



Latest results on the XYZ states from Belle and BaBar



S.Uehara (KEK)

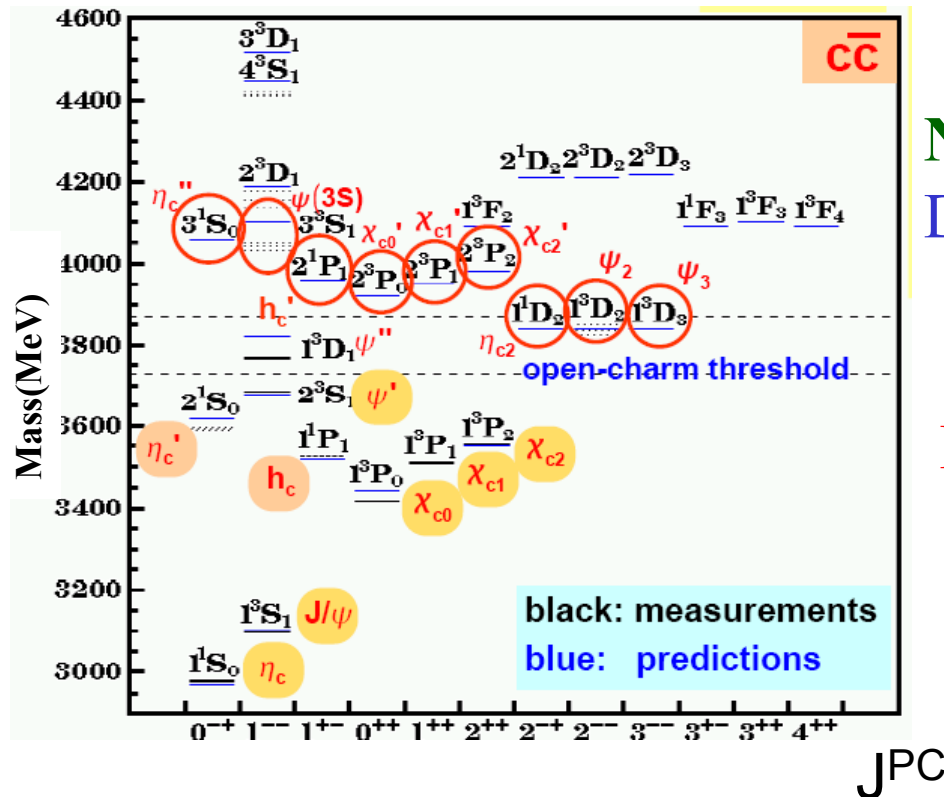


HADRON2009, Florida-S.U., Tallahassee, USA
Dec. 3, 2009



List of “XYZ”, Charmonium-like New particles

Sequences of ordinary charmonia



Ordinary-like charmonium

$\eta_c(2S)$ $Z(3930)=\chi_{c2}(2P)$

No clear charmonium assignment

Double charmonium production

$X(3940)$ $X(4160)$

Decays with ψ (or ψ')

$X(3872)$ $Y(4008)$

$Y(4260)$ $Y(4320)$

$Y(3940)$ $Y(4664)$

$Y(4140)$ and more ...?

Decays with ψ' (χ_{c1}) and Charged

$Z(4430)^+$ $Z_1(4058)^+$

$Z_2(4258)^+$

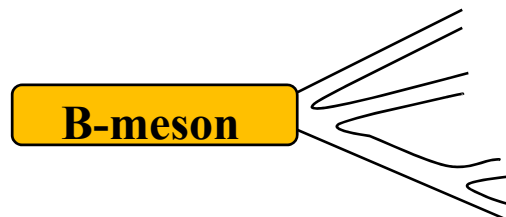
No correspondence or
Peculiar property

→ A candidate of Exotic states



XYZ production processes at B-factory Experiments

Hadronic decays of B meson

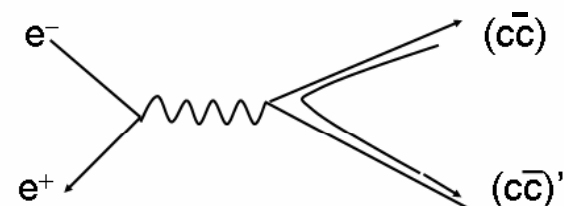
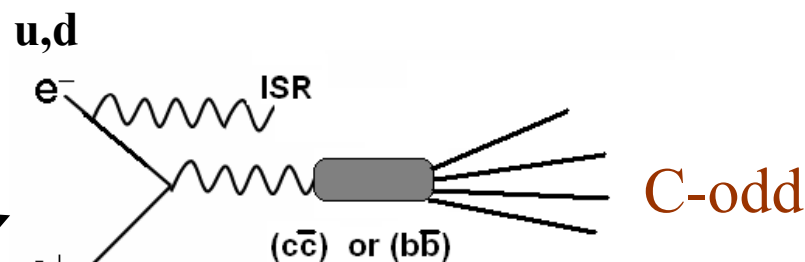


e^+e^- annihilation processes

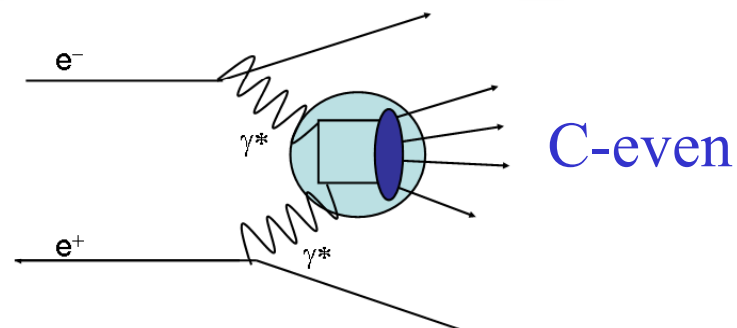
ISR processes

double charmonium production

$Y(nS)$ decays



Two-photon collisions

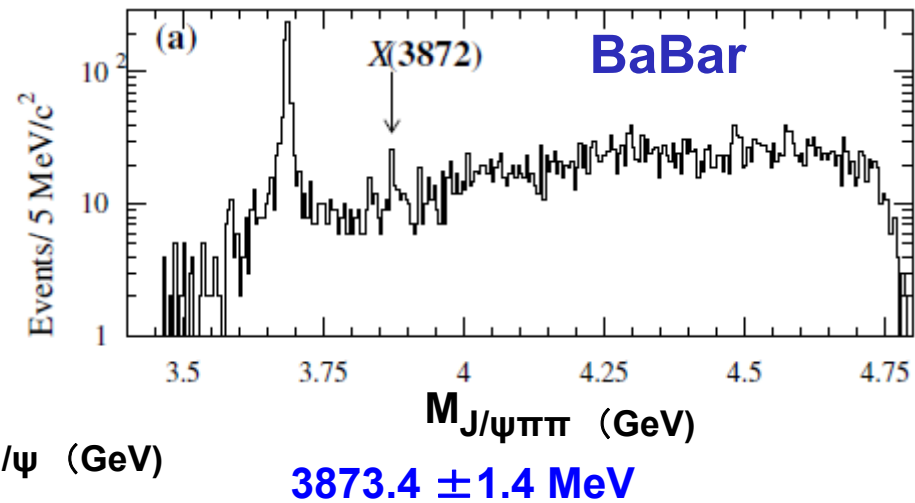
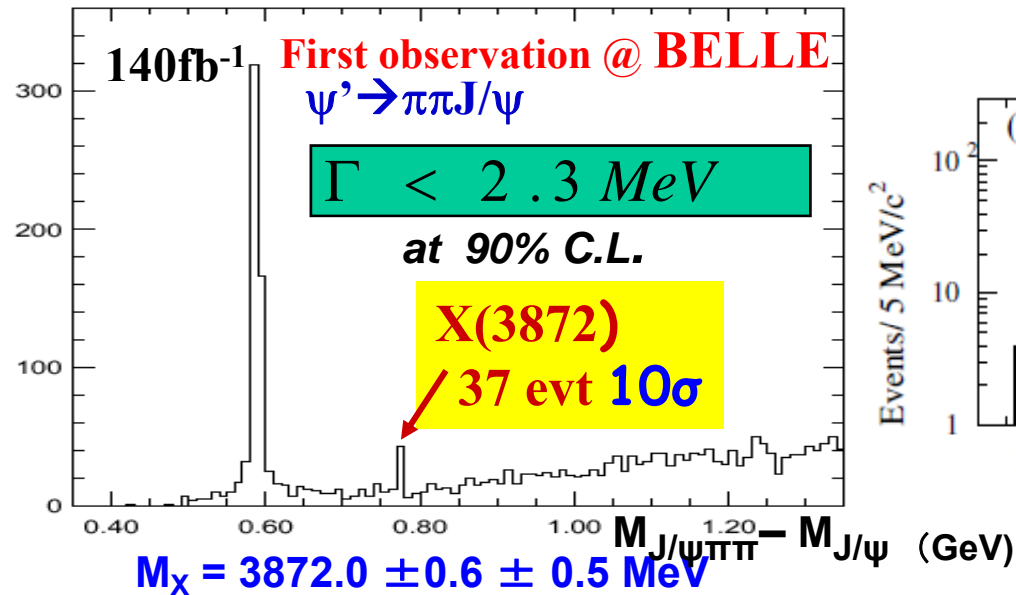


$X(3872)$

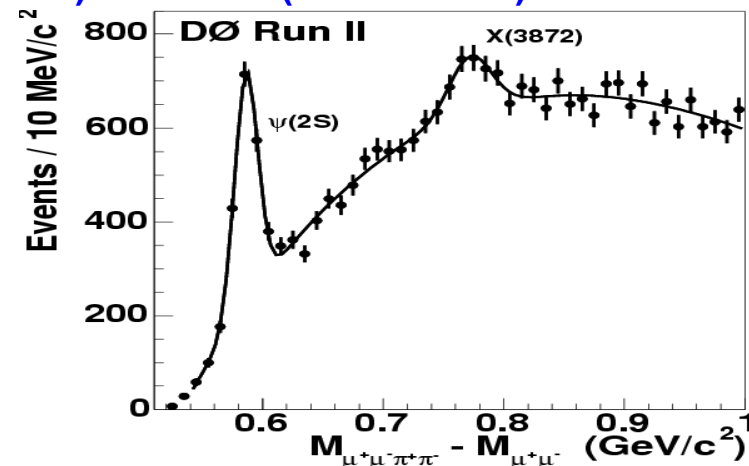
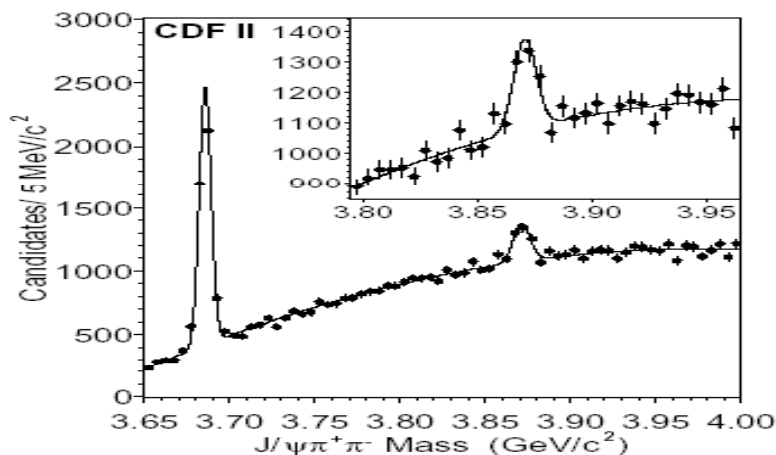


Discovery of X(3872) in 2003

Belle PRL 91, 262001 (2003)

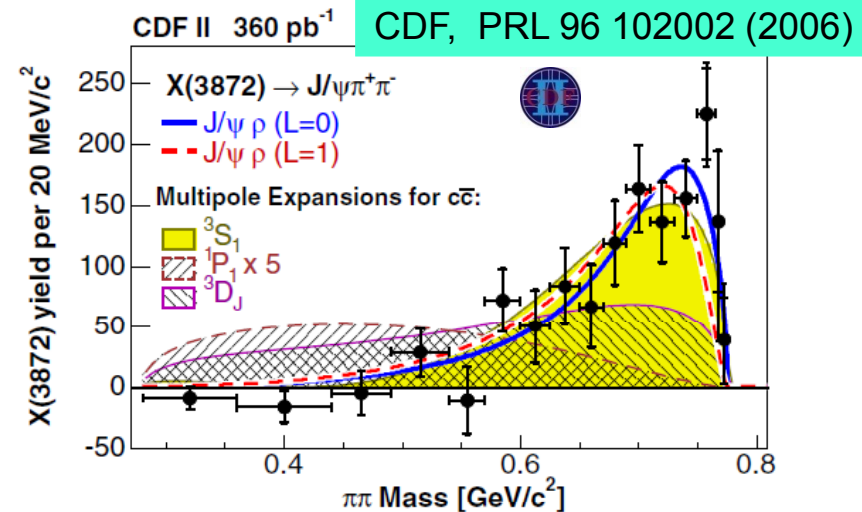
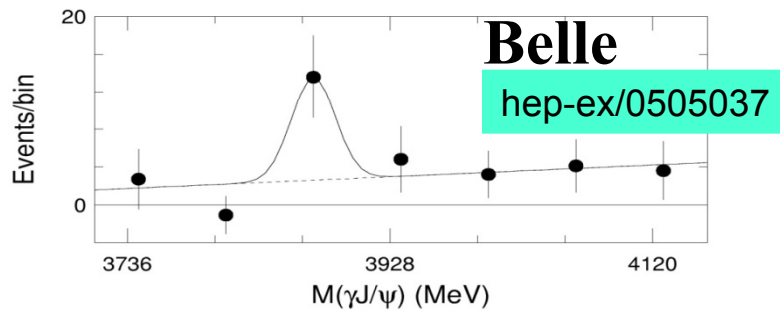


$$\text{Br}(B^- \rightarrow XK^-) \times \text{Br}(X \rightarrow J/\psi\pi\pi) = (1.3 \pm 0.3) \times 10^{-5} \quad (1.28 \pm 0.41) \times 10^{-5}$$

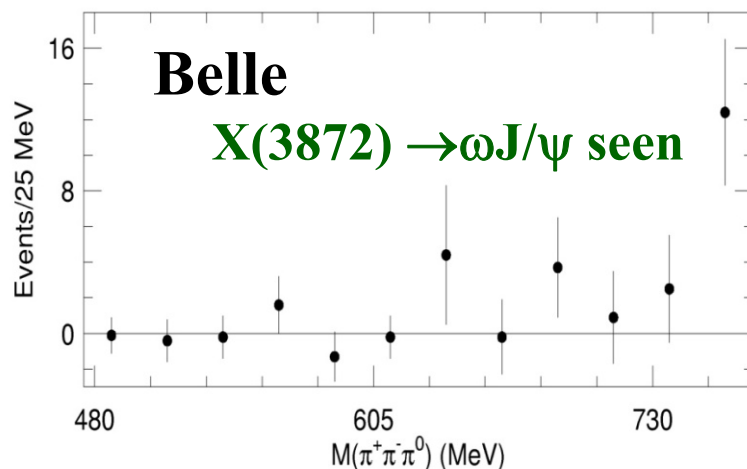


C=+ is established for X(3872)

X(3872) \rightarrow $\gamma J/\psi$ seen C-even
(in contrast to non-obs. of $\gamma\chi_c$)



$\Gamma(X \rightarrow \gamma J/\psi) / \Gamma(X \rightarrow \pi^+ \pi^- J/\psi) = 0.14 \pm 0.15$ A small radiative width –unlikely for χ'_c



Even parity is favored from the $\pi\pi$ invariant mass distribution (ρ -type $\pi\pi$)

Indication of isospin non-conservation

Angular analysis of $l^+ l^- \pi^+ \pi^-$

$J^P = 1^+$ is favored (Belle/ CDF)



X(3872) production modes

BF ratios and no-mass splitting

Doublet X?

Belle. Arxiv:0809.1224

$B^\pm \rightarrow X(3872)K^\pm$ and $B^0 \rightarrow X(3872)K_S^0$

605 fb⁻¹

BaBar, PRD 77,111101(R) (2008)

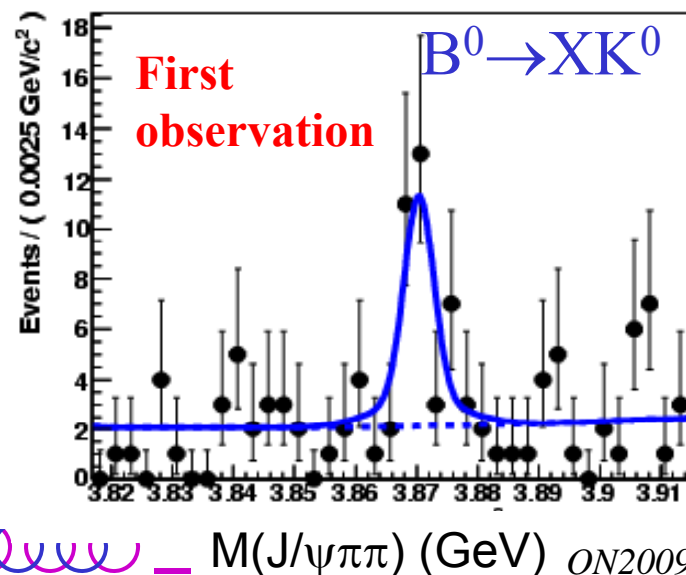
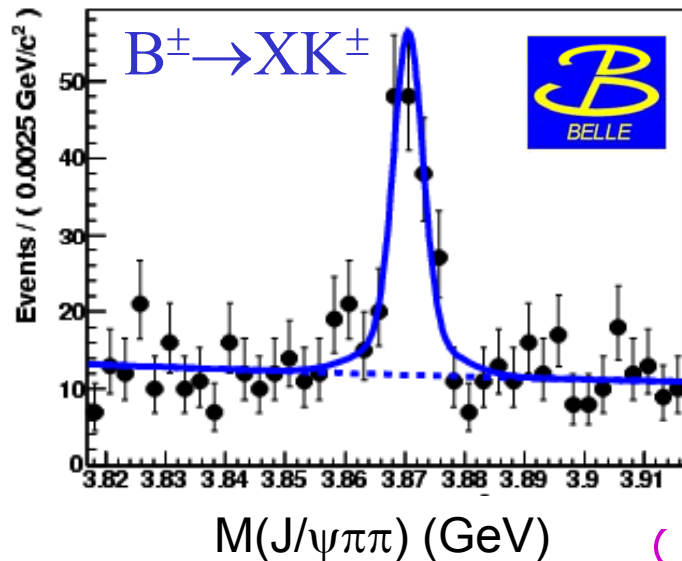
413 fb⁻¹

$$\begin{aligned} \text{BF}(B^0 \rightarrow XK^0) / \text{BF}(B^\pm \rightarrow XK^\pm) &= 0.41 \pm 0.24 \pm 0.05 \\ \delta M &= 2.7 \pm 1.6 \pm 0.4 \text{ MeV}/c^2 \end{aligned}$$

$$\begin{aligned} \text{BF}(B^0 \rightarrow XK^0) / \text{BF}(B^\pm \rightarrow XK^\pm) &= 0.82 \pm 0.22 \pm 0.05 \\ \delta M_x &= M(X \text{ from } B^\pm) - M(X \text{ from } B^0) \\ &= +0.18 \pm 0.89 \pm 0.26 \text{ MeV}/c^2 \end{aligned}$$

$$M_x = 3871.46 \pm 0.37 \pm 0.07 \text{ MeV}/c^2$$

$$M(D^0) + M(D^{*0}) = 3871.81 \pm 0.25 \text{ MeV}/c^2$$



CDF:
PRL 103,152001 (2009)

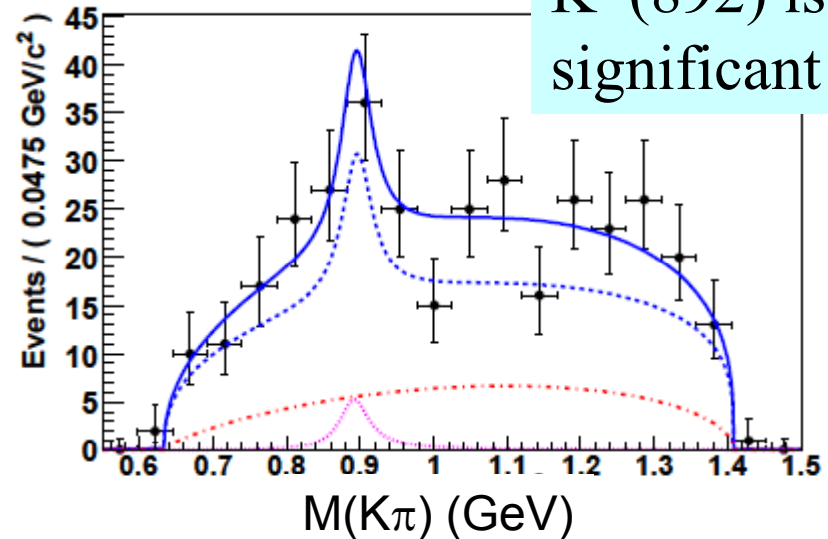
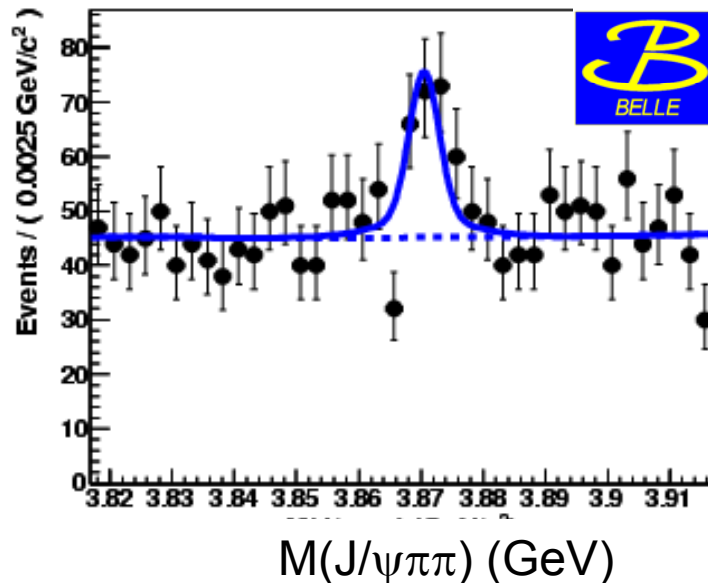
$$\begin{aligned} M_x &= 3871.61 \pm 0.16 \\ &\pm 0.19 \text{ MeV}/c^2 \end{aligned}$$

New production mode

Belle, Arxiv:0809.1224

$B^0 \rightarrow X(3872)(K^+\pi^-)_{\text{Non-Res}}$ observed

605 fb⁻¹



$$\text{BF}(B^0 \rightarrow X(K^+\pi^-)_{\text{NR}}) \text{BF}(X \rightarrow J/\psi \pi^+\pi^-) = (8.1 \pm 2.0^{+1.1}_{-1.4}) \times 10^{-6}$$

$$\text{BF}(B^0 \rightarrow X K^{*0}) \text{BF}(X \rightarrow J/\psi \pi^+\pi^-) < 3.4 \times 10^{-6} \text{ (90\% CL)}$$

K* is not significant, in contrast to B⁰→(J/ψ, ψ')K* decays etc.

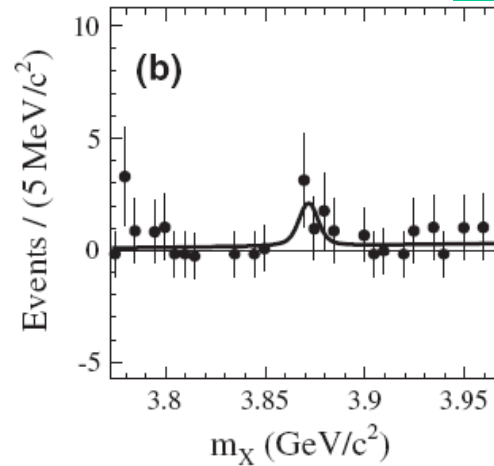
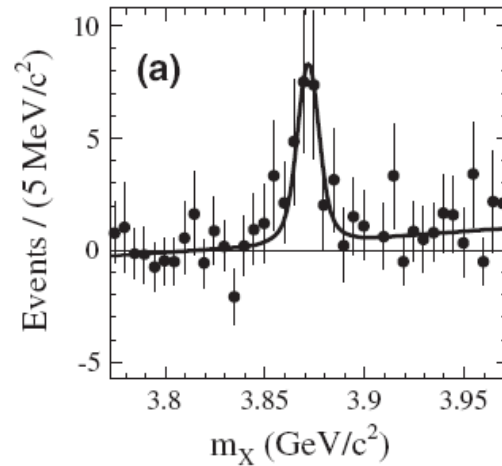


X(3872) decay modes: $\psi^{(\prime)}\gamma$

PRL 102, 132001 (2009)

$$B^\pm \rightarrow XK^\pm$$

$$X \rightarrow J/\psi \gamma$$



$$424 \text{ fb}^{-1}$$

$$B^0 \rightarrow XK_S^0$$

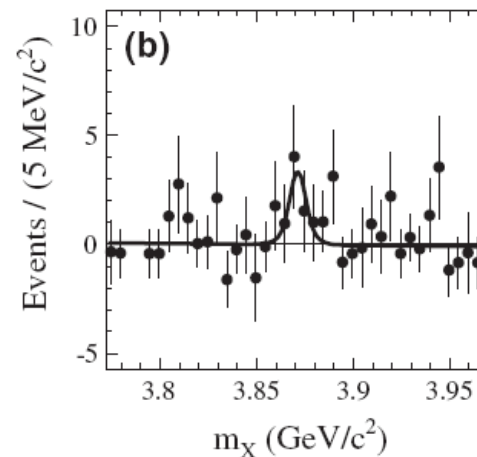
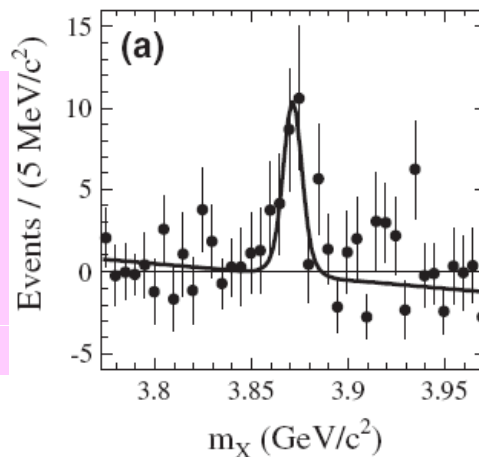
$$X \rightarrow J/\psi \gamma$$



$$B^\pm \rightarrow XK^\pm$$

$$X \rightarrow \psi(2S) \gamma$$

Evidence of
new decay mode



$$B^0 \rightarrow XK_S^0$$

$$X \rightarrow \psi(2S) \gamma$$

$$\mathcal{B}(B^\pm \rightarrow X(3872)K^\pm) \times \mathcal{B}(X(3872) \rightarrow \psi(2S)\gamma) = [9.5 \pm 2.7(\text{stat}) \pm 0.6(\text{syst})] \times 10^{-6}$$

$$\text{BF ratio, } \mathcal{B}(\psi(2S)\gamma)/\mathcal{B}(J/\psi\gamma) = 3.4 \pm 1.4$$

Inconsistent with a pure
 $D^0 \bar{D}^{*0}$ molecule state

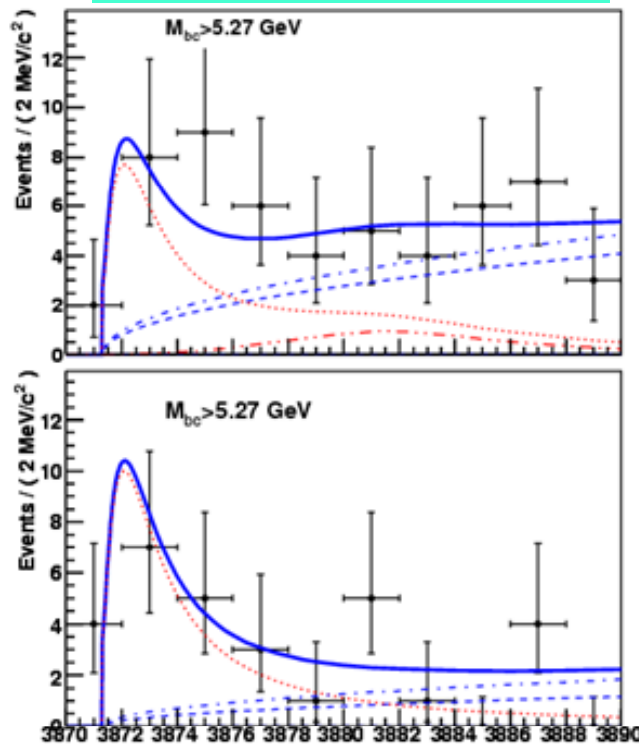


XYZ, HADRON_Z

$D^0 \bar{D}^{*0}$ mode

Use $D^{*0} \rightarrow D^0 \pi^0$ and $D\gamma$ assuming known BF ratio

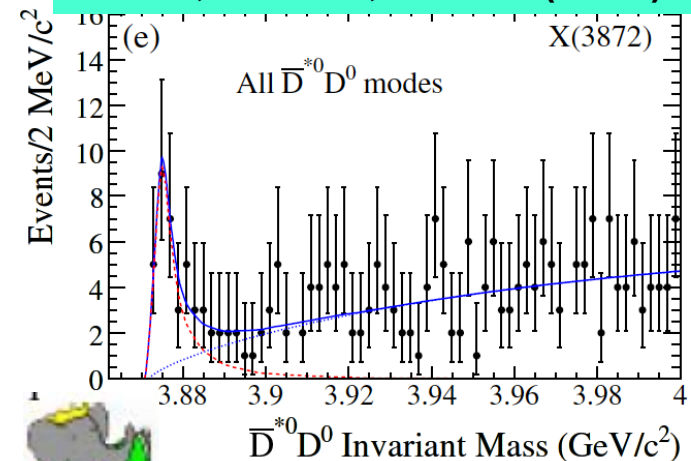
ArXiv: 0810.0358 (2008)



605 fb⁻¹



BaBar, PRD 77, 011102 (2008)



$3875.1^{+0.7}_{-0.5} \pm 0.5 \text{ MeV}$

$$M = (3872.6^{+0.5}_{-0.4} \pm 0.4) \text{ MeV}/c^2 \quad \Gamma(\text{BW}) = (3.9^{+2.5+0.8}_{-1.3-0.3}) \text{ MeV}/c^2$$

$$\text{BR}(B^0 \rightarrow XK) \times \text{BR}(X \rightarrow \bar{D}^{*0} D^0) = (0.73 \pm 0.17 \pm 0.08) \times 10^{-4}$$

No significant mass difference with the X in $J/\psi \pi^+ \pi^-$ mode

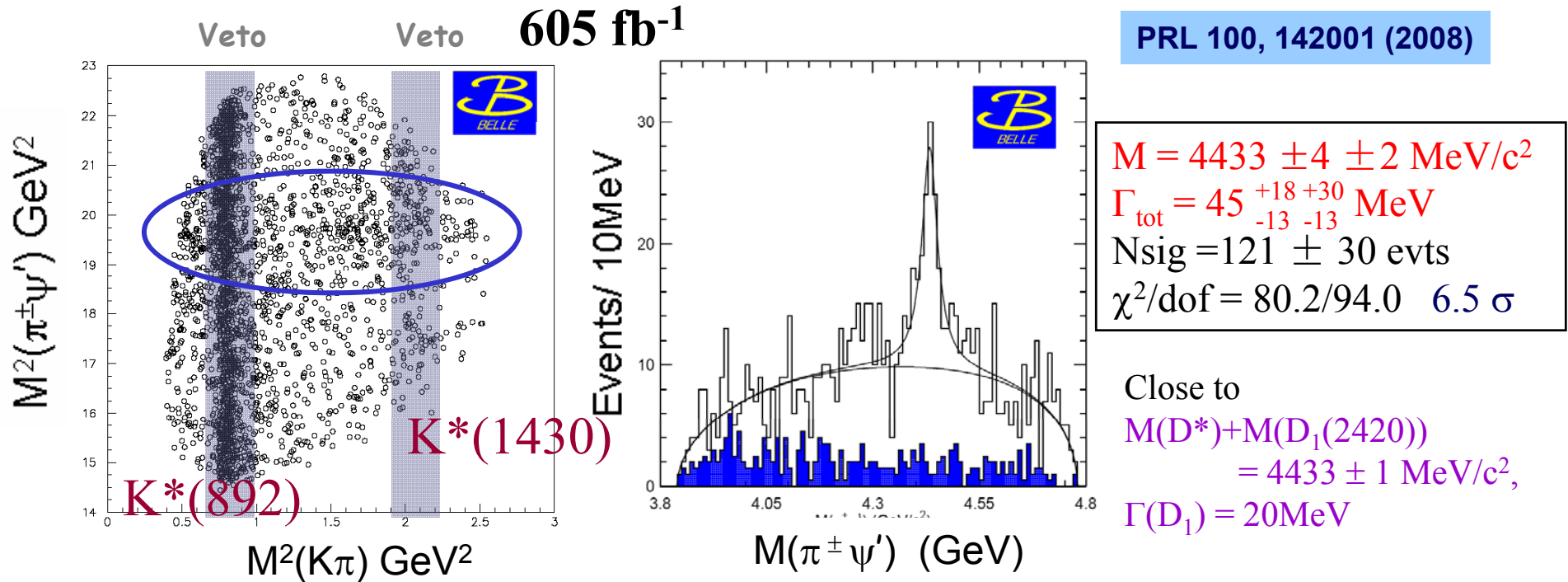


XYZ, HADRON2009, Nov.-Dec., 2009, S.Uehara

Z(4430)



$Z(4430)^+$: Charged charmonium-like state



$B \rightarrow \psi(2S)\pi^\pm K$ ($\psi' \equiv \psi(2S)$), $\psi' \rightarrow l^+l^-$, $J/\psi \pi^+\pi^-$
 B and K --- charged or neutral

$$BF(\bar{B}^0 \rightarrow Z^+ K) \times BF(Z^+ \rightarrow \psi(2S)\pi^+) = (4.1 \pm 1.0 \pm 1.4) \times 10^{-5}$$

Veto the $M(K\pi)$ regions of $K^*(892)$ and $K^*(1430)$

Enhancement at $M(\pi\psi') \sim 4.43 \text{ GeV}$

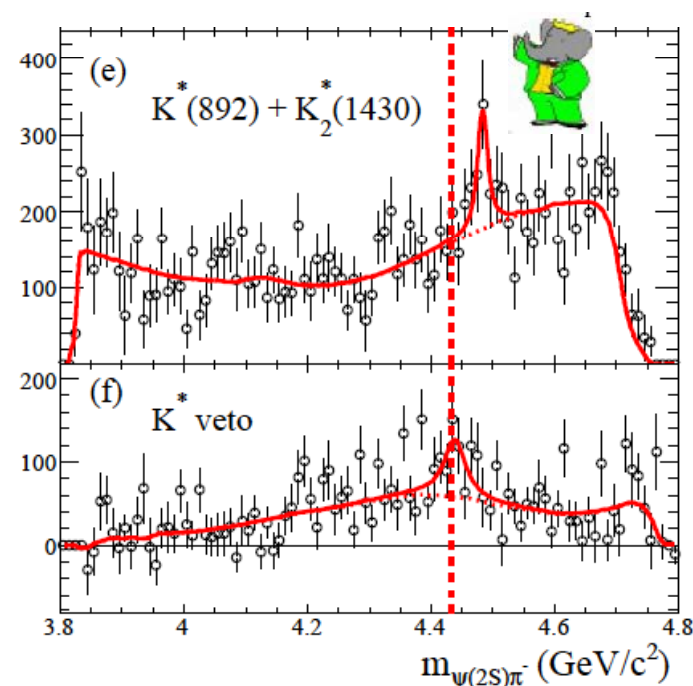
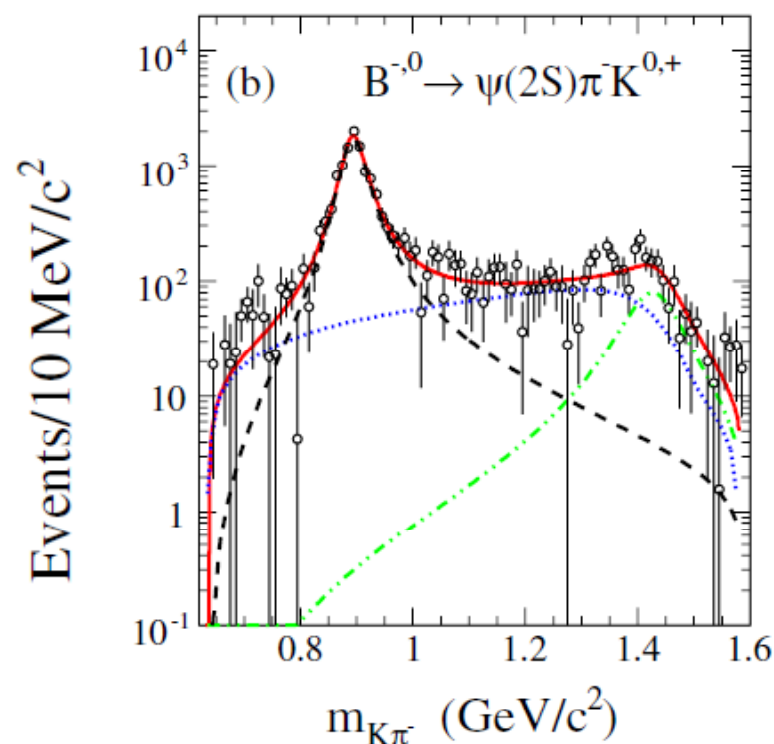
A “charged charmonium”!?
 composed by $[\bar{c}\bar{c}u\bar{d}]$
 Very serious tetraquark candidate



Search by BaBar using Dalitz analysis

Fits considering the distributions
of the K^* resonances in the Dalitz plane

BaBar, PRD 79, 112001 (2009)



BaBar's “possible signal”
in “Belle-like” analysis

--- $\sim 1.9\sigma$

$BF(\bar{B}^0 \rightarrow Z^+ K) \times BF(Z^+ \rightarrow \psi(2S)\pi^+) < 3.1 \times 10^{-5}$
(@95% CL)

No conclusive evidence for $Z(4430)^+$



Belle's Dalitz Analysis

Full Dalitz-plane analysis

K*s included in the analysis:

κ , $K^*(892)$, $K^*(1410)$, $K^*_0(1430)$,
 $K^*_2(1430)$, $K^*(1680)$

605 fb⁻¹

Belle, PRD 80,031104 (R)(2009)

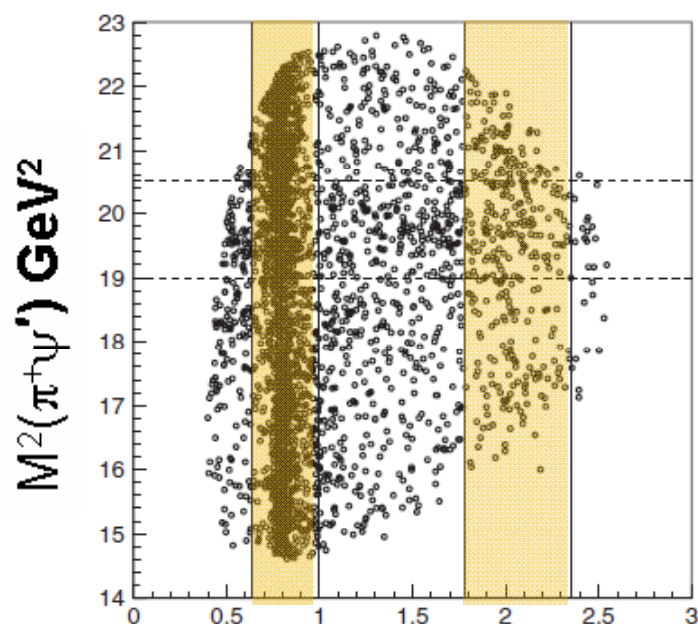
Belle confirms the original
 result of Z(4430) with 6.4 σ



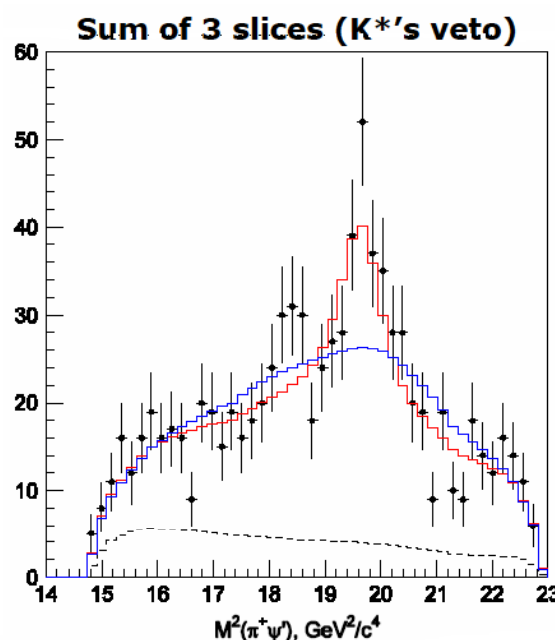
$$M = 4443^{+15+19}_{-12-13} \text{ MeV}/c^2$$

$$\Gamma = 107^{+86+74}_{-56} \text{ MeV}$$

The width gets larger than
 the original, although
 the uncertainty is large



$M^2(K\pi) \text{ GeV}^2$



Fit with Z

$$\text{BF}(\bar{B}^0 \rightarrow Z^+ K) \times \text{BF}(Z^+ \rightarrow \psi(2S)\pi^+) \\
= (3.2^{+1.8+5.3}_{-0.9-1.6}) \times 10^{-5}$$



X(3872) and Z(4430): So far known

	X(3872)	Z(4430) ⁺
Mass	~3872 MeV	~4430 MeV
Width	Narrow	Moderate
Charge	zero	+/- 1
Production	B decay (to XK) etc.	B decay (to ZK)
Decay at discovery	$J/\psi \pi^+ \pi^-$	$\psi' \pi^+$
C-parity	+	N/A (– for a neutral partner)
Spin-parity	probably 1+	unknown
Isospin	probably not-conserved	Non-zero
Mass close to	$m(D)+m(D^*)$	$m(D^*)+m(D_1)$

Neutral and Charged candidates of
 tetraquark or molecular states
 Found in two-body B decays associated by a kaon
 Decay to a lighter charmonium



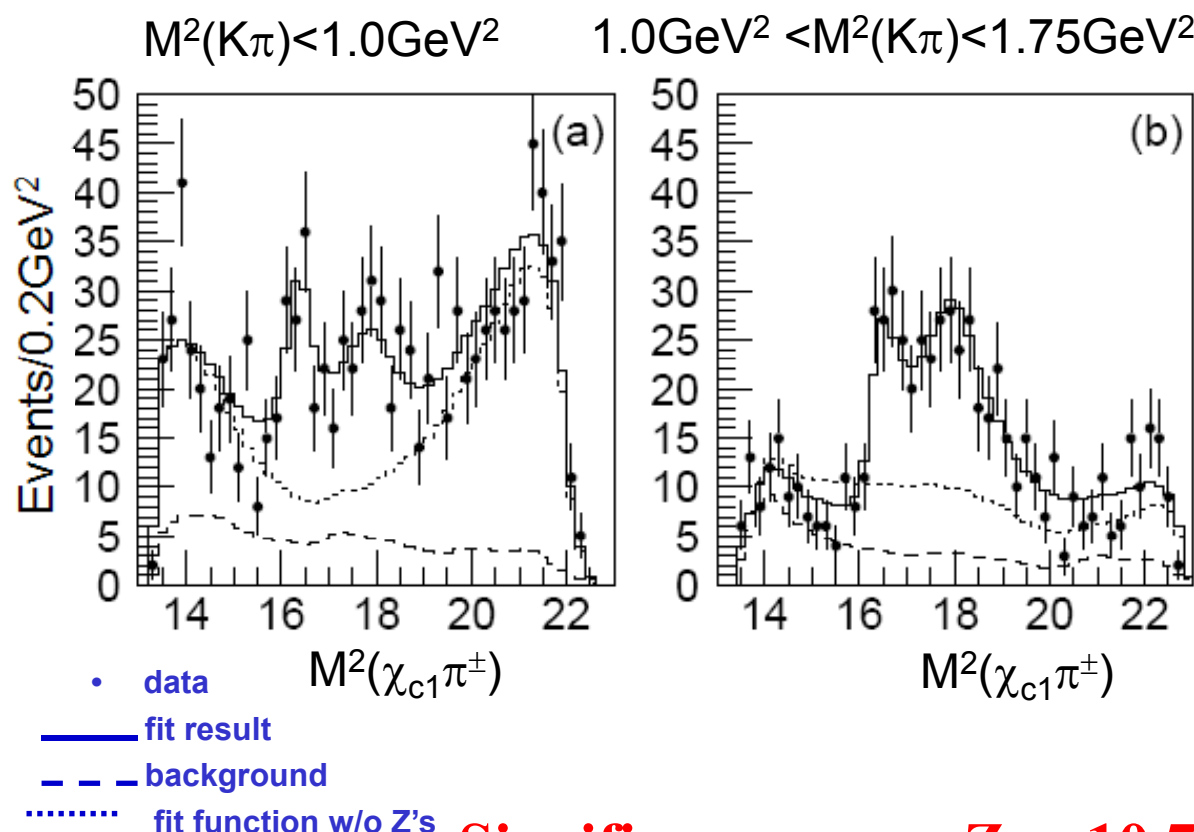
Additional two $\pi^+\chi_{c1}$ resonances (Z_1^+ & Z_2^+)

Belle, PRD 78, 072004 (2008)

Fit model: all known K^* resonances + two ($\chi_{c1}\pi$) resonances



605 fb⁻¹



$$\begin{aligned}
 M_1 &= (4051 \pm 14^{+20}_{-41}) \text{ MeV}/c^2, \\
 \Gamma_1 &= (82^{+21+47}_{-17-22}) \text{ MeV}, \\
 M_2 &= (4248^{+44+180}_{-29-35}) \text{ MeV}/c^2, \\
 \Gamma_2 &= (177^{+54+316}_{-39-61}) \text{ MeV},
 \end{aligned}$$

$$\begin{aligned}
 \text{BF}(B^0 \rightarrow ZK^-) \text{BF}(Z \rightarrow \pi^+ \chi_{c1}): \\
 \text{BFBF}(Z_1) &= (3.1^{+1.5+3.7}_{-0.9-0.17}) \times 10^{-5} \\
 \text{BFBF}(Z_2) &= (4.0^{+2.3+19.7}_{-0.9-0.5}) \times 10^{-5}
 \end{aligned}$$

Significances: one Z – 10.7 σ

two Z's over one -- 5.7 σ



X(3940)

Y(3940)

Z(3930)



The X,Y,Z near 3940 MeV

not seen in $\omega J/\psi$

X(3940)

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

probably
different

not seen in DD^*

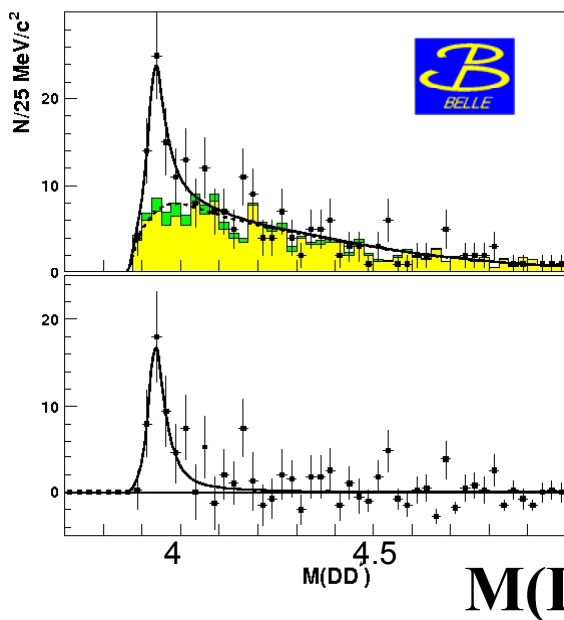
Y(3940)

$B \rightarrow K \omega J/\psi$

Probably the χ_{c2}'

Z(3930)

$\gamma\gamma \rightarrow D\bar{D}$

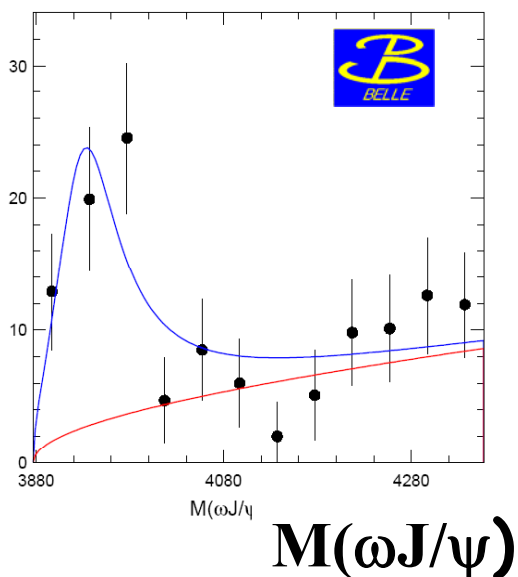


$$M = 3942^{+7}_{-6} \pm 6 \text{ MeV}$$

$$\Gamma_{\text{tot}} = 37^{+26}_{-15} \pm 12 \text{ MeV}$$

$$N_{\text{sig}} = 52^{+24}_{-16} \pm 11 \text{ evts}$$

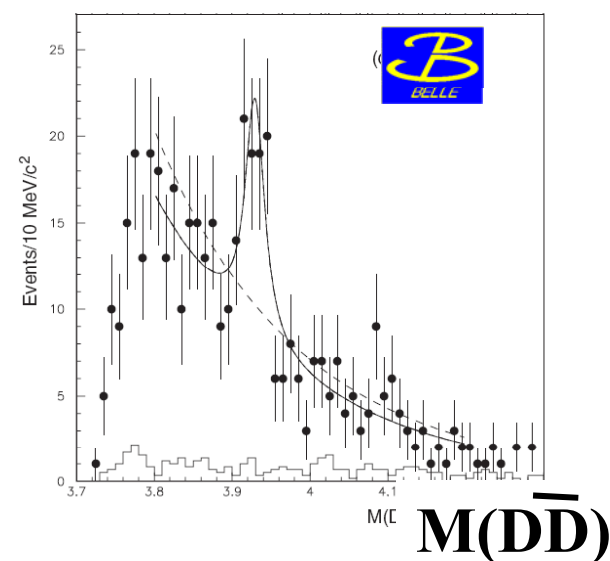
PRL 100, 202001 (2008)



$$M \approx 3940 \pm 11 \text{ MeV}$$

$$\Gamma \approx 92 \pm 24 \text{ MeV}$$

PRL 94, 182002 (2005)



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

$$\Gamma_{\text{tot}} = 29 \pm 10 \pm 2 \text{ MeV}$$

$$N_{\text{sig}} = 64 \pm 18 \text{ evts}$$

PRL 96, 082003 (2006)



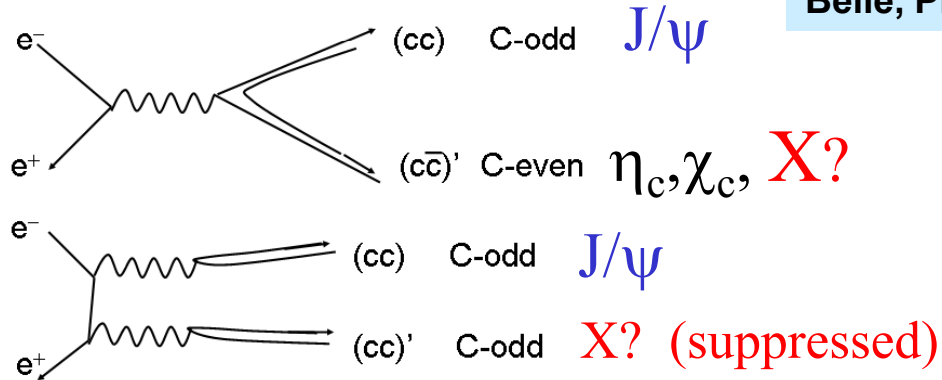
XYZ, HADRON2009, Nov.-Dec., 2009, S. Uehara

X(3940) in Double charmonium production

Tagging a J/ψ at one side

First Analysis: Belle PRD 70, 071102 (2004)

Belle, PRL 98, 082001 (2007)



Recoil masses

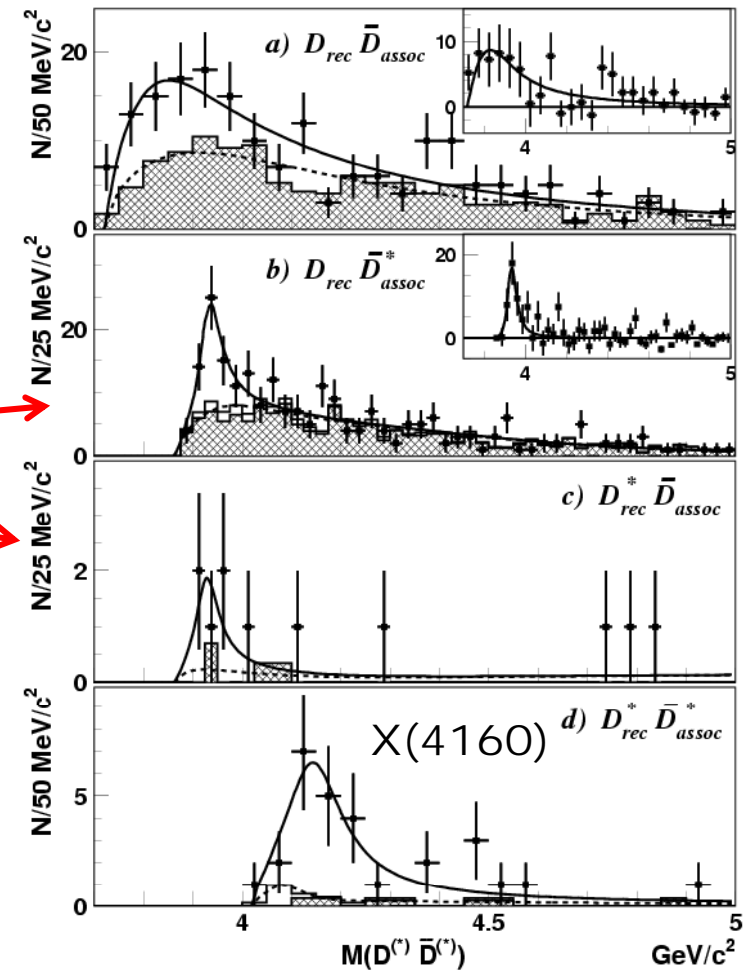
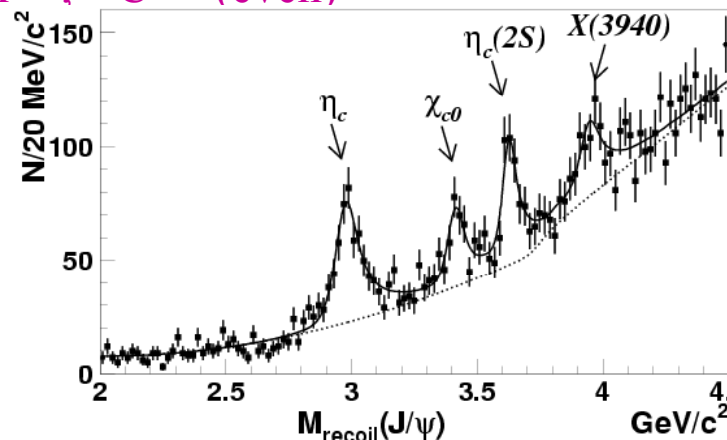
X(3940)

Others are...

$J=0, P=+ \text{ or } -, C=+ \text{ (even)}$

Here is

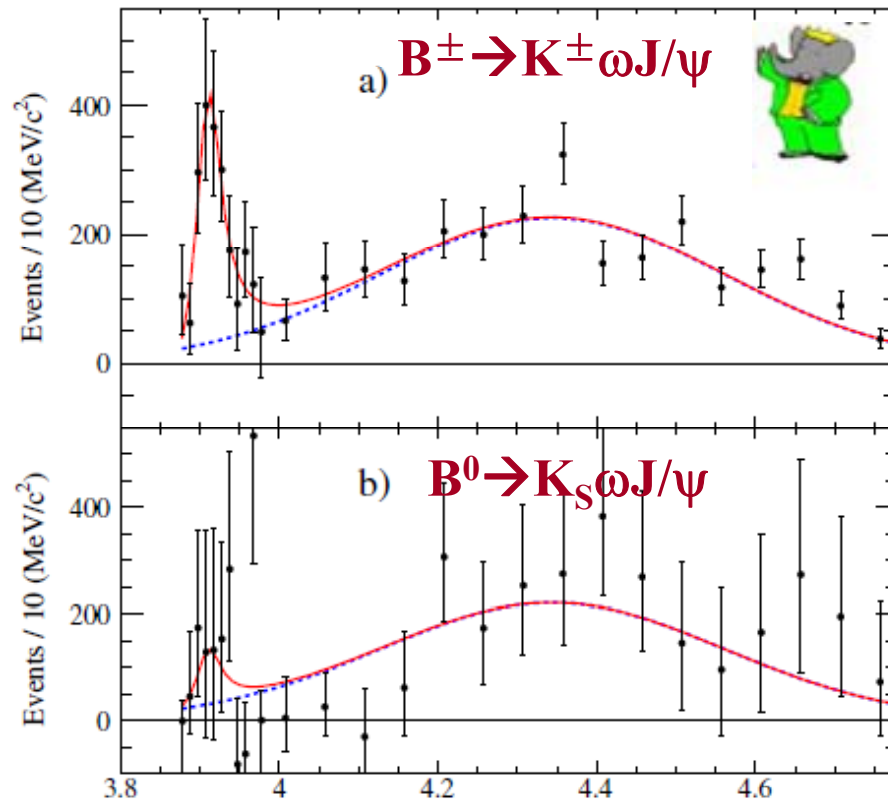
$X(3940) \rightarrow D\bar{D}^*$



XYZ, HADRON2009, Nov.-Dec., 2009, S. Uehara

Y(3940) → $\omega J/\psi$ confirmed

BaBar, PRL 101, 082001 (2008)



	Mass (MeV)	Γ (MeV)
Belle 253 fb ⁻¹	$3943 \pm 11(stat) \pm 13(syst)$	$87 \pm 22(stat) \pm 26(syst)$
BaBar 350 fb ⁻¹	$3914^{+3.8}_{-3.4} \pm 2.0$	$34^{+12}_{-8} \pm 5$

Comparison:
Some discrepancy in M & Γ ;
General features agree

$M(\omega J/\psi)$ (GeV/c²)

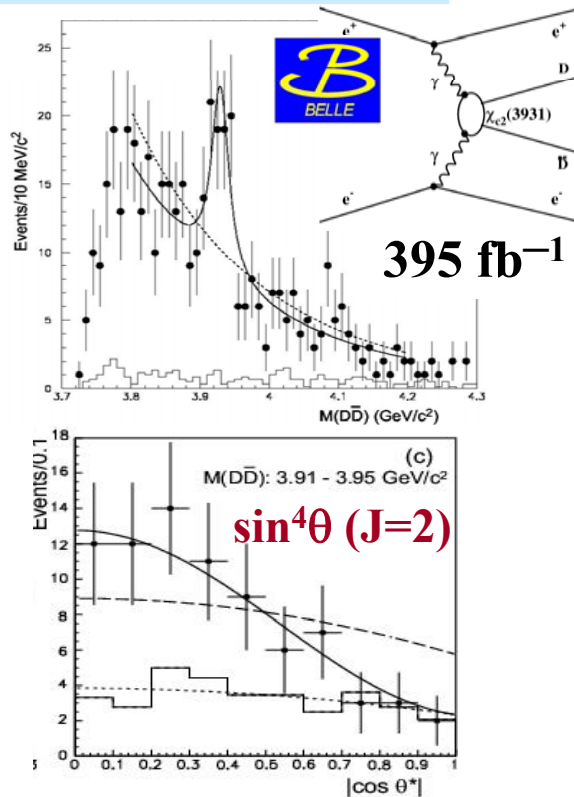


Looking BF ratios ($\rightarrow \omega J/\psi$) / ($\rightarrow D\bar{D}^*$)
Different particle from X(3940)

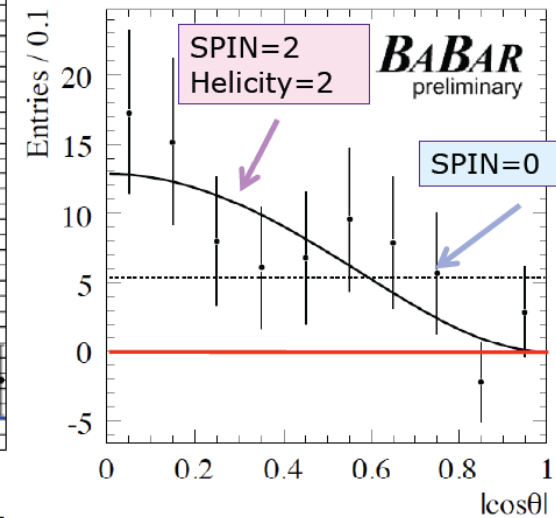
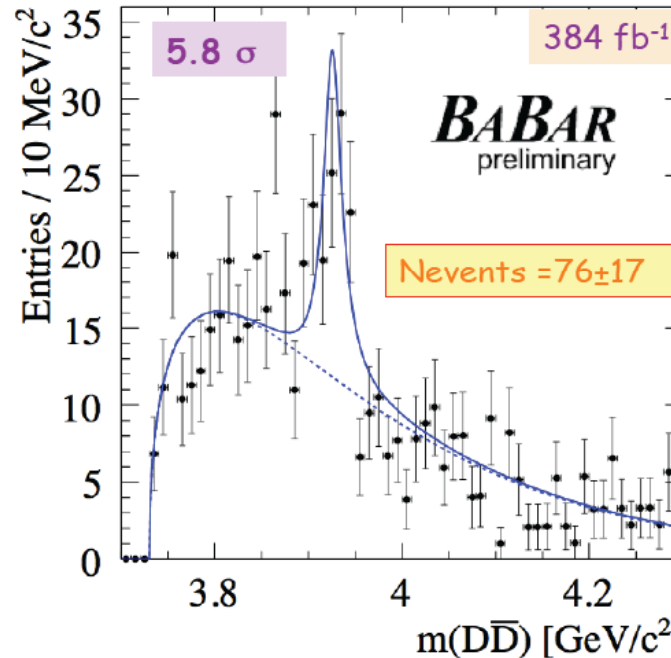


$\gamma\gamma \rightarrow Z(3930) \rightarrow D\bar{D}$

Belle PRL 96, 082003 (2006)



BaBar, V. Santoro, Parallel Session 3B, **This Conf.**



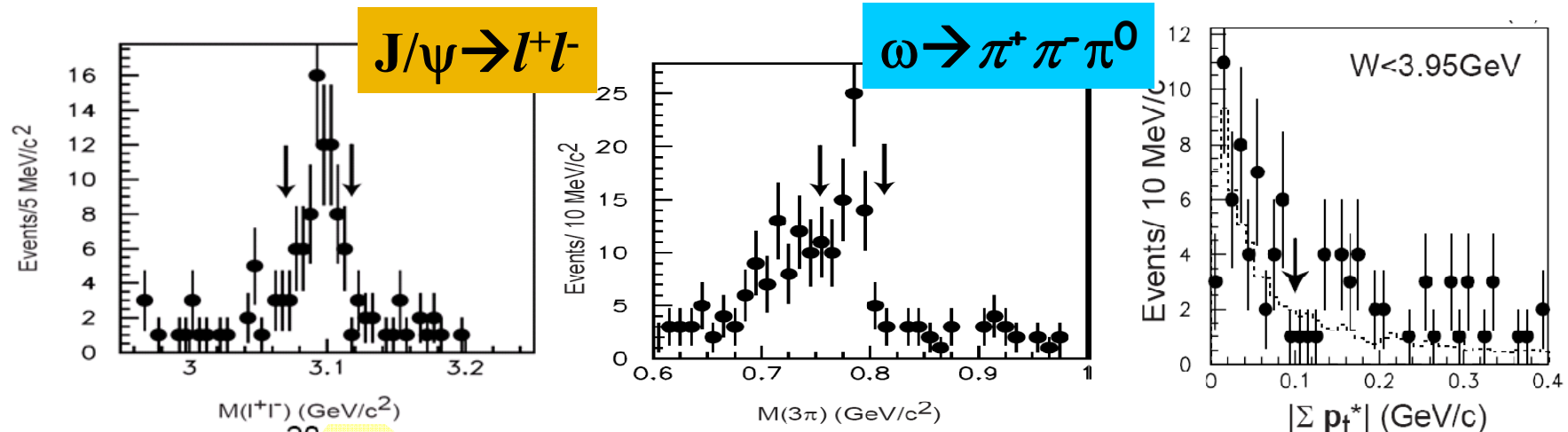
$m(3930) = 3926.7 \pm 2.7 \pm 1.1 \text{ MeV}/c^2$
 $\Gamma(3930) = 21.3 \pm 6.8 \pm 3.6 \text{ MeV}$
 $\Gamma_{\gamma\gamma} \cdot \text{BF}(Z(3930) \rightarrow D\bar{D}) = 0.241 \pm 0.054 \pm 0.043 \text{ keV}$

$m(3930) = 3929 \pm 5 \pm 2 \text{ MeV}/c^2$
 $\Gamma(3930) = 29 \pm 10 \pm 2 \text{ MeV}$
 $\Gamma_{\gamma\gamma} \cdot \text{BF}(Z(3930) \rightarrow D\bar{D}) = 0.18 \pm 0.05 \pm 0.03 \text{ keV}$

Belle and Babar results are consistent
Matches well χ_{c2} ' expectations

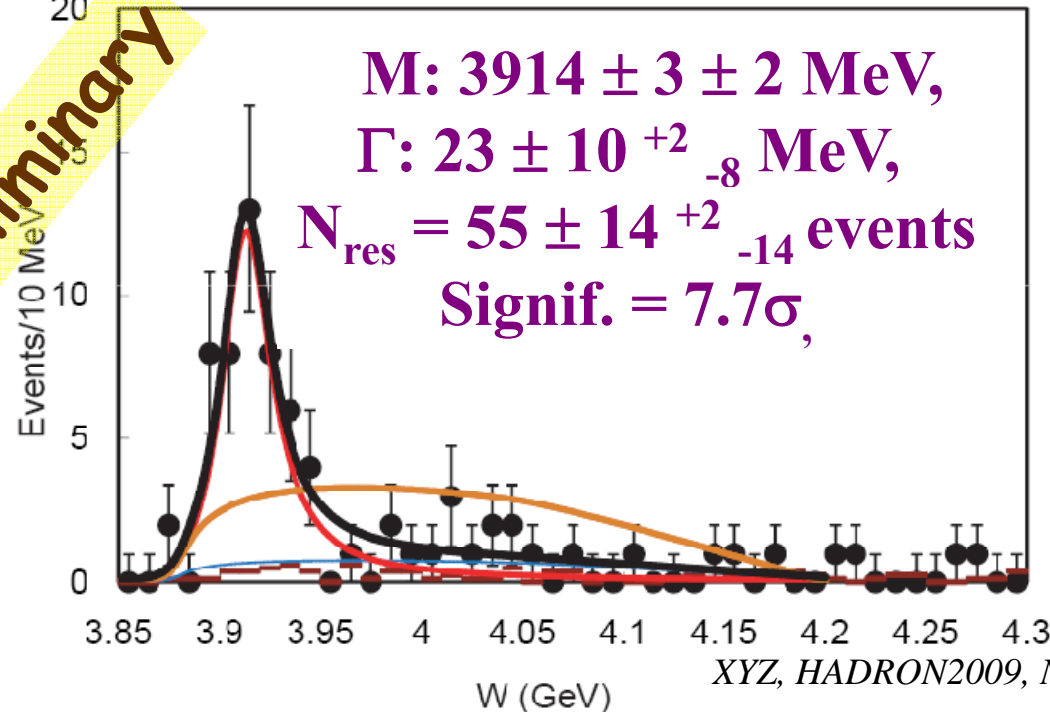


New peak in $\gamma\gamma \rightarrow \omega J/\psi$ from Belle



694 fb⁻¹

preliminary



Two-photon
production of
 $Y(3940)$?

or New decay
mode of $Z(3930)$?

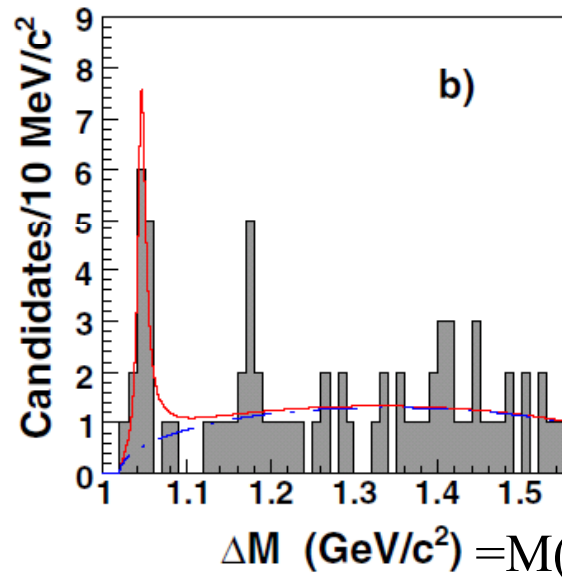
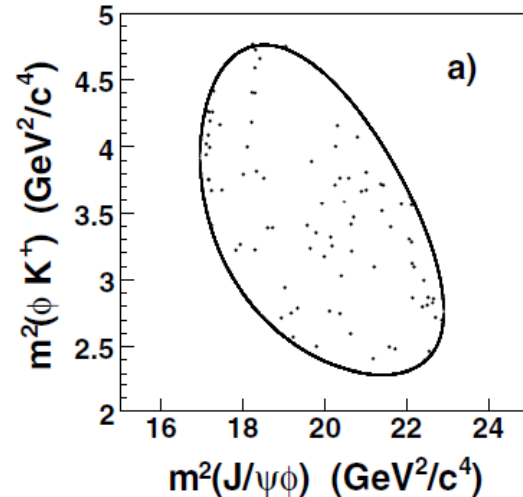
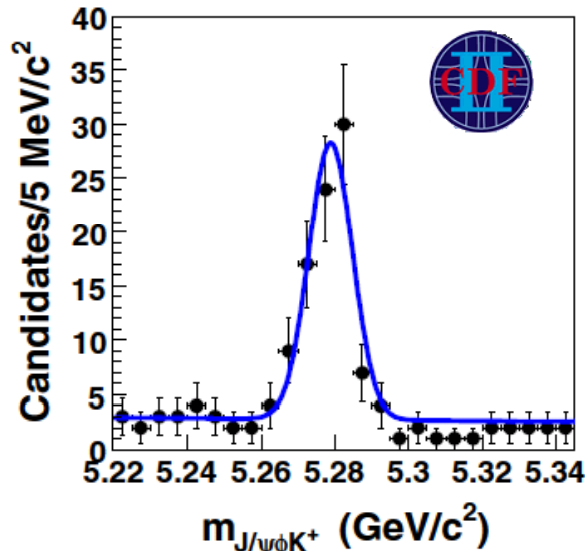
Y(4140)



Y(4140) → J/ψ φ

CDF, PRL 102, 242002 (2009)

CDF observed new charmonium-like particle



$B^+ \rightarrow J/\psi \phi K^+$
 14 ± 5 events (3.8σ)
 from 2.7 fb^{-1}

$$M = 4143.0 \pm 2.9 \pm 1.2 \text{ MeV}/c^2$$

$$\Gamma = 11.7^{+8.3}_{-5.0} \pm 3.7 \text{ MeV}$$

$Ds^* \bar{D}s^*$ molecule or tetraquark ?



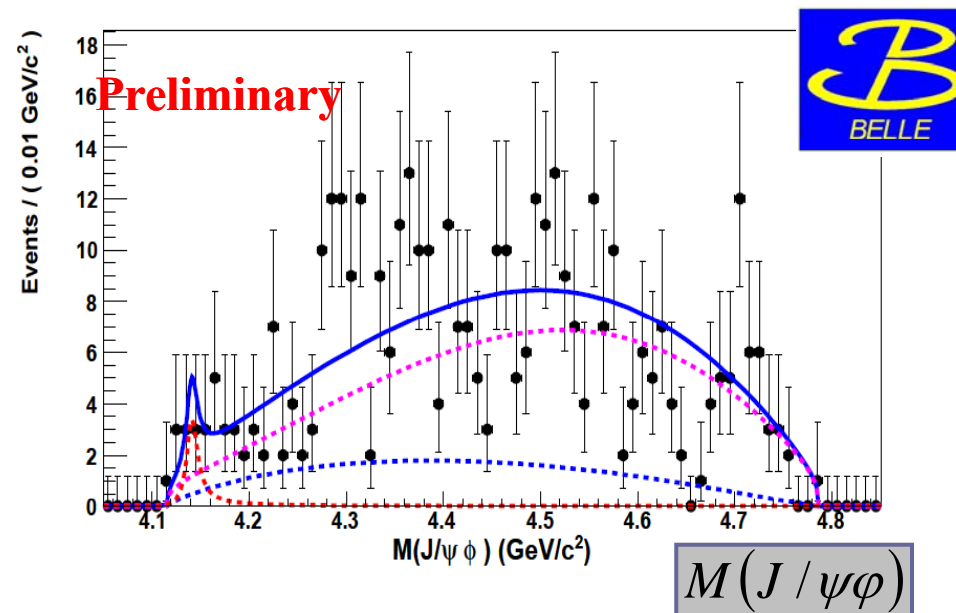
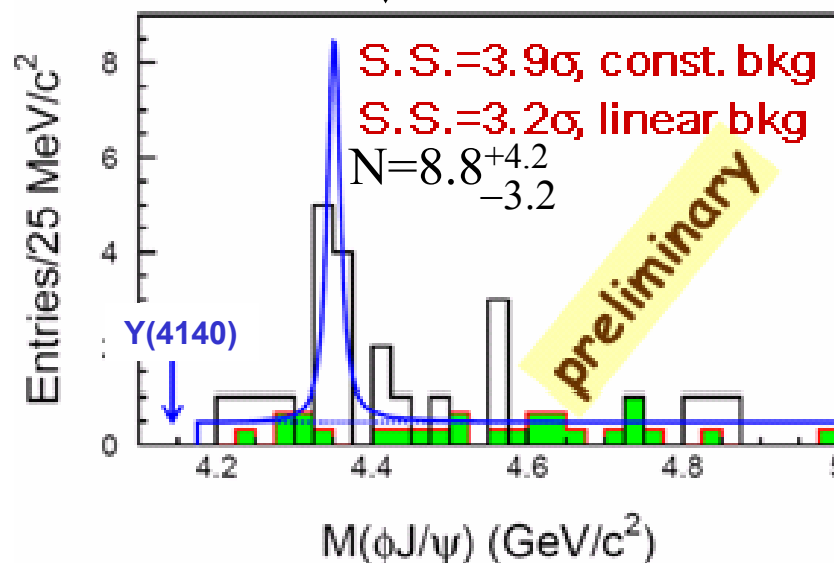
XYZ, HADRON2009, Nov.-Dec., 2009, S. Uehara

Searches at Belle

$$B^+ \rightarrow J/\psi \phi K^+ \longrightarrow$$

$$BF(B \rightarrow YK)BF(Y \rightarrow J/\psi \phi) < 6 \times 10^{-6} (@90\%CL)$$

$$\gamma\gamma \rightarrow J/\psi \phi \downarrow$$



Belle: Y(4140) not seen in B decays
or in two-photon

Instead, a new peak is seen
at around 4.35 GeV in $\gamma\gamma \rightarrow J/\psi \phi$

$$M = 4350.6^{+4.6}_{-5.1} \pm 0.7 \text{ MeV/c}^2$$

$$\Gamma = 13.3^{+17.9}_{-9.1} \pm 4.1 \text{ MeV}$$

Y(4260)

Y(4320)

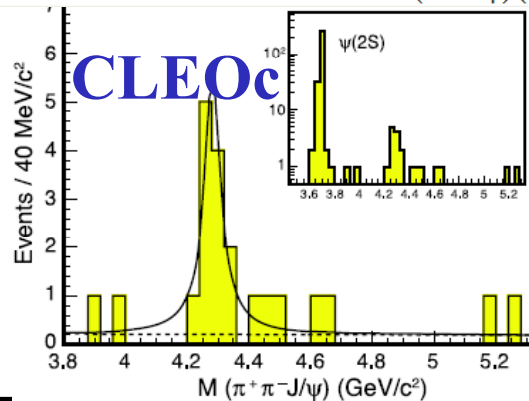
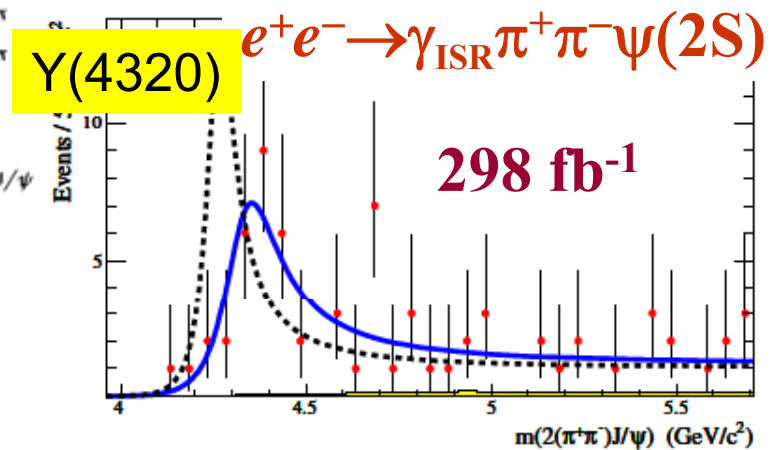
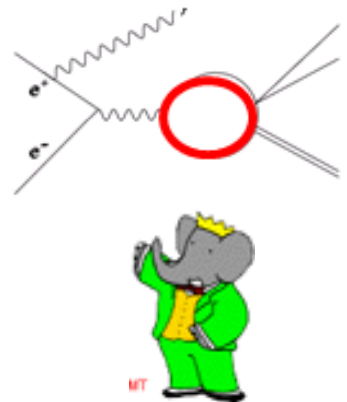
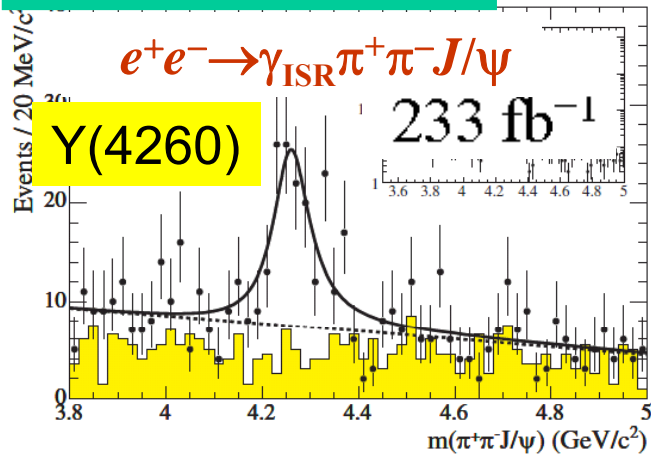
.....



$e^+e^- \rightarrow \gamma_{\text{ISR}} Y(4260)/Y(4320)$

BaBar, PRL95, 142001, (2005)

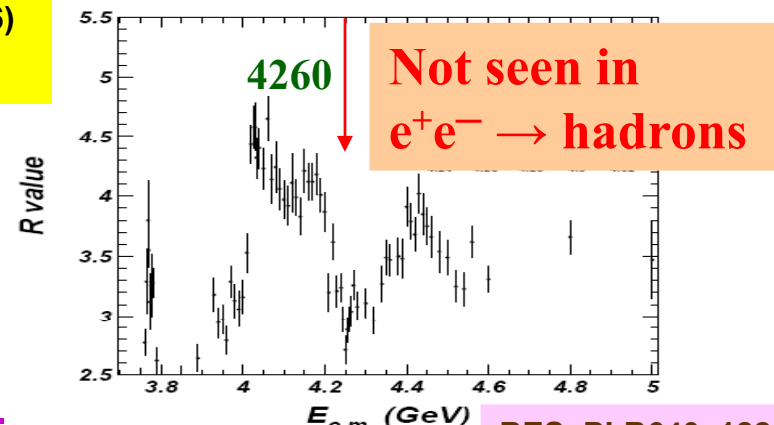
PRL 98, 212001 (2007)



CLEO,
PRD74, 091104(R) (2006)
PRL 96, 162003 (2006)

BaBar's Discovery Measurement
 $M = 4324 \pm 24 \text{ MeV}$
 $\Gamma = 172 \pm 33 \text{ MeV}$

BES data



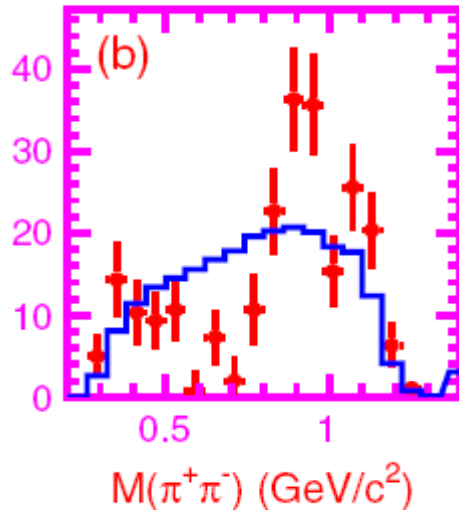
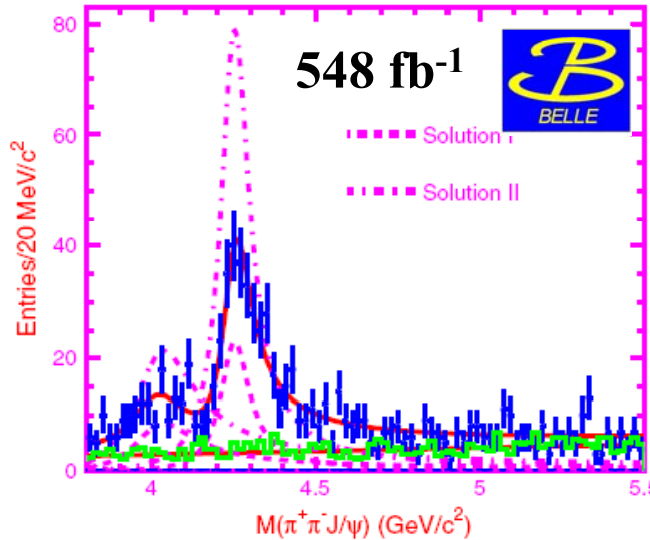
	BaBar	CLEOc
N	125 ± 23 ($\sim 8\sigma$)	$13.6^{+4.7}_{-3.9}$ (5.4σ)
Mass (MeV)	$4259 \pm 8^{+2}_{-6}$	$4284^{+17}_{-16} \pm 4$
Width (MeV)	$88 \pm 23^{+6}_{-4}$	$73^{+39}_{-25} \pm 5$



XYZ, HADRON2009, Nov.-Dec., 2009 BES, PLB640, 182 (2006)

Updates of Y(4260)

Belle, PRL 99, 182004 (2007)



Belle's Two-peak fit

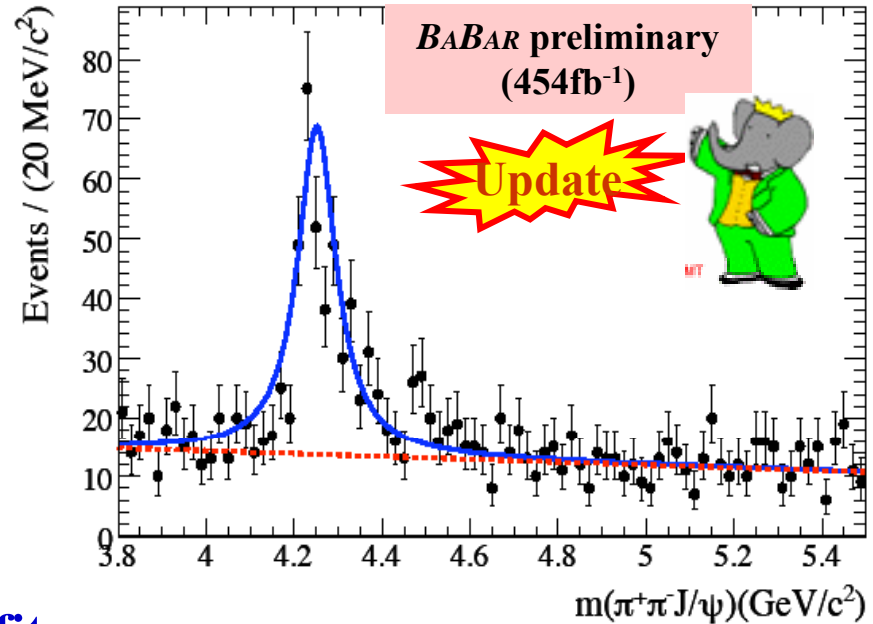
$$M=4008 \pm 40^{+114}_{-28} \text{ MeV}$$

$$\Gamma=226 \pm 44 \pm 87 \text{ MeV}$$

$$M=4247 \pm 12^{+17}_{-32} \text{ MeV}$$

$$\Gamma=108 \pm 19 \pm 10 \text{ MeV}$$

BaBar, arXiv:0808.1543(2008)

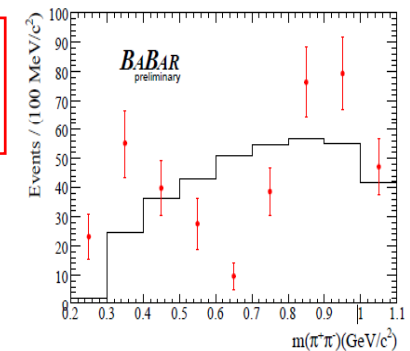


BaBar's single-peak fit

$$M=4252 \pm 6^{+2}_{-3} \text{ MeV}$$

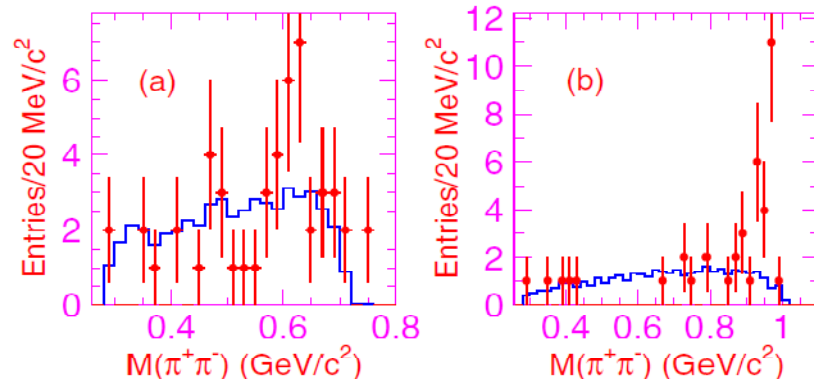
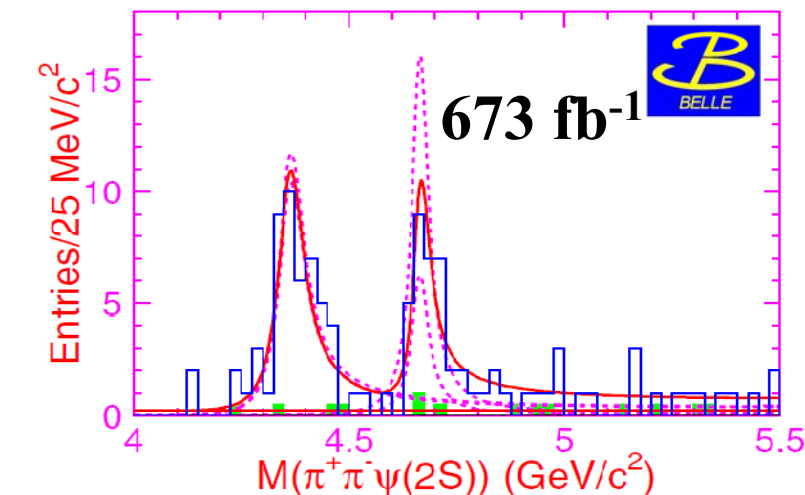
$$\Gamma=105 \pm 18^{+4}_{-6} \text{ MeV}$$

Y(4008) is not evident.



Y(4320) and Y(4664), and X(4630) in $\Lambda_c^+ \Lambda_c^-$

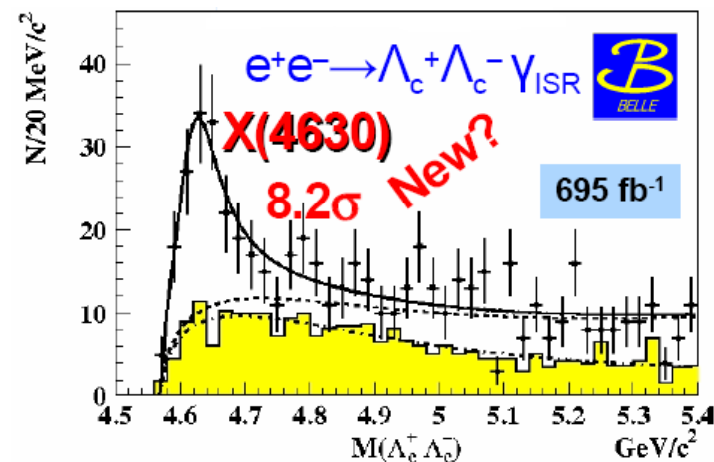
Belle, PRL 99, 142002 (2007)



$M = 4361 \pm 9 \pm 9 \text{ MeV}$
 $\Gamma = 74 \pm 15 \pm 10 \text{ MeV}$

$M = 4664 \pm 11 \pm 5 \text{ MeV}$
 $\Gamma = 48 \pm 15 \pm 3 \text{ MeV}$

Belle, PRL 101, 172001(2008)



State	M, MeV/c ²	Γ_{tot} , MeV
X(4630)	4634^{+8+5}_{-7-8}	92^{+40+10}_{-24-21}
Y(4660)	$4664 \pm 11 \pm 5$	$48 \pm 15 \pm 3$

Or, a popular nature of
 Baryon-antibaryon
 near-threshold structures



XYZ, HADRON2009, Nov.-Dec., 2009, S.Uehara

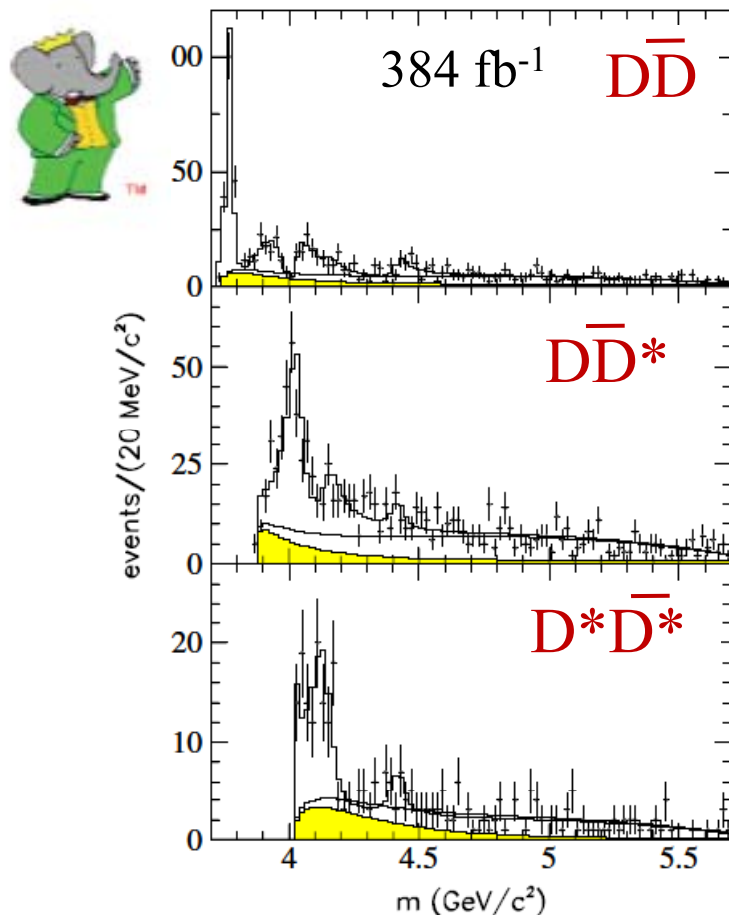
$$e^+e^- \rightarrow D(*)\overline{D}(*)$$

and Y particles



ISR – $D^{(*)}\bar{D}^{(*)}$: from ψ states, and Y states?

BaBar, PRD 79 092001 (2009)




- Full reconstruction of hadronic part
- Both charged and neutral final states
- Fit by sum of ψ states with fixed masses&widths from PDG (due to limited statistics)

BF ratios among $\psi \rightarrow D^{(*)}\bar{D}^{(*)}$

Ratio	Measurement
1) $\mathcal{B}(\psi(4040) \rightarrow D\bar{D})/\mathcal{B}(\psi(4040) \rightarrow D^*\bar{D})$	$0.24 \pm 0.05 \pm 0.12$
2) $\mathcal{B}(\psi(4040) \rightarrow D^*\bar{D}^*)/\mathcal{B}(\psi(4040) \rightarrow D^*\bar{D})$	$0.18 \pm 0.14 \pm 0.03$
3) $\mathcal{B}(\psi(4160) \rightarrow D\bar{D})/\mathcal{B}(\psi(4160) \rightarrow D^*\bar{D}^*)$	$0.02 \pm 0.03 \pm 0.02$
4) $\mathcal{B}(\psi(4160) \rightarrow D^*\bar{D})/\mathcal{B}(\psi(4160) \rightarrow D^*\bar{D}^*)$	$0.34 \pm 0.14 \pm 0.05$
5) $\mathcal{B}(\psi(4400) \rightarrow D\bar{D})/\mathcal{B}(\psi(4400) \rightarrow D^*\bar{D}^*)$	$0.14 \pm 0.12 \pm 0.03$
6) $\mathcal{B}(\psi(4400) \rightarrow D^*\bar{D})/\mathcal{B}(\psi(4400) \rightarrow D^*\bar{D}^*)$	$0.17 \pm 0.25 \pm 0.03$

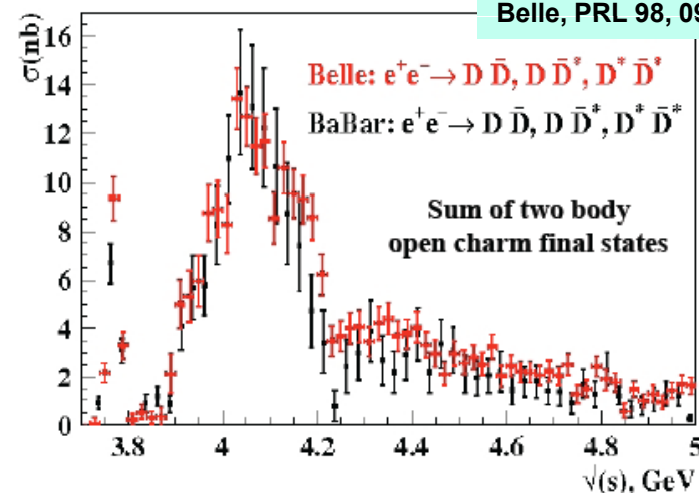
No evidence is found for $Y(4260) \rightarrow DD, DD^*, D^*D^*$



$$\frac{\mathcal{B}(Y(4260) \rightarrow D^*\bar{D})}{\mathcal{B}(Y(4260) \rightarrow J/\psi\pi^+\pi^-)} < 34$$

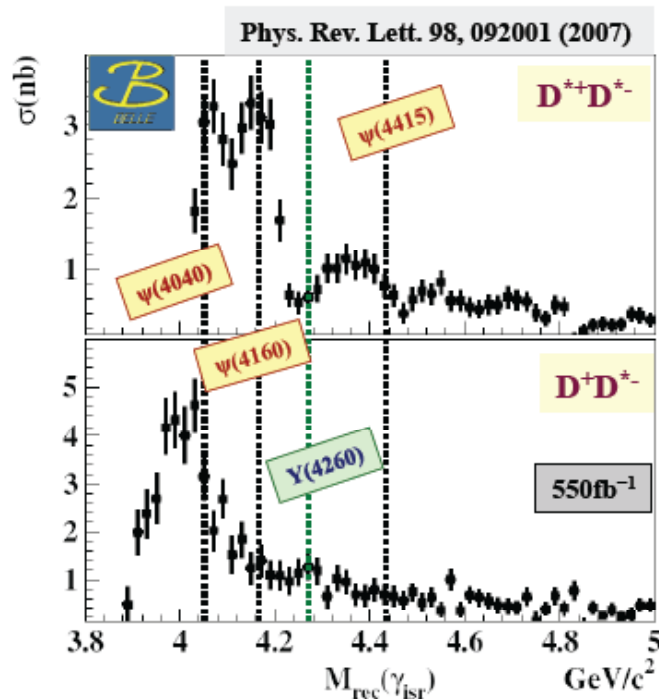
$$\frac{\mathcal{B}(Y(4260) \rightarrow D^*\bar{D}^*)}{\mathcal{B}(Y(4260) \rightarrow J/\psi\pi^+\pi^-)} < 40$$

Belle, PRL 98, 092001 (2007)



Uehara

ISR – $D^*\bar{D}^{(*)}(\pi)$ measurements from Belle



Systematic errors \approx statistical errors

D^+D^+

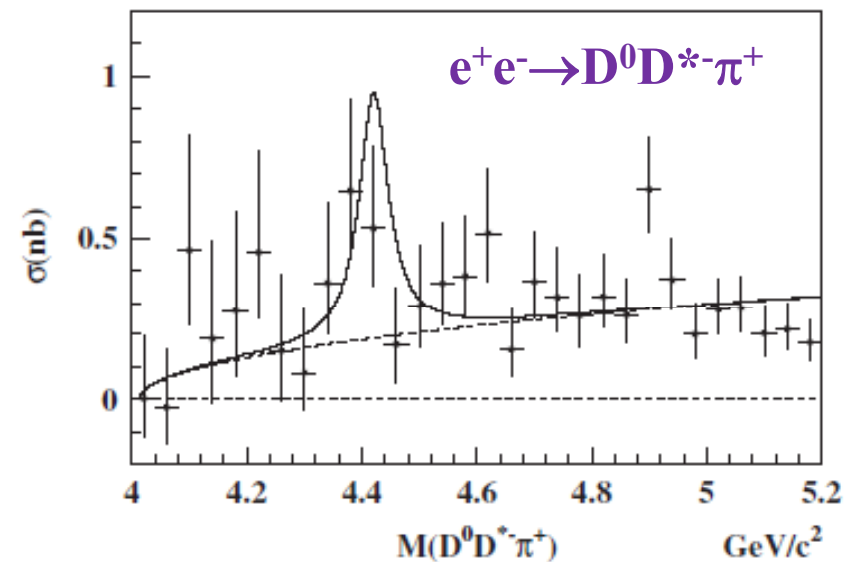
- complicated shape of cross section
- clear dip at $M(D^+D^+) \sim 4260$ GeV (similar to inclusive R)

DD^*

- broad peak at threshold (shifted relative to 4040 GeV)

Belle, PRD 80, 091101 (R)(2009)

695 fb^{-1}

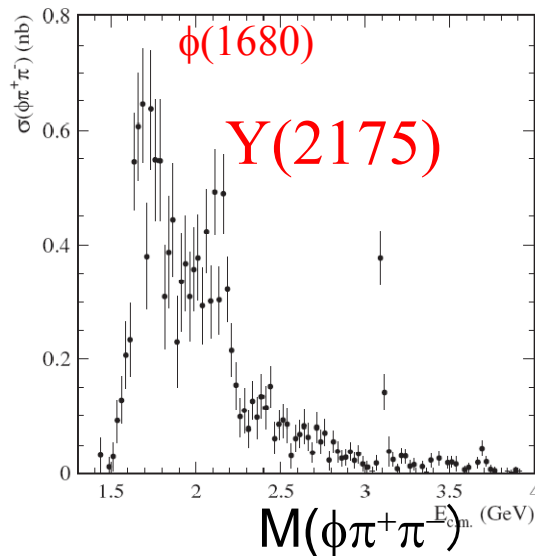


$$\mathcal{B}(Y(4260) \rightarrow D^0D^{*-}\pi^+)/\mathcal{B}(Y(4260) \rightarrow \pi^+\pi^-J/\psi) < 9 \text{ (@90\%CL)}$$

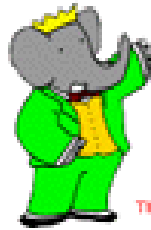
No evidence of open-charm decay of these Y particles found so far.



$s\bar{s}$ sector; $e^+e^- \rightarrow Y(2175) \rightarrow \phi\pi^+\pi^-$



PRD76,012008(2007)



BaBar: A clear structure above $\phi(1680)$, Identified as $Y(2175)$.

$$m_x = 2.175 \pm 0.010 \pm 0.015 \text{ GeV}/c^2$$

$$\Gamma_x = 0.058 \pm 0.016 \pm 0.020 \text{ GeV}/c^2$$

BESII
confirms

$$\text{Mass} = 2.186 \pm 0.010 \pm 0.006 \text{ GeV}/c^2$$

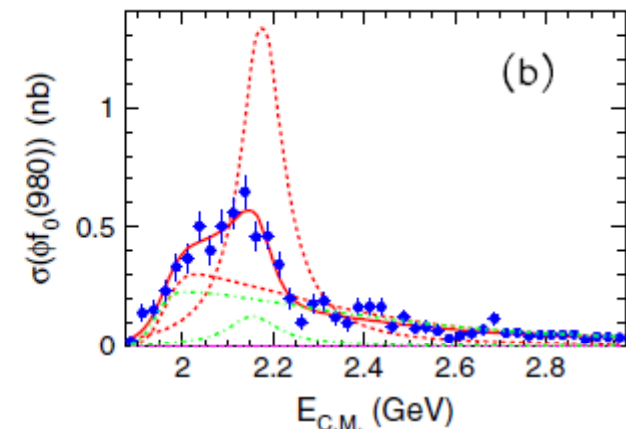
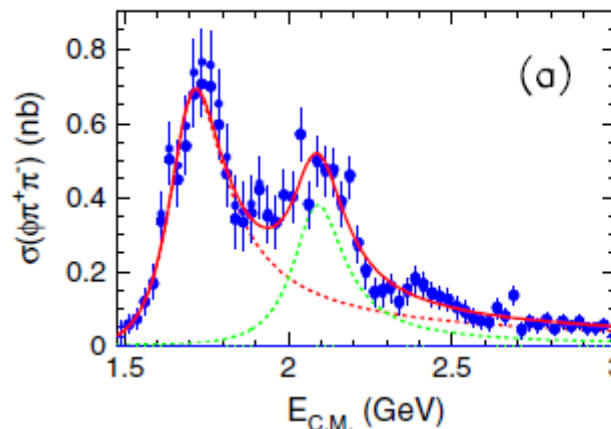
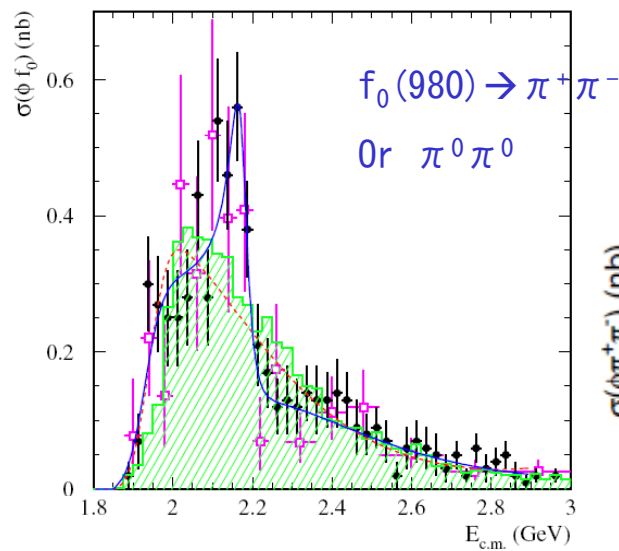
$$\text{Width} = 0.065 \pm 0.023 \pm 0.017 \text{ GeV}/c^2$$



$$M(Y(2175)) = 2079 \pm 13^{+79}_{-28} \text{ MeV}/c^2$$

$$\Gamma(Y(2175)) = 192 \pm 23^{+25}_{-61} \text{ MeV}/c^2$$

PRD 80, 031101(R) (2009)



XYZ, HADRON2009, Nov.-Dec., 2009, S.Uehara

Summary

More and more new states since 2003 from
Belle, BaBar, and CLEO, CDF, ...

Recent updates on XYZ resonances

X(3872) : Mass splitting is not found in decays from B mesons

BaBar results for $X(3872) \rightarrow \gamma J/\psi$ & $\gamma \psi'$

Z(4430): No evidence from BaBar

Confirmation with the Dalitz analysis by Belle

Very New Topics:

CDF's new particle $Y(4140) \rightarrow J/\psi \phi$, not seen at Belle

New structures seen in two-photon processes, $\gamma\gamma \rightarrow J/\psi \omega$ and $J/\psi \phi$

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

Unified analysis of $e^+e^- \rightarrow D^{(*)}\bar{D}^{(*)}$ for separating ψ/Y resonance effects

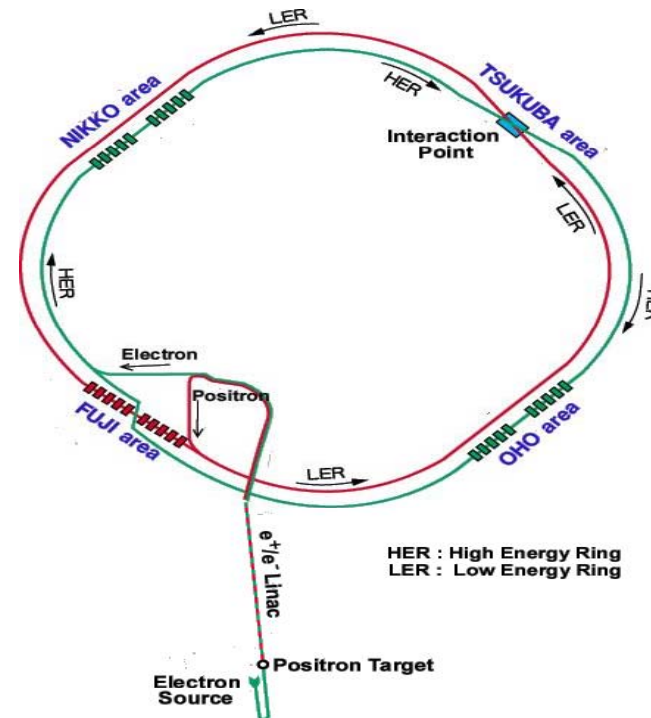


Backup slides



KEKB Accelerator and Belle Detector

- Asymmetric $e^- e^+$ collider
8 GeV e^- (HER) x 3.5 GeV e^+ (LER)
 $\sqrt{s}=10.58 \text{ GeV} \Leftrightarrow \Upsilon(4S)$ and other energies
Beam crossing angle: 22mrad
- Continuous injection
- Luminosity
 $L_{\text{max}}=2.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 $\int L dt \sim 955 \text{ fb}^{-1} \quad (2009\text{-June})$



High momentum/energy resolutions

CDC+Solenoid, CsI

Vertex measurement – Si strips

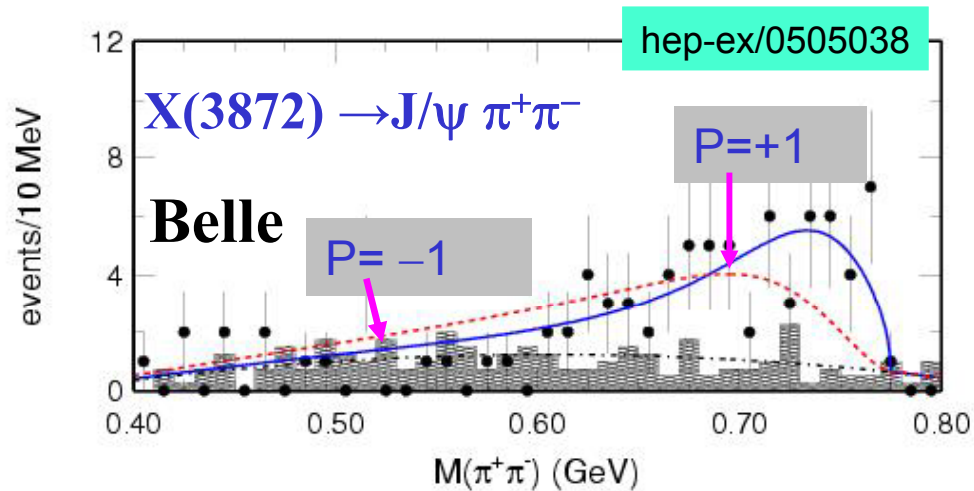
Particle identification

TOF, Si-aerogel, CDC- dE/dx ,

RPC for $K_L/\mu\text{on}$



Spin-parity of X(3872); 0^+ , 0^- or 1^+ ?



Belle's Dalitz Analysis

Full Dalitz-plane analysis

K*s included in the analysis:

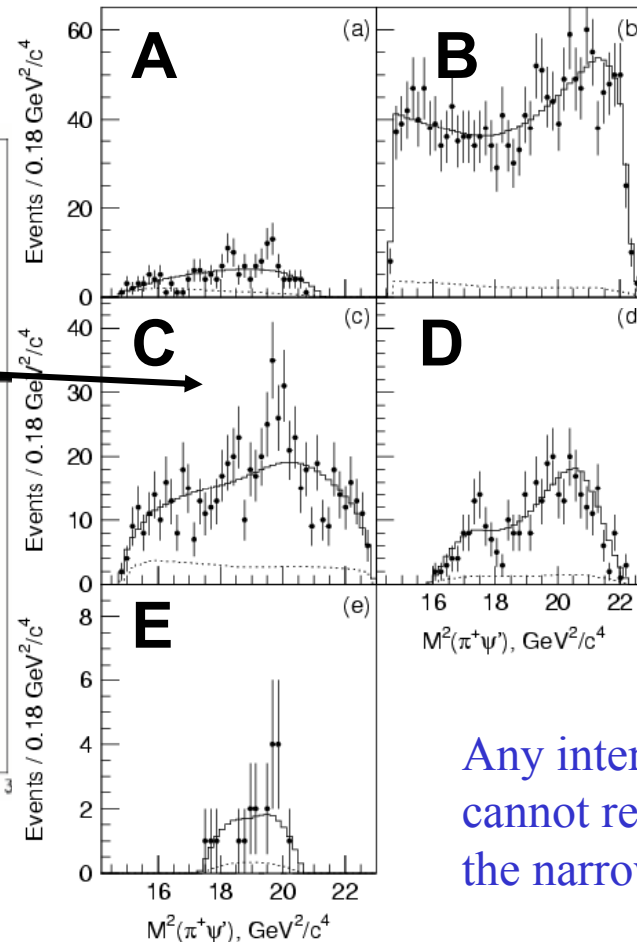
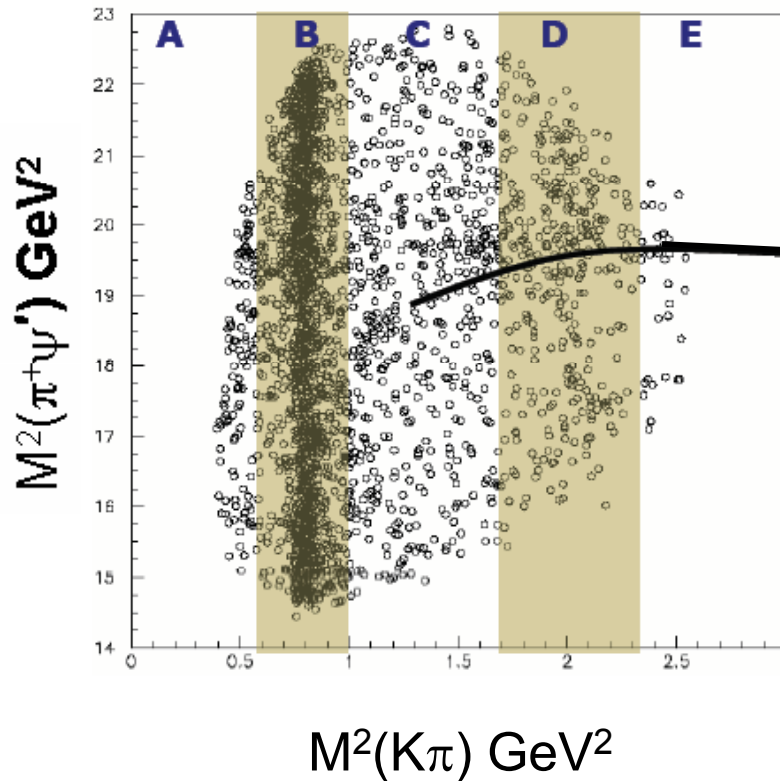
κ , $K^*(892)$, $K^*(1410)$, $K^*_0(1430)$,
 $K^*_2(1430)$, $K^*(1680)$

605 fb⁻¹

Preliminary

Presented at QWG6 (2008)

Fit **without** a Z resonance:
 CL=0.1%

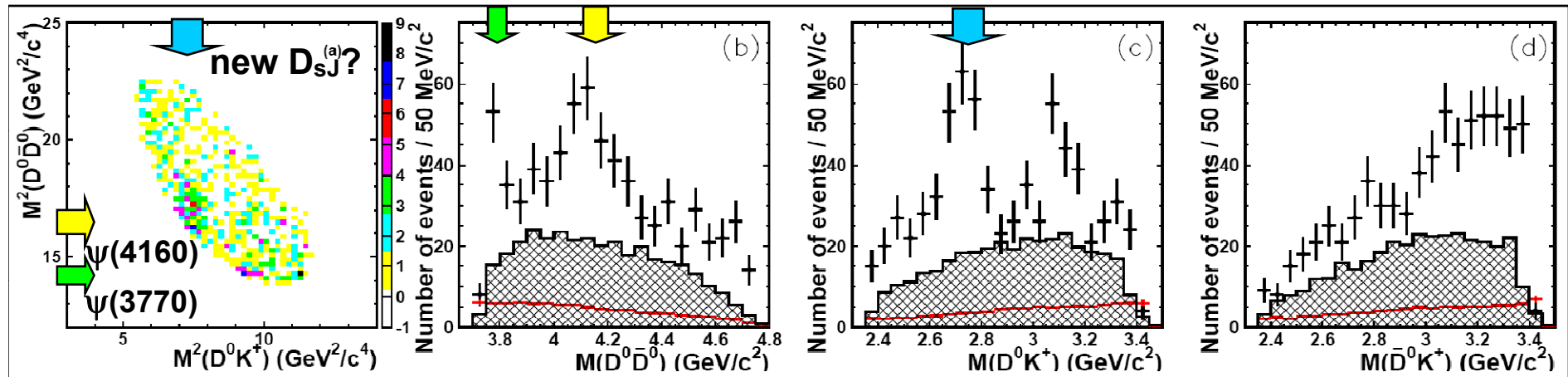
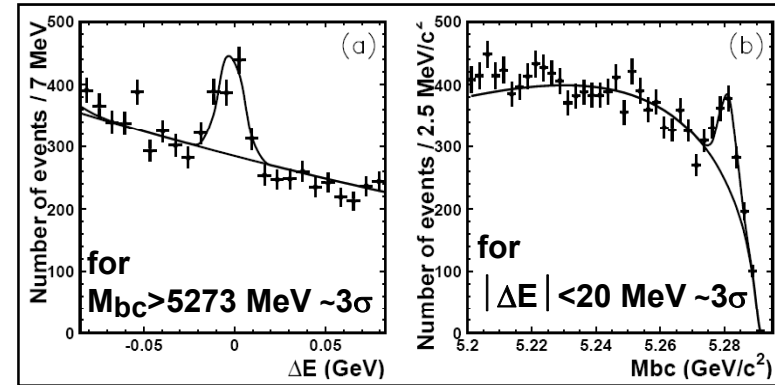
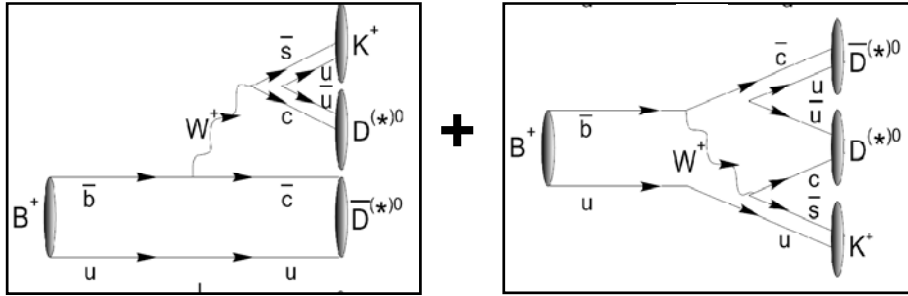


CL = 0.1%

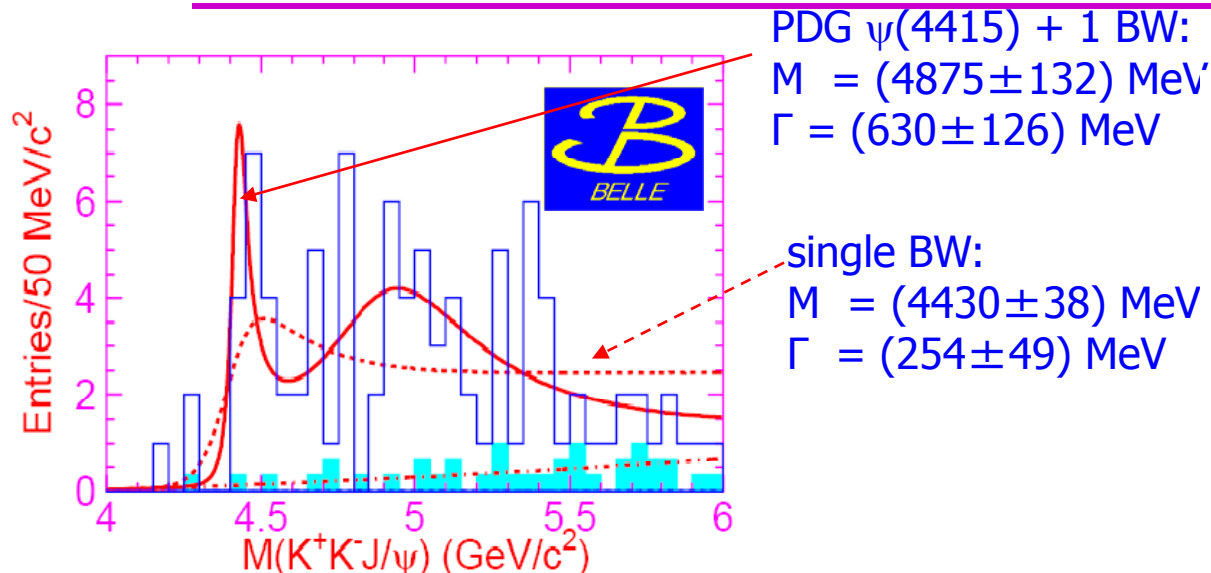
Any interferences among K*'s
 cannot reproduce
 the narrow peak



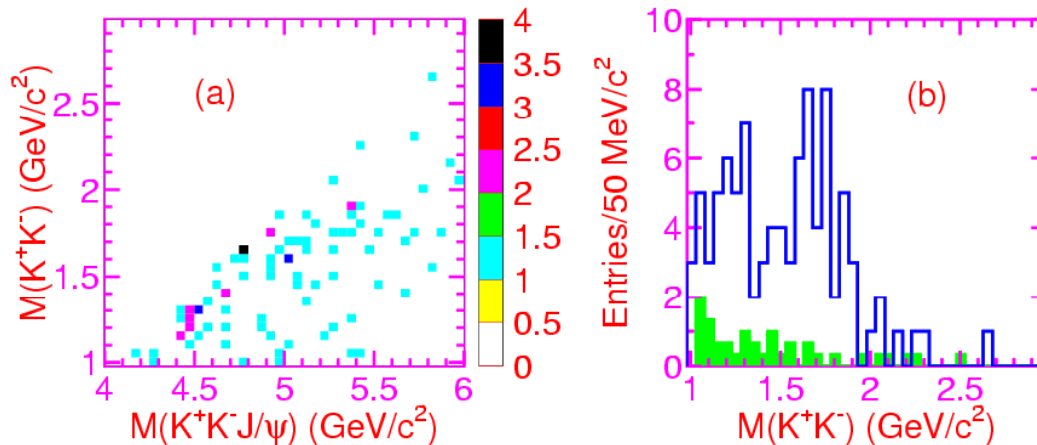
New D_s meson in $B^+ \rightarrow D^0 \bar{D}^0 K^+$



$e^+e^- \rightarrow K^+K^-J/\psi$ at Belle



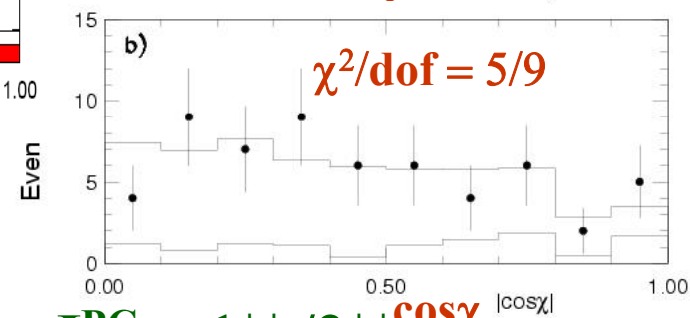
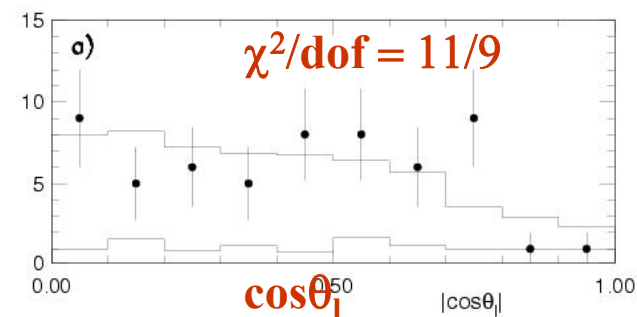
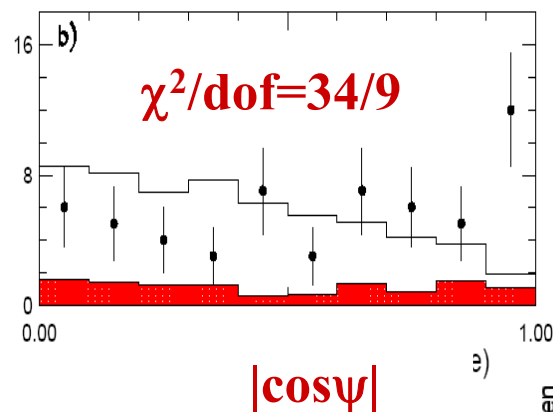
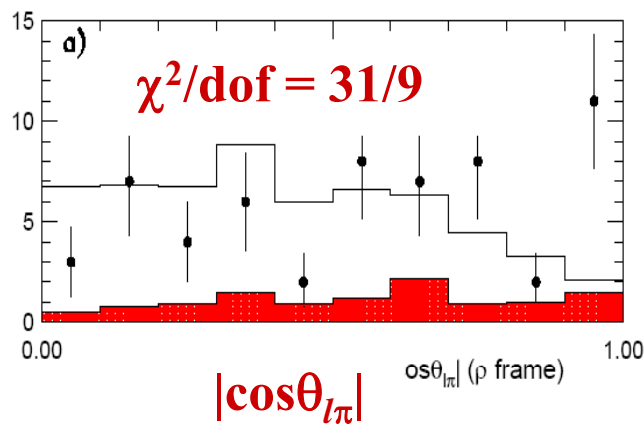
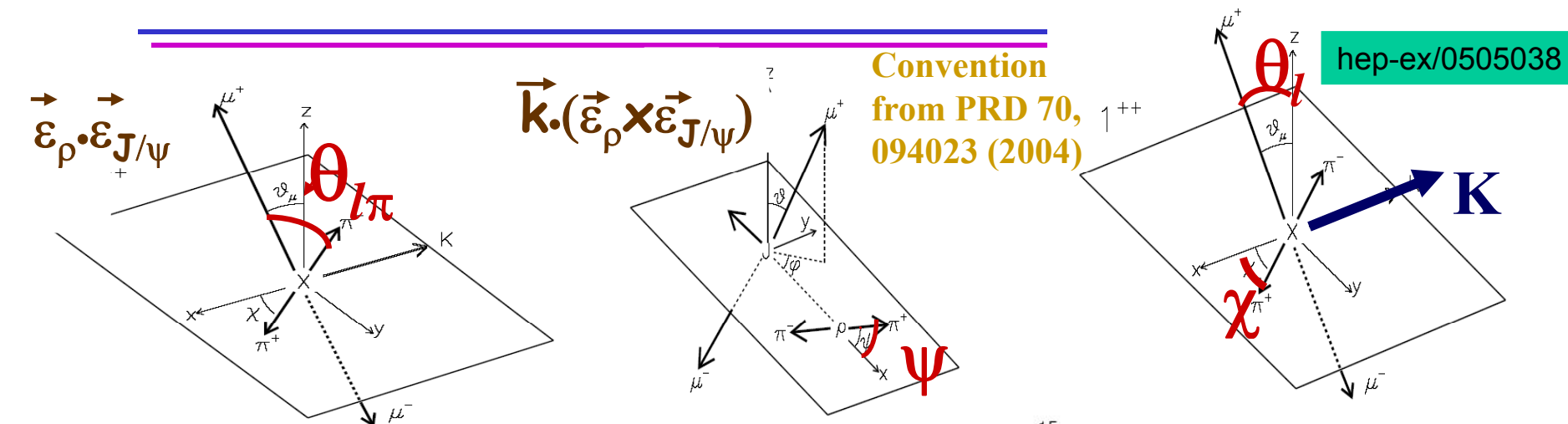
The figure is still not clear. New resonance or just continuum production, or other mechanism? Larger data sample from future B factories should give an answer.



Similarly, KK invariant mass tends to be large!

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

Spin-parity of X(3872); 0^+ , 0^- or 1^+ ?



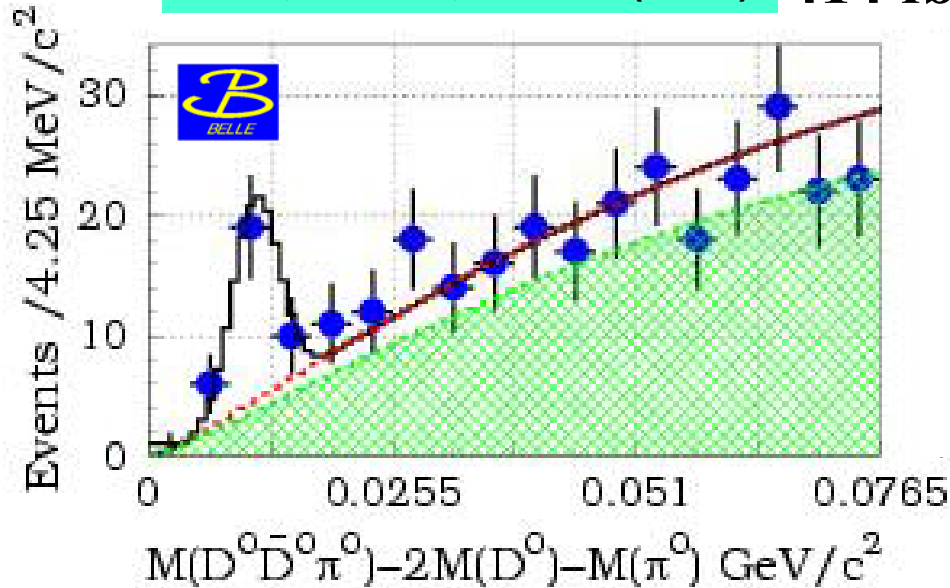
rule out 0^{++} & 0^{-+}

X(3872) in B-decay $\Rightarrow J^{PC} = 1^{++} / 2^{++} \cos\chi$



Observation of $D^0\bar{D}^0\pi^0$ threshold peak

Belle, PRL 97, 162002 (2006) 414 fb⁻¹

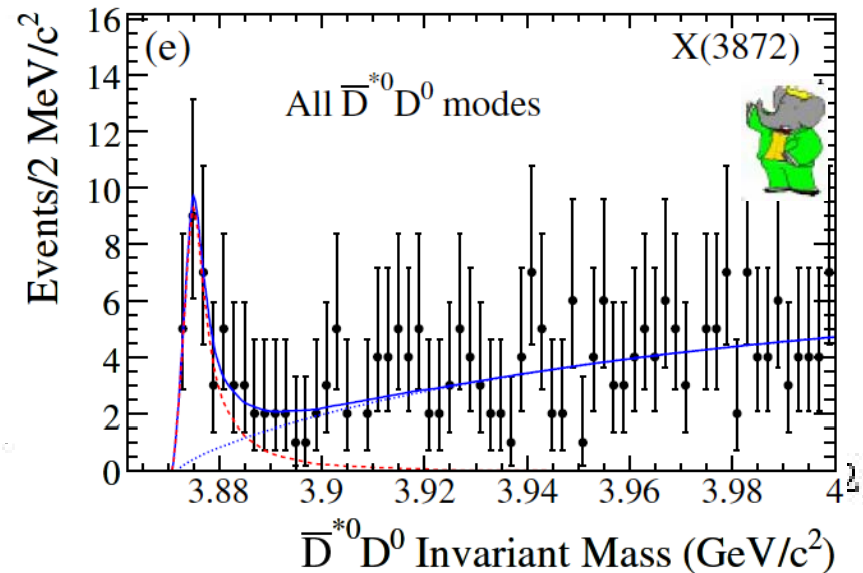


$$M = 3875.4 \pm 0.7^{+0.7}_{-1.7} \pm 0.8 \text{ MeV}/c^2$$

$$\frac{\text{Br}(X \rightarrow D^0 \bar{D}^0 \pi^0)}{\text{Br}(X \rightarrow \pi^+ \pi^- J/\psi)} = 9 \pm 4$$

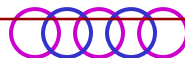
2⁺ is less favorable
 (D-wave needed somewhere in *PPP*)
J^{PC} = 1⁺⁺ favored

BaBar, PRD 77, 011102 (2008)



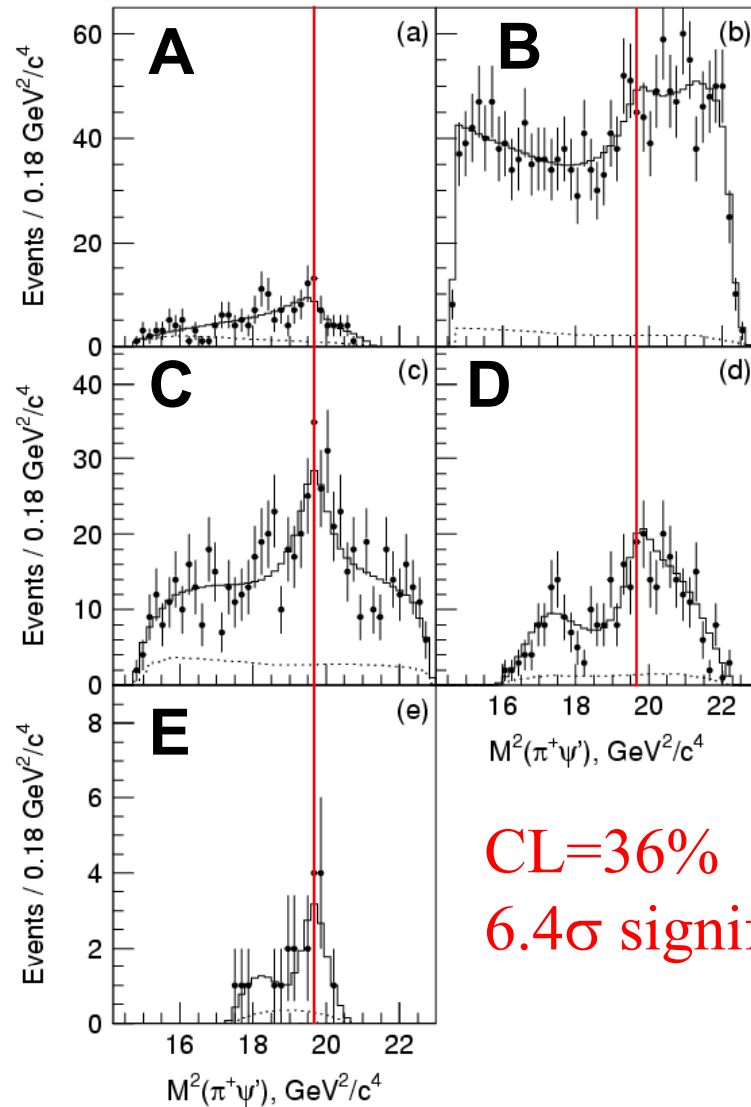
$$3875.1^{+0.7}_{-0.5} \pm 0.5 \text{ MeV}$$

A heavier mass by 3 – 4 MeV/c²
 than in $X \rightarrow J/\psi \pi^+ \pi^-$ observed



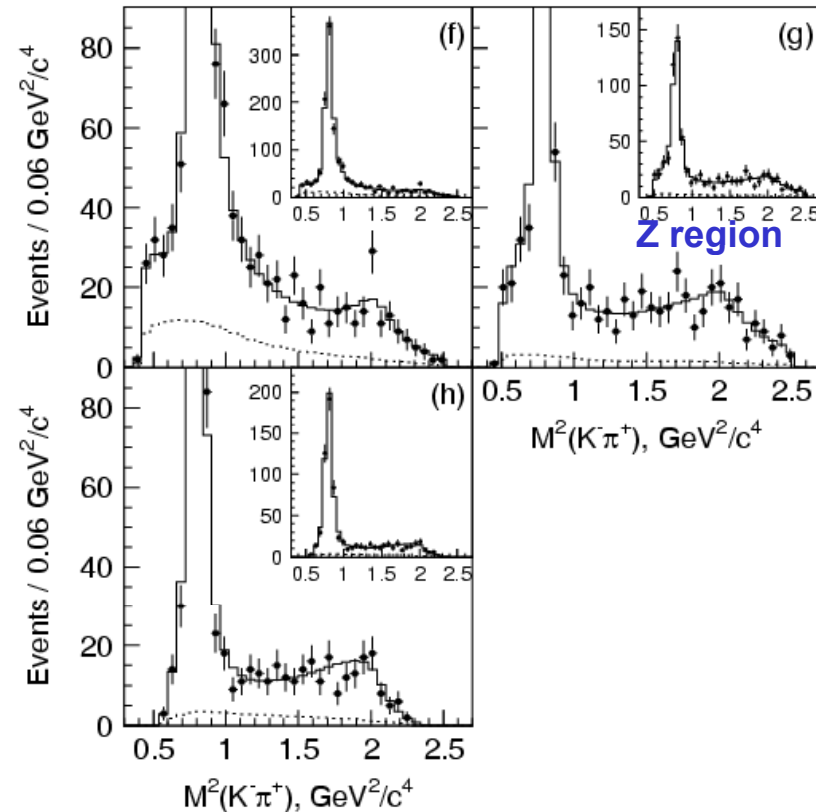
Belle's Dalitz Analysis

Fit with Z



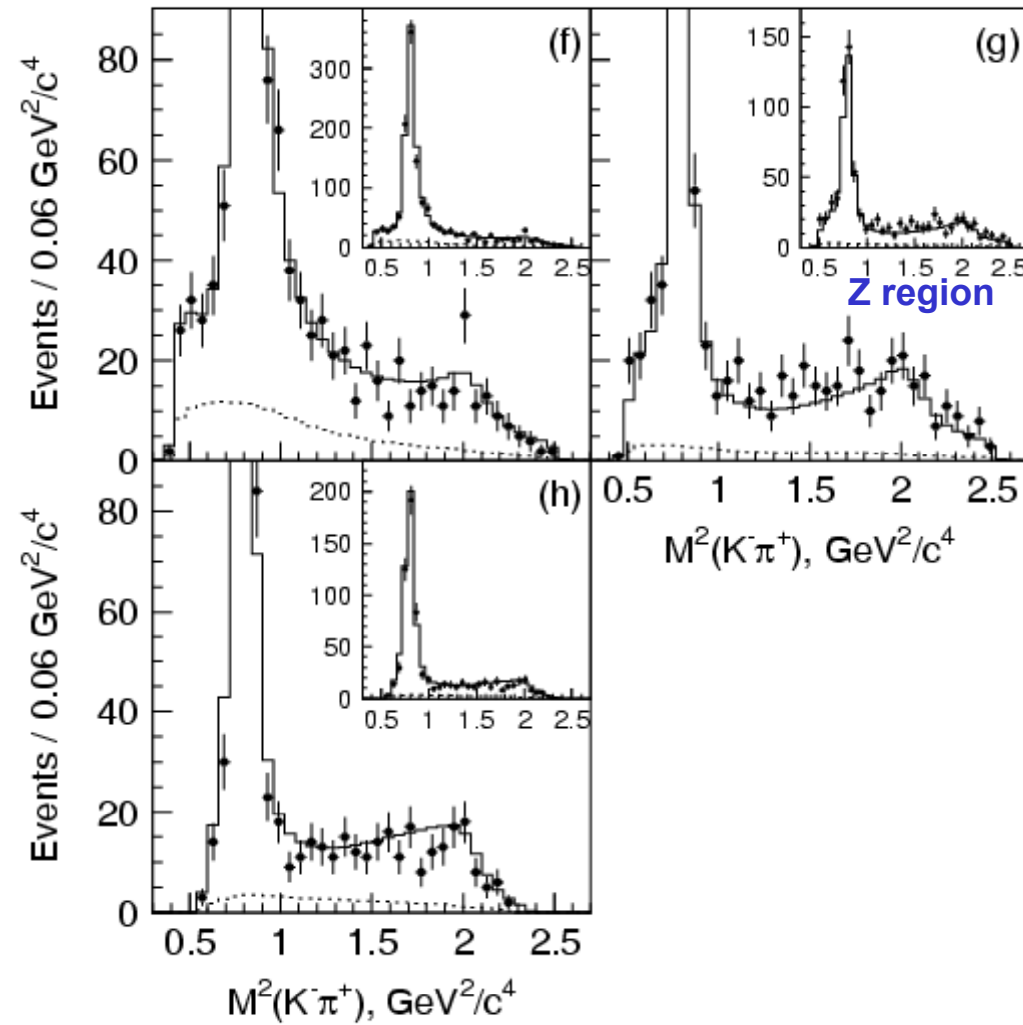
CL=36%
6.4 σ significance

The fits in $K\pi$ mass with Z



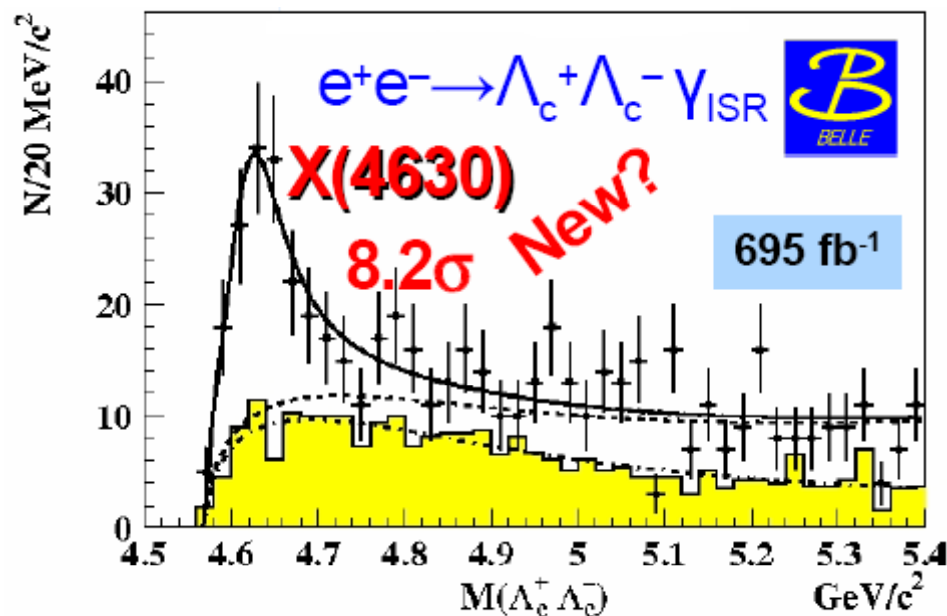
No characteristic features
in view of $K\pi$ spectrum

The fits in $K\pi$ mass without Z



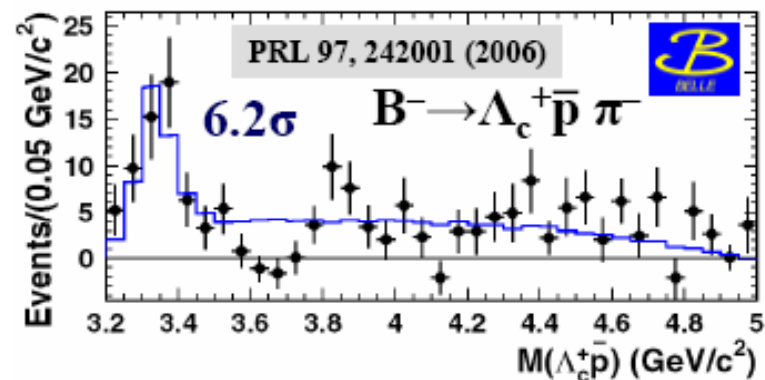
Study of $e^+e^- \rightarrow \gamma_{\text{ISR}} \Lambda_c \bar{\Lambda}_c$

PRL 101, 172001(2008)

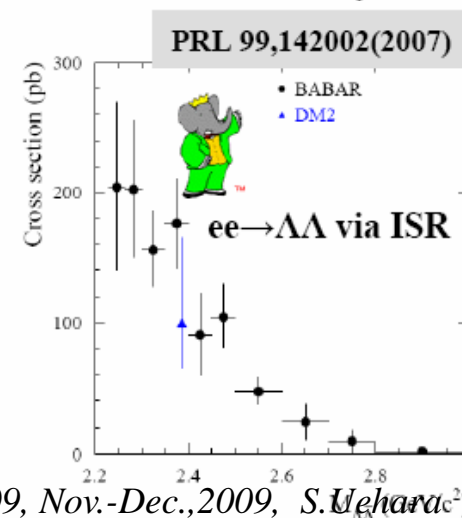


State	M, MeV/c ²	Γ_{tot} , MeV
X(4630)	4634⁺⁸⁺⁵₋₇₋₈	92⁺⁴⁰⁺¹⁰₋₂₄₋₂₁
Y(4660)	4664 ± 11 ± 5	48 ± 15 ± 3

A popular nature of
Baryon-antibaryon
near-threshold structures



No peak
for $\Lambda \bar{\Lambda}$



XYZ, HADRON2009, Nov.-Dec., 2009, S. Uehara