Charmonium-like Spectroscopy: Potentials of Current Generation of Experiments

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Introduction

- A huge amount of results on states with $c\bar{c}$ content are being reported.
  - *BABAR* and Belle are contributing enormously exploiting largest datasets.
  - great contributions also by BES, CLEO and Tevatron.
  - 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 recent results do not fit well within the ordinary charmonium picture.
- Charmonium: bound states of c and $\bar{c}$.
  - not all J^{PC} quantum numbers allowed (e.g. 0^{--}, 0^{+-}, 1^{-+}, …);
  - below $D\bar{D}$ threshold, only electromagnetic or α_s-suppressed decays: mostly narrower states;
  - above $D\bar{D}$ threshold, mostly broader states.
- QCD foresees a richer spectroscopy: hybrids, tetraquarks, molecules, etc…
  - are we seeing hints of this richer spectroscopy ?

The States with Hidden Charm

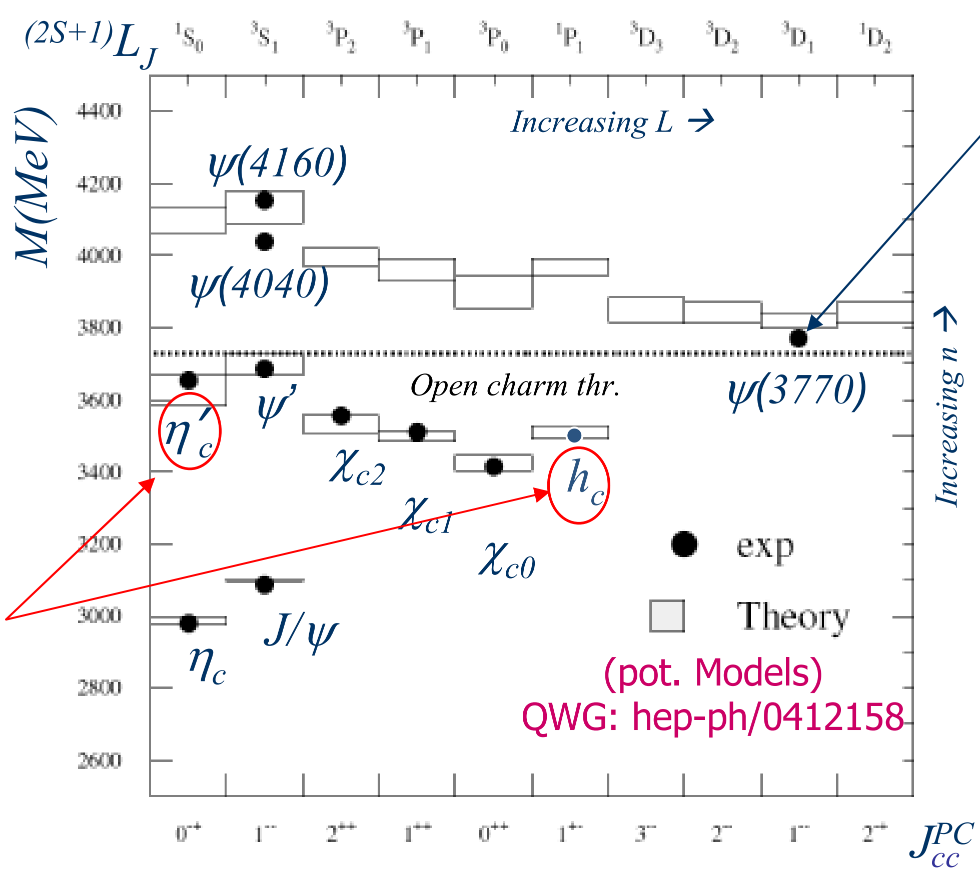
- Several **ordinary charmonia** above threshold are missing: important to identify them.
  - A few are expected to be narrow: $^1D_2$, $^3D_2$ (and $^3D_3$): detectable into $h_c/\chi_c\gamma$ and $\eta_c/\psi\pi\pi$.
  - Many broad states: open charm decays.
- **Hybrids**: $q\bar{q}$+gluons → lightest state 1^{-+}; main decays $D\bar{D}^{**}$.
- **Tetraquarks**: $[qq'][\overline{qq'}]$ → several states foreseen; narrow widths.
- **Molecules**: $[q\bar{q}^{(')}][q\bar{q}^{(')}]$ → less states; also narrow widths.

- **Some clear exotic signatures:**
  - **quantum numbers,**
  - **charged states,**
  - **unnaturally small widths**

- At B-Factories, these states can be accessed using **various production mechanisms**:
  - formation in e^+e^- ISR: can only produce 1^{--} states via single virtual photon;
  - $\gamma\gamma$ collisions: produce C=+ states;
  - B decays: all quantum numbers in principle accessible;
  - $e^+e^- \to \gamma^* \to X_{c\bar{c}} Y_{c\bar{c}}$: the quantum numbers of X and Y must combine to form 1^{--};
  - decays from higher mass charmonium(-like) states: selection rules apply.
- **Large statistics** is very important, especially for $D\bar{D}^{(*)}$ decays.
- Hadron colliders have limited power:
  - can't access all final states; less capabilities of measuring J^{PC}.

Spectrum of Charmonium States

same J^{PC} as J/ψ but mostly D wave



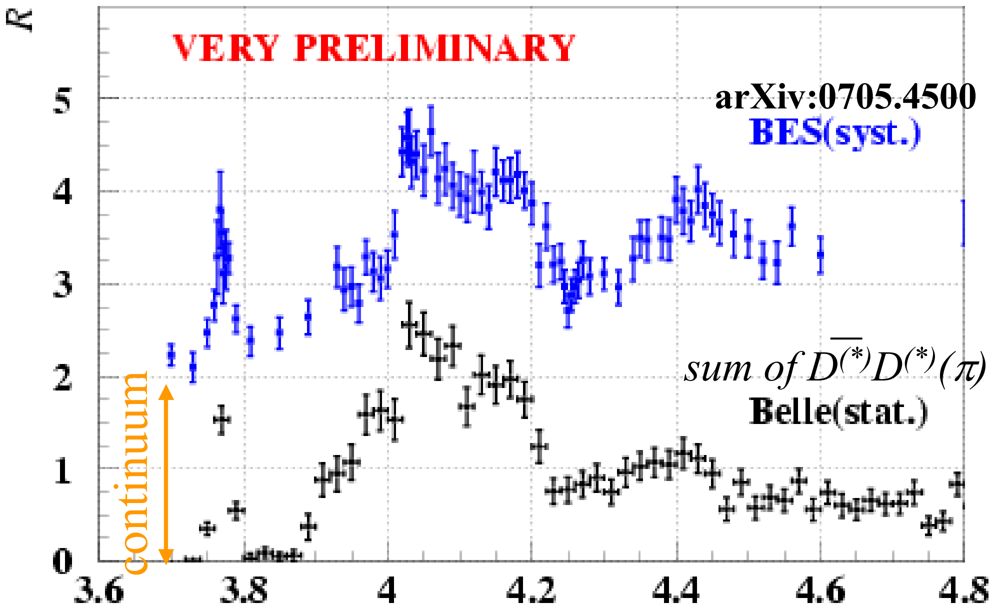
Recent acquisitions

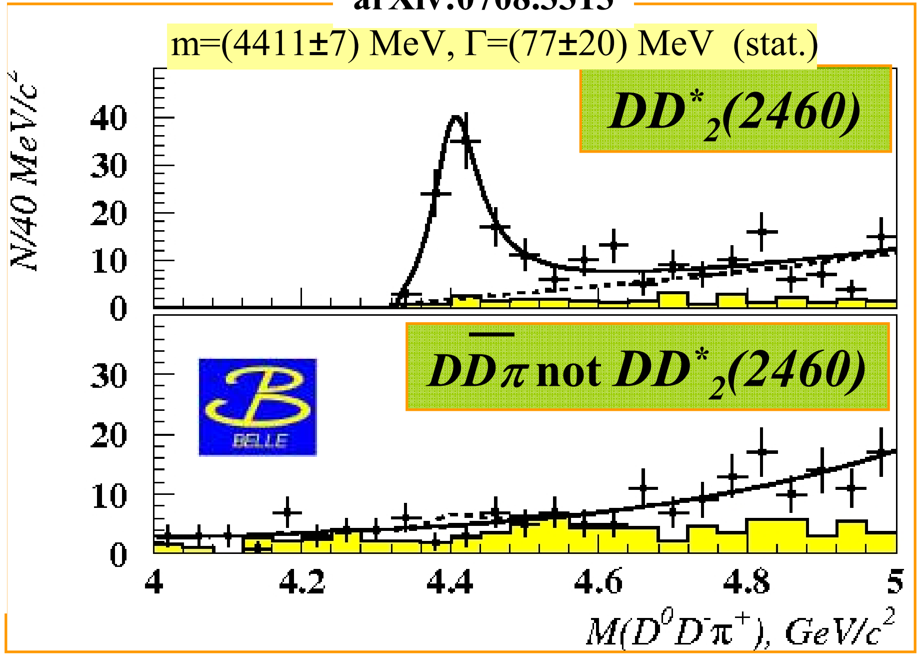
- Basically all states below the open charm threshold are observed and explained.
- Several levels above threshold are still missing.
    - Many states are being discovered in this mass region, but not all fit well within the expected spectrum.

New States Above Threshold

State	experiments	M (MeV)	Γ (MeV)	J^{PC}	Decay modes	Production mechanisms
X(3872)	Belle, CDF, D0, BABAR	3871.2±0.5	< 2.3	1^{++} (2^{-+}?)	$\pi^+\pi^- J/\psi$, $\pi^+\pi^-\pi^0 J/\psi$	B decays, $p\bar{p}$
	Belle, BABAR	$3875.4\pm0.7^{+1.2}_{-2.0}$ $3875.1^{+0.7}_{-0.5}\pm0.5$	$3.0^{+1.9}_{-1.4}\pm 0.9$		$D^0 \bar{D}^0 \pi^0$, DD^*	B decays
Z(3930)	Belle	3929±5±2	29±10±2	2^{++}	$D^0\bar{D}^0, D^+D^-$	$\gamma\gamma$
Y(3940)	Belle, BABAR	3943±11±13 $3914.3^{+3.8}_{-3.4}\pm1.9$	87±22±26 $33^{+12}_{-8}\pm5$	$?^{??}$	$\omega J/\psi$	B decays
X(3940)	Belle	$3942^{+7}_{-6}\pm6$	$37^{+25}_{-15}\pm8$	$?^{?+}$	DD^*	$e^+e^-\rightarrow J/\psi X$
Y(4008)	Belle	$4008\pm40^{+72}_{-28}$	$226\pm44^{+87}_{-79}$	1^{--}	$\pi^+\pi^- J/\psi$	ISR
X(4160)	Belle	$4156^{+25}_{-20}\pm15$	$139^{+111}_{-61}\pm21$	$?^{?+}$	D^*D^*	$e^+e^-\rightarrow J/\psi X$
Y(4260)	BABAR, Cleo, Belle	$4259\pm8^{+8}_{-6}$ $4284^{+17}_{-16}\pm4$ $4247\pm12^{+17}_{-32}$	$88\pm23^{+6}_{-4}$ $73^{+39}_{-25}\pm5$ 108±19±10	1^{--}	$\pi^+\pi^- J/\psi$, $\pi^0\pi^0 J/\psi$, $K^+K^- J/\psi$	ISR
Y(4350)	BABAR Belle	4324±24 4361±9±9	172±33 74±15±10	1^{--}	$\pi^+\pi^-\psi(2S)$	ISR
Z^+(4430)	Belle	4433±4±1	$44^{+17}_{-13}{}^{+30}_{-11}$	$?^{??}$	$\pi^+\psi(2S)$	B decays
Y(4620)	Belle	4664±11±5	48±15±3	1^{--}	$\pi^+\pi^-\psi(2S)$	ISR

Updates on 1^{--} Charmonium States





BES fit: interference and energy-dependent hadronic width taken into account:

	$\psi(3770)$	$\psi(4040)$	$\psi(4160)$	$\psi(4415)$
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**

- CLEO: ratios between $\Gamma(\chi_{cJ}\gamma)$ consistent with $\psi(3770)$ being dominantly $^3D_1$ **PRD 74, 031106 (2006)**
- **No sign of any of the new Y states! Different wrt ordinary charmonia!**

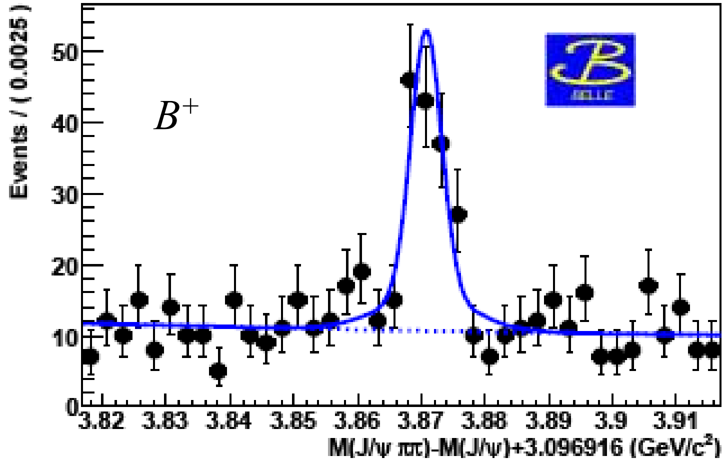
X(3872)

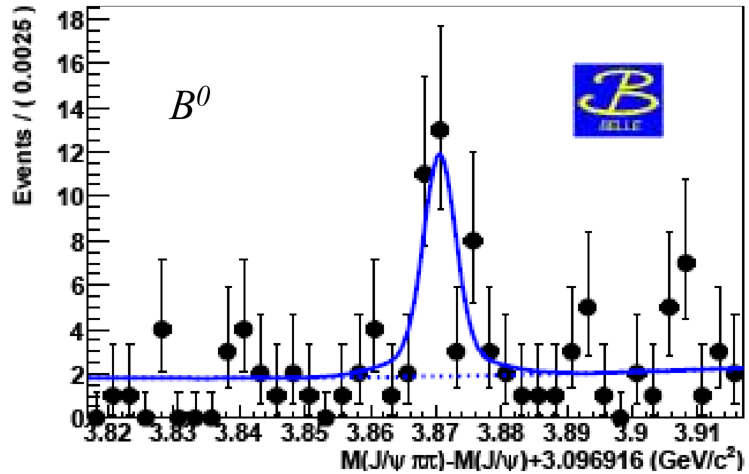
Belle: PRL 91 (2003) 262003
BaBar: PRD71 (2005) 071103
BaBar: PRD73 (2006) 011101
BaBar: PRD74 (2006) 071101
CDF: PRL93 (2004) 072001
D0: PRL93 (2004) 162002

- Decays
  - $X \rightarrow J/\psi \pi^+ \pi^-$
    - Possibly $J/\psi\, \rho$
    - Discovered by Belle; confirmed by *BABAR*, CDF, D0
  - BF($J/\psi\, \omega$) ~ BF($J/\psi\, \rho$)
  - $X \rightarrow J/\psi\, \gamma$
  - 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 → 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**)

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

Belle-CONF-0711



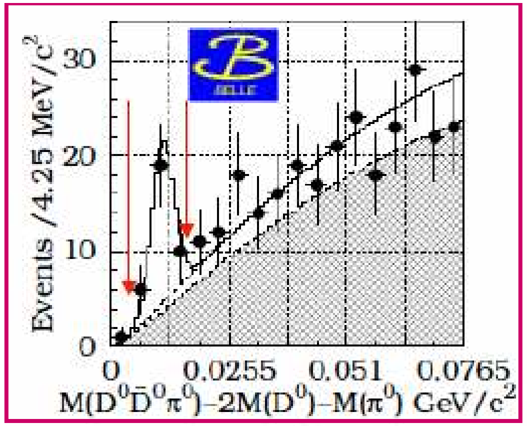


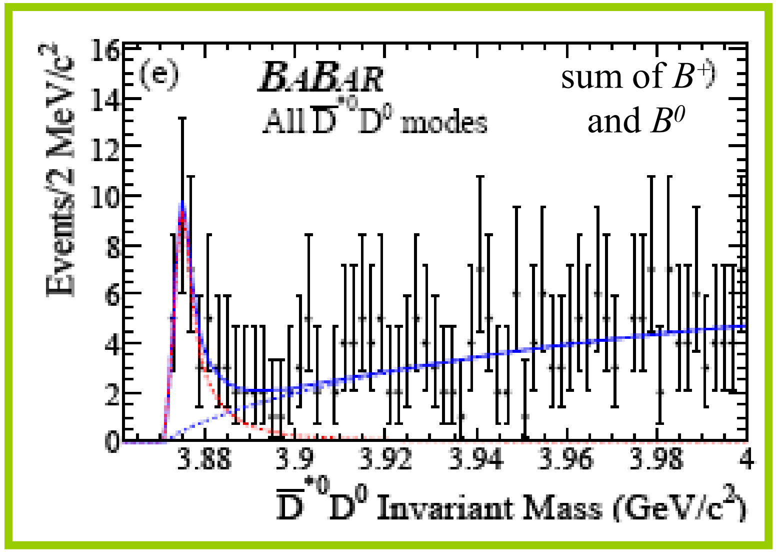
$$\Delta M = (0.22 \pm 0.90 \pm 0.27)\,MeV$$

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

consistent with no mass and rate difference

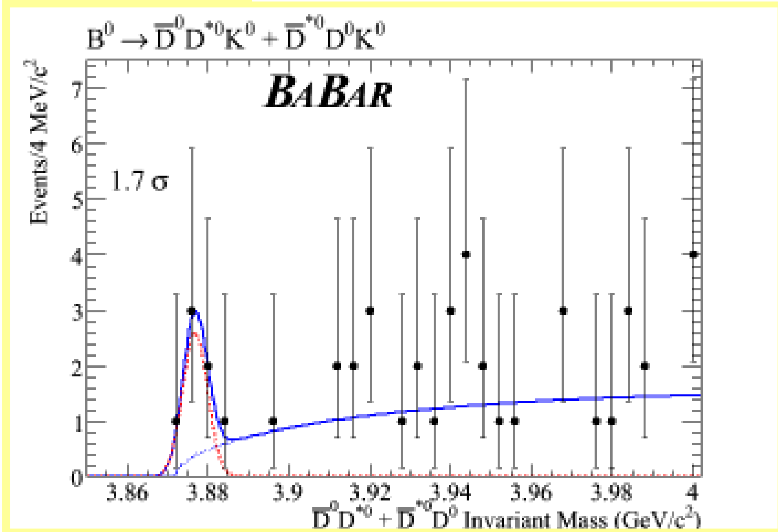
- Belle [**PRL 97, 162002 (2006)**] observed $X(3872) \to D^0\overline{D}^0\pi^0$
  - $BR(B \to X K,\ X \to \overline{D}^0 D^0 \pi^0) = (1.22 \pm 0.31^{+0.23}_{-0.39}) \times 10^{-4}$
- Confirmation by *BaBar* in $B \to D\overline{D}^{*}K$
  - $D^{*0} \to D^0\pi^0$ and $D^0\gamma$





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

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

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

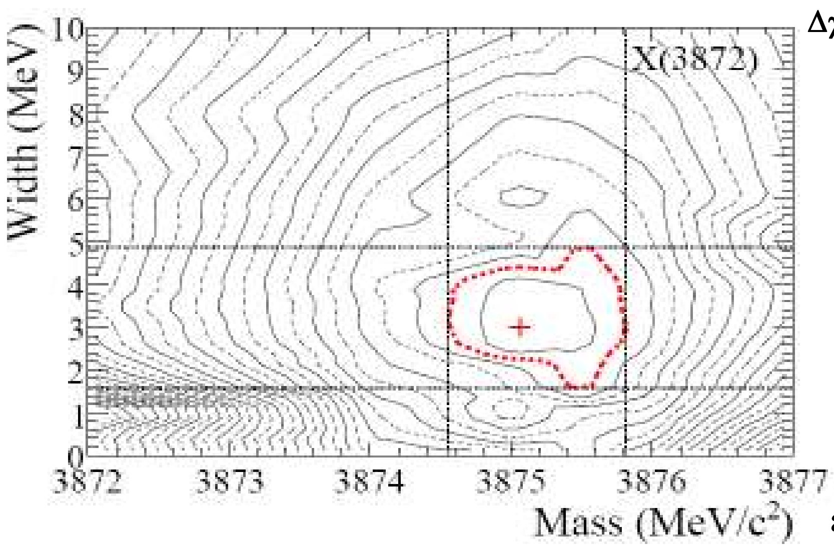
$R_{0/+} = (1.33 \pm 0.69 \pm 0.43)$

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

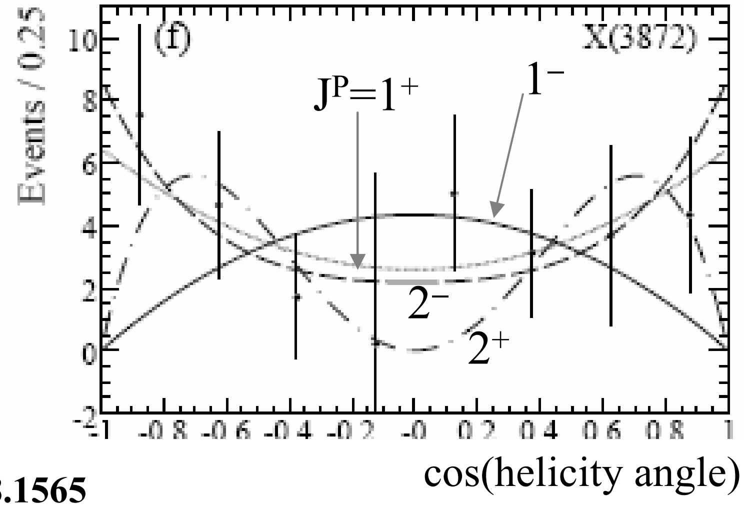
- $D\overline{D}^*$ is favoured over $J/\psi\pi\pi$ and $J/\psi\gamma$:

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

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



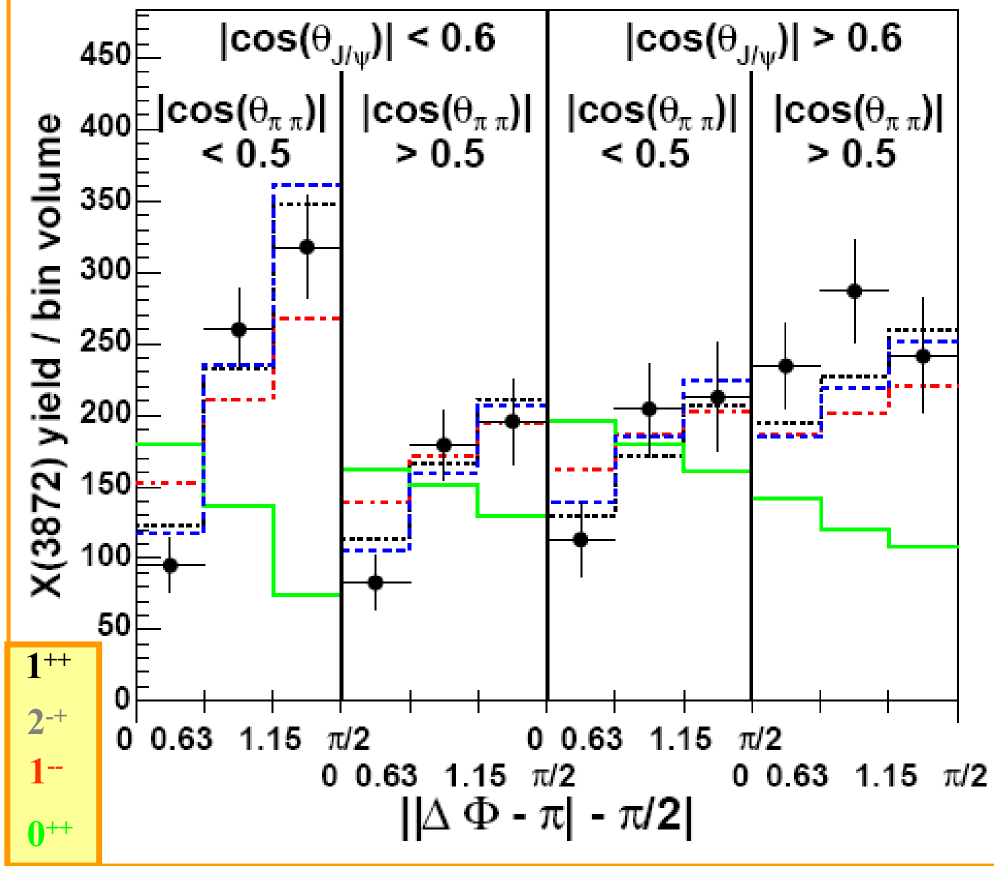
$D\bar{D}^*$



arXiv:0708.1565

$J/\psi\pi\pi$

PRL 98,132002 (2007)

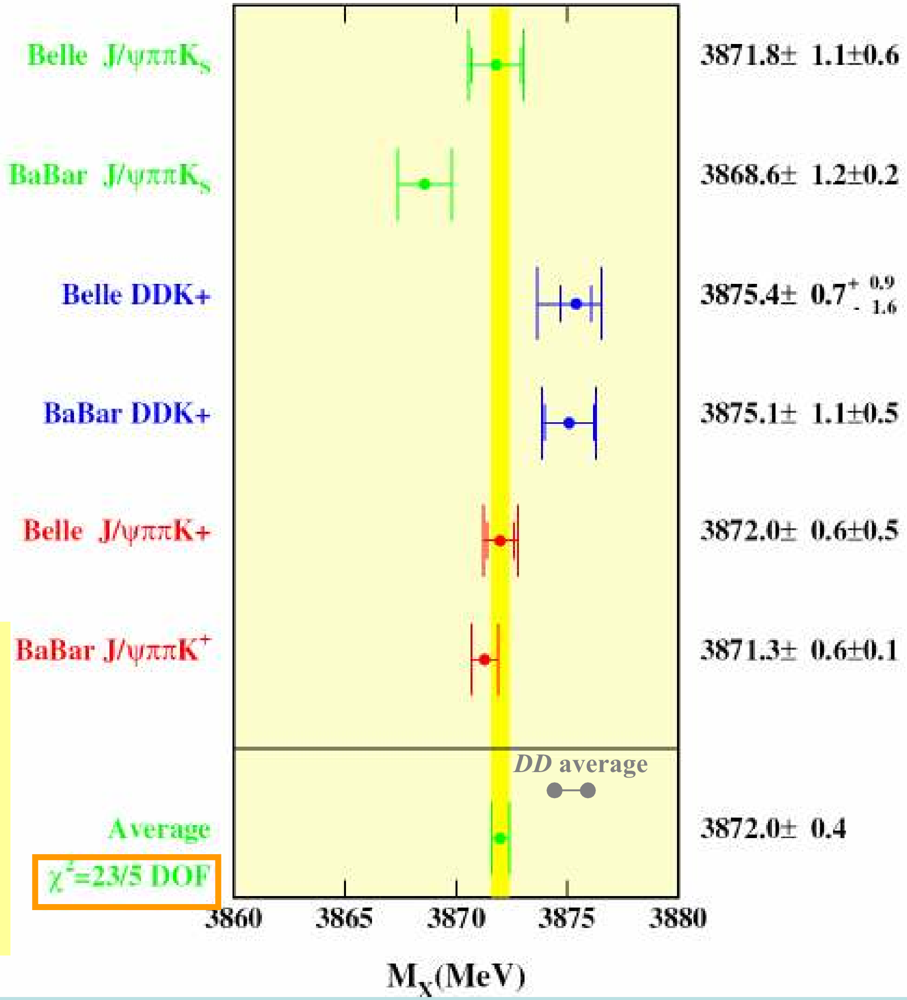


Only compatible options $J^{PC}=1^{++}$ or 2^{-+} (and with $J(\pi\pi)=1$)

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

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

Summary of *BABAR* and Belle mass measurements



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

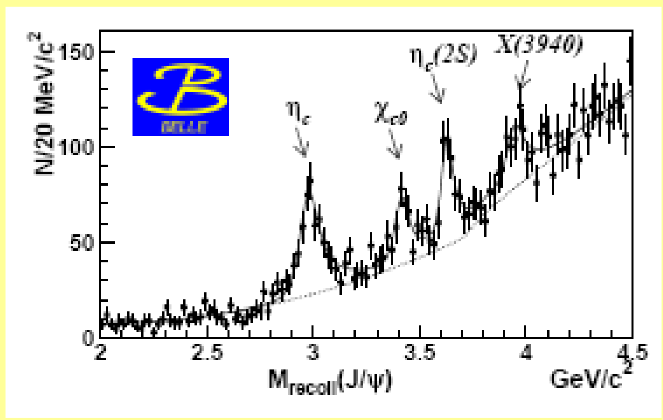
- $D\overline{D}^*$ molecule ?
  - Right above the threshold, but R_{0+} expected smaller.
  - Favours $D\overline{D}^*$ decay over $J/\psi\pi\pi$ over $J/\psi\gamma$ (as observed)
- Tetraquark ?
  - Explains small width
  - Predicts a set of 4 states (2 charged and 2 neutral). Finding the charged states is critical
- Other hypotheses (threshold cusp, charmonium χ_{c1}(2P), hybrid) mostly ruled out.

What can be done on X(3872)

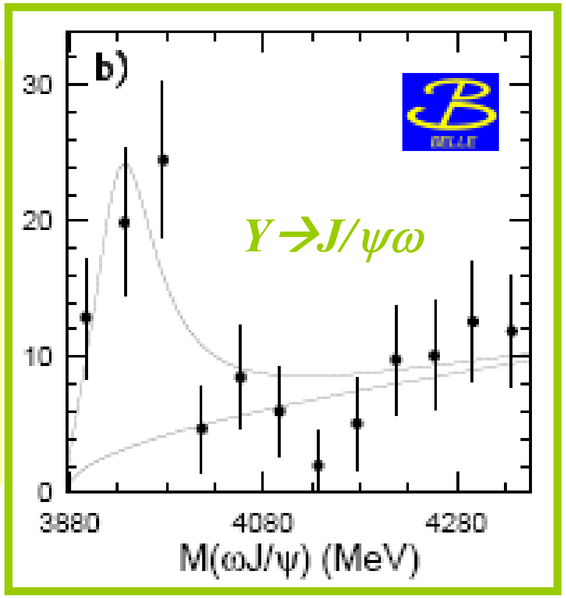
- Resolve the puzzle of how many X states are there.
  - Improve knowledge of lineshape in DD^*
  - Modes with $D^{(*)}$ currently suffer from low statistics
- Resolve between 1^{++} and 2^{-+}
  - Angular analyses require large statistics.
- Reduce the uncertainty on mass differences:
  - The state seen in B^+ and B^0 may be different in some models
- Reduce the uncertainty on R_{0+}:
  - The ratio is different from 1 in some models
- Identify or put more stringent limits on charged partners
- Search for more decay modes and production mechanisms
  - Limits on $J/\psi\pi^0\pi^0$
  - $X \rightarrow \psi(2S)\,\gamma$;
  - B decays other than XK^+ and XK_s.
  - …

States Around 3940 MeV

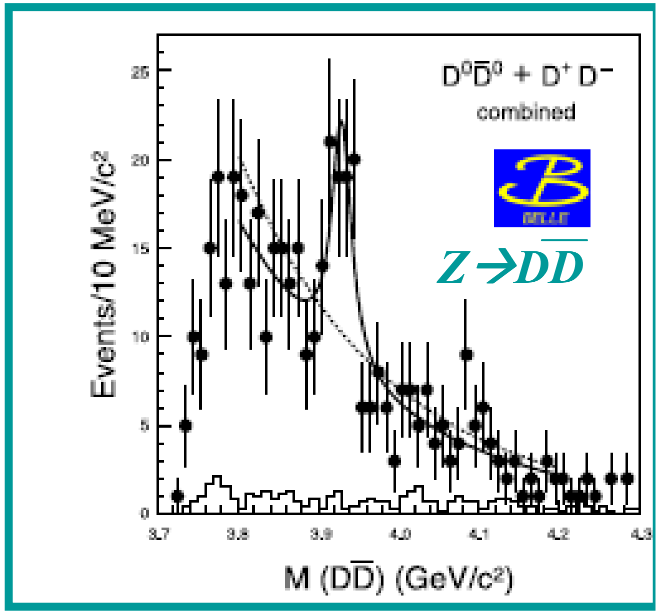
- Discovered by Belle.



PRL 98, 082001 (2007)



PRL 94, 182002 (2005)



PRL 96, 082003 (2006)

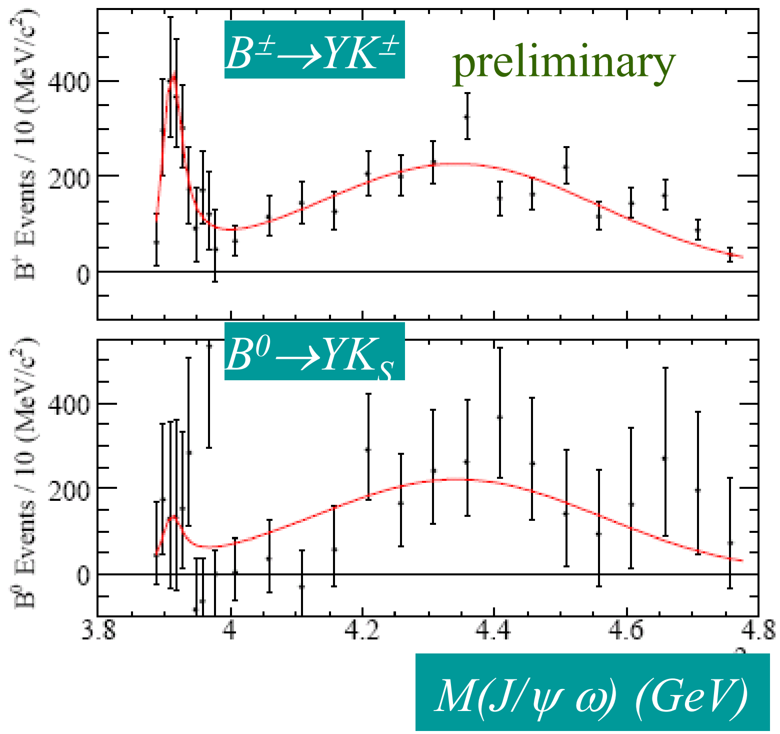
	Observed in	J^{PC} (?)	M (MeV)	Γ (MeV)
X	$e^+e^- \to J/\psi\, X\ (X \to D\overline{D^*})$	$0^{-+}, 1^{++}$	3943±8	<39
Y	$B \to Y K\ (Y \to J/\psi\ \omega)$	1^{++},…	3943±17	87±34
Z	$\gamma\gamma \to Z\ (Z \to D\overline{D})$	2^{++}	3929±5	29±10

Z: properties consistent with χ_{c2}(2P).

- 3 different states or maybe less?

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.

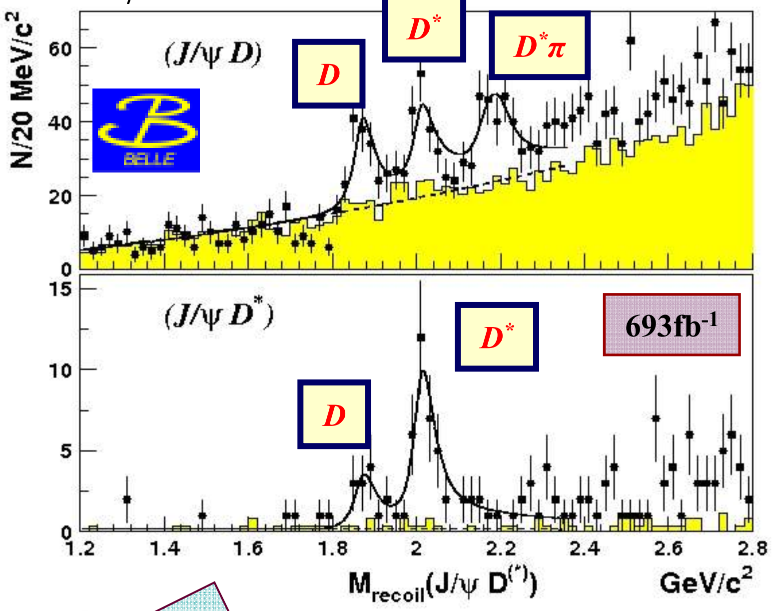
$$\frac{BR(B^0 \to Y K^0) \times BR(Y \to J/\psi\,\omega)}{BR(B^+ \to Y K^+) \times BR(Y \to J/\psi\,\omega)} = 0.30^{+0.29}_{-0.24}{}^{+0.04}_{-0.01} < 0.79,\ 95\%\ \mathrm{C.L.}$$

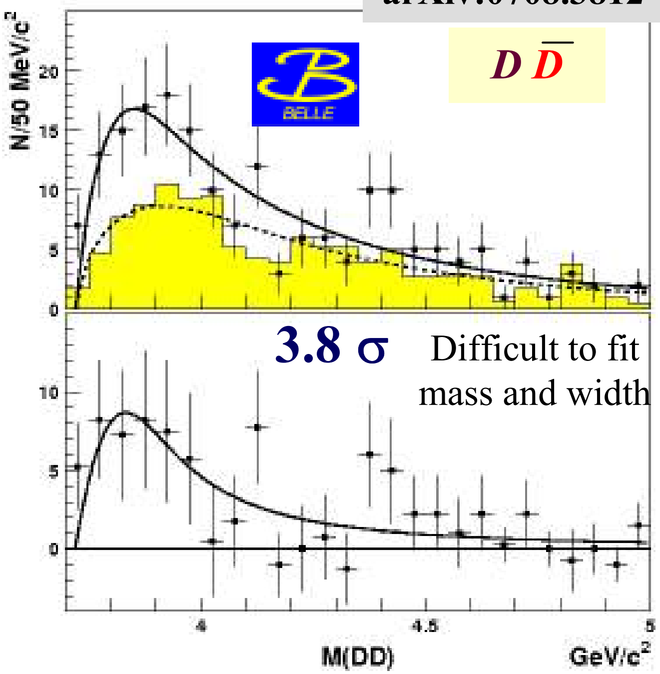
- Study of $e^+e^- \to J/\psi X$ and $\gamma\gamma \to D\overline{D}$ by *BABAR* in progress: results awaited soon.

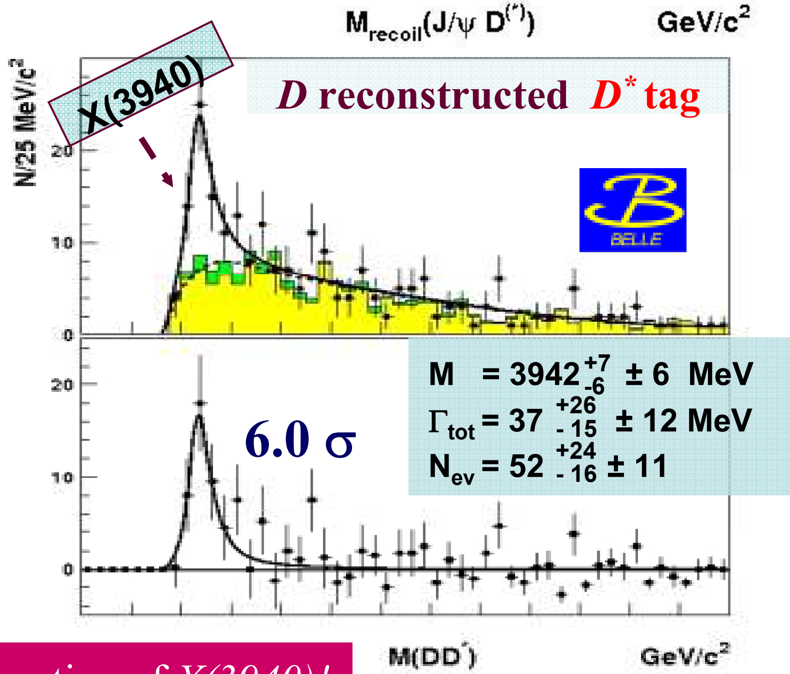
Study of $e^+e^- \to J/\psi\, D^{(*)}\bar{D}^{(*)}$

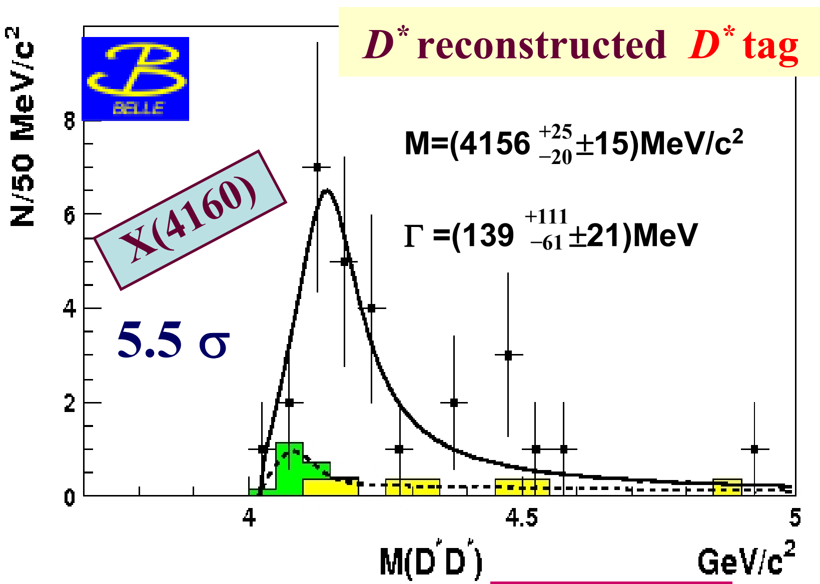
- Reconstruct ψ and one $D^{(*)}$

arXiv:0708.3812









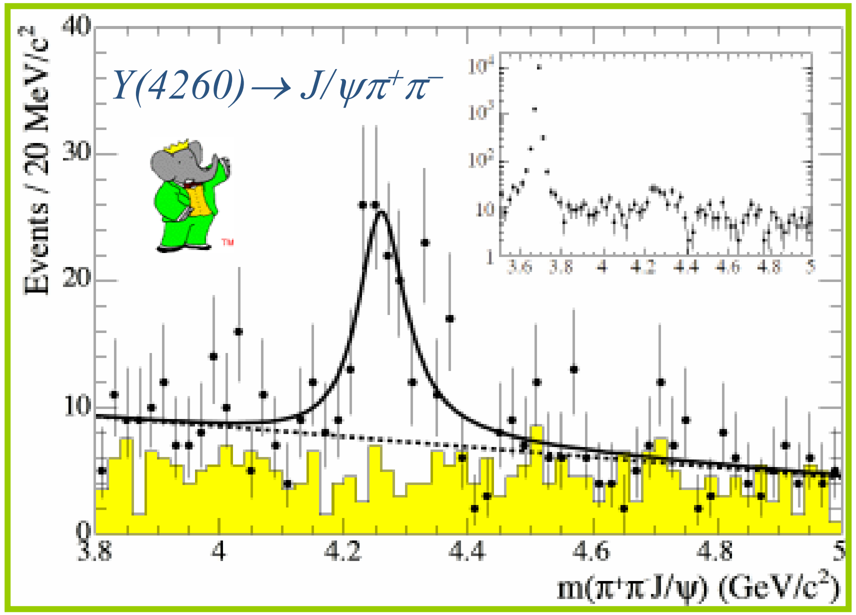
Confirmation of *X(3940)*!

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

How to Improve on XYZ(3940)

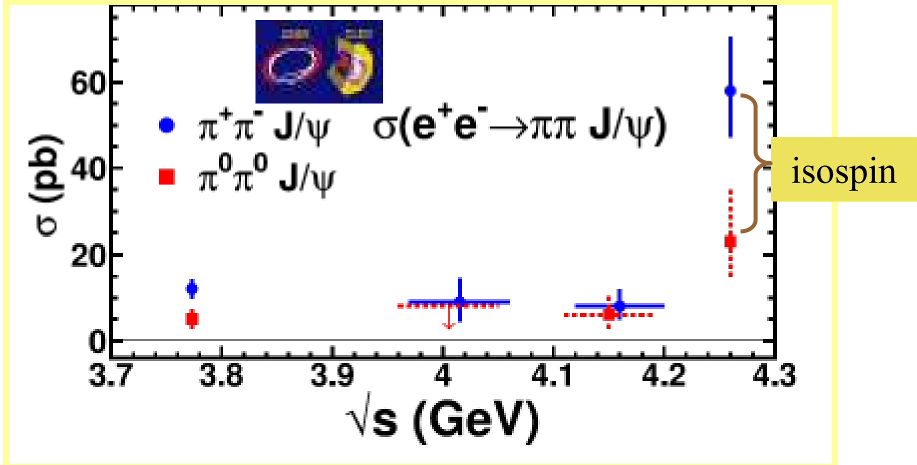
- At least some of these may be ordinary charmonia:
  - Important to test against expectations for this hypothesis.
- Z(3930) is consistent with χ_{c2}(2P).
- Where are the missing χ_{cJ}(2P) states?
  - Y(3940) might be χ_{c1}(2P) ?
    - mass not far from expectations, especially in the case of BABAR;
    - $J/\psi\ \omega$ is rather large (~10%): main decays should be $DD^*\rightarrow$ important to set bounds on this.
  - The threshold enhancement seen by Belle in $e^+e^-\rightarrow J/\psi D\overline{D}$ could be χ_{c0}(2P) ?
- X(3940) might be consistent with an η_c(nS)
  - BR(DD^*)>45%
  - But… somewhat large splitting with ψ(3S)
- Yet a new state to place X(4160): another η_c(nS) ???
- Important to confirm these states, to reduce uncertainty on mass (exp. Y(3940)), establish all J^{PC} quantum numbers
  - Important role of $DD^{(*)}$ modes: require large statistics.

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



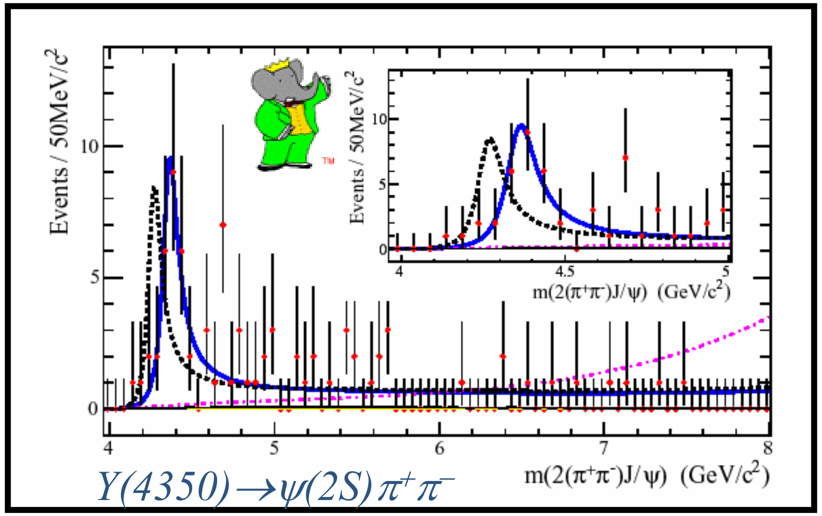
A new state: *Y(4260)*
PRL 95, 142001 (2005)

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)



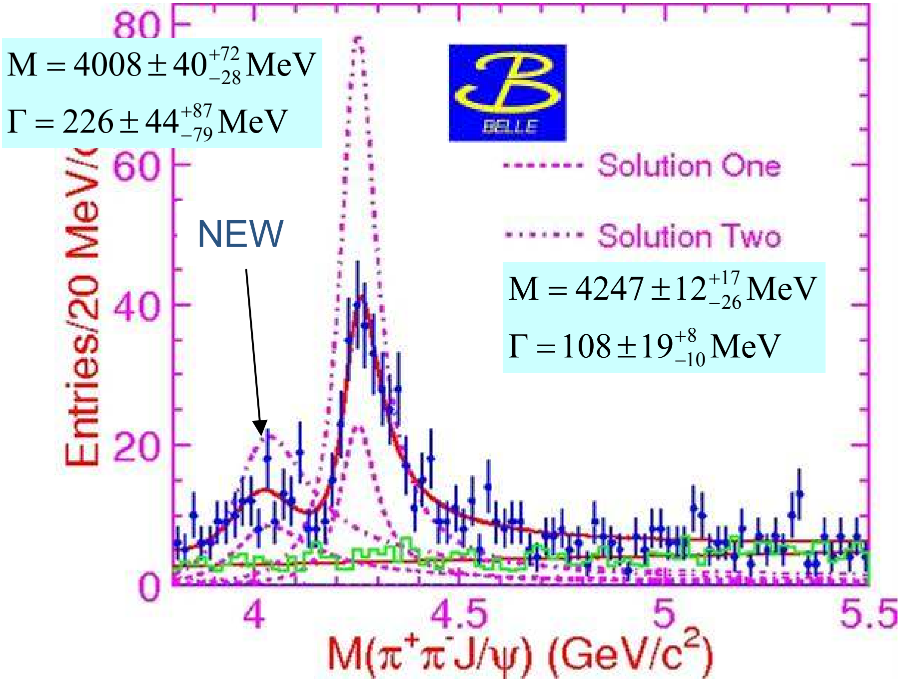
Confirmation + $J/\psi\pi^0\pi^0$; also $J/\psi KK$
CLEO PRD74, 091104 (2006)
CLEO PRL 96, 162003 (2006)

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



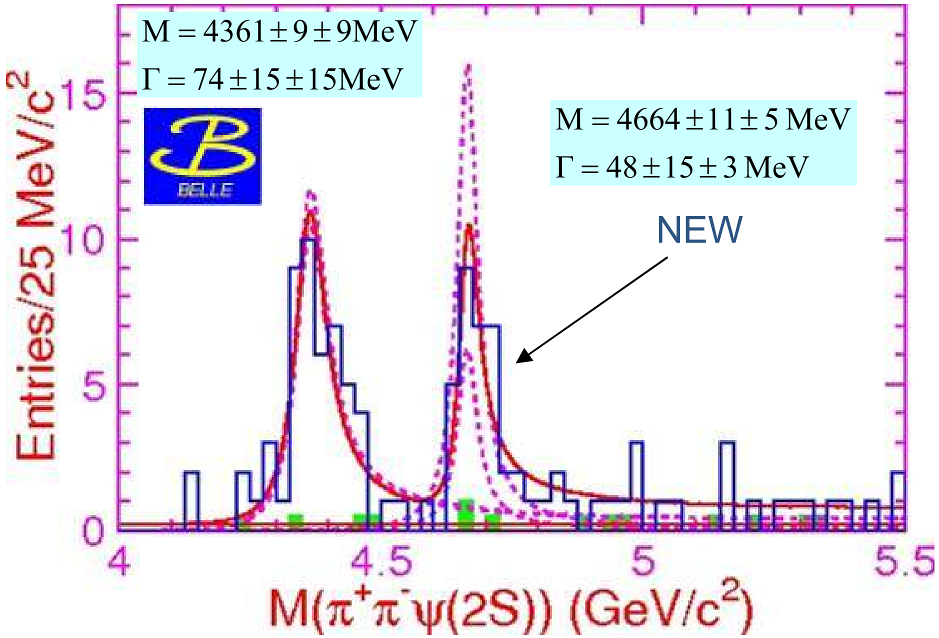
$J/\psi\ \pi^+\ \pi^-$

arXiv:0707.2541

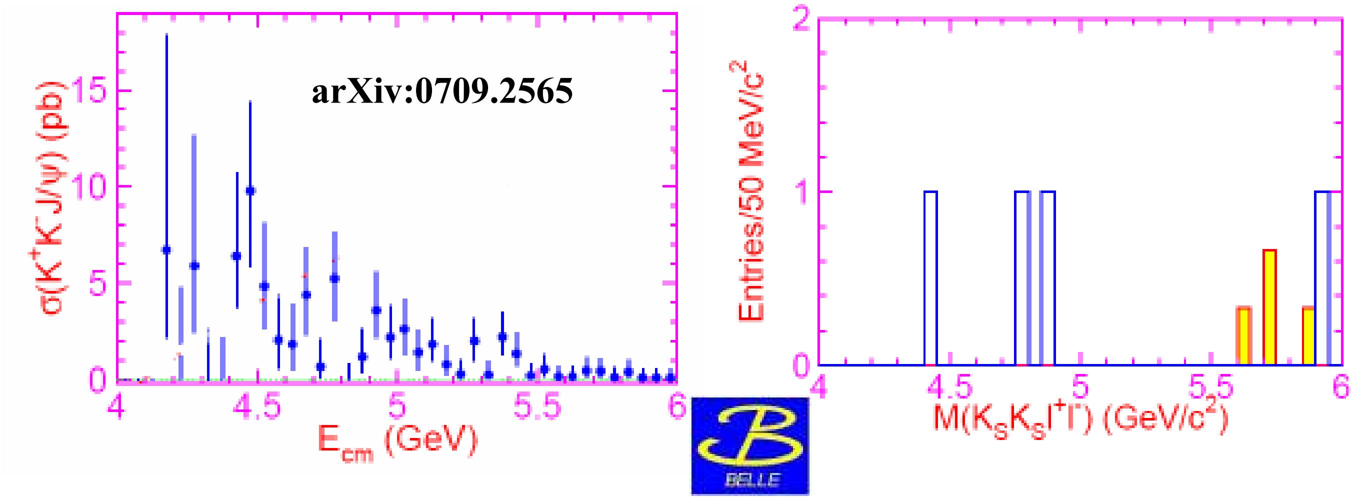


$\psi(2S)\ \pi^+\ \pi^-$

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



$J/\psi\ K\ K$



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

consistent with isospin (0.5)

How to Improve on 1^{--} Y States

- Not necessarily all belong to the same family
- Little space for ordinary charmonium assignements (1^{--} slots all taken)
  - May Y(4008) be ψ(4040) ?
- Unlikely molecules and threshold effects.
- Important to search for partners of these states:
  - In the hybrid scenario, the 1^{--} state should be degenarate with $0^{-+}, 1^{-+}, 2^{-+}$ states
- So far only seen to decay to ψ(')PP:
  - important to measure branching fractions;
  - important to search for other decay modes: no hints in $p\overline{p}$, $D\overline{D}$, $D\overline{D}^*$, $D^*\overline{D}^*$, $D\overline{D}\pi$
- So far observed in ISR
  - Y(4260) also in e^+e^- at CLEO;
  - A hint of Y(4260) in *B* decays: important to confirm and measure branching fraction. Can help distinguish models.

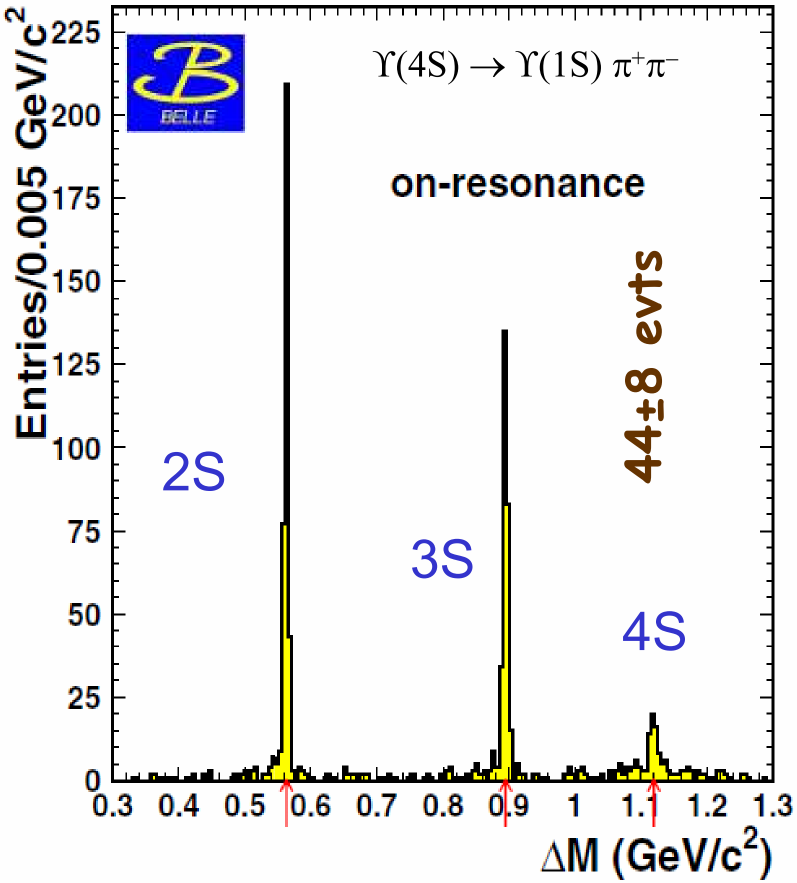
Not Forgetting to Look Somewhere Else

S. Olsen, Joint BES-Belle-CLEO-BABAR workshop

$\Upsilon(4S) \rightarrow \pi\pi\Upsilon(1S)$
477 fb^{-1} from Belle

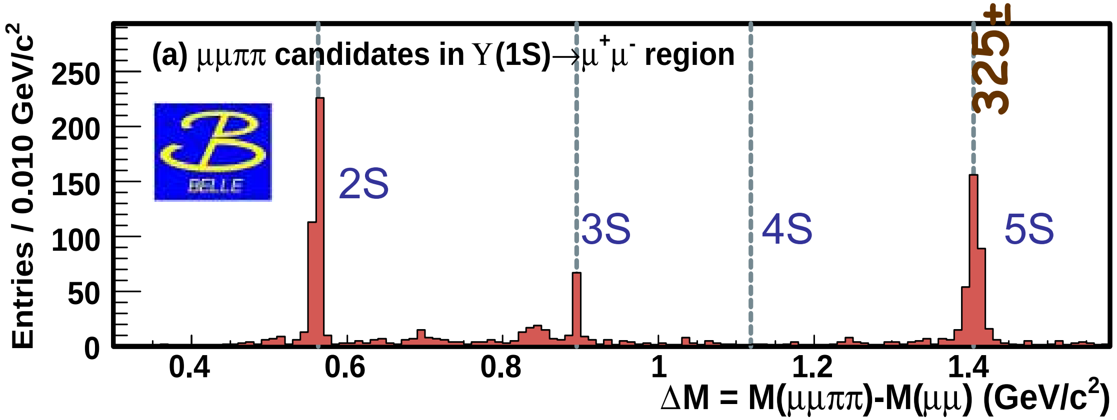
(1/20 times the data &
~1/10th the crosssection)

8 times as many events!



PHYSICAL REVIEW D 75, 071103(R) (2007)

"$\Upsilon(5S)$"$\rightarrow \pi\pi\Upsilon(1S)$
23.6 fb^{-1} from Belle



Belle
0710.2577

- Very large decay width to $\Upsilon\pi\pi$, like Y(4260)!

Assume “Υ(5S)” = Υ(5S)

PDG value taken for Υ(nS) properties

Process	N_s	Σ	Eff.(%)	σ(pb)	$\mathcal{B}$(%)	Γ(MeV)
$\Upsilon(1S)\pi^+\pi^-$	325^{+20}_{-19}	20σ	37.4	$1.61 \pm 0.10 \pm 0.12$	$0.53 \pm 0.03 \pm 0.05$	$0.59 \pm 0.04 \pm 0.09$
$\Upsilon(2S)\pi^+\pi^-$	186 ± 15	14σ	18.9	$2.35 \pm 0.19 \pm 0.32$	$0.78 \pm 0.06 \pm 0.11$	$0.85 \pm 0.07 \pm 0.16$
$\Upsilon(3S)\pi^+\pi^-$	$10.5^{+4.0}_{-3.3}$	3.2σ	1.5	$1.44^{+0.55}_{-0.45} \pm 0.19$	$0.48^{+0.18}_{-0.15} \pm 0.07$	$0.52^{+0.20}_{-0.17} \pm 0.10$

3

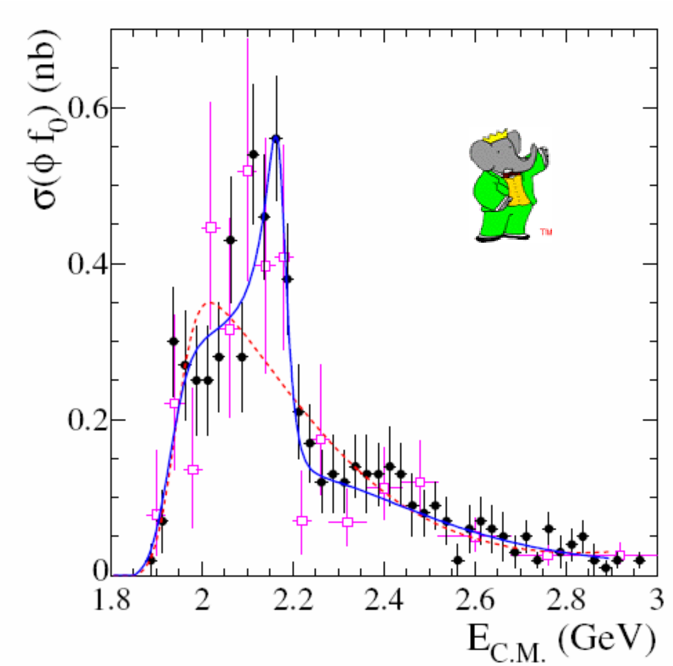
N.B. Resonance cross section 0.302 ± 0.015 nb at 10.87 GeV
PRD **98,** 052001 (2007) [Belle]

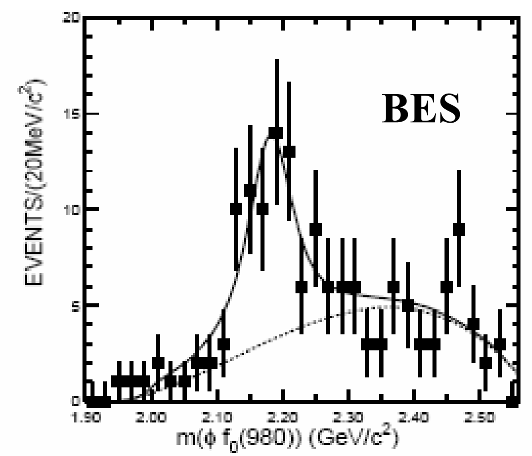
>100 times bigger!!

Cfr

Υ(2S) → Υ(1S)$\pi^+\pi^-$	**~ 6**	**keV**
Υ(3S)	**0.9**	**keV**
Υ(4S)	**1.8**	**keV**

Also $X(2175) \rightarrow \Phi f_0$

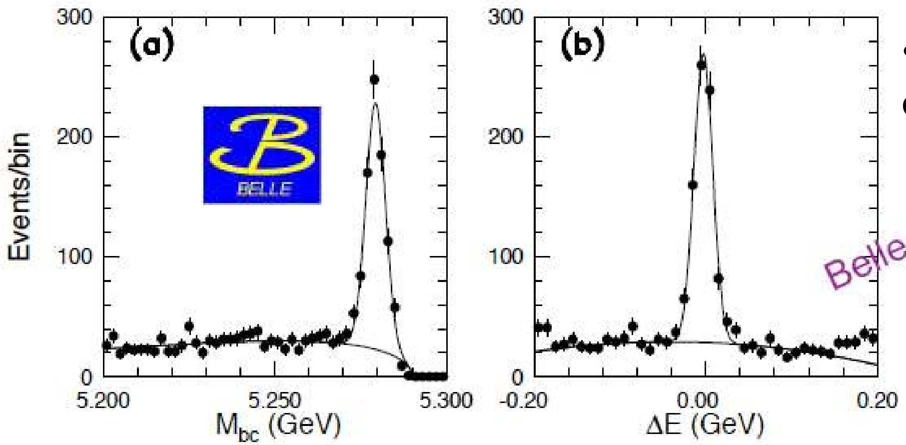




Counterparts of Y(4260) ?

A tetraquark near the Y(5S)? Or the 5S itself?!

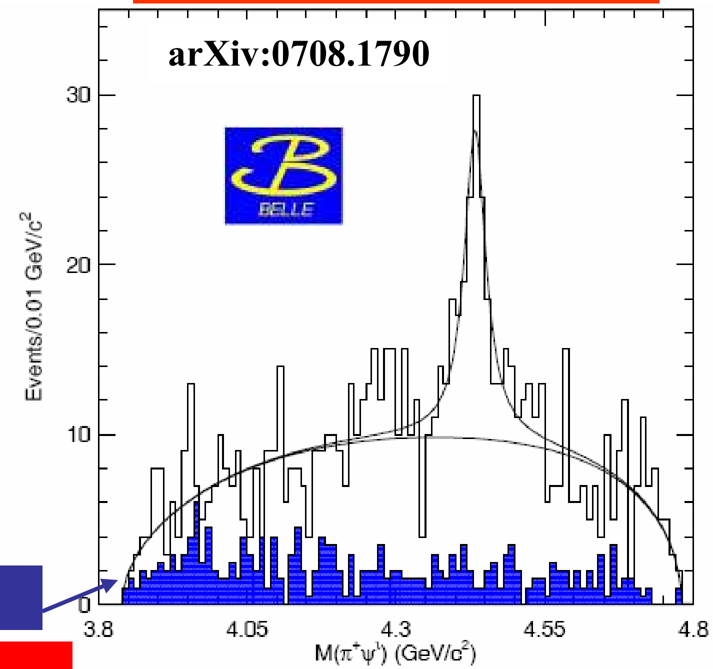
$Z(4430)^{\pm}$



Belle preliminary

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

$B^{-} \to Z^{-}K_{s}$ or $B^{0} \to Z^{-}K^{+}$
$Z^{-} \to \psi(2S)\pi^{-}$



Total significance: 7.3σ

$M = (4433 \pm 4 \pm 1)$ 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

- **First charged charmonium-like object !**
  - If it's a meson, it's exotic!
- Important to confirm and establish quantum numbers.
- What about $J/\psi\pi^{\pm}$?
- There must be isospin partners: important to search for $\psi\pi^{0}$

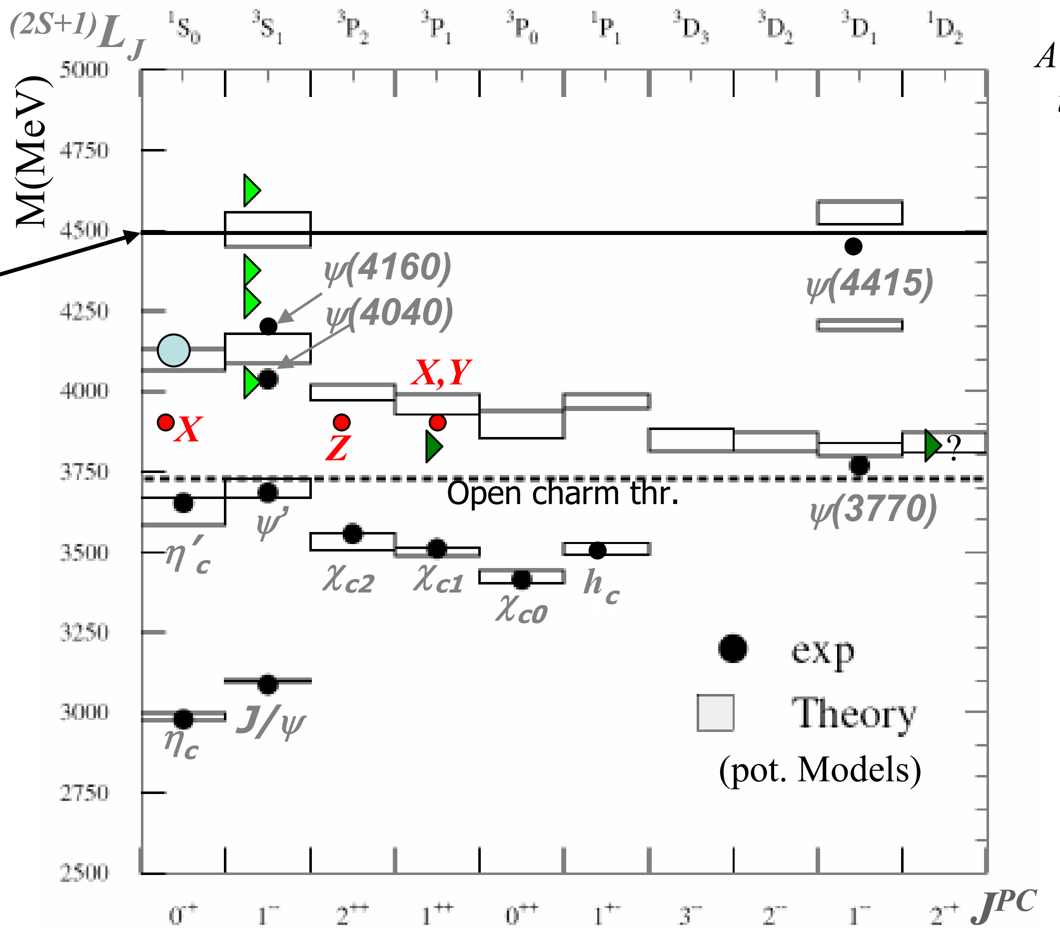
BF and mass consistent between $B^{\pm}$ and B^{0} within errors;
$BF_{\pm}/BF_{0} = 1.0 \pm 0.4$

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

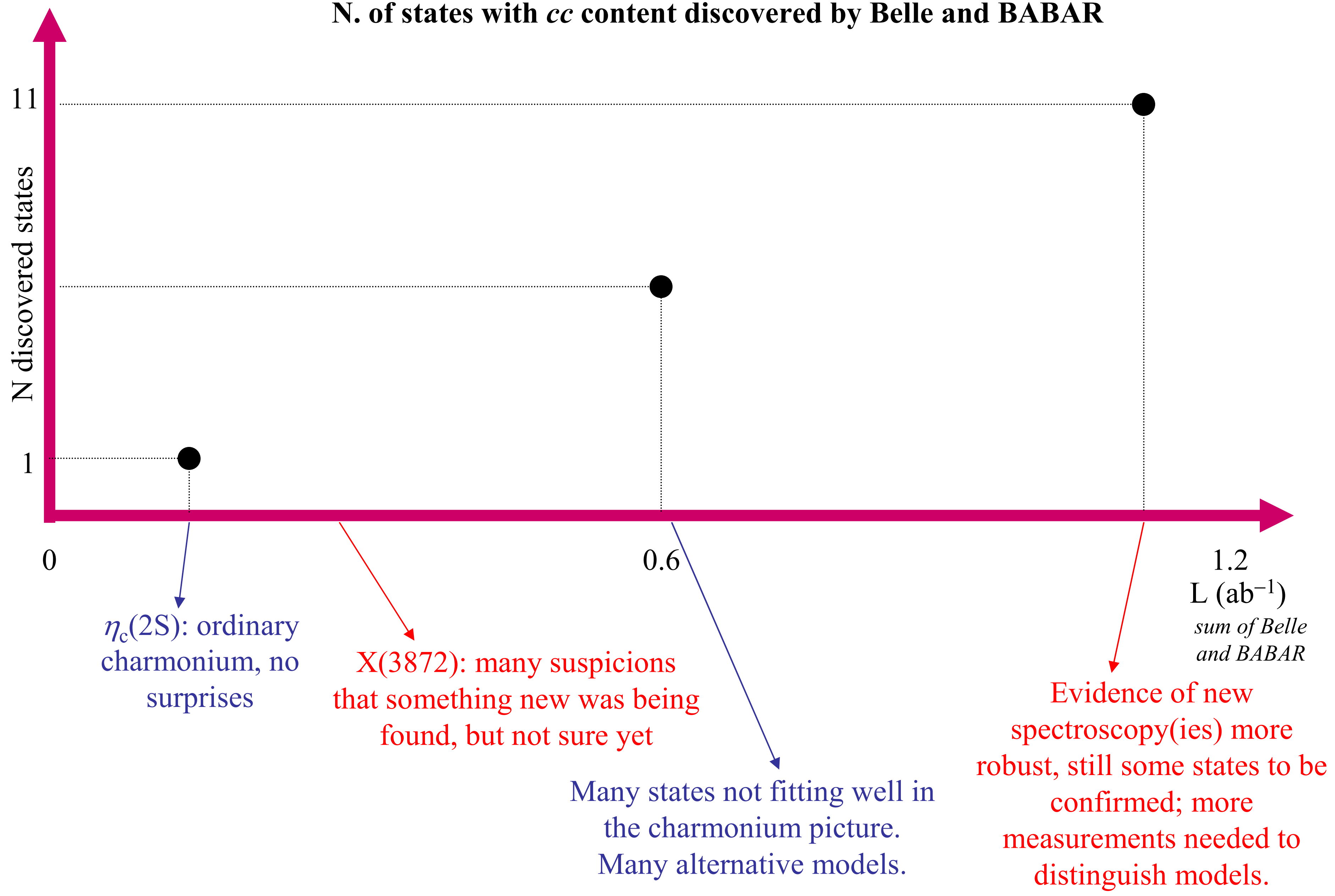


A drawing just to guide the discussion!

- Very large number of new results on $c\bar{c}$ states with constant improvement of the properties
  - And yet new states are being reported! New spectroscopies unveiled?
- Important not only to find more states but to help classify them: *B*-Factories with large statistics are an ideal laboratory.

An exercise, not to be taken too seriously…

N. of states with $c\bar{c}$ content discovered by Belle and BABAR



Backup Slides

The *BaBar* Experiment

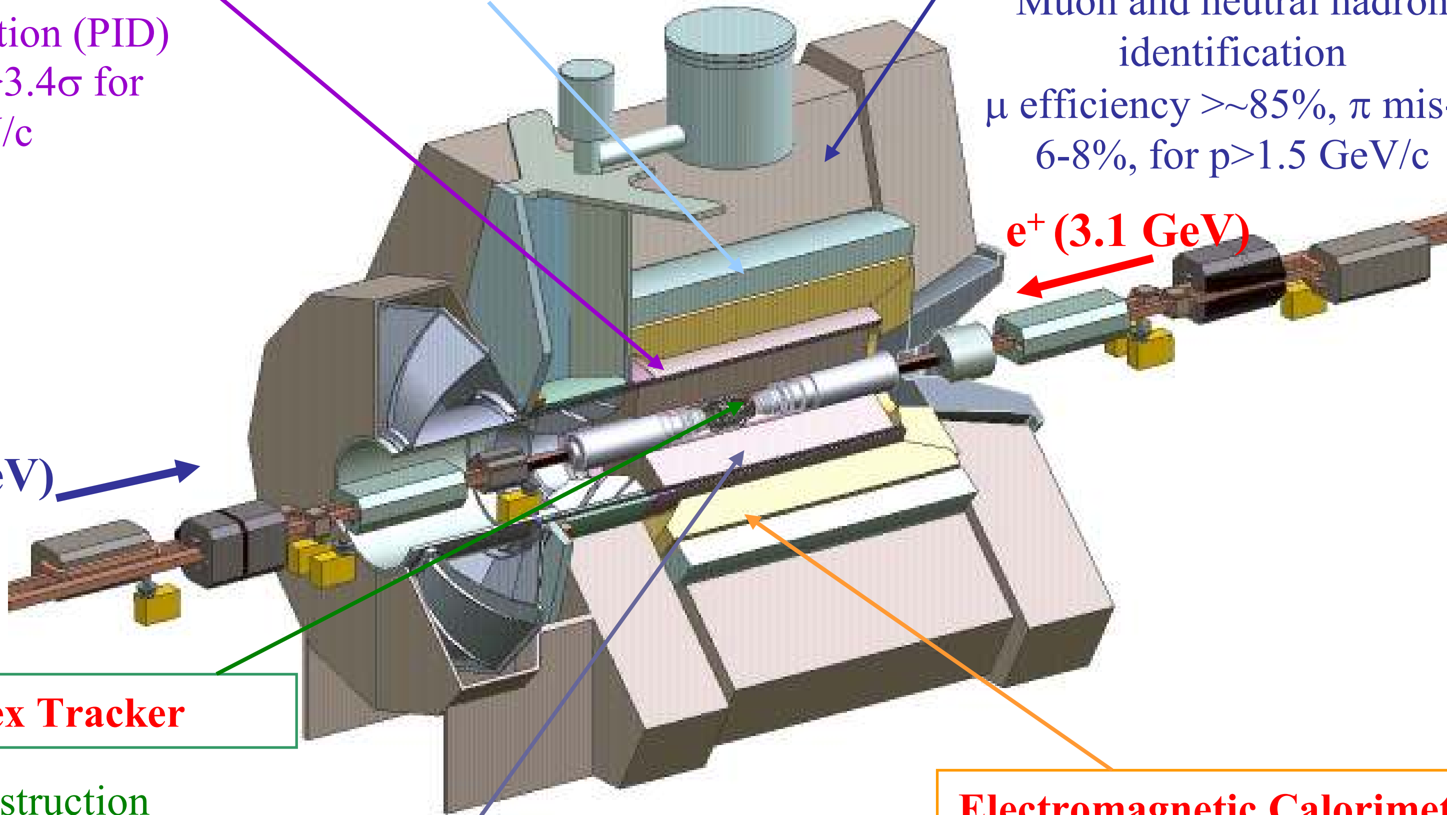
Cherenkov Detector

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%

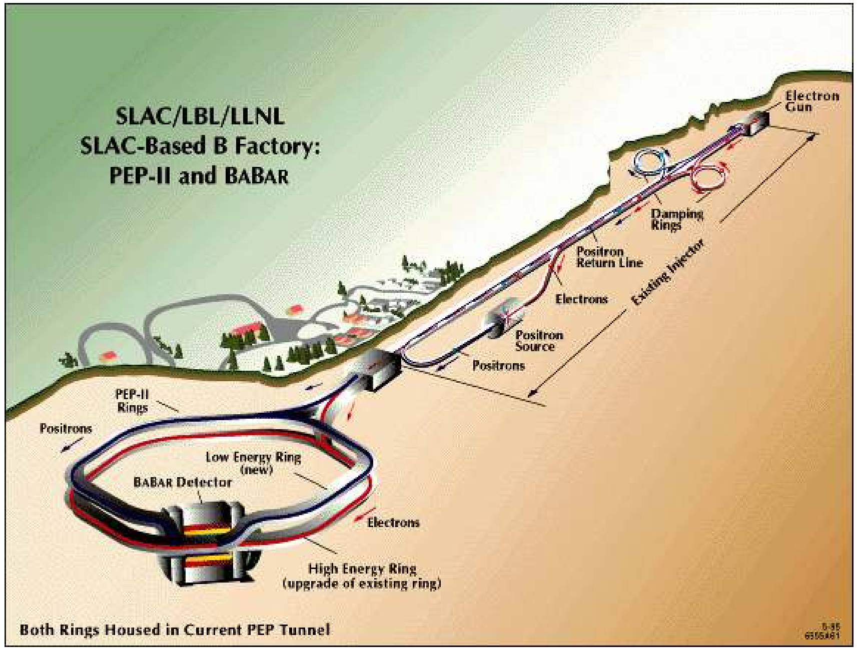
Drift Chamber

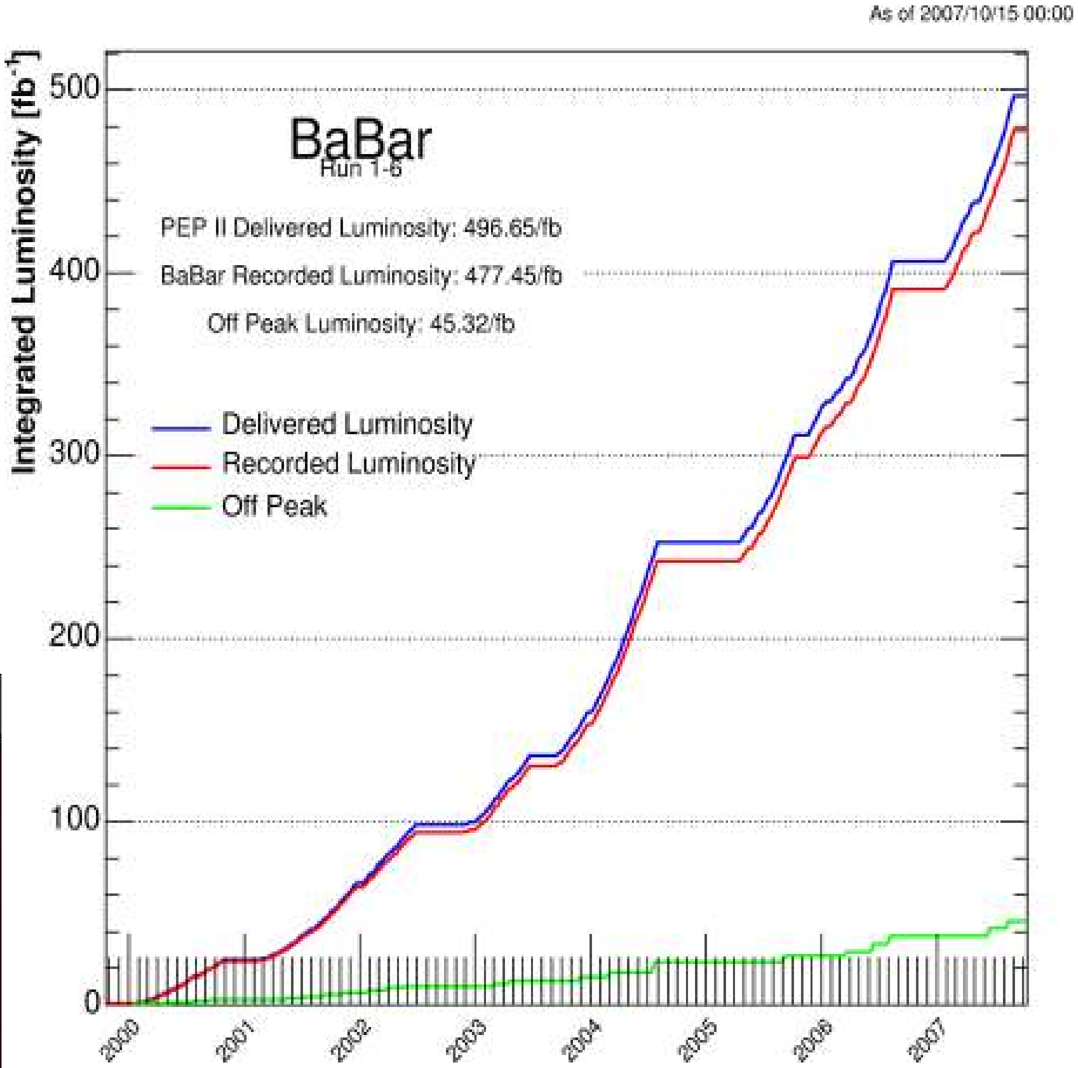
Momentum measurement for charged particles + dE/dx.
$\sigma(p_T)/p_T = 0.13\% p_T \oplus 0.45\%$

Electromagnetic Calorimeter

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

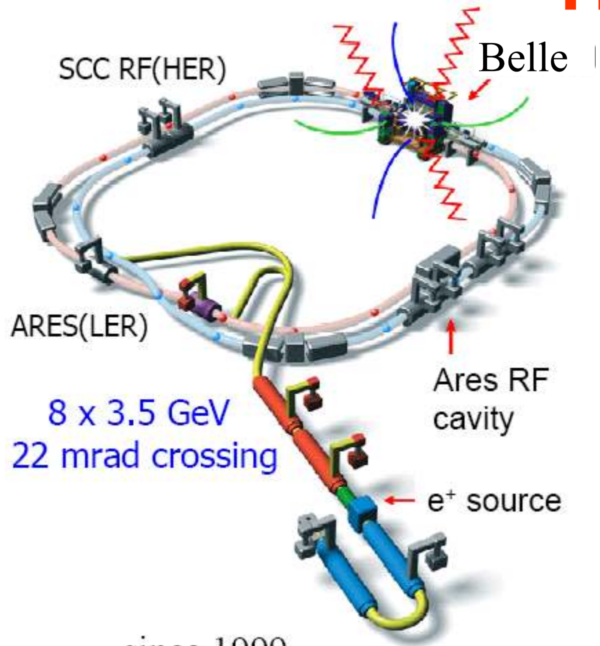
- Beam energies: 9 GeV e^- / 3.1 GeV e^+
- Instantaneous luminosity:
  $L_{peak} \approx 12 \times 10^{33}\ cm^{-2}\ s^{-1}$
- Boost: $\beta\gamma \sim 0.56$





Current data sample

The Belle Experiment

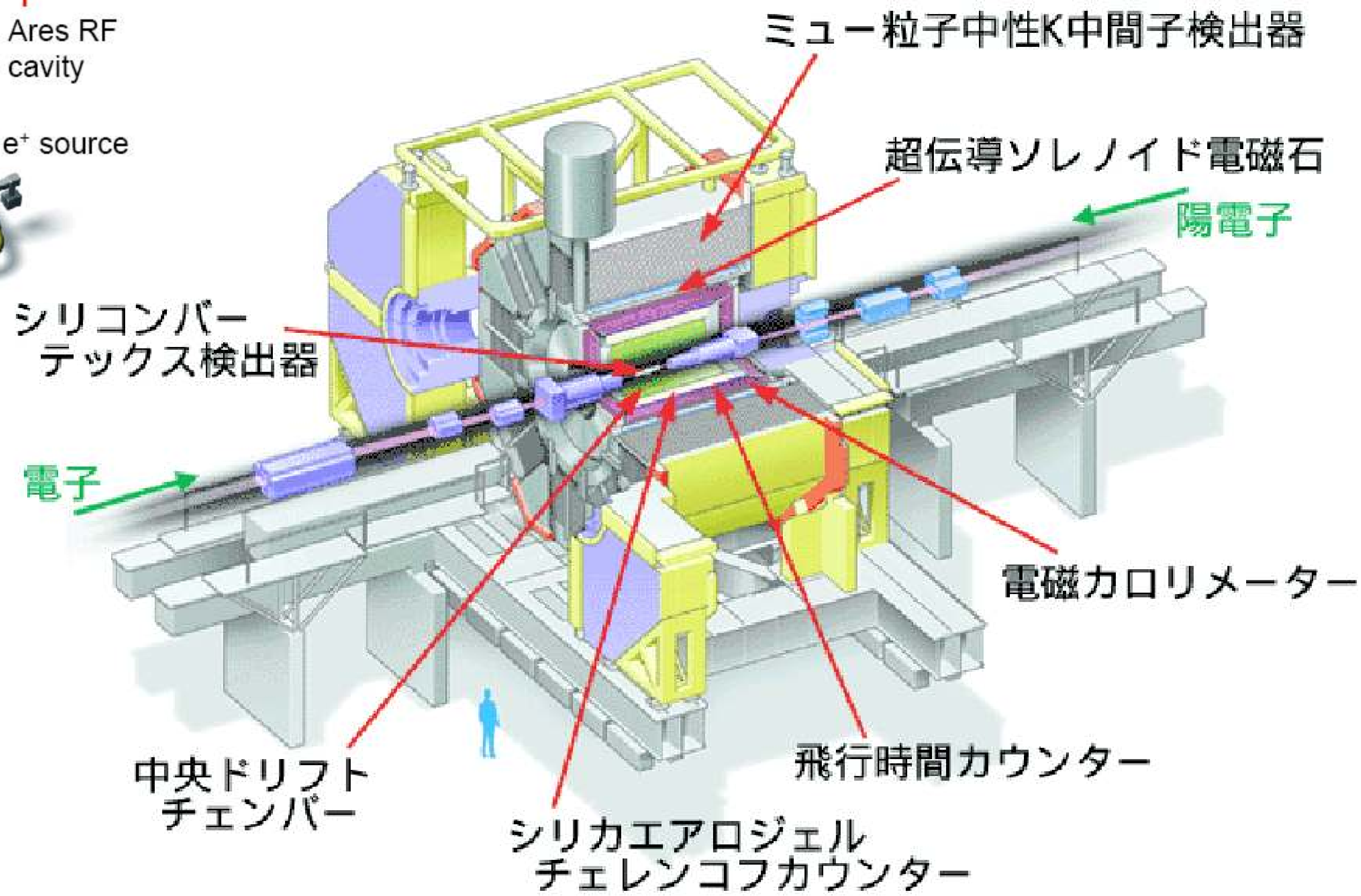


since 1999

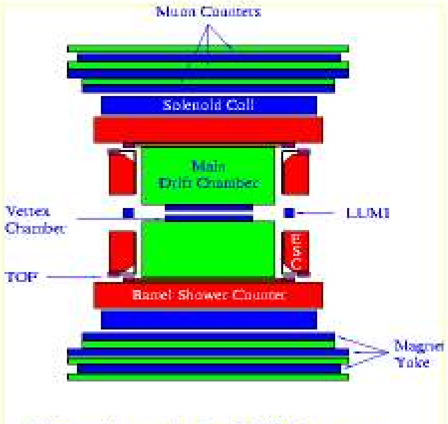
World record:

L = 1.7 x 10^{34}/cm^2/sec

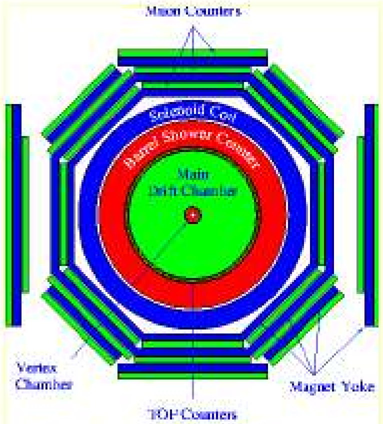
Continuous injection → 1.2 fb^{-1}/day; L_{int} = 743 fb^{-1}



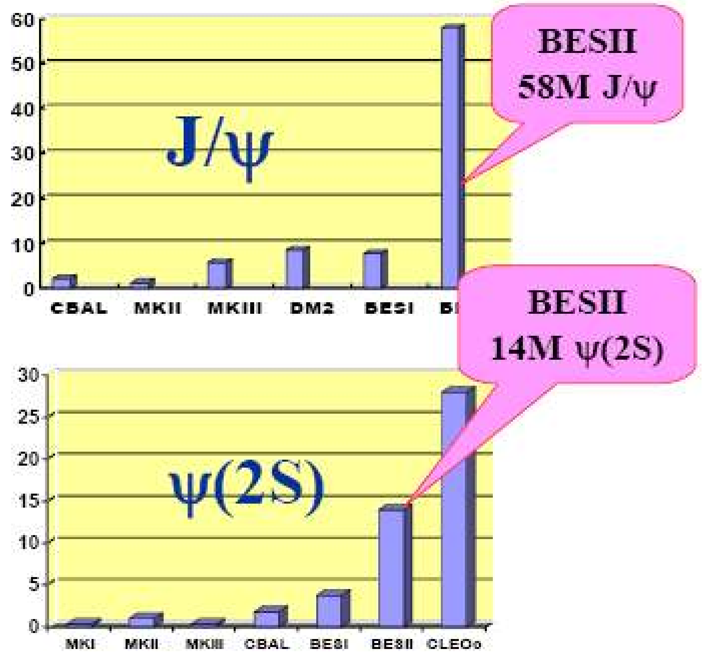
The BES Experiment



Side view of the BES detector



End view of the BES detector



VC: $\sigma_{xy} = 100\ \mu m$

MDC: $\sigma_{xy} = 220\ \mu m$

$\sigma_{dE/dx} = 8.5\ \%$

$\Delta p/p = 1.78\sqrt{(1+p^2)}$

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 ~ 5×10^{30} /cm^2·s

at J/ψ

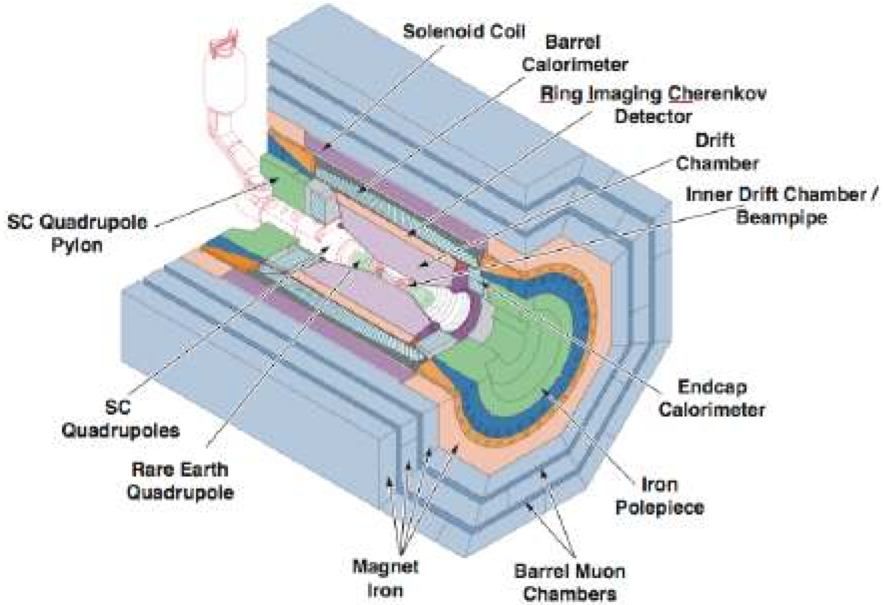
E_{beam} ~ 1 - 2.5 GeV

The CLEO-c Experiment

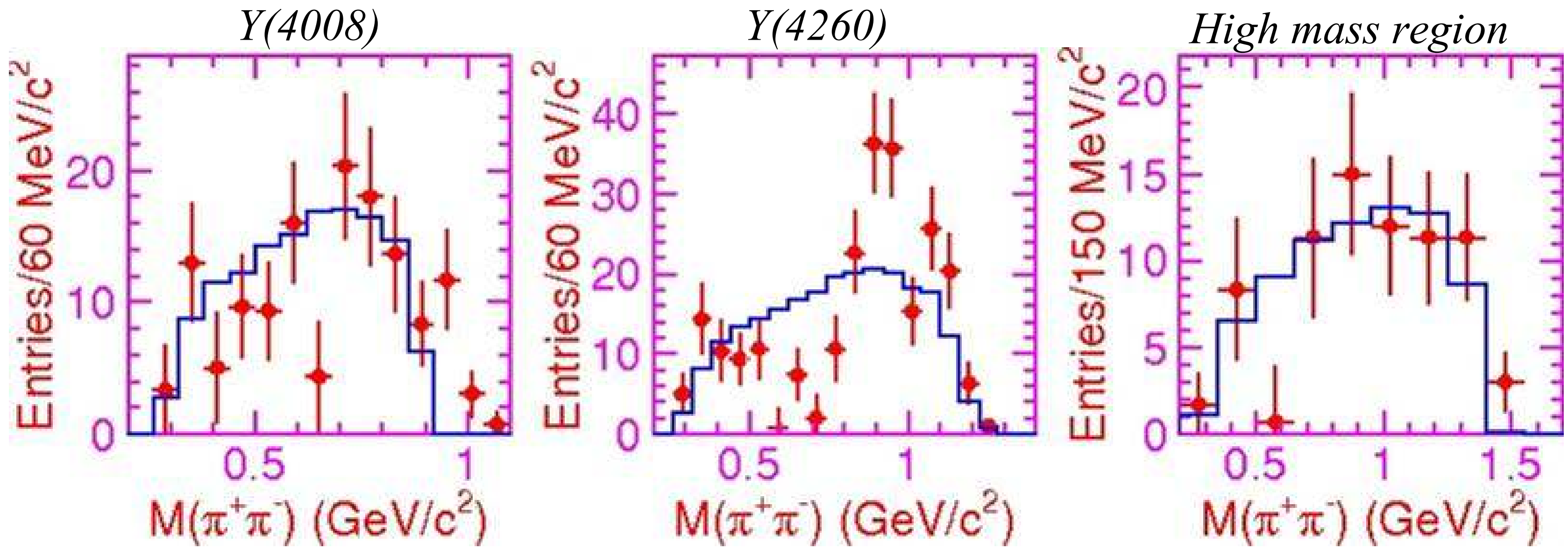
e^+e^- collisions at $\sqrt{s}$ ~ 4 GeV

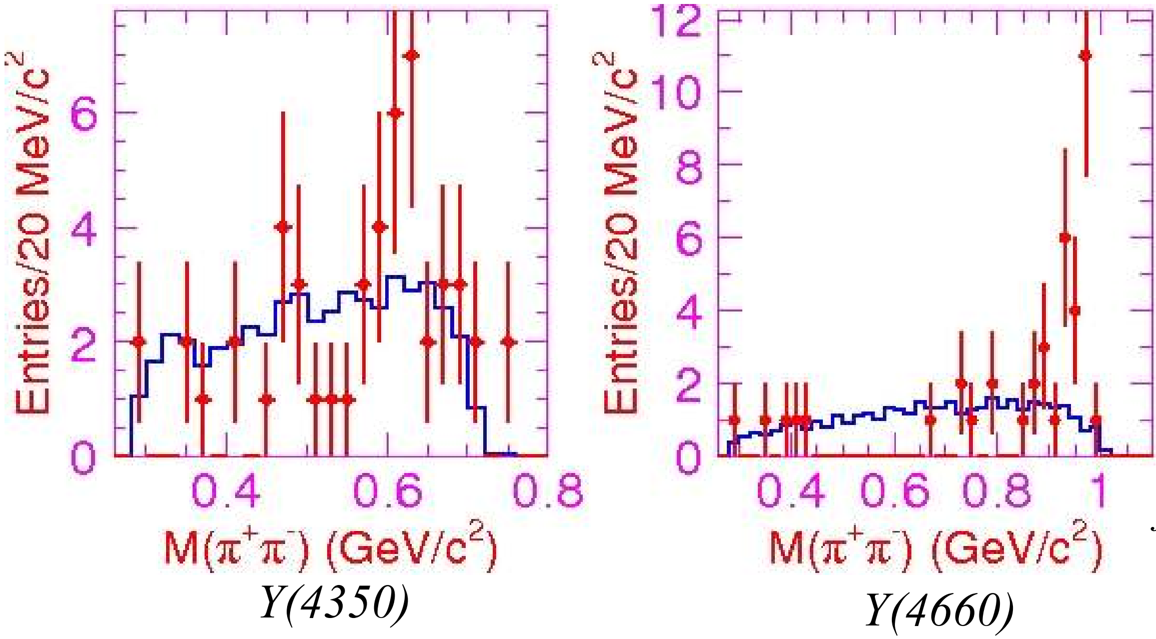
2003 - present

- 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



Study of $\pi\pi$ invariant masses



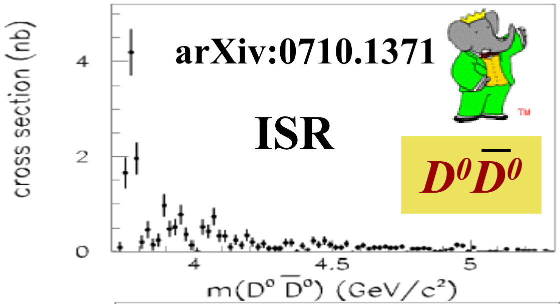


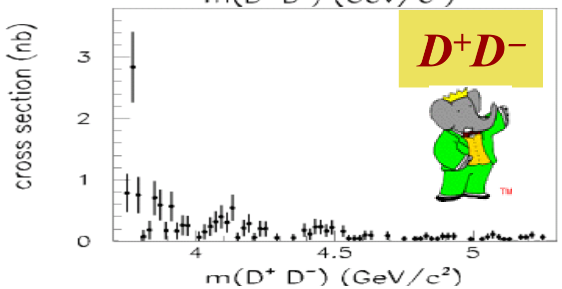
f_0 dominating?
Threshold effects?

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

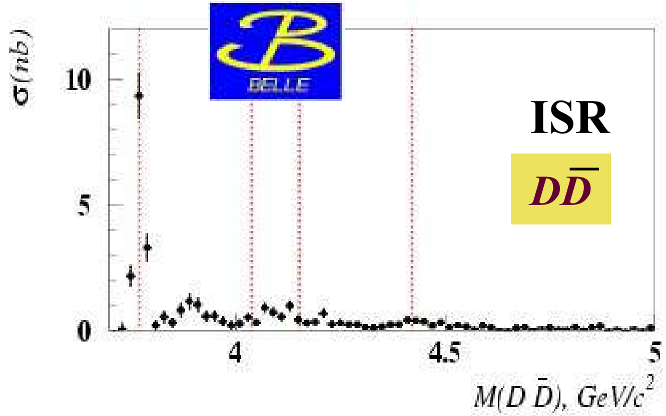
- Can these new 1^{--} states be seen in $D^{(*)}\overline{D}^{(*)}$ decays?

arXiv:0710.1371

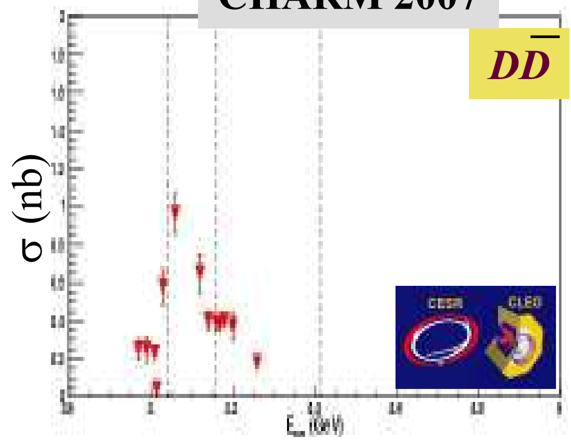




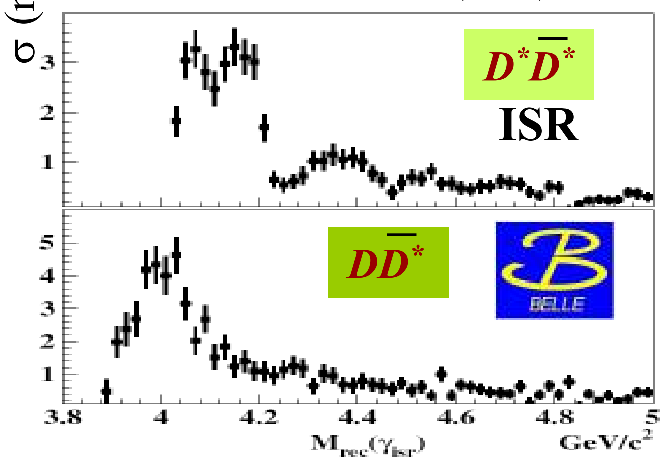
arXiv:0708.0082



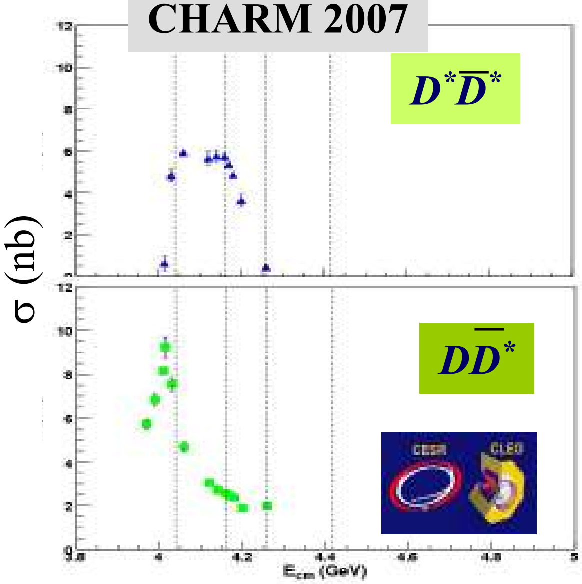
CHARM 2007

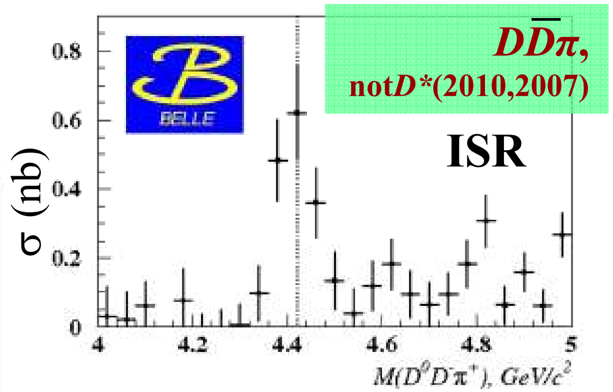


PRL 98, 092001 (2007)

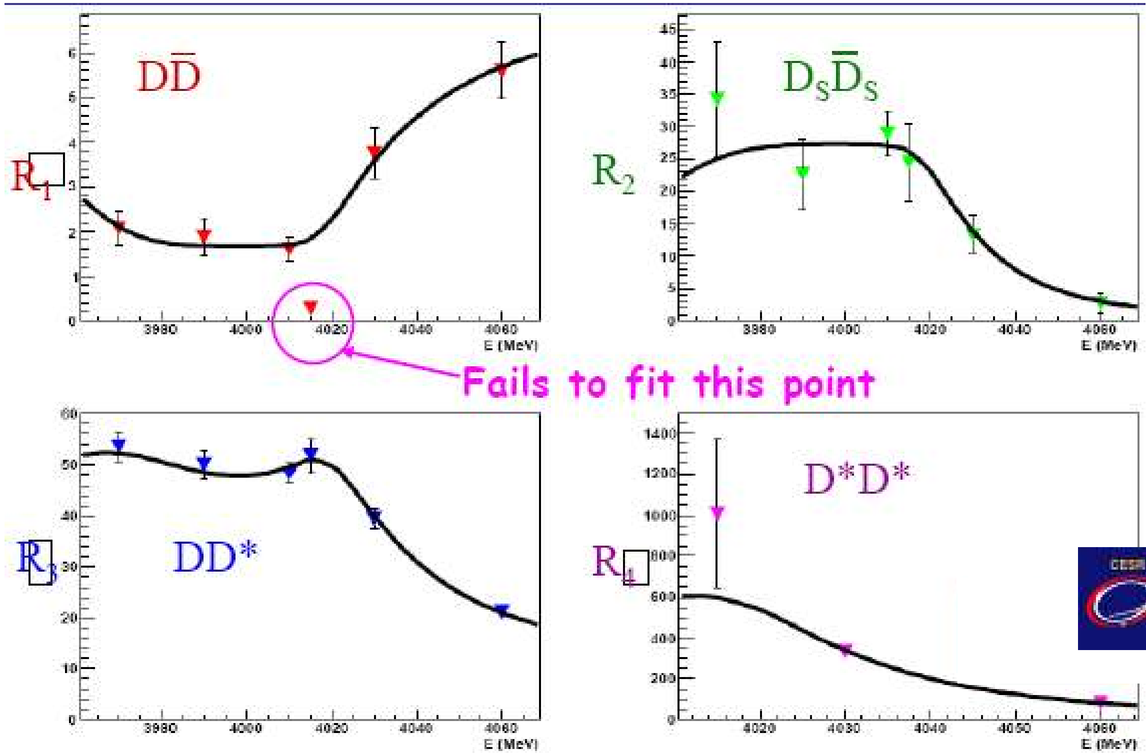


CHARM 2007





arXiv:0708.3313



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

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