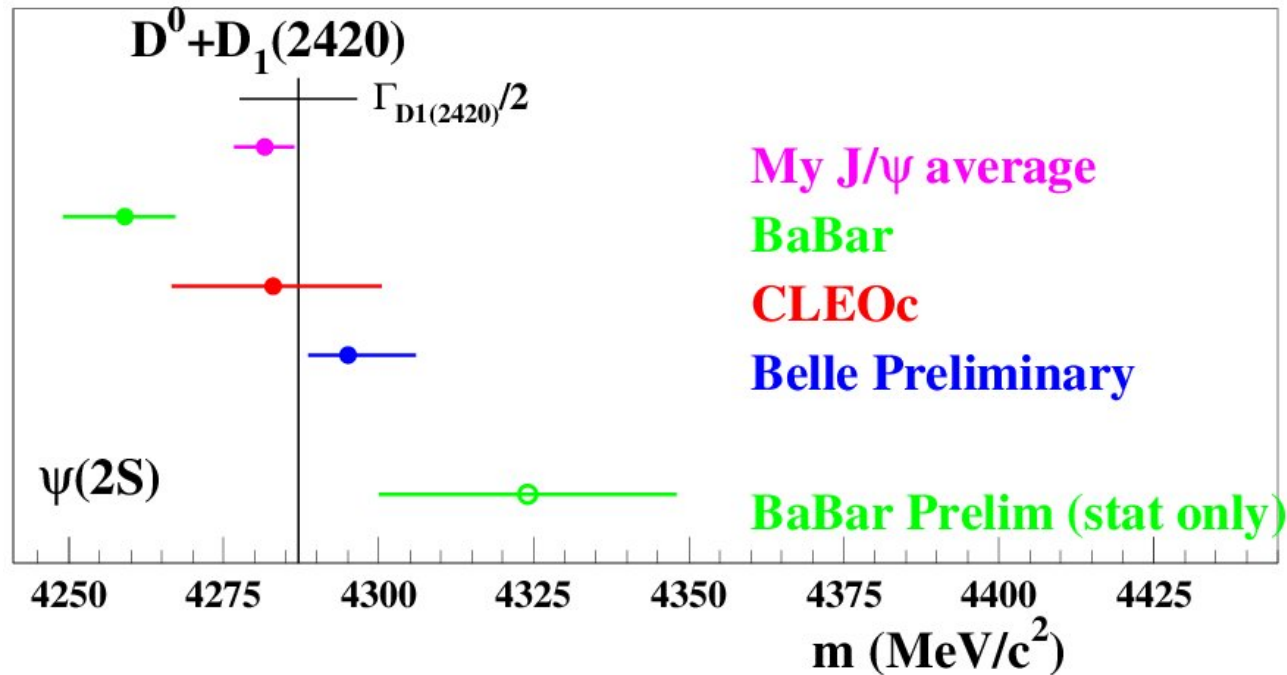
298 fb<sup>-1</sup>

hep-ex/0610057

(mass range used in fit shorter than that used in X. Lou @ ICHEP 06)



# $Y$ : One or Two States ?

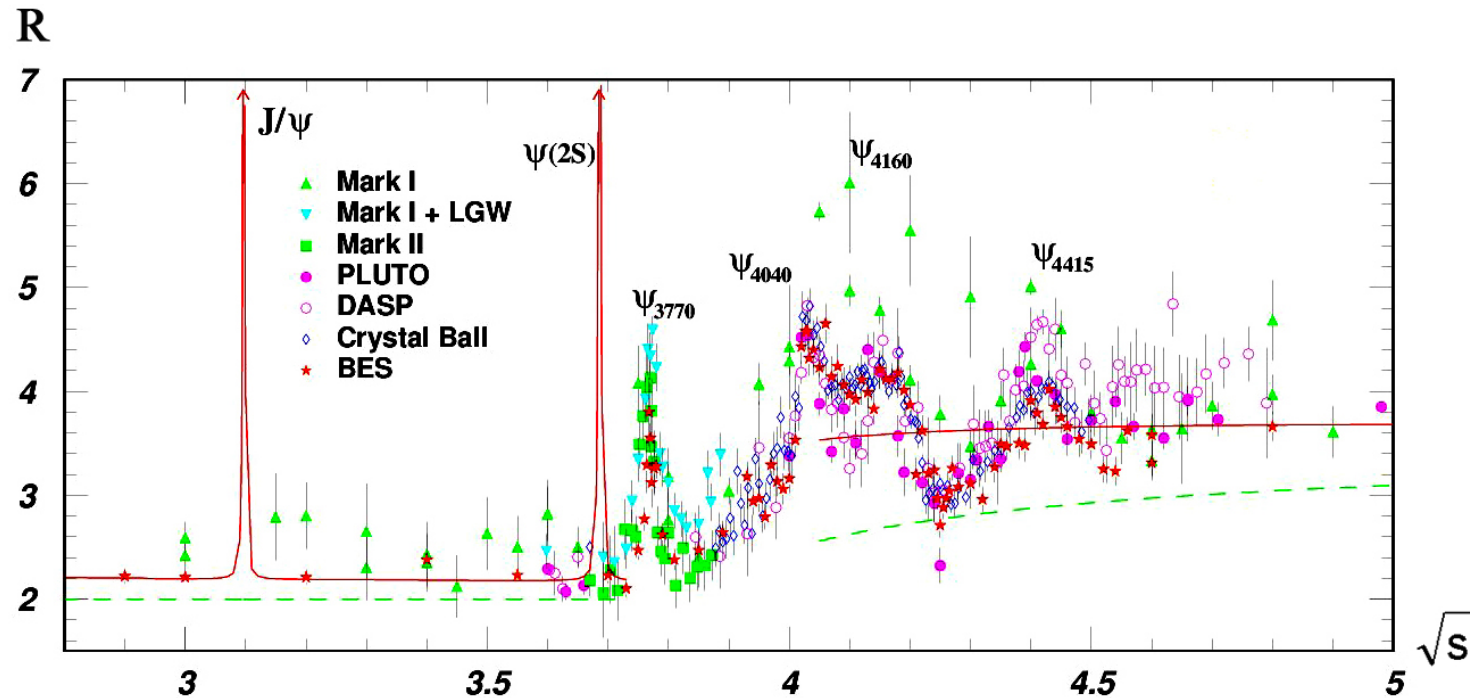


	$m$ (MeV/c <sup>2</sup> )	$\Gamma$ (MeV)		
$J/\psi \pi^+ \pi^-$	$4259 \pm 8_{-6}^{+2}$	$88 \pm 23_{-4}^{+6}$	$> 8\sigma$	BaBar
	$4283_{-16}^{+17} \pm 4$	$70_{-25}^{+40} \pm 5$	$4.9\sigma$	CLEOc
	$4295 \pm_{-5}^{+11} \pm 4$	$133 \pm 26_{-6}^{+13}$	$> 7\sigma$	Belle Preliminary
$\psi(2S) \pi^+ \pi^-$	$4324 \pm 24$	$172 \pm 33$		BaBar Preliminary (stat only)

# $c\bar{c}$ Meson ? Bizarre

If  $1^{--}$ , should be produced directly in  $e^+e^-$  collisions

$$R(\sqrt{s}) = \sigma(e^+e^- \rightarrow \text{hadrons}) / \sigma(e^+e^- \rightarrow \mu\mu)$$



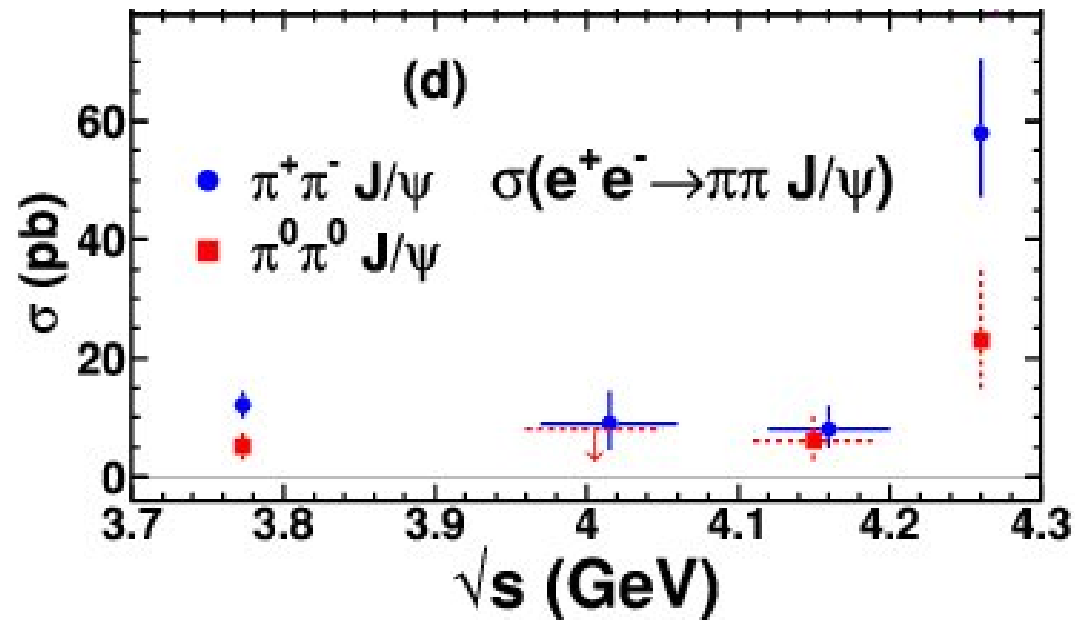
PDG 04

# Direct Production in $e^+e^-$ Collision

Scan by CLEOc



Phys.Rev.Lett.96 :162003,2006



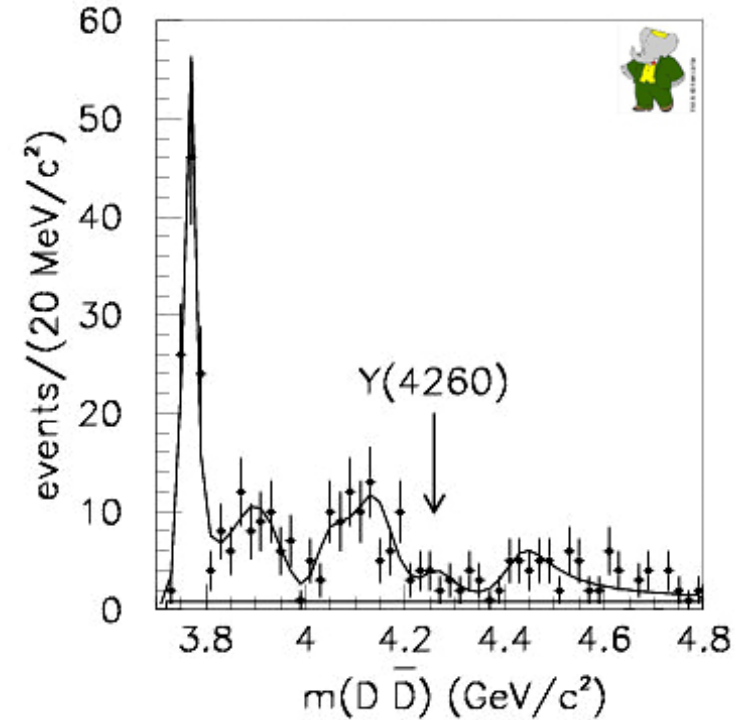
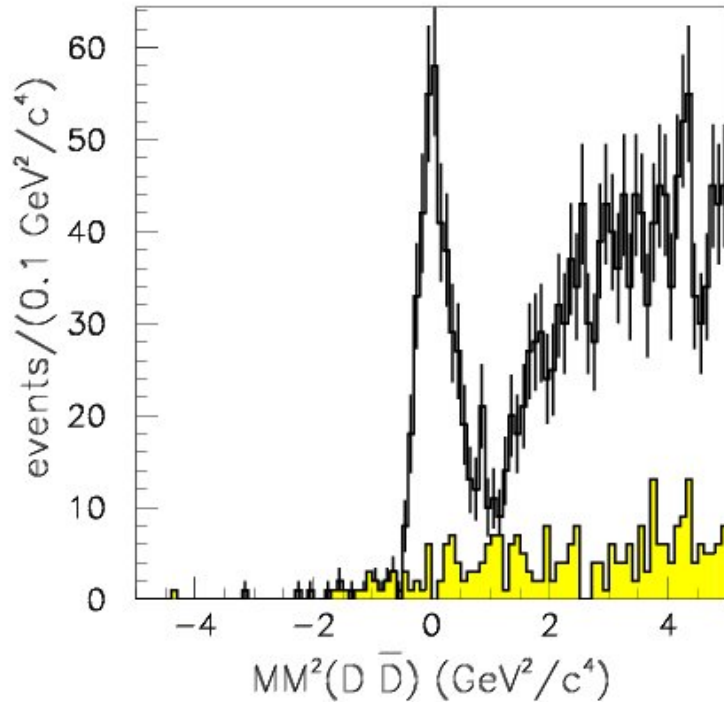
- $J/\psi \pi^+ \pi^- : 11\sigma$
- $J/\psi \pi^0 \pi^0 : 5.1\sigma$
- $\pi^0 \pi^0$  seen as expected for S-wave dipion with  $I \neq 1$
- $\pi^+ \pi^- / \pi^0 \pi^0 \approx 2$  confirms  $I = 0$

Kills  $\chi_{c1} \rho^0$  molecule model Liu et al., Phys.Rev.D72 :054023,2005

# Search for $Y(4260) \rightarrow D\bar{D}$ in ISR

$D^0$  and  $D^\pm$  reconstructed in a series of 2 – 4 body decays.

Detection of ISR  $\gamma$  not required



$$r = \frac{\mathcal{B}(Y(4260) \rightarrow D\bar{D})}{\mathcal{B}(Y(4260) \rightarrow J/\psi \pi^+ \pi^-)} < 7.6 \text{ at } 95\% \text{ C.L.}$$

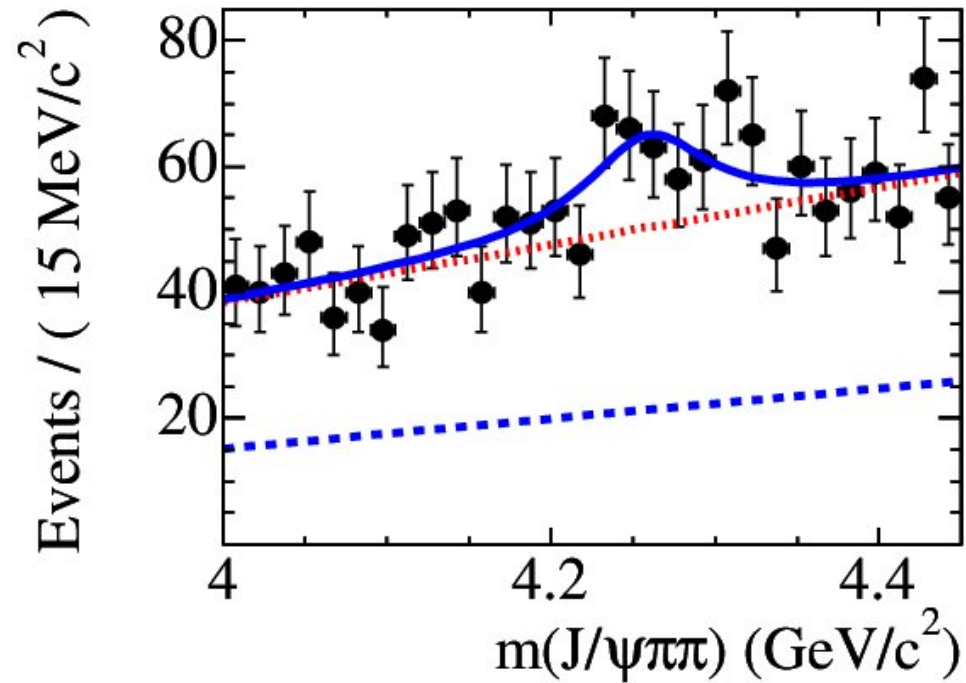
$$(r \approx 500 \text{ for } \psi(3770))$$



288.5  $\text{fb}^{-1}$

hep-ex/0607083 (ICHEP 06)

# Search $B \rightarrow Y K$ Decays



- $\mathcal{B}_Y = \mathcal{B}(B^- \rightarrow Y(4260)K^-, Y(4260) \rightarrow J/\psi \pi^+ \pi^-) = (2.0 \pm 0.7 \pm 0.2) \times 10^{-5}$ .  
 $< 2.9 \times 10^{-5}$  @ 95% C.L.
- Not conclusive ( $3.1\sigma$ )

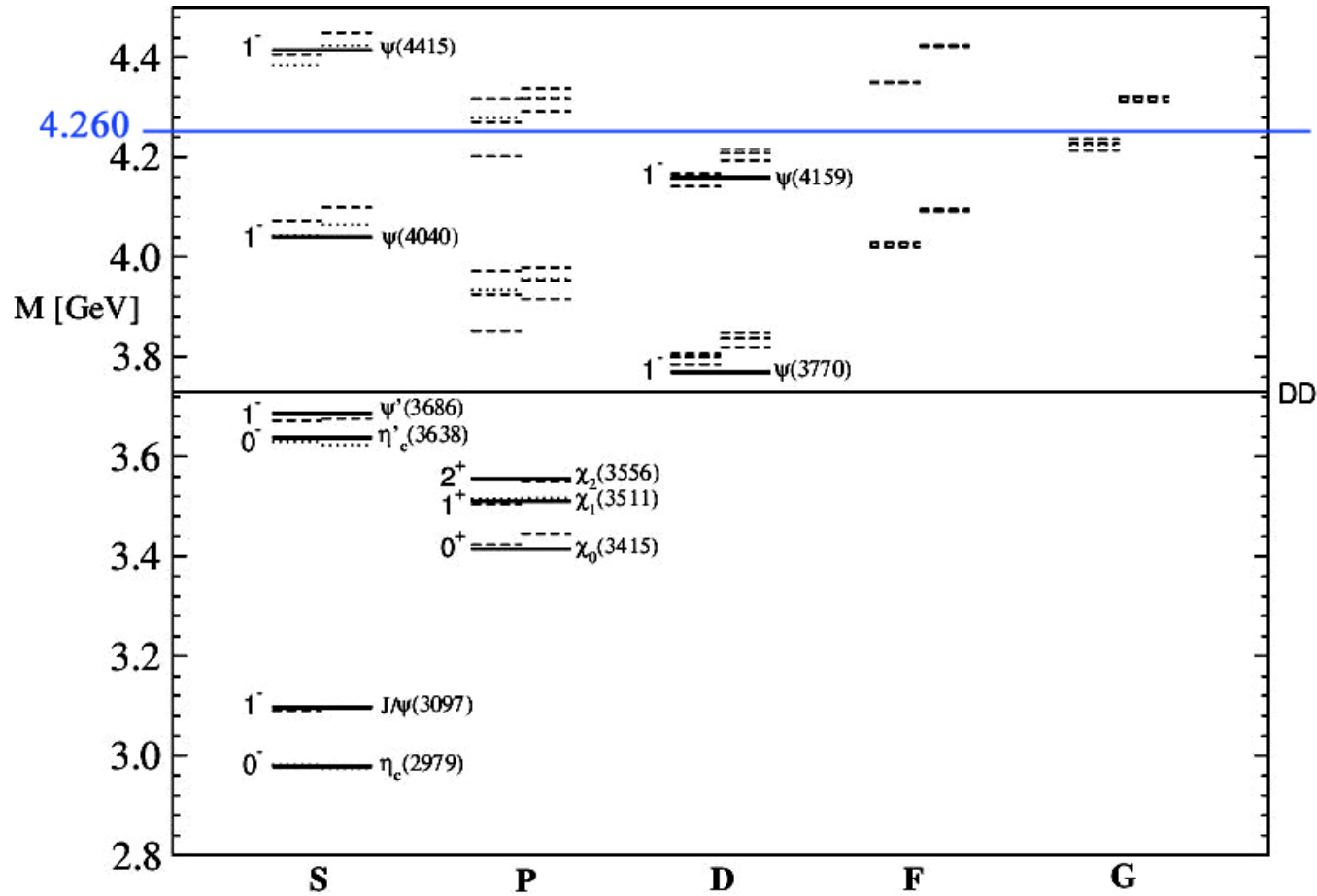


211 fb<sup>-1</sup>

Phys.Rev.D73 :011101,2006

# Not a Charmonium Meson

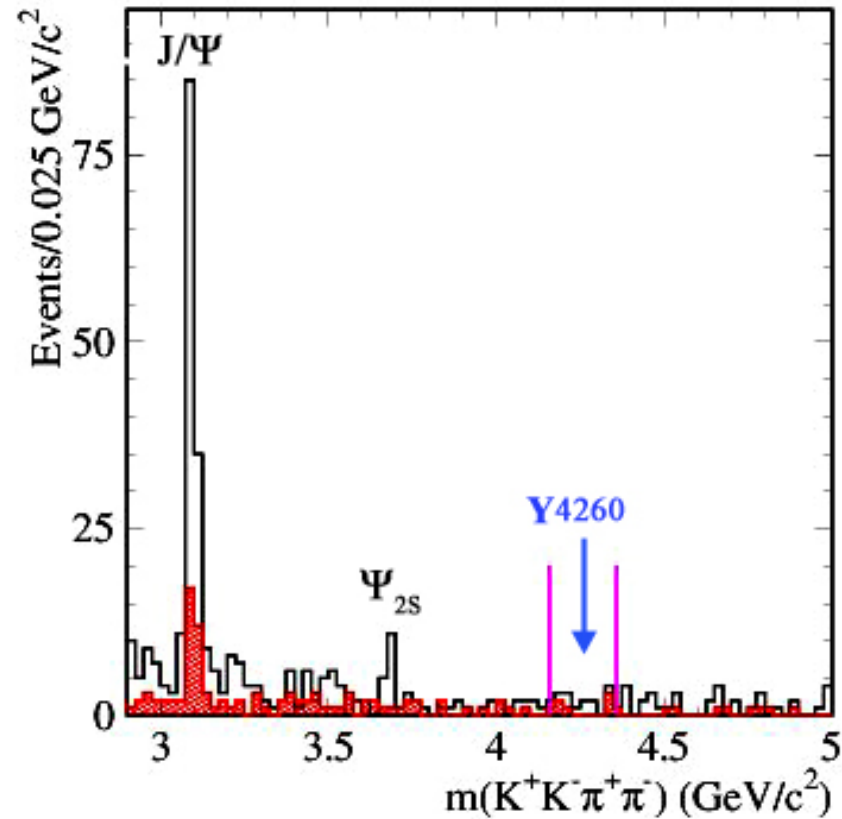
$1^{--}$  slots :  $S, D$



- T. Barnes, S. Godfrey and E. S. Swanson, Phys.Rev.D72 :054026,2005

# Glueball ?

If  $ggg$ , flavorblind decays (Zhu, Phys.Lett.B625 :212,2005)



No :  $\mathcal{B}_{Y \rightarrow \phi \pi^+ \pi^-} \cdot \Gamma_{ee}^Y < 0.4 \text{ eV}$  (90% C.L.)

Detection of ISR  $\gamma$  required



232 fb<sup>-1</sup>

Preliminary (Moriond 2006).

## Other Models

- TetraQuark?  $(cs)(\bar{c}\bar{s})$  predicts  $D_s^+ \bar{D}_s^- \gg D\bar{D}$

– searches of  $D_s^+ \bar{D}_s^-$ ,  $D\bar{D}^*$  in progress

L.Maiani et al. Phys.Rev.D72 :031502,2005

- An  $\omega\chi_{c1}$  Molecule?

–  $\Gamma(Y \rightarrow \chi_{c1}\pi^+\pi^-\pi^0) \approx \Gamma(Y \rightarrow J/\psi\pi^+\pi^-)$

–  $\Gamma(Y \rightarrow J/\psi\pi^+\pi^-\pi^0) \approx \Gamma(Y \rightarrow J/\psi\pi^+\pi^-)/2$

C.Z. Yuan, P. Wang, X.H. Mo, Phys.Lett.B634 :399-402,2006



# An Hybrid Meson ?

$c\bar{c}g$  bound states, searched for for ages ...

$J^{PC} = 1^{-+}$  is the lightest

TABLE I. Predicted  $1^{-+}$  hybrid masses.

State	mass (GeV)	Model	Ref.
$H_{u,d}$	1.3–1.8	Bag model	[19]
	1.8–2.0	Flux tube model	[11–14]
	2.1–2.5	QCD sum rules (most after 1984)	[26–28]
$H_c$	$\approx 3.9$	Adiabatic bag model	[20]
	4.2–4.5	Flux tube model	[12–14]
	4.1–5.3	QCD sum rules (most after 1984)	[26–28]
	4.19(3) $\pm$ syst.	HQLGT	[23]

- Hybrids favored 2-body decay to ( $P = +, P = -$ )  $D\bar{D}, D^*\bar{D}^*, D\bar{D}^*$  suppressed
- $Y$  Decays to  $\bar{D}D_1(2420)$  should dominate!!

Search for companions with other quantum numbers!

- T. Barnes, F. E. Close and E. S. Swanson, Phys.Rev.D52 :5242-5256,1995
- Kou, Pene, Phys.Lett.B631 :164-169,2005

$Y(4260)$  on the (quenched) Lattice QCD :  $1^{--}$  :  $m = 4.38 \pm 0.15 \text{ GeV}/c^2$  😊

Xiang-Qian Luo, Yan Liu, Phys.Rev.D74 :034502,2006

# *Spectroscopy : Charmonium / baryons)*

B factories are yielding many results besides CKM Physics.

Today : A sample only : Charmonium : A new revolution ?

- Charmonium meson slots filling up (many tests still to be made)
- X(3872) :  $1^{++}$  ! might be Tetraquark ; Molecule ? diquark-antidiquark ?
- Y(4260) :  $1^{--}$  ! Hybrid ?

Stay tuned :

- Data taking
- Extension to other final states

will continue for the next years : much more to come !