

New results on XYZ states from e^+e^- experiments

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IHEP, Beijing

The 6th International Workshop on Charm Physics
31 Aug - 4 Sept 2013; Manchester, England

Outline

- Introduction

- New information on the X(3872)



new

- Update the ISR Y-family analyses

and more ...



Absolutely new

- $Z_c(3900)$, $Z_c(4020)$ & $Z_c(4025)$

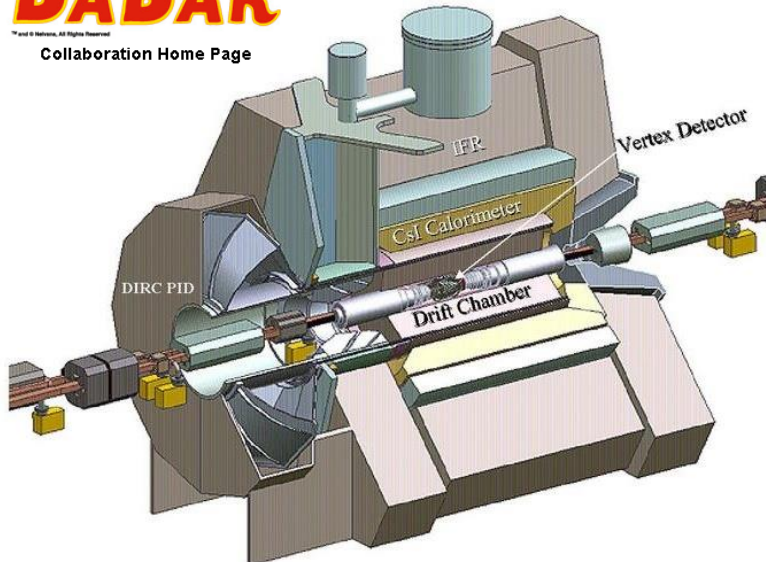
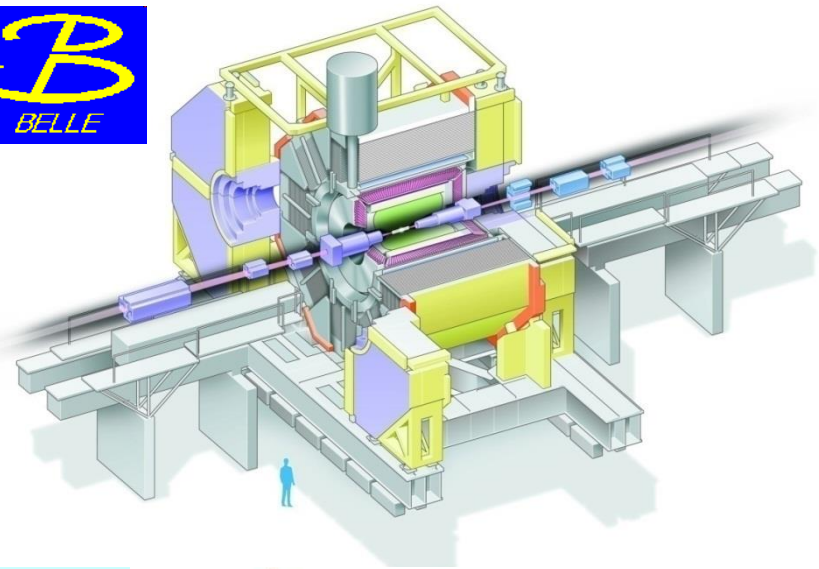
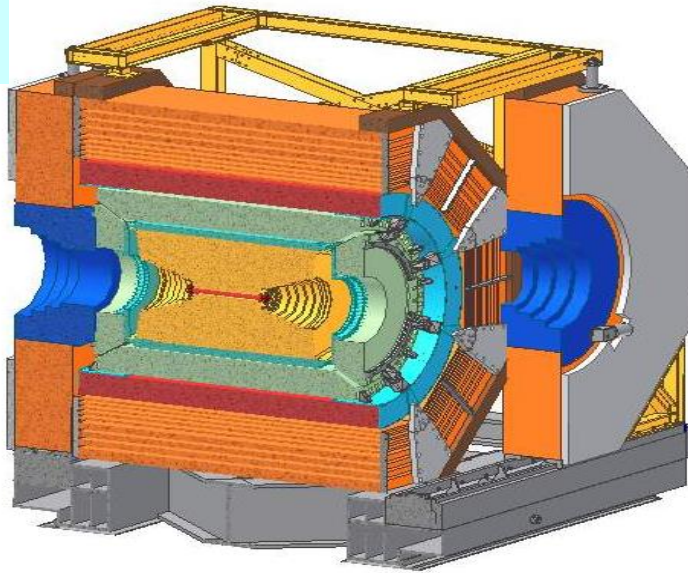


new

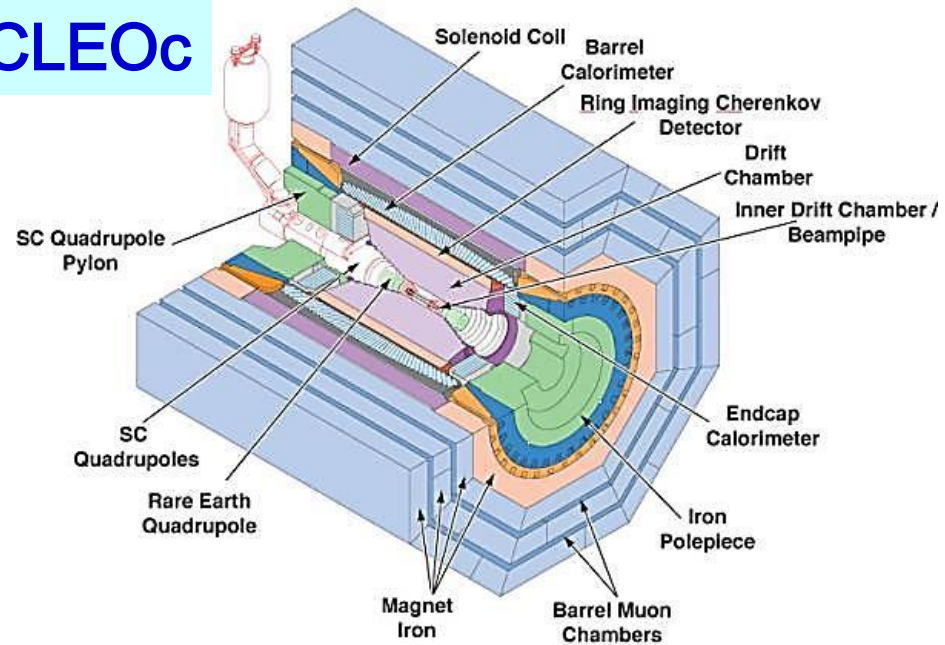
- Summary & Outlook

Results are from these experiments

BESIII

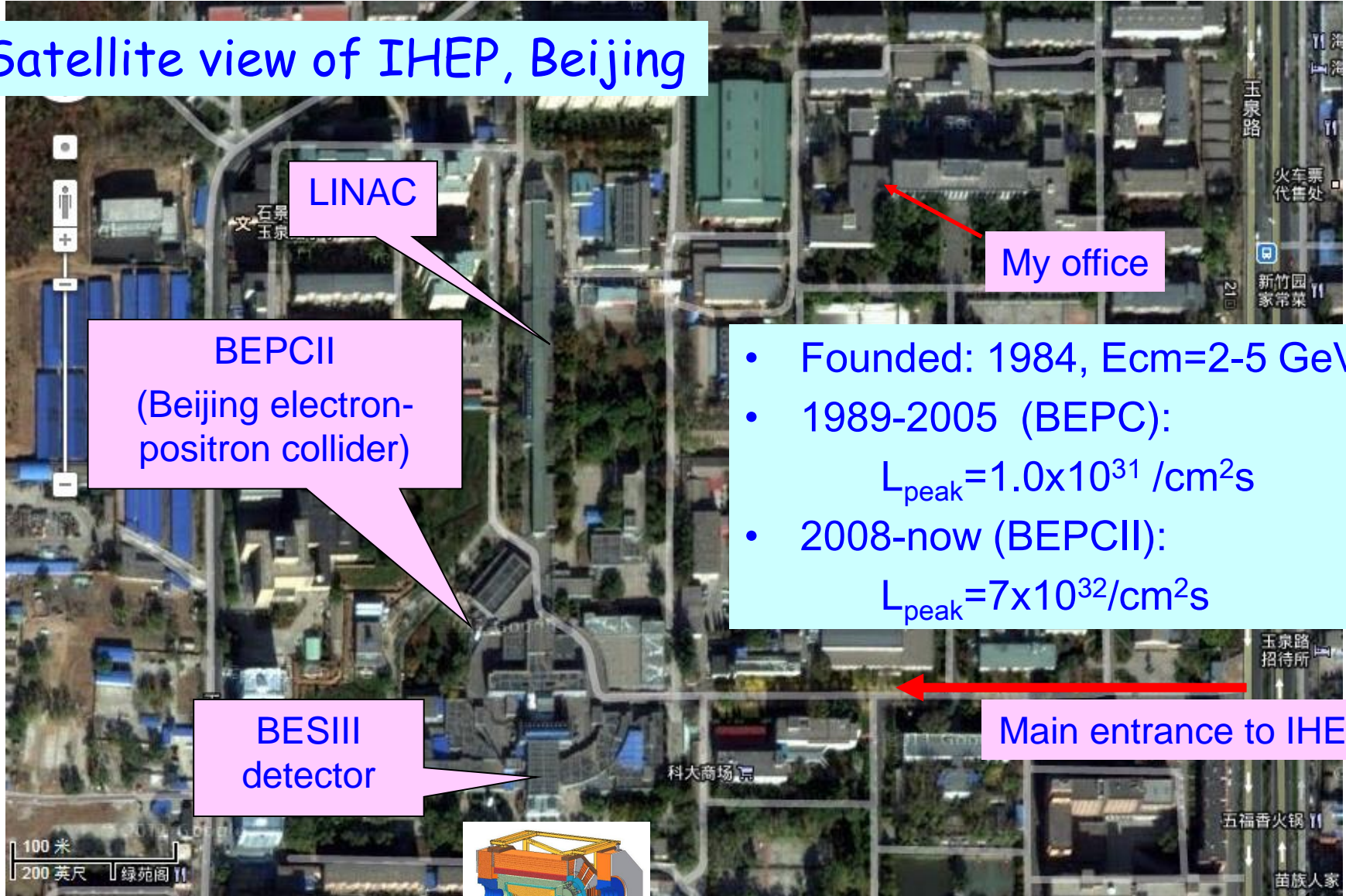


CLEOc



The Beijing Electron Positron Collider

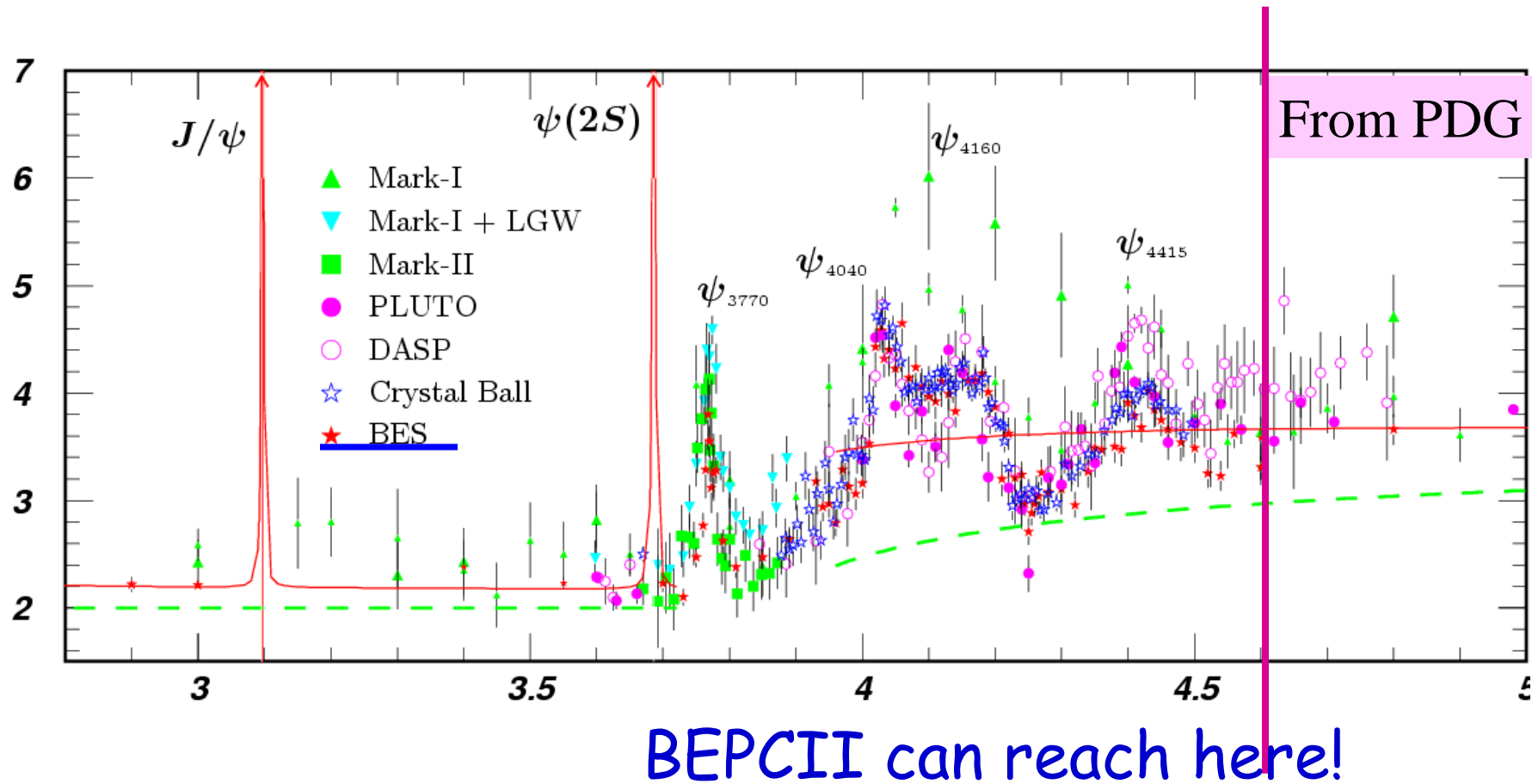
Satellite view of IHEP, Beijing



- Founded: 1984, $E_{cm}=2-5$ GeV
- 1989-2005 (BEPC):
 $L_{peak}=1.0 \times 10^{31} / \text{cm}^2 \text{s}$
- 2008-now (BEPCII):
 $L_{peak}=7 \times 10^{32} / \text{cm}^2 \text{s}$

BESIII: production of charmonium(like) states

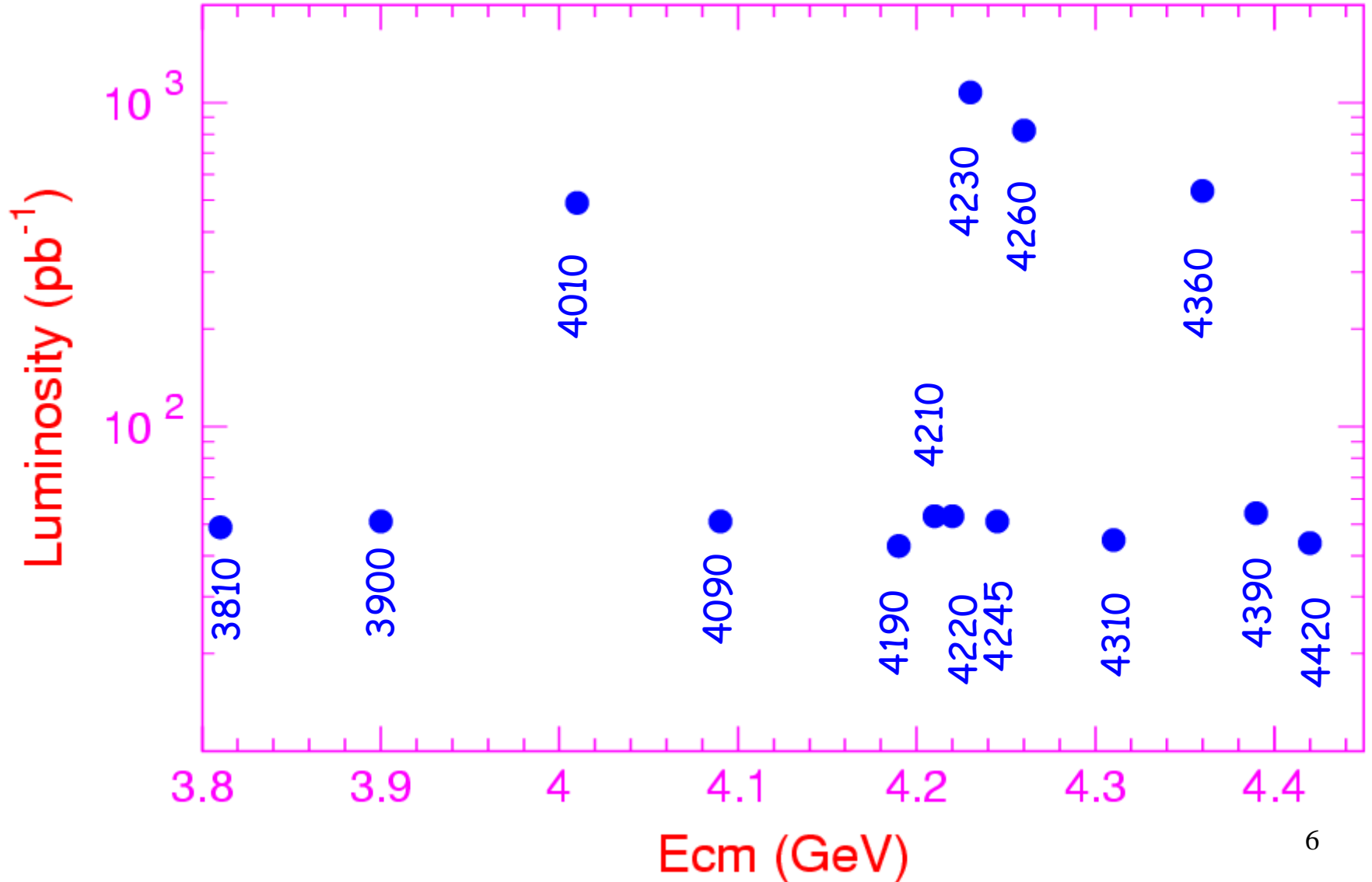
R

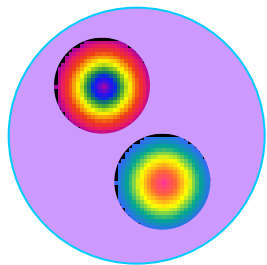


Vector ψ/Y states can be produced directly

C-even states can be produced from radiative transitions

BESIII collected 3.3/fb for XYZ study

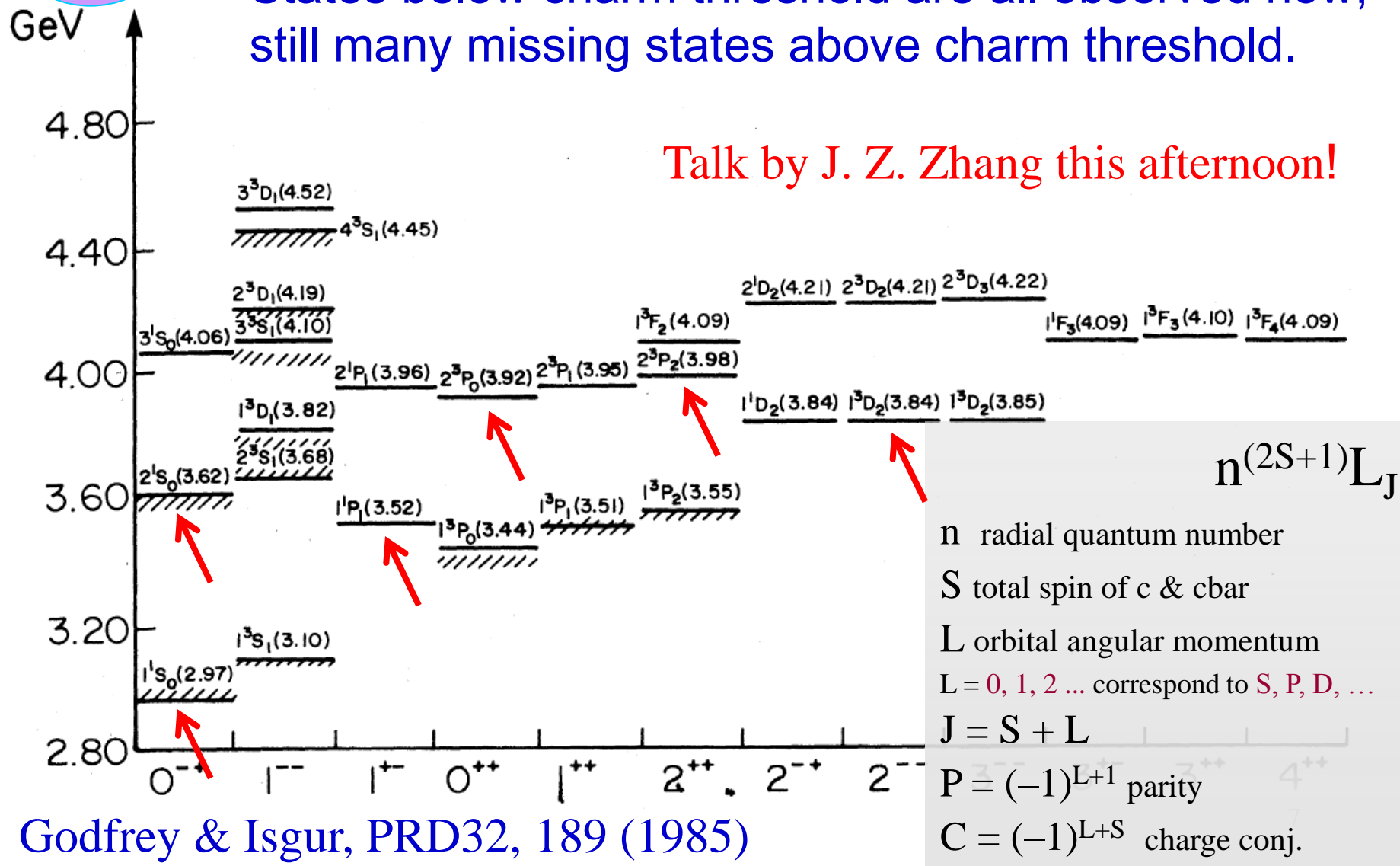




Charmonium spectroscopy

States below charm threshold are all observed now, still many missing states above charm threshold.

Talk by J. Z. Zhang this afternoon!



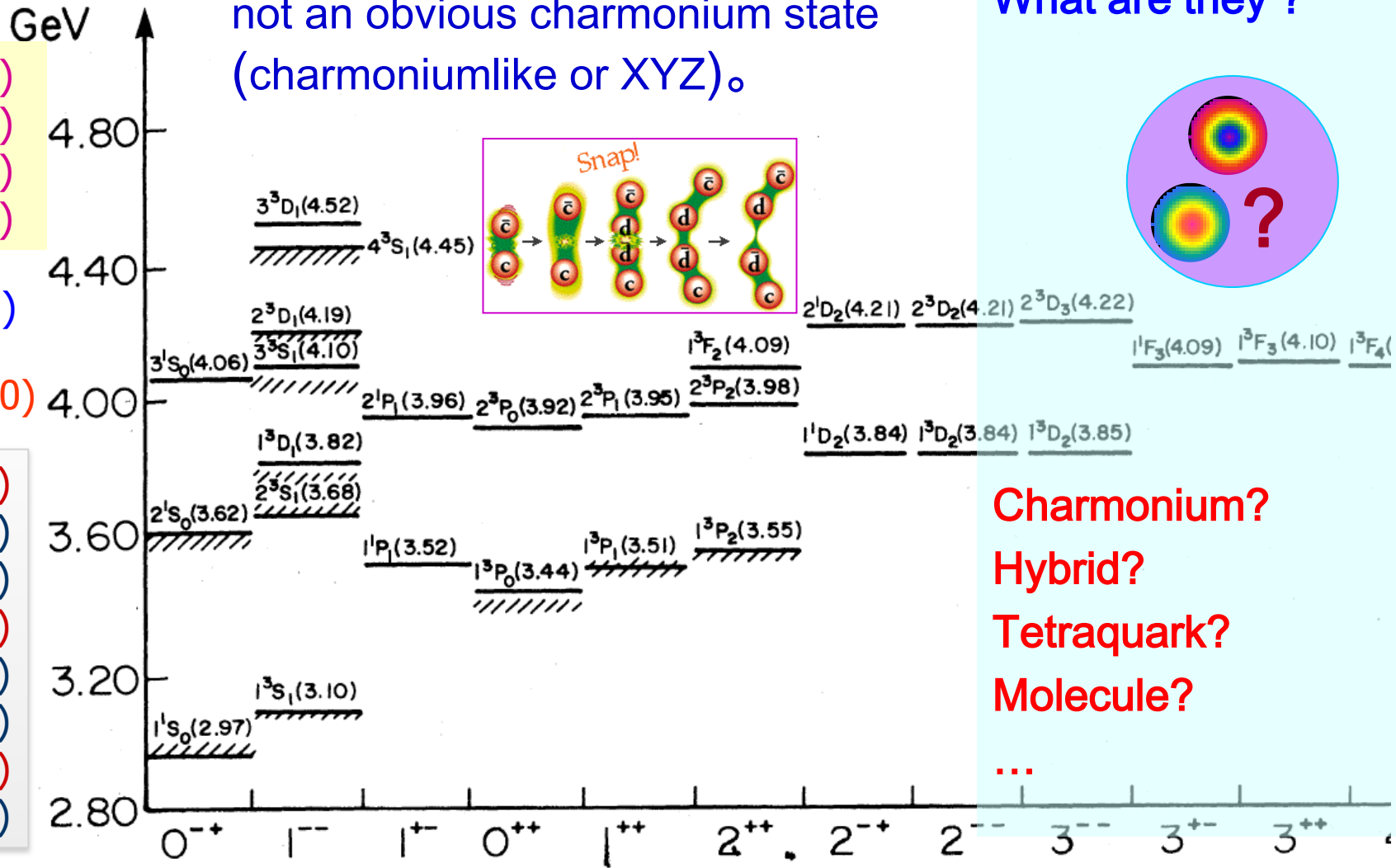
There are lots of XYZ states

Charmonium in the final state, but not an obvious charmonium state (charmoniumlike or XYZ).

What are they ?



- Z(4430)
- Z(4250)
- Z(4050)
- Z(3900)
- X(3872)
- XYZ(3940)
- X(3915)
- X(4160)
- Y(4008)
- Y(4140)
- Y(4260)
- Y(4360)
- X(4350)
- Y(4660)

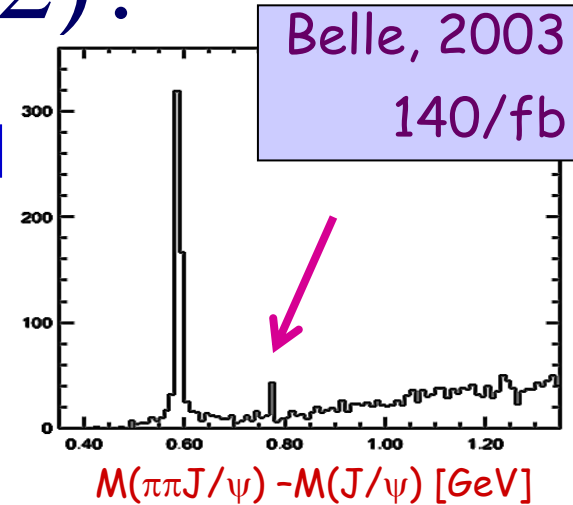


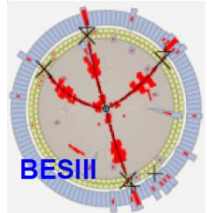
- Charmonium?
- Hybrid?
- Tetraquark?
- Molecule?
- ...

Not all of them are charmonia!

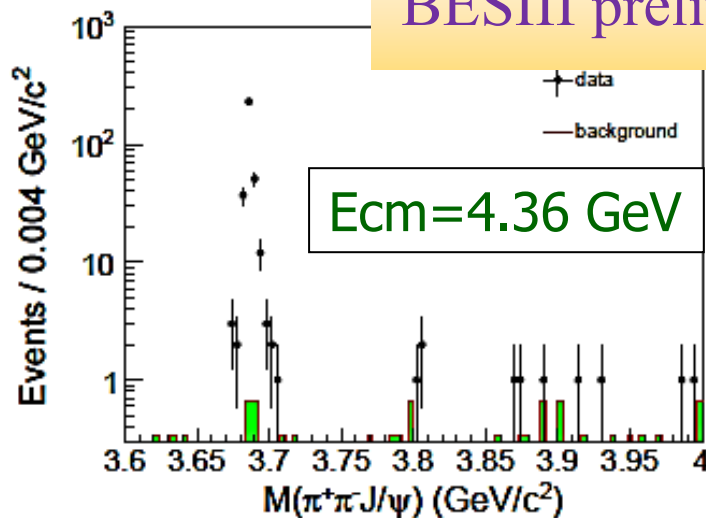
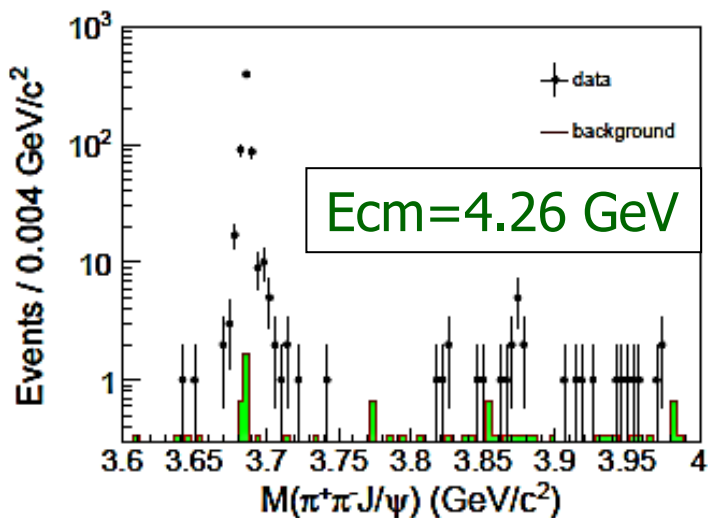
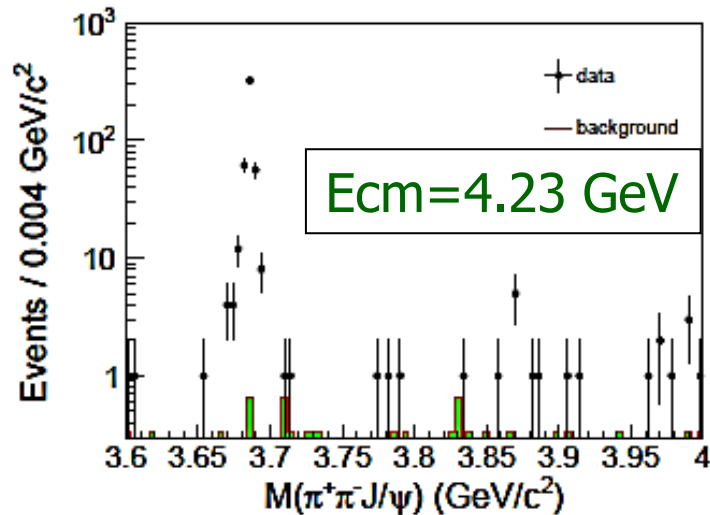
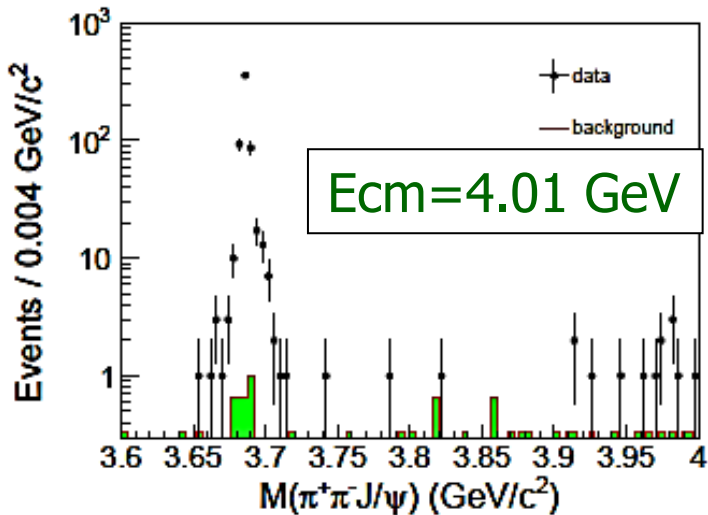
What is the X(3872)?

- Mass: Very close to $\bar{D}^0 D^{*0}$ threshold
- Width: Very narrow, < 1.2 MeV
- $J^{PC} = 1^{++}$ [LHCb]
- Production
 - in $\bar{p}p/pp$ collision – rate similar to charmonia
 - In B decays – KX similar to $\bar{c}c$, K^*X smaller than $\bar{c}c$
 - $Y(4260) \rightarrow \gamma + X(3872)$ [BESIII, see next slides]
- Decay BR: open charm $\sim 50\%$, charmonium $\sim O(\%)$
- Nature (very likely exotic)
 - Loosely $\bar{D}^0 D^{*0}$ bound state (like deuteron?)?
 - Mixture of excited χ_{c1} and $\bar{D}^0 D^{*0}$ bound state?
 - Many other possibilities (if it is not χ'_{c1} , where is χ'_{c1} ?)



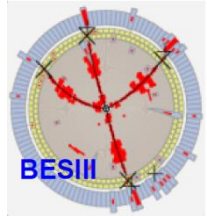


Observation of $e^+e^- \rightarrow \gamma X(3872) \rightarrow \gamma \pi^+ \pi^- J/\psi$

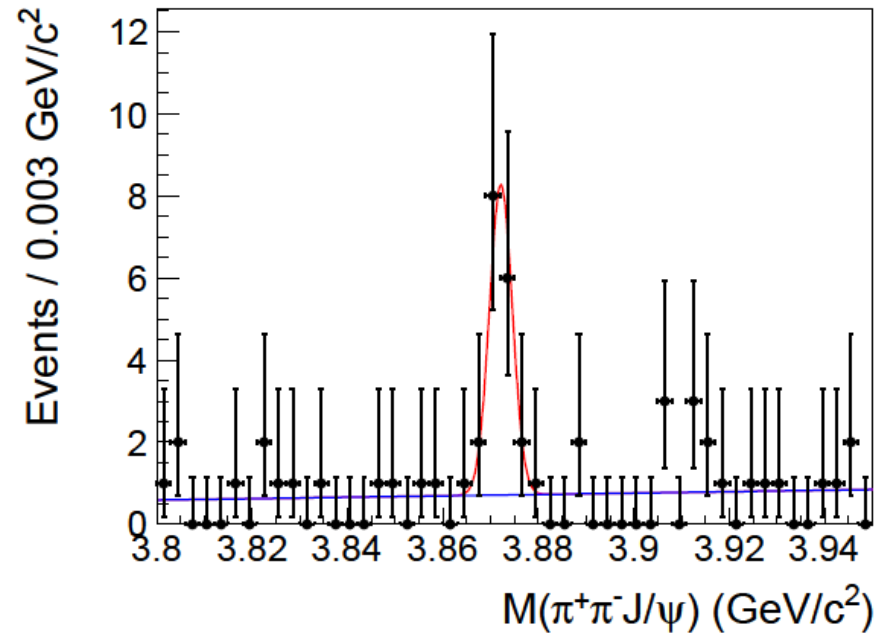
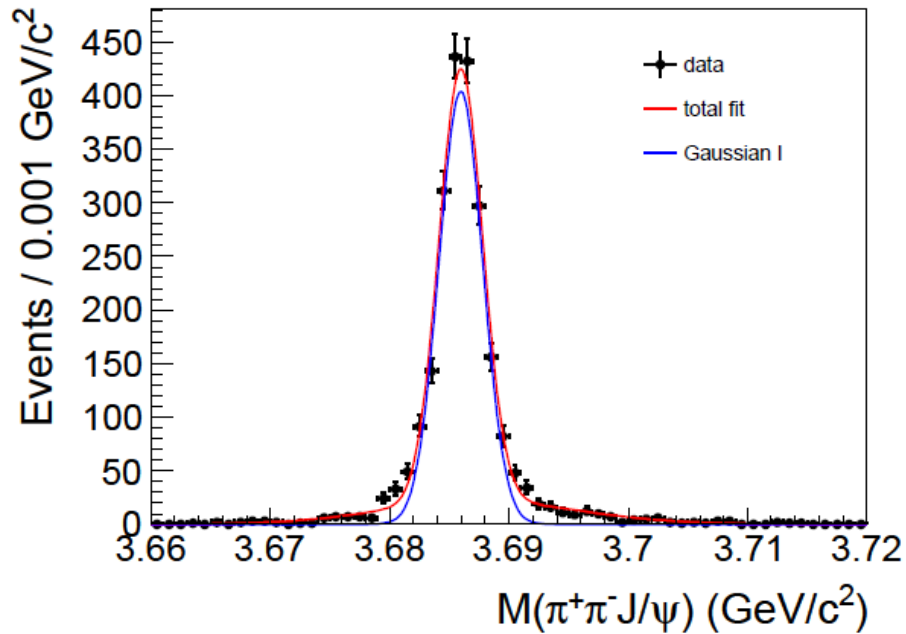


BESIII preliminary

Clear ISR ψ' signal for data validation
X(3872) signal at around 4.23-4.26 GeV



Observation of $e^+e^- \rightarrow \gamma X(3872)$



ISR ψ' signal is used for rate, mass, and mass resolution calibration.

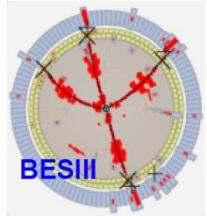
$N(\psi')=1242$; $Mass=3685.96 \pm 0.05$ MeV; $\sigma_M=1.84 \pm 0.06$ MeV

BESIII preliminary

$N(X(3872))=15.0 \pm 3.9$

5.3 σ

$M(X(3872)) = 3872.1 \pm 0.8 \pm 0.3$ MeV [PDG: 3871.68 ± 0.17 MeV]



Observation of $e^+e^- \rightarrow \gamma X(3872)$

\sqrt{s} (GeV)	$\sigma^B[e^+e^- \rightarrow \gamma X(3872)] \cdot \mathcal{B}(X(3872) \rightarrow \pi^+\pi^- J/\psi)$ (pb)
4.009	< 0.13 at 90% C.L.
4.230	$0.32 \pm 0.15 \pm 0.02$
4.260	$0.35 \pm 0.12 \pm 0.02$
4.360	< 0.39 at 90% C.L.

It seems $X(3872)$ is from $Y(4260)$ decays. **At 4.26 GeV,**

$$\sigma^B(e^+e^- \rightarrow \pi^+\pi^- J/\psi) = (62.9 \pm 1.9 \pm 3.7) \text{ pb},$$

$$\frac{\sigma[e^+e^- \rightarrow \gamma X(3872)] \cdot \mathcal{B}(X(3872) \rightarrow \pi^+\pi^- J/\psi)}{\sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)} = (5.6 \pm 2.0) \times 10^{-3}$$

If we take $\mathcal{B}(X(3872) \rightarrow \pi^+\pi^- J/\psi) \sim 5\%$, ($>2.6\%$ in PDG)

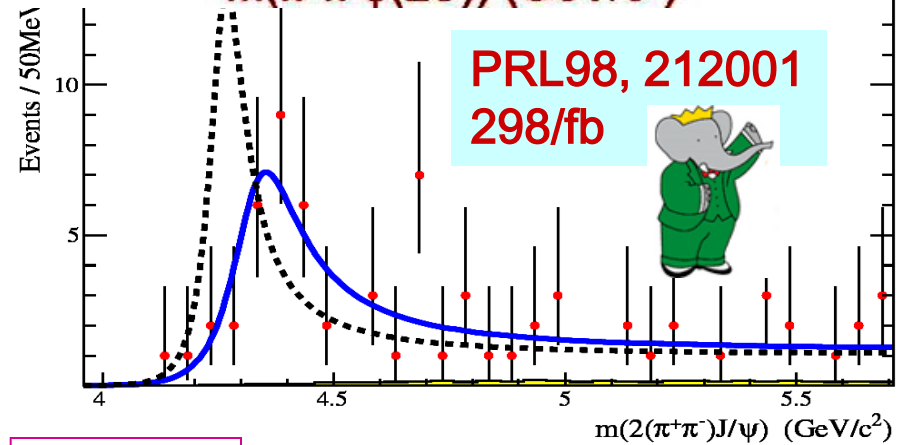
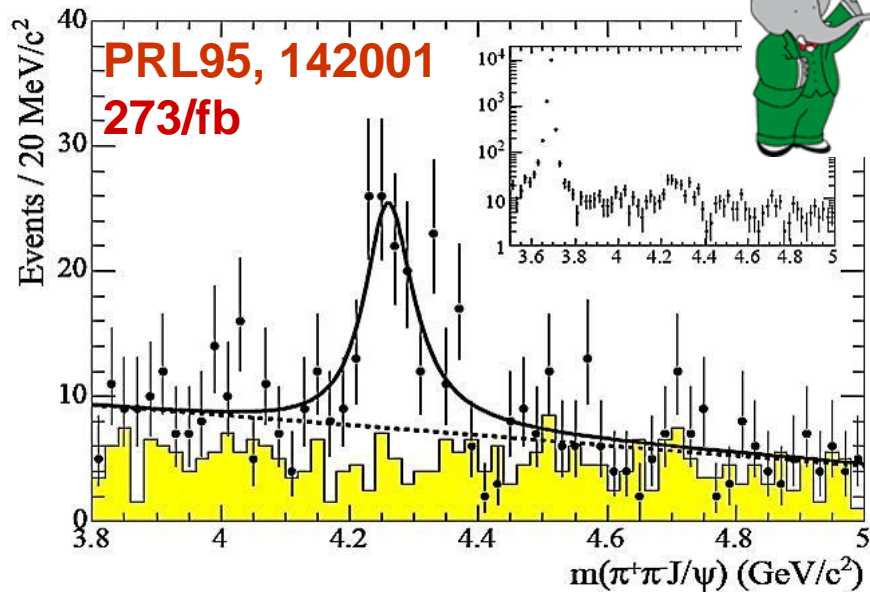
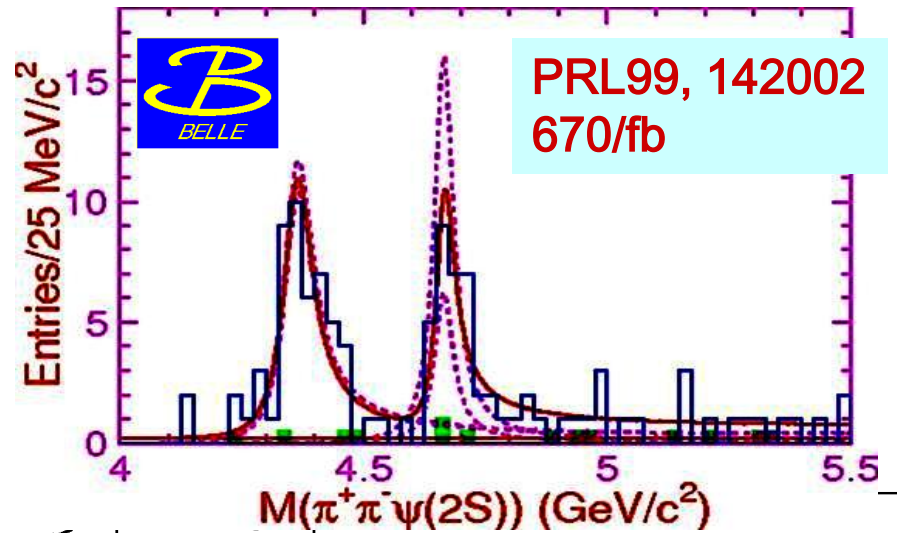
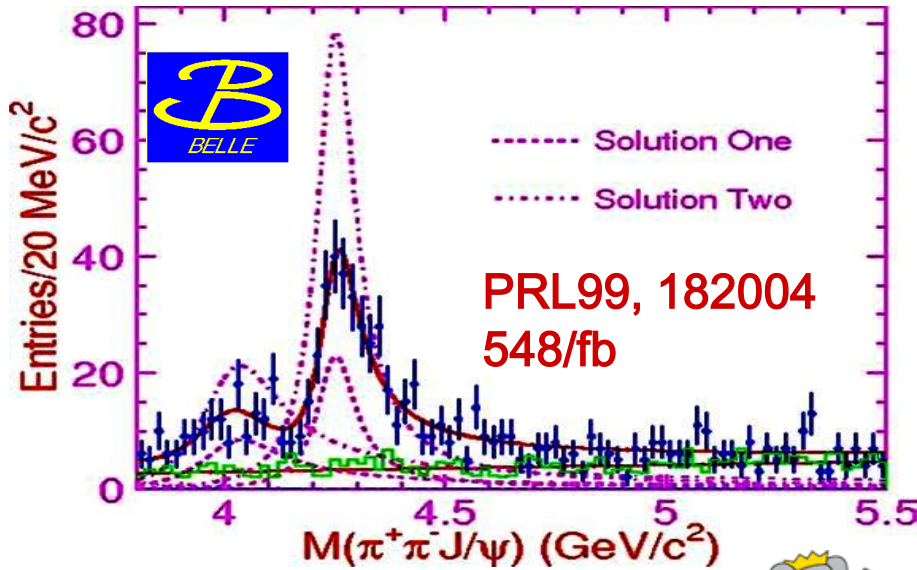
$$\frac{\sigma(e^+e^- \rightarrow \gamma X(3872))}{\sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)} \sim 11.2\% \quad \text{Large transition ratio !}$$

Y-family states

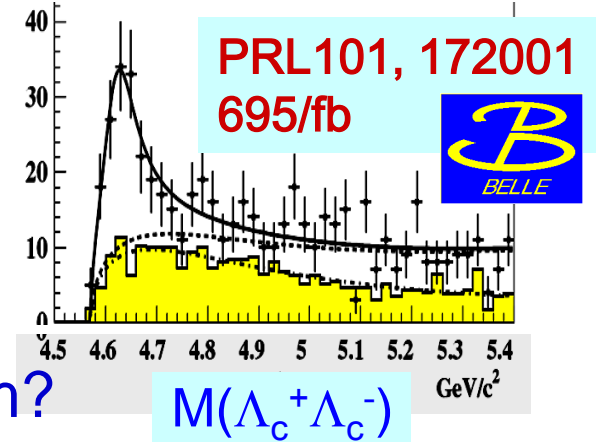
(vectors observed in Initial State Radiation)

+ $e^+e^- \rightarrow \pi^+\pi^-h_c$ from BESIII

The Y states



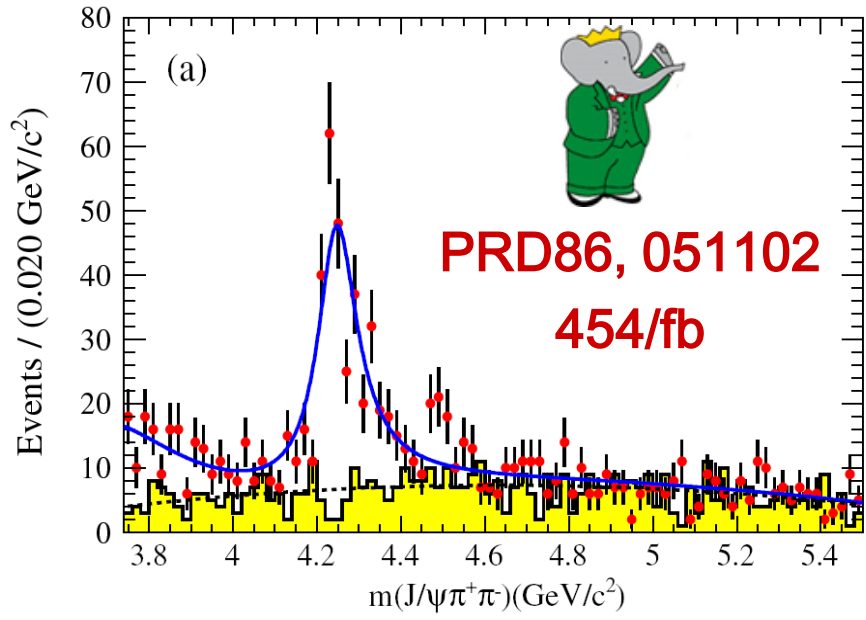
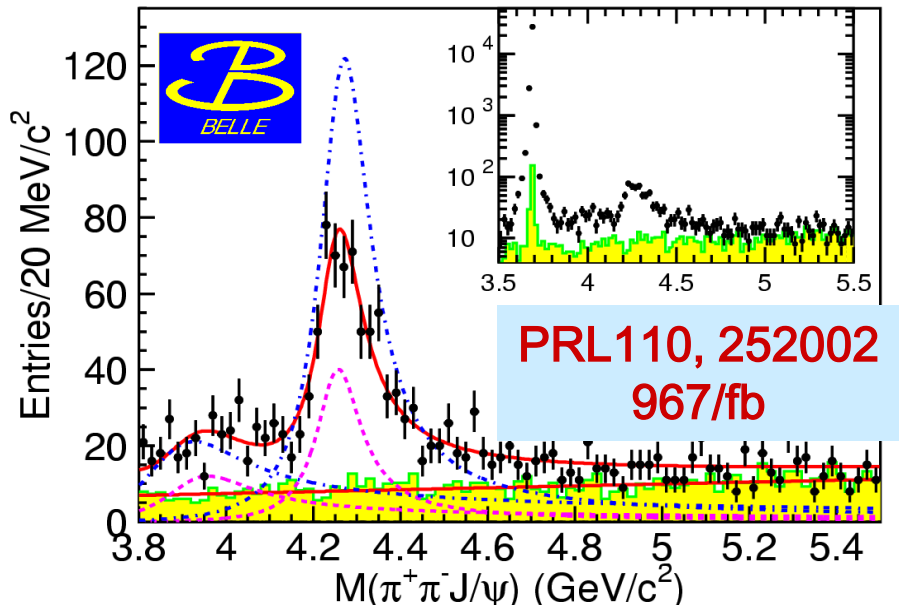
- Y(4008)
- Y(4260)
- Y(4360)
- Y(4660)
- Y(4630)



Above $\bar{D}D$ threshold, decay to open charm?

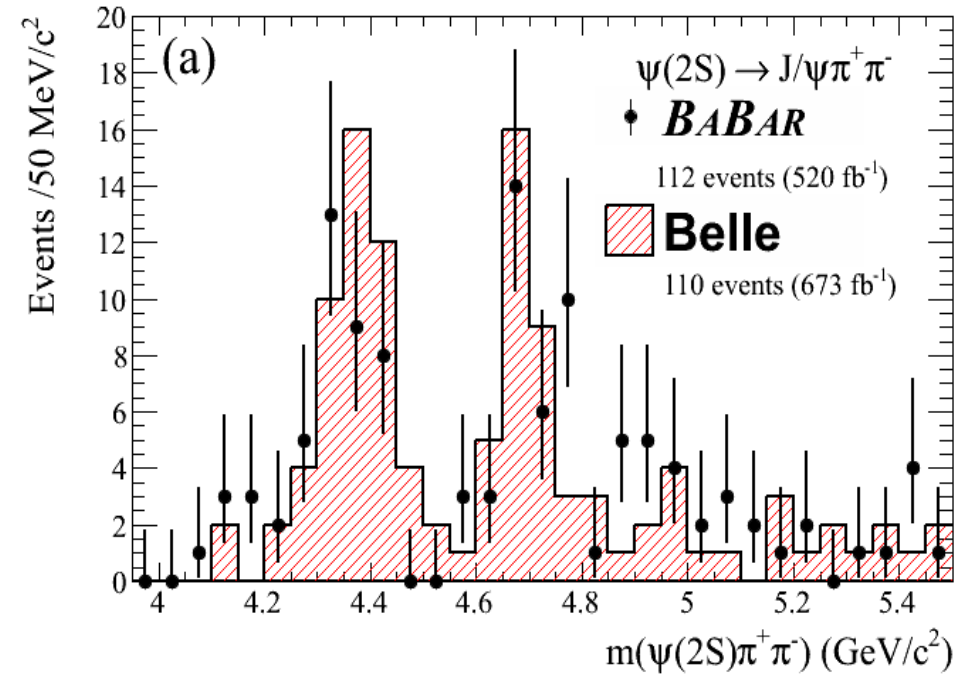
$M(\Lambda_c^+\Lambda_c^-)$

The Y states



Belle: PRL99, 142002, 673/fb

BaBar: 1211.6271, 520/fb



Y(4008): confirmed by Belle with more data; events observed at BaBar, fit with exponential

Wait for BESIII

Y(4660): confirmed by BaBar

Y(4630): no data, a bit beyond

BEPCCII/BESIII limit

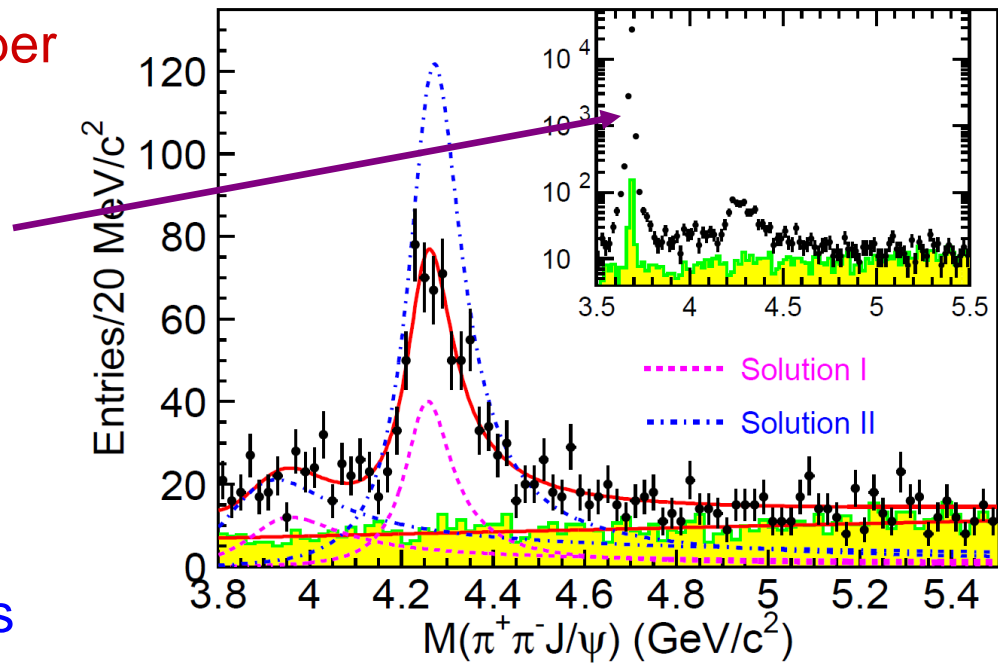


Update ISR $\pi^+\pi^-J/\psi$ analysis

Lum=967fb⁻¹

Event selections are almost the same as in previous Belle published paper PRL99, 182004 (2007)

- ▼ Clean $\psi(2S)$ signal events are obtained, purity>99%.
- ▼ Fit with double Gaussian yields $M(\psi(2S)) = (3686.1 \pm 0.2) \text{ MeV}$, $\sigma=4.8\text{MeV}$
- ▼ ISR $\Psi(2S)$ production cross sections agree with calculations



	e^+e^-	$\mu^+\mu^-$	QED
$\sigma(\Upsilon(4S))$	$(14.12 \pm 0.18 \pm 0.85) \text{ pb}$	$(15.09 \pm 0.11 \pm 0.79) \text{ pb}$	$(14.25 \pm 0.26) \text{ pb}$
$\sigma(\Upsilon(5S))$	$(13.79 \pm 0.44 \pm 0.83) \text{ pb}$	$(13.33 \pm 0.25 \pm 0.70) \text{ pb}$	$(13.42 \pm 0.25) \text{ pb}$
$\sigma(\Upsilon(2S))$	$(16.75 \pm 0.85 \pm 1.01) \text{ pb}$	$(16.63 \pm 0.54 \pm 0.87) \text{ pb}$	$(16.03 \pm 0.29) \text{ pb}$

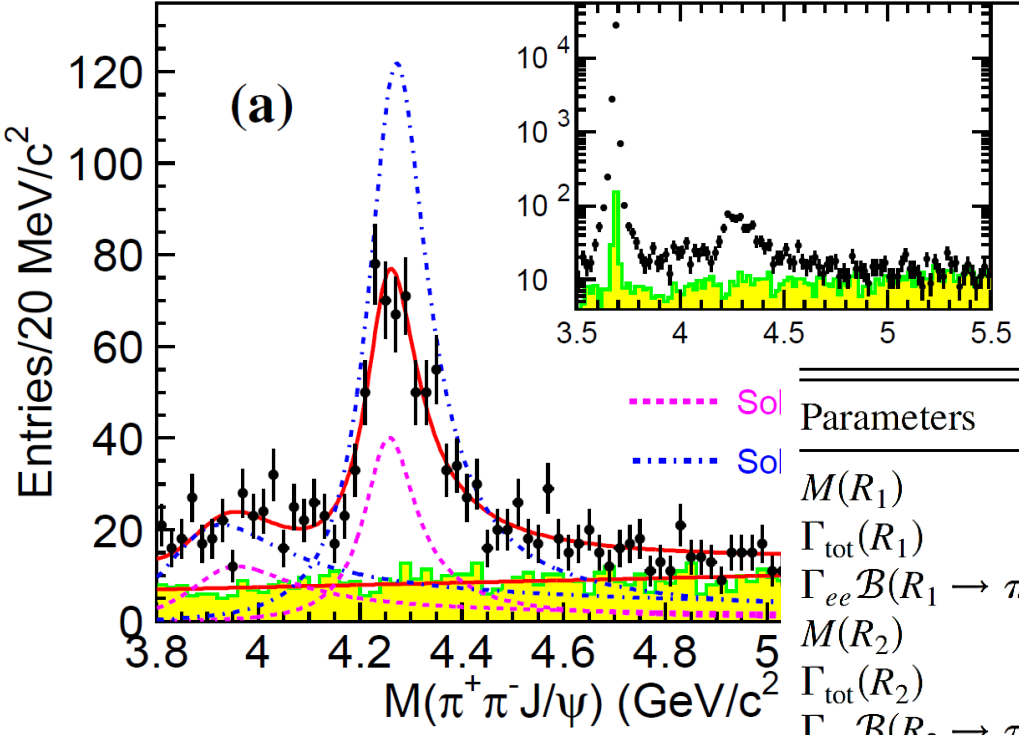
Belle also observed a few $\psi(3770) \rightarrow \pi^+\pi^-J/\psi$ events ($N=54 \pm 20$, 2.8σ)
 $B(\psi(3770) \rightarrow \pi^+\pi^-J/\psi) = (5.5 \pm 2.1) \times 10^{-3}$, PDG (1.28×10^{-3})



Two-resonance fit

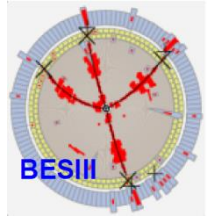
Still observed two resonances, Y(4008) and Y(4260), agrees with Belle's previous results.

$R_1=Y(4008)$
 $R_2=Y(4260)$

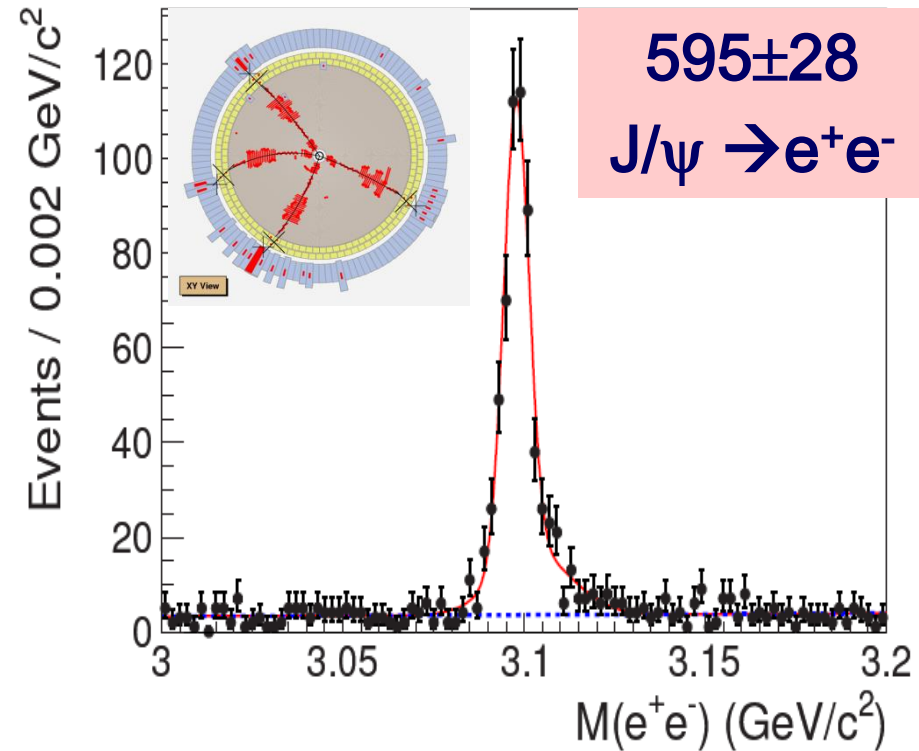
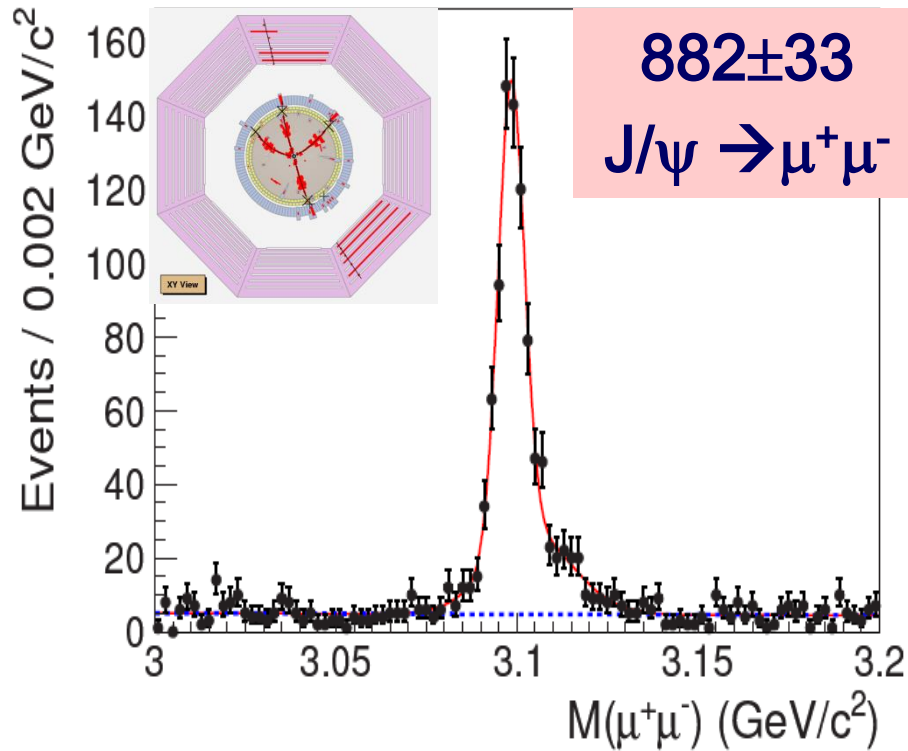


Parameters	Solution I	Solution II
$M(R_1)$	$3890.8 \pm 40.5 \pm 11.5$	
$\Gamma_{\text{tot}}(R_1)$	$254.5 \pm 39.5 \pm 13.6$	
$\Gamma_{ee} \mathcal{B}(R_1 \rightarrow \pi^+ \pi^- J/\psi)$	$(3.8 \pm 0.6 \pm 0.4)$	$(8.4 \pm 1.2 \pm 1.1)$
$M(R_2)$	$4258.6 \pm 8.3 \pm 12.1$	
$\Gamma_{\text{tot}}(R_2)$	$134.1 \pm 16.4 \pm 5.5$	
$\Gamma_{ee} \mathcal{B}(R_2 \rightarrow \pi^+ \pi^- J/\psi)$	$(6.4 \pm 0.8 \pm 0.6)$	$(20.5 \pm 1.4 \pm 2.0)$
ϕ	$59 \pm 17 \pm 11$	$-116 \pm 6 \pm 11$

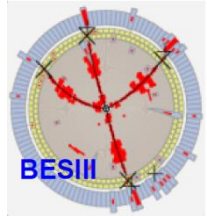
1. Fit with two coherent resonances $|BW_1 + BW_2 \exp(i\phi)|^2 + \text{bkg.}$
2. Mass of Y(4008) is lower than before
3. Fit quality: $\chi^2/\text{ndf} = 101/84$, confidence level is 9.3%



Select $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ at 4.26 GeV



- Select 4 charged tracks and reconstruct J/ψ with lepton pair.
- Very clean sample, very high efficiency ($\sim 45\%$).
- $\sigma(e^+e^- \rightarrow \pi^+\pi^-J/\psi) = (62.9 \pm 1.9 \pm 3.7) \text{ pb}$

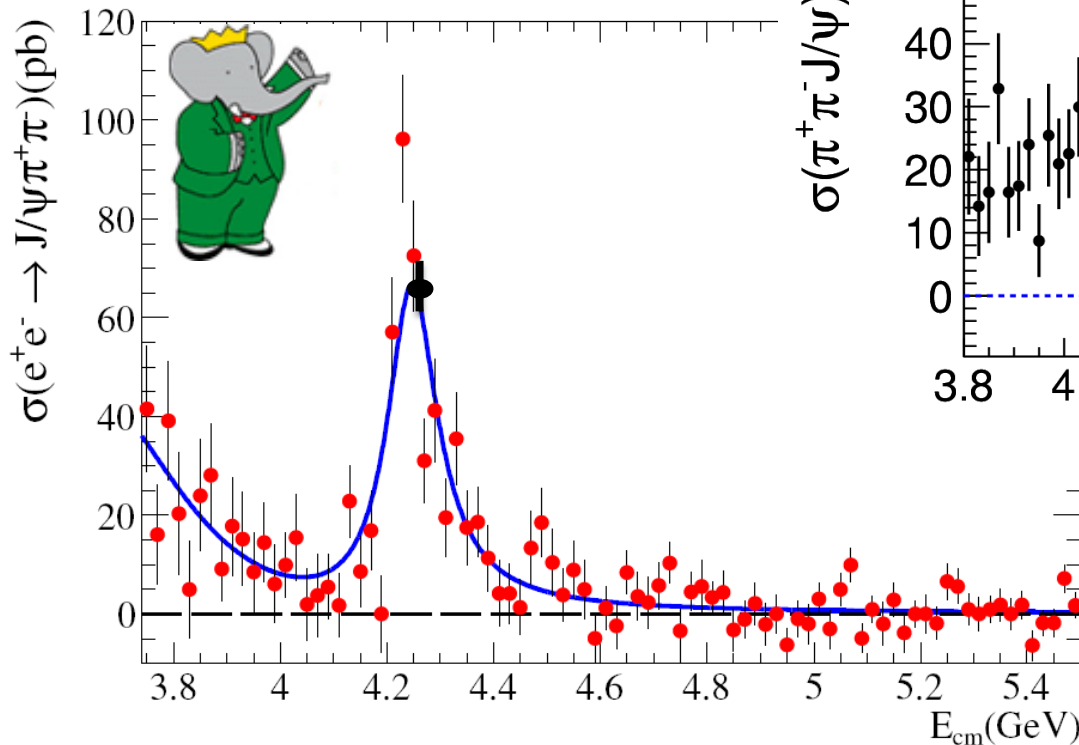


Cross section of $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

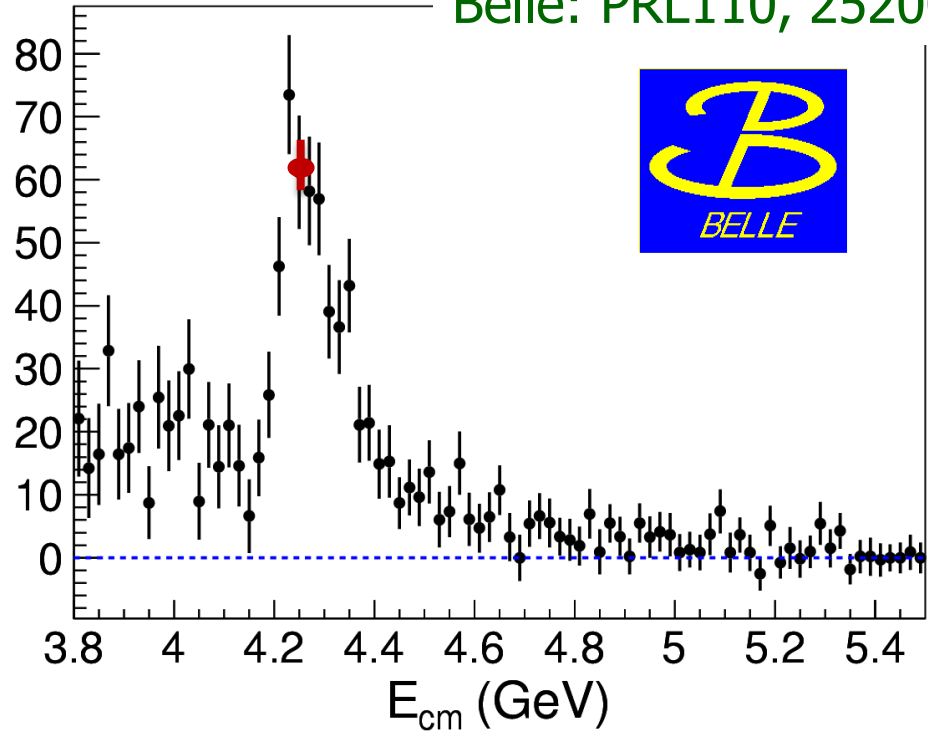
Belle: PRL110, 252002



BaBar: PRD86, 051102 (2012)



$\sigma(\pi^+\pi^-J/\psi)$ (pb)



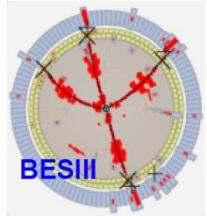
BESIII: PRL110, 252001

$$\text{BESIII: } \sigma(e^+e^- \rightarrow \pi^+\pi^-J/\psi) = (62.9 \pm 1.9 \pm 3.7) \text{ pb}$$

Agree with BaBar & Belle!

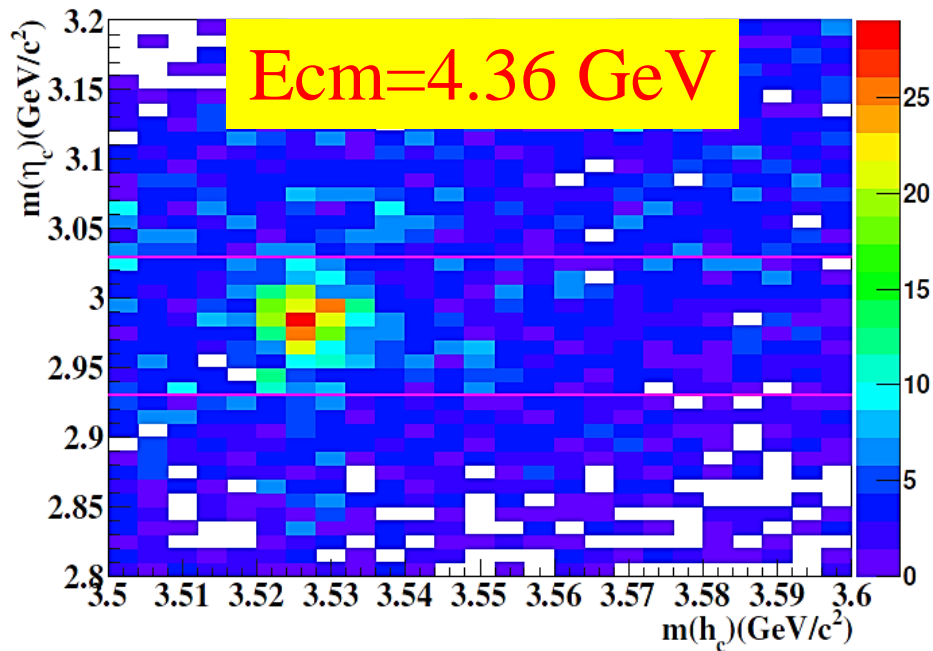
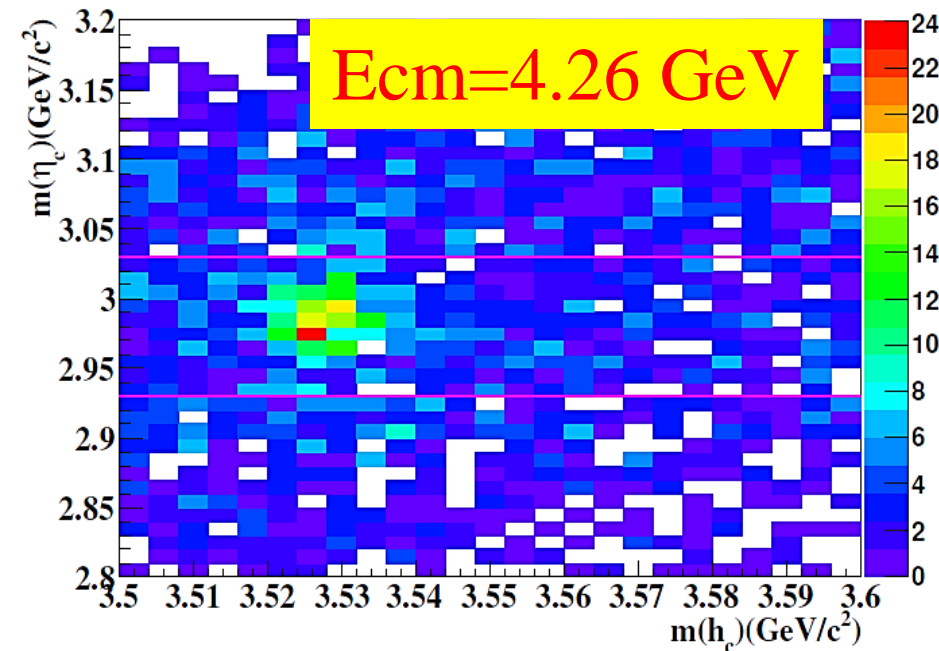
Best precision!

BESIII is measuring cross sections at more energy points, and will take more data!

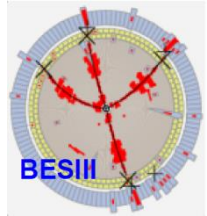


$e^+e^- \rightarrow \pi^+\pi^-h_c(1P)$ at BESIII

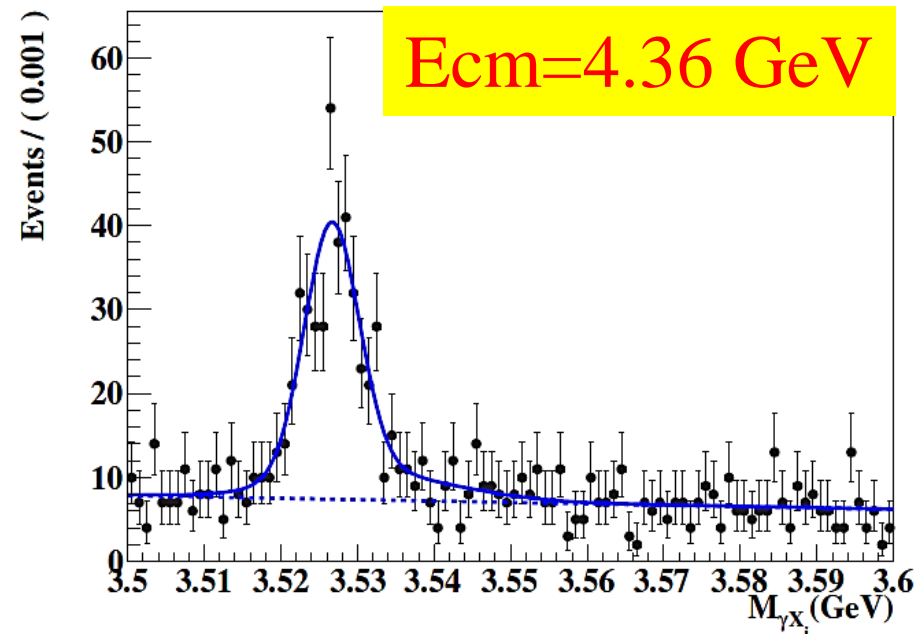
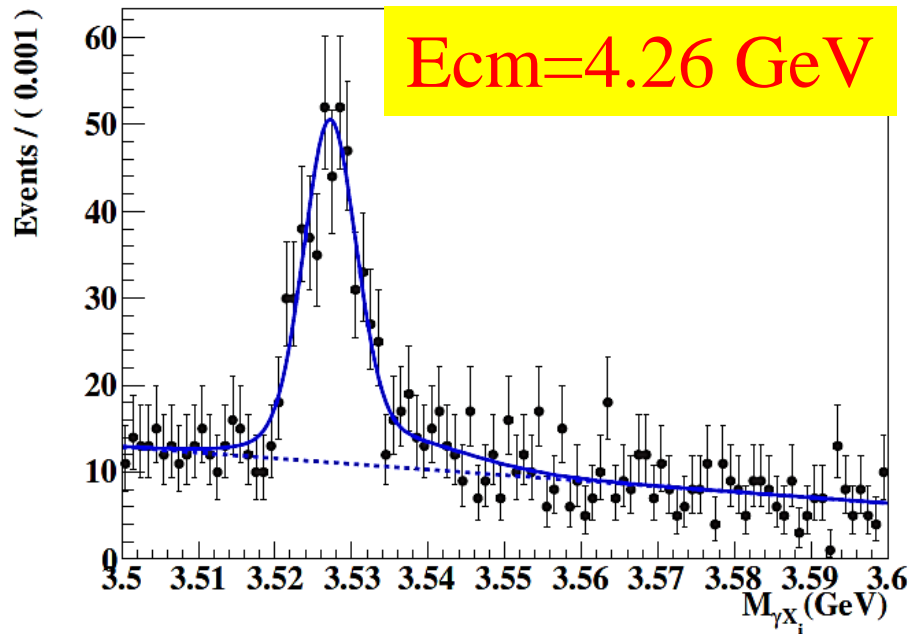
- $h_c \rightarrow \gamma\eta_c$, $\eta_c \rightarrow$ hadrons [16 exclusive decay modes]
 - $p \bar{p}$, $\pi^+\pi^-K^+K^-$, $\pi^+\pi^-p \bar{p}$, $2(K^+K^-)$, $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$
 - $2(\pi^+\pi^-)K^+K^-$, $K_S^0K^+\pi^-+c.c.$, $K_S^0K^+\pi^-\pi^+\pi^-+c.c.$, $K^+K^-\pi^0$
 - $p \bar{p}\pi^0$, $K^+K^-\eta$, $\pi^+\pi^-\eta$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-\eta)$, $2(\pi^+\pi^-\pi^0)$



BESIII preliminary



Observation of $e^+e^- \rightarrow \pi^+\pi^-h_c(1P)$



$$N(h_c)=416\pm 28$$

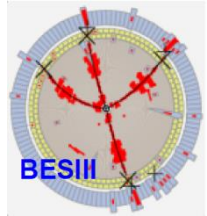
$$\text{Lum}=827/\text{pb}$$

$$\sigma^B=41.0\pm 2.8\pm 7.4 \text{ pb}$$

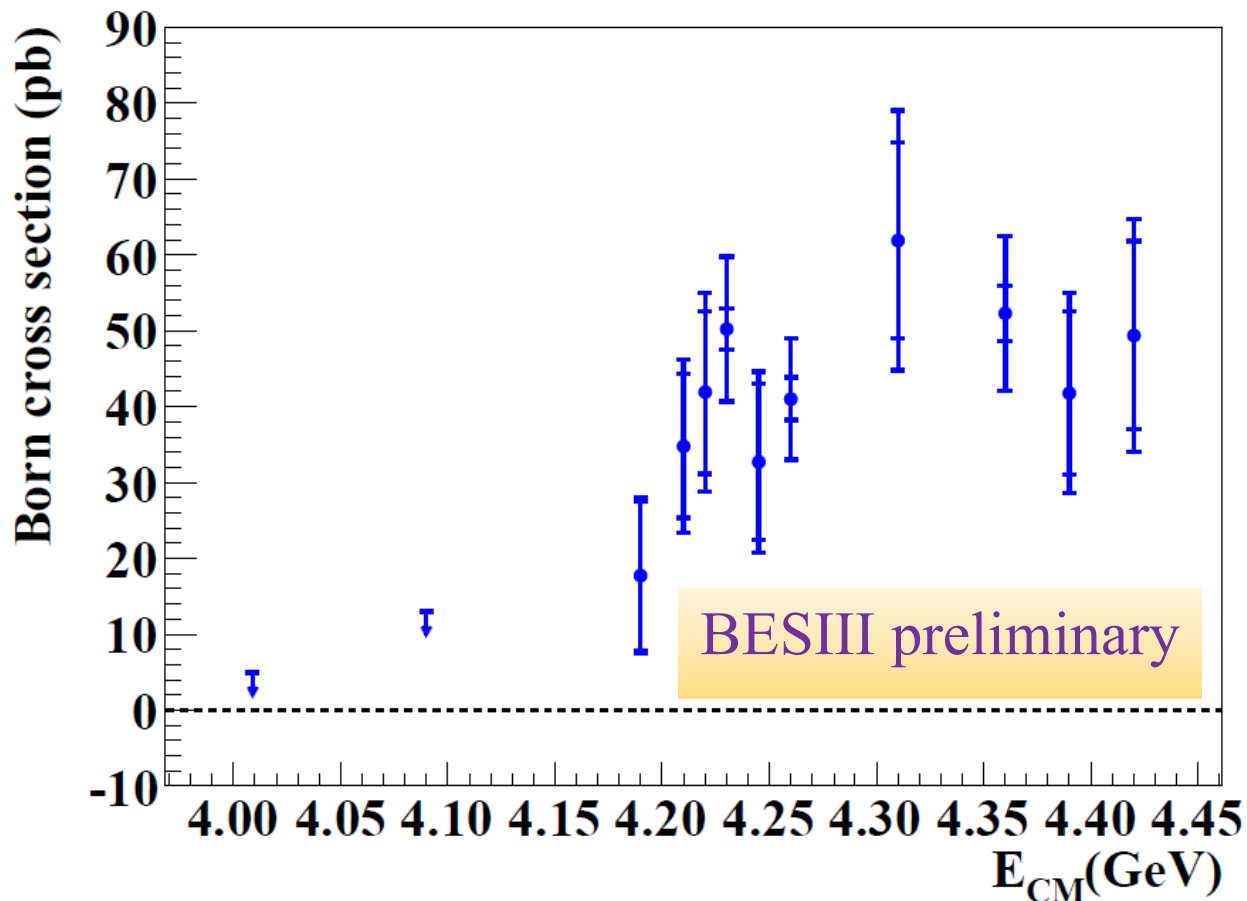
$$N(h_c)=357\pm 25$$

$$\text{Lum}=544/\text{pb}$$

$$\sigma^B=52.3\pm 3.7\pm 9.2 \text{ pb}$$

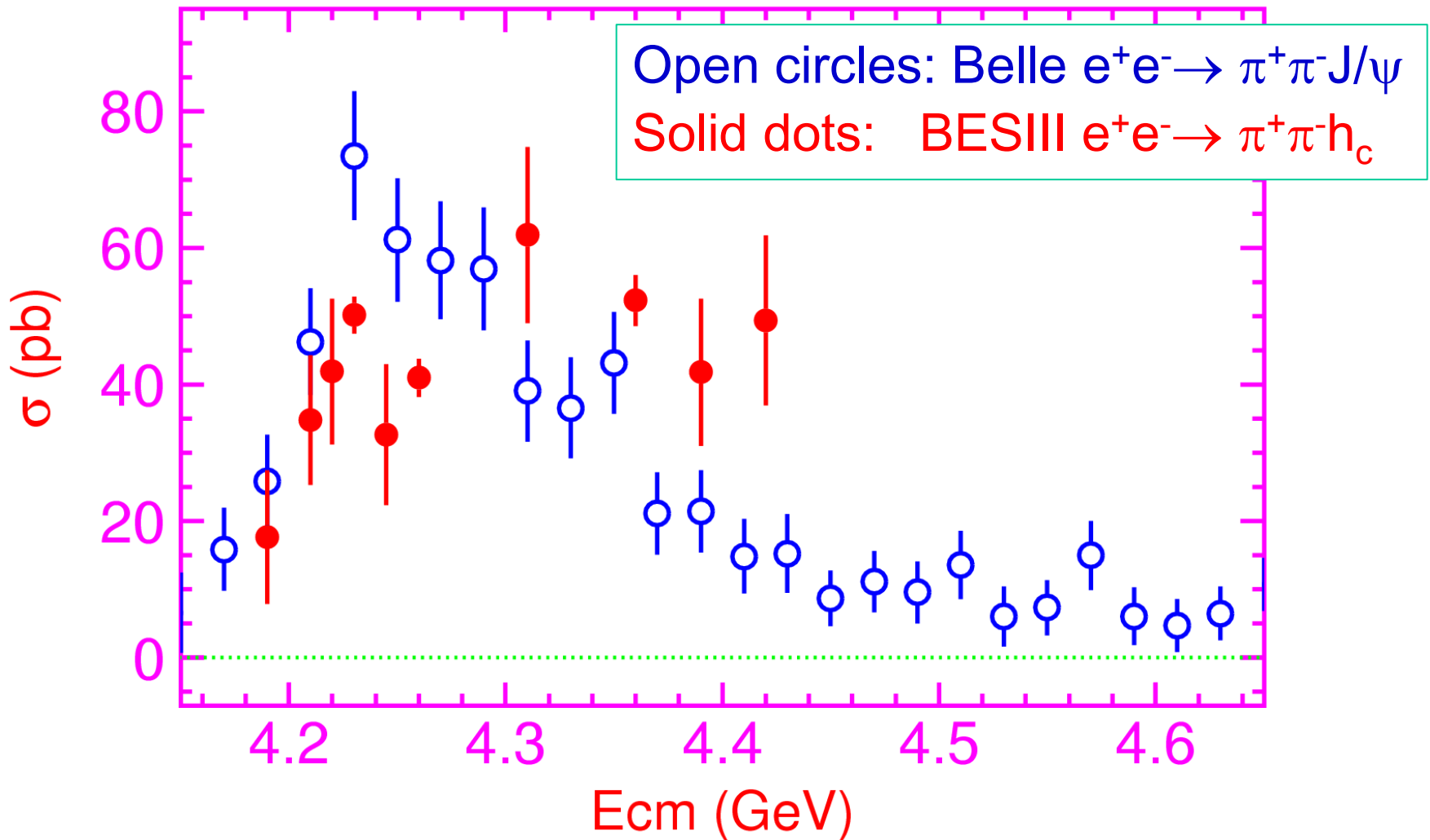


Observation of $e^+e^- \rightarrow \pi^+\pi^-h_c(1P)$



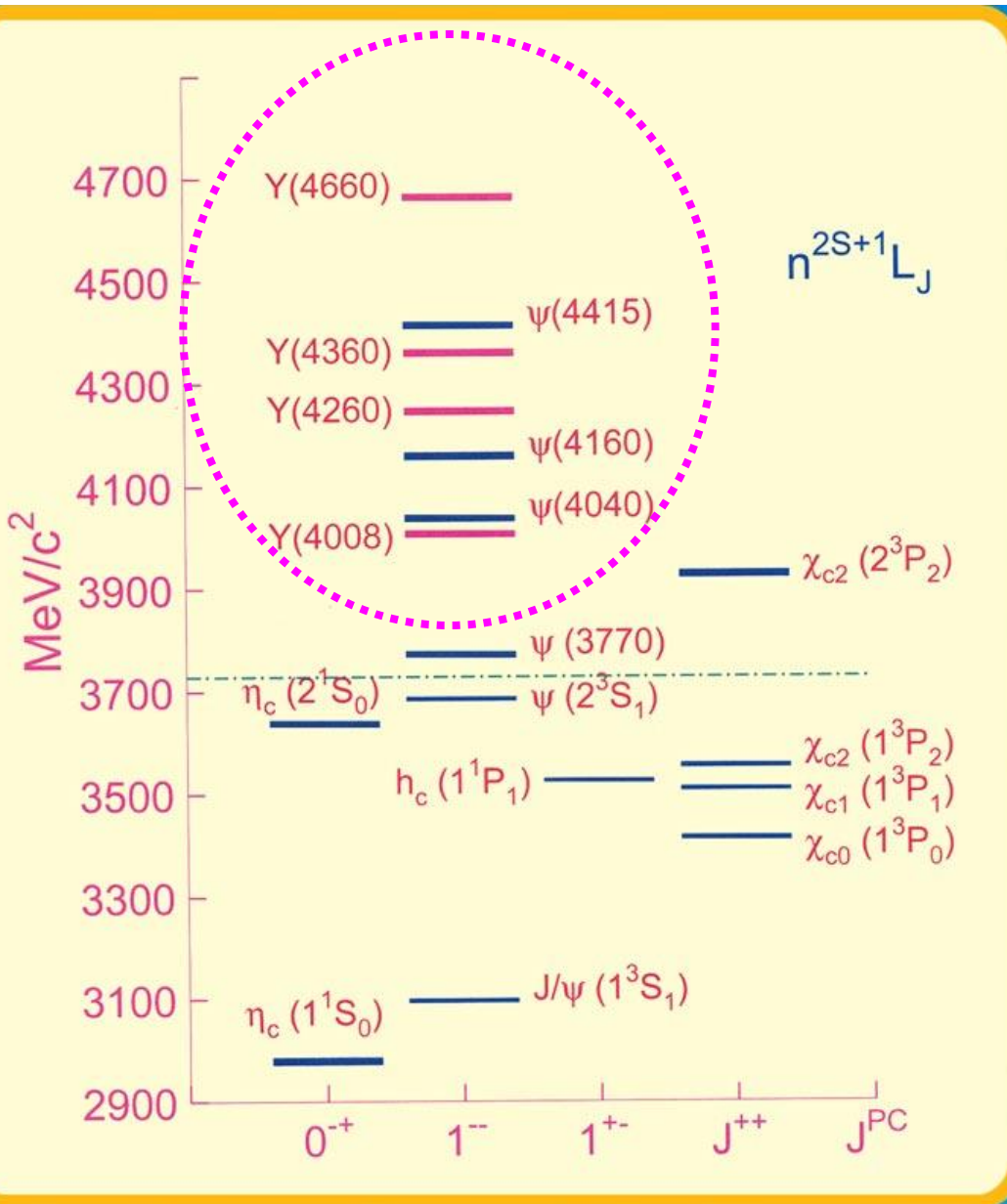
- $\sigma(e^+e^- \rightarrow \pi^+\pi^-h_c) \sim \sigma(e^+e^- \rightarrow \pi^+\pi^-J/\psi)$ but line shape different
- Local maximum ~ 4.23 GeV
- Hint for a vector $\bar{c}c g$ hybrid? [PRD78, 056003 (Guo); 094504 (Dudek): $\bar{c}c$ in spin-singlet in hybrids!]

Comparison of $e^+e^- \rightarrow \pi^+\pi^-h_c$ and $\pi^+\pi^-J/\psi$



Broad structure at ~ 4.4 GeV? Need more data at high energies to complete the line shape measurement.

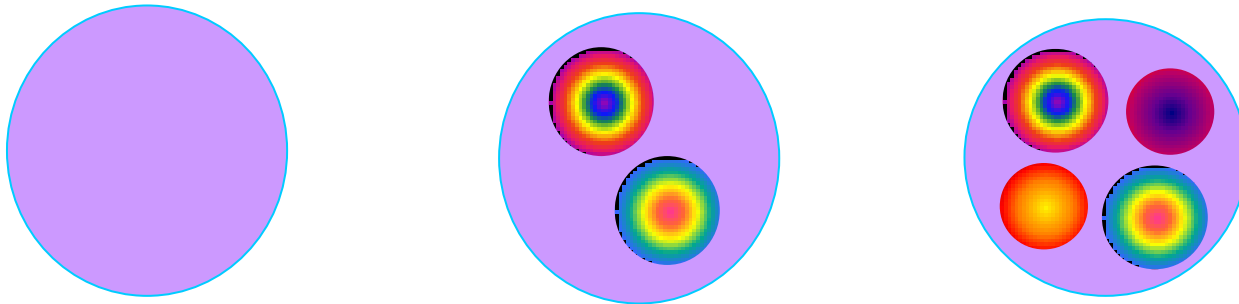
What are the Y states?



- Between 4 and 4.7 GeV, at most 5 states expected (3S, 2D, 4S, 3D, 5S), 7 observed
- Hybrids are expected in this mass region
- Molecular states?
- Cannot rule out threshold effect/FSI/...
- Y(4260), Y(4360), Y(4660) are all narrow and similar

Z_c : charged charmoniumlike states

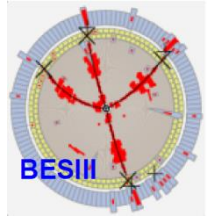
- Find a clear signature for exotic state!



- Decays to charmonium thus has a $\bar{c}c$ pair!
- With electric charge thus has two more light quarks!

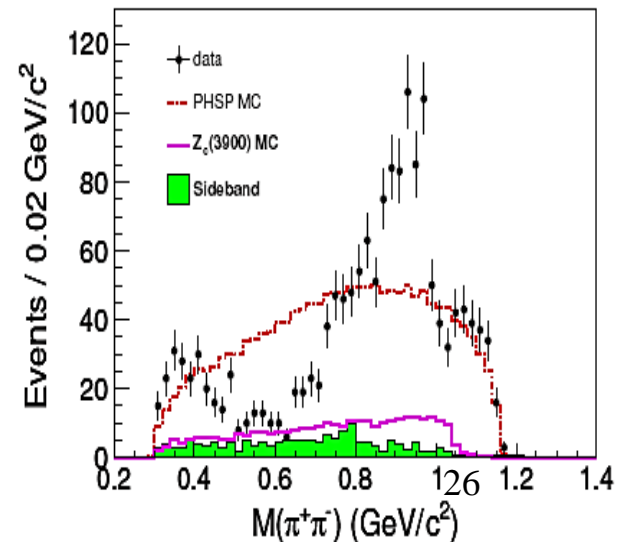
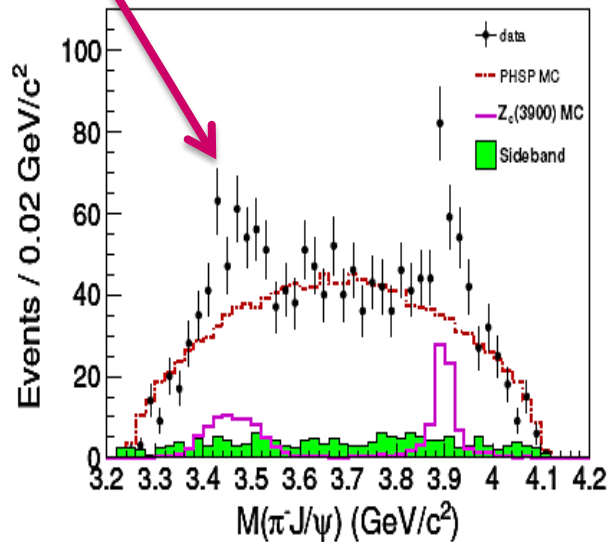
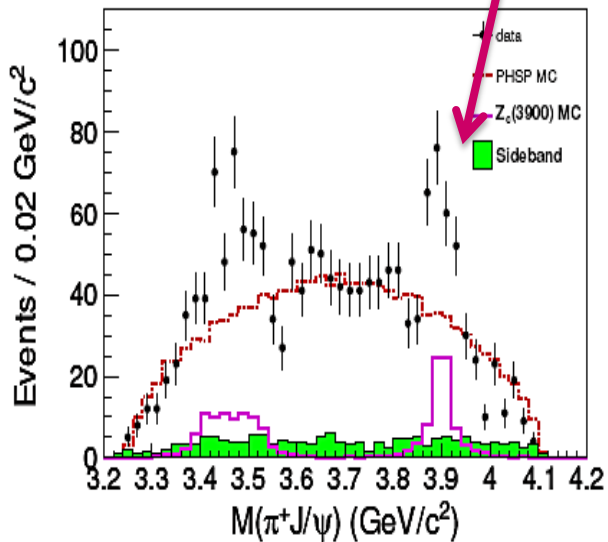
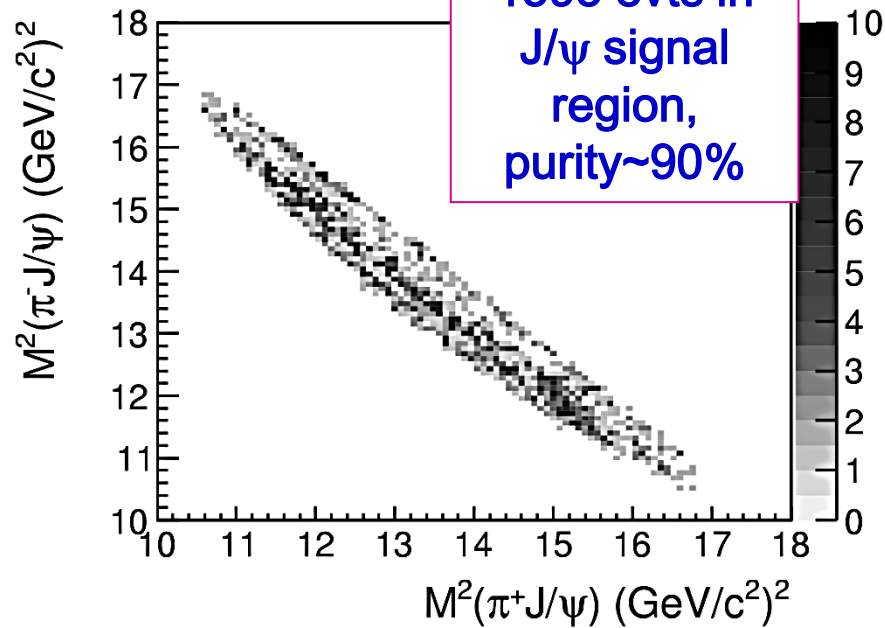
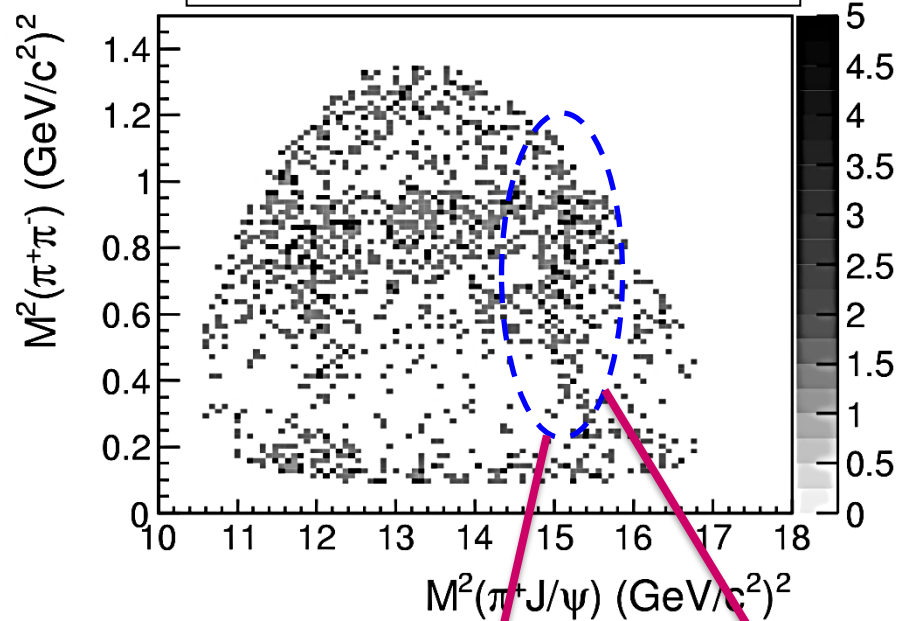
$$\rightarrow N_{\text{quark}} \geq 4 !$$

- Do searches in $\pi^\pm J/\psi$, $\pi^\pm h_c(1P)$, $\pi^\pm \psi(2S)$, $\pi^\pm \chi_{cJ}$, ...
- BESIII: $e^+e^- \rightarrow \pi^\pm + \text{exotics}$, $\rho^\pm + \text{exotics}$, ...



$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ at $E_{cm}=4.26$ GeV

BESIII: PRL110, 252001

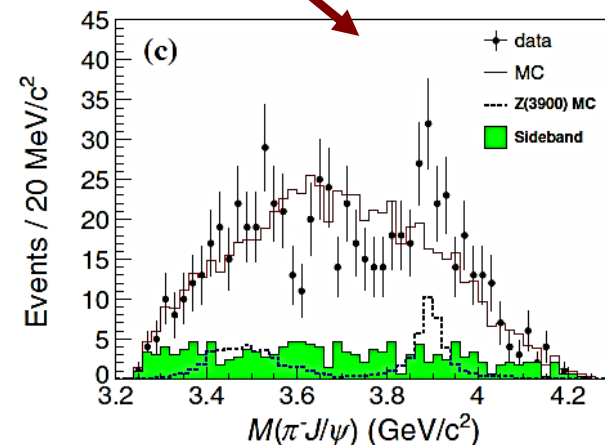
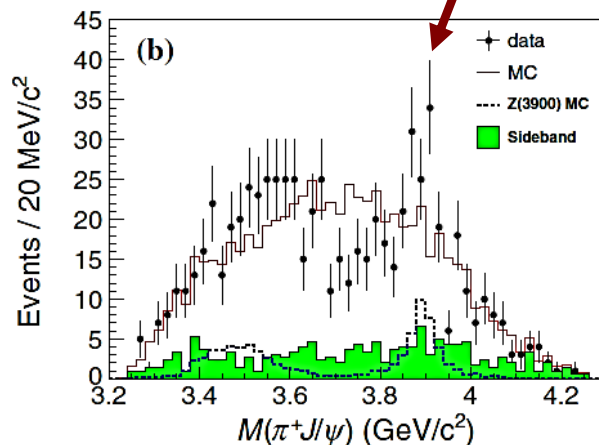
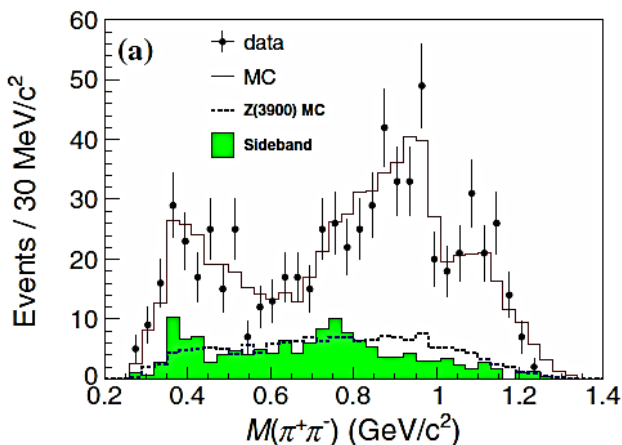
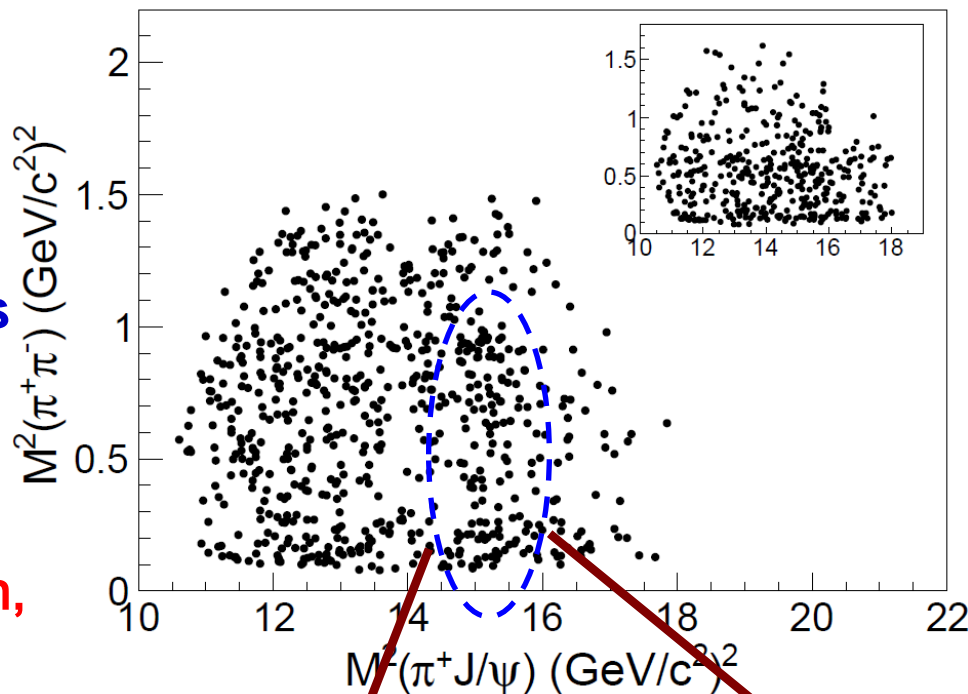




$e^+e^- \rightarrow \pi^+\pi^-J/\psi$ from ISR

Belle: PRL110, 252002

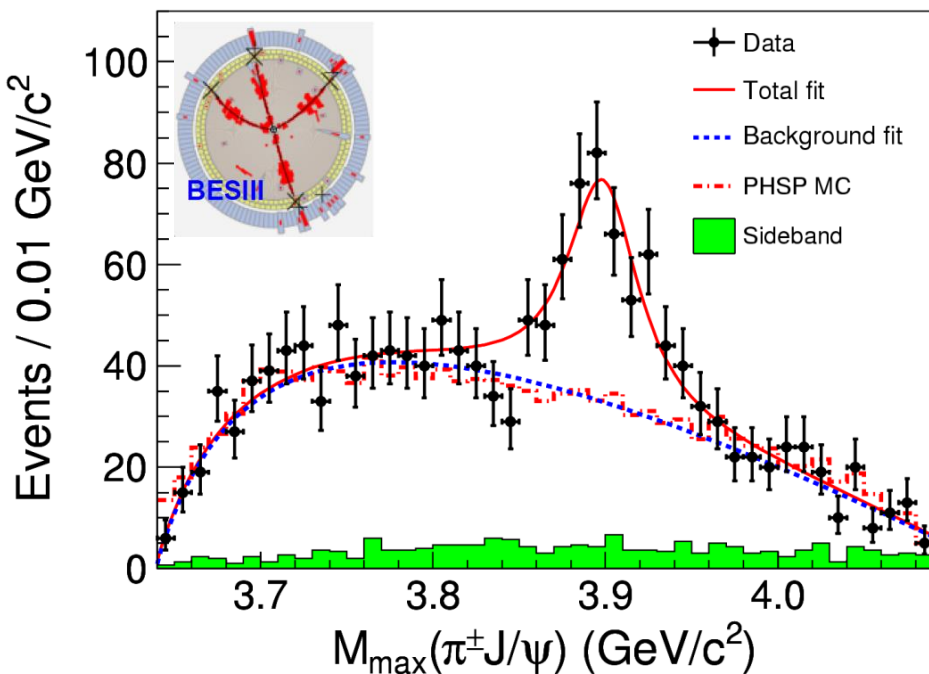
1. $M^2(\pi\pi)$ vs. $M^2(\pi J/\psi)$ for $4.15 < M(\pi\pi J/\psi) < 4.45$ GeV
2. (inset) Background events in J/ψ -mass sidebands
3. Structures both in $\pi\pi$ and $\pi J/\psi$ systems
4. 689 evts in J/ψ signal region, purity~80%



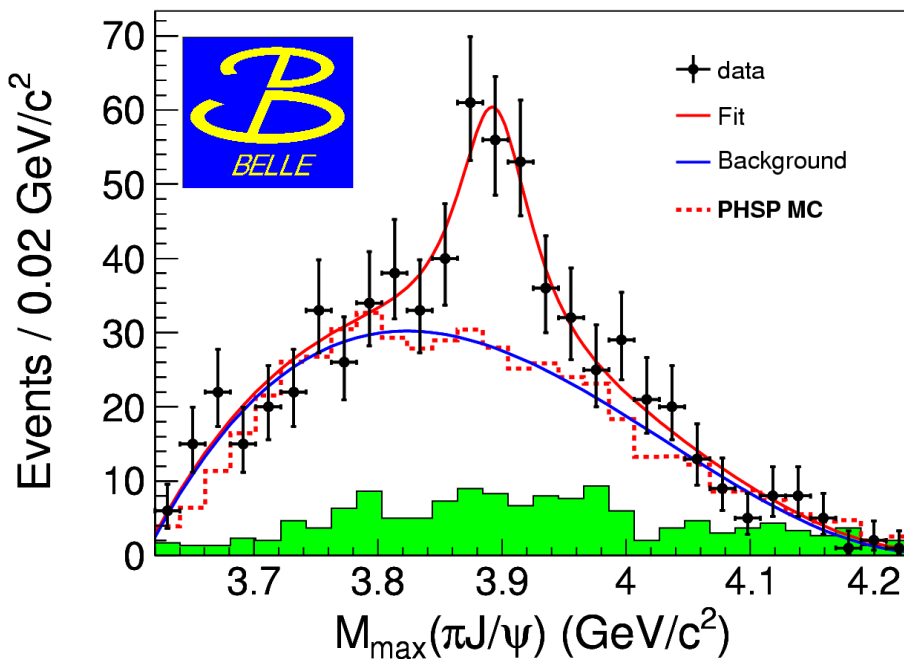
$Z_c(3900)$ observed in two experiments!

BES3 at 4.26 GeV: 1303.5949

Belle with ISR: 1304.0121



- $M = 3899.0 \pm 3.6 \pm 4.9$ MeV
- $\Gamma = 46 \pm 10 \pm 20$ MeV
- 307 ± 48 events
- $>8\sigma$

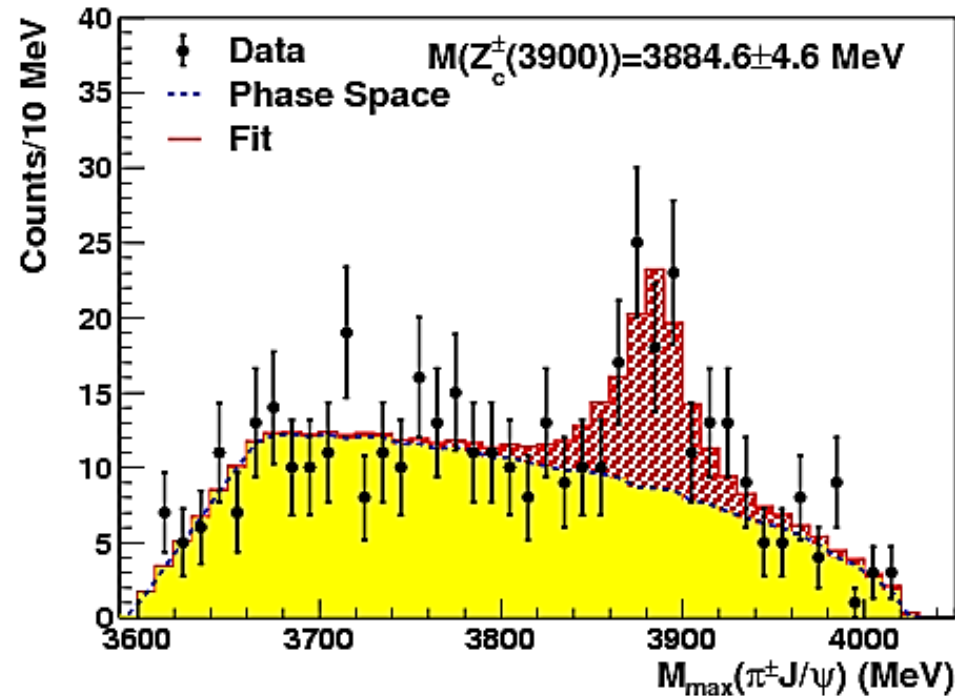


- $M = 3894.5 \pm 6.6 \pm 4.5$ MeV
- $\Gamma = 63 \pm 24 \pm 26$ MeV
- 159 ± 49 events
- $>5.2\sigma$

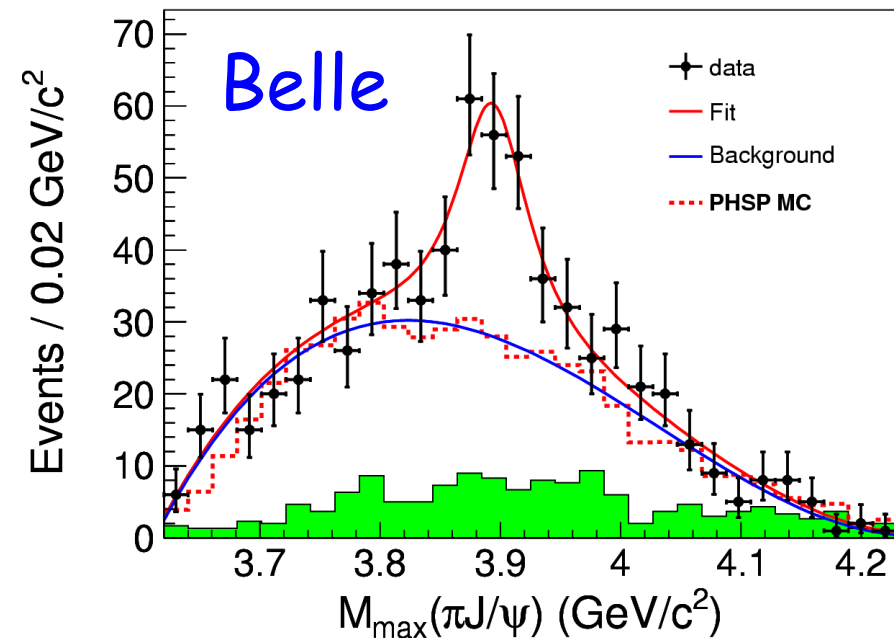
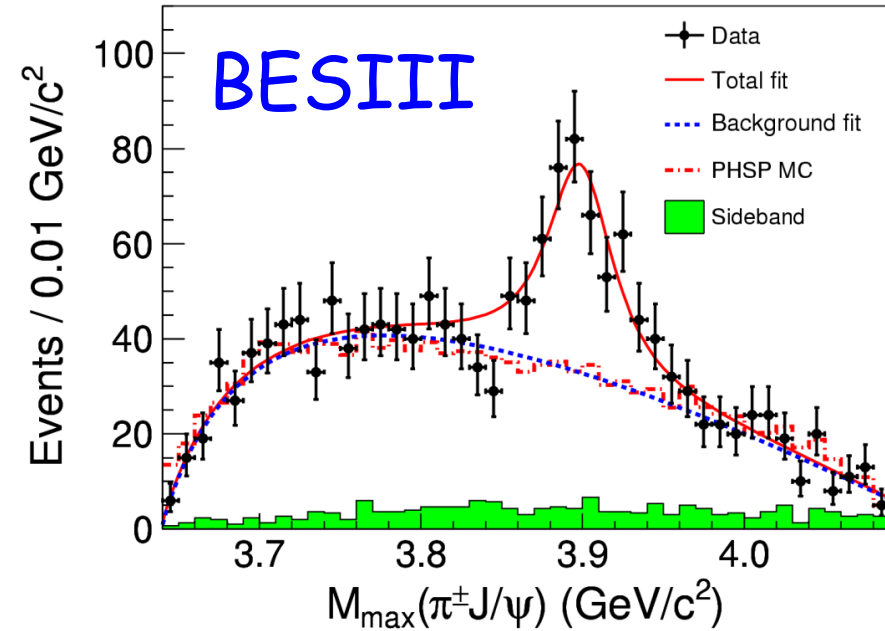
→ Talk by Zhiqing Liu on Monday

Confirmed with CLEOc data!

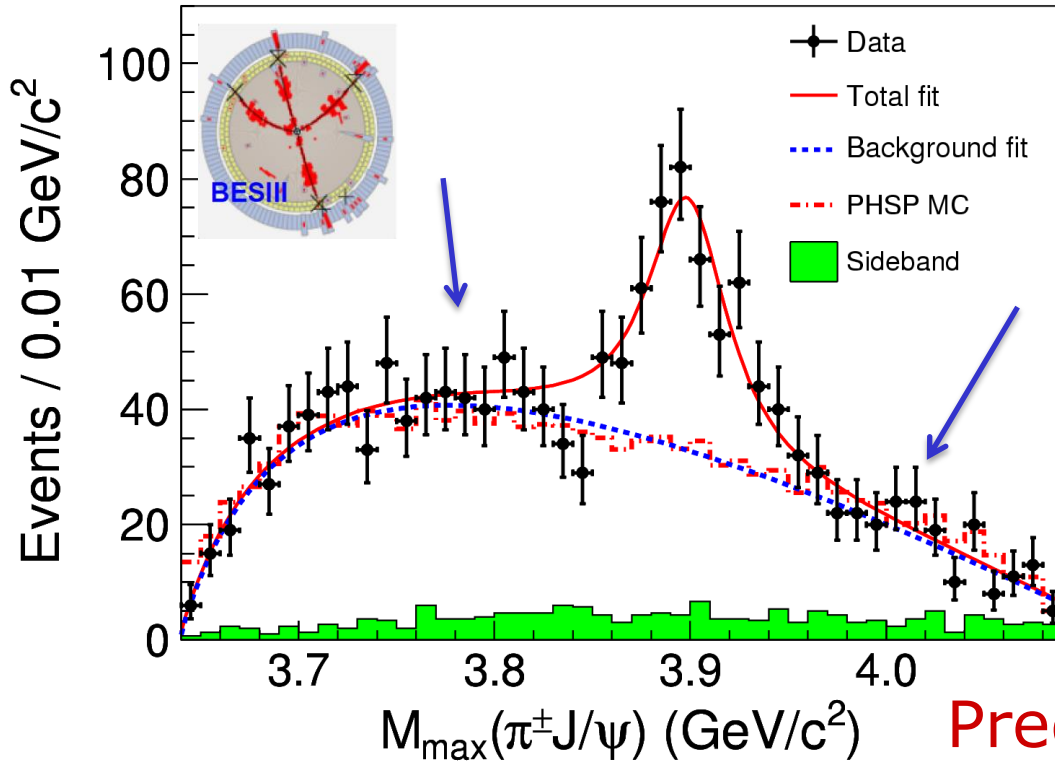
CLEOc data at 4.17 GeV:
1304.3036



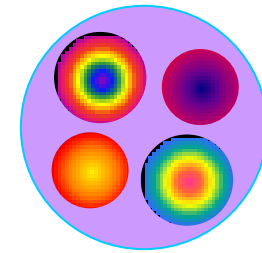
- $M = 3885 \pm 5 \pm 1 \text{ MeV}$
- $\Gamma = 34 \pm 12 \pm 4 \text{ MeV}$
- $81 \pm 20 \text{ events}$
- 6.1σ



What is $Z_c(3900)$?



- Couples to $\bar{c}c$
- Has electric charge
- At least 4-quarks
- What is its nature?

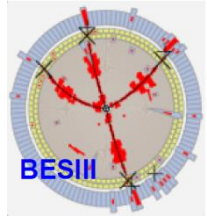


- $\bar{D}D^*$ molecule?
- Tetraquark state?
- Cusp?
- Threshold effect?
- ...

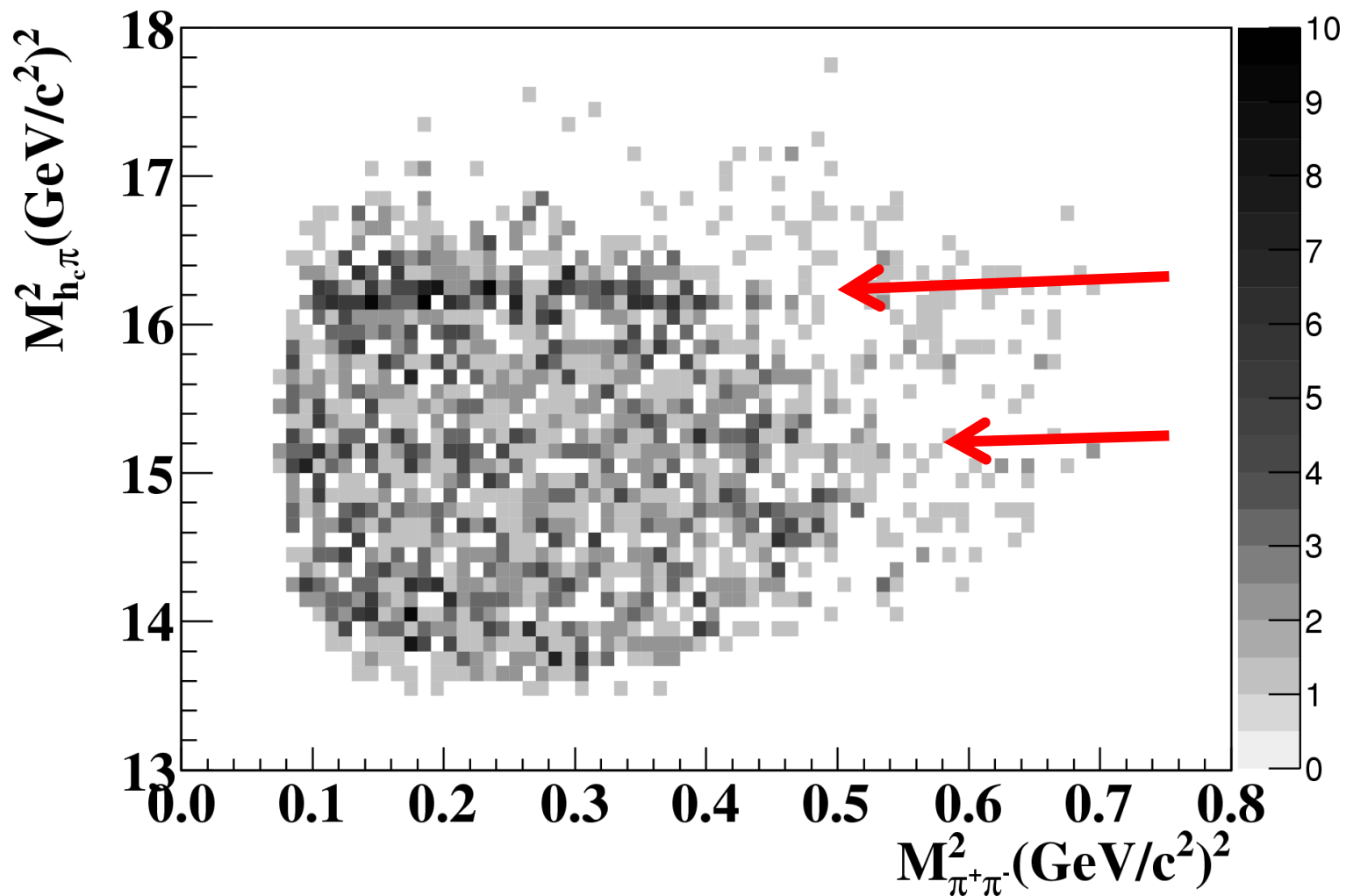
Predictions and more experimental information will be essential to understand its nature.

→ A partner below/above Z_c ?

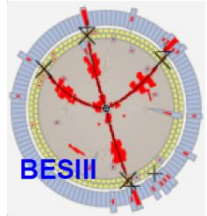
→ Panel discussions on Monday



Dalitz plot of $e^+e^- \rightarrow \pi^+\pi^-h_c(1P)$

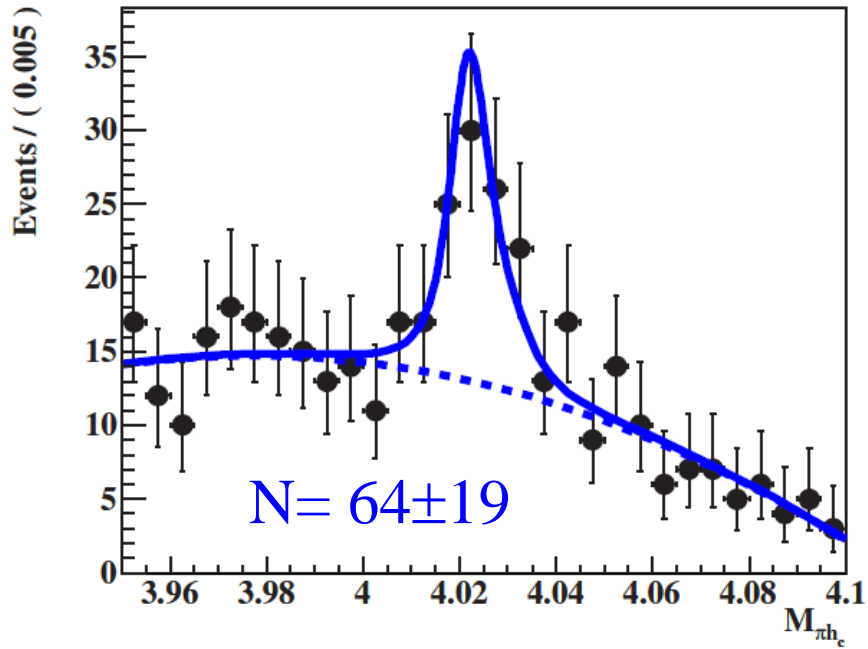


BESIII preliminary

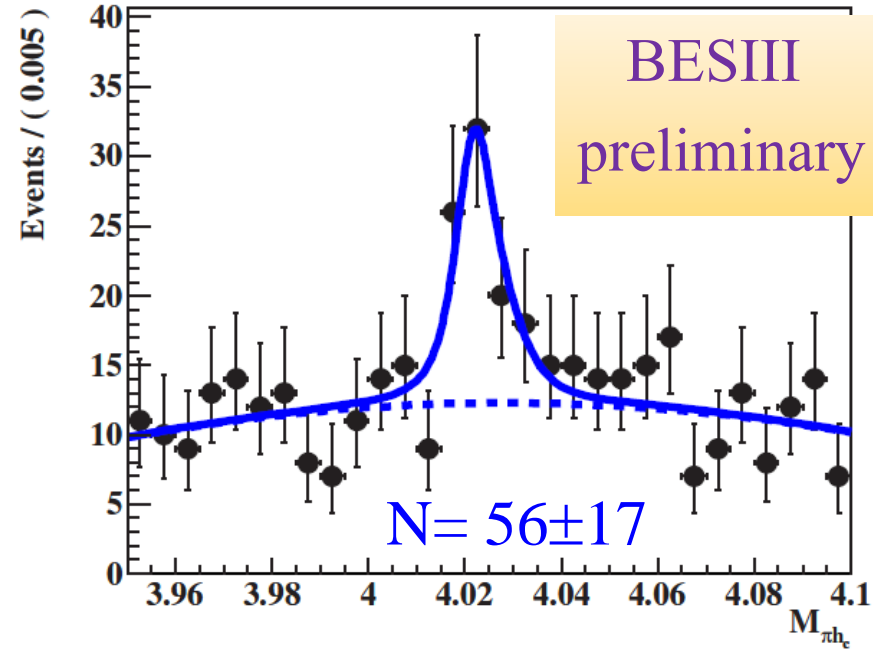


$e^+e^- \rightarrow \pi Z_c(4020) \rightarrow \pi^+\pi^-h_c(1P)$

$E_{cm}=4.26$ GeV



$E_{cm}=4.36$ GeV

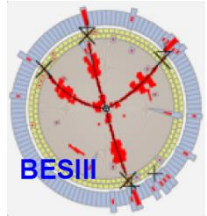


Simultaneous fit to 4.26/4.36 GeV data and 16 η_c decay modes. 6.4σ

$M(Z_c(4020)) = 4021.8 \pm 1.0 \pm 2.5$ MeV; $\Gamma(Z_c(4020)) = 5.7 \pm 3.4 \pm 1.1$ MeV

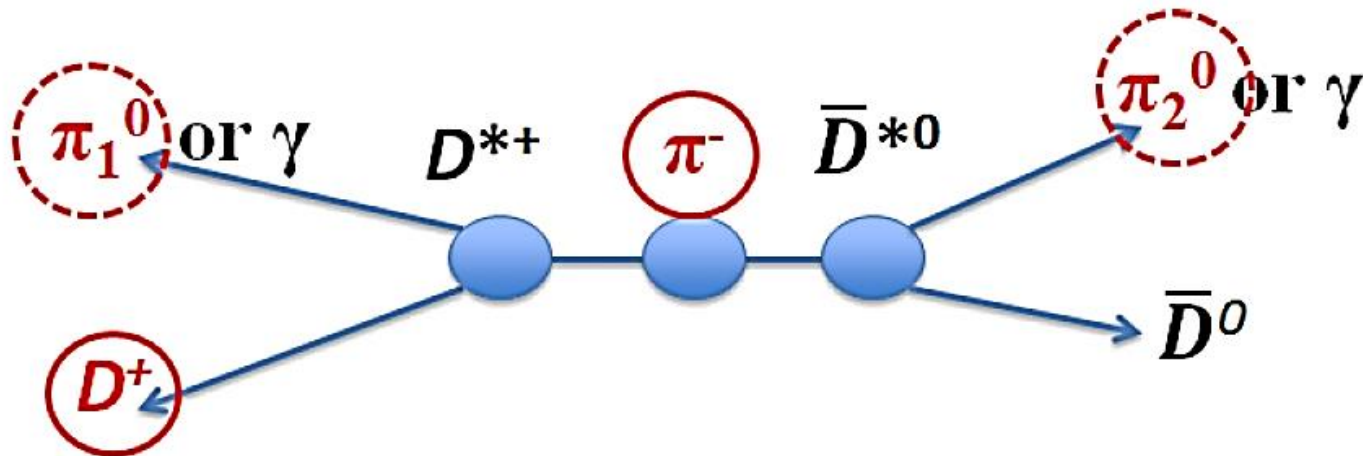
$$R = \frac{\sigma(e^+e^- \rightarrow \pi^+ Z_c^-(4020) \rightarrow \pi^+ \pi^- h_c(1P))}{\sigma(e^+e^- \rightarrow \pi^+ \pi^- h_c(1P))} = (16.2 \pm 4.1 \pm 0.7)\% \quad (16.6 \pm 5.2 \pm 0.8)\%$$

32

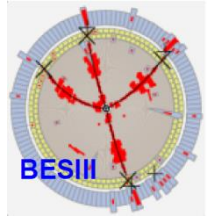


$e^+e^- \rightarrow \pi^- (D^* \underline{D}^*)^+ + \text{c.c.}$ at BESIII

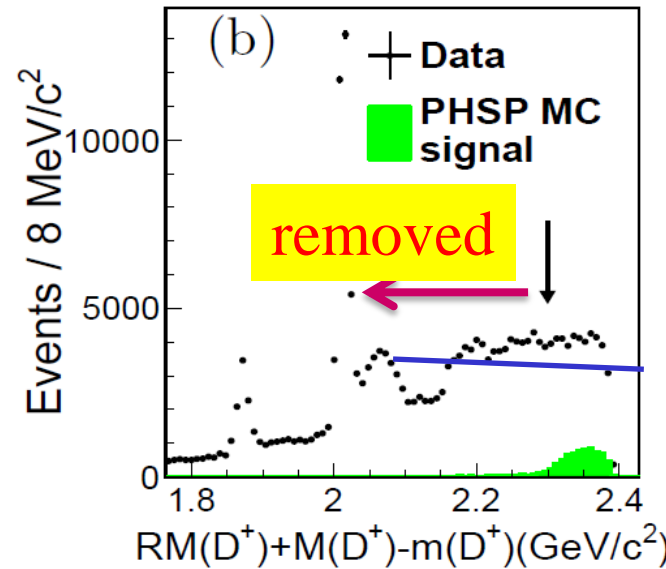
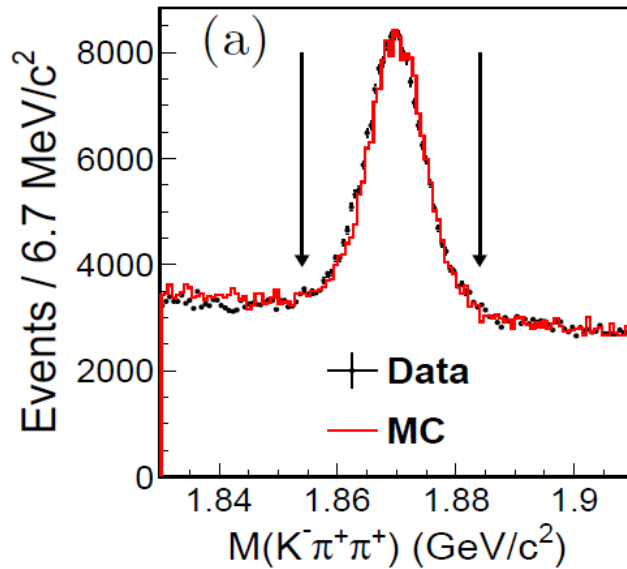
- 827 pb^{-1} data at $E_{\text{cm}}=4.26$ GeV
- Tag a D^+ and a bachelor π^- , reconstruct one π^0 to suppress the background.



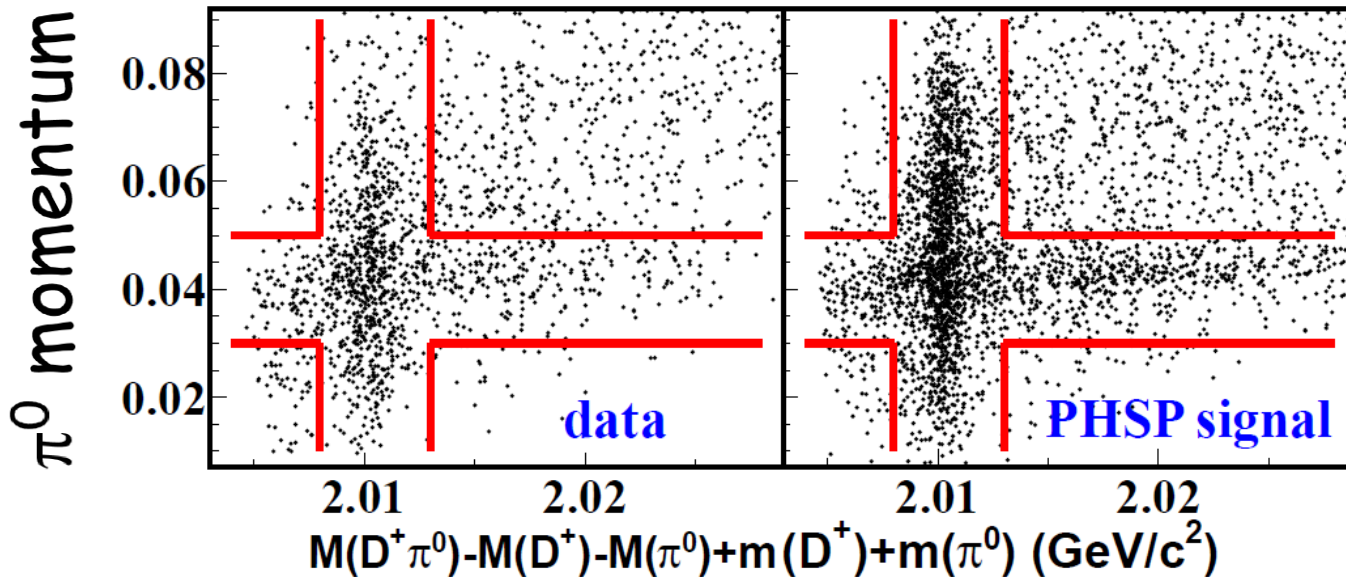
Topology of the decays of the signal process. Thick line circled D^+ and π^- are detected in the final states and at least one of the dashed line circled π_1^0 or π_2^0 is tagged.



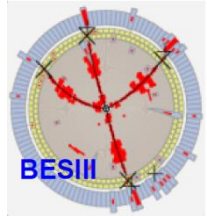
$e^+e^- \rightarrow \pi^- (D^* \underline{D}^*)^+ + \text{c.c.}$ at BESIII



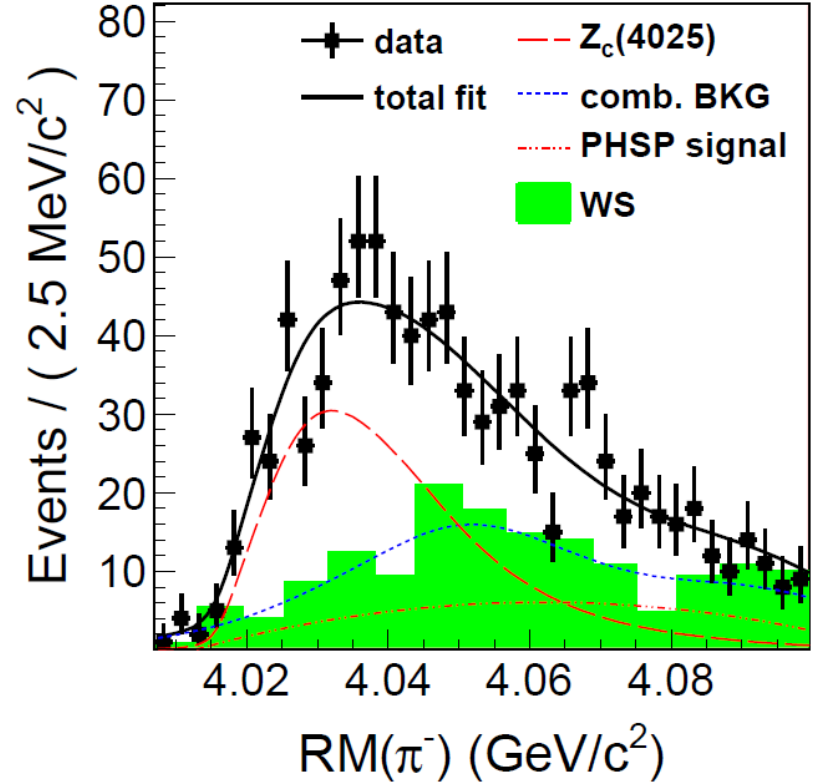
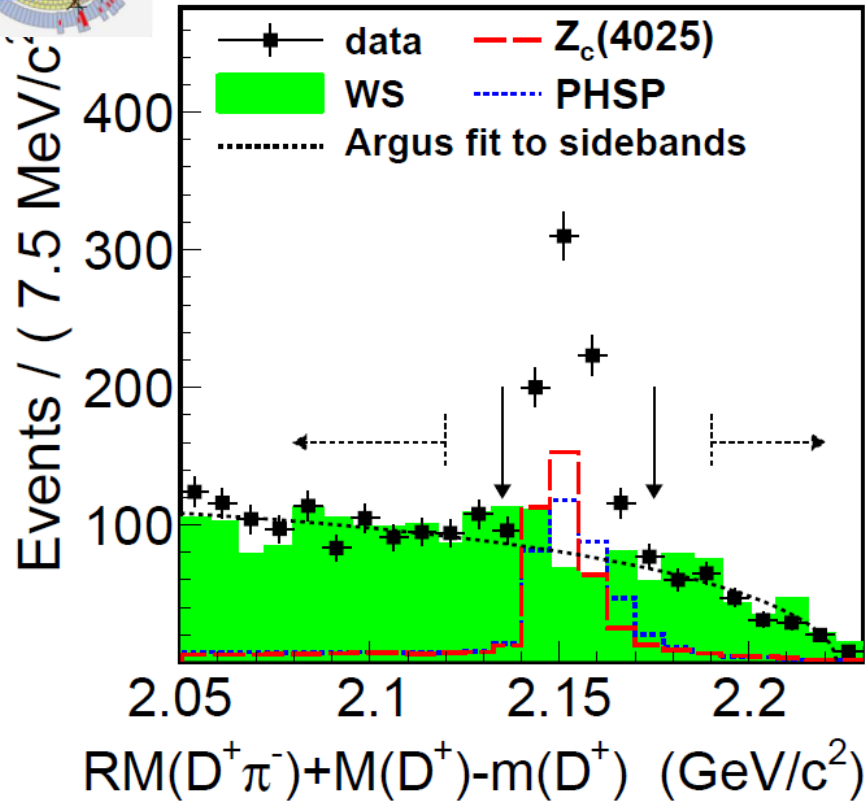
Remove
DD, DD*,
D*D*,
DsDs, ...



BESIII
1308.2760



$e^+e^- \rightarrow \pi Z_c(4025) \rightarrow \pi^- (D^* \underline{D}^*)^+ + c.c.$

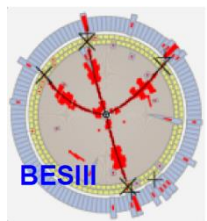


Fit to π^\pm recoil mass yields 401 ± 47 $Z_c(4025)$ events. **>10 σ**

$M(Z_c(4025)) = 4026.3 \pm 2.6 \pm 3.7$ MeV; $\Gamma(Z_c(4025)) = 24.8 \pm 5.6 \pm 7.7$ MeV

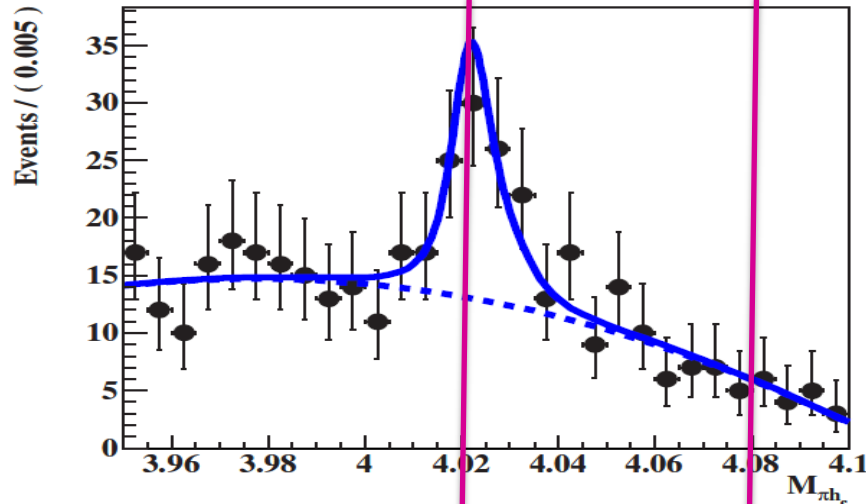
$$R = \frac{\sigma(e^+e^- \rightarrow \pi^\pm Z_c^\mp(4025) \rightarrow \pi^\pm (D^* \overline{D}^*)^\mp)}{\sigma(e^+e^- \rightarrow \pi^\pm (D^* \overline{D}^*)^\mp)} = (65 \pm 9 \pm 6)\%$$

$$\sigma(e^+e^- \rightarrow \pi^\pm (D^* \overline{D}^*)^\mp) = (137 \pm 9 \pm 15) \text{ pb}$$



$Z_c(4020) = Z_c(4025)?$

Y(4260)



- $M(4020) = 4021.8 \pm 1.0 \pm 2.5$ MeV
- $M(4025) = 4026.3 \pm 2.6 \pm 3.7$ MeV
- $\Gamma(4020) = 5.7 \pm 3.4 \pm 1.1$ MeV
- $\Gamma(4025) = 24.8 \pm 5.6 \pm 7.7$ MeV

Close to D^*D^* threshold = 4017 MeV

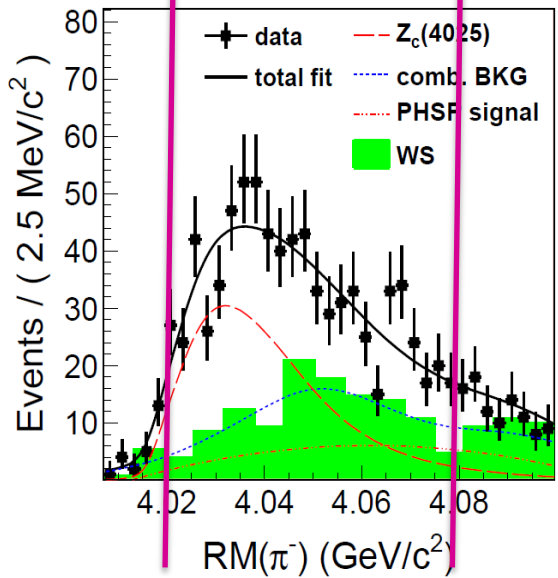
Mass consistent with each other but width $\sim 2\sigma$ difference

Interference with other amplitudes may change the results

Coupling to \bar{D}^*D^* is much larger than to $\pi\pi_c$ if they are the same state

Will fit with Flatte formula

BESIII preliminary
 The Z_c ' is found!



What next at BESIII?

- Precise resonant parameters
- Spin-parity of Z_c and Z_c'
- More decay modes [$\pi\psi'$, $\rho\eta_c$, open charm,...]
- Production mechanisms, production rates
- Test various theoretical models
- Neutral partners of Z_c and Z_c'
- Excited Z_c , Z_c' states? $Z_{cs} \rightarrow KJ/\psi$ states?
- Other XYZ states?
- ...

Summary

- Lots of progress in XYZ studies in e^+e^- experiments
- BESIII started study of the XYZ particles
- Observation of $Y(4260) \rightarrow \gamma X(3872)$
- New information on the Y's from BaBar and Belle. $Y(4660)$ confirmed, $Y(4008)$ not confirmed; large $\pi^+\pi^-h_c$ production rate above 4.2 GeV
- First confirmed exotic state with at least four quarks, $Z_c(3900)^+$, at BESIII & Belle
- Observation of the Z_c' at BESIII
- More results will come soon, stay tuned!

Thanks a lot!

Thanks a lot!

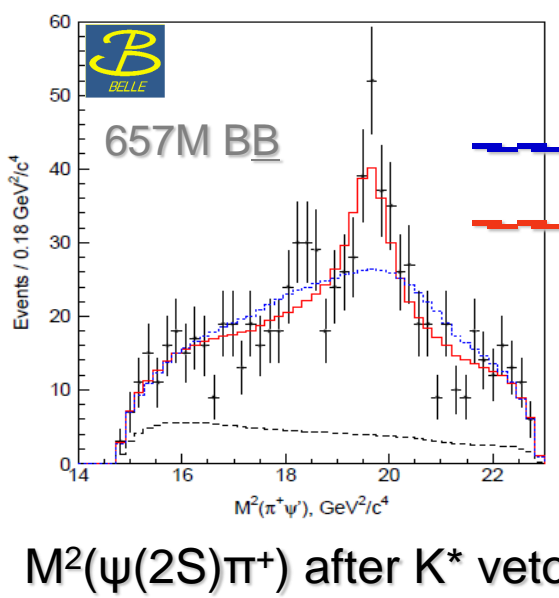
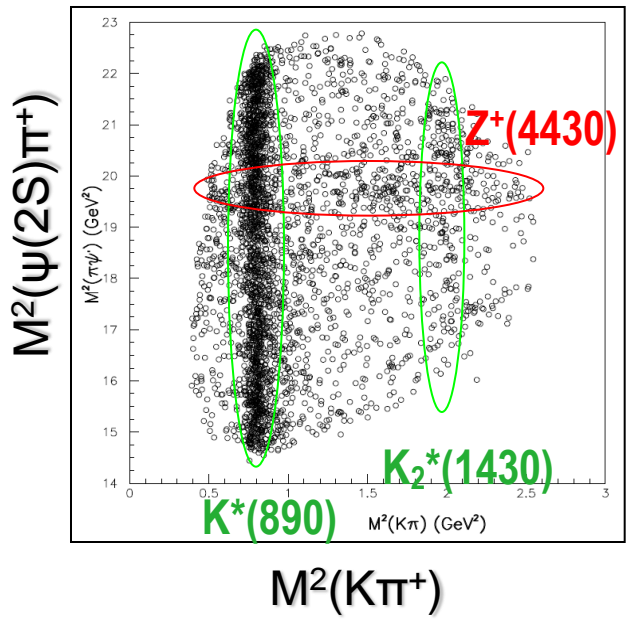


Belle observed $Z(4430)^\pm \rightarrow \psi(2S)\pi^\pm$

PRL100, 142001 (2008)

- Found in $\psi(2S)\pi^+$ from $B \rightarrow \psi(2S)\pi^+K$. Z parameters from fit to $M(\psi(2S)\pi^+)$
- Confirmed through Dalitz-plot analysis of $B \rightarrow \psi(2S)\pi^+K$
- $B \rightarrow \psi(2S)\pi^+K$ amplitude: coherent sum of Breit-Wigner contributions
- Models: all known $K^* \rightarrow K\pi^+$ resonances only**

all known $K^* \rightarrow K\pi^+$ and $Z^+ \rightarrow \psi(2S)\pi^+ \Rightarrow$ favored by data



Significance: 6.4σ

- fit for model with K^* 's only
- fit for model with K^* 's and Z

$$M = 4433^{+15}_{-12} {}^{+19}_{-13} \text{ MeV}$$

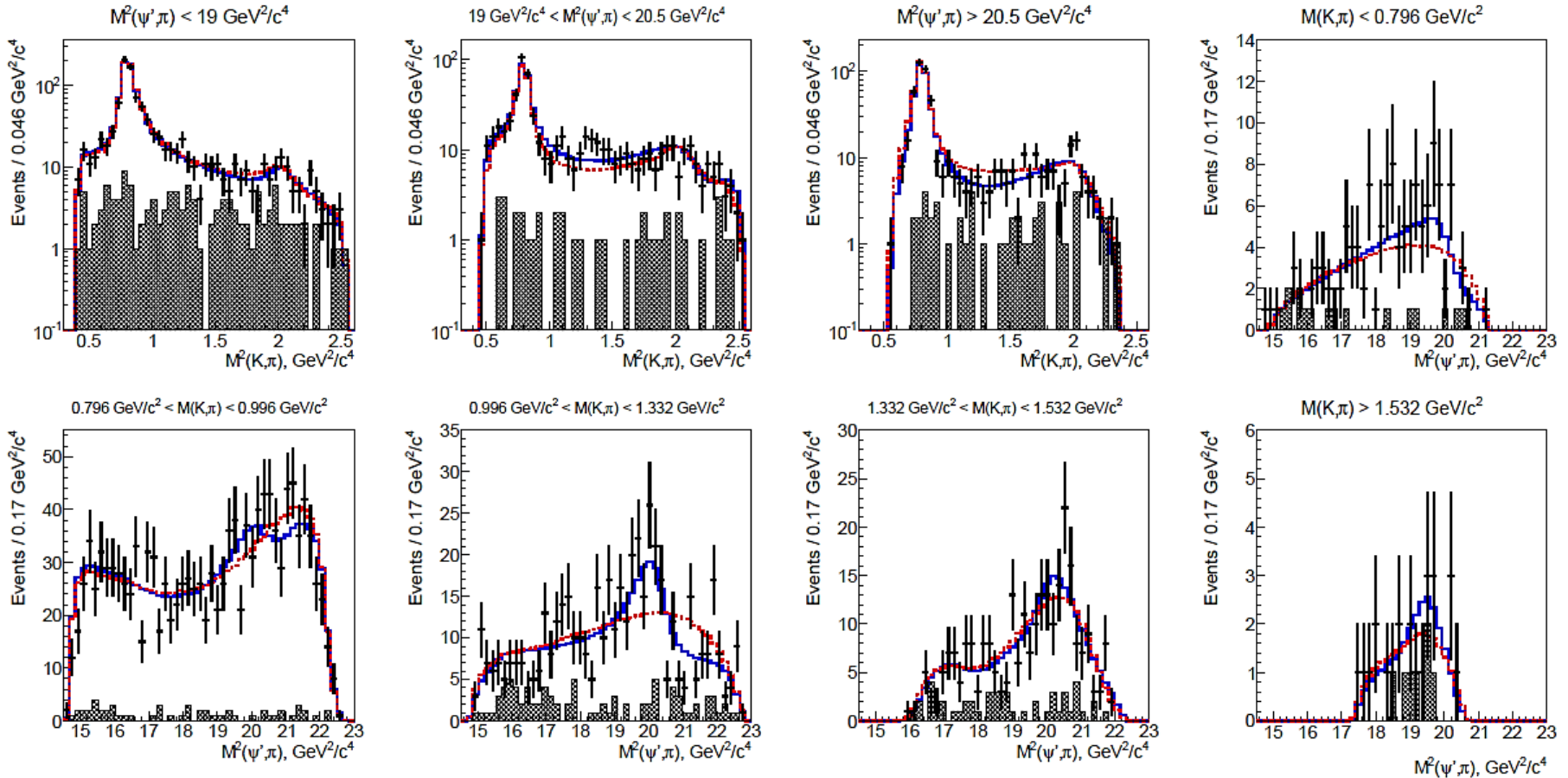
$$\Gamma = 107^{+86}_{-43} {}^{+74}_{-53} \text{ MeV}$$

PRD80, 031104 (2009)

- [cu][cd] tetraquark? neutral partner in $\psi'\pi^0$ expected**
- $D^*\underline{D}_1(2420)$ molecule? should decay to $D^*\underline{D}^*\pi$**

Spin-parity of the $Z(4430)^\pm$

- $B \rightarrow \psi(2S)\pi^+K$ amplitude: coherent sum of Breit-Wigner contributions

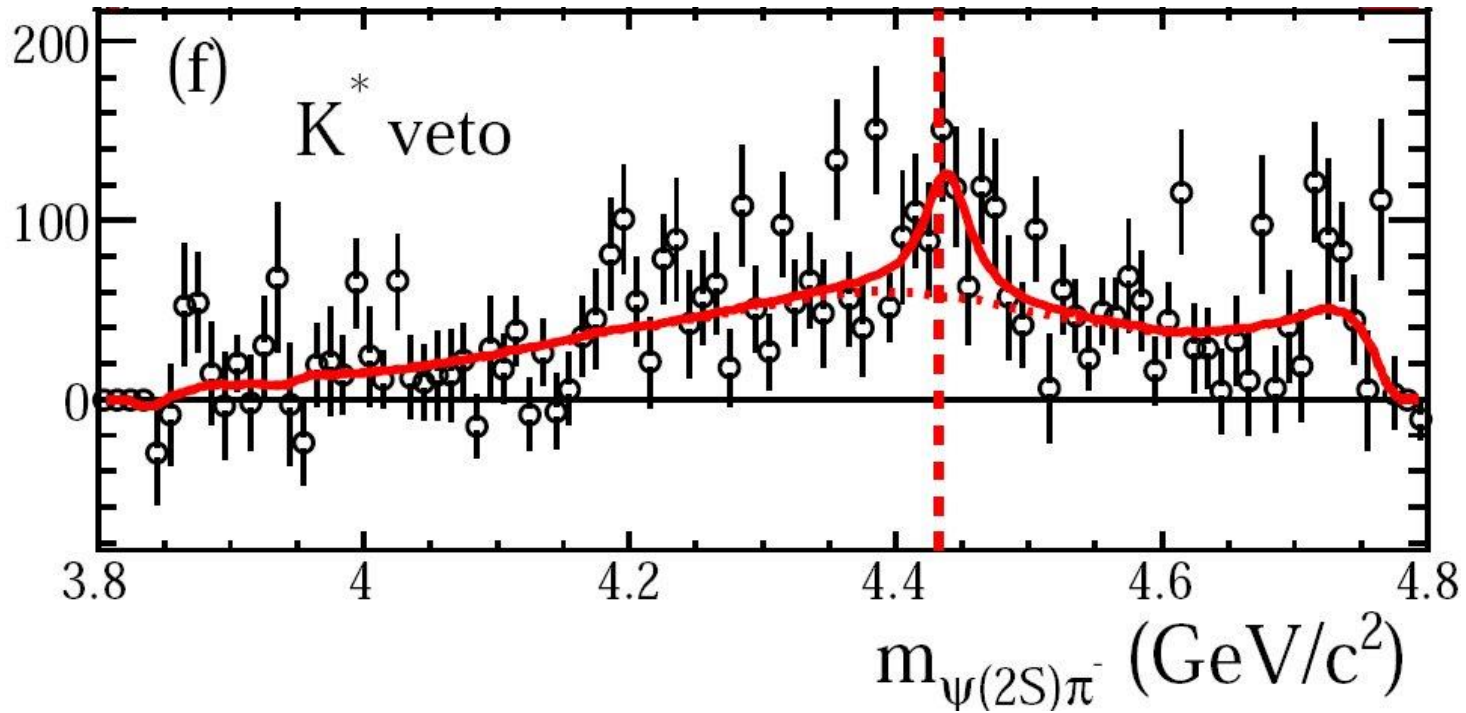


$J^P = 1^+$	$M = 4500$	$^{+14}_{-13}$	$^{+16}_{-9}$	MeV	$\Gamma = 126$	$^{+30}_{-26}$	$^{+3}_{-26}$	MeV
$J^P = 0^-$	$M = 4470$	$^{+26}_{-30}$	$^{+83}_{-23}$	MeV	$\Gamma = 139$	$^{+52}_{-39}$	$^{+17}_{-32}$	MeV



BaBar doesn't see a significant $Z(4430)^+$

PRD79, 112001 (2009)



“For the fit ... equivalent to the Belle analysis...we obtain mass & width values that are consistent with theirs,... but only $\sim 1.9\sigma$ from zero; fixing mass and width increases this to only $\sim 3.1\sigma$.”

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

$$\text{Belle PRL: } (4.1 \pm 1.0 \pm 1.4) \times 10^{-5}$$



Belle observed Two $Z^\pm \rightarrow \chi_{c1} \pi^\pm$

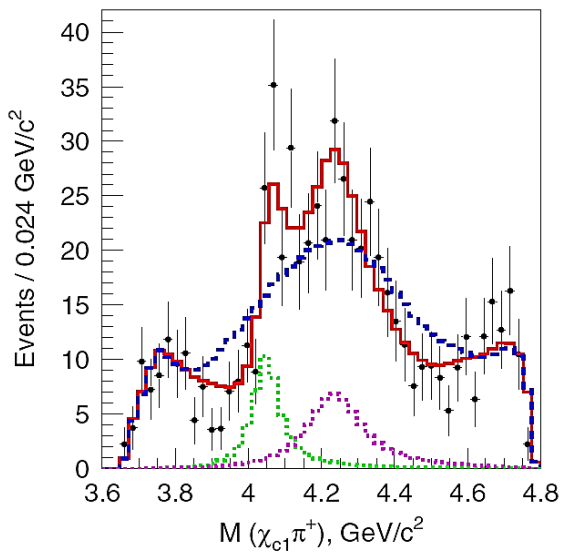
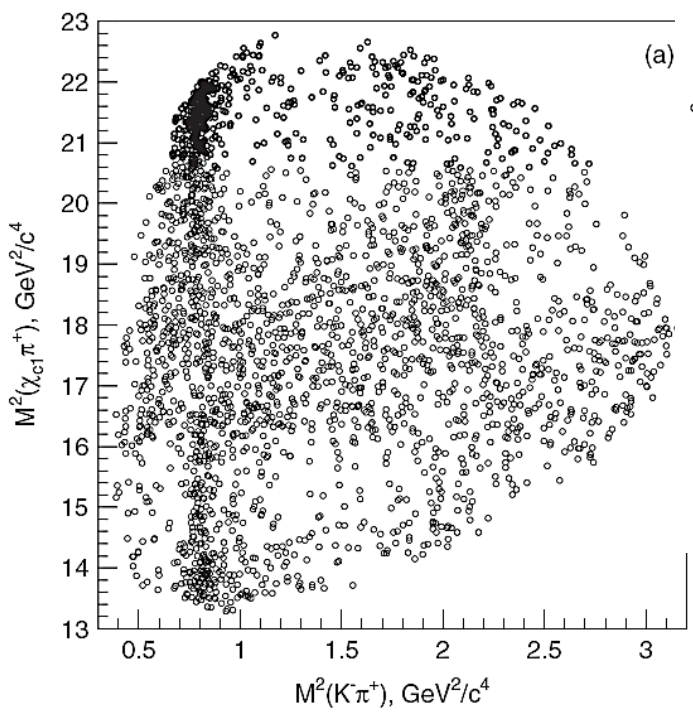
- Dalitz-plot analysis of $\underline{B}^0 \rightarrow \chi_{c1} \pi^+ K^-$ $\chi_{c1} \rightarrow J/\psi \gamma$ with 657M $\underline{B}\underline{B}$
- Dalitz plot models: known $K^* \rightarrow K\pi$ only

K^* 's + one $Z \rightarrow \chi_{c1} \pi^\pm$

K^* 's + two Z^\pm states \Rightarrow favored by data

PRD 78, 072004 (2008)

Significance: 5.7σ



- fit for model with K^* 's
- fit for double Z model
- Z_1 contribution
- Z_2 contribution

$$M_{Z_1} = 4051 \pm 14^{+20}_{-41} \text{ MeV}$$

$$\Gamma_{Z_1} = 82^{+21+47}_{-17-22} \text{ MeV}$$

$$M_{Z_2} = 4248^{+44+180}_{-29-35} \text{ MeV}$$

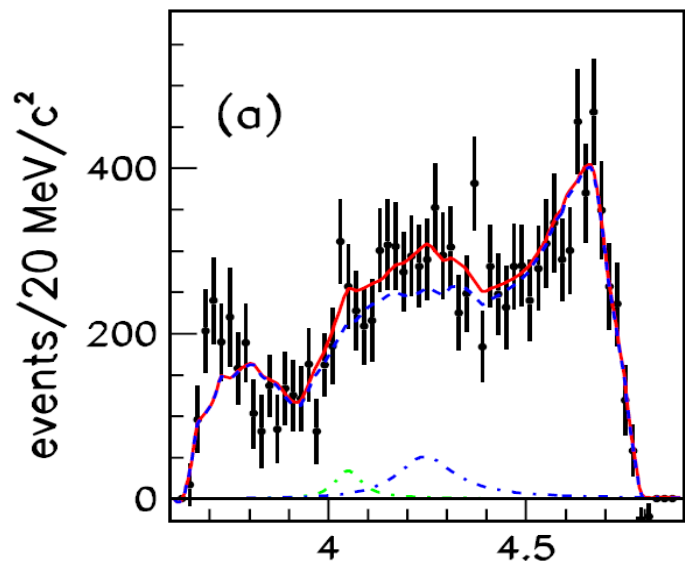
$$\Gamma_{Z_2} = 177^{+54+316}_{-39-61} \text{ MeV}$$

$M(\chi_{c1}\pi^+)$
for $1 < M^2(K\pi^+) < 1.75 \text{ GeV}^2$



BaBar doesn't see significant $Z^\pm \rightarrow \chi_{c1} \pi^\pm$

PRD85, 052003 (2012)

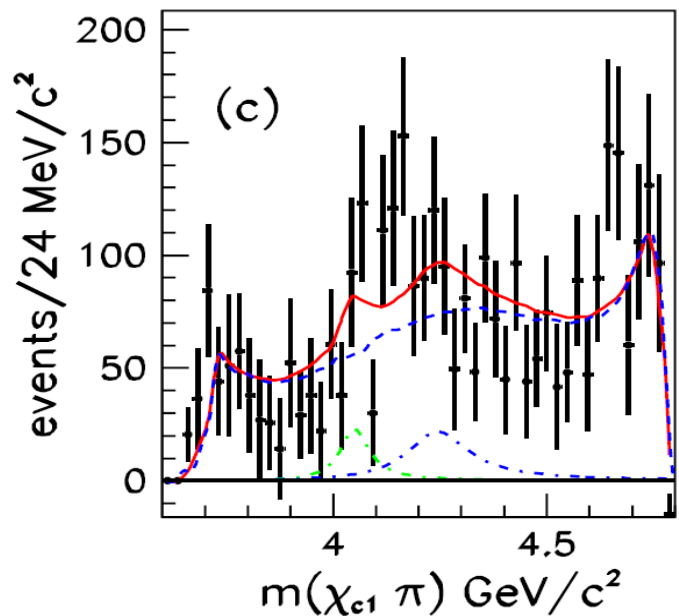


$$\mathcal{B}(\bar{B}^0 \rightarrow Z_1(4050)^+ K^-) \times \mathcal{B}(Z_1(4050)^+ \rightarrow \chi_{c1} \pi^+) < 1.8 \times 10^{-5},$$

$$\text{Belle: } (3.0^{+1.5}_{-0.8} {}^{+3.7}_{-1.6}) \times 10^{-5}$$

$$\mathcal{B}(\bar{B}^0 \rightarrow Z_2(4250)^+ K^-) \times \mathcal{B}(Z_2(4250)^+ \rightarrow \chi_{c1} \pi^+) < 4.0 \times 10^{-5},$$

$$\text{Belle: } (4.0^{+2.3}_{-0.9} {}^{+19.7}_{-0.5}) \times 10^{-5}$$



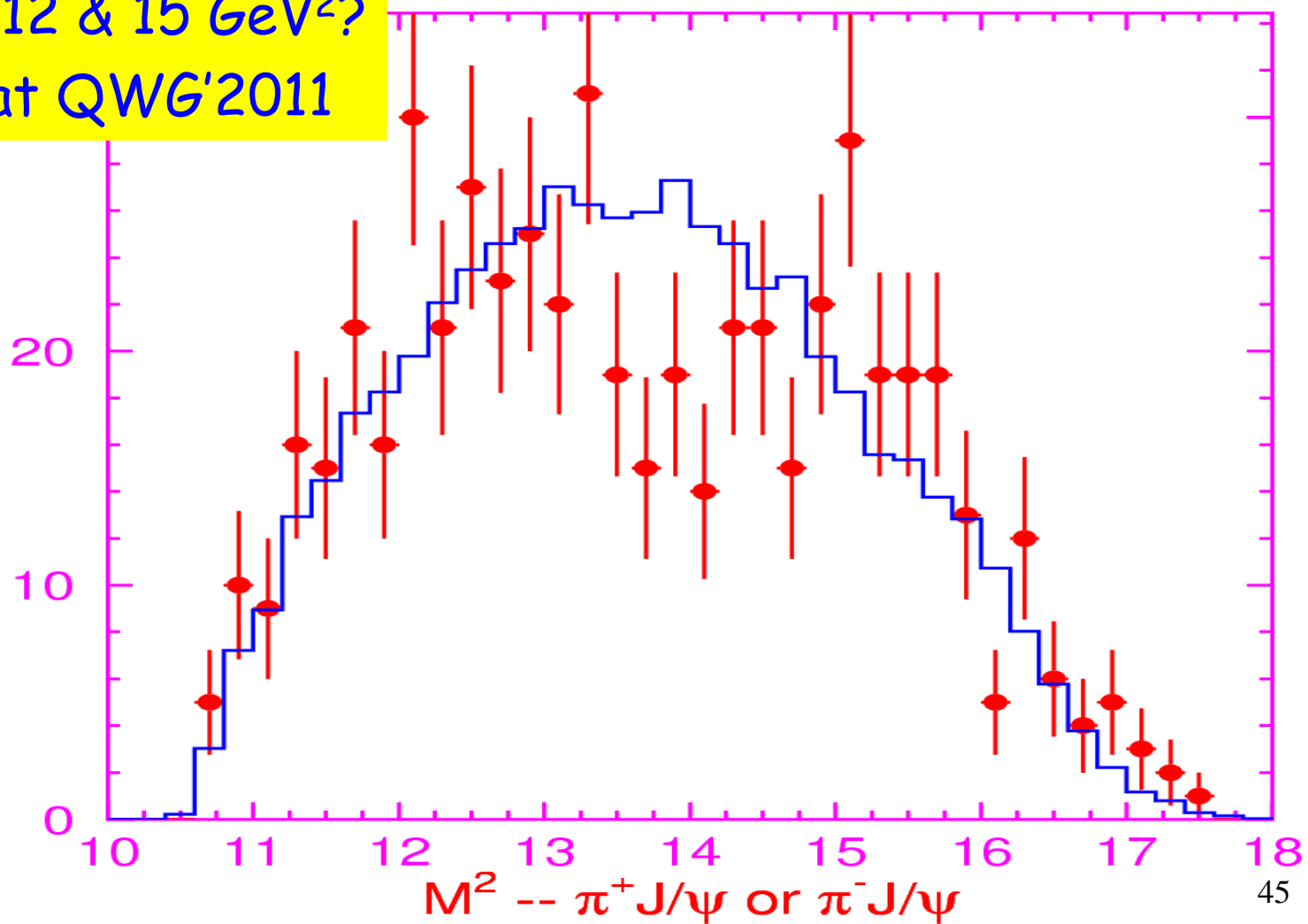
“We find that it is possible to obtain a good description of our data without the need for additional resonances in the $\chi_{c1} \pi$ system.”



$M(\pi\pi J/\psi) \in [4.2, 4.4] \text{ GeV}$ via ISR

548/fb at 10.58 GeV
Peaks at 12 & 15 GeV²?
Shown at QWG'2011

2007/02/14 16



Observation of the X(3823)

arXiv:1304.3975 (submitted to PRL)

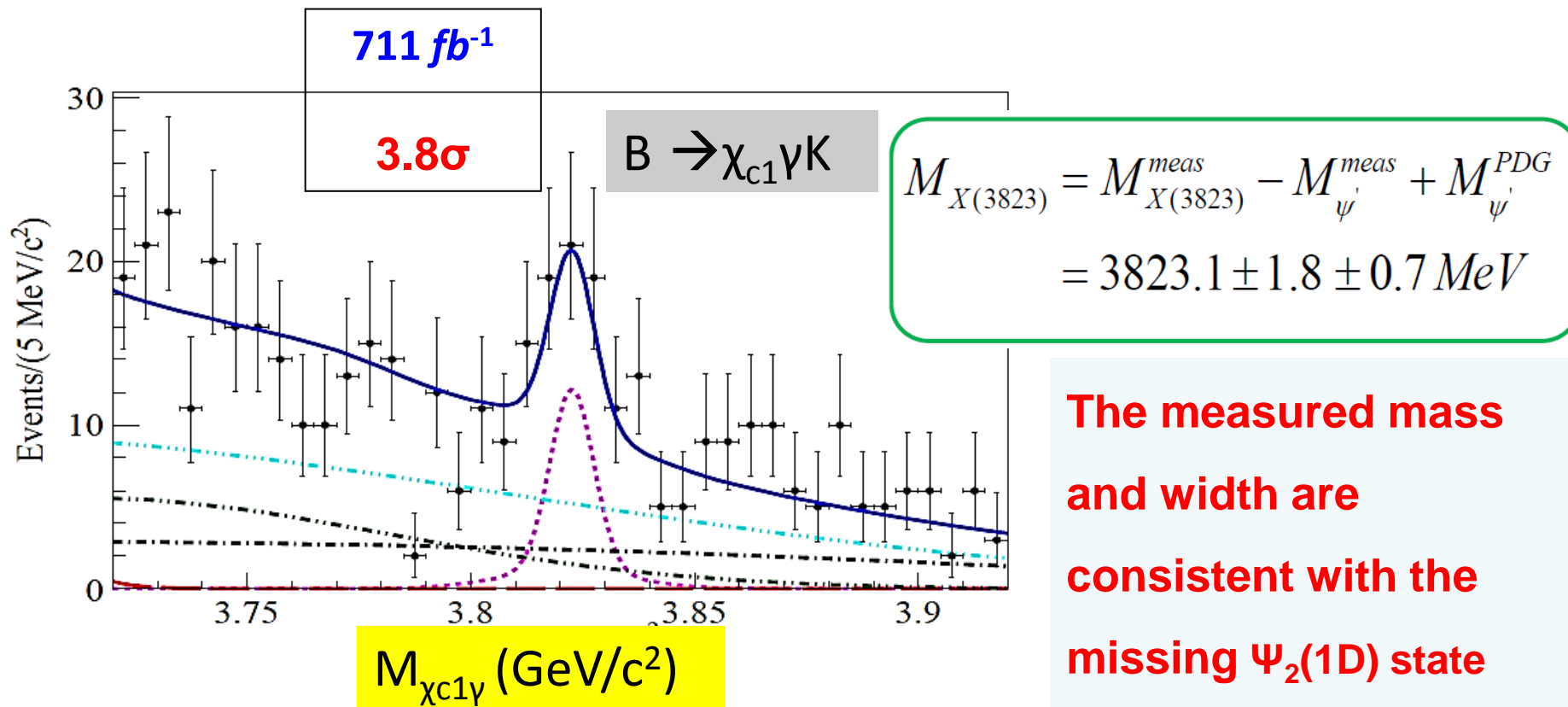
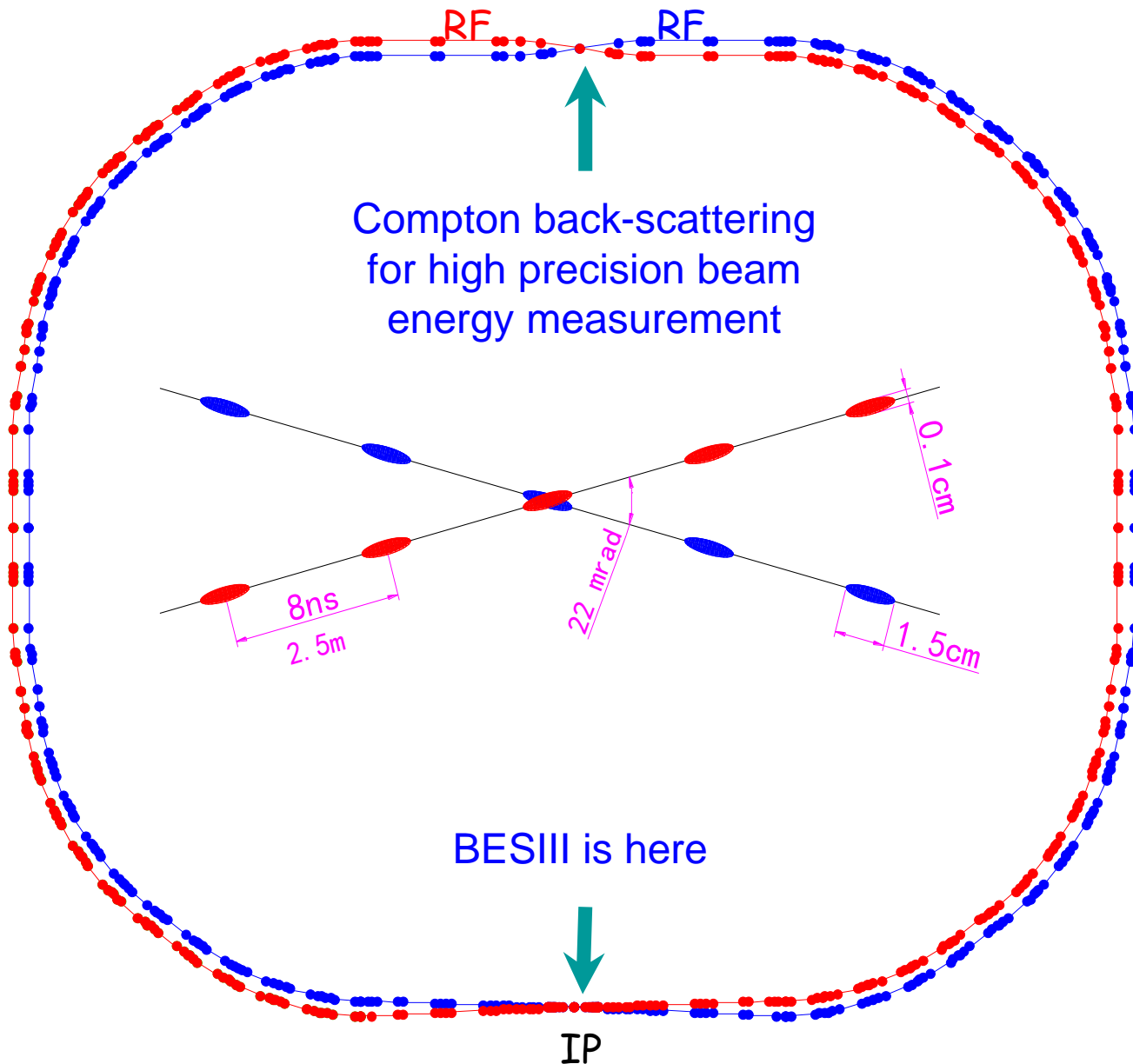


FIG. 4: 2D UML fit projection of $M_{\chi_{c1}\gamma}$ distribution for the simultaneous fit of $B^{\pm} \rightarrow (\chi_{c1}\gamma)K^{\pm}$ and $B^0 \rightarrow (\chi_{c1}\gamma)K_S^0$ decays for $M_{bc} > 5.27 \text{ GeV}/c^2$. The curves used in the fits are described in [33].

BEPC II: Large crossing angle, double-ring



Beam energy:

1-2.3 GeV

Luminosity:

$1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

Optimum energy:

1.89 GeV

Energy spread:

5.16×10^{-4}

No. of bunches:

93

Bunch length:

1.5 cm

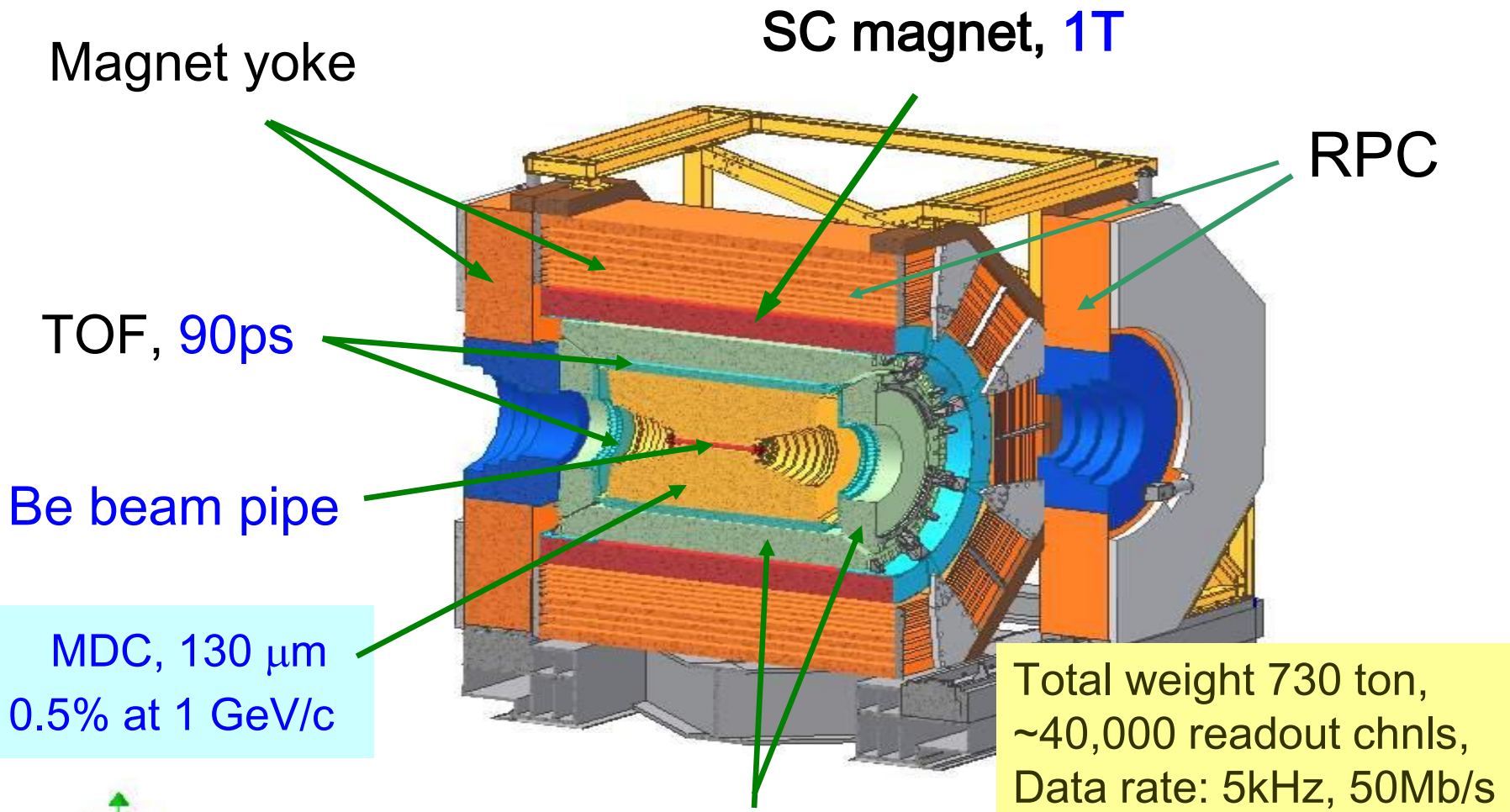
Total current:

0.91 A

SR mode:

0.25A @ 2.5 GeV⁴⁷

BESIII Detector



Magnet yoke

SC magnet, 1T

RPC

TOF, 90ps

Be beam pipe

MDC, 130 μm
0.5% at 1 GeV/c

Total weight 730 ton,
~40,000 readout chnls,
Data rate: 5kHz, 50Mb/s

CsI(Tl) calorimeter, 2.5% @ 1 GeV

