Charmonium Spectroscopy and Decay

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on behalf of the BABAR Collaboration

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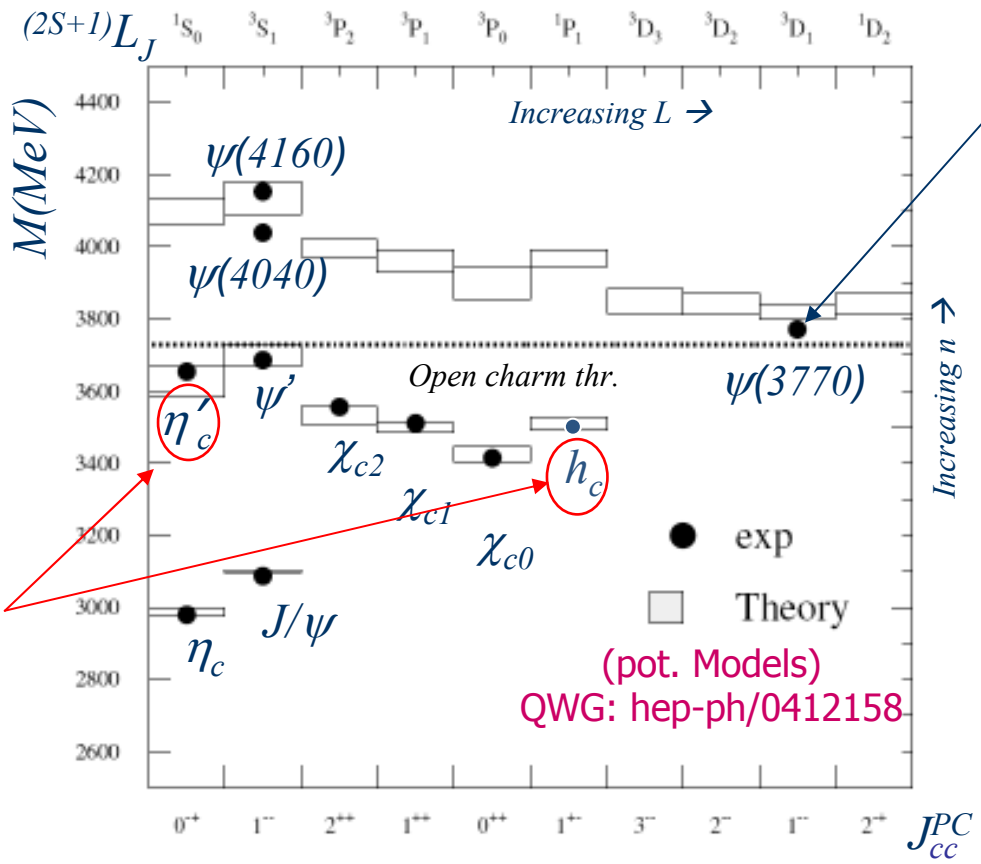
Introduction

- A huge amount of results on states with $c\bar{c}$ content are being reported.
  - *BABAR*, Belle, BES and CLEO are contributing enormously exploiting largest datasets.
  - Several production mechanisms are used: prompt production, continuum production, ISR, $\gamma\gamma$ collisions, B decays, ….
- Bound states of $c\bar{c}$ quarks are a fundamental laboratory to study QCD.
  - Some results do not fit well within the ordinary charmonium picture.
- QCD foresees a richer spectroscopy: hybrids, tetraquarks, molecules, etc…
  - are we seeing hints of this richer spectroscopy ?
- Here, a (small!) selection of the latest results only
  - see also talks by H. Chen, H. Nakazawa, S. Olsen, P. Pakhlov, G. Rong, X. Shen, M. Shepherd, K. Trabelsi and C.Z. Yuan

The States with Hidden Charm

- Charmonium: bound states of c and $\overline{c}$.
  - not all J^{PC} quantum numbers allowed (e.g. 0^{--}, 0^{+-}, 1^{-+}, …);
  - below $D\overline{D}$ threshold, only electromagnetic or α_s-suppressed decays: mostly narrower states;
  - above $D\overline{D}$ threshold, mostly broader states.
- Hybrids: $q\overline{q}$+gluons → lightest state 1^{-+}
- Tetraquarks: $[qq'][\overline{qq'}]$ → several states foreseen; narrow widths also above threshold.
- Molecules: $[q\overline{q}^{(')}][q\overline{q}^{(')}]$ → less states; also narrow widths.
- These states can be accessed using various production mechanisms:
  - formation in e^+e^- and ISR: can only produce 1^{--} states via single virtual photon;
  - $\gamma\gamma$ collisions: produces C=+ states;
  - formation in $p\bar{p}$: all quantum numbers in principle accessible;
  - B decays: all quantum numbers in principle accessible;
  - $e^+e^- \to \gamma^* \to X_{cc}Y_{cc}$: the quantum numbers of X and Y must combine to form 1^{--};
  - decays from higher mass charmonium(-like) states: selection rules apply.

Spectrum of Charmonium States



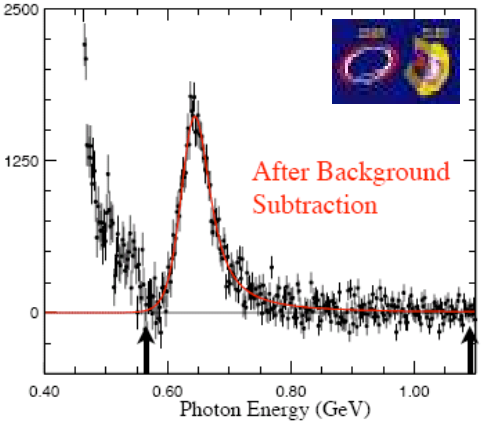
same J^{PC} as J/ψ but mostly D wave

Recent acquisitions

- Basically all states below the open charm threshold are observed and explained.

States Below $D\bar{D}$ Threshold

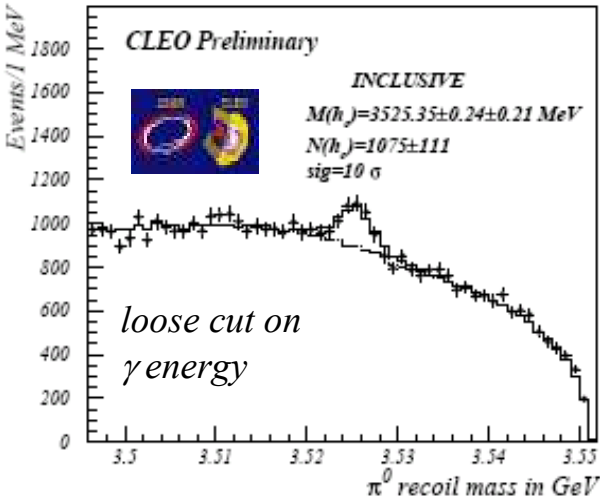
- Several new measurements on charmonium states below $D\bar{D}$ threshold
  - many results on χ_{c0}, χ_{c2}, η_c and $\eta_c(2S)$ in $\gamma\gamma$ by Belle: see H. Nakazawa's talk
  - many results by BES: see X.Shen & H.Chen's talks
  - CLEO: $\psi(2S) \to \gamma\, \eta_c$ and $\psi(2S) \to h_c \pi^0$, $h_c \to \gamma\, \eta_c$; see also: M. Shepherd's talk

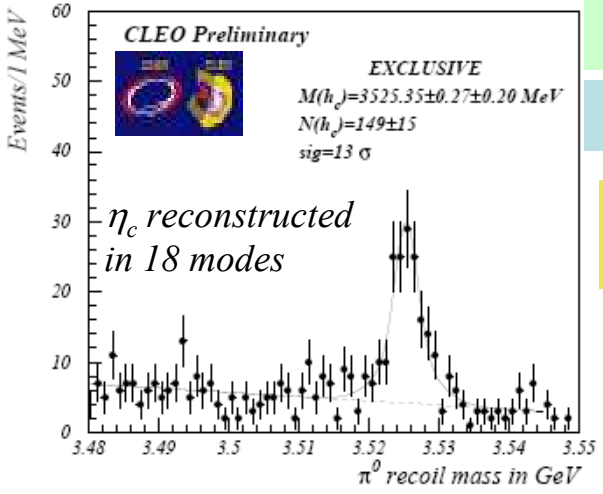


$$BR(\psi(2S) \to \gamma\, \eta_c) = (4.02 \pm 0.11 \pm 0.52) \times 10^{-3}$$

very difficult to fit η_c lineshape.

QWG07





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

$m(h_c) = (3525.35 \pm 0.19 \pm 0.15)$ MeV

very close to χ_{cJ} center of gravity (3525.4 ± 0.1) MeV

PRL 95, 102003 (2005), update at QWG07

– CLEO: 2–, 3– and 4– body χ_{cJ} decays from $\psi(2S) \to \gamma \chi_{cJ}$.

– χ_{cJ} decays to baryon-antibaryon: $p\bar{p}$, $\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$

QWG07

some disagreement with theory

$\Gamma(\Lambda\bar{\Lambda})/\Gamma(p\bar{p})$

χ_{c1}			χ_{c2}		
Theory	BES	CLEO	Theory	BES	CLEO
~0.6	4.6±2.3	1.3±0.3	~0.45	5.1±3.1	2.2±0.4

– χ_{cJ} decays to PP: $\pi^+\pi^-$, $\pi^0\pi^0$, K^+K^-, K_sK_s, $\eta^{(\prime)}\eta^{(\prime)}$

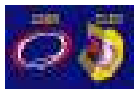
QWG07; PRD 75, 071101 (2007)

consistent with isospin expectations

	χ_{c0}		χ_{c2}	
	Belle	CLEO	Belle	CLEO
K_sK_s/K^+K^-	0.49±0.11	0.54±0.03	0.70±0.24	0.47±0.05
$\pi^0\pi^0/\pi^+\pi^-$		0.46±0.05		0.43±0.13

– $\Gamma(\chi_{cJ} \to \gamma\gamma)$

	χ_{c0}	χ_{c1}	χ_{c2}
$\Gamma(\chi_{cJ} \to \gamma\gamma)$ keV	2.65±0.38±0.17±0.25	$< 3.6 \times 10^{-5}$, 90% C.L.	0.62±0.07±0.05±0.06



– *BABAR*: J/ψ and $\psi(2S)$ decays from ISR

arXiv:0708.2461
arXiv:0710.4451

$J/\psi \to K^+K^-\pi^+\pi^-\pi^0$	$(1.92\pm0.08\pm0.15) \times 10^{-2}$
$J/\psi \to K^+K^-\pi^+\pi^-\eta$	$(4.7\pm0.6\pm0.3) \times 10^{-3}$
$J/\psi \to K(892)^{*\pm}K^{-+}$	$(5.2\pm0.3\pm0.2) \times 10^{-3}$
$J/\psi \to K^+K^-\eta$	$(8.7\pm1.3\pm0.7) \times 10^{-4}$
$J/\psi \to \Lambda\bar{\Lambda}$	$(1.92\pm0.21) \times 10^{-3}$
$J/\psi \to \pi^+\pi^-\pi^0\pi^0$	$(5.74\pm0.74) \times 10^{-3}$
$\psi(2S) \to 2(\pi^+\pi^-)\eta$	$(1.2\pm0.6\pm0.1) \times 10^{-3}$
$\psi(2S) \to \Lambda\bar{\Lambda}$	$(6.0\pm1.5) \times 10^{-4}$
$\psi(2S) \to K^+K^-\pi^+\pi^-\eta$	$(1.3\pm0.7\pm0.1) \times 10^{-3}$

improvements over previous world averages

previously unobserved modes

– … many many more!!

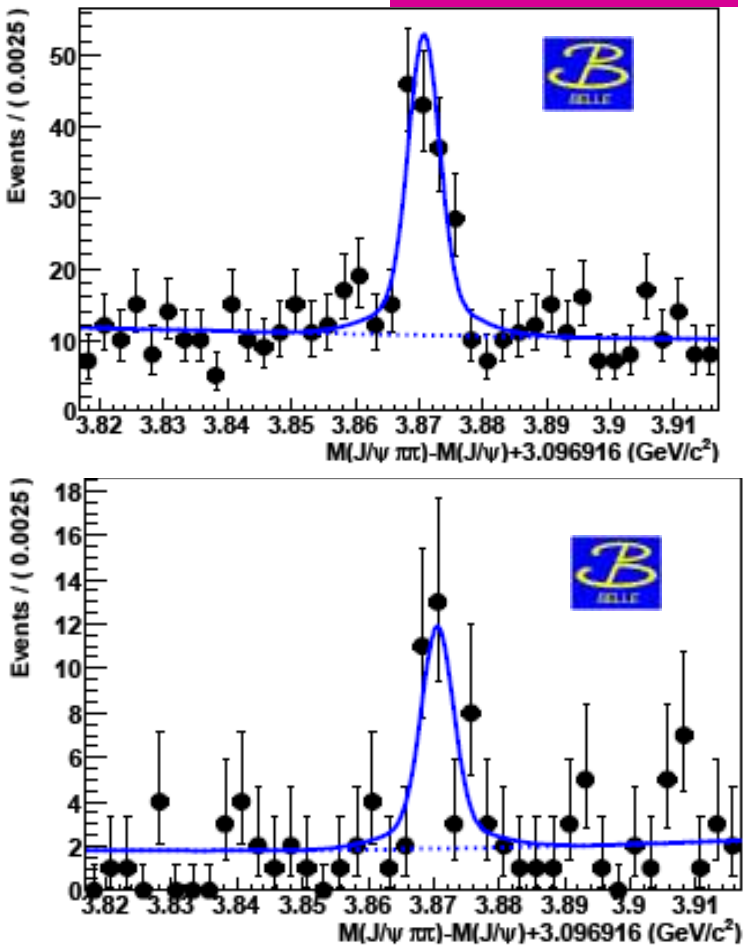
X(3872)

Belle: PRL 91 (2003) 262003
BaBar: PRD71 (2005) 071103
BaBar: PRD73 (2006) 011101
BaBar: PRD74 (2006) 071101
CDF: PRL93 (2004) 072001
D0: PRL93 (2004) 162002

- Decays
  - $X \to J/\psi\pi^+\pi^-$
    - Possibly $J/\psi\,\rho$
    - Discovered by Belle; confirmed by *BABAR*, CDF, D0
  - BF$(J/\psi\,\omega) \sim$ BF$(J/\psi\,\rho)$
  - $X \to J/\psi\,\gamma$
  - Charged partners in $J/\psi\pi^+\pi^0$ not seen
- Implications:
  - C$(X) = +1$
  - C$(\pi\pi$ in $J/\psi\pi\pi$ decay$) = -1$
  - I$(\pi\pi)$=L$(\pi\pi)$=1 $\to$ consistent with $J/\psi\,\rho$ decay
- Production
  - *B*-meson decays at *B*-Factories;
  - inclusive production in $p\bar{p}$ collisions at Tevatron;
  - no prompt e^+e^- production observed (*BABAR* **Phys.Rev.D76, 071102, 2007**)

$\sigma(e^+e^- \to X(3872)X) \times BR(X(3872) \to J/\psi\,\gamma) \times BR(X \to (N_{ch}>2)) < 5.1$ fb, 90% C.L.

Belle-CONF-0711 K.Trabelsi's talk

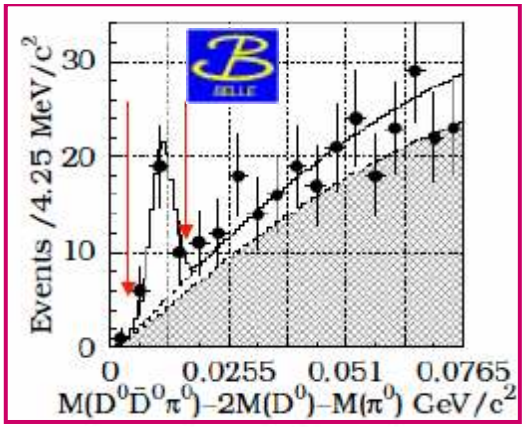


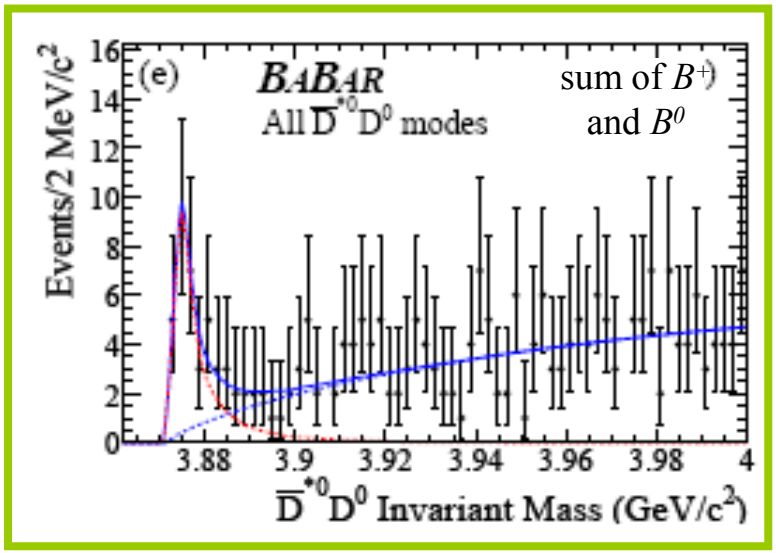
$$\Delta M = (0.22 \pm 0.90 \pm 0.27)\,MeV$$

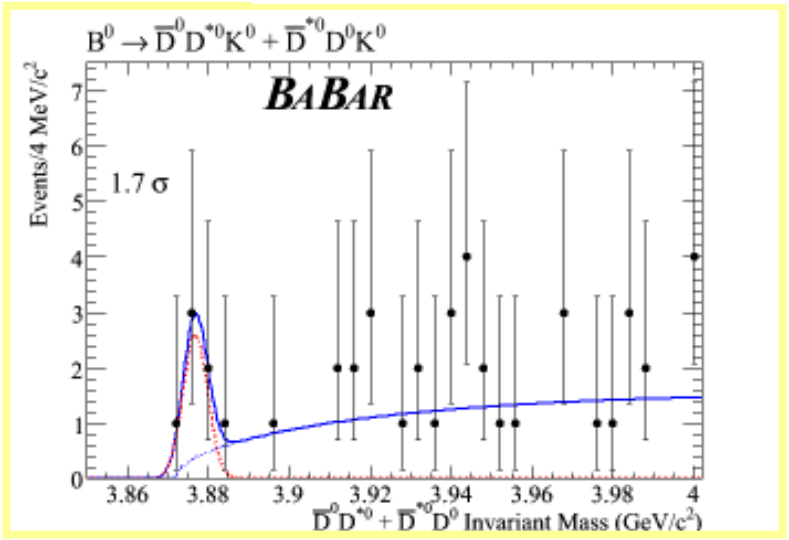
$$\frac{Br(B^+ \to XK^+; X \to J/\psi\pi\pi)}{Br(B^0 \to XK_S; X \to J/\psi\pi\pi)} = 0.94 \pm 0.24 \pm 0.10$$

consistent with no mass and rate difference

- Belle [**PRL 97, 162002 (2006)**] observed $X(3872) \to D^0 \bar{D}^0 \pi^0$
  - $BR(B \to X K,\ X \to \bar{D}^0 D^0 \pi^0) = (1.22 \pm 0.31^{+0.23}_{-0.39}) \times 10^{-4}$
- Confirmation by *BABAR* in $B \to D\bar{D}^* K$
  - $D^{*0} \to D^0 \pi^0$ and $D^0 \gamma$







Mass, width and BR measurement

arXiv:0708.1565

Hint of X in neutral B decays

$m = (3875.1^{+0.7}_{-0.5} \pm 0.5)$ MeV, $\Gamma = (3.0^{+1.9}_{-1.4} \pm 0.9)$ MeV

$BR(B^+ \to X K^+,\ X \to D^0 \bar{D}^{*0}) = (1.67 \pm 0.36 \pm 0.47) \times 10^{-4}$

$\Delta m = (0.7 \pm 1.9 \pm 0.3)$ MeV

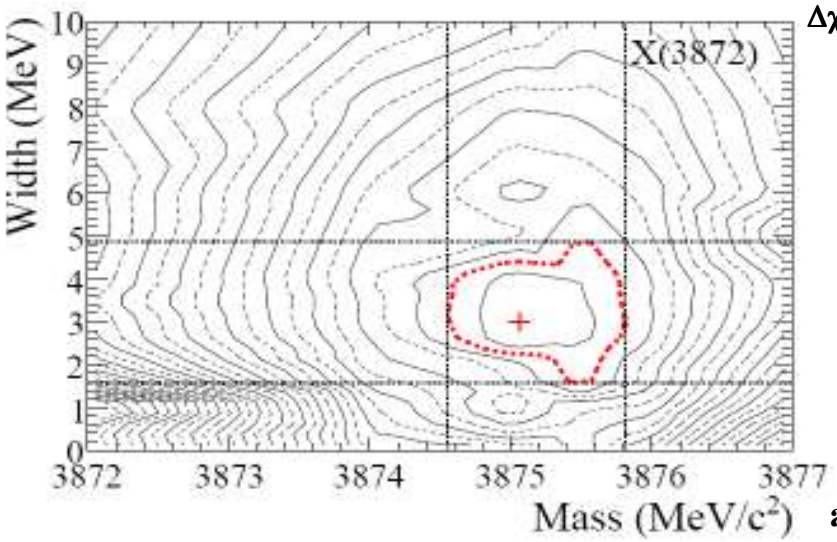
$R_{0/+} = (1.33 \pm 0.69 \pm 0.43)$

• $D^0 \bar{D}^0 \pi^0 / D^0 \bar{D}^0 \gamma = 1.37 \pm 0.56$: expected 1.3 if via D^{*0} only.

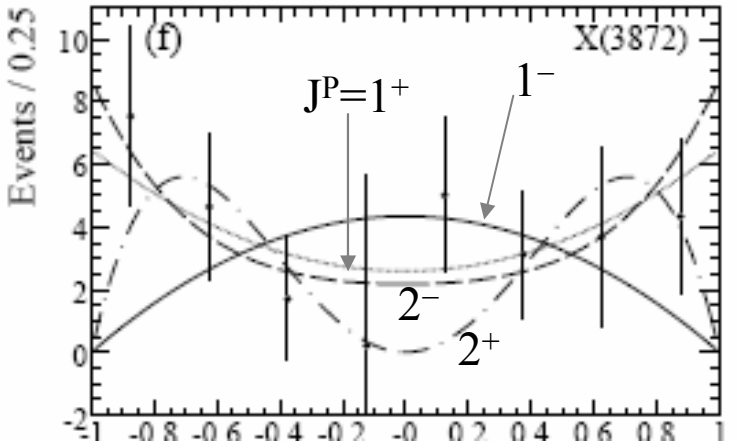
• $D\bar{D}^*$ is favoured over $J/\psi\pi\pi$ and $J/\psi\gamma$:

$BR(B^+ \to X K^+,\ X \to J/\psi \pi^+ \pi^-) = (1.16 \pm 0.19) \times 10^{-5}$ (HFAG 07)

$BR(B^+ \to X K^+,\ X \to J/\psi\, \gamma) = (2.2 \pm 0.5) \times 10^{-6}$ (HFAG 07)



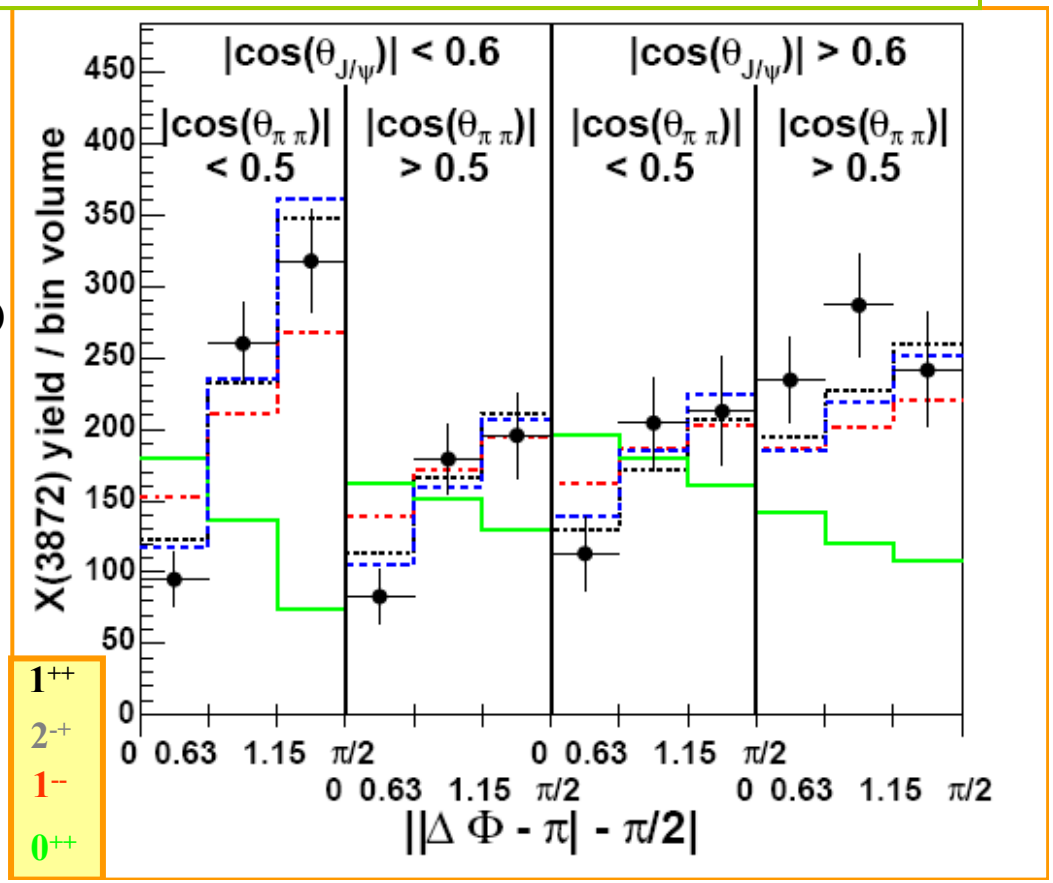
$D\bar{D}^*$



arXiv:0708.1565

$J/\psi\pi\pi$

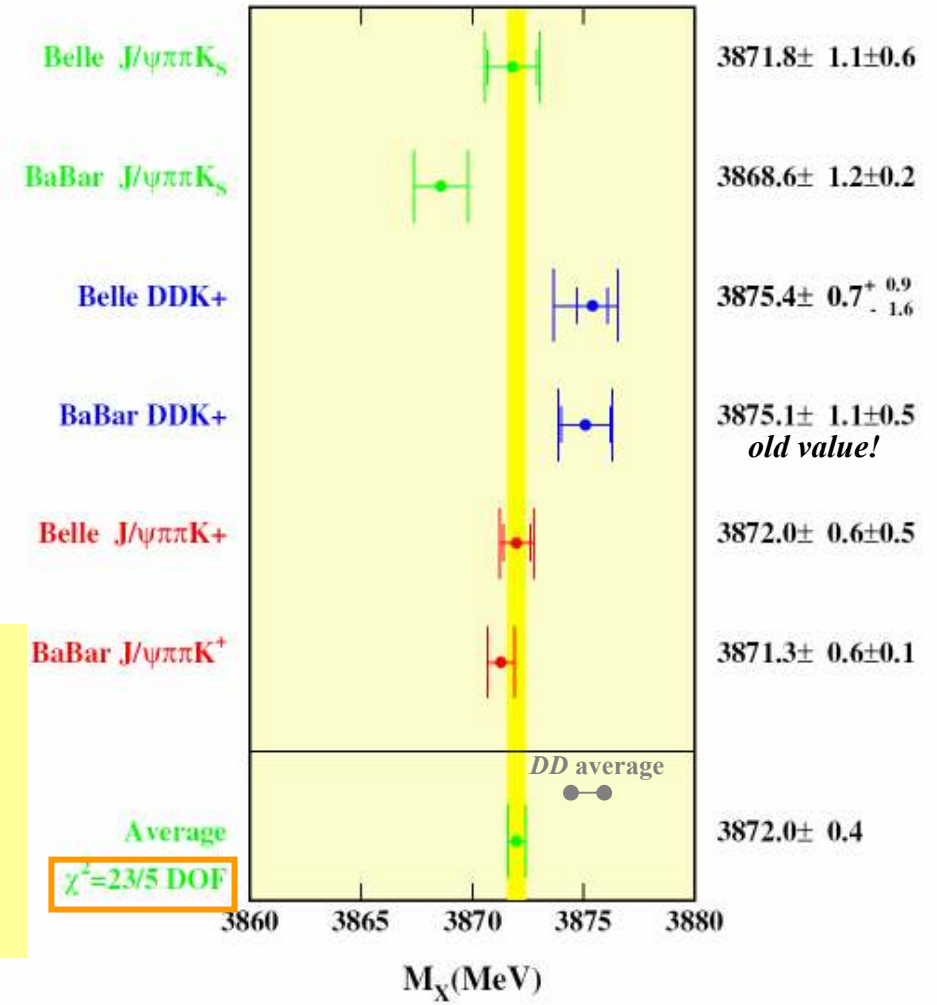
PRL 98,132002 (2007)



Only compatible options $J^{PC}=1^{++}$ or 2^{-+} (and with $J(\pi\pi)=1$)

Belle (**hep-ex/0505038**) disfavours $P = -1 \rightarrow J^{PC}=1^{++}$ is favoured; 2^{-+} not excluded (arXiv:0710.5191).

- Poor agreement among mass measurements:
  - $X \to J/\psi\pi^+\pi^-$ and $X \to D\bar{D}^{(*)}$ differ by ~3σ
  - $X \to J/\psi\pi^+\pi^-$ in neutral and charged B mesons differ by ~1.5σ
- Two different states maybe?

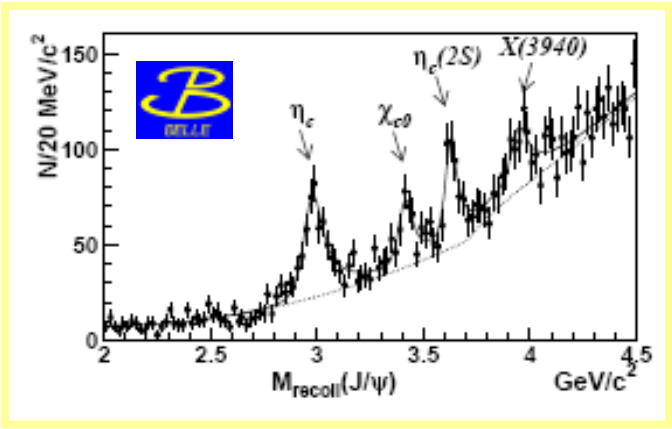


- What is the X ?
  - Not fitting well in the $c\bar{c}$ spectrum.
  - Above $D\bar{D}$ threshold: allowed decays to open charm if $1^{++} \to$ should have larger width
  - $J/\psi\,\rho$ highly suppressed for charmonium (isospin violation)

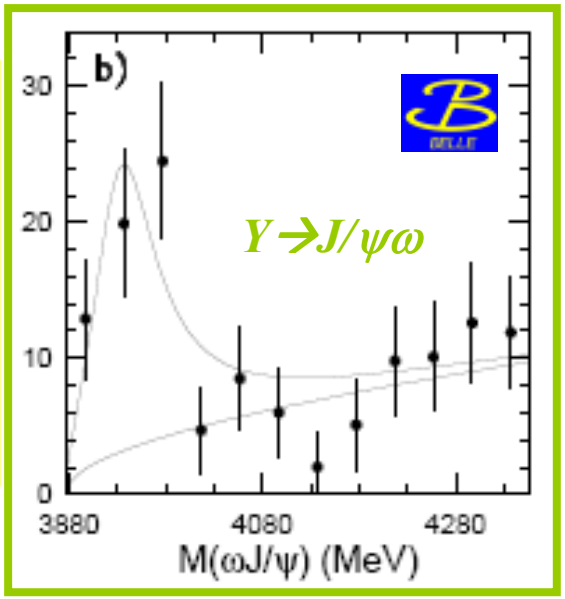
- $D\bar{D}^*$ molecule ?
  - Right above the threshold
  - Favours $D\bar{D}^*$ decay over $J/\psi\pi\pi$ over $J/\psi\gamma$ (as observed)
- Tetraquark ?
  - Explains small width
  - Predicts a set of 4 states (2 charged and 2 neutral). Finding the charged states is critical

States Around 3940 MeV

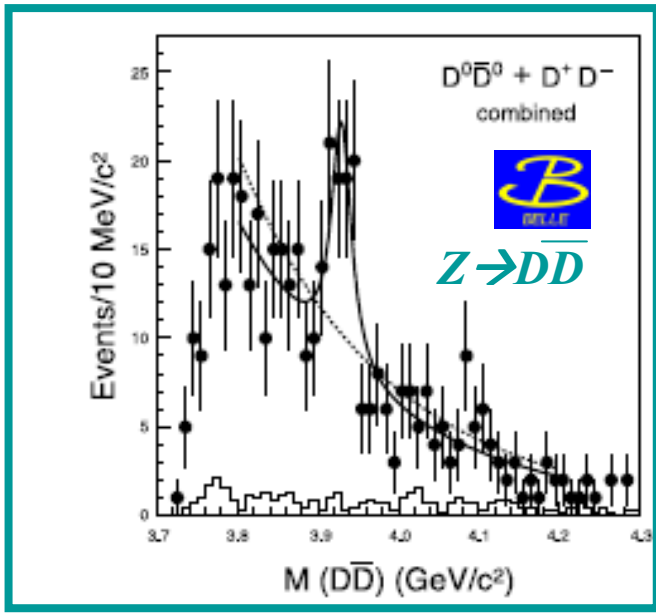
- Discovered by Belle.



PRL 98, 082001 (2007)



PRL 94, 182002 (2005)



PRL 96, 082003 (2006)

	Observed in	J^{PC} (?)	M (MeV)	Γ (MeV)
X	$e^+e^- \to J/\psi X\ (X \to D\bar{D}^*)$	$0^{-+}, 1^{++}$	3943±8	<39
Y	$B \to Y K\ (Y \to J/\psi\ \omega)$	1^{++},…	3943±17	87±34
Z	$\gamma\gamma \to Z\ (Z \to D\bar{D})$	2^{++}	3929±5	29±10

Z: properties consistent with $\chi_{c2}(2P)$.

- 3 different states?

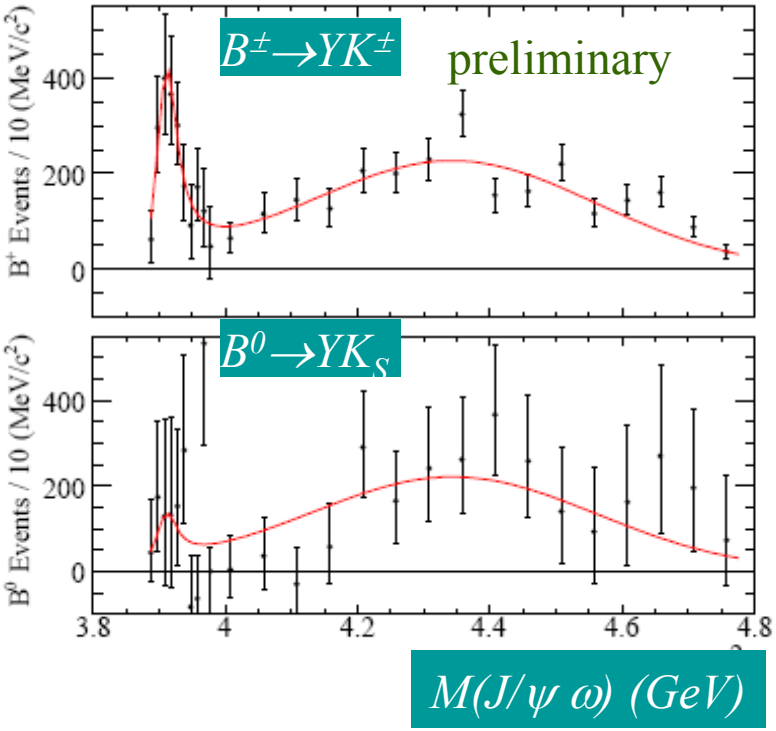
arXiv:0711.2047

ω: $0.7695 < m(\pi^+\pi^-\pi^0) < 0.7965$ GeV

- *Y(3940):* new result, based on 350 fb^{-1}:

$$M(Y) = (3914.6^{+3.8}_{-3.4}(stat)^{+1.9}_{-1.9}(syst))\ \mathrm{MeV}/c^2$$
$$\Gamma(Y) = (33^{+12}_{-8}(stat)^{+5}_{-5}(syst))\ \mathrm{MeV}.$$

- Belle's result for $B \to Y K$, $Y \to J/\psi\omega$ confirmed
  - ~30MeV lower mass than Belle's
  - Narrower width
  - Clear demonstration of decay into ω
  - Preliminary BF estimate similar to Belle (~10^{-5})
- No evidence of $X(3872) \to J/\psi\,\omega$ in the m(3π) analysis window for ω.



$$\frac{BR(B^0 \to Y K^0) \times BR(Y \to J/\psi\,\omega)}{BR(B^+ \to Y K^+) \times BR(Y \to J/\psi\,\omega)} = 0.30^{+0.29}_{-0.24}{}^{+0.04}_{-0.01} < 0.79,\ 95\%\ \mathrm{C.L.}$$

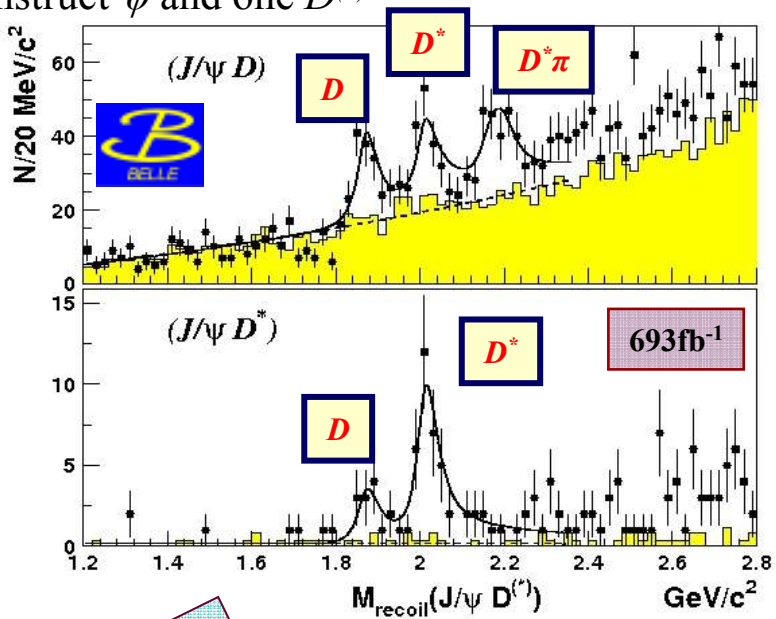
- Study of $e^+e^- \to J/\psi\,X$ and $\gamma\gamma \to D\overline{D}$ by *BABAR* in progress: results awaited soon.

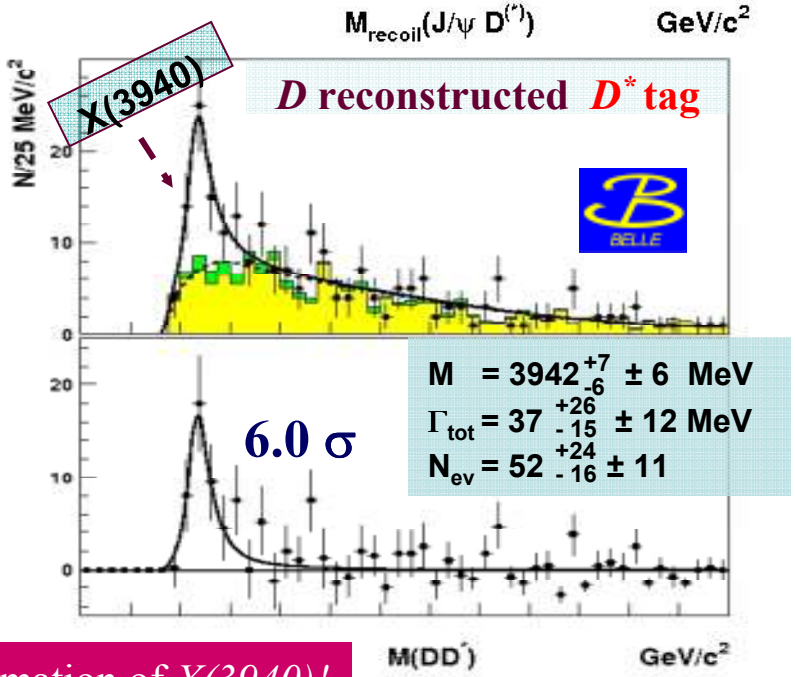
Study of $e^+e^- \to J/\psi\, D^{(*)}\bar{D}^{(*)}$

P.Pakhlov's talk

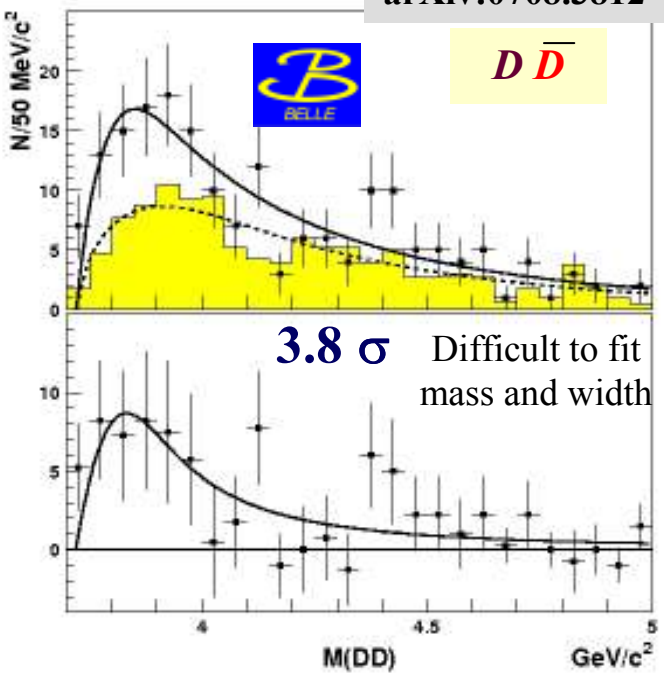
arXiv:0708.3812

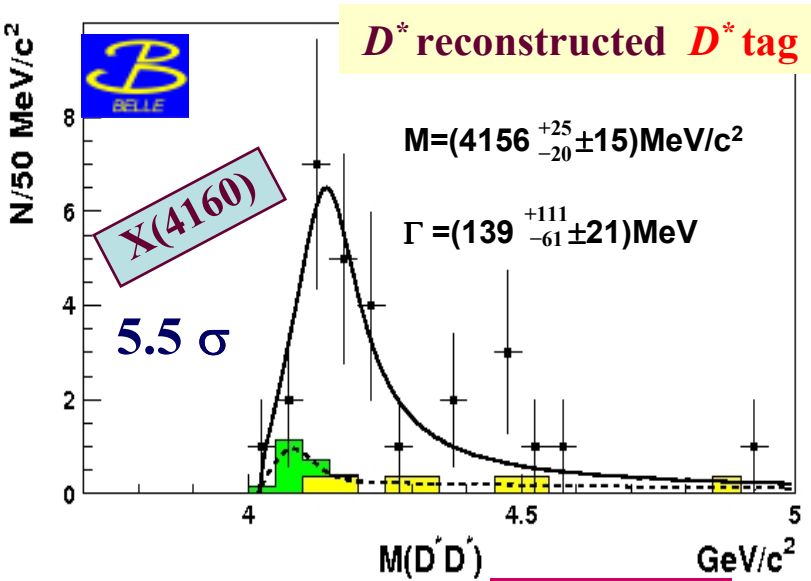
- Reconstruct ψ and one $D^{(*)}$





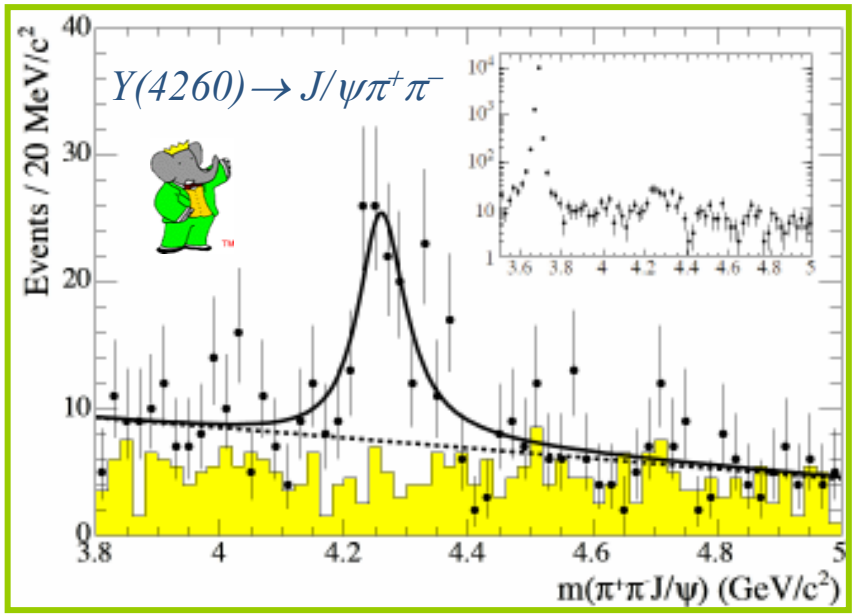
Confirmation of *X(3940)!*





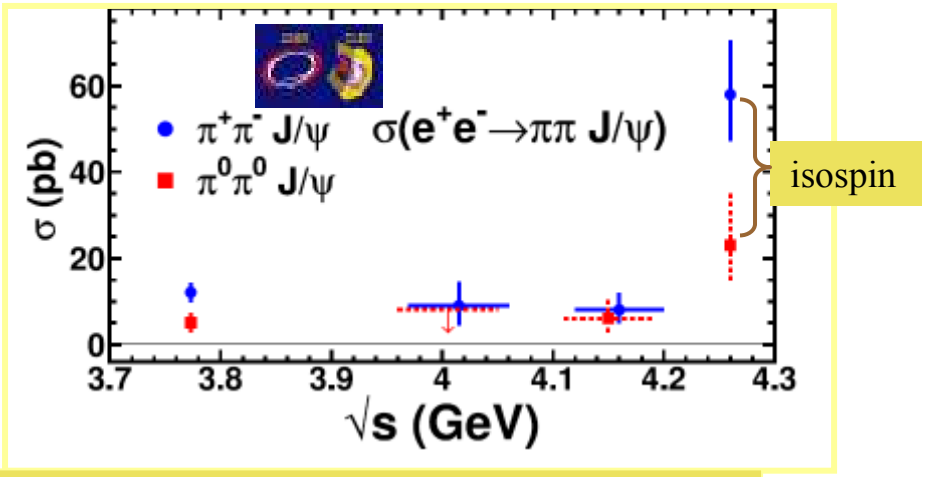
Very unlikely $\psi(4160)$. A new state?

New $J^{PC} = 1^{--}$ States

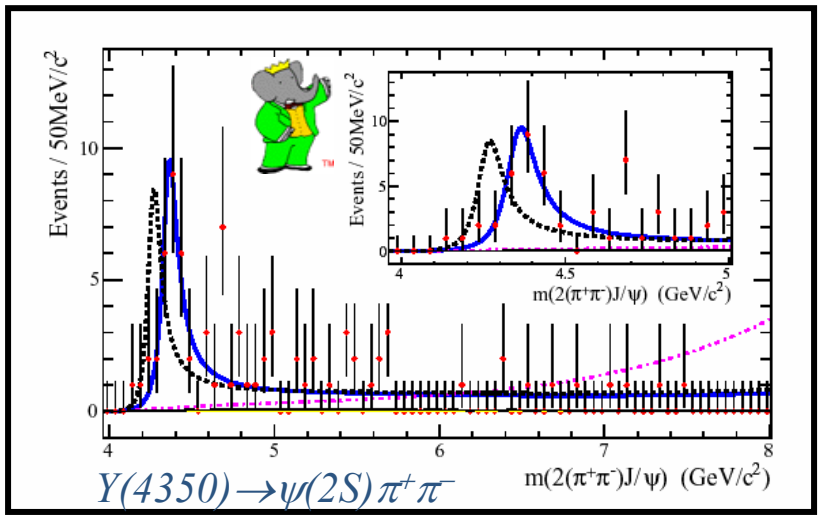


A new state: *Y(4260)*
PRL 95, 142001 (2005)

Evidence of *Y(4260)* also in *B* decays:
$BR(B^+ \to YK^+, Y \to \psi\pi^+\pi^-) = (2.00 \pm 0.70 \pm 0.20) \times 10^{-5}$
PRD73, 011101 (2006)



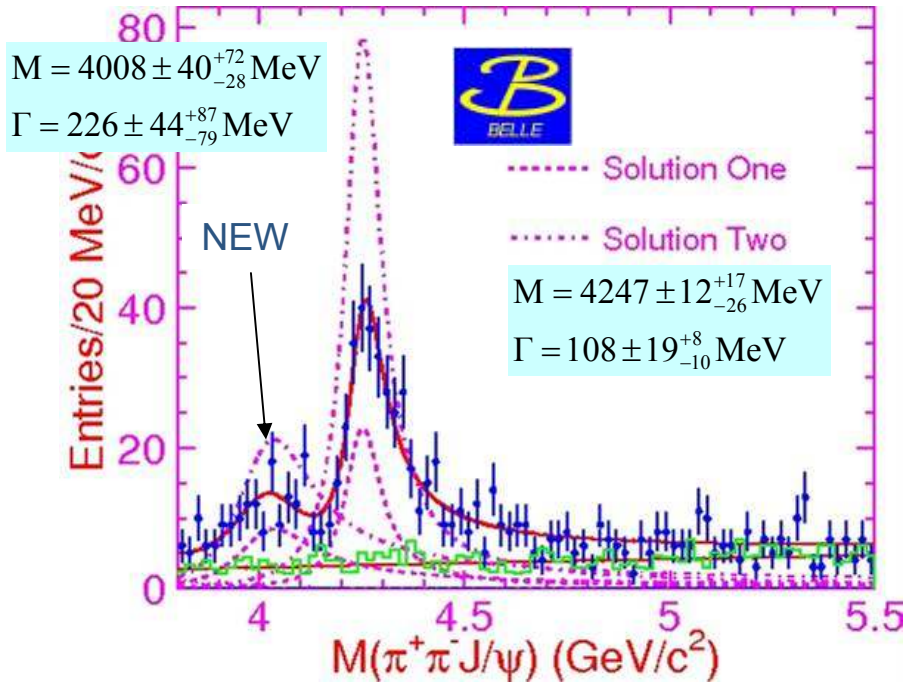
Confirmation + $J/\psi\pi^0\pi^0$; also $J/\psi KK$
CLEO PRD74, 091104 (2006)
CLEO PRL 96, 162003 (2006)



Yet another state *Y(4350)*
PRL 98, 212001 (2007)

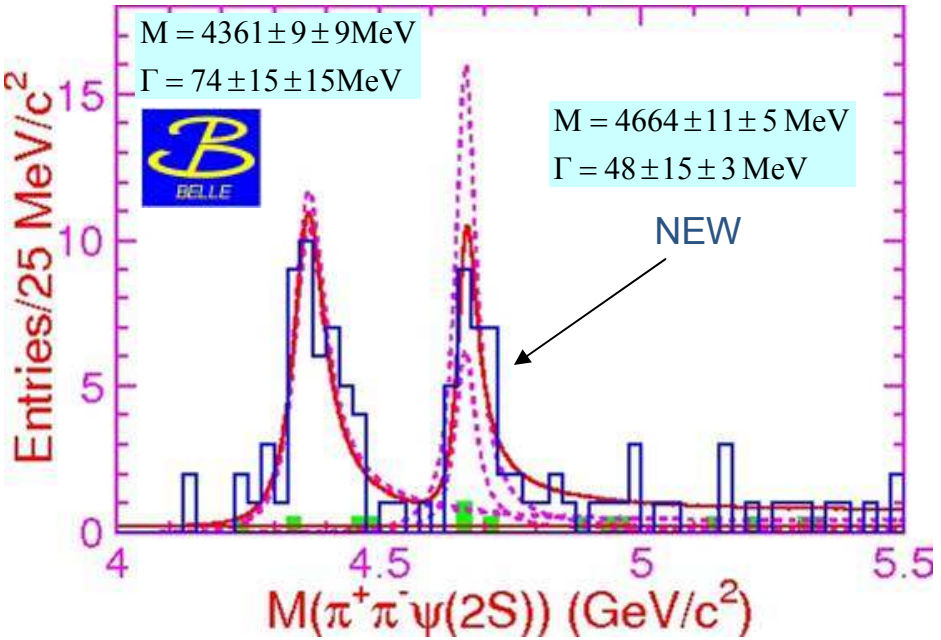
$J/\psi\ \pi^+\ \pi^-$

arXiv:0707.2541



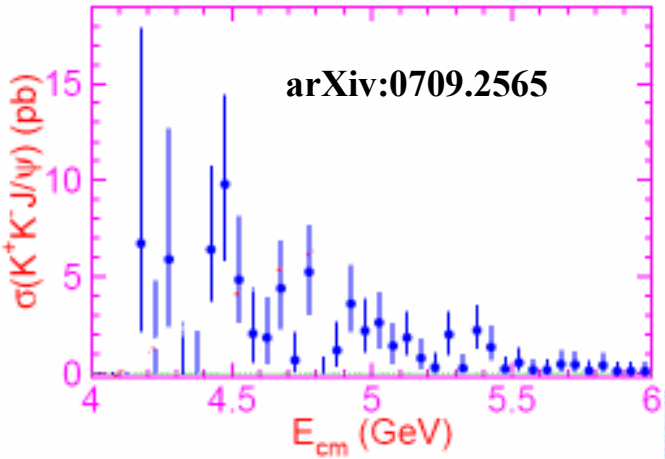
$\psi(2S)\ \pi^+\ \pi^-$

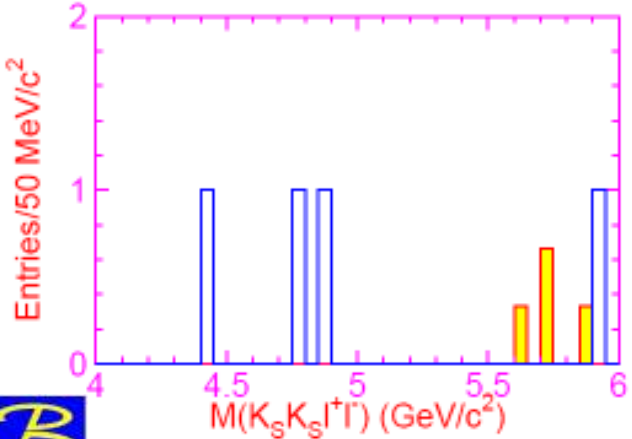
Phys.Rev.Lett. 99, 142002 (2007)



$J/\psi\ K\ K$

arXiv:0709.2565





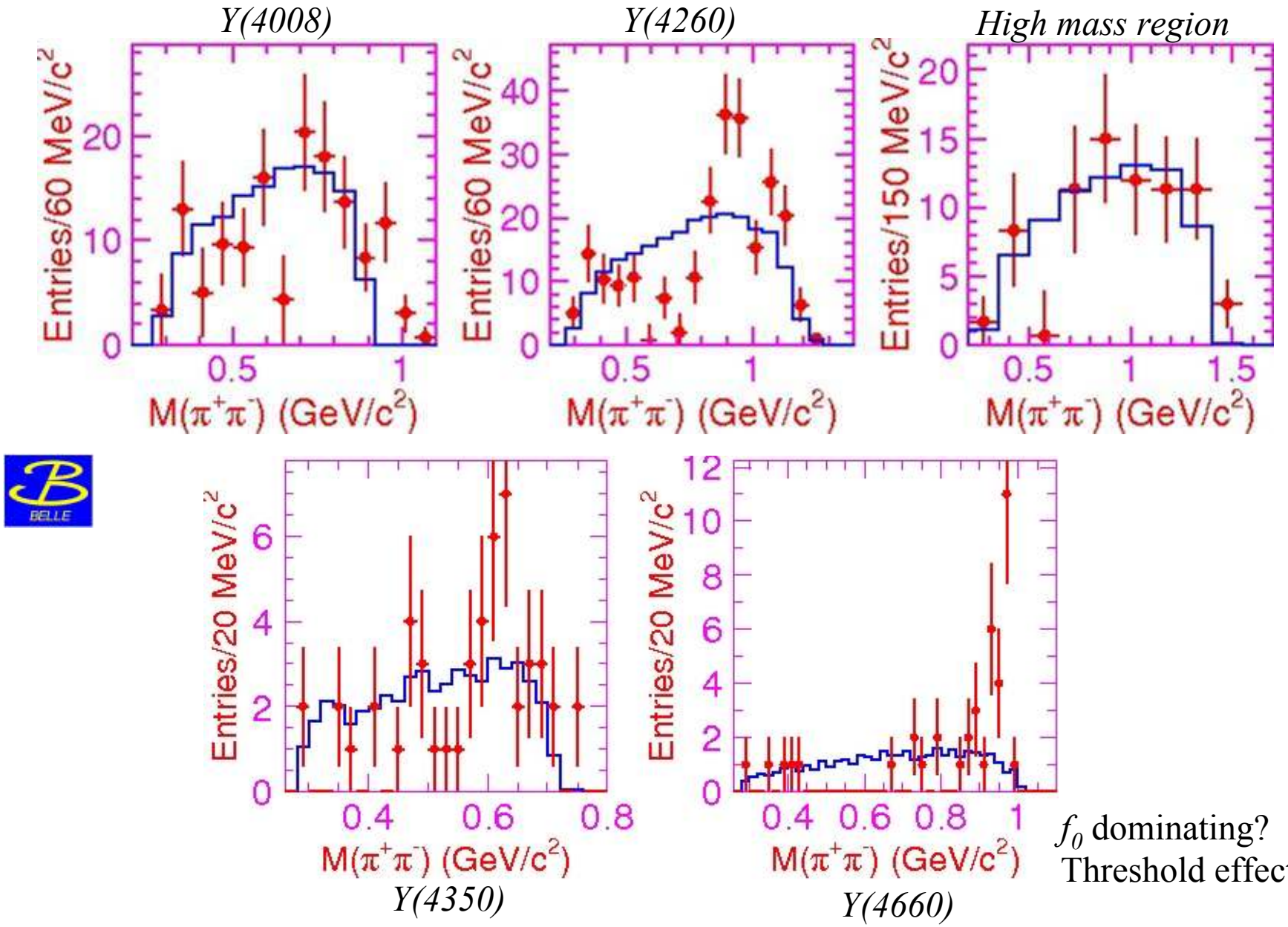
$$\frac{\sigma(e^+e^- \to J/\psi K_s K_s)}{\sigma(e^+e^- \to J/\psi K^+K^-)} = 0.6^{+0.5}_{-0.4}$$

consistent with isospin (0.5)

C.Z. Yuan's talk

Study of $\pi\pi$ invariant masses

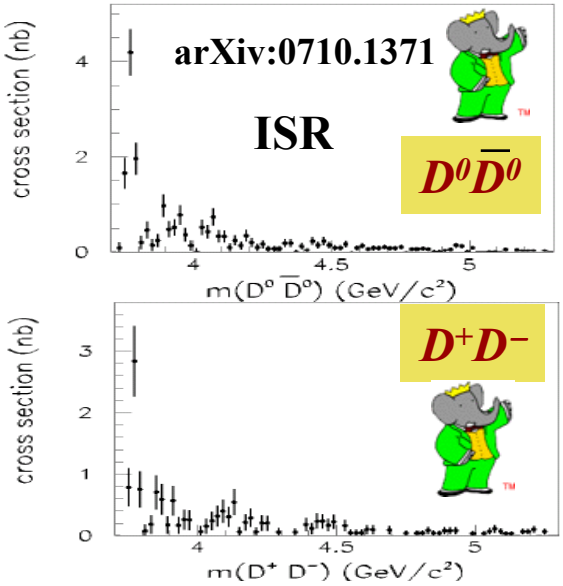
C.Z. Yuan's talk

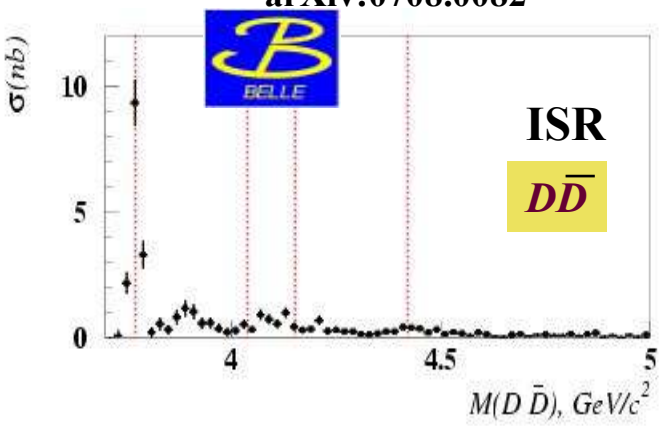


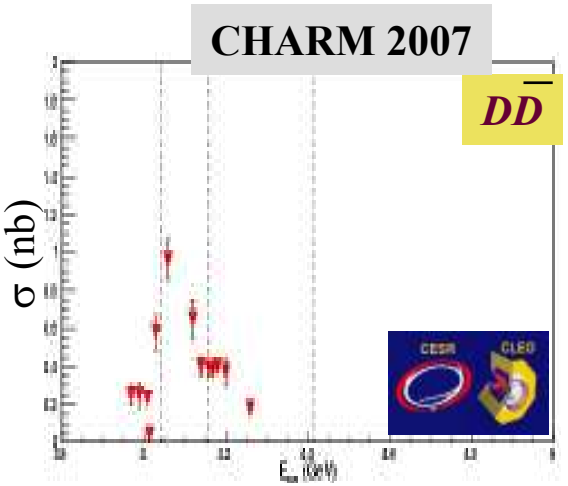
f_0 dominating?
Threshold effects?

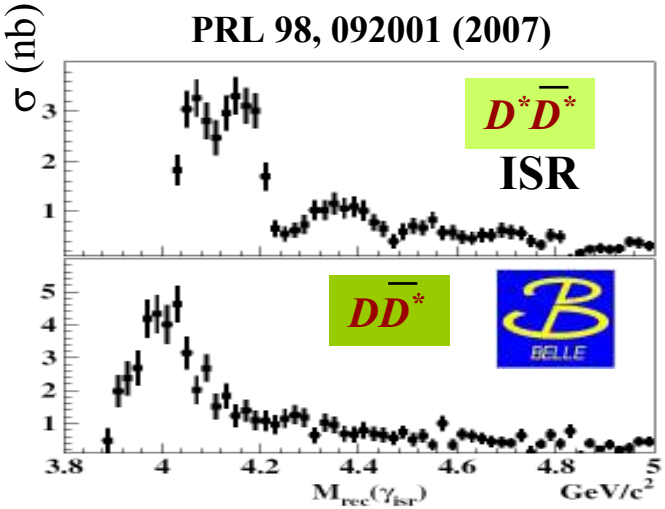
Search for $Y \to D^{(*)}\bar{D}^{(*)}$ Decays

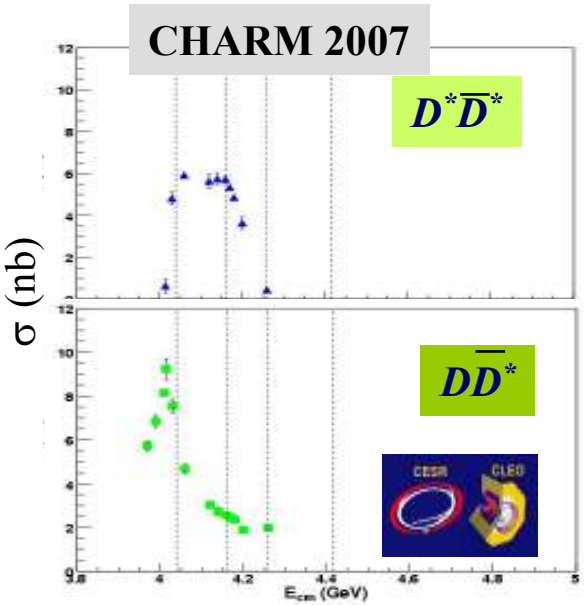
- Can these new 1^{--} states be seen in $D^{(*)}\bar{D}^{(*)}$ decays?

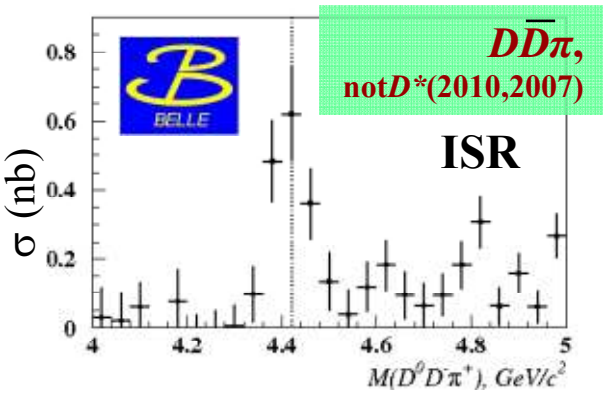








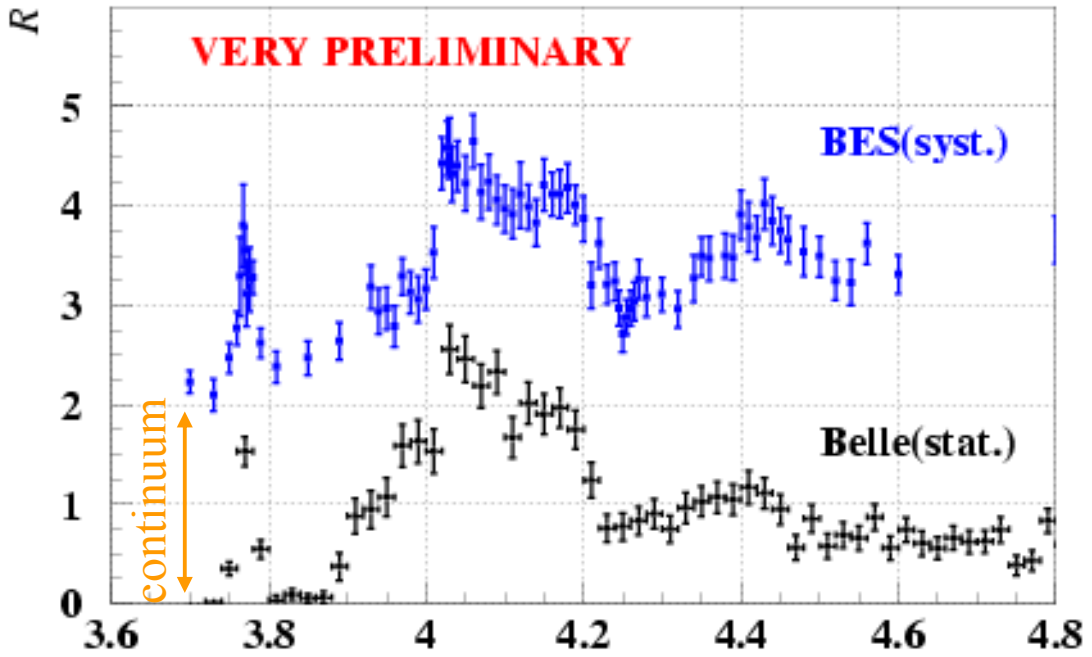




arXiv:0708.3313

C.Z. Yuan's talk

- Summing up all $D^{(*)}\overline{D}^{(*)}(\pi)$ contributions:

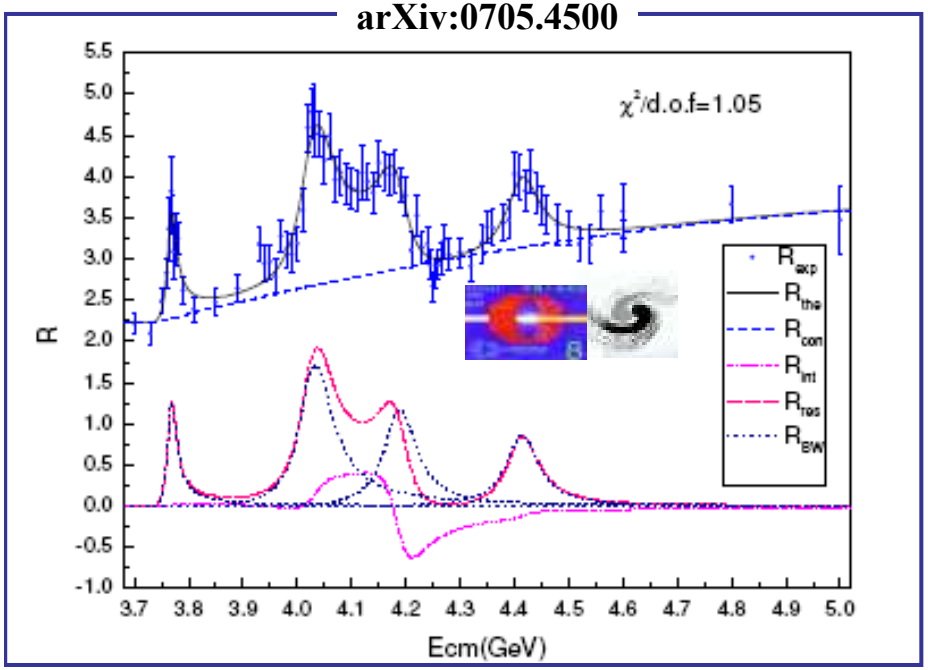


arXiv:0705.4500

- Regular charmonia are clearly visible, nothing else.
- No decays other than $J/\psi PP$ or $\psi(2S)PP$ seen for the new Y states so far.

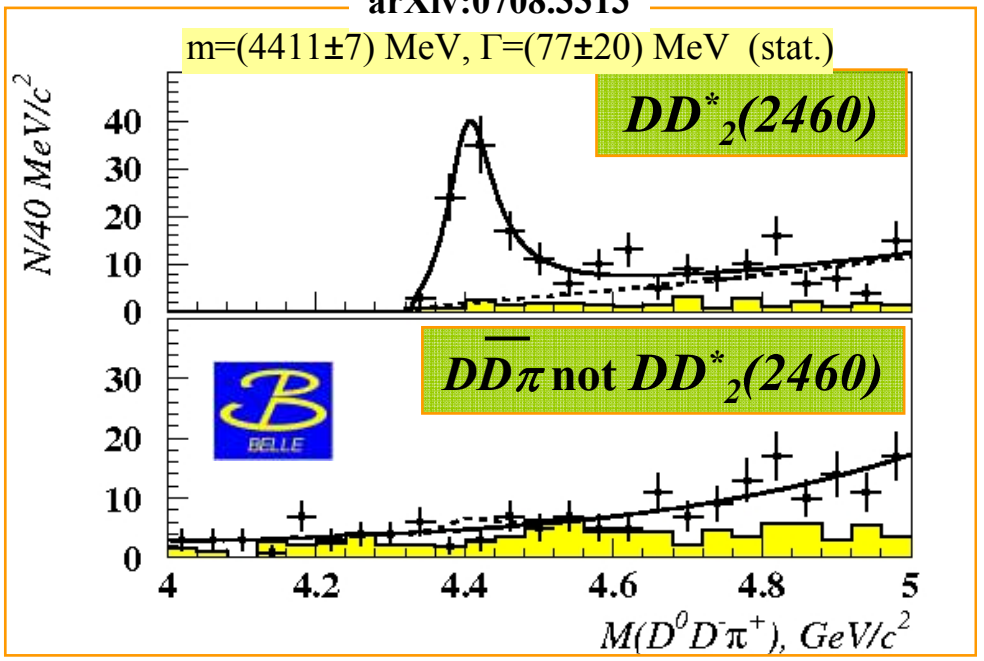
Updates on 1^{--} Charmonium States

arXiv:0705.4500



Interference and energy-dependent hadronic width taken into account.

arXiv:0708.3313



	$\psi(3770)$	$\psi(4040)$	$\psi(4160)$	$\psi(4415)$
M (MeV)	3771.4±1.8	4039±5	4192±6	4415±8
Γ (MeV)	25±7	81±14	73±15	73±21
δ (°)	0	133±68	301±61	246±86

First exclusive decay observed for $\psi(4415)$: $DD^*_2(2460)$ [dominant] $\rightarrow {}^3D_1$ candidate

P.Pakhlov's talk

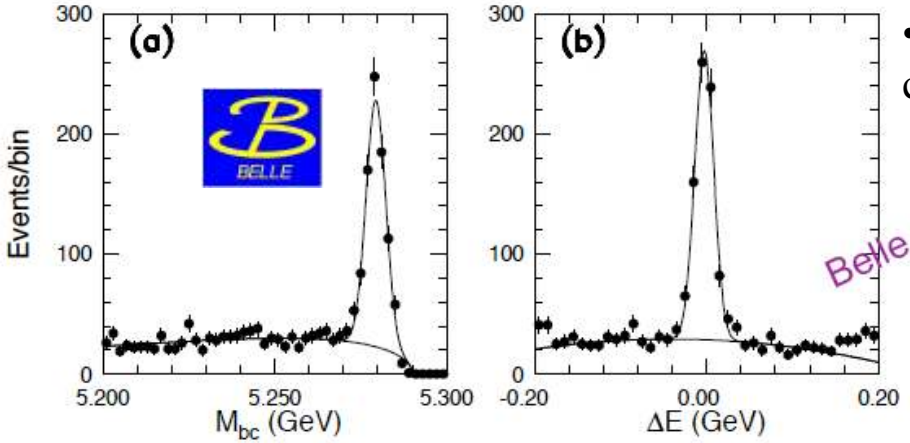
Several results on non-$D\bar{D}$ decays of $\psi(3770)$ by BES and CLEO

BES: see G.Rong's talk

CLEO observes $\psi(3770) \rightarrow \chi_{c0}\gamma$: ratios between $\Gamma(\chi_{cJ}\gamma)$ consistent with $\psi(3770)$ being dominantly ${}^3D_1$
Phys. Rev. D 74, 031106 (2006)

$Z(4430)^{\pm}$

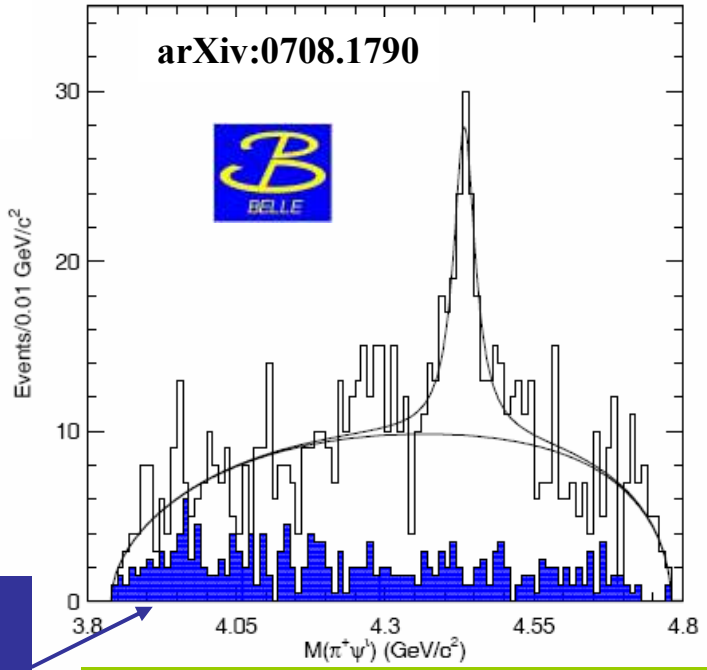
S.Olsen's talk



• Reconstruction of $B \to \psi(2S)\pi^+ K$ ($K\pi$ pairs consistent with $K^*(890)$ and $K^*(1430)$ removed)

Belle preliminary

$B^- \to Z^- K_s$ or $B^0 \to Z^- K^+$
$Z^- \to \psi(2S)\pi^-$



Total significance: 7.3σ

M = (4433±4±1) MeV
$\Gamma = (44^{+17}_{-13}{}^{+30}_{-11})$ MeV

Too narrow to be a reflection

$BF(B \to KZ) \times BF(Z \to \psi(2S)\pi) = (4.1 \pm 1.0 \pm 1.3) \times 10^{-5}$

Background from ΔE sideband

BF and mass consistent between $B^{\pm}$ and B^0 within errors;
$BF_{\pm}/BF_0 = 1.0 \pm 0.4$

- **First charged charmonium-like object !**
- If it's a meson, it's exotic!

- Analysis by *BABAR* in progress.

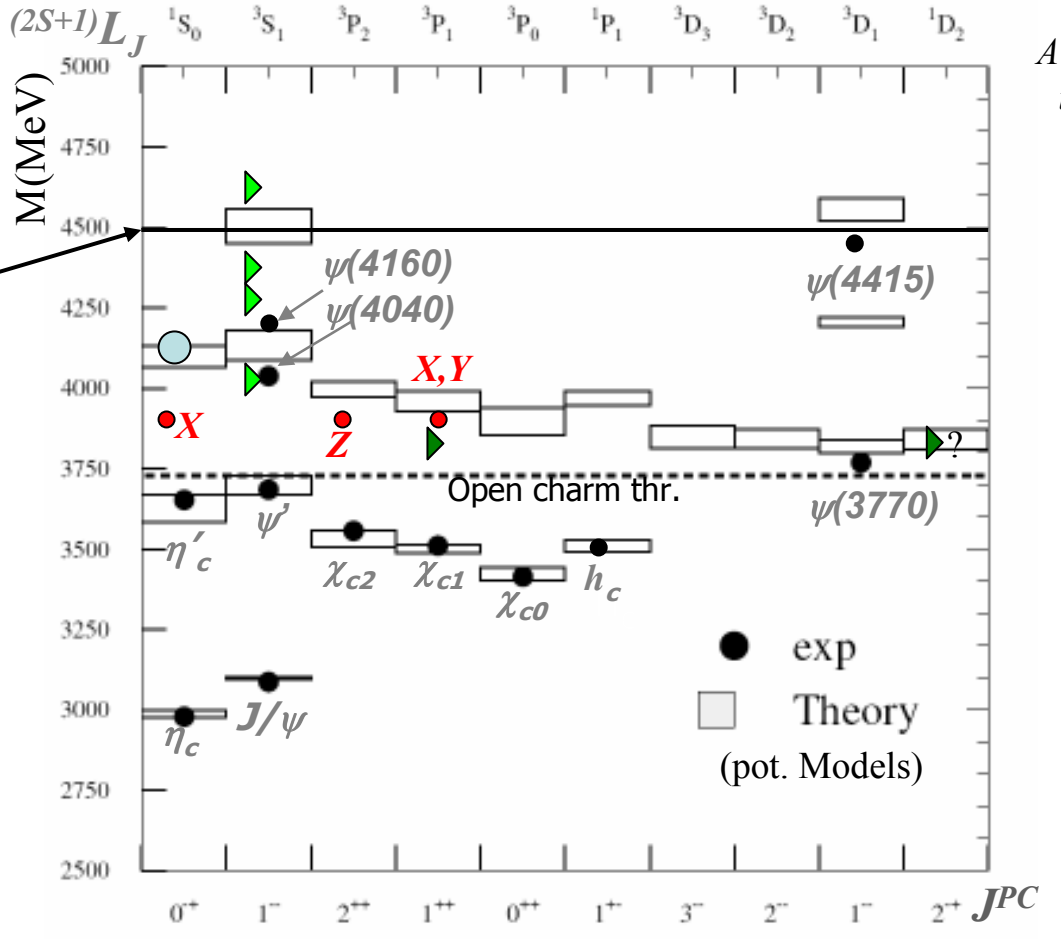
Summary and Conclusions

- New 1^{--} states: charmonia, tetraquarks, molecules, hybrids?!?

$Z(4430)^+$: first charged state. J^{PC} to be measured.

- $X(4160)$: an $\eta_c(nS)$?
- The "3940 family"

- $X(3872)$ the best tetraquark candidate



A drawing just to guide the discussion!

- A very large number of new results reported by *BABAR*, Belle, BES and CLEO.
- Constant improvement of the properties of states with hidden charm.
- And yet new states are being reported! New spectroscopies unveiled?

Backup Slides

The *BABAR* Experiment

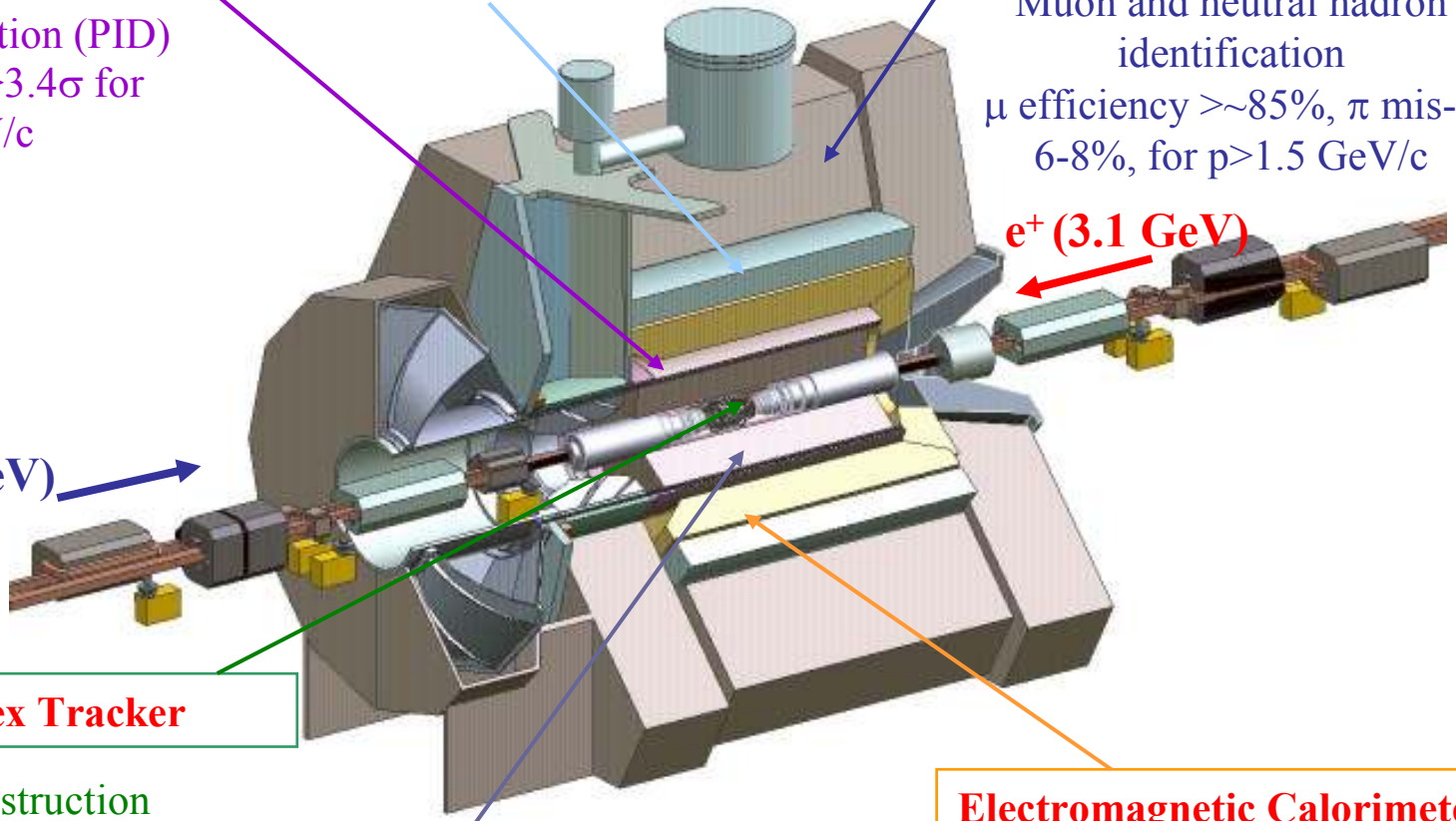
Cherenkov Detector

Particle identification (PID)
K-π separation >3.4σ for
p<3.5GeV/c

Solenoid 1.5T

Instrumented Flux Return

Muon and neutral hadron identification
μ efficiency >~85%, π mis-id 6-8%, for p>1.5 GeV/c



Silicon Vertex Tracker

Vertex reconstruction and tracking + dE/dx.
Efficiency ~ 97%

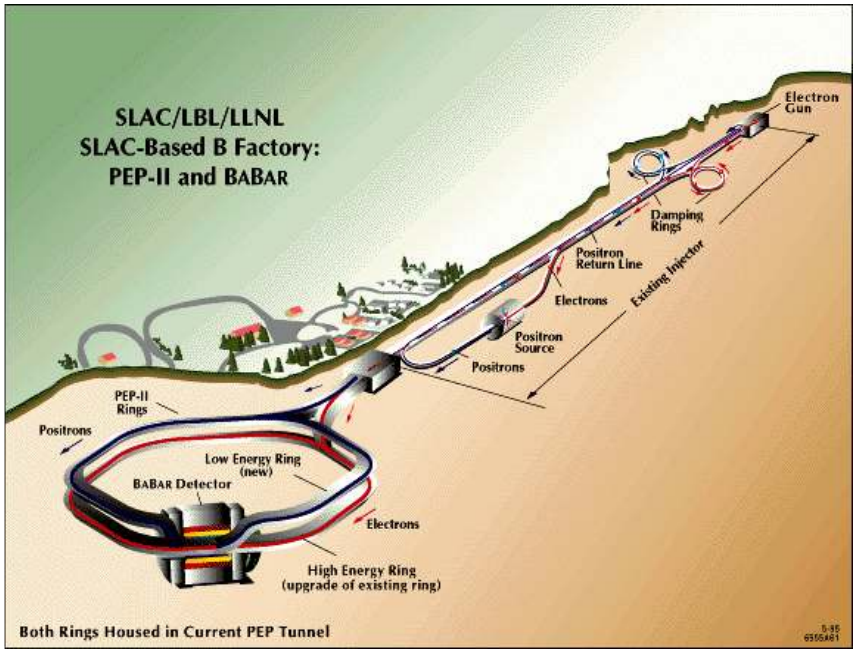
Drift Chamber

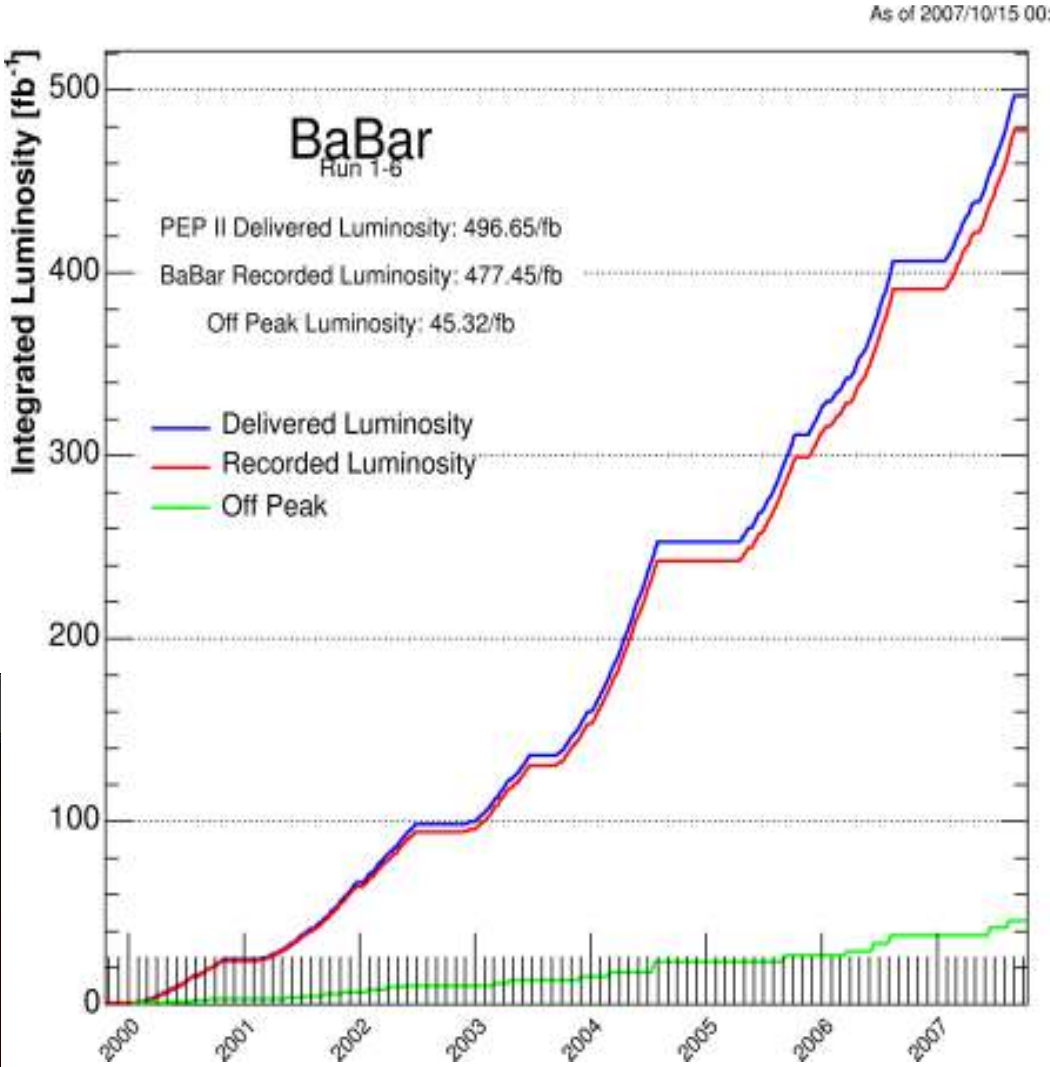
Momentum measurement for charged particles + dE/dx.
$\sigma(p_T)/p_T = 0.13\% p_T \oplus 0.45\%$

Electromagnetic Calorimeter

Electron and photon energy measurement.
$\sigma(E)/E = 1.33\% E^{-1/4} \oplus 2.1\%$

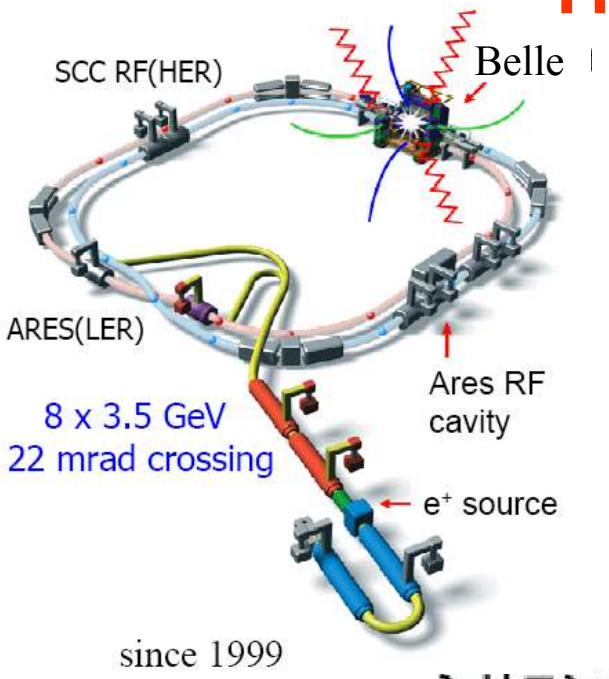
- Beam energies: 9 GeV e^- / 3.1 GeV e^+
- Instantaneous luminosity:
  $L_{peak} \approx 12 \times 10^{33}\ cm^{-2}\ s^{-1}$
- Boost: $\beta\gamma \sim 0.56$





Current data sample

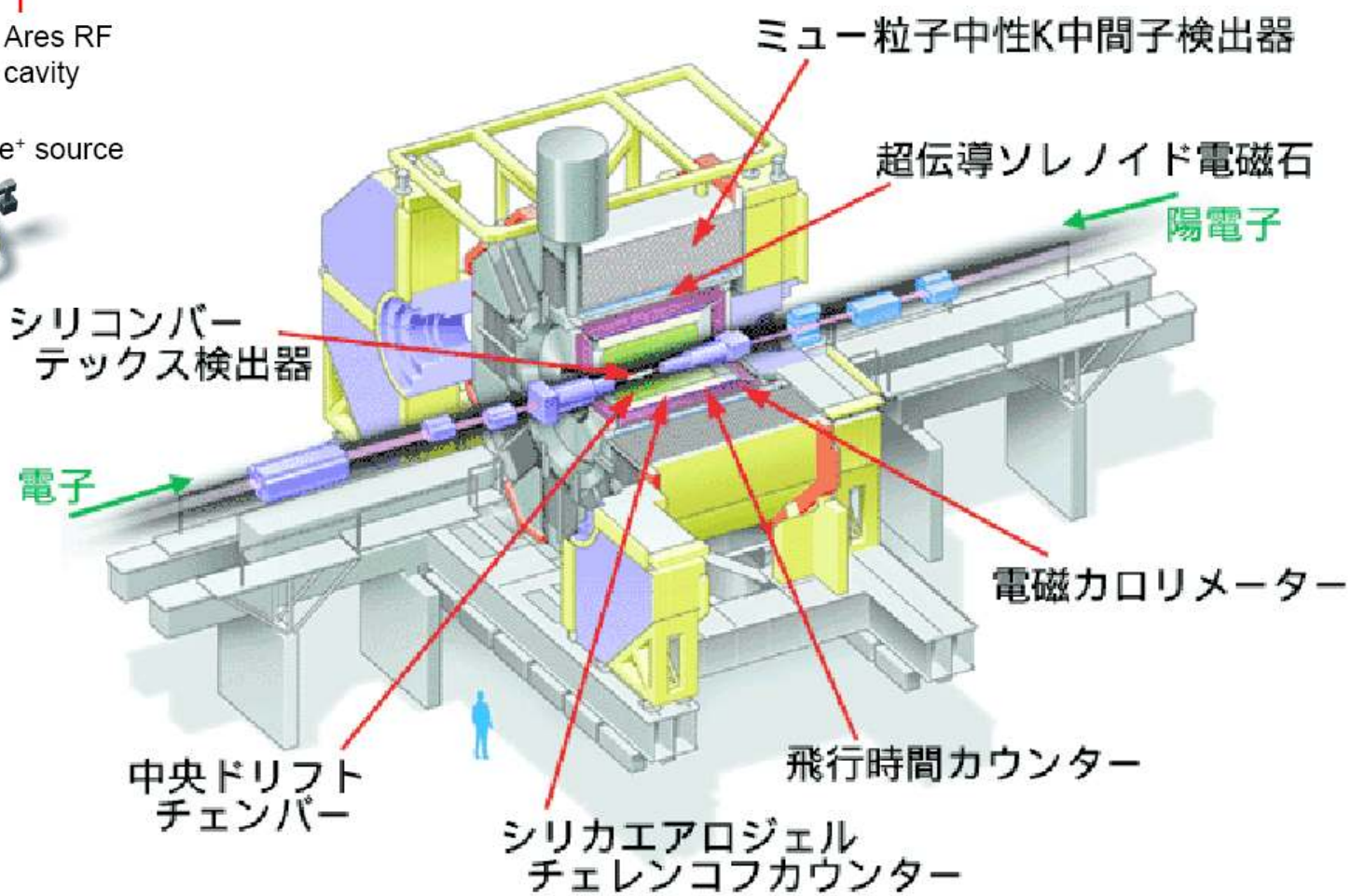
The Belle Experiment



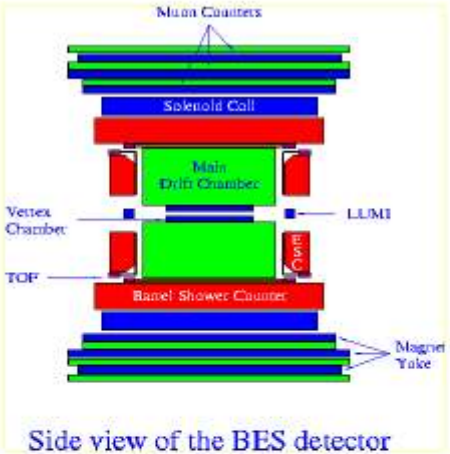
World record:

$L = 1.7 \times 10^{34}/cm^2/sec$

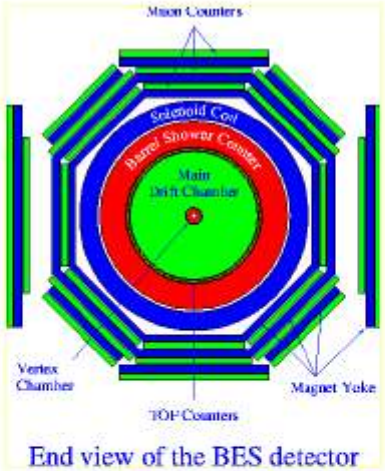
Continuous injection → 1.2 fb^{-1}/day; L_{int} = 743 fb^{-1}



The BES Experiment

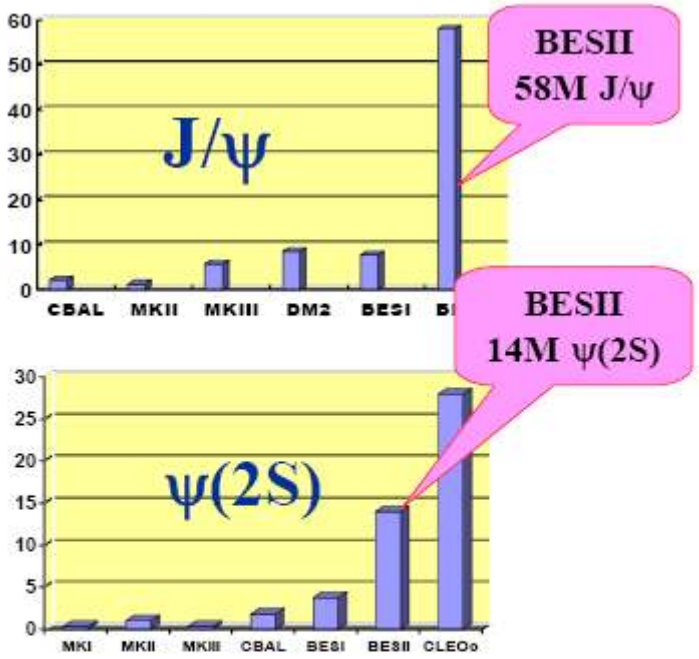


Side view of the BES detector



End view of the BES detector

VC: $\sigma_{xy} = 100$ μm
MDC: $\sigma_{xy} = 220$ μm
$\sigma_{dE/dx} = 8.5$ %
$\Delta p/p = 1.78\sqrt{(1+p^2)}$
μ counter: $\sigma_{r\phi} = 3$ cm
$\sigma_z = 5.5$ cm
TOF: $\sigma_T = 180$ ps
BSC: $\Delta E/\sqrt{E} = 21$ %
$\sigma_\phi = 7.9$ mr
$\sigma_z = 2.3$ cm
B field: 0.4 T



33 pb^{-1} ψ(3770) data

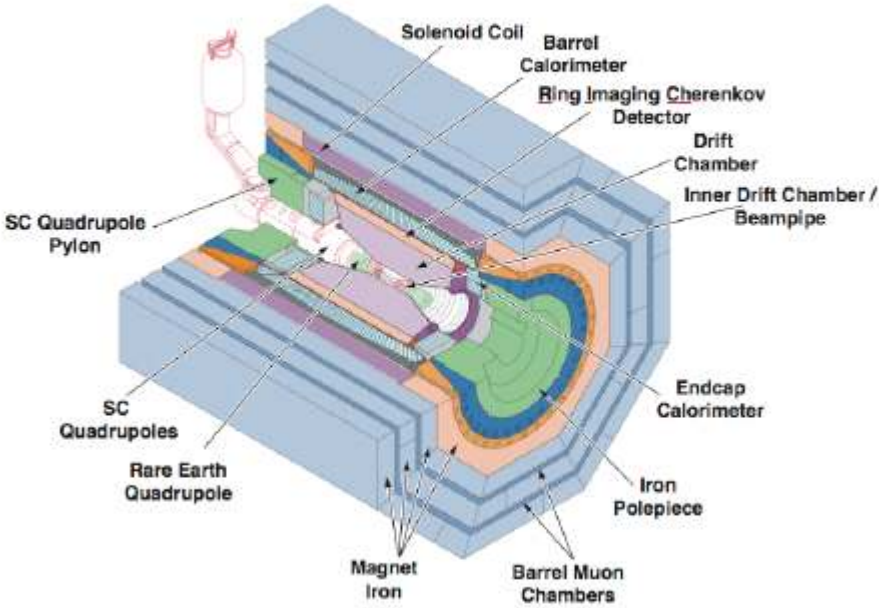
$L \sim 5 \times 10^{30}$ /cm^2·s
at J/ψ
$E_{beam} \sim 1 - 2.5$ GeV

The CLEO-c Experiment

e^+e^- collisions at $\sqrt{s} \sim 4$ GeV

2003 - present

- CLEO-c has collected the following data:
  - 572 pb^{-1} on the $\psi(3770)$
  - about 27 million $\psi(2S)$ decays
  - 21 pb^{-1} of continuum below the $\psi(2S)$
  - 47 pb^{-1} of scan data near $E_{cm} = 4170$ MeV
  - 13 pb^{-1} of data at $E_{cm} = 4260$ MeV
  - 314 pb^{-1} of data at $E_{cm} = 4170$ MeV for D_s physics
  - December 2007: resume data taking at $E_{cm} = 4170$ MeV



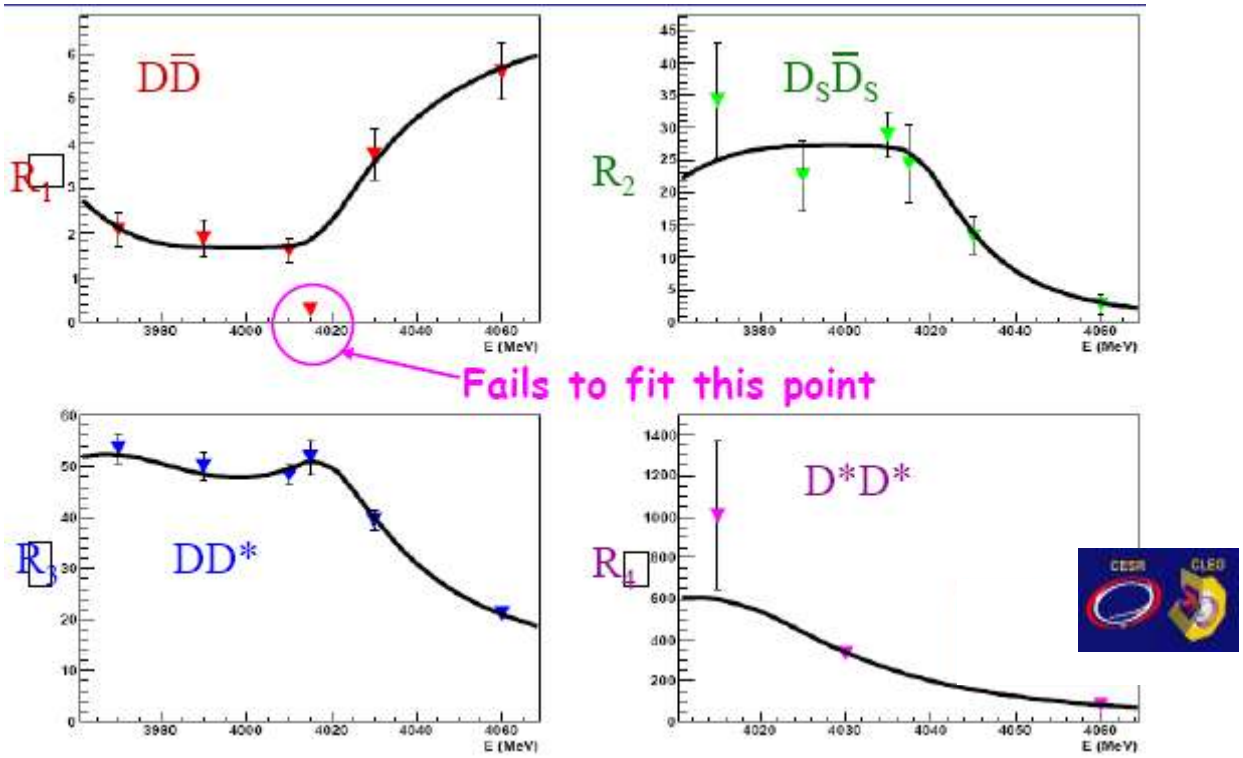
$J/\psi \to K^+K^-\pi^+\pi^-\pi^0$	$(1.92\pm0.08\pm0.15)\times10^{-2}$	$(1.20\pm0.30)\times10^{-2}$
$J/\psi \to K^+K^-\pi^+\pi^-\eta$	$(4.7\pm0.6\pm0.3)\times10^{-3}$	/
$J/\psi \to K(892)^{*+}K^-$	$(5.2\pm0.3\pm0.2)\times10^{-3}$	$(4.2\pm0.4)\times10^{-3}$
$J/\psi \to K^+K^-\eta$	$(8.7\pm1.3\pm0.7)\times10^{-4}$	/
$J/\psi \to \Lambda\Lambda$	$(1.92\pm0.21)\times10^{-3}$	$(1.54\pm0.19)\times10^{-3}$
$J/\psi \to \pi^+\pi^-\pi^0\pi^0$	$(5.74\pm0.74)\times10^{-3}$	/
$\psi' \to 2(\pi^+\pi^-)\eta$	$(1.2\pm0.6\pm0.1)\times10^{-3}$	/
$\psi' \to \Lambda\Lambda$	$(6.0\pm1.5)\times10^{-4}$	$(2.5\pm0.7)\times10^{-4}$
$\psi' \to K^+K^-\pi^+\pi^-\eta$	$(1.3\pm0.7\pm0.1)\times10^{-3}$	/

	$\eta\eta$	$\eta\eta'$	$\eta'\eta'$
χ_{c0}	3.18±0.13±0.18±0.16	< 0.25	2.12±0.13±0.11±0.11
χ_{c2}	0.51±0.05±0.03±0.03	< 0.05	< 0.10

	$\pi^+\pi^-$	$\pi^0\pi^0$	K^+K^-	K_sK_s
χ_{c0}	6.37±0.11±0.20±0.32	2.94±0.07±0.16±0.15	6.47±0.11±0.29±0.32	3.49±0.01±0.15±0.17
χ_{c2}	1.59±0.04±0.06±0.10	0.68±0.03±0.05±0.04	1.13±0.03±0.05±0.07	0.53±0.03±0.02±0.03

CLEO preliminary

PDG CLEO	χ_{c0}	χ_{c1}	χ_{c2}
$p\bar{p}$	22.5±2.7 25.7±1.5±1.5±1.3	7.2±1.3 9.0±0.8±0.4±0.5	6.8±0.7 7.7±0.8±0.4±0.5
$\Lambda\bar{\Lambda}$	47±16 33.8±3.6±2.3±1.7	26±12 11.6±1.8±0.7±0.7	34±17 17±2.2±1.1±1.1
$\Sigma^0\bar{\Sigma}^0$	- 44.1±5.6±2.5±2.2	- <4	- <6
$\Sigma^+\bar{\Sigma}^+$	- 32.5±5.7±4.9±1.7	- <6	- <6
$\Xi^-\bar{\Xi}^-$	<103 51.4±6.0±3.8±2.6	<34 8.6±2.2±0.6±0.5	<37 14.5±1.9±1.0±0.9
$\Xi^0\bar{\Xi}^0$	- 33.4±7.0±3.2±1.7	- <5	- <9



Model of Dubynskiy – Voloshin:
Mod.Phys.Lett. A21, 2779 (2006)

Need interference with a narrow resonance at *D*D** threshold