The BES-III experiment

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for the BES-III collaboration

JINR Dubna

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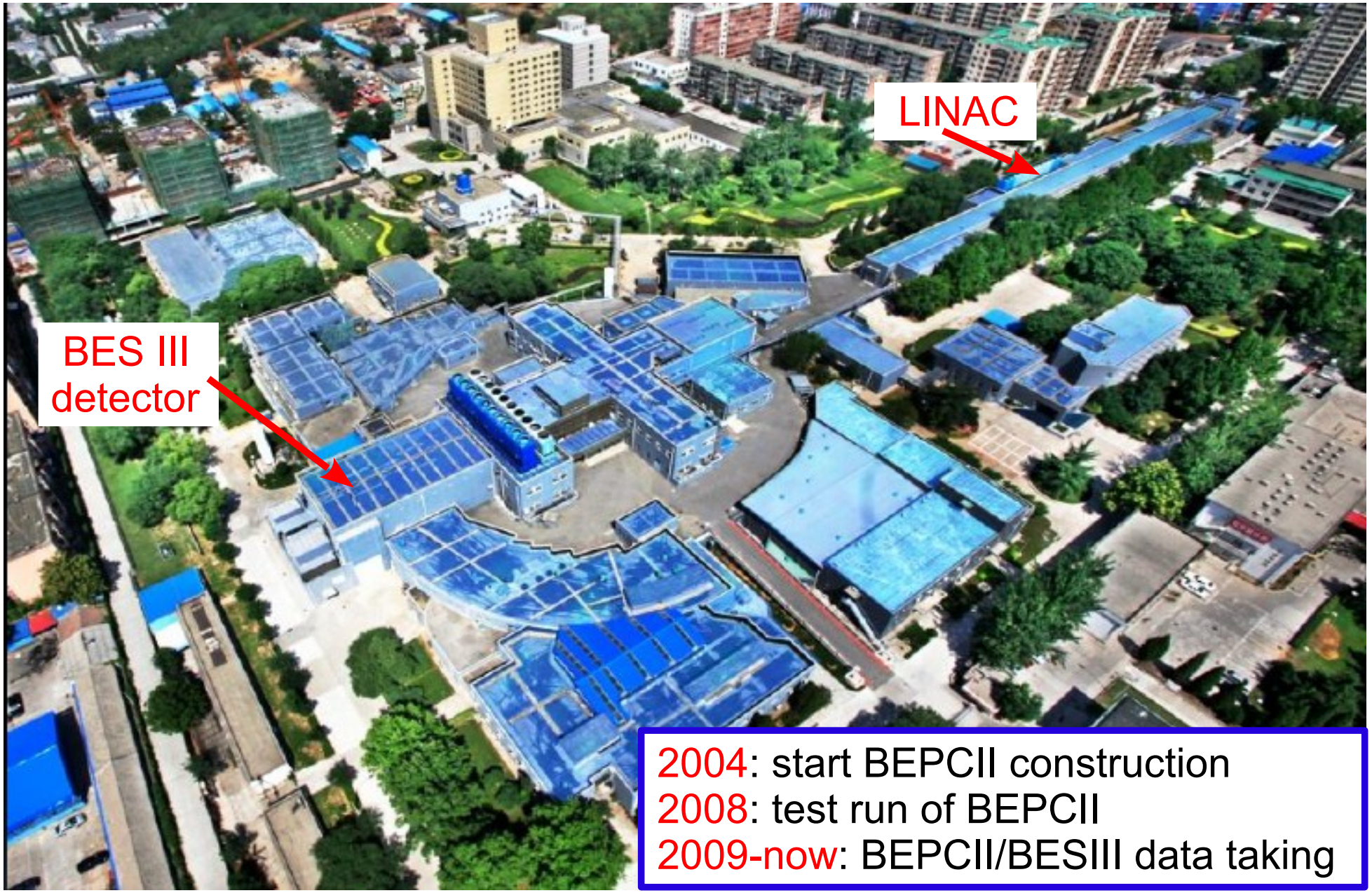
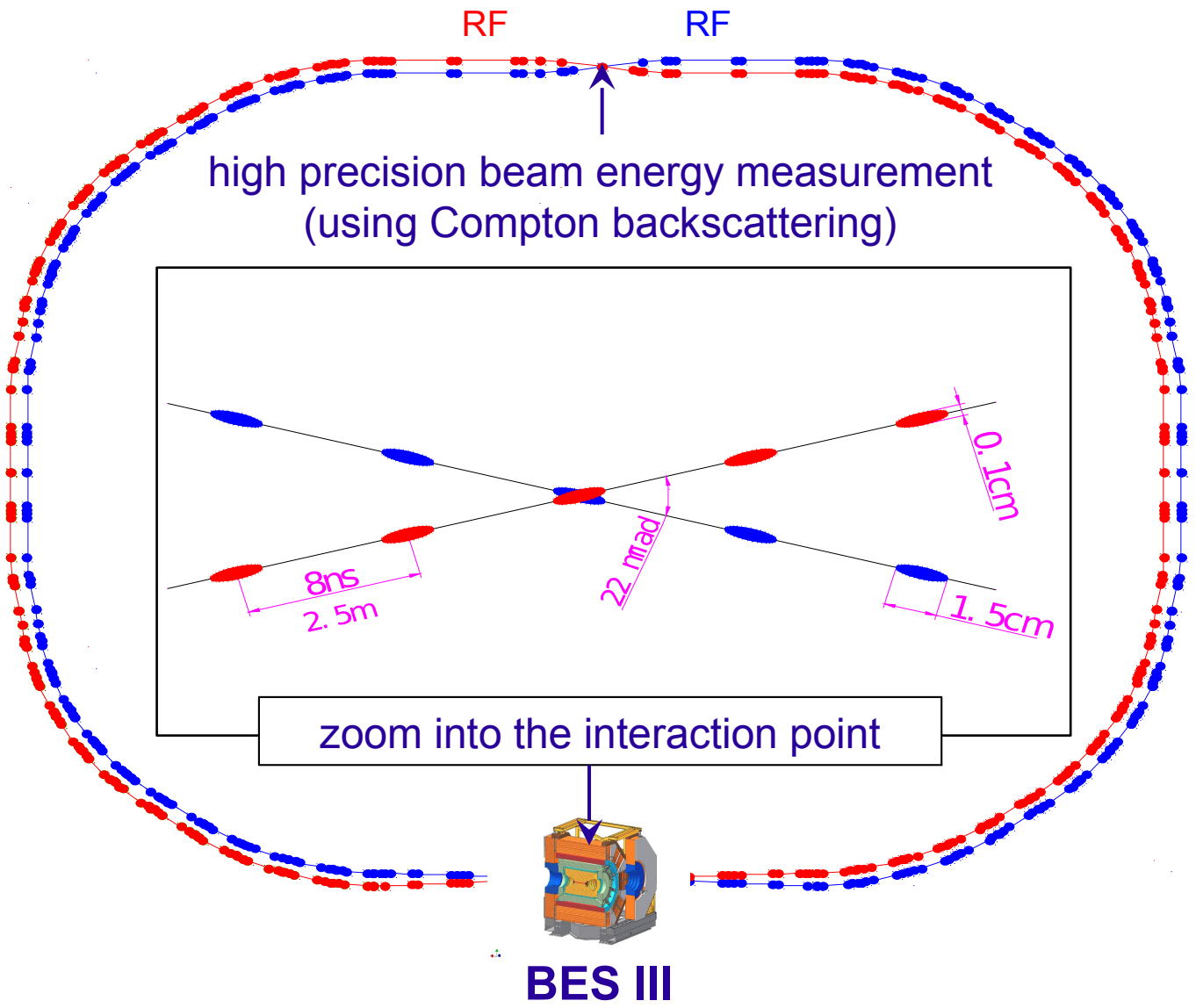
BEPCII/BESIII at IHEP (Beijing)



2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BEPCII/BESIII data taking

Beijing Electron Positron Collider (BEPCII)

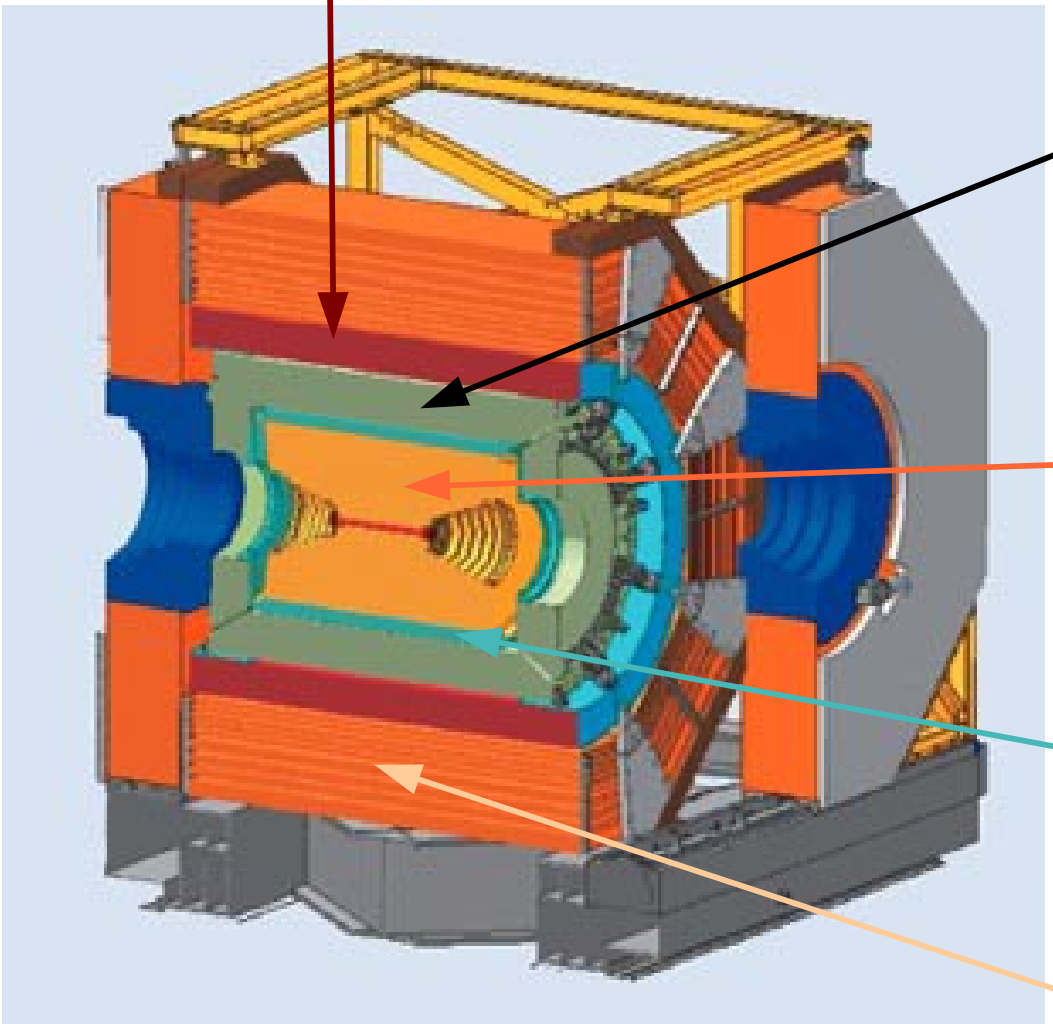


- Doble-ring
- Large crossing angle
- Beam energy:
  1.0 - 2.3 GeV
- Energy spread:
  5.16×10^{-4}
- Design luminosity:
  1×10^{33} /cm^2 /s
  @ψ(3770)
- Achieved luminosity:
  ~0.65×10^{33} /cm^2 /s
- Beam energy measurement:
  5×10^{-5}

The BES-III detector

NIM A614, 345(2010)

Super conducting magnet: 1 T



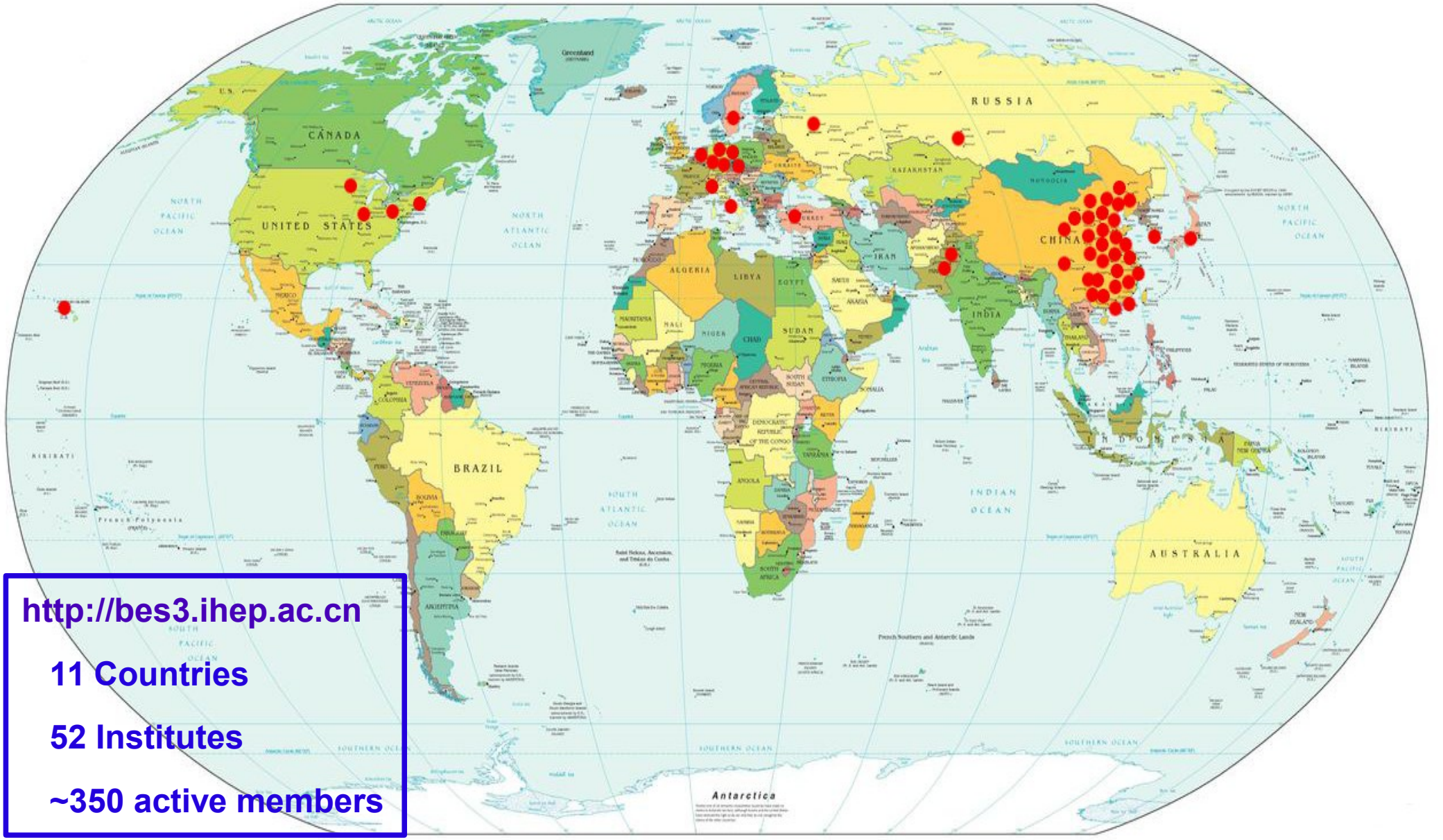
EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

MDC:
- Spatial resolution: σ_{xy}**= 120μm**
- Momentum resolution:**0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF:
Time resolution: **100ps** (barrel)
110ps (endcaps)

Muon ID:
9 layers RPC, 8 for endcaps

The BES-III Collaboration



http://bes3.ihep.ac.cn

11 Countries

52 Institutes

~350 active members

Data samples at BES-III

July 19, 2008: first e+e- collision event in BES-III

Energy & physics	N or L	Comments
J/ψ at 3.097 GeV	1.3 x10^9	2009+2012: 20 x BES-II
ψ(2S) at 3.686 GeV	0.4 x10^9	2009+2012: 20 x CLEO-c
ψ(3770) at 3.773 GeV	2.9 fb^{-1}	2010+2011: 3.5 x CLEO-c
ψ(4040) at 4.009 GeV	0.5 fb^{-1}	2011: world only data
tau mass scan around 3.554 GeV	24 pb^{-1}	2011
Y(4260) at 4.23 and 4.26 GeV	1.9 fb^{-1}	2013
Y(4360) at 4.36 GeV	0.5 fb^{-1}	2013
Y scan: 4.10 – 4.40 GeV	0.5 fb^{-1}	2013
R scan: 3.85 – 4.59 GeV	0.8 fb^{-1}	2014
4.60 GeV	0.5 fb^{-1}	2014

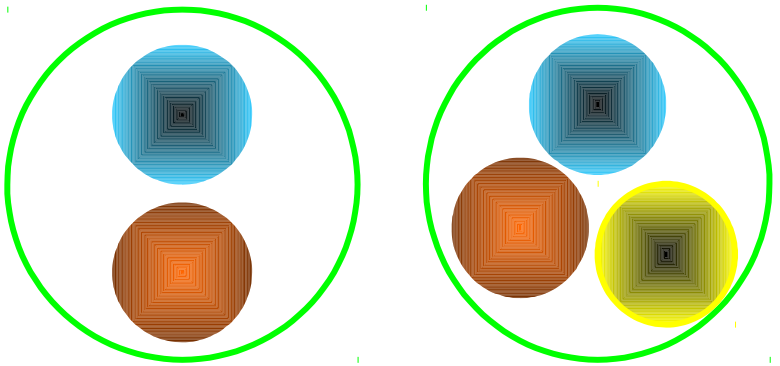
Data used for analyzes presented today

Observation of charged charmonium-like states

- Introduction
- Discovery of Zc(3900) & Zc(3885)
  - $e^+e^- \to Y(4260) \to \pi^+\pi^- J/\psi$: PRL110, 252001 (2013)
  - $e^+e^- \to \pi^+(D\bar{D}^*)^-$ + c.c. : PRL 112, 022001 (2014)
- Observation of Zc(4025) & Zc(4020)
  - $e^+e^- \to \pi^+\pi^- h_c$: PRL111, 242001 (2013)
  - $e^+e^- \to D^{*+}\bar{D}^{*0}\pi^-$ (c.c.) : PRL112, 132001 (2014)

Exotic hadrons

- Quark model: mesons – 2 quarks, baryons – 3 quarks

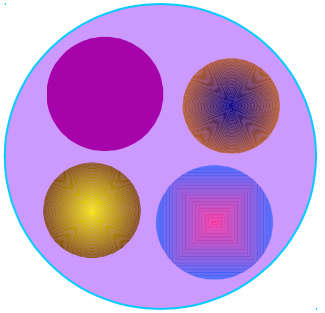


QCD imposes no restrictions on the number of quarks in hadrons:

- glueball: Nquarks = 0 (gg, ggg, …)
- hybrid: Nquarks = 2 (or more) + excited gluon
- multiquark state: Nquarks > 3
- molecule: bound state of more than 2 hadrons

Z_c – charged charmonium-like meson

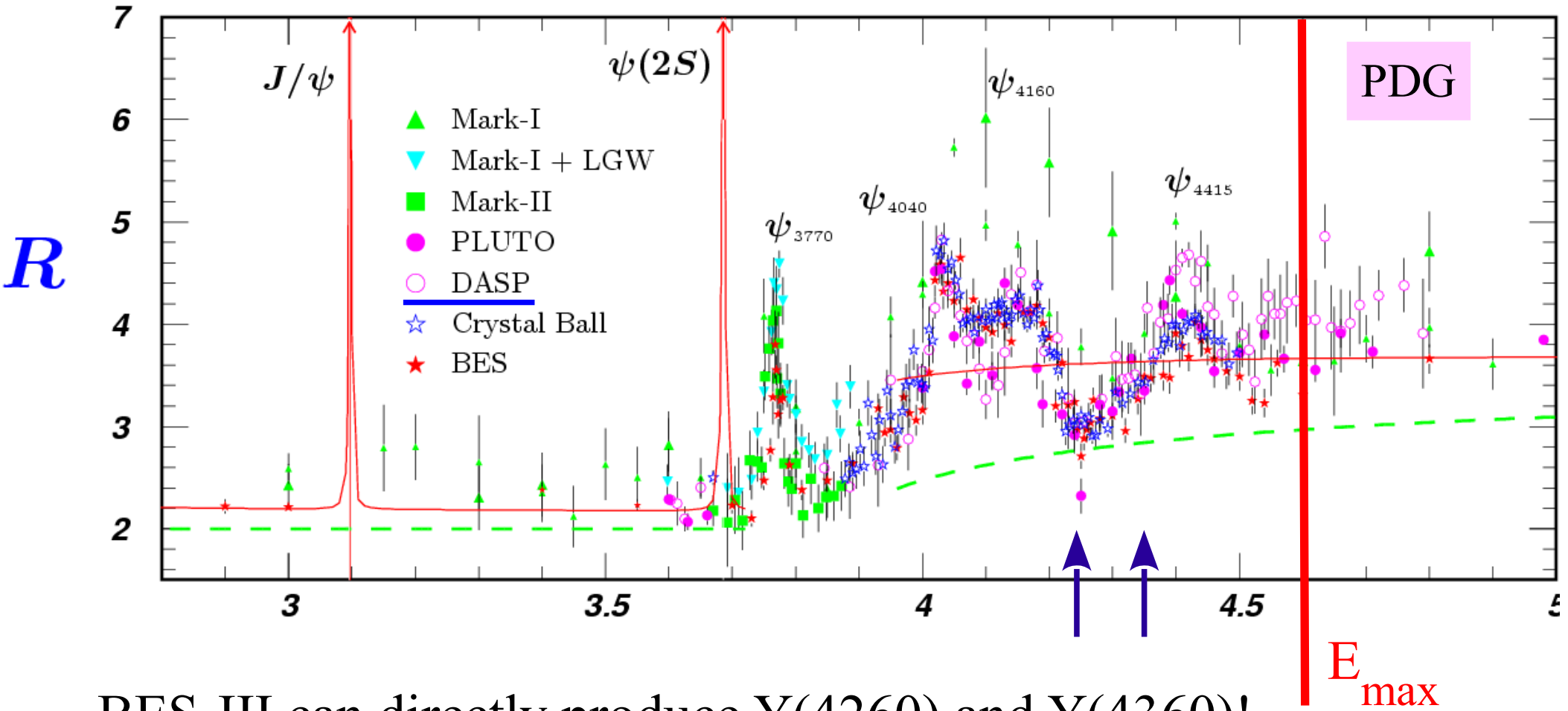
- Well defined signature of event:
  - decay into known charmonium state
  - electric charge $\Rightarrow$ Nquark ≥ 4



- Possible directions of searches:
  $\pi^{\pm} J/\psi$, $\pi^{\pm} h_c(1P)$, $\pi^{\pm} \psi(2S)$, $\pi^{\pm} \chi_{cJ}$ ...

- BES-III: $e^+e^- \rightarrow \pi^{\pm} + Z_c$; $e^+e^- \rightarrow \rho^{\pm} + Z_c$ ...

What can we do at BES-III?

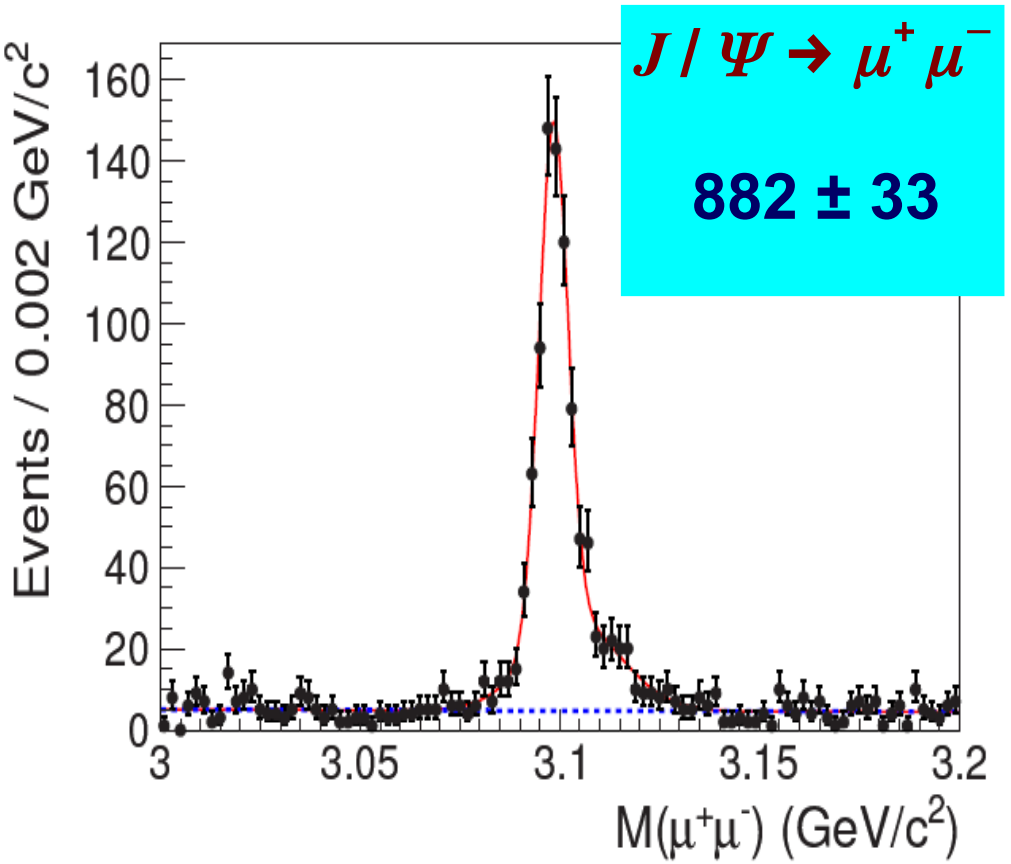


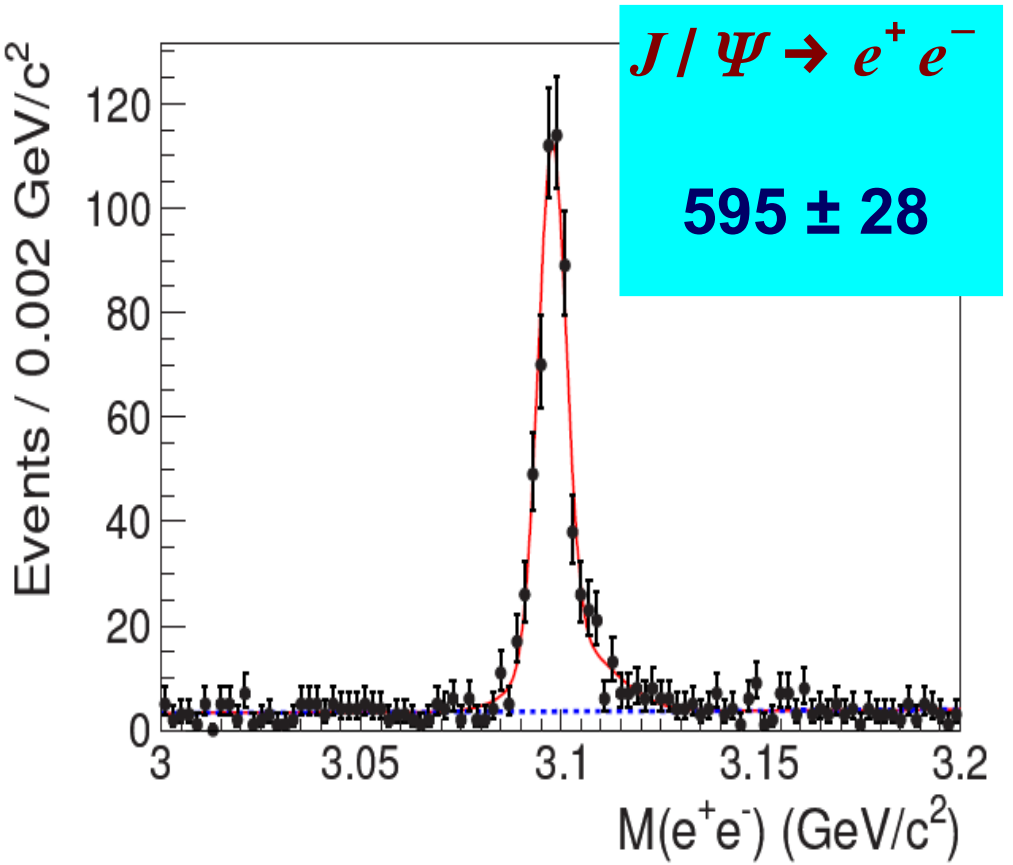
BES-III can directly produce Y(4260) and Y(4360)!

$\sigma(e^+e^- \to \pi^+\pi^- J/\Psi)$ maximal for these energies

$e^+e^- \rightarrow Y(4260) \rightarrow \pi^+\pi^- J/\psi$

BES-III: PRL110, 252001

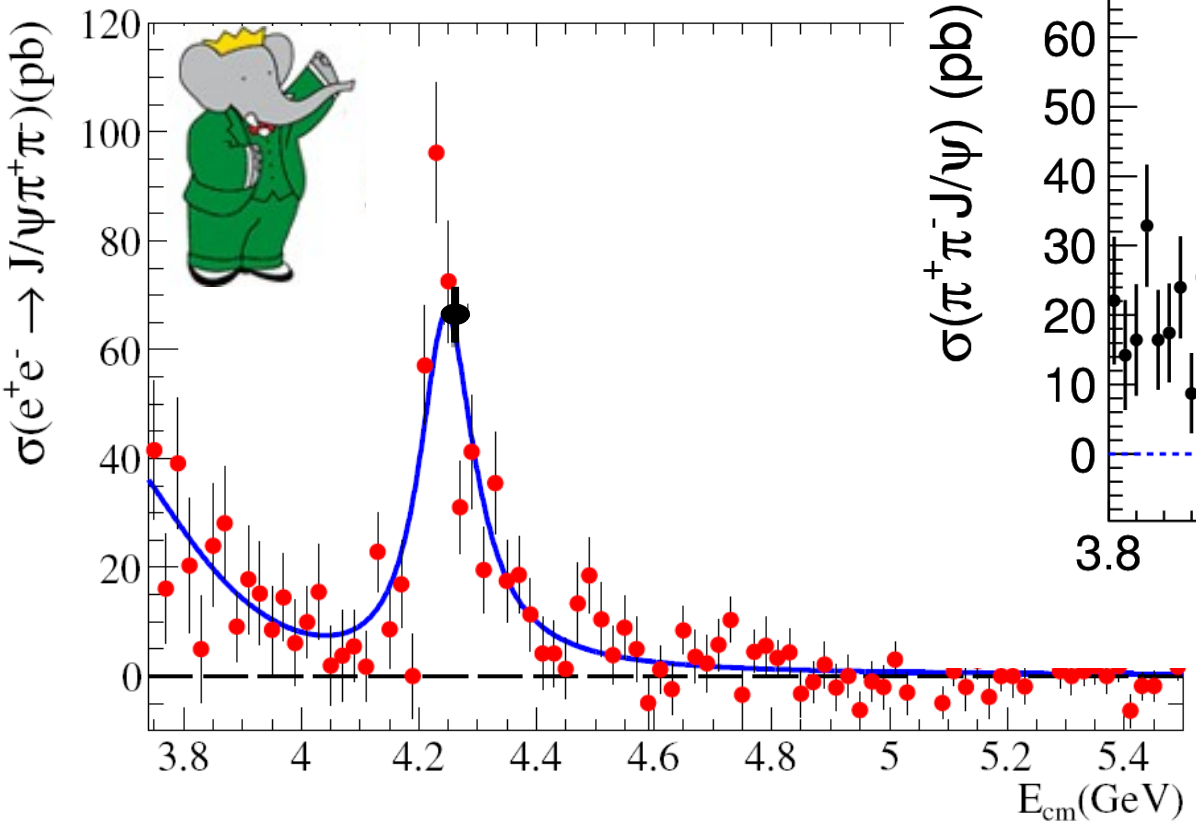




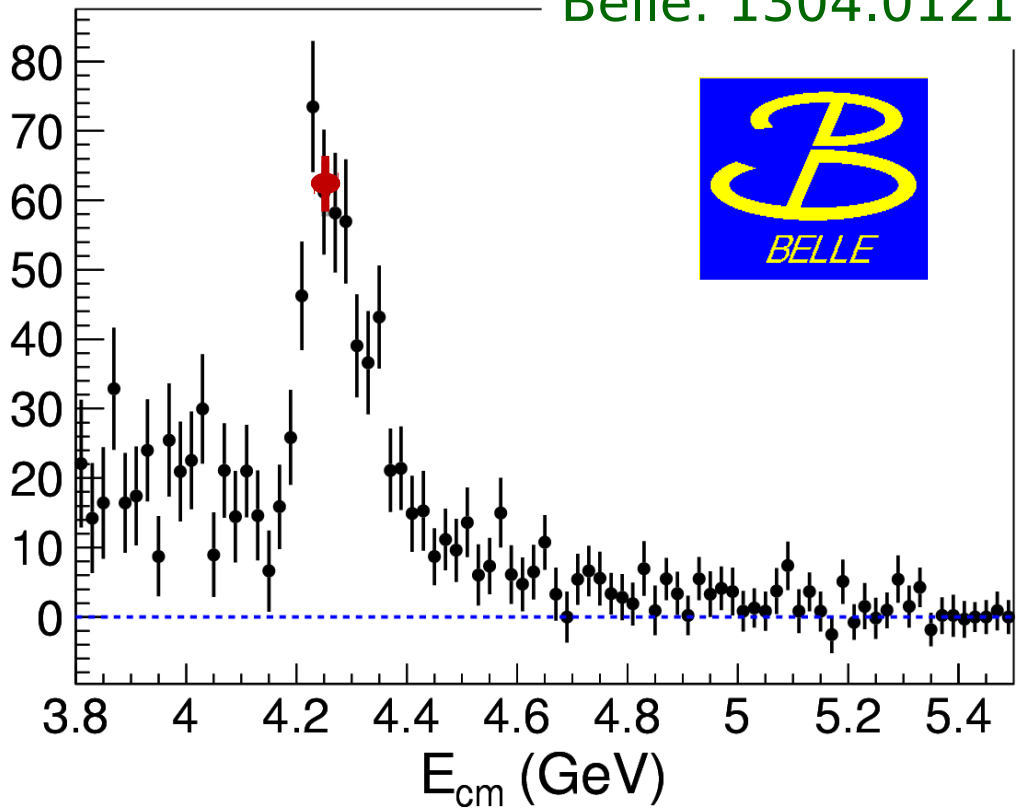
- Lum = 525 pb^{-1}
- J/ψ clearly identified in dilepton decay modes

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

BaBar: PRD86, 051102 (2012)



Belle: 1304.0121

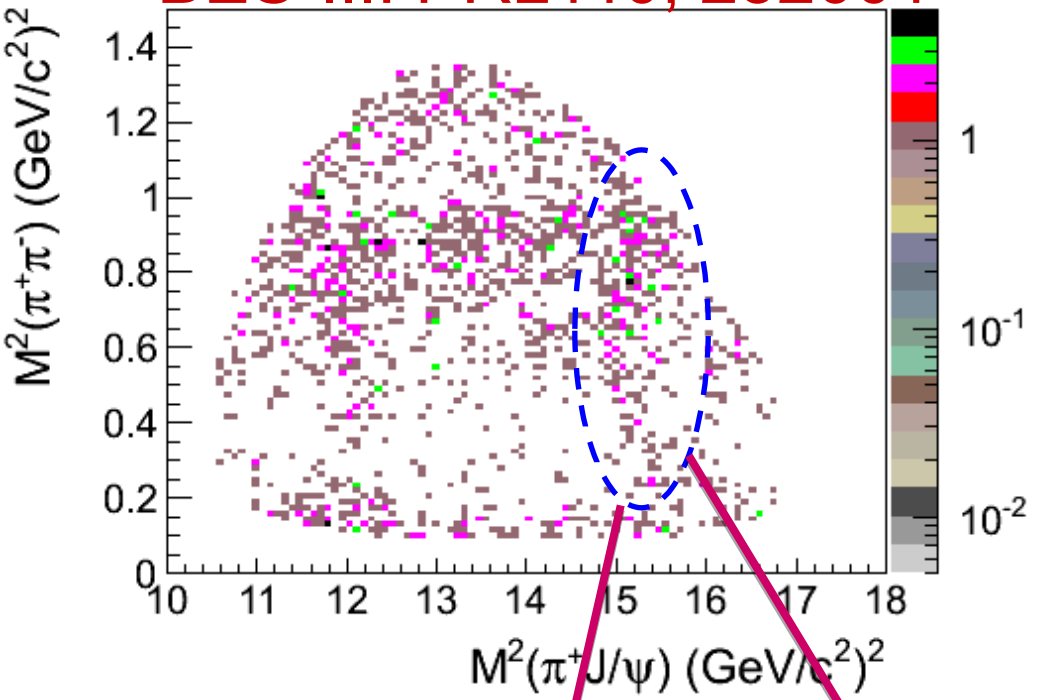


BES-III: PRL110, 252001: $\sigma(e^+e^- \to \pi^+\pi^- J/\Psi) = 62.9 \pm 1.9 \pm 3.7$ pb

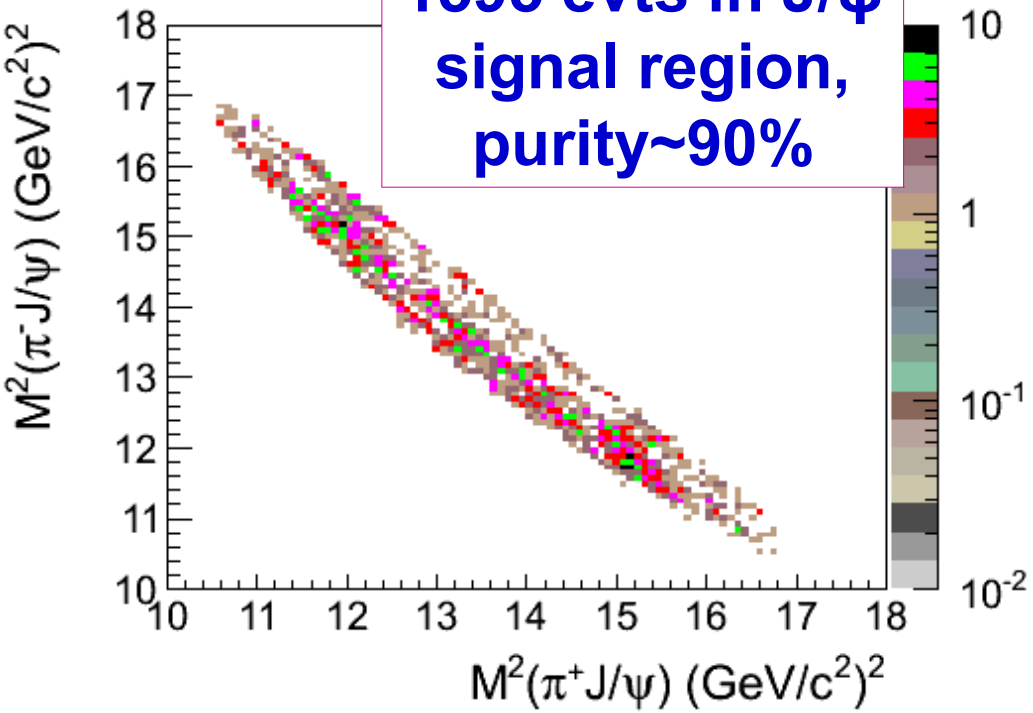
- good agreement with BaBar and Belle

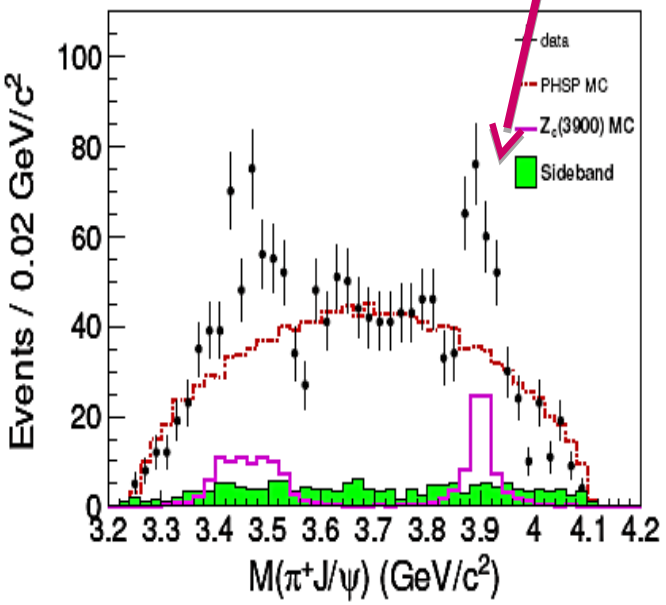
Dalitz plots

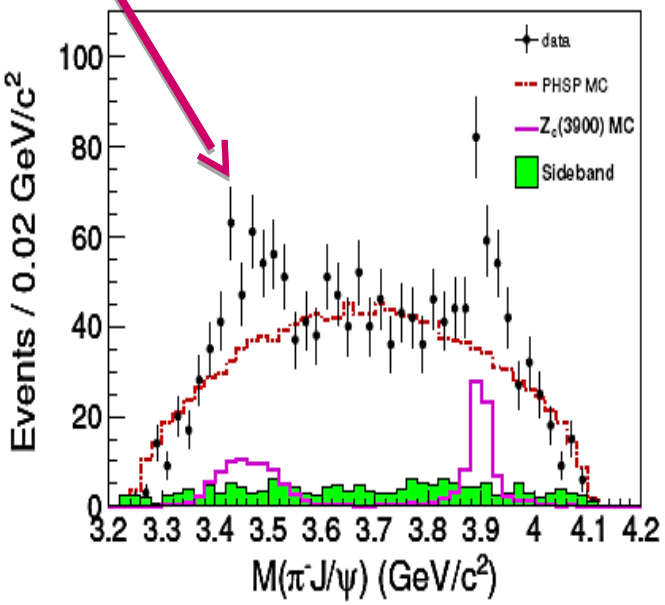
BES-III: PRL110, 252001

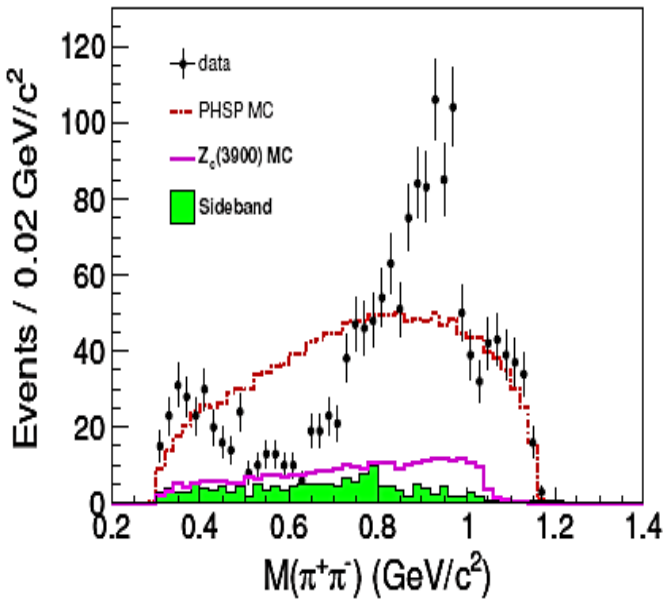


1595 evts in J/ψ signal region, purity~90%

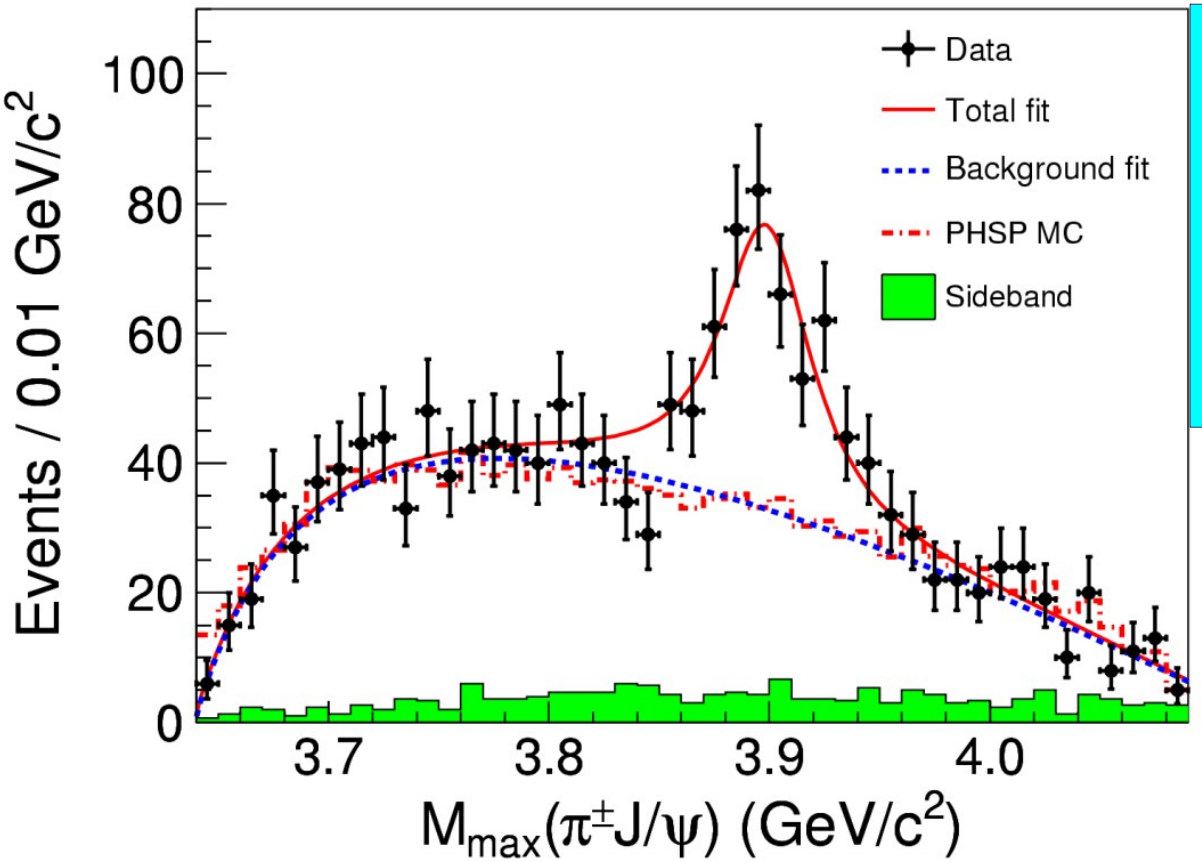








Zc(3900) in BES-III at 4.26 GeV



M = 3899.0±3.6±4.9 MeV

Γ = 46±10±20 MeV

307 ± 48 events

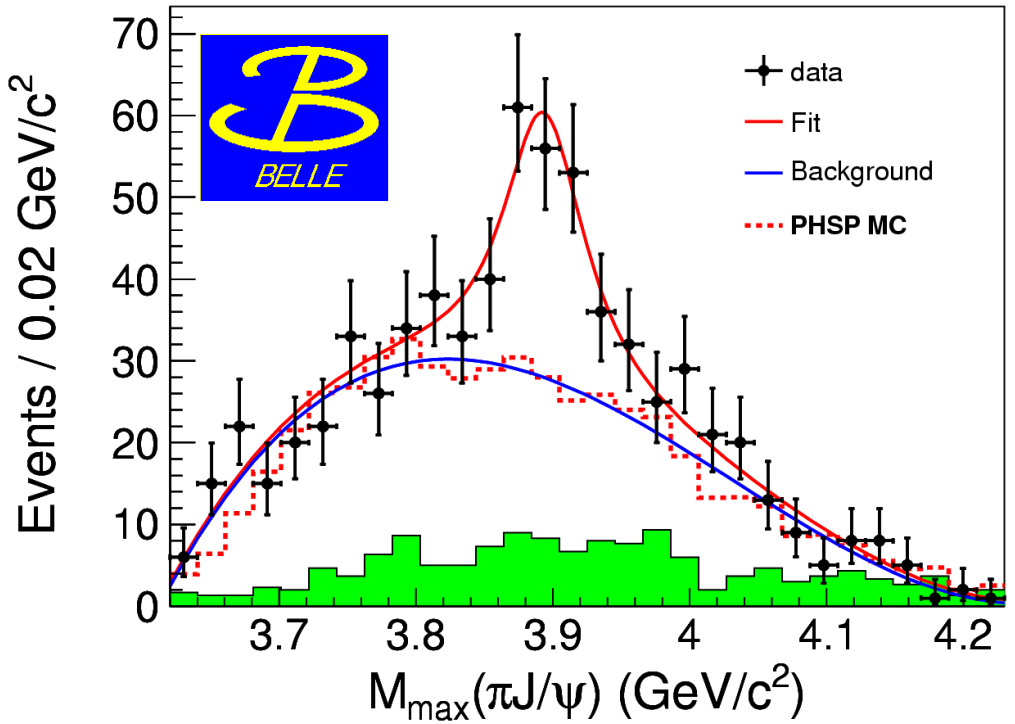
Significance > 8σ

PRL 110, 252001 (2013): >150 citations

$Z_c^{\pm}(3900)$ – the first charged charmonium-like state confirmed by other experiments!

Belle: $e^+e^- \to \gamma(ISR) + \pi^+\pi^- J/\psi$

Belle: PRL110, 252002



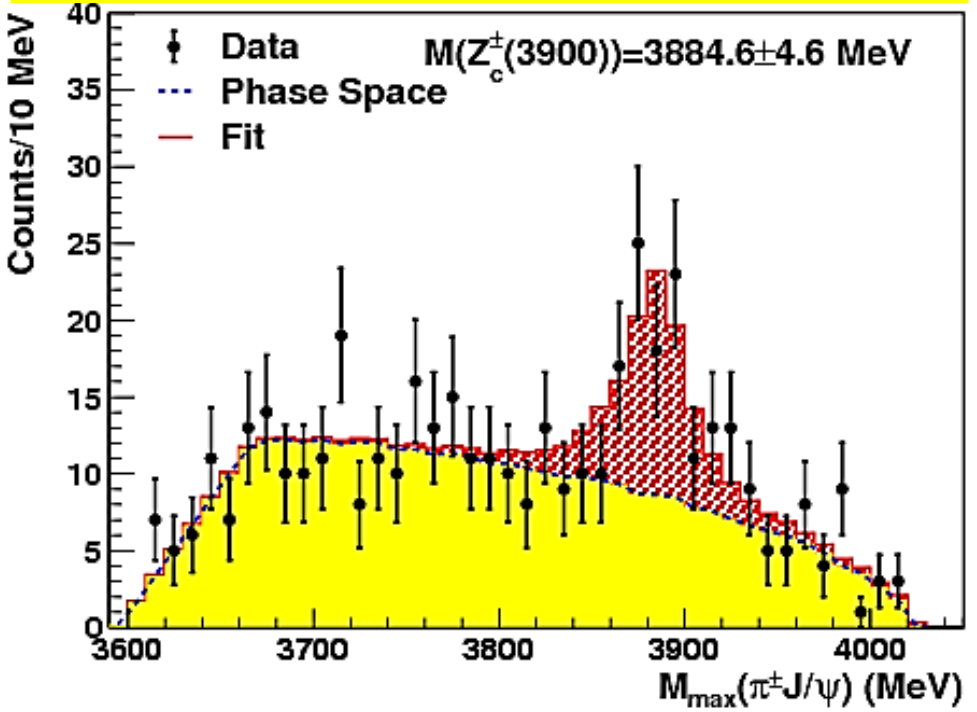
$M = 3894.5 \pm 6.6 \pm 4.5$ MeV

$\Gamma = 63 \pm 24 \pm 26$ MeV

159 ± 49 events

$> 5.2\sigma$

CLEOc: $e^+e^- \to \psi(4160) \to$ $\to \pi^+\pi^- J/\psi$ (PLB727,366)



$M = 3886 \pm 4 \pm 2$ MeV

$\Gamma = 37 \pm 4 \pm 8$ MeV

81 ± 16 events

$> 5\sigma$

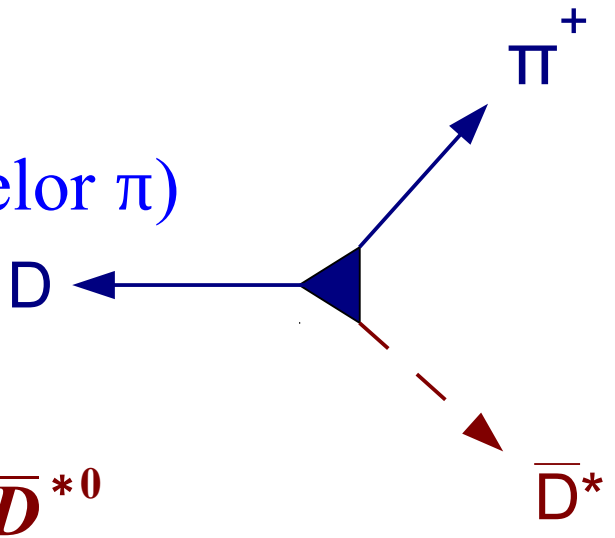
$e^+e^- \to \pi^+(D\bar{D}^*)^- + c.c.$ at $\sqrt{s} = 4.26$ GeV

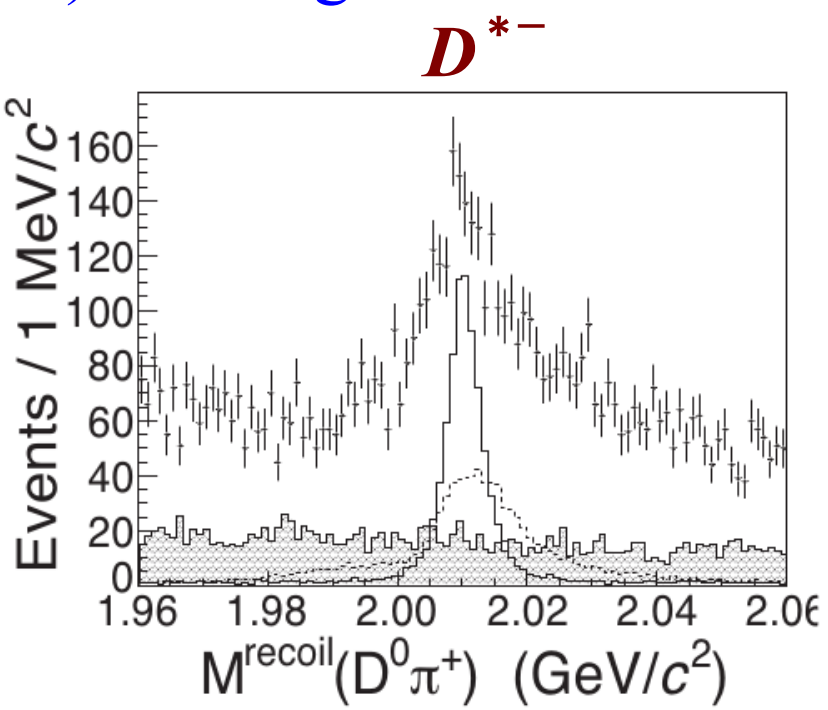
Strategy:

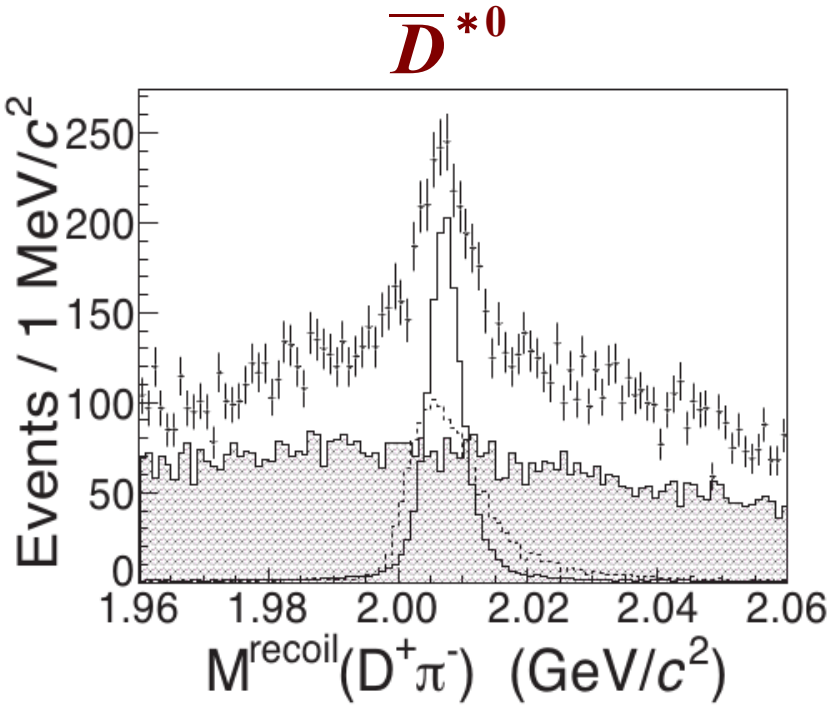
1) π^+ or π^- from primary vertex (a bachelor π)

2) $D^0 \to K^-\pi^+$ or $D^+ \to K^-\pi^+\pi^+$

3) missing mass of D*:

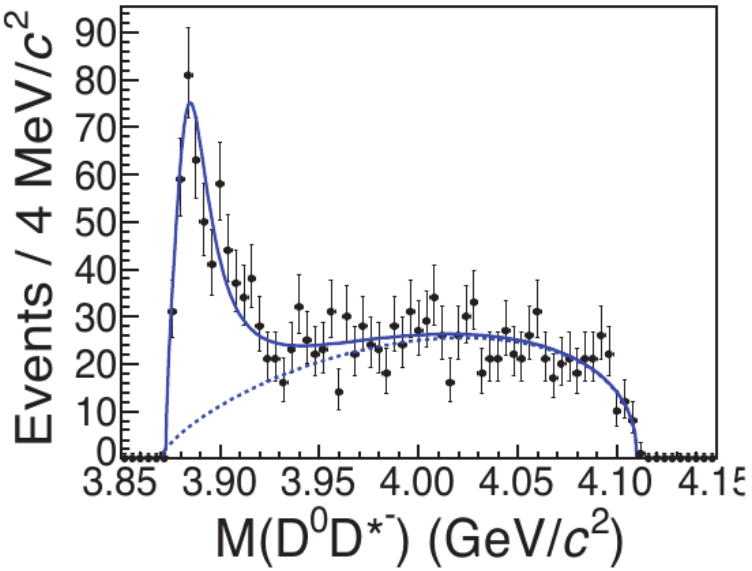


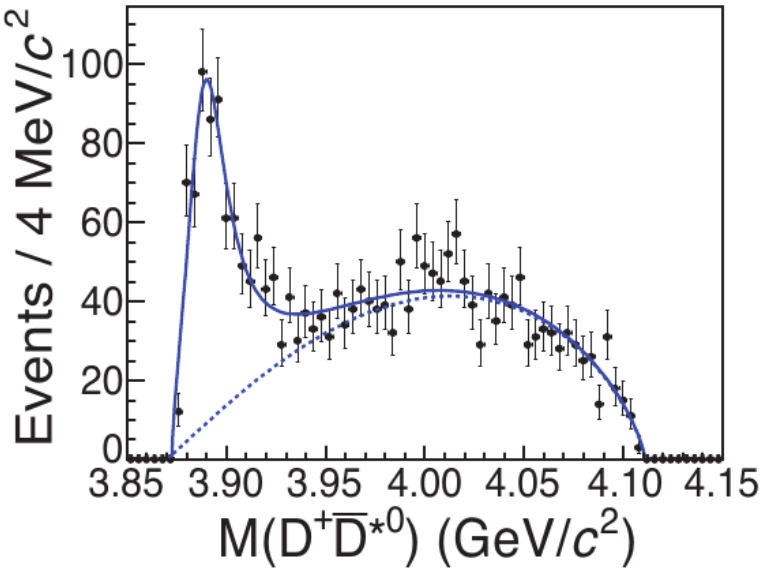




$e^+e^- \to \pi^\pm Zc(3885) \to \pi^\pm (D\bar{D}^*)^\mp$

PRL 112, 022001 (2014)





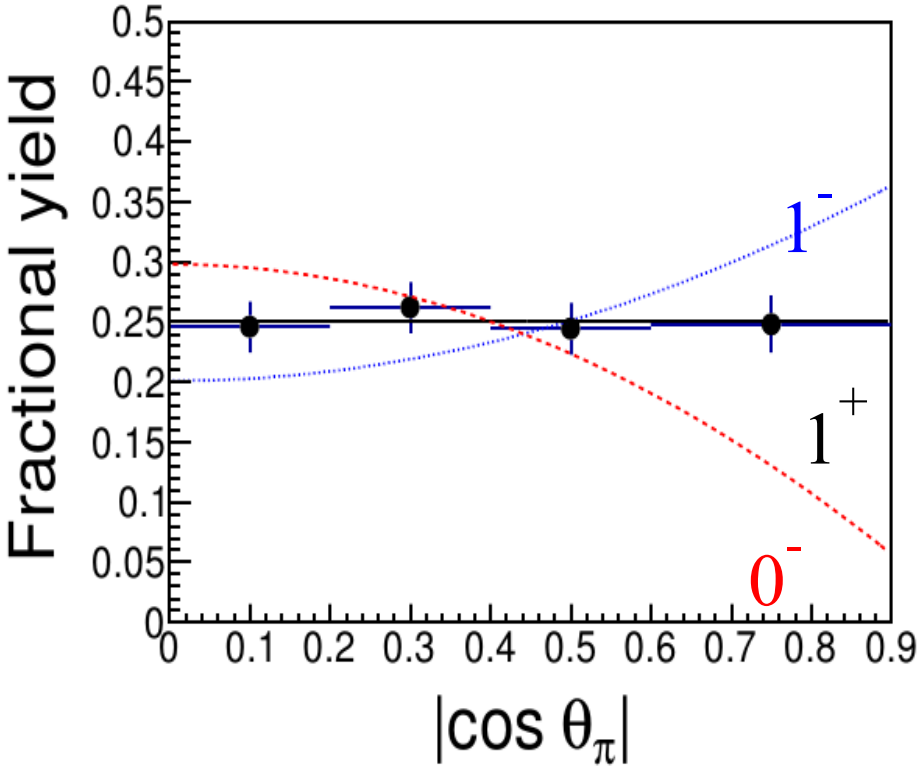
M = 3882.2±1.5 MeV
Γ = 24.6±3.3 MeV
N(Zc)=502 ± 41

M = 3885.5±1.5 MeV
Γ = 24.9±3.2 MeV
N(Zc)=710 ± 54

M = 3883.9±1.5±4.2 MeV
Γ = 24.8±3.3±11.0 MeV

Quantum numbers of Zc(3885)

PRL 112, 022001 (2014)



$\cos(\theta_\pi)$ – angle of bachelor π^+ in the CMS

$J^P=0^-$, $dN/d\cos(\theta_\pi) \sim 1-\cos^2(\theta_\pi)$

$J^P=1^-$, $dN/d\cos(\theta_\pi) \sim 1+\cos^2(\theta_\pi)$

$J^P=1^+$, $dN/d\cos(\theta_\pi) \sim$ flat

$J^P=0^+$, parity conservation

- If Zc(3885) is Zc(3900): $\dfrac{\Gamma(Z_c(3900) \to D\overline{D^*})}{\Gamma(Z_c(3900) \to \pi J/\psi)} = 6.2 \pm 1.1 \pm 2.7$

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

PRL 111, 242001 (2013)

- Data: 13 energy points in [3.90; 4.42] GeV; Lum = 827 pb^{-1}

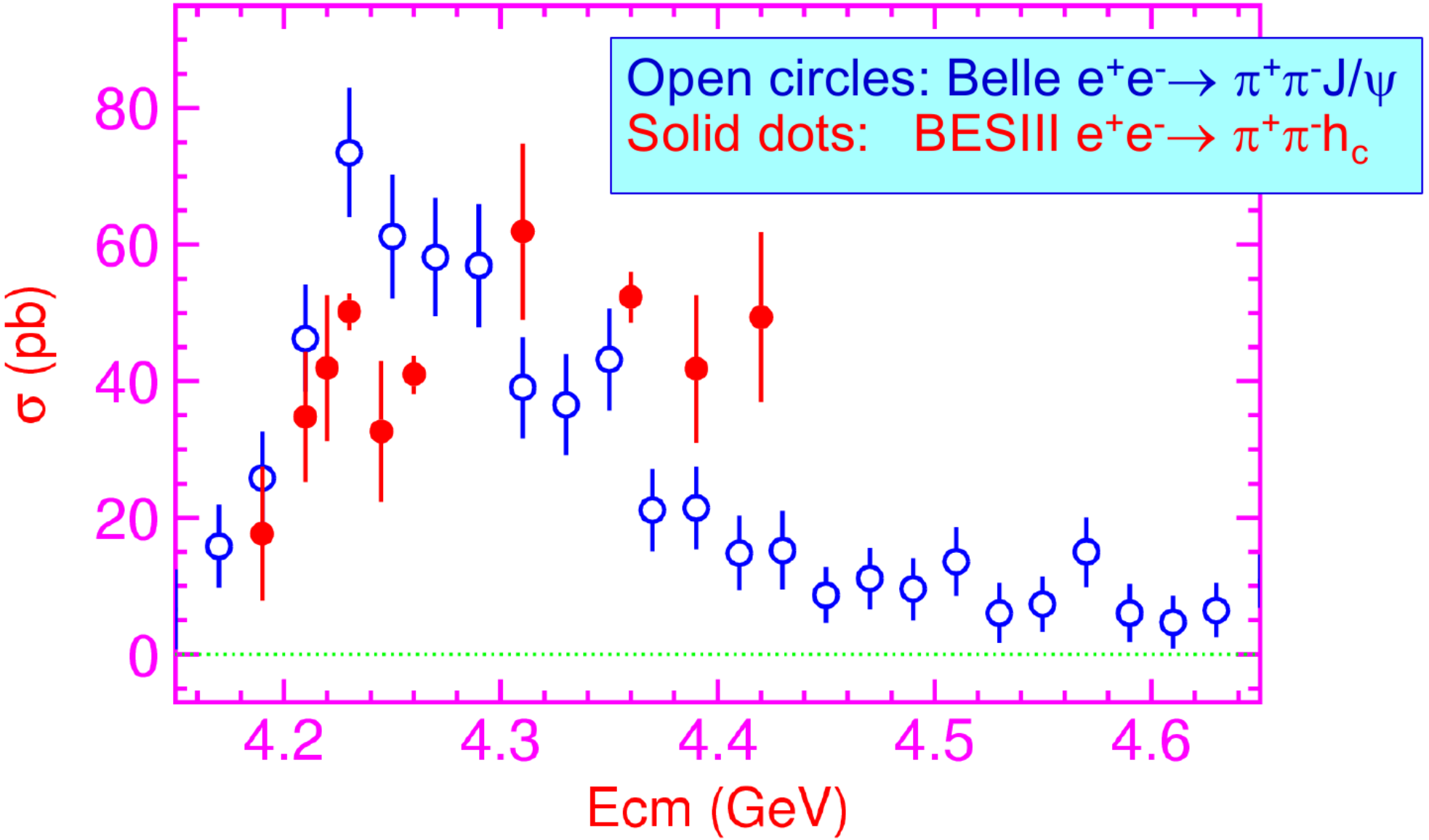
- $h_c \to \gamma \eta_c$ (~50% all decays of h_c);
  $\eta_c \to p\bar{p}$, $2(\pi^+\pi^-)$, $2(K^+K^-)$, $K^+K^-\pi^+\pi^-$ ...
  16 exclusive decay modes

Currently the most precise measurements parameters of η_c BES-III: PRL 108, 222002 (2012)

$$M(\eta_c) = 2984.3 \pm 0.6 \pm 0.6\ \text{MeV}$$
$$\Gamma(\eta_c) = 32.0 \pm 1.2 \pm 1.0\ \text{MeV}$$

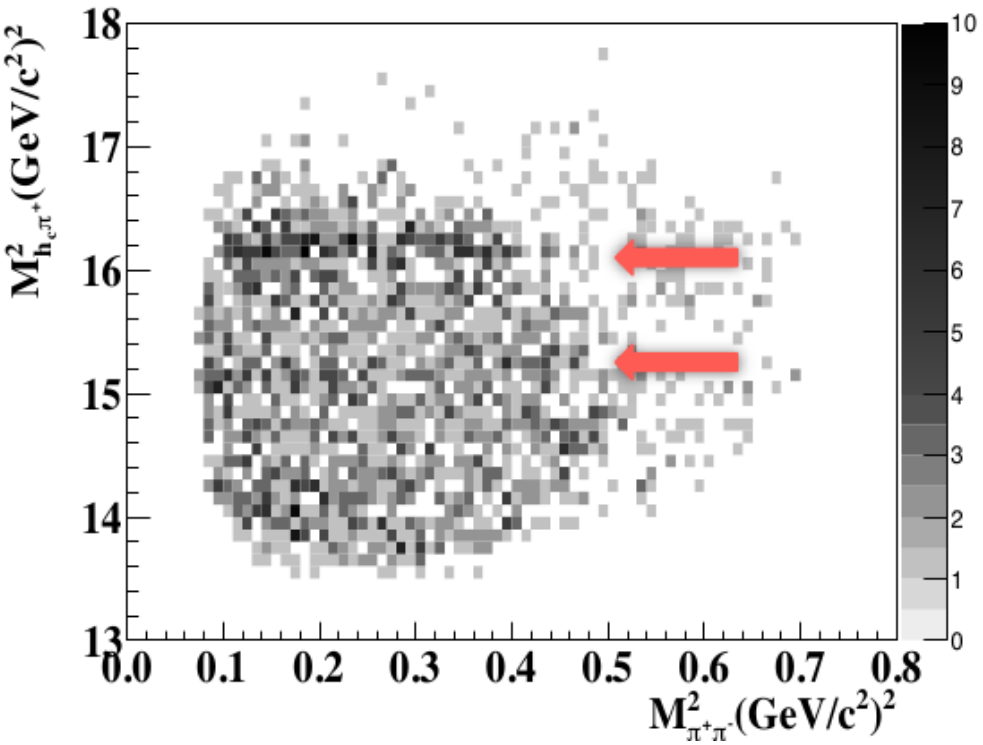
Cross-section:

$e^+e^- \to \pi^+\pi^- h_c$ vs $e^+e^- \to \pi^+\pi^- J/\psi$



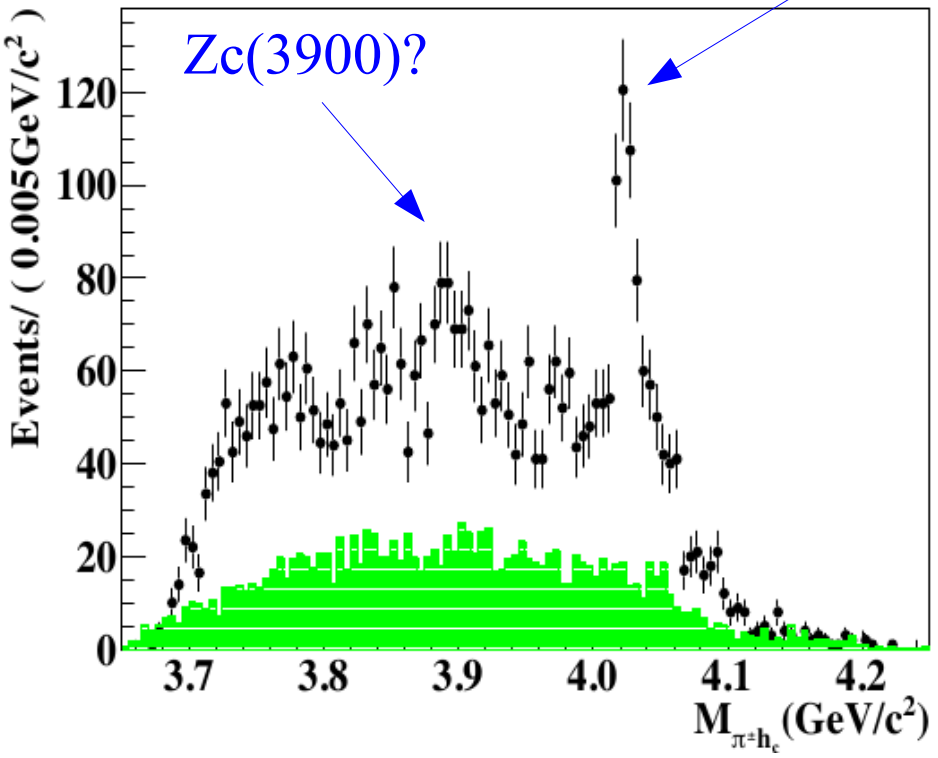
Dalitz plot

All data combined!

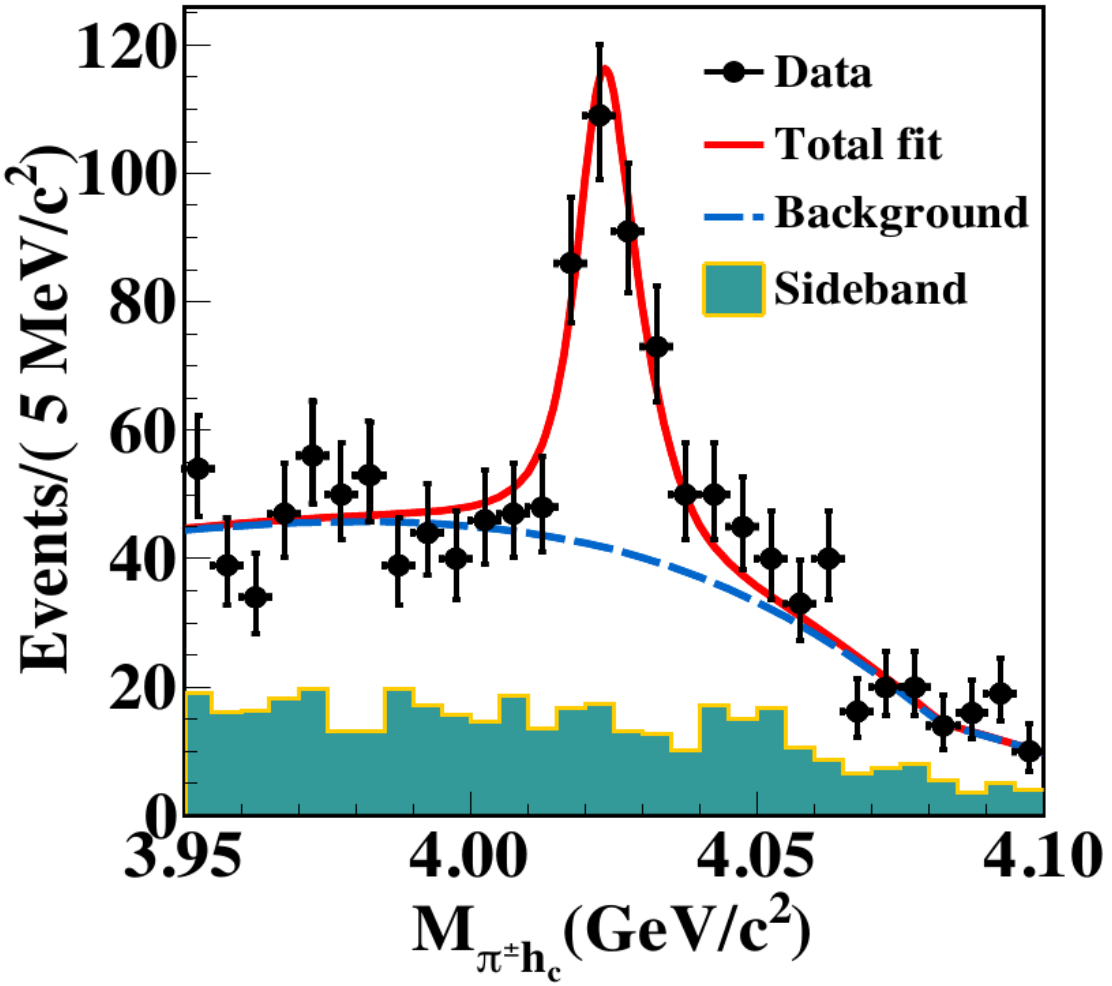


Zc(4020)!

Zc(3900)?



$e^+e^- \to \pi^\pm Zc(4020)^\mp \to \pi^+\pi^- h_c$



PRL 111, 242001 (2013)

M = 4022.9±0.8±2.7 MeV

Γ = 7.9±2.7±2.6 MeV

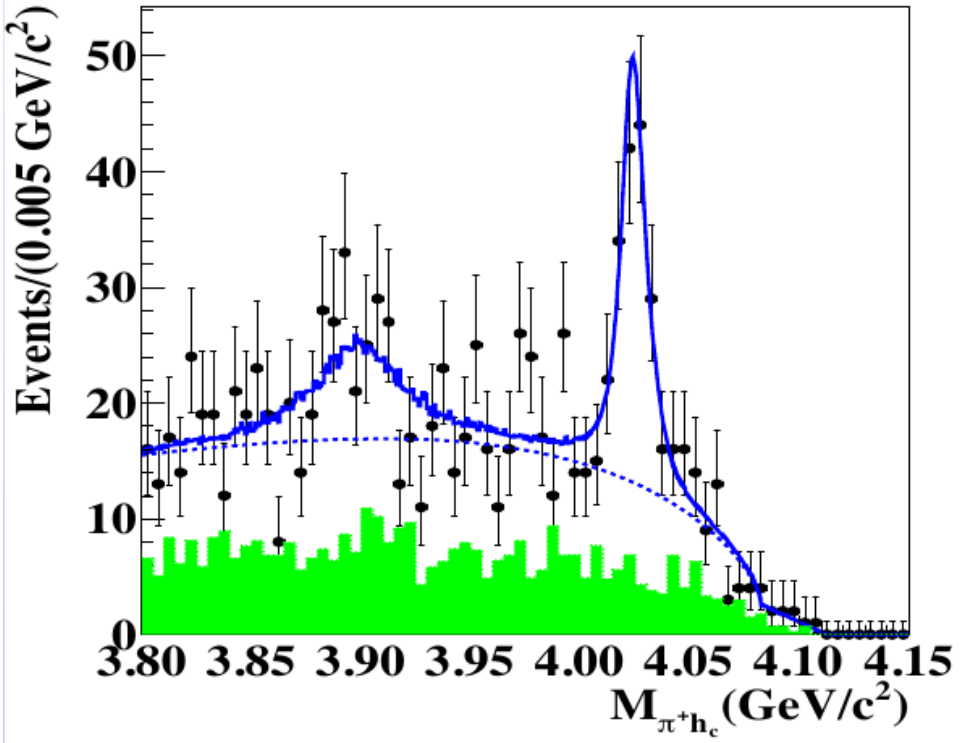
Significance > 8.9 σ

E [GeV]	N(Zc(4020)$^\pm$)
4.23	114±25
4.26	72±17
4.36	67±15

- independent fit of each period of the data set
- independent fit of $\pi^+ h_c$ and $\pi^- h_c$

What about Zc(3900) → $\pi^{\pm}h_c$?

- only 4.23 and 4.26 GeV
- parameters of Zc(3900) were fixed at the previous BES-III measurements



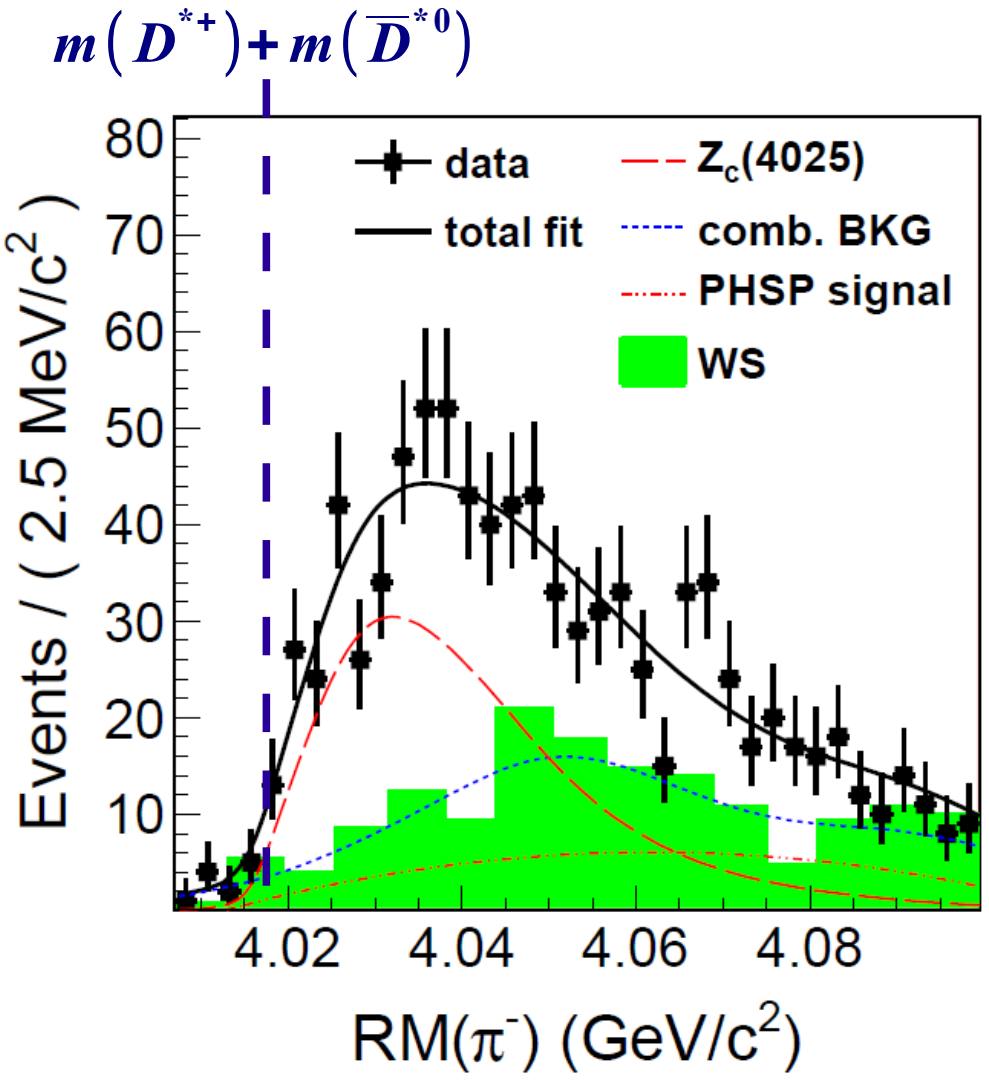
significance ~ 2.1σ

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

E [GeV]	σ [pb]	90% CL
4.23		< 13
4.26		< 11

$e^+e^- \to \pi^- Zc(4025)^+ \to \pi^- (D^* \bar{D}^*)^+$

- data: 827pb^{-1} at 4.26 GeV



PRL 112, 132001 (2014)

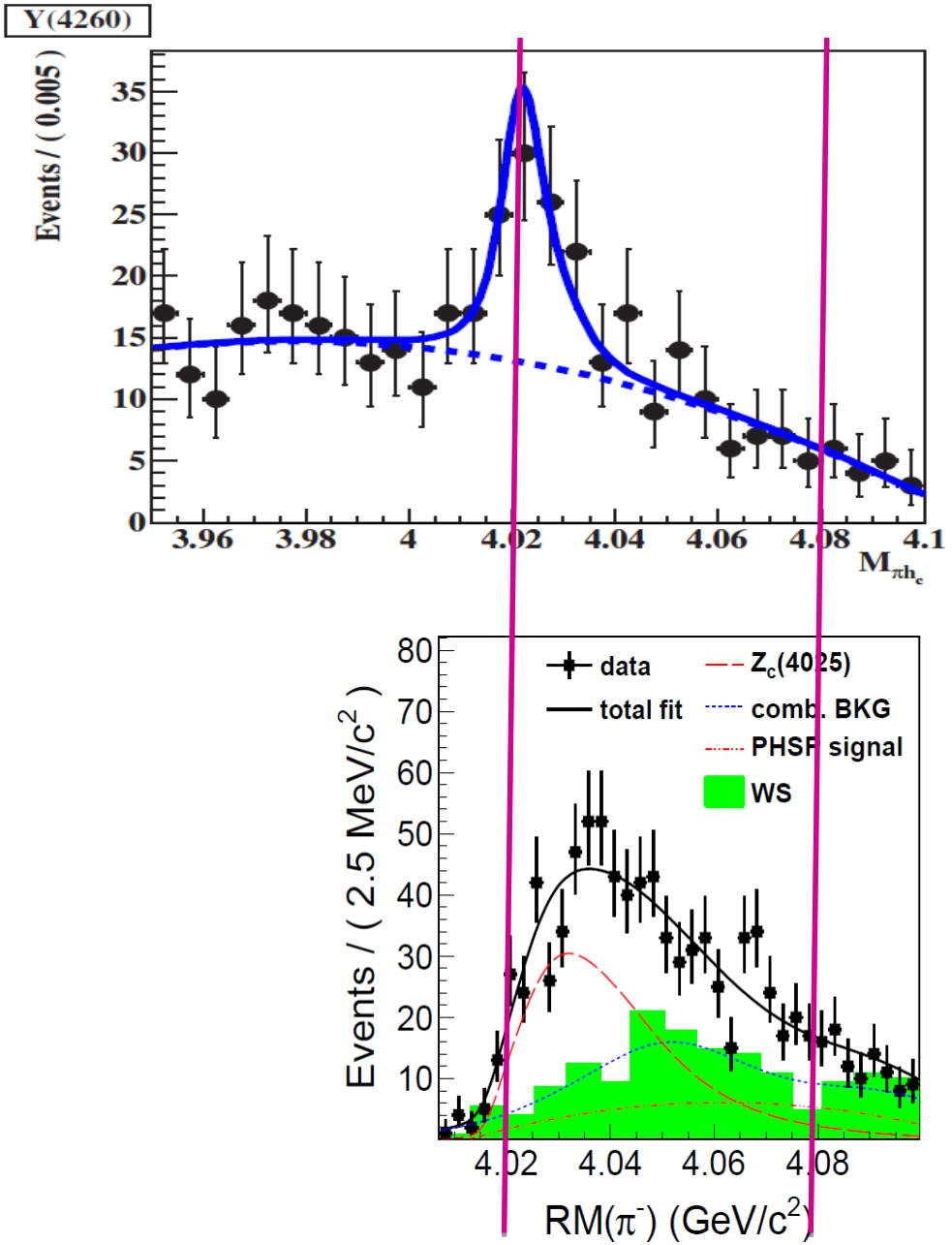
M = 4026.3±2.6±3.7 MeV

Γ = 24.8±5.6±7.7 MeV

N = 401±47

Significance > 10 σ

Zc(4025) = Zc(4020)?



- M(4020) = 4022.9±0.8±2.7 MeV
- M(4025) = 4026.3±2.6±3.7 MeV
- Γ(4020) = 7.9±2.7±2.6 MeV
- Γ(4025) = 24.8±5.6±7.7 MeV

Mass consistent with each other but width ~1.5σ difference

Close to D*D* threshold (4017 MeV)

Interference with other amplitudes may change the results

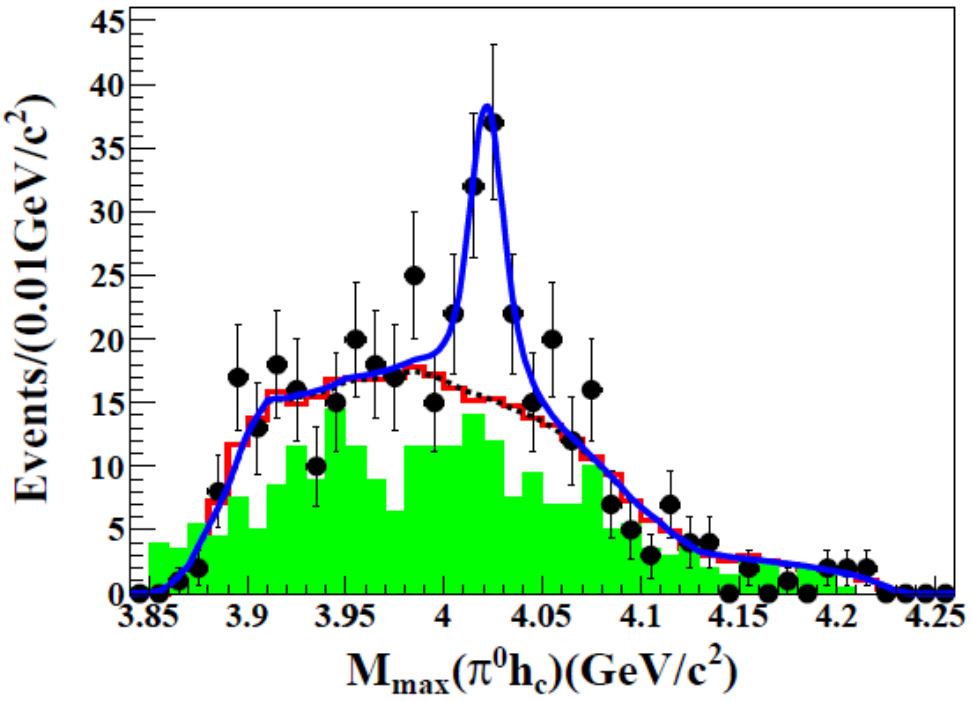
Summary of Zc mesons

Channel	Mass [MeV/c^2]	Width [MeV]
$J/\psi\,\pi^+$	$3899.0 \pm 3.6 \pm 4.9$	$46 \pm 10 \pm 20$
$(D\bar{D}^*)^+$	$3883.9 \pm 1.5 \pm 4.2$	$24.8 \pm 3.3 \pm 11.0$
$h_c\pi^+$	$4022.9 \pm 0.8 \pm 2.7$	$7.9 \pm 2.7 \pm 2.6$
$(D^*\bar{D}^*)^+$	$4026.3 \pm 2.6 \pm 3.7$	$24. \pm 5.6 \pm 7.7$

- Zc(3900) & Zc(3885) close to $D\bar{D}^*$ threshold (3875MeV)
- Zc(4020) & Zc(4025) close to $D^*\bar{D}^*$ threshold (4017MeV)

Neutral isospin partner of Zc(4020): $e^+e^- \to \pi^0 Zc(4020)^0 \to \pi^0\pi^0 h_c$

- Simultaneous fit of 4.23; 4.26 and 4.36 GeV data



PRELIMINARY BES-III

M = 4023.6±2.2±3.9 MeV

Γ – fixed to charged $Zc(4020)^{\pm}$

Significance $> 5\,\sigma$

Summary

- **BES-III successfully takes data since 2009. World largest data samples of J/ψ, ψ(2S), ψ(3770), ψ(4040) and Y(4260) are collected and are growing.**
- **Number of physical results are published, among recent:**
  - **Observation of a charged charmoniumlike structure in $e^+e^- \to \pi^+\pi^- J/\psi$ at $\sqrt{s}$ = 4.26 GeV *(PRL 110, 252001(2013))***
  - **Observation of a charged $(D\bar{D}^*)$ - mass peak in $e^+e^- \to \pi^+ (D\bar{D}^*)$ at Ecm = 4.26 GeV *(PRL 112, 022001(2014))***
  - **Observation of a charged charmoniumlike structure Zc(4020) and search for the Zc(3900) in $e^+e^- \to \pi^+\pi^- h_c$ *(PRL 111, 242001(2013))***
  - **Observation of a charged charmoniumlike structure in $e^+e^- \to \pi^-(D^*\bar{D}^*)^+$ at $\sqrt{s}$ = 4.26 GeV *(PRL 112, 132001(2014))***
- **Preliminary observation of neutral partner of Zc(4020) is presented.**
- **Expect much more results from BES-III in coming years.**