The BESIII Experiment

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The Experiment: BESIII at BEPCII

BEPCII, IHEP, Beijing, China

e⁻   e⁺

Muon Counter

SC magnet

TOF

Be beam pipe

Drift Chamber

CsI(Tl) calorimeter
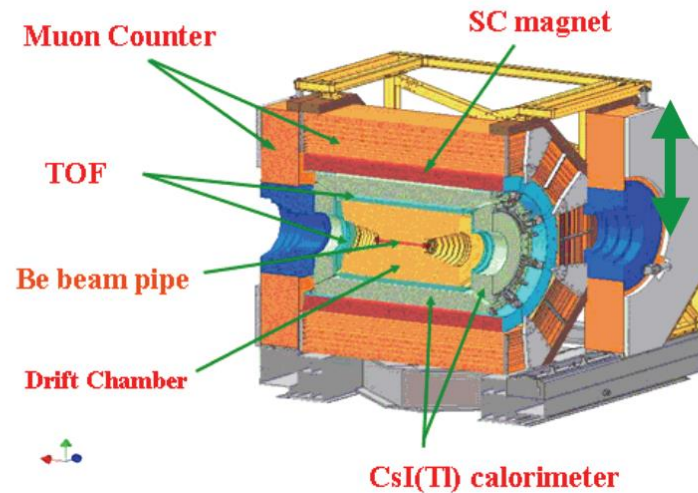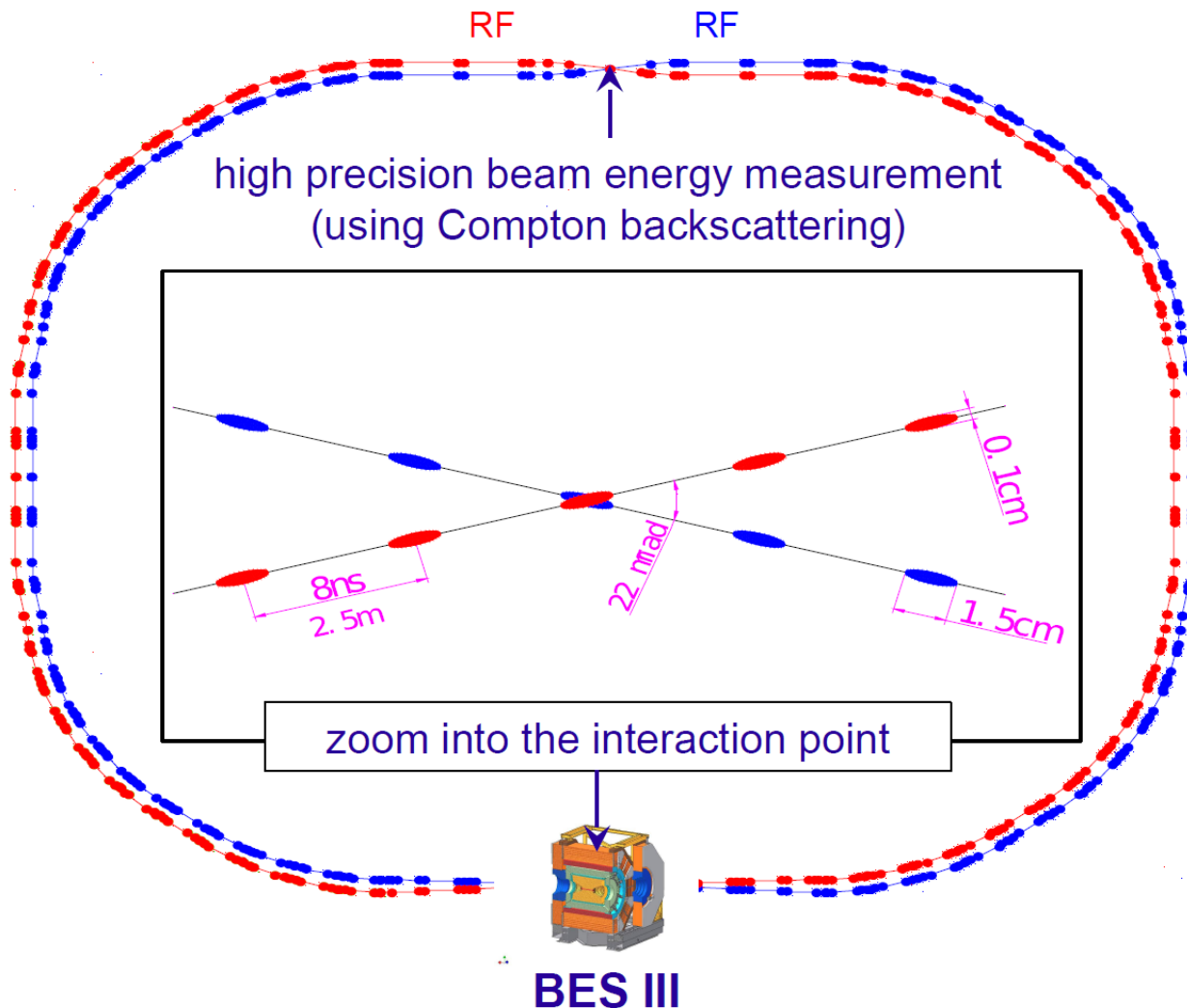
BES III

Multipurpose Detector

(Scale)

$e{+}e^{-}$ Collisions with E_{cm} from ≈2 GeV to 4.6 GeV

Running in 4 GeV region since late 2012

Beijing Electron Positron Collider (BEPCII)

RF   RF

high precision beam energy measurement
(using Compton backscattering)

0.1cm

22 mrad

8ns
2.5m

1.5cm

zoom into the interaction point

BES III

- Double ring
- Large crossing angle
- Beam energy:
  1.0 - 2.3 GeV
- Energy spread:
  5.16×10^{-4}
- Design luminosity:
  1×10^{33} /cm^2 /s
  @ψ(3770)
- Achieved luminosity:
  ~ 0.7×10^{33} /cm^2 /s
- Beam energy
  measurement:
  5×10^{-5}

The BES-III Collaboration

http://bes3.ihep.ac.cn

11 Countries

53 Institutes

~350 active members

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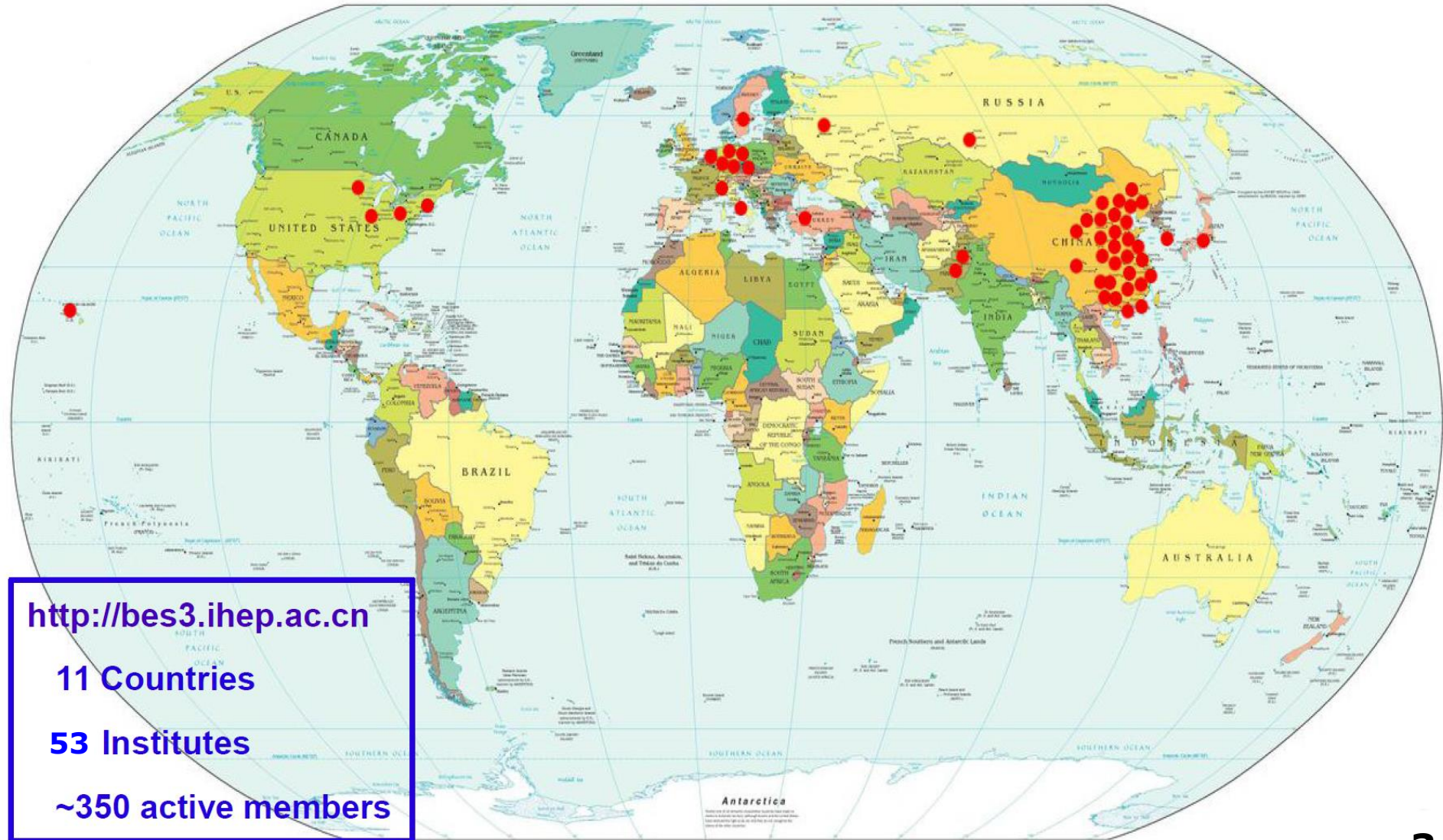
The Available Data

Data sets collected by BESIII since 2009

Energy & physics	L or N	Physics Topics
3097 MeV: J/ψ	1.3×10^{9}	light hadron spectroscopy
3686 MeV: ψ'	0.5×10^{9}	charmonium transitions; light hadron spectroscopy
ψ(3770)	2.9 fb^{-1}	D decays; precision flavor physics
ψ(4040)	0.5 fb^{-1}	charmonium spectroscopy
3554 MeV	0.024 fb^{-1}	precision determination of τ mass
4230 MeV - 4260 MeV	1.9 fb^{-1}	charmonium spectroscopy; study of Y(4260)
4360 MeV	0.5 fb^{-1}	charmonium spectroscopy; study of Y(4360)
4100 MeV - 4400 MeV	0.5 fb^{-1}	coarse scan; Y spectroscopy
3850 MeV - 4590 MeV	0.8 fb^{-1}	fine scan; R measurement; Y spectroscopy
4600 MeV	0.5 fb^{-1}	charmonium spectroscopy
4420 MeV	**1fb^{-1}**	Study of Ψ(4415)

(Red: partial or full data sets for the analyses presented today)

Physics program @ BESIII

Light hadron physics
 -meson & baryon spectroscopy
 -multiquark states
 -threshold effects
 -glueballs & hybrids
 -two-photon physics
 -p & n form-factors

Charmonium physics:
 - precision spectroscopy
 - transitions and decays

QCD & τ-physics:
 - precision R-measurement
 - τ decays

Charm physics:
 - semi-leptonic form factors
 - f_D & f_{D_s} decay consts.
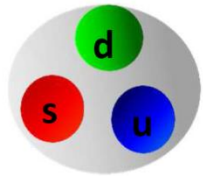 - CKM matrix: V_{cd}, V_{cs}
 - D^0-D^0 mixing and CPV
 - strong phases

Precision mass measurements:
 - τ mass
 – D^0 , D^+ & D_s masses

XYZ meson physics:
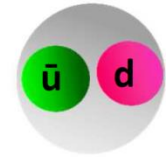 -$Y(4260) \rightarrow \pi\pi h_c$ decays
 - searches for new states
 - .....

QCD : real particles are color singlet

Baryons are red-blue-green triplets

Λ=usd

Mesons are color-anticolor pairs

π=ūd

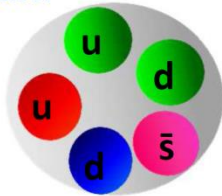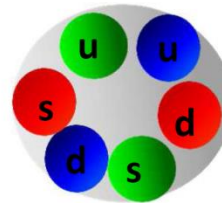Other possible combinations of quarks and gluons :
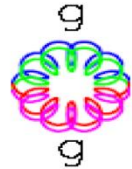
Pentaquark

S= +1
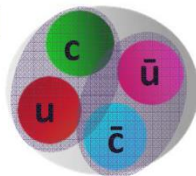Baryon

H di-Baryon

Tightly bound
6 quark state
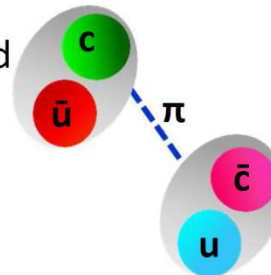
Glueball

Color-singlet multi-gluon bound state

Tetraquark

Tightly bound
diquark &
anti-diquark
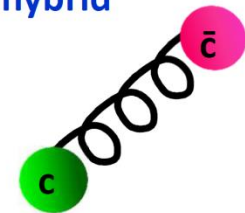
Molecule

loosely bound
meson-antimeson
"molecule"

qq̄ -gluon hybrid mesons

X(3872)

- well-established neutral state just at or below $D^0 D^{*0}$ threshold

  - discovered by Belle in B decay [PRL 91, 262001 (2003)]

- decay to $(\pi^+\pi^-)_\rho J/\psi$ is atypical of conventional charmonium

- popular explanation: bound $D^0 \bar{D}^{*0}$ "molecular" state

- recent developments:

  - $J^{PC} = 1^{++}$ firmly established by LHCb [PRL 110, 222001 (2013)]

  - LHCb observes radiative transition to ψ' (arXiv:1404.0275)

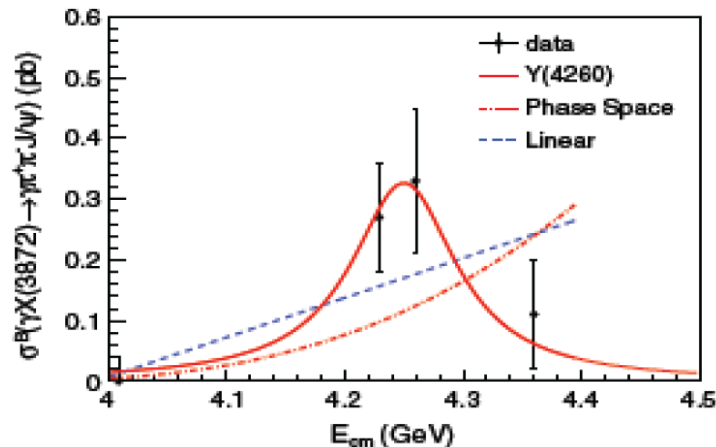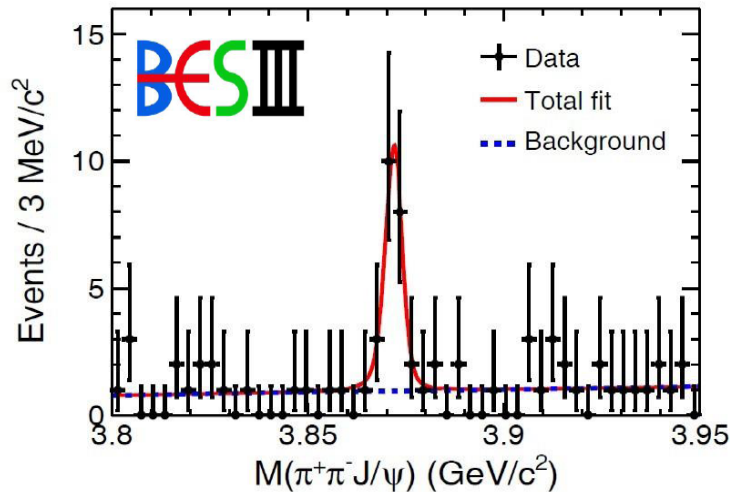 - BESIII observes production in $e^+e^- \rightarrow \gamma X(3872)$

PRL 91, 262001 (2003)

$B^{\pm} \rightarrow K^{\pm}\pi^+\pi^- J/\psi$

$M(\pi\pi J/\psi) - M(J/\psi)$ [GeV]
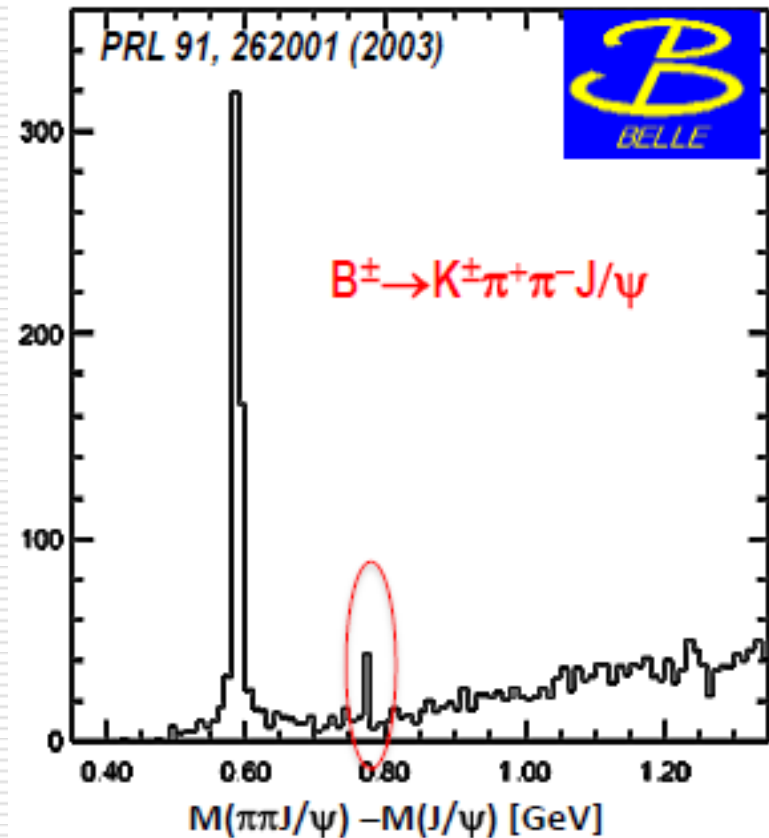
The X(3872) was first observed by Belle, soon confirmed by several experiments
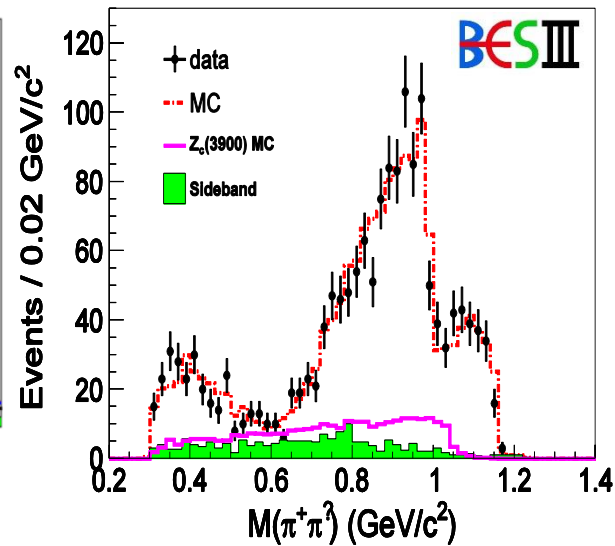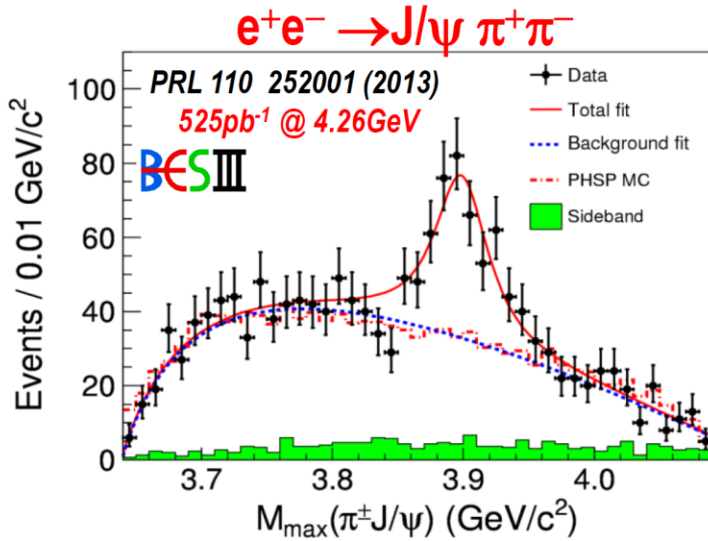
X(3872), new production mode

- E_{cm} = 4230, 4260, 4360MeV [2.4fb^{-1}]
- Significance : 6.3σ
- Mass : 3871.9$\pm$0.7$\pm$0.2MeV [PDG : 3871.68$\pm$0.17MeV]
- Width : <2.4MeV with 90%C.L.
- X-sec. is an order higher than NRQCD calculation of continuum process.
- The radiative transition production in Y(4260) decay suggestive, but not conclusive
- Assume   B(X(3872)→$\pi^+\pi^-$J/ψ) = 5%

$$\frac{\sigma(Y(4260)\rightarrow\gamma X(3872))}{\sigma(Y(4260)\rightarrow\pi^+\pi^- J/\psi)} \sim 11\%$$

A new decay mode of Y(4260)?

Any commonality in nature of Y(4260), Z_c(3900) and X(3872)?
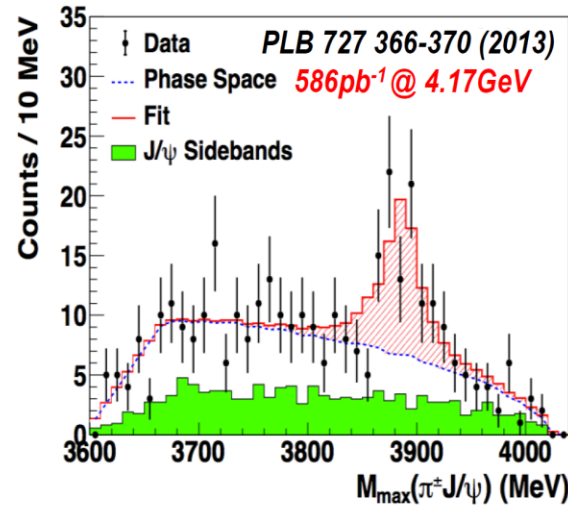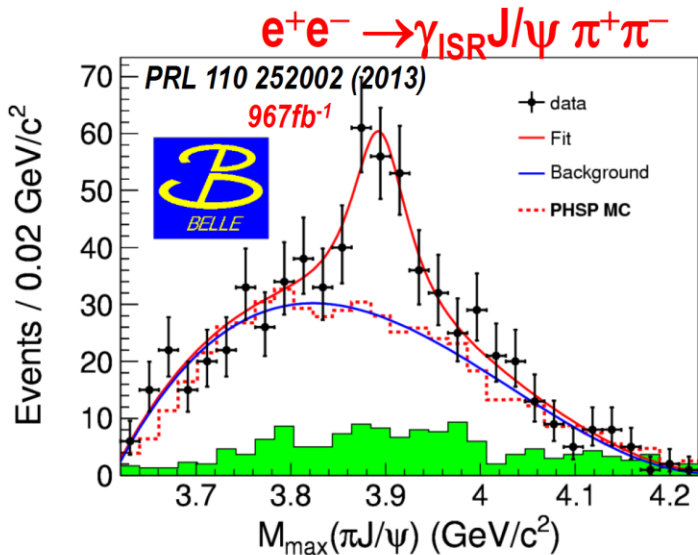
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$Z_c(3900)$ observed in two experiments!

$e^+e^- \to J/\psi \, \pi^+\pi^-$

PRL 110 252001 (2013)
525pb^{-1} @ 4.26GeV

BESIII

Data — Total fit --- Background fit -·- PHSP MC ▪ Sideband

$M_{max}(\pi^\pm J/\psi)$ (GeV/c^2)

data --- MC — $Z_c(3900)$ MC ▪ Sideband

BESIII

$M(\pi^+\pi^-)$ (GeV/c^2)

$e^+e^- \to \gamma_{ISR} J/\psi \, \pi^+\pi^-$

PRL 110 252002 (2013)
967fb^{-1}

BELLE

data — Fit — Background --- PHSP MC

$M_{max}(\pi J/\psi)$ (GeV/c^2)

Data PLB 727 366-370 (2013)
--- Phase Space 586pb^{-1} @ 4.17GeV
— Fit ▪ J/ψ Sidebands

$M_{max}(\pi^\pm J/\psi)$ (MeV)

BESIII

M = 3899.0±3.6±4.9 MeV

Γ = 46±10±20 MeV

307 ± 48 events, >8σ

BELLE

M = 3894.5±6.6±4.5 MeV

Γ = 63±24±26 MeV

159 ± 49 events, >5.2σ

CLEO-c Data

M = 3886±4±2 MeV

Γ = 37±4±8 MeV
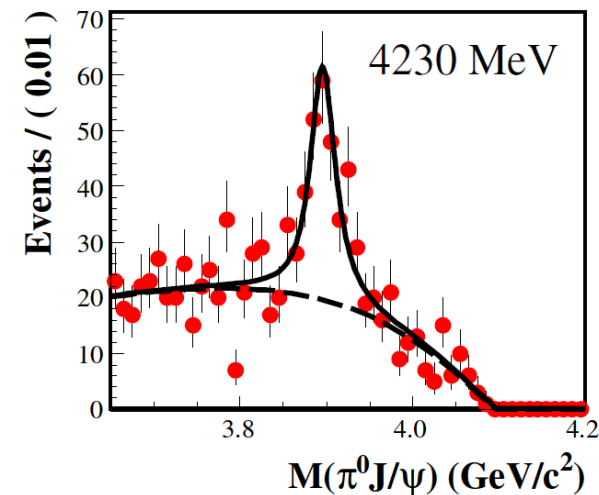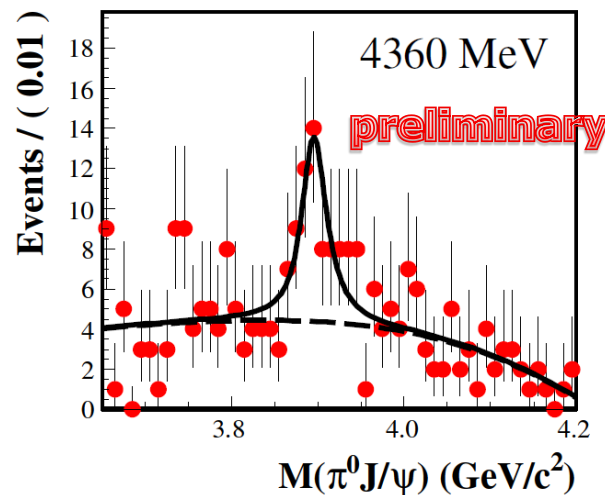
81 ± 16 events, >5σ
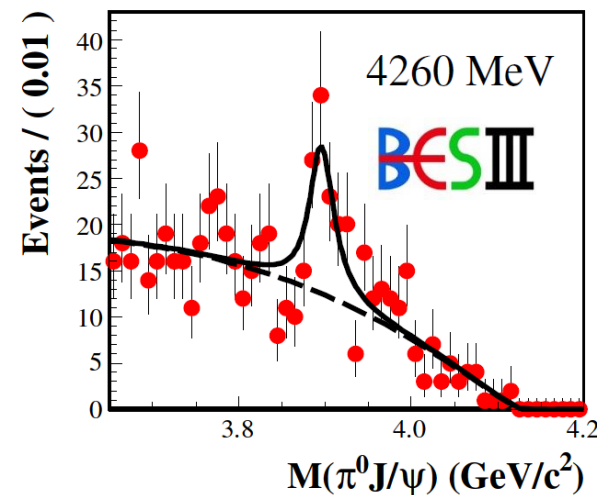
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Zc(3900)⁰ in e⁺e⁻ →π⁰π⁰J/ψ
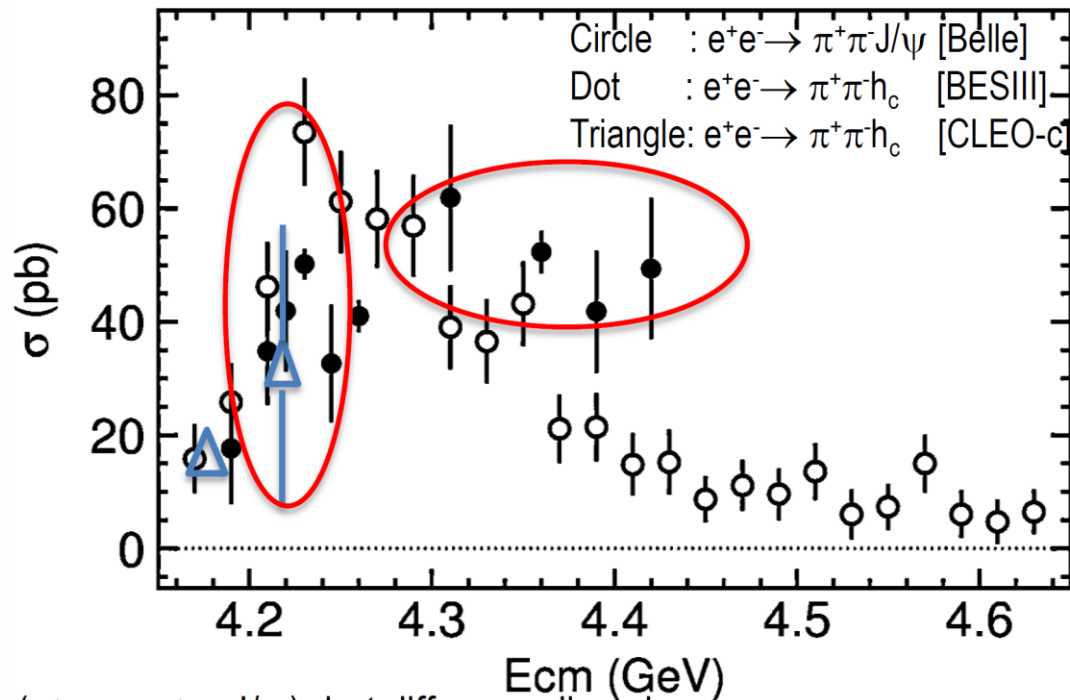
NEW

Has an isospin partner, $Z_c(3900)^0$?

BESIII Preliminary
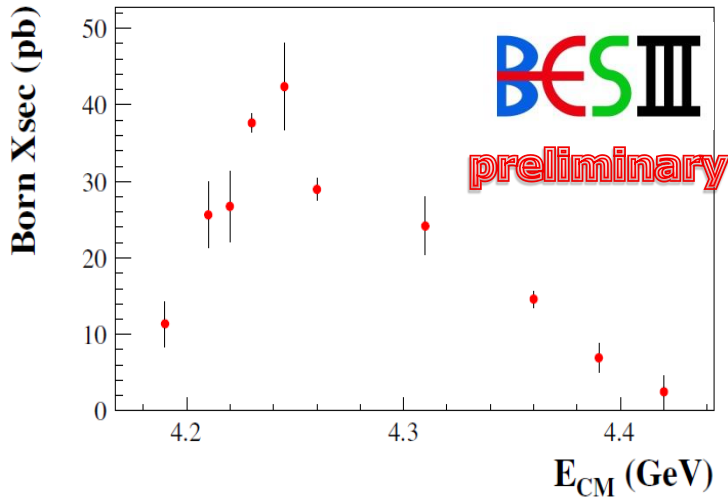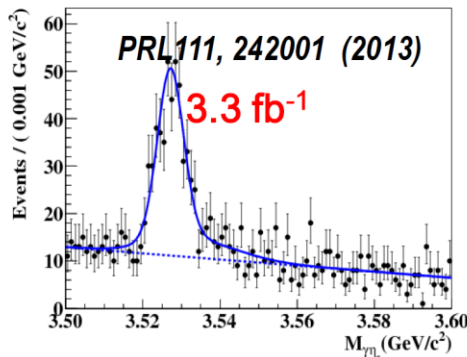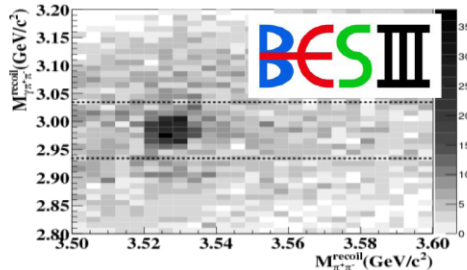

- 2.8fb⁻¹ data at 10 energy points from 4260~4420 MeV
- $Z_c(3900)^0$ is observed clearly at E_{cm} = 4230, 4260, 4360MeV
- BESIII preliminary results :
  - M= 3894.8±2.3 MeV, Γ = 29.6±8.2 MeV
  - Significance = 10.4 σ
- $R(Z_c^0/\pi^0\pi^0 J/\psi)$=$N(Z_c^0(3900))/N(\pi^0\pi^0 J/\psi)$, E_{cm} dependence

Neutral isospin partner, $Z_c(3900)^0$ observed

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

- Significant $\pi^+\pi^-h_c$ production reported by CLEO @ 4170MeV [PRL 107, 041803 (2011)]
- Correlated with observed Y(4260) or others charmonium states?
- 3.3fb^{-1} data at 13 energy points from 3900~4420 GeV
- $h_c \rightarrow \gamma\eta_c$, $\eta_c \rightarrow$ hadrons [16 exclusive decay modes, ~35% of the h_c decays]

PRL 111, 242001 (2013)

3.3 fb^{-1}

Circle : $e^+e^- \rightarrow \pi^+\pi^- J/\psi$ [Belle]
Dot   : $e^+e^- \rightarrow \pi^+\pi^- h_c$ [BESIII]
Triangle: $e^+e^- \rightarrow \pi^+\pi^- h_c$ [CLEO-c]

- $\sigma(e^+e^- \rightarrow \pi^+\pi^- h_c) \sim \sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)$, but difference line shape.
- Local maximum ~ 4230 MeV, broad structure at ~ 4400 MeV?
- Correlation with Y(4260) or Y(4360) unclear

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Zc(4020)± in π±hc

- no sharp structure in π⁺π⁻h_c cross section

  - correlation with Y(4260) or Y(4360) unclear

- narrow π±h_c structure observed

M = 4022.9±0.8±2.7 MeV/c²
Γ = 7.9±2.7±2.6 MeV
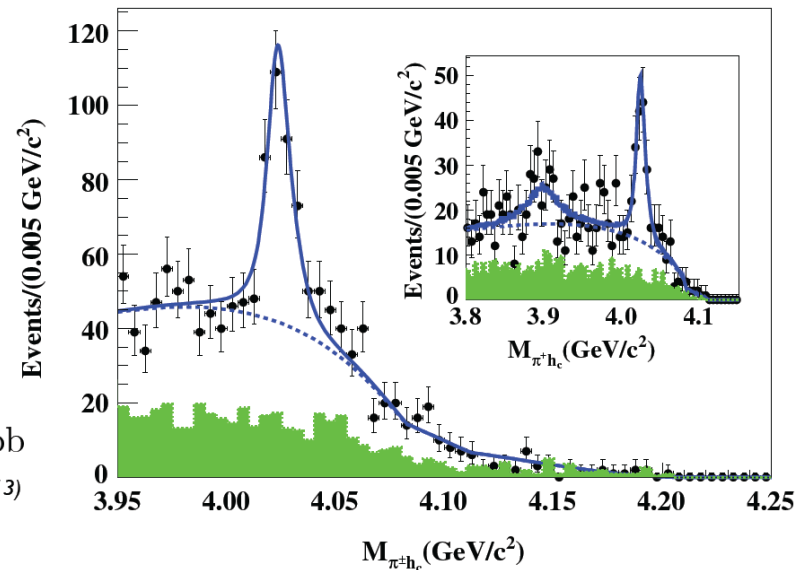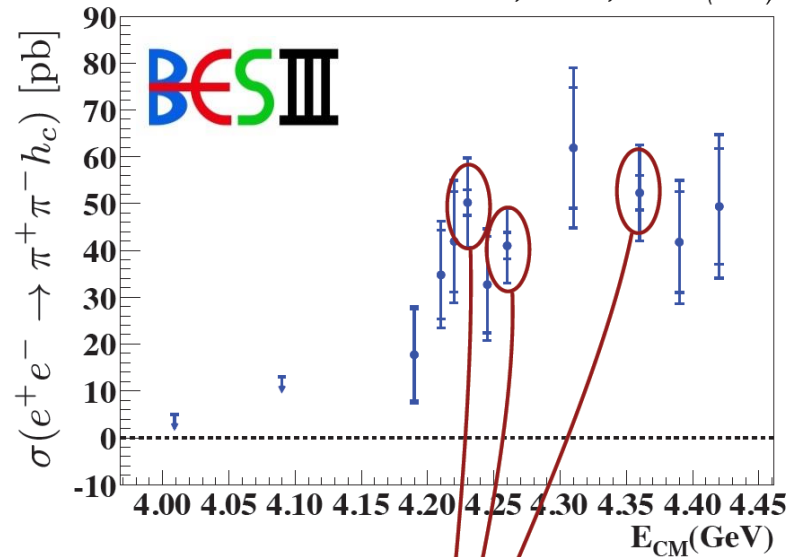
- no significant evidence for $Z_c(3900) \to \pi^\pm h_c$

  - at E_{cm} = 4260 MeV:

$$\sigma(e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- h_c) < 11 \text{ pb}$$

$$\sigma(e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi) = 13 \pm 5 \text{ pb}$$

DEPARTMENT OF PHYSICS
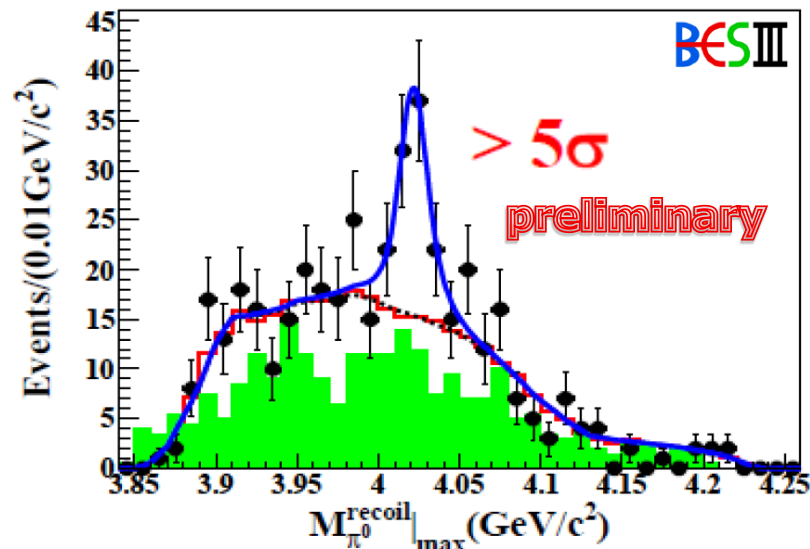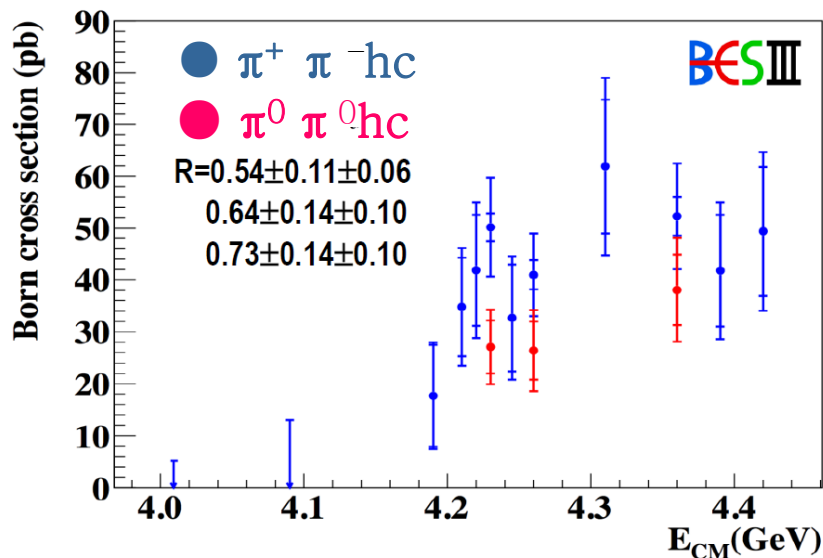
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Zc(4020)⁰ in π⁰h_c

BESIII Preliminary

- Study $e^+e^- \rightarrow \pi^0\pi^0 h_c$ at E_{cm} = 4230, 4260, 4360 MeV

- X-sec. is about half of that charged process, agree with the expectation of isospin symmetry

- Observe $Z_c(4020)^0$ structure in $\pi_0 h_c$ mass distribution

- BESIII preliminary Result :

  – $M[Z_c(4020)^0]$ = 4023.6±2.2±3.9 MeV

  $[M[Z_c(4020)^\pm]$ = 4022.9±0.8±2.7 MeV]

  – Width fixed to charged $Z_c(4020)$

Neutral partner of the charged Zc(4020) observed!
Observation of Zc(3900)⁰ and Zc(4020)⁰ → isovector nature of the Zc states

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$e^+e^- \rightarrow \pi^+(D\bar{D}^*)^- + $ c.c. at $\sqrt{s} = 4.26$ GeV

PRL112, 022001 (2014)
525pb^{-1} @ 4.26GeV
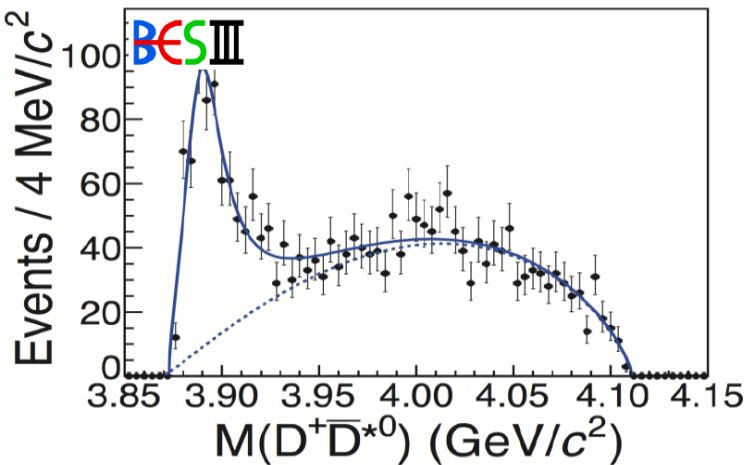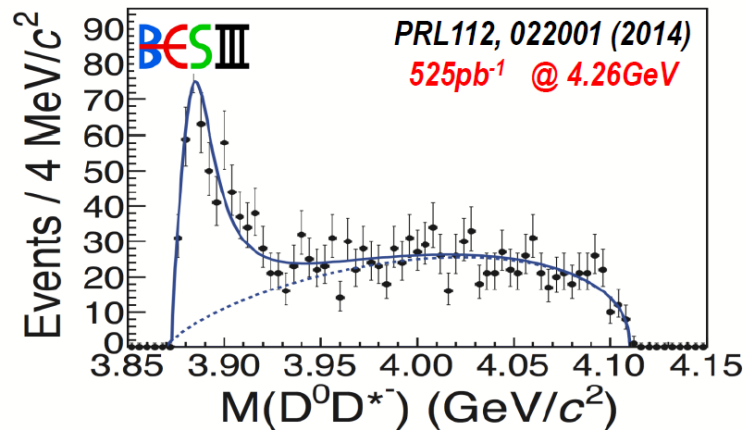
M[$Z_c(3885)$] = 3883.9±1.5±4.2MeV

Γ[$Z_c(3885)$] = 24.8±3.3±11.0MeV

2σ/1σ below those of $Z_c(3900)$

- Bachelor π angular distribution :

favors a J^p=1$^+$ assignment

1$^-$: P wave
1+cos$^2\theta_\pi$

1$^+$: S/D wave
Flat distribution

0$^-$: P wave
sin$^2\theta_\pi$
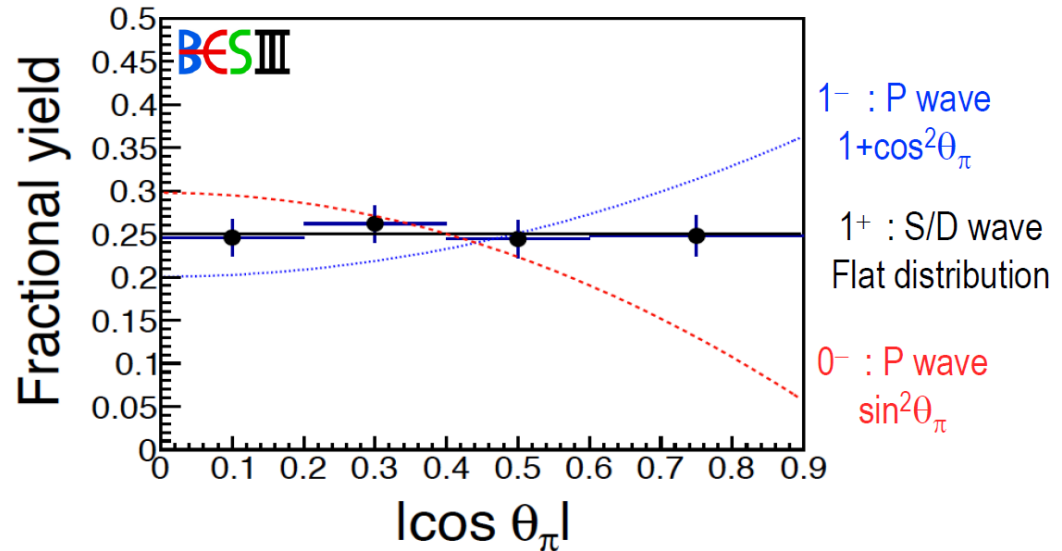
Are $Z_c(3900)$ and $Z_c(3885)$ same states?

- If $Z_c(3885)$ is $Z_c(3900)$:

$$\frac{\Gamma(Z_c(3900) \rightarrow D\bar{D}^*)}{\Gamma(Z_c(3900) \rightarrow \pi J/\psi)} = 6.2 \pm 2.9$$

Large non-DDbar coupling
Typical values : $\psi(3770)\sim 500$, $\psi(4040)\sim 200$

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$e^+e^- \rightarrow \pi^\pm(D^*\bar{D}^*)^\mp$ at E_{cm} = 4260 MeV
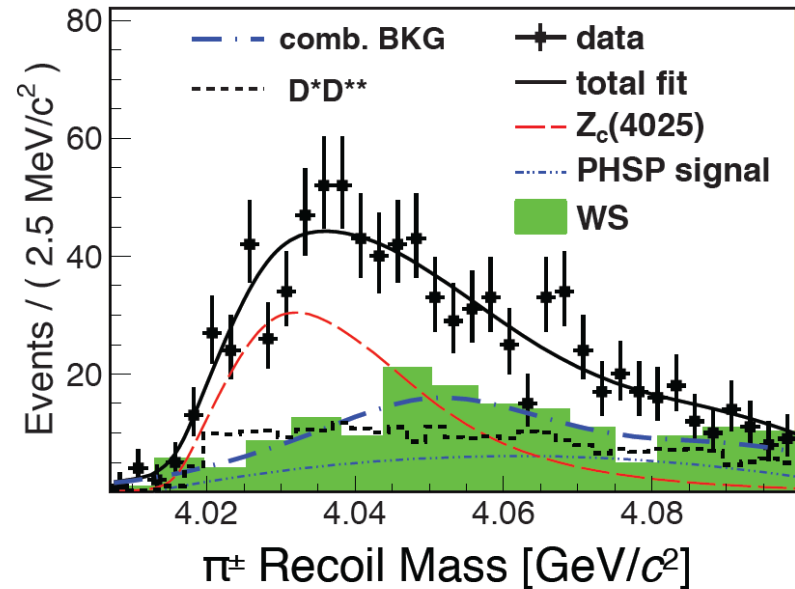
BES III

- deviation from phase space decay

  - could be described by a charged state decaying to $D^*\bar{D}^*$

- if $Z_c(4025)^\pm$ is the $Z_c(4020)^\pm$ observed in the $\pi^\pm h_c$ spectrum:

$$\frac{\Gamma(Z_c(4020) \rightarrow D^*\bar{D}^*)}{\Gamma(Z_c(4020) \rightarrow \pi h_c)} = 12 \pm 5$$

  - similar behavior to $Z_c(3900)^\pm$

BESIII Collaboration, PRL 112, 132001 (2014)

Legend: comb. BKG, D*D**, data, total fit, $Z_c(4025)$, PHSP signal, WS

$\pi^\pm$ Recoil Mass [GeV/c^2]

M = 4026.3±2.6±3.7 MeV/c^2

Γ = 24.8±5.6±7.7 MeV

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the Zc states at BESIII

Channel	Mass (MeV/c^2)	Width (MeV)
$\pi J/\psi$	3899.0$\pm$3.6$\pm$4.9 3894.8$\pm$2.3(Prel.)	46$\pm$10$\pm$20 29.6$\pm$8.2 (Prel.)
(D $\bar{\text{D}}$*)$^\pm$	3883.9$\pm$1.5$\pm$4.2	24.8$\pm$3.3$\pm$11.0
	2σ difference	1σ difference
πh_c	4022.9$\pm$0.8$\pm$2.7 4023.6$\pm$2.2$\pm$3.9 (Prel.)	7.9$\pm$2.7$\pm$2.6
(D* $\bar{\text{D}}$*)$^\pm$	4026.3$\pm$2.6$\pm$3.7	24.8$\pm$5.6$\pm$7.7
	1σ difference	2σ difference

Close to D $\bar{\text{D}}$* threshold (3875 MeV)

Close to D* $\bar{\text{D}}$* threshold (4017 MeV)

- $\bar{\text{D}}^{(*)}$D* molecule?
- Tetraquark state?
- Cusp?
- Threshold effect?
- …

- At least 4-quarks; Charged; Near threshold;
- Isospin: I=1, hint of a new spectroscopy ?
- **Whether they are two states need further understanding (couple channel analysis? quantum number determination? interference?)**

$e^+e^- \rightarrow \omega\chi_{c0}$

E_{cm}= 4230 MeV   *preliminary*

BESIII Preliminary

E_{cm}= 4260 MeV

$\omega\chi_{c0}$ threshold
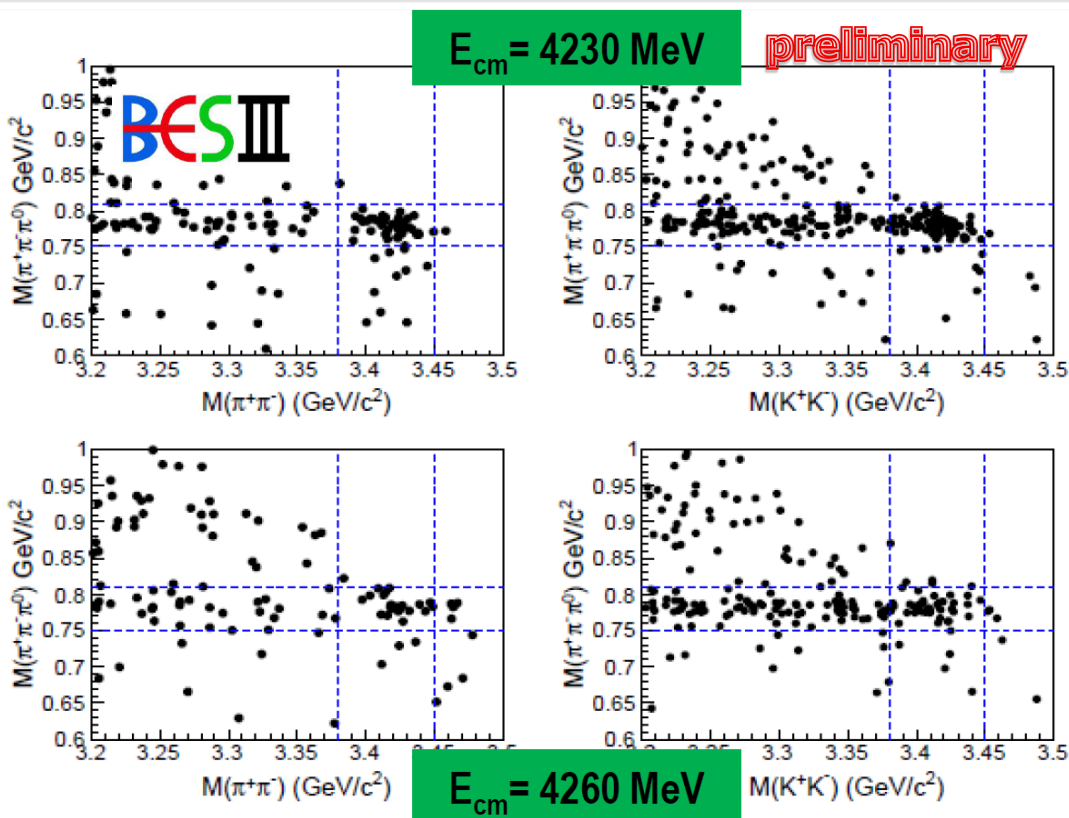
preliminary
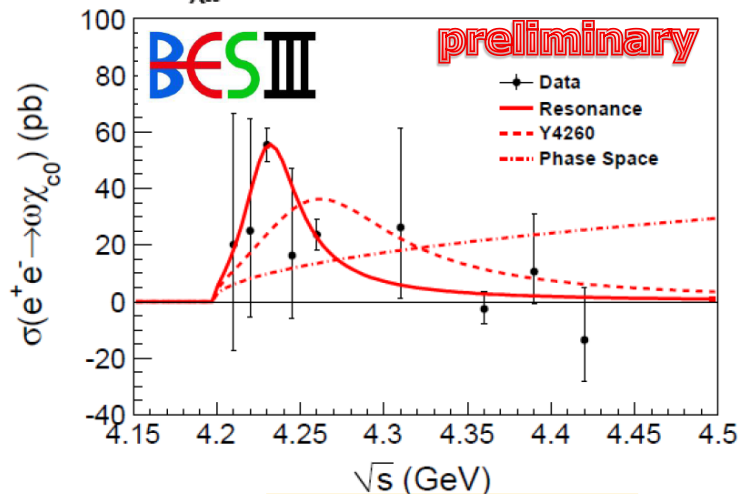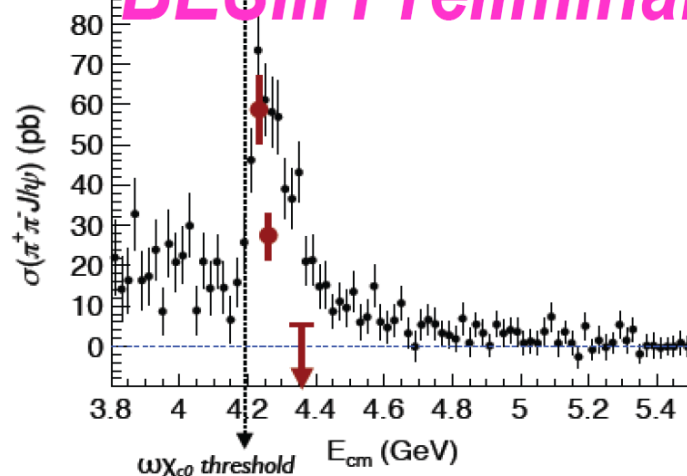
- Observation of $\omega\chi_{c0}$ at 4230, 4260 MeV data
- No evidence at 4360MeV
- Line shape seems inconsistent with Y(4260)
- Assuming signal from a resonance, a BW fitting get a narrow structure around 4230MeV.

M=4229±11±6MeV

Γ=40±14±2MeV

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Summary

● Some charged Zc states were observed at BESIII using above 4GeV data.

● $e^+e^- \rightarrow \gamma X(3872)$ at 4230, 4260, 4360 MeV was observed clearly. The signals are from the process $Y(4260) \rightarrow \gamma X(3872)$? More energy points are needed.

●$Zc(3900)^0$ and $Zc(4020)^0$ were found without surprise, which Indicates the isovector nature of the Zc states

● $e^+e^- \rightarrow \omega \chi_{c0}$ at 4.23 and 4.26 GeV were observed. It seems the observed signals are not from Y(4260) ?

Thanks!