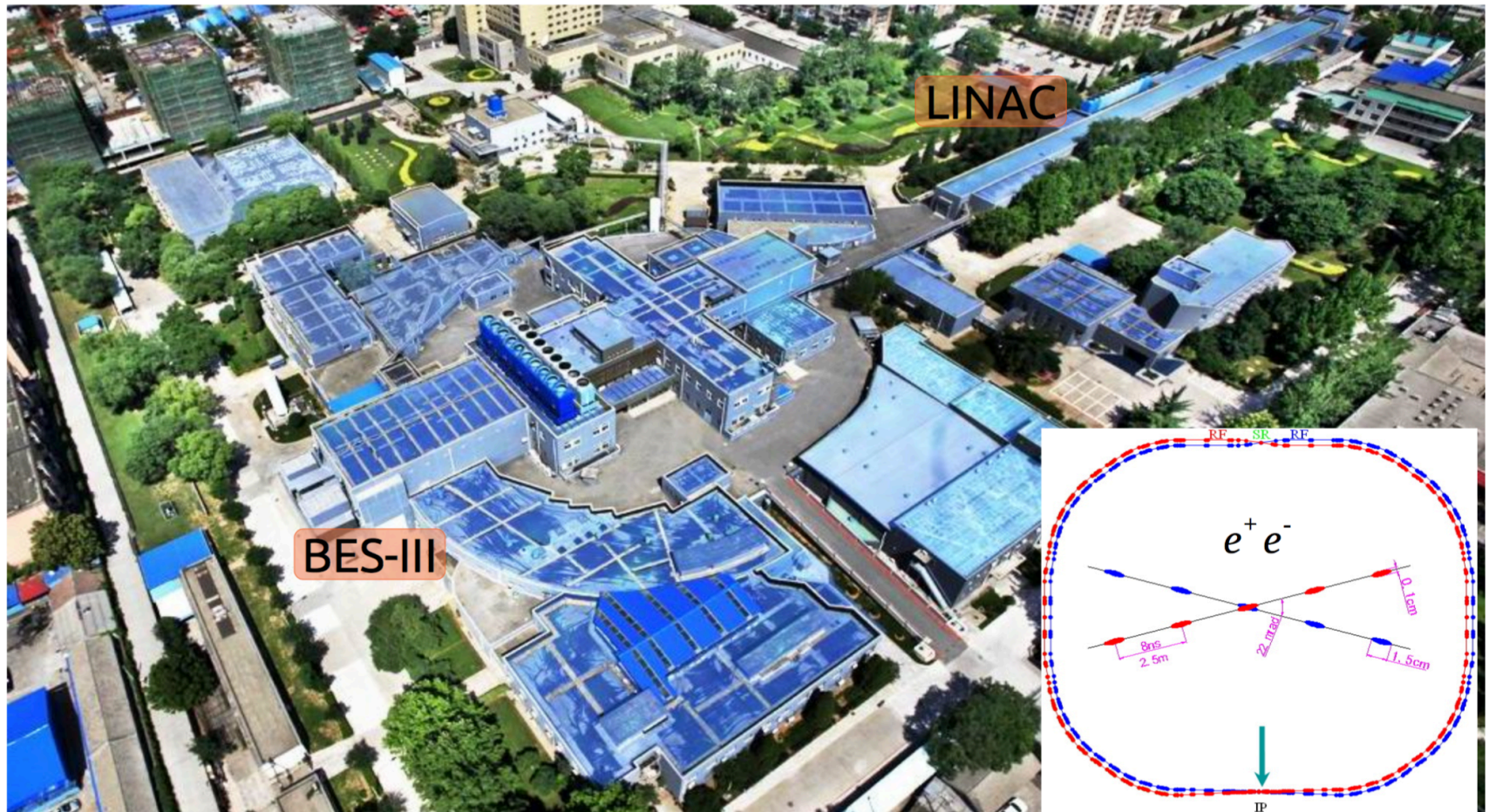# XYZ studies at BESIII

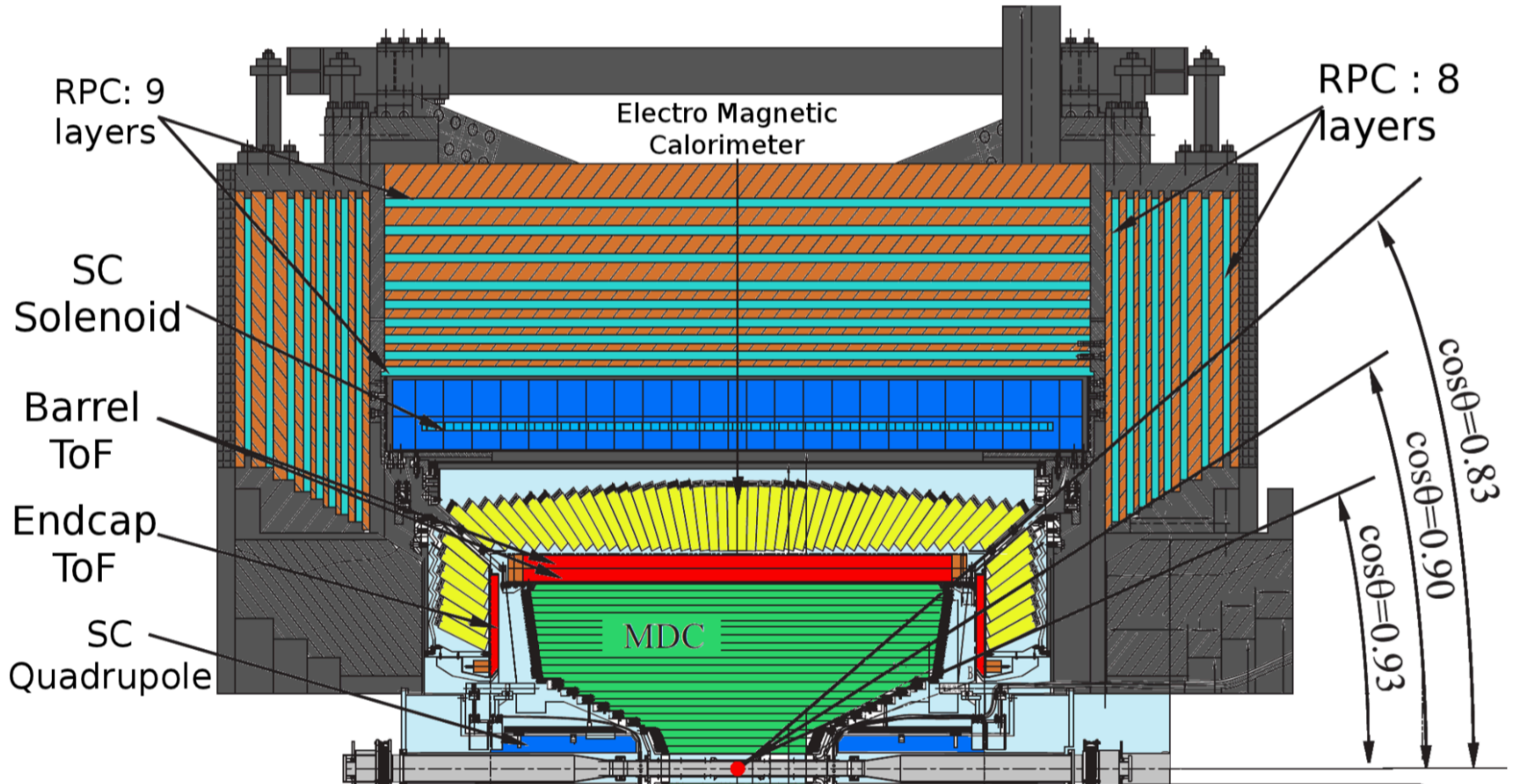**Liangliang WANG** (IHEP, Beijing, China)

On behalf of BESIII **Collaboration**
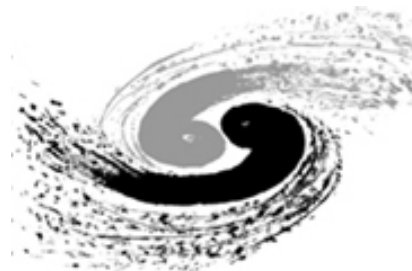
BEPCII and BESIII: a τ-charm factory

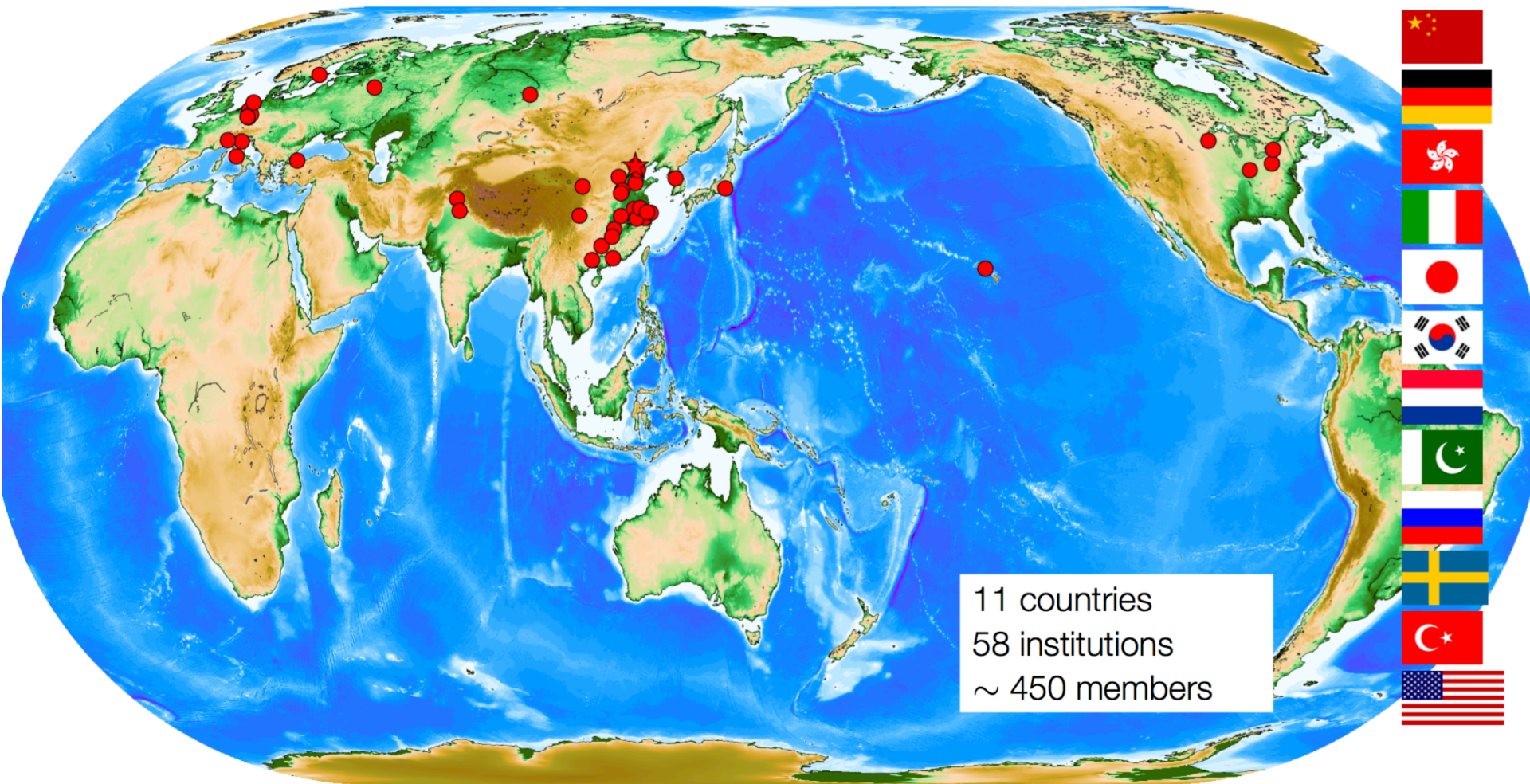Beam Energy: 1~2.3 GeV
Beam current: 0.91 A
Crossing angle: ±11 mrad

Design luminosity: 10^{33}cm^{-2}s^{-1} @1.89GeV
Achieved on 5th April, 2016!

BESIII detector

BESIII Collaboration

11 countries
58 institutions
∼ 450 members

Physics program
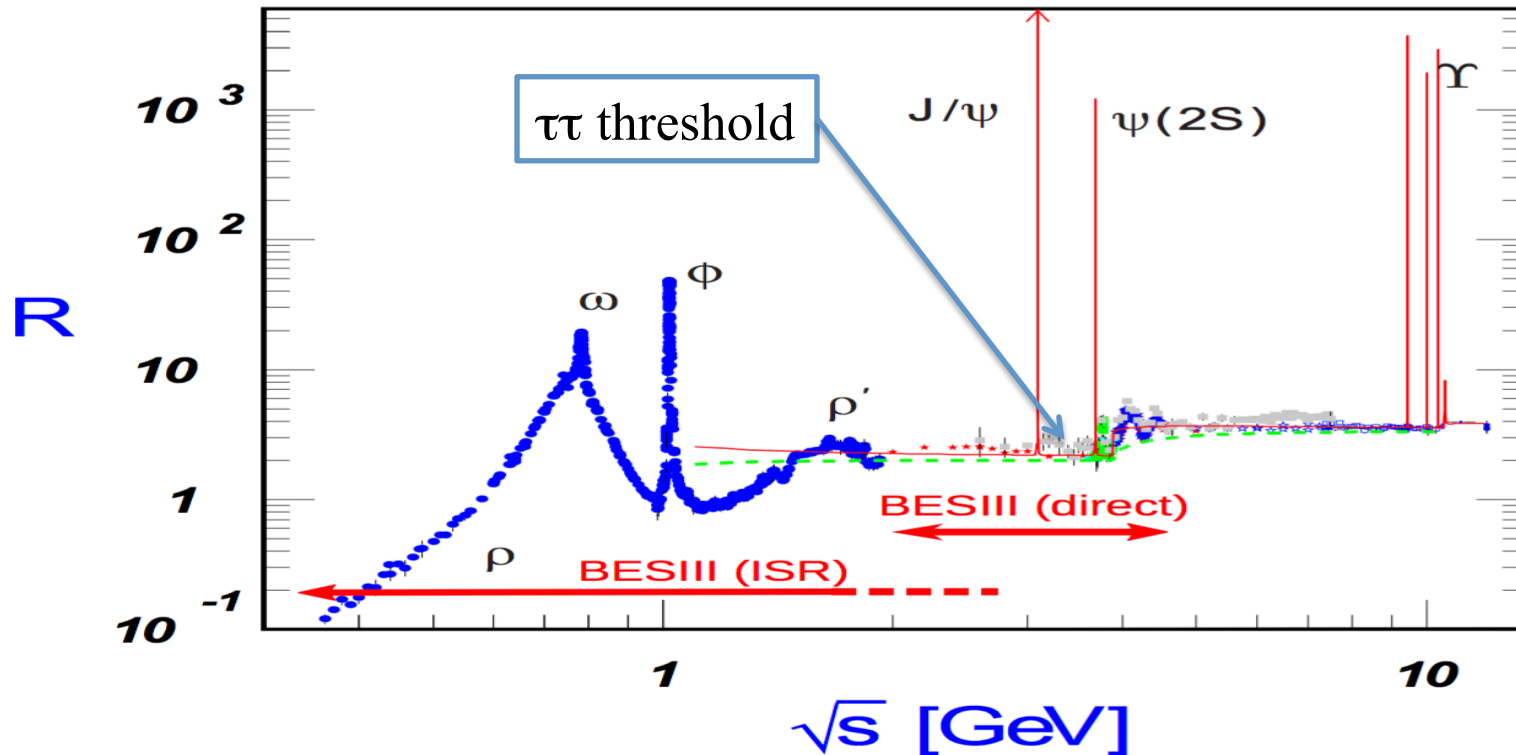
- ✓ R and QCD
- ✓ τ physics
- ✓ Light hadron physics

- ✓ Charmonium physics
- ✓ Charm Physics
- ✓ **XYZ meson physics (this talk)**

Data 4~4.6GeV for XYZ studies

e+e- → Y/ψ/γ*

$\gamma, \pi\pi \ldots$ → X states

π → Z$_c$ states

$\gamma, \eta, \pi\pi \ldots$ → Charmonium states

Open charm
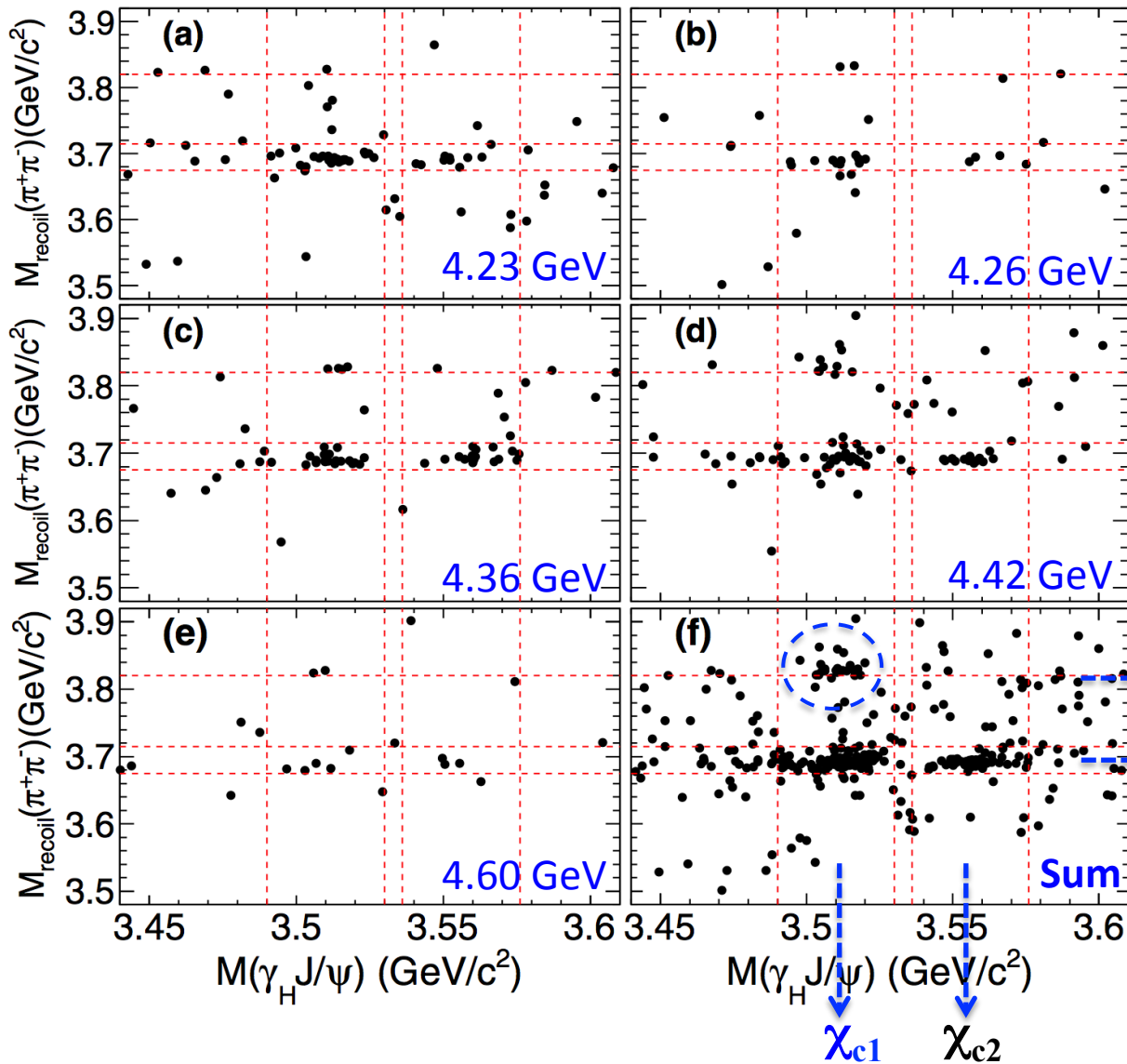
others
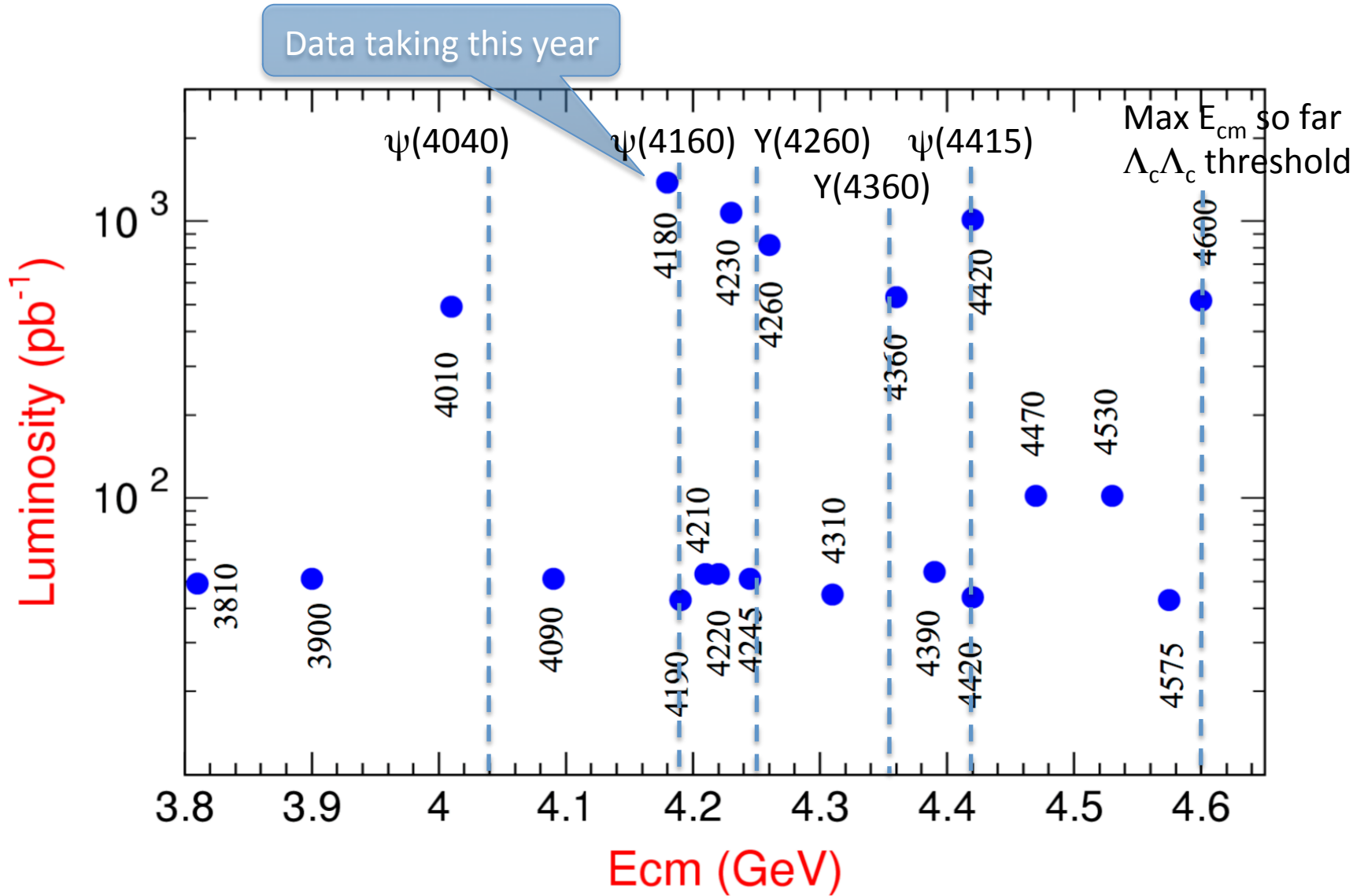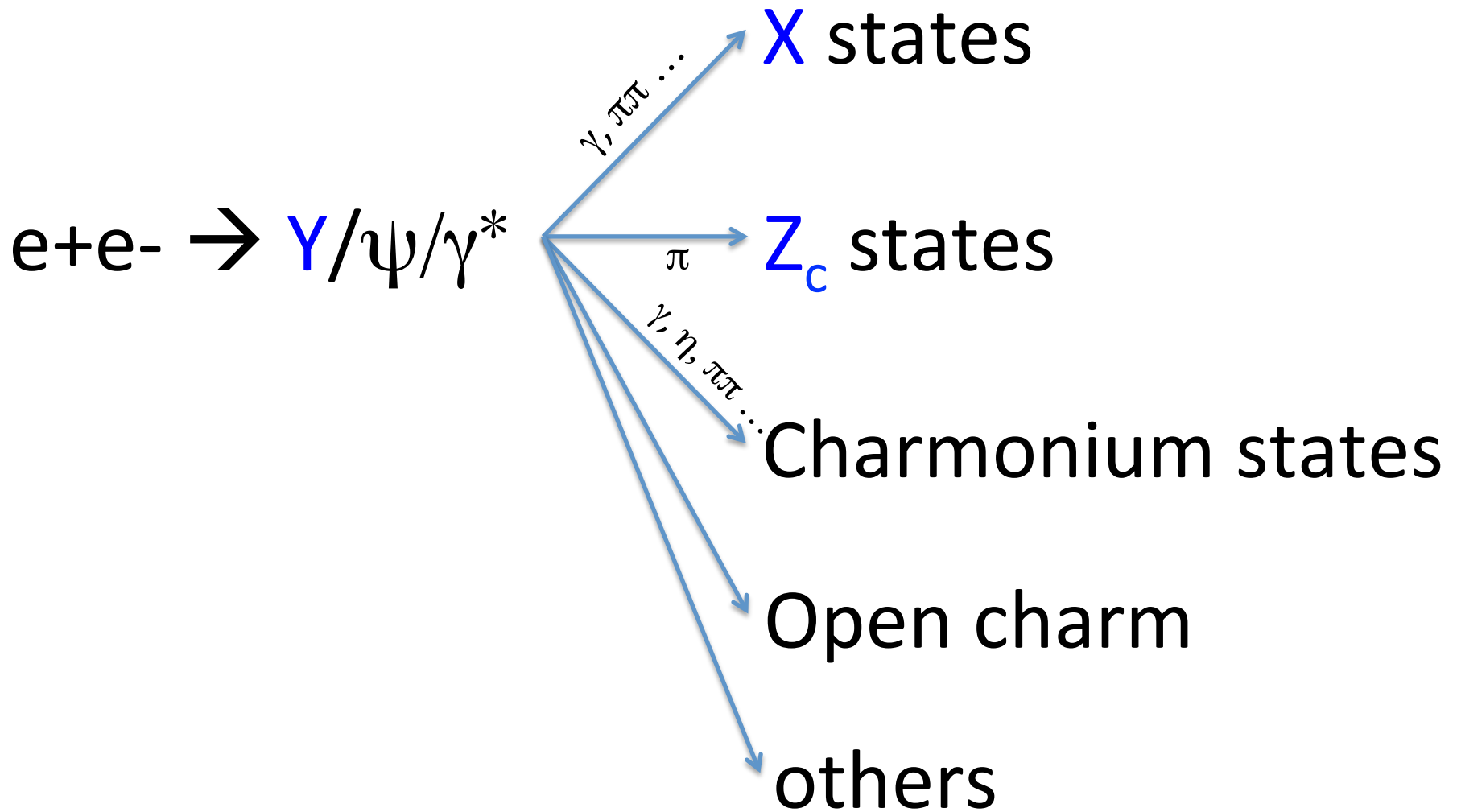
The X states

- Neutral charmonium-like/exotic states
- J^{PC} is not 1^{--}
- Searched by photon/hadron transition at BESIII

$e^+e^- \rightarrow \pi^+\pi^- X(3823)$, $X(3823) \rightarrow \chi_{c1}\gamma$ at BESIII

BES III

PRL **115**, 011803

- Reconstruct $\chi_{c1/2} \rightarrow \gamma J/\psi$, $J/\psi \rightarrow ll$ (l=e/m)
- Five large data sets used (~4.1 fb^{-1})

$e^+e^- \to \pi^+\pi^- X(3823)$, $X(3823) \to \chi_{c1}\gamma$ at BESIII
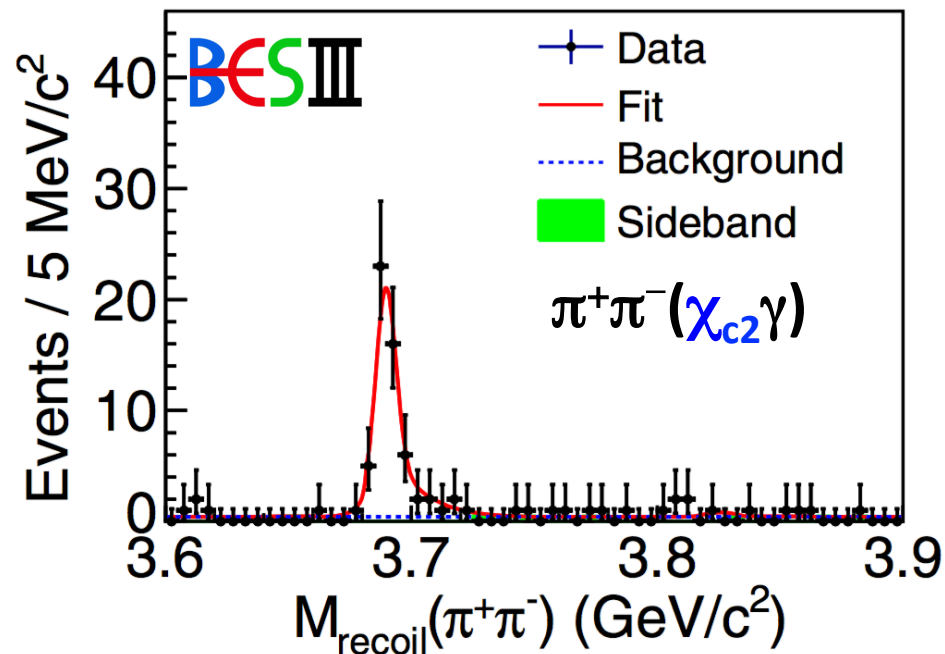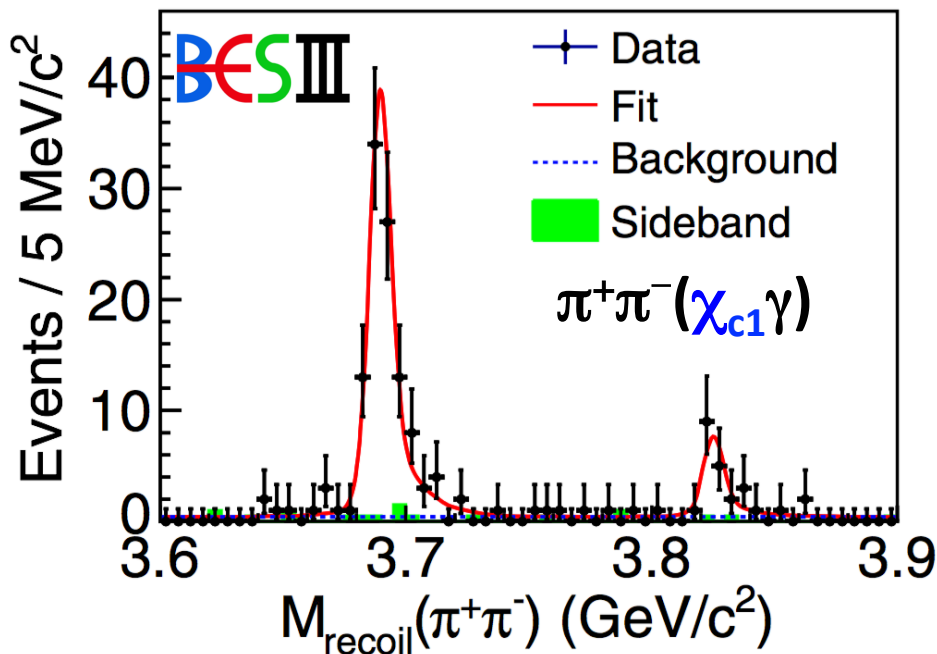
- A simultaneous fit of different data sets
- Signal: MC simulated shape
  Background: linear function
- M=3821.7±1.3±0.7 MeV; Significance: 6.2σ, observation !
- Mass and narrow width agree with potential model prediction for $\psi(1^3D_2)$

Observation of X(3872) at BESIII

via $e^+e^- \rightarrow \gamma\pi^+\pi^- J/\psi$ @ 4.26GeV for the first time
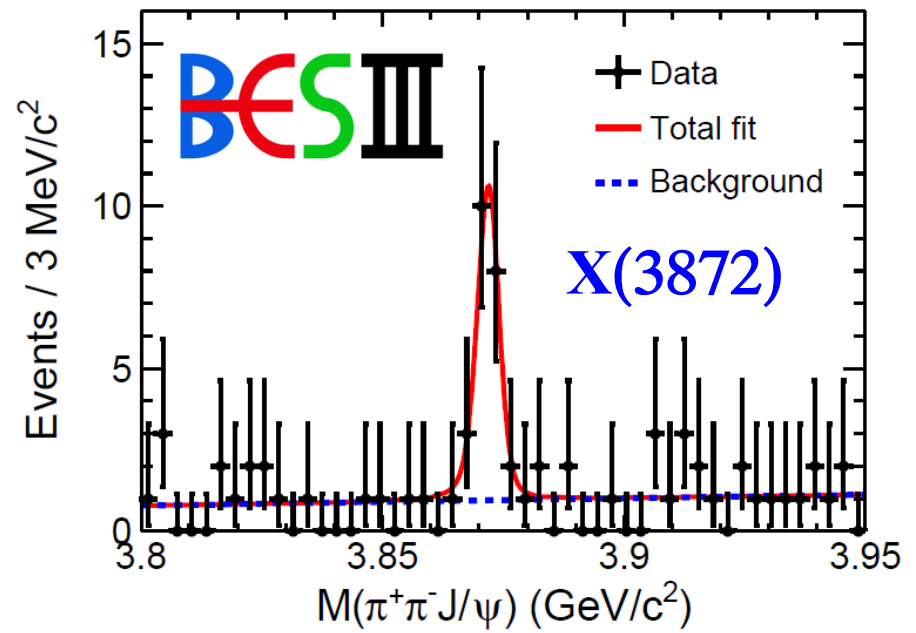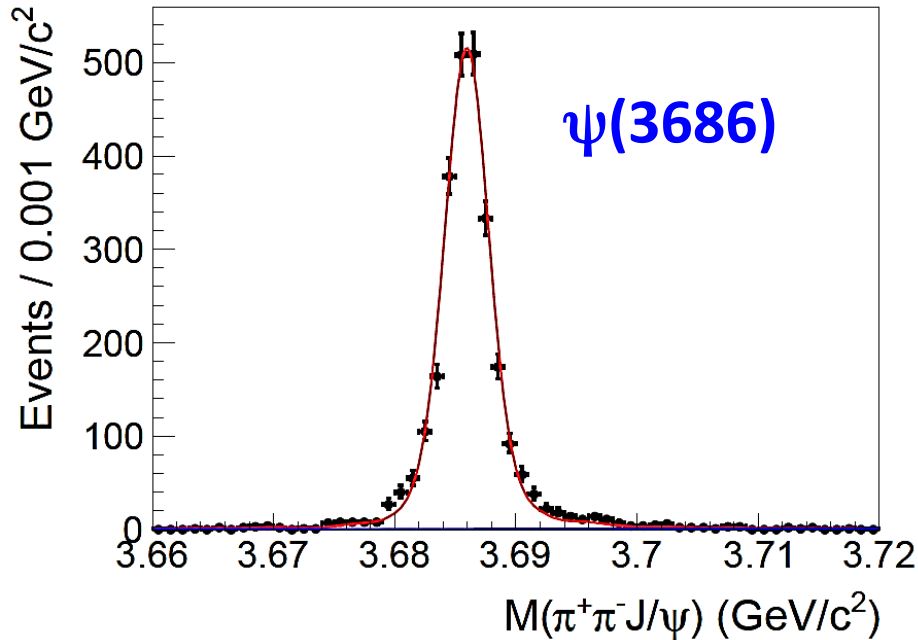
ISR ψ' signal is used for mass, and resolution calibration.
N=1818; ΔM=0.34±0.04 MeV; $\Delta\sigma_M$=1.14 ±0.07 MeV

N(X(3872)) = 20.1±4.5   **6.3σ**   PRL 112, 092001 (2014)
M(X(3872)) = 3871.9±0.7±0.2 MeV   [PDG: 3871.68 ±0.17 MeV]

The Z_c family

- Charged exotic states
- Observed via π transition at BESIII

ee→πZ$_c$(3900)$^{±/0}$→π(πJ/ψ)

PRL 110, 252001 (2013)

ee→π$^+$Z$_c$(3900)$^-$(π$^-$J/ψ) @4.26GeV
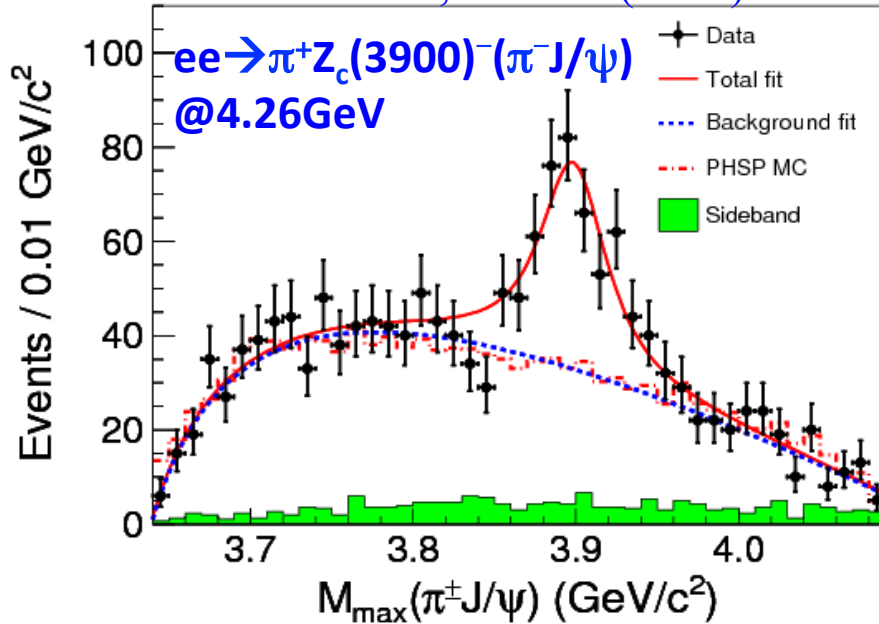
PRL 115, 112003(2015)

ee→π^{0}Z$_c$(3900)^0(π^{0}J/ψ)
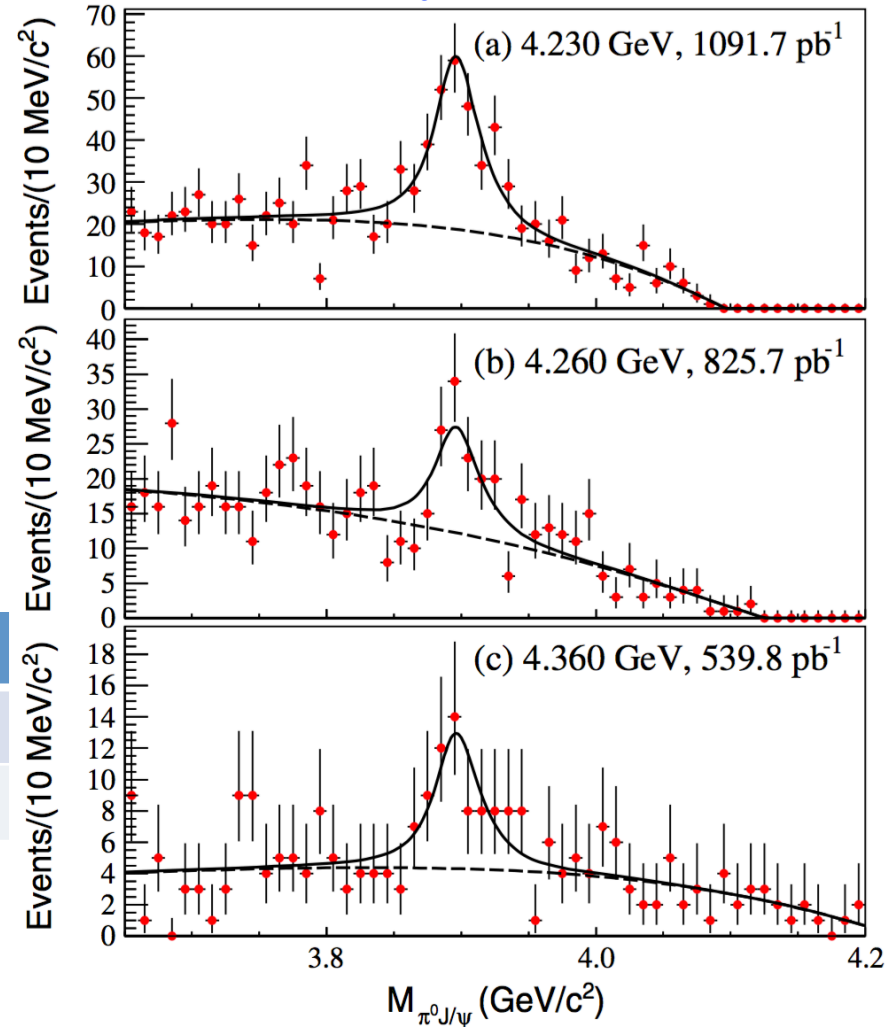
Z$_c$(3900)	Mass(MeV)	Width(MeV)
Z$_c$(3900)$^±$	3899.0±3.6±4.9	46±10±20
Z$_c$(3900)^0	3894.8±2.3±2.7	29.6±8.2±8.2

Mass ~ m(DD*)

ee→πZ$_c$(3885)$^{±/0}$→π(DD*)$^{±/0}$
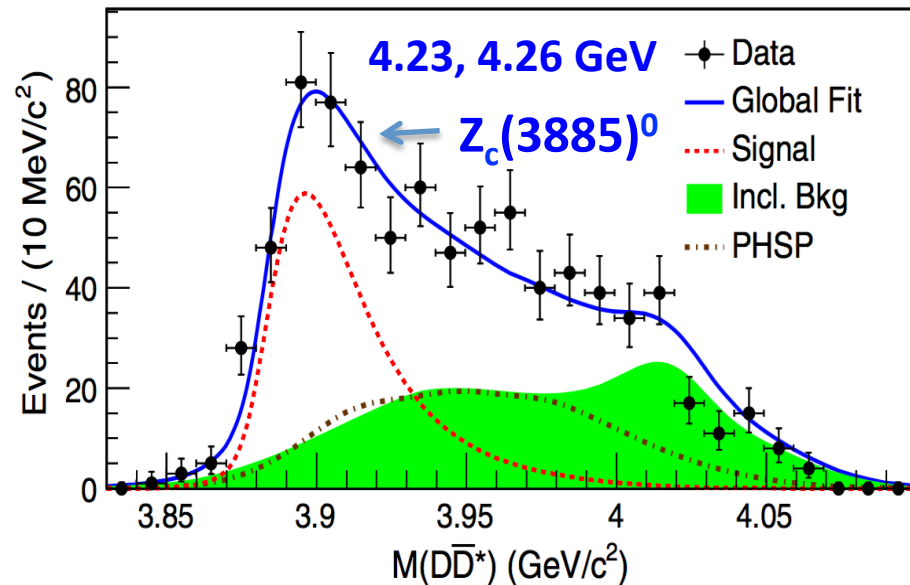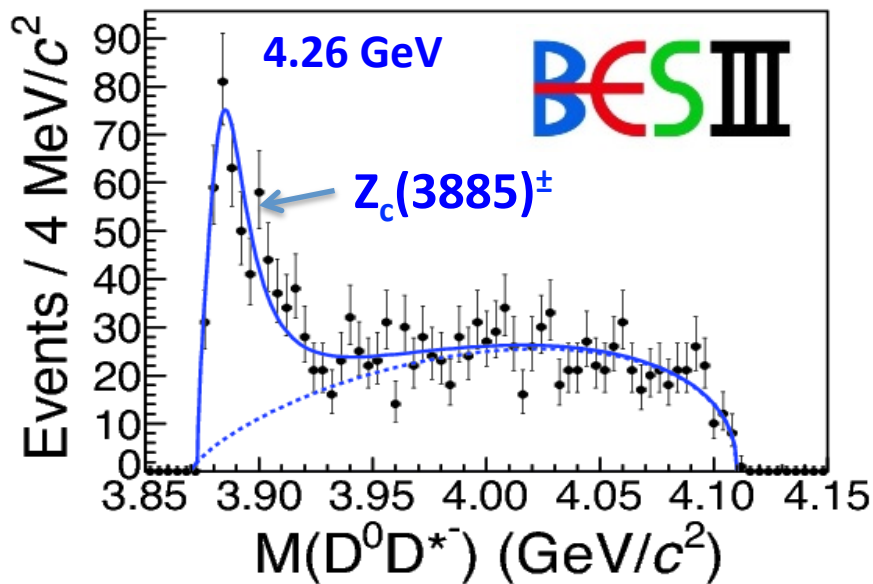
Z$_c$(3885)	Mass(MeV)	Width(MeV)	reference
Z$_c$(3885)$^±$ (single D-tag)	3883.9±1.5±4.2	24.8±3.3±11.0	PRL 112, 022001(2014)
Z$_c$(3885)$^±$ (double D-tag)	3881.7±1.6±2.6	26.6±2.0 ±2.3	PRD 92, 092006 (2015)
Z$_c$(3885)^0 (single D-tag)	3885.7$^{+4.3}_{-5.7}$±8.4	35$^{+11}_{-12}$±15	PRL 115, 222002 (2015)

Search for ee➔πZ_c(3900)➔π(ωπ)
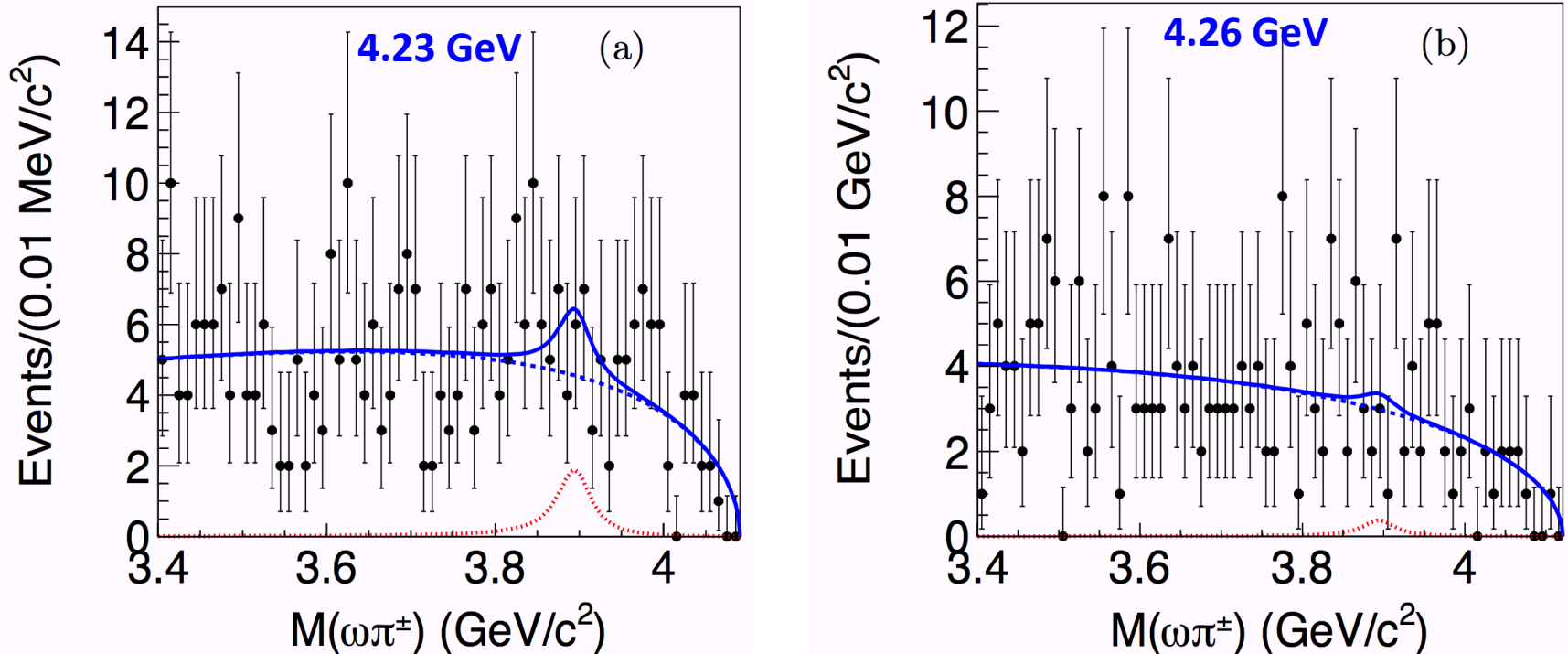
- **Searching for new decays of Zc(3900) to light hadrons: distinguish a resonance from threshold effects**
- **No significant Zc➔ωπ is observed:**
  σ(e+e-➔Zcπ, Zc ➔ωπ) < 0.26 pb @ 4.23 GeV
  σ(e+e-➔Zcπ, Zc ➔ωπ) < 0.18 pb @ 4.26 GeV

ee→πZ$_c$(4020)$^{±/0}$→π(πh$_c$)

Sum of 4.23, 4.26, 4.36GeV data

8.9σ

Z$_c$(4020)$^±$

4.23+4.26 data

BESIII

4230 + 4260+4360 MeV
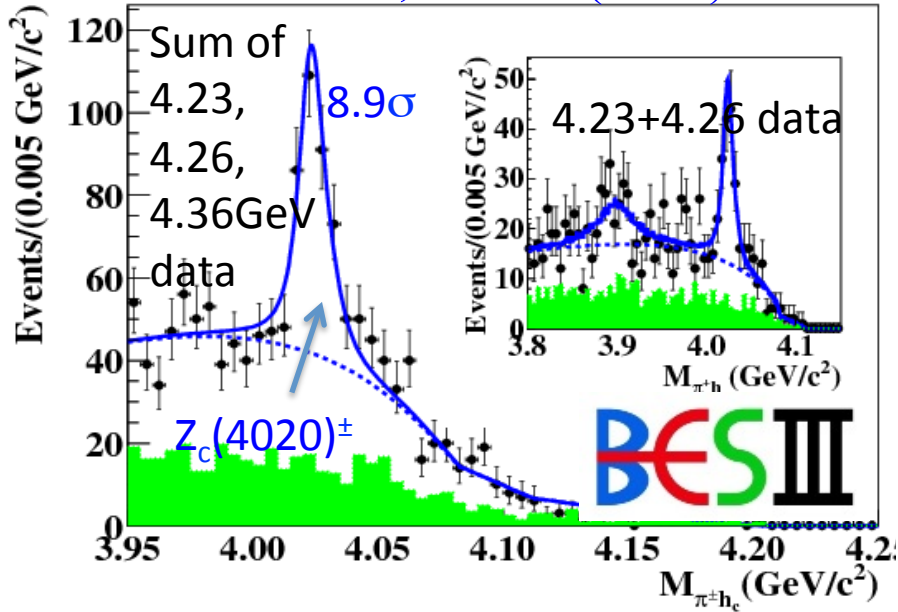
Significance > 5σ

Z$_c$(4020)^0

No significant signal for Z$_c$(3900)$^±$→π$^±$h$_c$

Z$_c$(4020)	Mass(MeV)	Width(MeV)
Z$_c$(4020)$^±$	4022.9±0.8±2.7	7.9±2.7±2.6
Z$_c$(4020)^0	4023.8±2.2±3.8	Fixed (7.9)

~m(D*D*)

e+e-→πZc(4025)±/0→π(D*D*)±/0
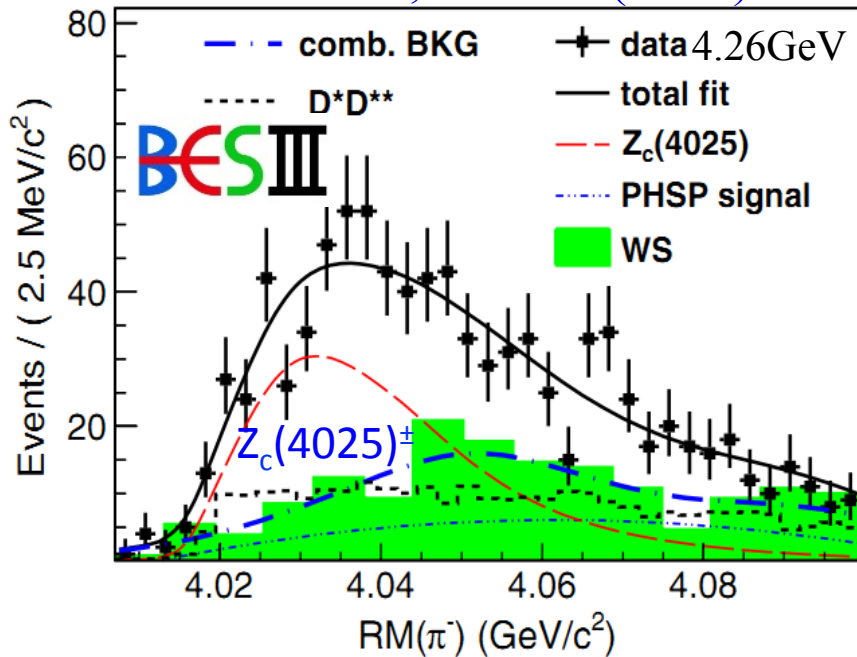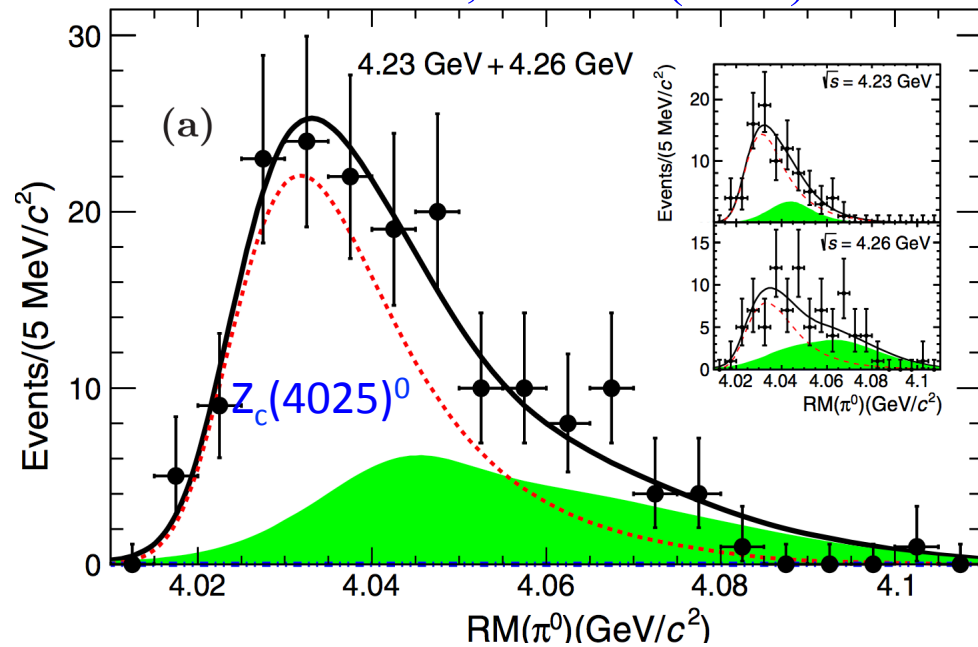
Zc(4025)	Mass(MeV)	Width(MeV)
$Z_c(4025)^\pm$	$4026.3 \pm 2.6 \pm 3.7$	$24.8 \pm 5.6 \pm 7.7$
$Z_c(4025)^0$	$4025.5^{+2.0}_{-4.7} \pm 3.1$	$23.0 \pm 6.0 \pm 1.0$

Discussion of the Z_c family

Z_c	Mass (MeV/c^2)	Width (MeV)	Decay mode (X_i)	J^P	
$Z_c(3900)^+$	3899.0±3.6±4.9	46±10±20	$\pi^+ J/\psi$	1$^+$	Preliminary result from PWA
$Z_c(3900)^0$	3894.8±2.3±2.7	29.6±8.2±8.2	$\pi^0 J/\psi$		
$Z_c(3885)^+$	3882.3±1.1± 1.9$^\#$	26.5±1.7±2.3$^\#$	$(DD^*)^+$	1$^+$	From angular distribution
$Z_c(3885)^0$	3885.7$^{+4.3}_{-5.7}$±8.4	35$^{+11}_{-12}$±15	$(DD^*)^0$		
$Z_c(4020)^+$	4022.9±0.8±2.7	7.9±2.7±2.6	$\pi^+ h_c$		# combined results of single and double D-tag
$Z_c(4020)^0$	4023.8±2.2±3.8	Fixed to 7.9	$\pi^0 h_c$		
$Z_c(4025)^+$	4026.3±2.6±3.7	24.8±5.6±7.7	$(D^*D^*)^+$		
$Z_c(4025)^0$	4025.5$^{+2.0}_{-4.7}$±3.1	23.0±6.0±1.0	$(D^*D^*)^0$		

- Charged Z_c decays into $\pi J/\psi$ (πh_c ...) => at least has four quark components
- Production of charged and neutral Z_c is consistent with isospin relationship => Isospin triplet?
- Are the $Z_c(3900)$ and $Z_c(3885)$ ($Z_c(4020)$ and $Z_c(4025)$) are the same state/ structure?
  Masses and widths are consistent each other within 2σ
  Favor the same J^P

The Y states (vectors)

- Can be directly produced in e+e- annihilation
- Can not be seen from the inclusive hadronic cross section (R-scan): measure exclusive hadronic cross sections at BESIII

$\sigma(ee \rightarrow X+(\pi\pi,\gamma))$

$ee \rightarrow \pi+\pi- X(3823)(\gamma\chi_{c1})$
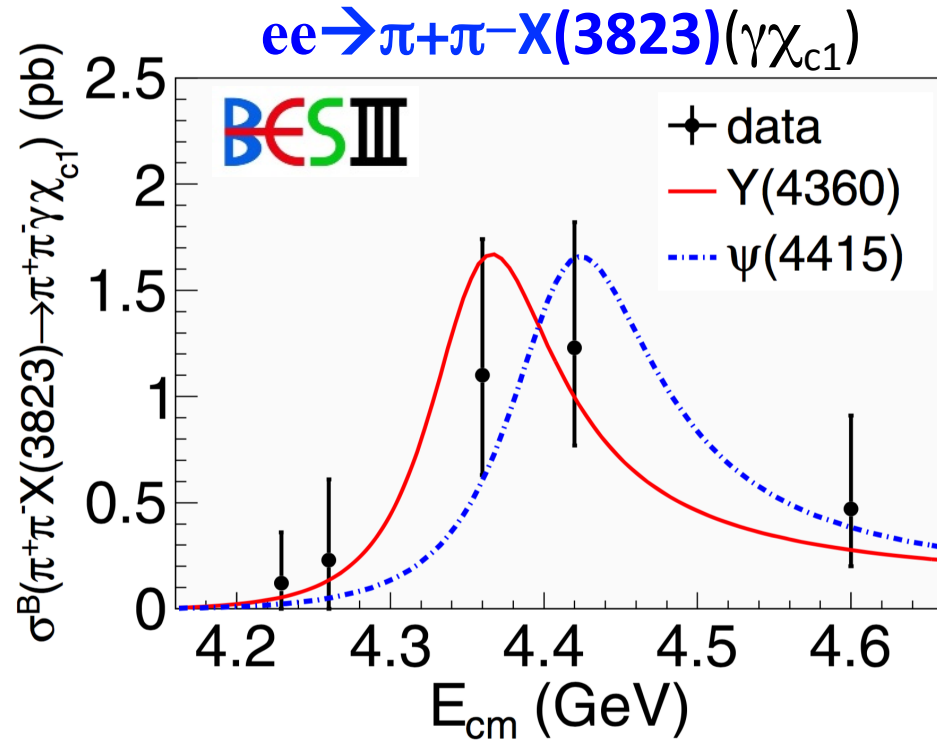
Data can not distinguish
Y(4360) and $\psi(4415)$

PRL 115, 011803 (2015)

$ee \rightarrow \gamma X(3872)(\pi+\pi-J/\psi)$
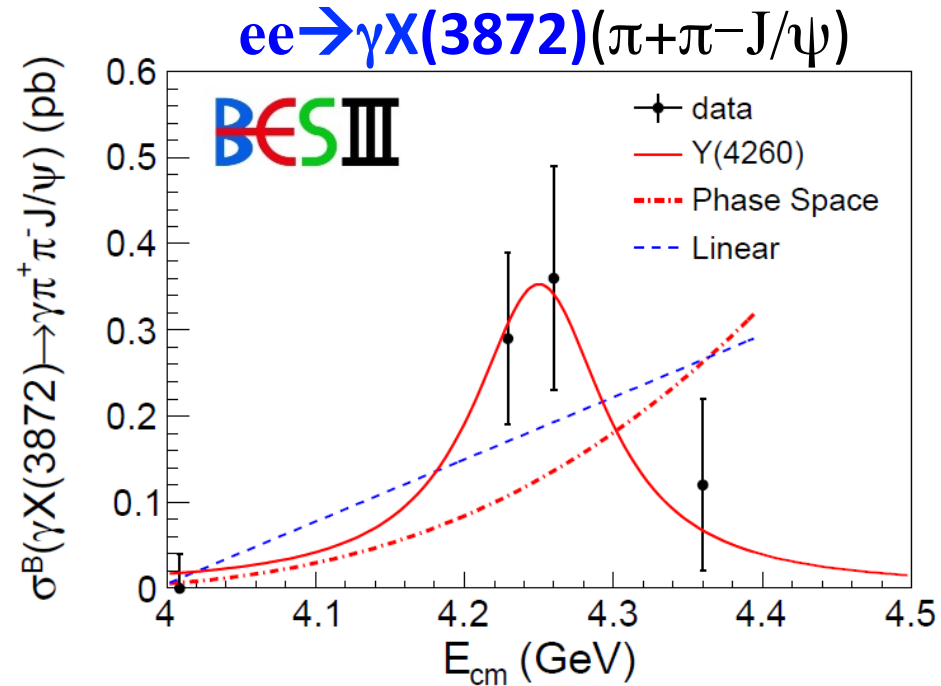
Data suggests Y(4260)$\rightarrow\gamma$X(3872)

PRL 112, 092001 (2014)

$\sigma(ee \rightarrow \pi^0 Z_c(3900)^0)$ and $\sigma(\pi^0\pi^0 J/\psi)$

$$\frac{\sigma(ee \rightarrow \pi^0 Z_c(3900)^0)}{\sigma(ee \rightarrow \pi^0\pi^0 J/\psi)}$$

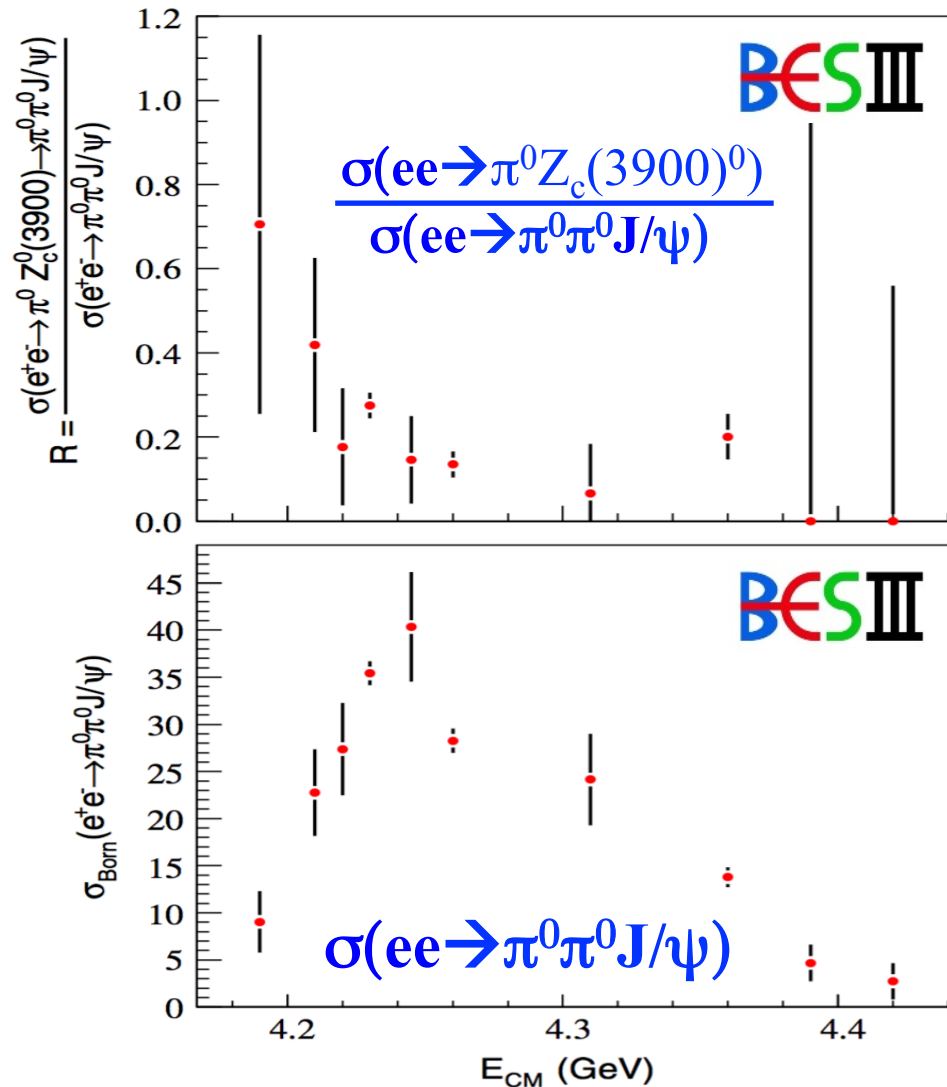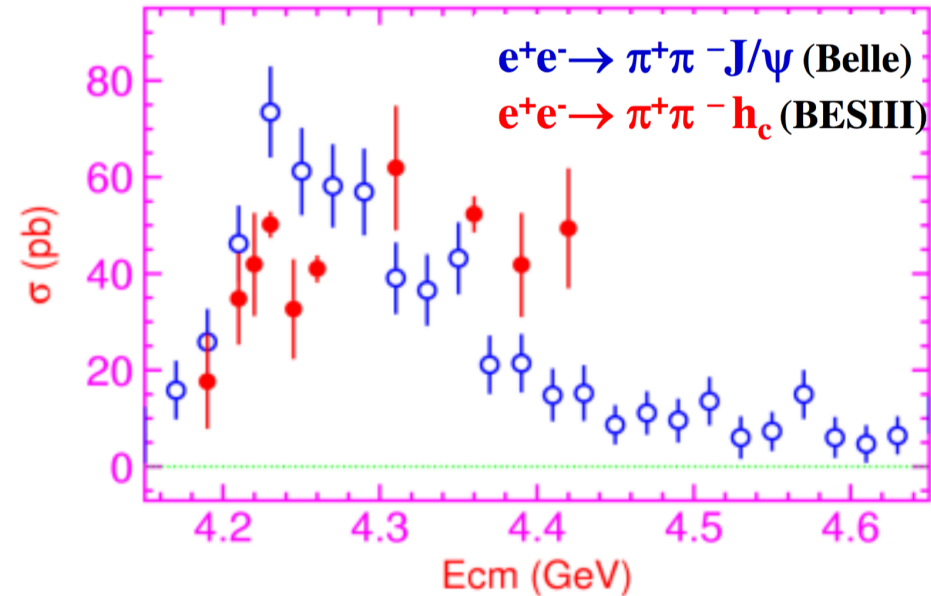$$\sigma(ee \rightarrow \pi^0\pi^0 J/\psi)$$

- Measured $\sigma(ee \rightarrow \pi^0\pi^0 J/\psi)$ ~ half of $\sigma(ee \rightarrow \pi^+\pi^- J/\psi)$ by Belle
- $Y(4260) \rightarrow \pi^0\pi^0 J/\psi$?
- Maximum cross section is around 4.23 GeV
- R@4.23GeV > R@4.26GeV
  R: Relative $Z_c(3900)^0$ production ratio in $\sigma(ee \rightarrow \pi^0\pi^0 J/\psi)$
  =>
  $\sigma(ee \rightarrow \pi^0 Z_c(3900)^0)$ has sharper peak at 4.23 GeV than $\sigma(ee \rightarrow \pi^0\pi^0 J/\psi)$
- Rich Y states/structures between 4.2~4.3 GeV?

$\sigma(ee \rightarrow \pi\pi h_c)$

PRL 111, 242001(2013)

PRL 113, 212002 (2014)
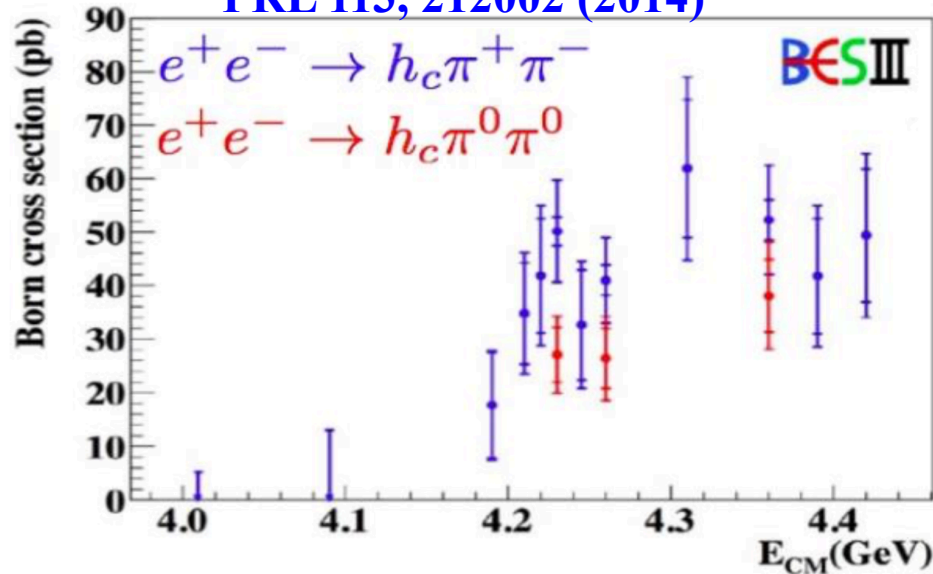
- Improved measurement of $\sigma(\pi+\pi-h_c)$ (CLEO studied in 2011)
- First observation of $\pi^0\pi^0 h_c$
- $\sigma(\pi^0\pi^0 h_c)/\sigma(\pi^+\pi^- h_c)=0.63\pm0.09$

- $\sigma(\pi+\pi-h_c) \sim \sigma(\pi+\pi-J/\psi)$, but different line shape
- Unlikely originate from Y(4260)
- Hint of a more complicated underlying dynamics

$\sigma(ee \rightarrow \pi^0/\eta/\eta' + J/\psi)$

- No significant $ee \rightarrow \pi^0 J/\psi$ observed

$\sigma(ee \rightarrow \eta J/\psi)$

PRD 86, 071101(R) (2012)
PRD 91, 112005 (2015)

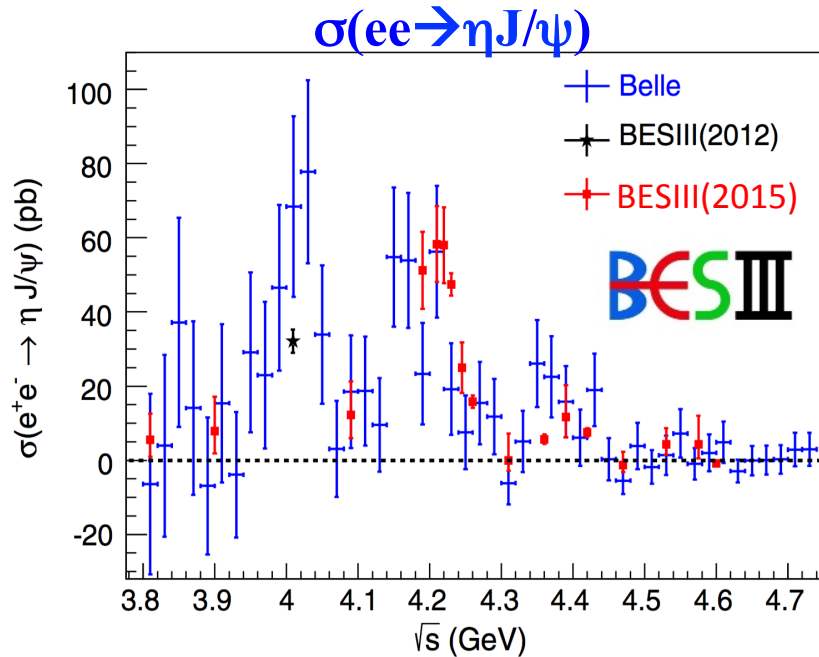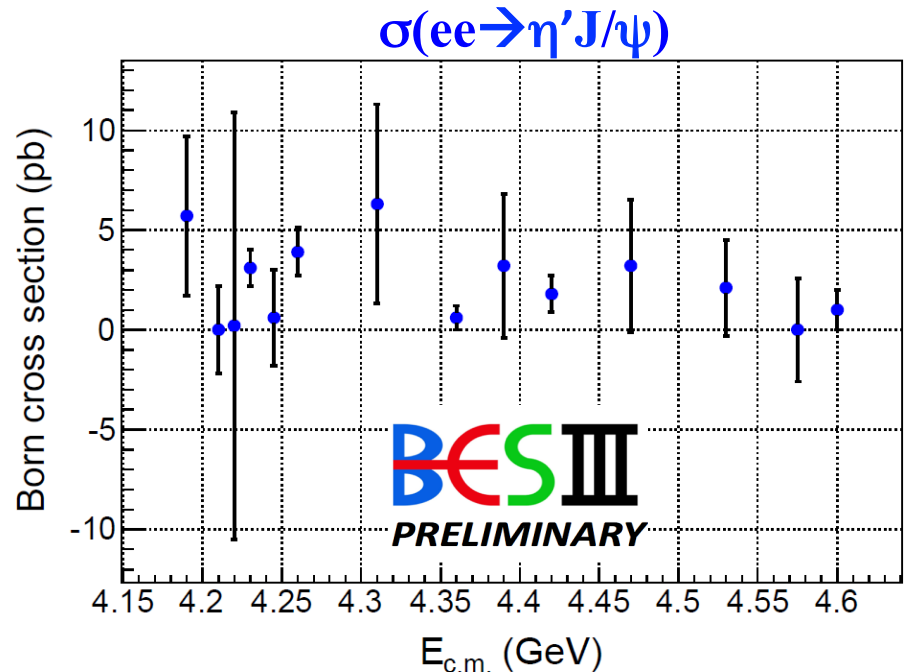- Consistent with Belle
  (PRD 87, 051101(R) (2013))
- More precise
- Line shape is different from $\sigma(ee \rightarrow \pi\pi J/\psi)$

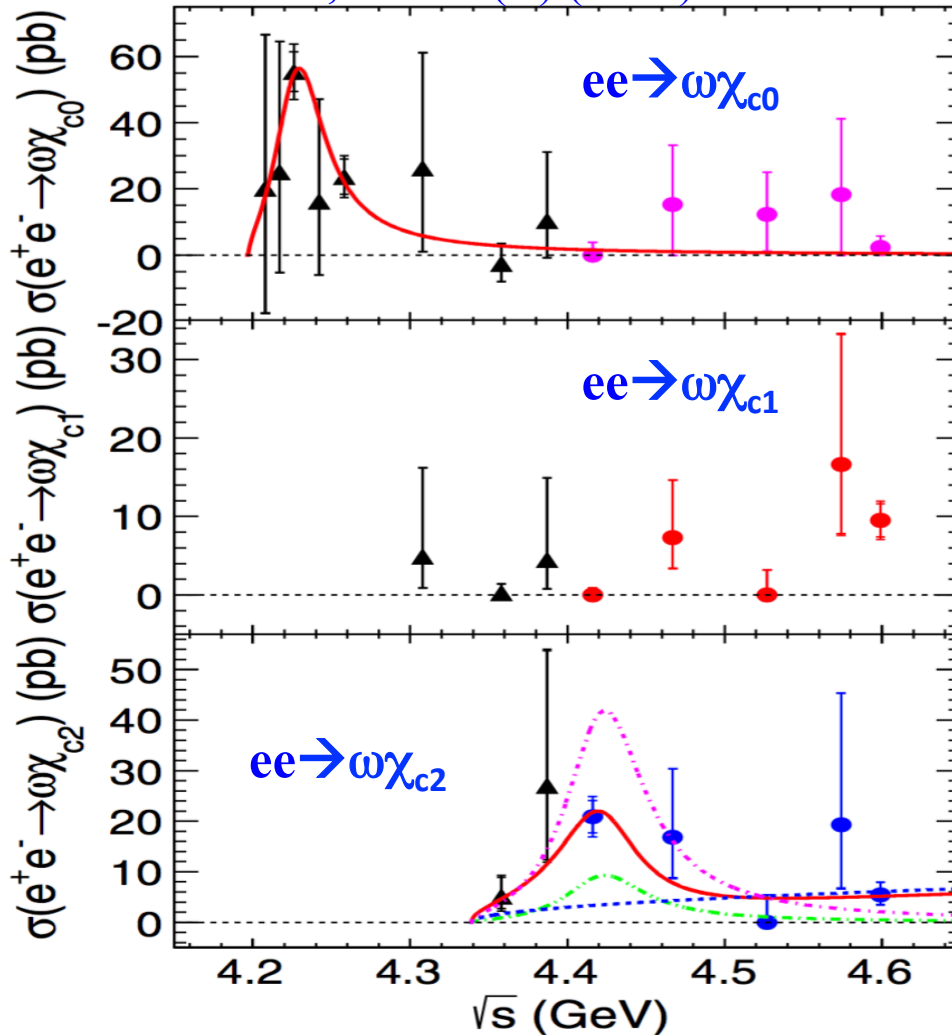### $\sigma(ee \rightarrow \eta' J/\psi)$

- $\psi(4160) \rightarrow \eta' J/\psi$?
- No evidence for $\psi(4415)$
- Much lower than $\sigma(ee \rightarrow \eta J/\psi)$,
  in contradiction to the calculation
  in the framework of NRQCD
  (PRD 89, 074006 (2014))

$\sigma(ee \rightarrow \omega\chi_{cJ})$

PRL 114, 092003 (2015)
PRD 93, 011102(R) (2016)

Peak at ~4.23 GeV
- Fit to a phase-space modified BW:
  M=4226±8±6 MeV/c2
  Γ= 39±12±2MeV
- Inconsistent with Y(4260)

- No significant ee→ωχ$_{c1}$ events below 4.5 GeV

Can by described by ψ(4415)
- Fit to |BW+Phase-Space|^2
- Mass and width fixed to ψ(4415)
- Two solutions with the same fitting quality

Summary and outlook

- BESIII has accumulated ee data between 4~4.6GeV: large luminosity around $\psi(4040)$, $\psi(4160)$, $\psi(4415)$ and Y(4260), Y(4360), 4.6GeV

- X: first observation of ee$\rightarrow\pi+\pi-$X(3823)$\rightarrow\pi+\pi-(\chi_{c1}\gamma)$ first observation of ee$\rightarrow\gamma$X(3872)$\rightarrow\gamma(\pi+\pi-$J/$\psi)$

- Z_c family discovered: $Z_c(3900)$, $Z_c(3885)$, $Z_c(4020)$, $Z_c(4025)$

- Y studied in exclusive hadronic cross section: data indicates connections between Y and X/Z_c, fine structures 4.2~4.3GeV

- More data and new results expected at BESIII: e.g. exclusive open charm cross sections, amplitude analysis of the process involving exotic states and so on.

Merci! Thanks!