Overview on BESIII results

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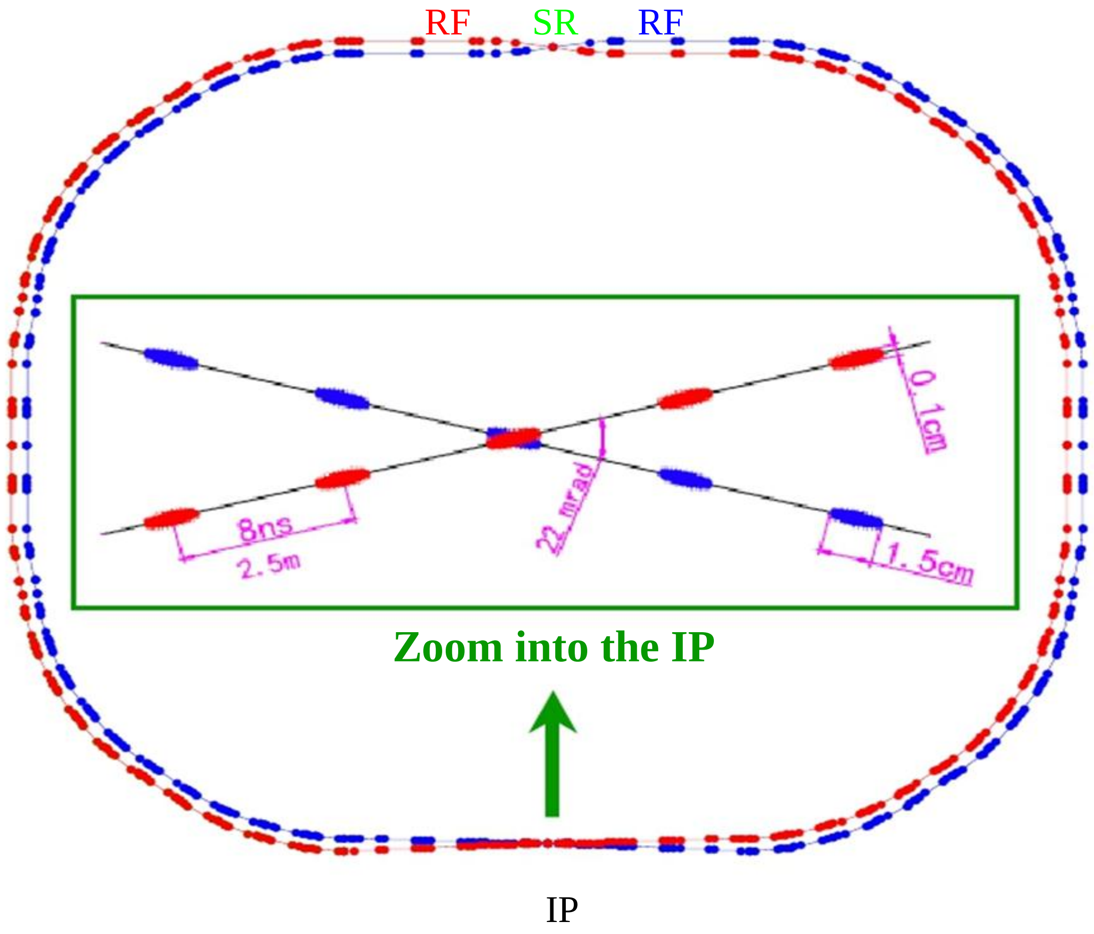
For BESIII Collaboration

Outline

- Introduction
  - BPECII
  - BESIII
  - Data set list
- Hadron Spectroscopy
- XYZ Physics
- Summary

BEPCII

Two-ring, large crossing angle, multi-bunch, high-current



- Design -

Beam energy:
1 - 2.3 GeV

Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

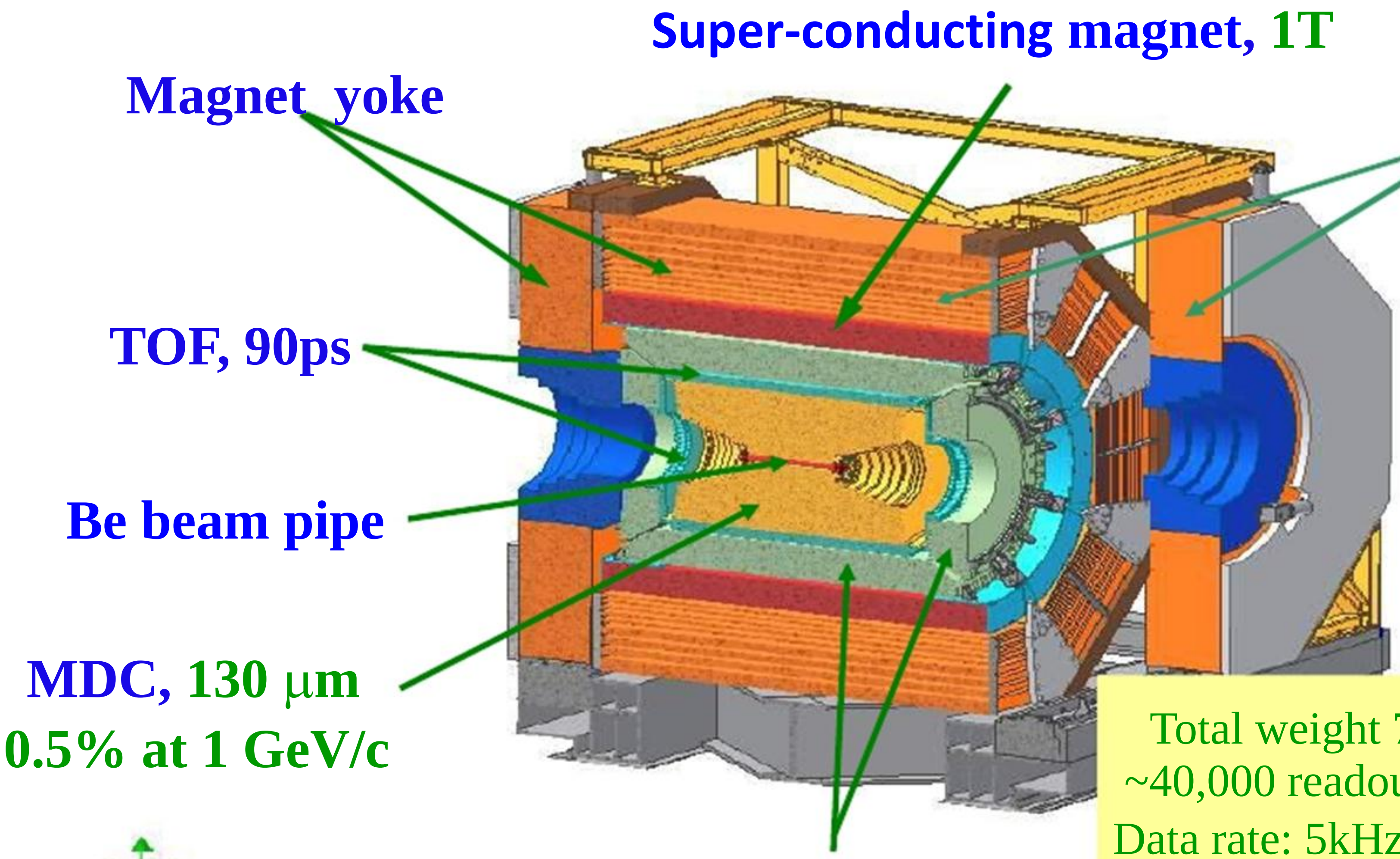
No. of bunches:
93

Bunch length:
1.5 cm

Total current:
0.91 A

SR mode:
0.25A @ 2.5 GeV

BESIII Spectrometer



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

CsI(Tl) calorimeter, 2.5% @ 1 GeV

BESIII Collaboration

http://bes3.ihep.ac.cn

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

Korea (1)

Seoul Nat. Univ.

US (6)

Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Japan (1)

Tokyo Univ.

China(30)

IHEP, CCAST, GUCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.

Europe (13)

Germany: Univ. of Bochum,
Univ. of Giessen, GSI
Univ. of Johannes Gutenberg
Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino,
Frascati Lab, Univ. of Ferrara
Netherland: KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

~350 members
11 countries

53 institutions
22 outside China

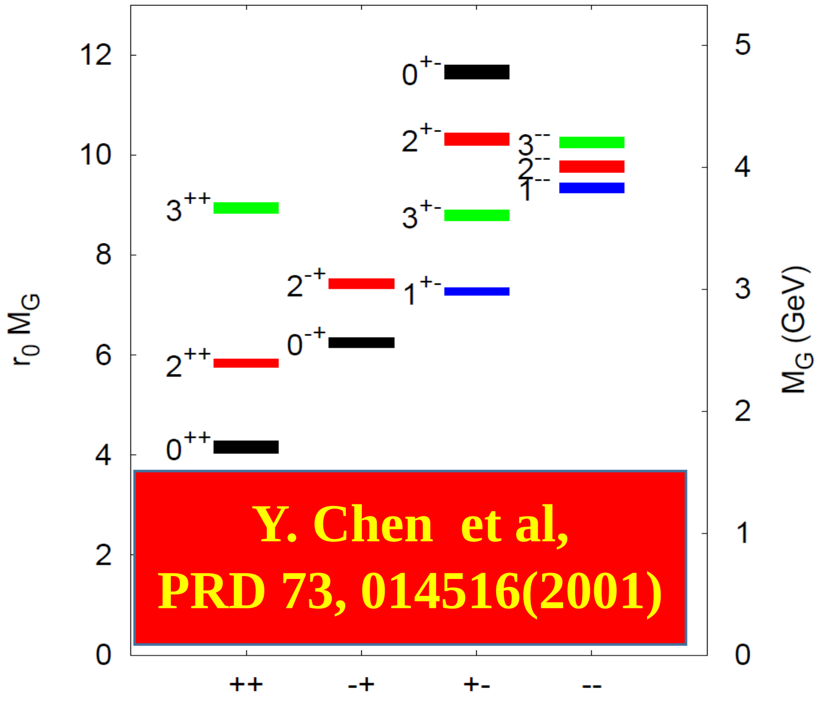
BESIII started data taking for physics since 2009

1.3×10^9	J/ψ at Ecm=3.097 GeV,	**2009** (0.225×10^9) + **2012**
0.4×10^9	ψ' at Ecm=3.686 GeV,	**2009** (0.106×10^9) + **2012**
2.9 fb^{-1}	$\psi(3770)$ at 3.773 GeV,	**2010** + **2011**
0.5 fb^{-1}	$\psi(4040)$ at 4.009 GeV,	**2011**
0.024 fb^{-1}	τ **mass scan** at around 3.554 GeV,	**2011**
1.9 fb^{-1}	**Y(4260)** at 4.23 and 4.26 GeV,	**2013**
0.5 fb^{-1}	**Y(4360)** at 4.36 GeV,	**2013**
0.5 fb^{-1}	**Y(4260) and Y(4360) scan,**	**2013**
0.8 fb^{-1}	**R scan,** 104 energy points between 3.85 and 4.59 GeV, **2014**	
0.5 fb^{-1}	**at 4.60** GeV,	**2014**

Hadron Spectroscopy

Scalar Glueball

- **Eur. Phys. J. C 21, 531–543 (2001)**
  - ✓ **f$_0$(1370):** Large $n\bar{n}$, small $s\bar{s}$ and **significant Glue** content
  - ✓ f$_0$(1500): $s\bar{s}$ and $n\bar{n}$ out of phase
  - ✓ f$_0$(1710): Large $s\bar{s}$ content
- **Physics Reports 389 (2004) 61**
  - ✓ f$_0$(1370) Largely $n\bar{n}$
  - ✓ **f$_0$(1500)** mainly **Glue**
  - ✓ f$_0$(1710) mainly $s\bar{s}$
- **PRL 110, 021601 (2013)**
  - ✓ **f$_0$(1710)** dominant **Glueball** components
- ...



J^{PC}	$r_0 M_G$	M_G (MeV)
0^{++}	4.16(11)(4)	1710(50)(80)
2^{++}	5.83(5)(6)	2390(30)(120)
0^{-+}	6.25(6)(6)	2560(35)(120)
1^{+-}	7.27(4)(7)	2980(30)(140)
2^{-+}	7.42(7)(7)	3040(40)(150)
3^{+-}	8.79(3)(9)	3600(40)(170)
3^{++}	8.94(6)(9)	3670(50)(180)
1^{--}	9.34(4)(9)	3830(40)(190)
2^{--}	9.77(4)(10)	4010(45)(200)
3^{--}	10.25(4))(10)	4200(45)(200)
2^{+-}	10.32(7)(10)	4230(50)(200)
0^{+-}	11.66(7)(12)	4780(60)(230)

$J/\psi \to \gamma\eta\eta$

first studied by

Crystal Ball (1982):

f0(1710)

- **Crystal Barrel (1995):**

  f0(1500) [pp→π0ηη]

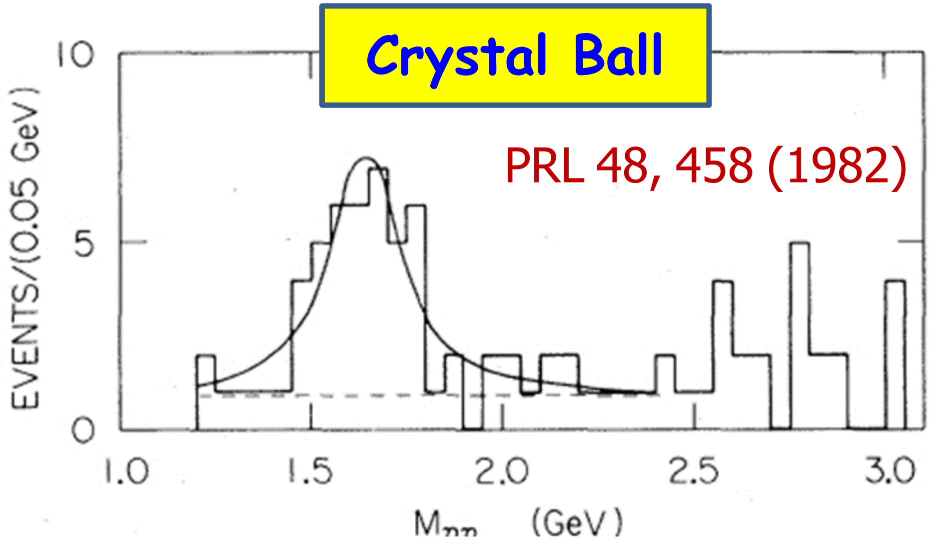
- **E835 (2006):**

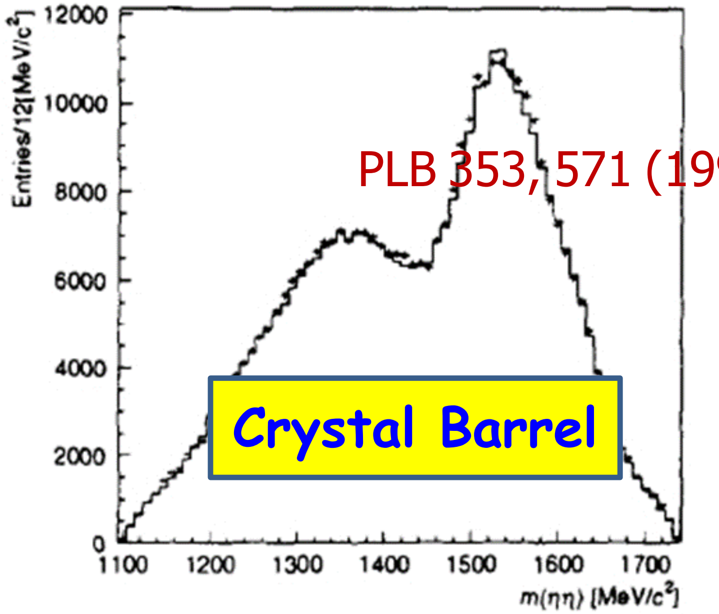
  f0(1500) [pp→π0ηη]

  f0(1710) [pp→π0ηη]

- **WA102, GAMS:**

  f0(1500) [ηη mode]

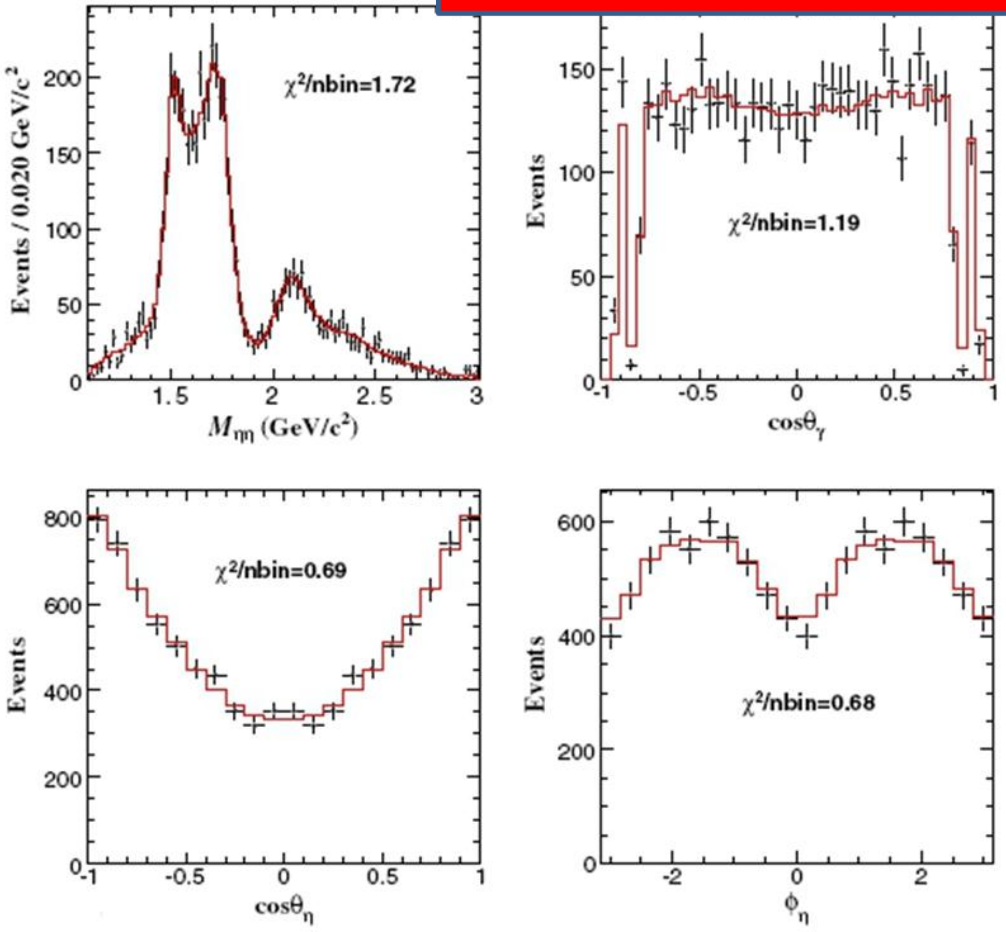




BESIII: PWA of $J/\psi \to \gamma\eta\eta$, $\eta \to \gamma\gamma$

PRD 87,092009

- **best solution:**
  - f0(1500),f0(1710), f0(2100); f2′(1525), f2(1810), f2(2340); 0++ phase space, ϕη
- **no significant evidence of:**
  - scalar: f0(1370), f0(1790), f0(2020), f0(2200), f0(2330)
  - tensor: f2(2010), f2(2150), **fJ(2220)**
  - source of sys. unc.
- **ϕη background:**
  - interference of ϕ tail accounted for source of systematic uncertainties



BESIII: PWA of $J/\psi \to \gamma\eta\eta$, $\eta \to \gamma\gamma$

Resonance	Mass(MeV/c^2)	Width(MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	$8.2\ \sigma$
$f_0(1710)$	$1759 \pm 6^{+14}_{-25}$	$172 \pm 10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	$25.0\ \sigma$
$f_0(2100)$	$2081 \pm 13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$	$13.9\ \sigma$
$f_2'(1525)$	$1513 \pm 5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	$11.0\ \sigma$
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	$6.4\ \sigma$
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	$7.6\ \sigma$

no significant evidence of:

- scalar: $f_0(1370)$, $f_0(1790)$, $f_0(2020)$, $f_0(2200)$, $f_0(2330)$
- tensor: $f_2(2010)$, $f_2(2150)$, $f_J(2220)$

Decay rate of pure glueball from LQCD

- Pure scalar-glueball rate in J/ψ radiative decays

  $BR(J/\psi \to \gamma G(0^{++})) = 3.8(9) \times 10^{-3}$

  Long-Cheng Gui et al. PRL 110 (2013) 021601

  $BR(J/\psi \to \gamma f_0(1710) \to \gamma K\bar{K}) = (8.5^{+1.2}_{-0.9}) \times 10^{-4}$

  $BR(J/\psi \to \gamma f_0(1710) \to \gamma \pi\pi) = (4.0 \pm 1.0) \times 10^{-4}$

  $BR(J/\psi \to \gamma f_0(1710) \to \gamma \omega\omega) = (3.1 \pm 1.0) \times 10^{-4}$

  $BR(J/\psi \to \gamma f_0(1710) \to \gamma \eta\eta) = (2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$

  Exp.

- Pure Tensor-glueball rate in J/ψ radiative decays

  $BR(J/\psi \to \gamma G(2^{++})) = 1.1(2) \times 10^{-2}$

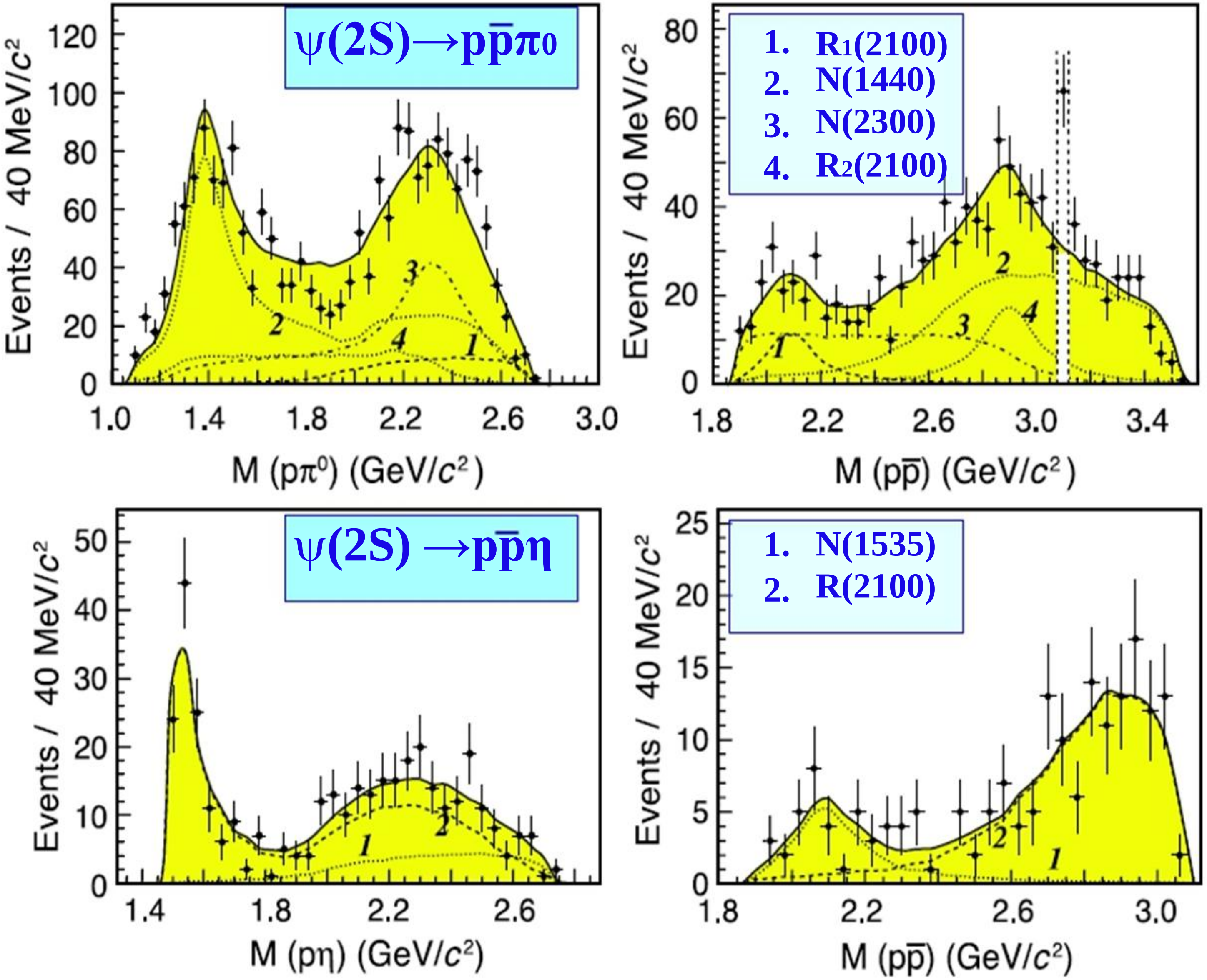
  Yi-Bo Yang et al. PRL 111, 091601

  Large decay rate is predicted

  Need more experimental information!

PWA of $\psi(2S) \to p\bar{p}\pi^0$ and $\psi(2S) \to p\bar{p}\eta$

CLEOc: 24.5 M $\psi(2S)$ [PRD 82, 092002]



Without interference effects

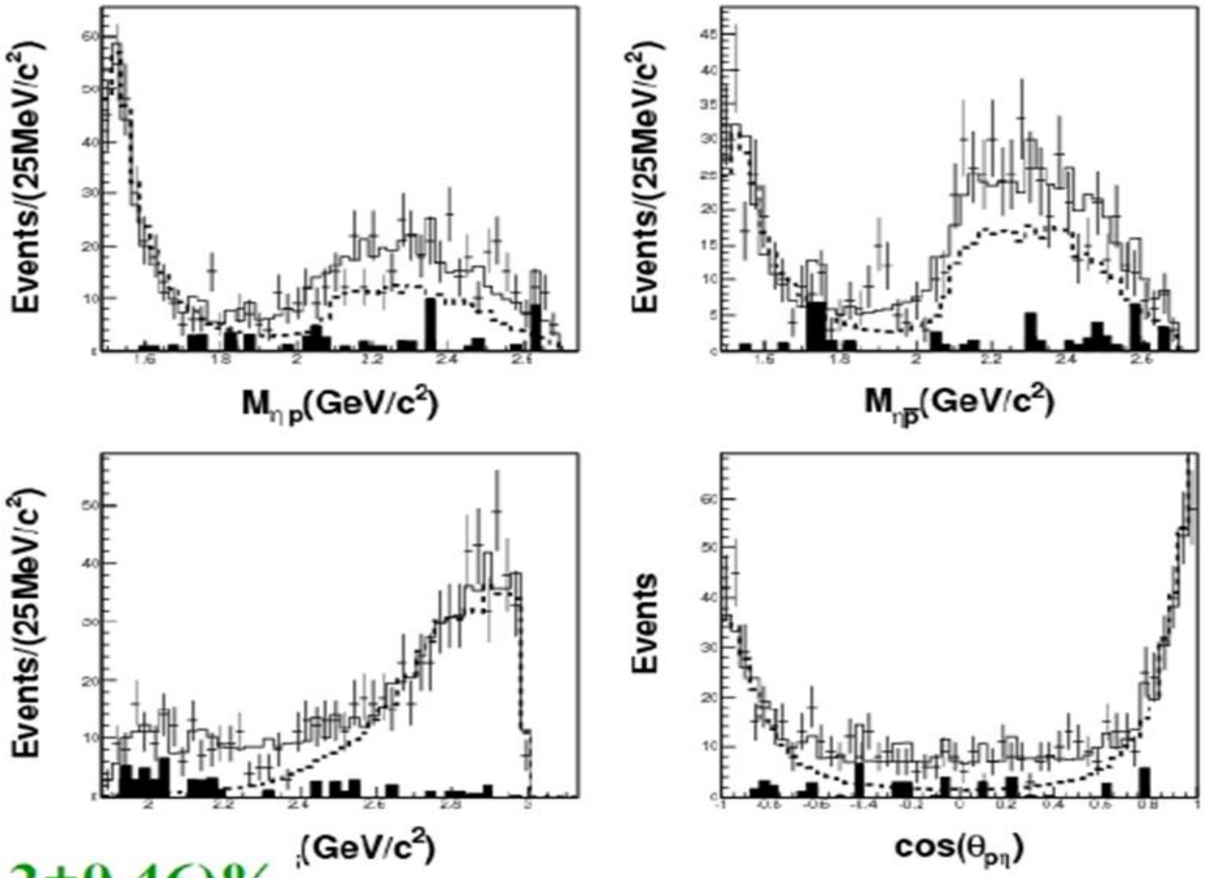
BESIII: PWA of $\psi' \to p\bar{p}\eta$

PRD 88, 032010

- **Low background:**
  - sidebands and continuum
- **Best solution:**
  - N(1535) combined with an interfering phase space
- $p\bar{p}$ **enhancement: <3σ**
- **N(1535):**

  M=(1524±5+10) MeV/c2

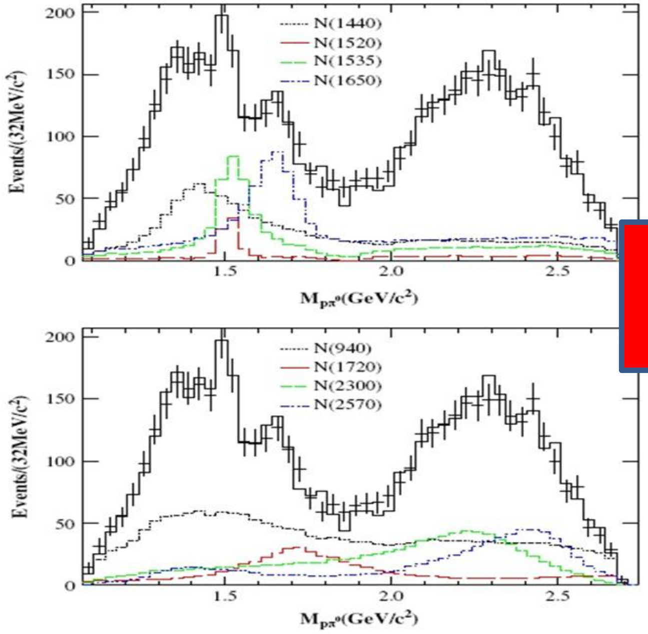
  Γ= (130+27+10) MeV/c2
- **Suppressed (<12%):**



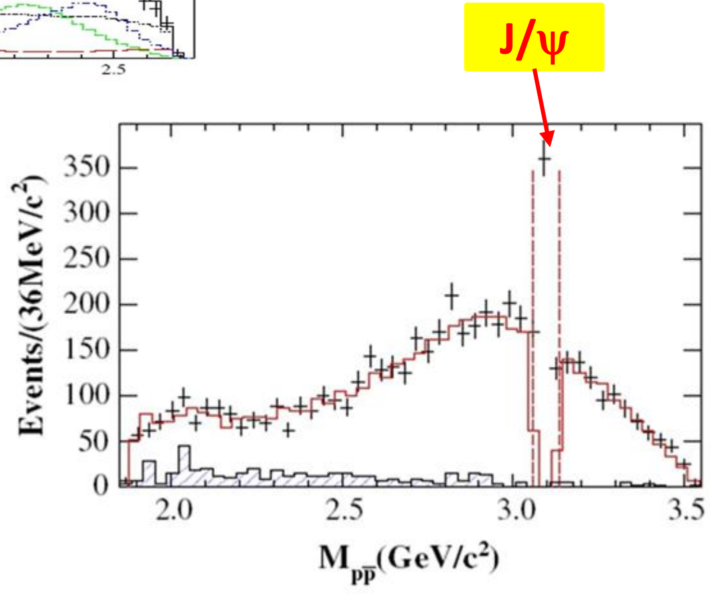
$$Q_{p\bar{p}\eta} = \frac{\mathcal{B}(\psi(2S) \to p\bar{p}\eta)}{\mathcal{B}(J/\psi \to p\bar{p}\eta)} = (3.2 \pm 0.46)\%$$

BESIII: PWA of $\psi(2S)\to p\bar{p}\pi^0$

- **2-body decay:**
  - $\psi(2S)\to X\pi^0$, $X\to p\bar{p}$
  - $\psi(2S)\to p\overline{N^*}$, $\overline{N^*}\to\bar{p}\pi^0$+c.c.
- **isospin conservation:**
  Δsuppressed
- **best solution:**
  N(940), N(1440), N(1520), N(2090), N(1535),N(1650), N(1720),
  N(2300) [1/2+], N(2570) [5/2-]
- **no significant evidence:**
  - N(1885), N(2065)
  - $p\bar{p}$ enhancement
- **systematic uncertainties:**
  - additional possible resonances



PRL 110, 022001



BESIII: PWA of $\psi(2S)\rightarrow p\bar{p}\pi^0$

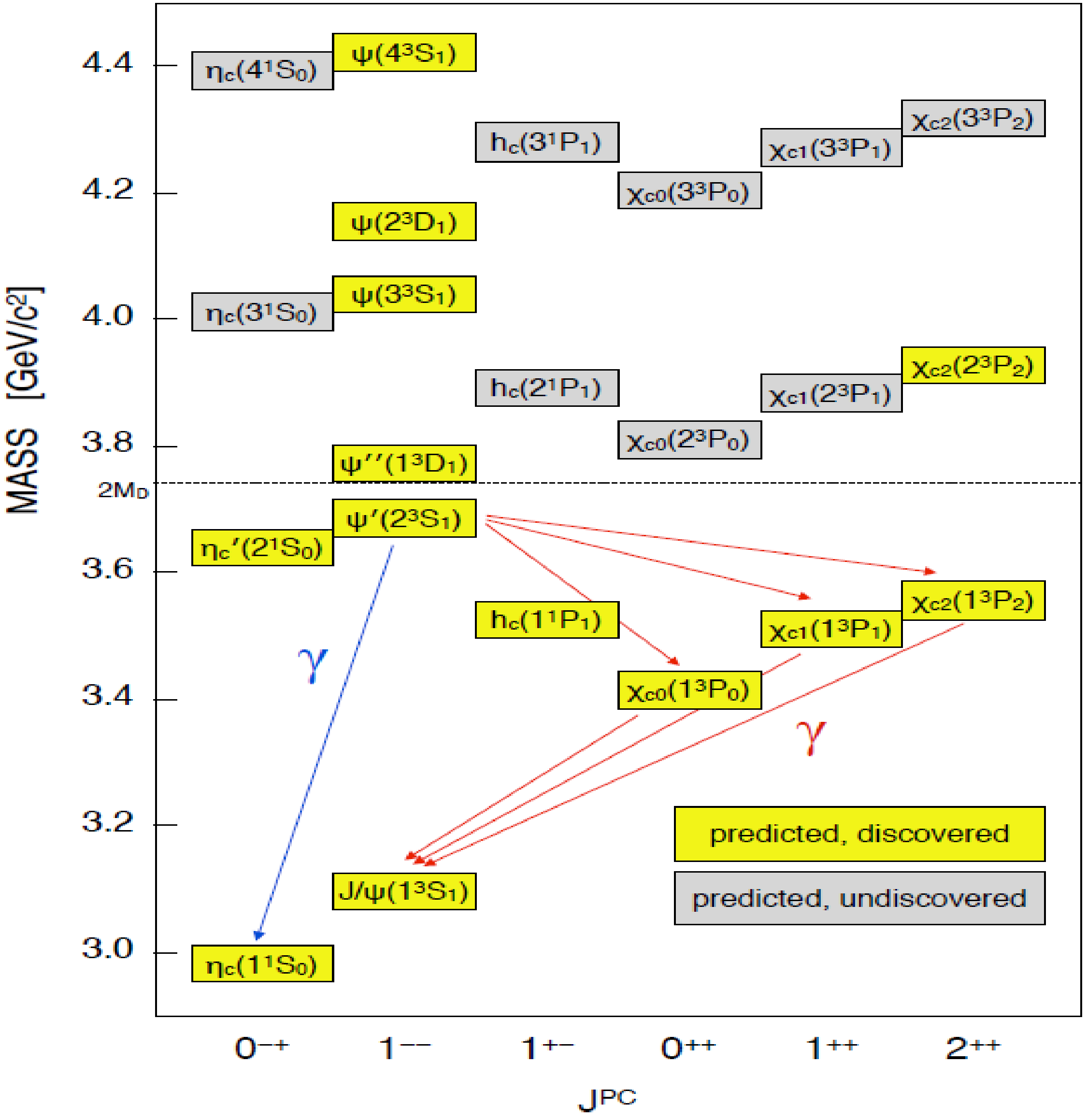
- **branching fraction:**
  $\mathcal{B}(\psi(2S)\rightarrow p\bar{p}\pi^0) = (1.65\pm0.03\pm0.15)\times10^{-4}$

PRL 110, 022001

Resonance	N	$\epsilon(\%)$	B.F.($\times\ 10^{-5}$)
$N(940)$	$1870^{+90+487}_{-90-327}$	27.5 ± 0.4	$6.42^{+0.20+1.78}_{-0.20-1.28}$
$N(1440)$	$1060^{+90+459}_{-90-227}$	27.9 ± 0.4	$3.58^{+0.25+1.59}_{-0.25-0.84}$
$N(1520)$	190^{+14+64}_{-14-48}	28.0 ± 0.4	$0.64^{+0.05+0.22}_{-0.05-0.17}$
$N(1535)$	$673^{+45+263}_{-45-256}$	25.8 ± 0.4	$2.47^{+0.28+0.99}_{-0.28-0.97}$
$N(1650)$	$1080^{+77+382}_{-77-467}$	27.2 ± 0.4	$3.76^{+0.28+1.37}_{-0.28-1.66}$
$N(1720)$	$510^{+27+50}_{-27-197}$	26.9 ± 0.4	$1.79^{+0.10+0.24}_{-0.10-0.71}$
$N(2300)$	$948^{+68+394}_{-68-213}$	34.2 ± 0.4	$2.62^{+0.28+1.12}_{-0.28-0.64}$
$N(2570)$	$795^{+45+127}_{-45-83}$	35.3 ± 0.4	$2.13^{+0.08+0.40}_{-0.08-0.30}$
Total	4515 ± 93	25.8 ± 0.4	$16.5\pm0.3\pm1.5$

XYZ Physics

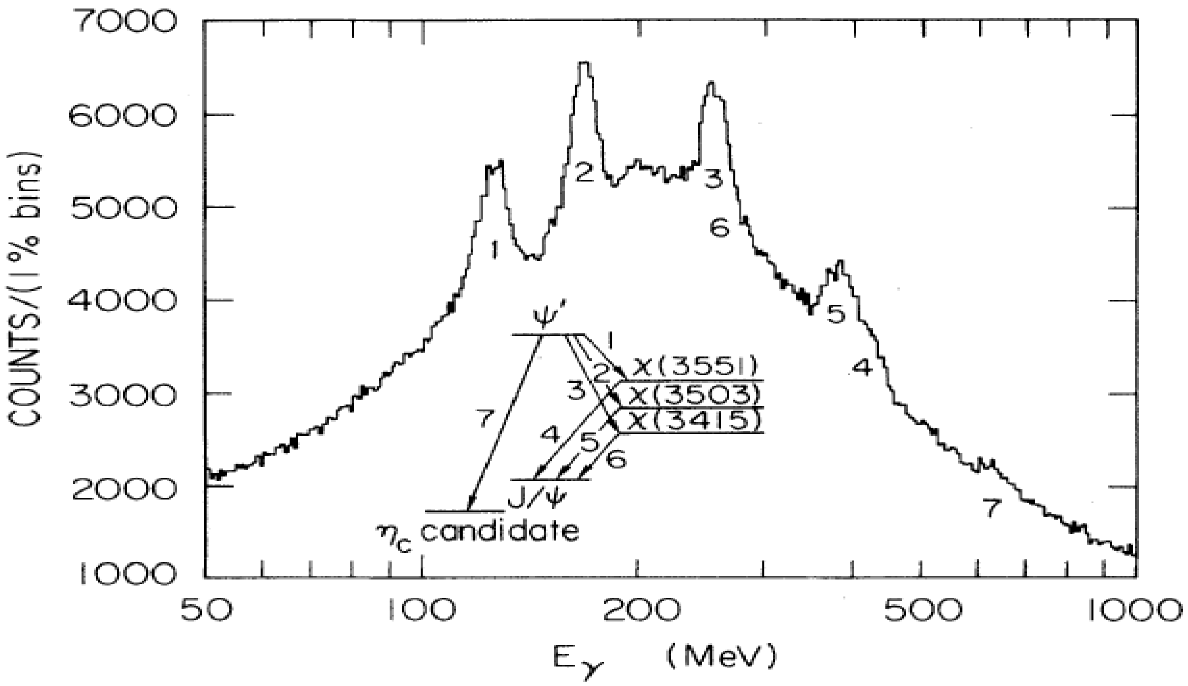
Connecting the XYZ at BESIII



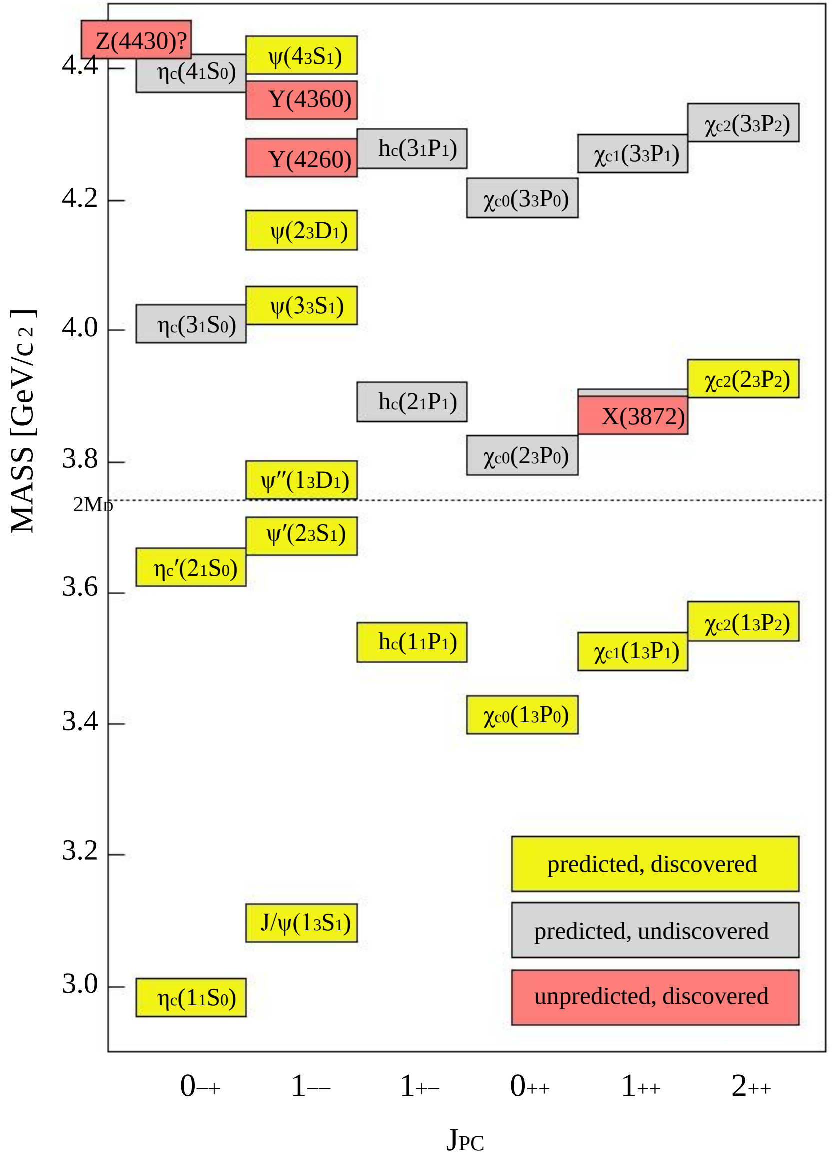
(I) The quark model describes most of charmonium remarkably well. $(c\bar{c})$

Crystal Ball at SLAC

(discovery of η_c)



PRL45, 1150 (1980)



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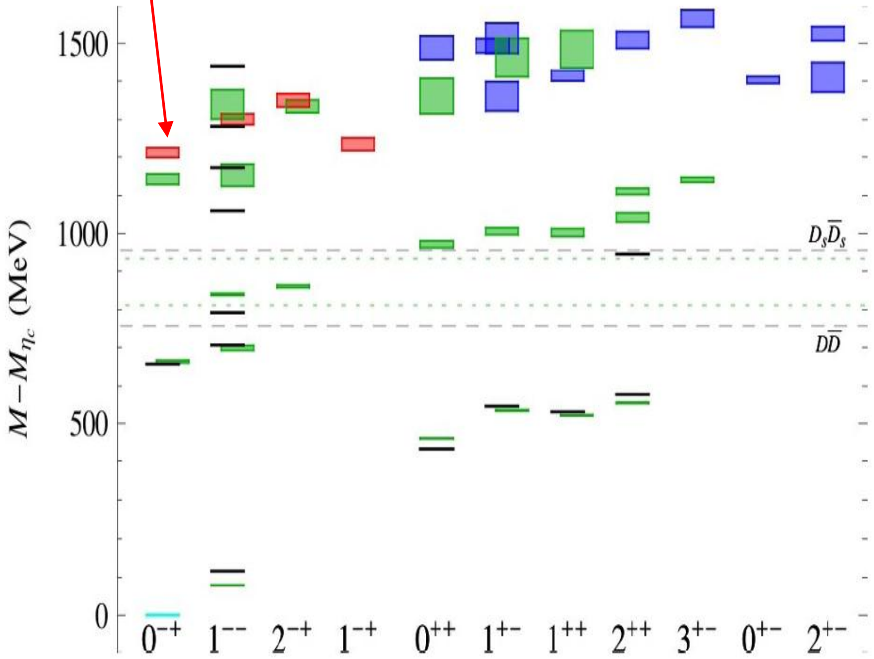
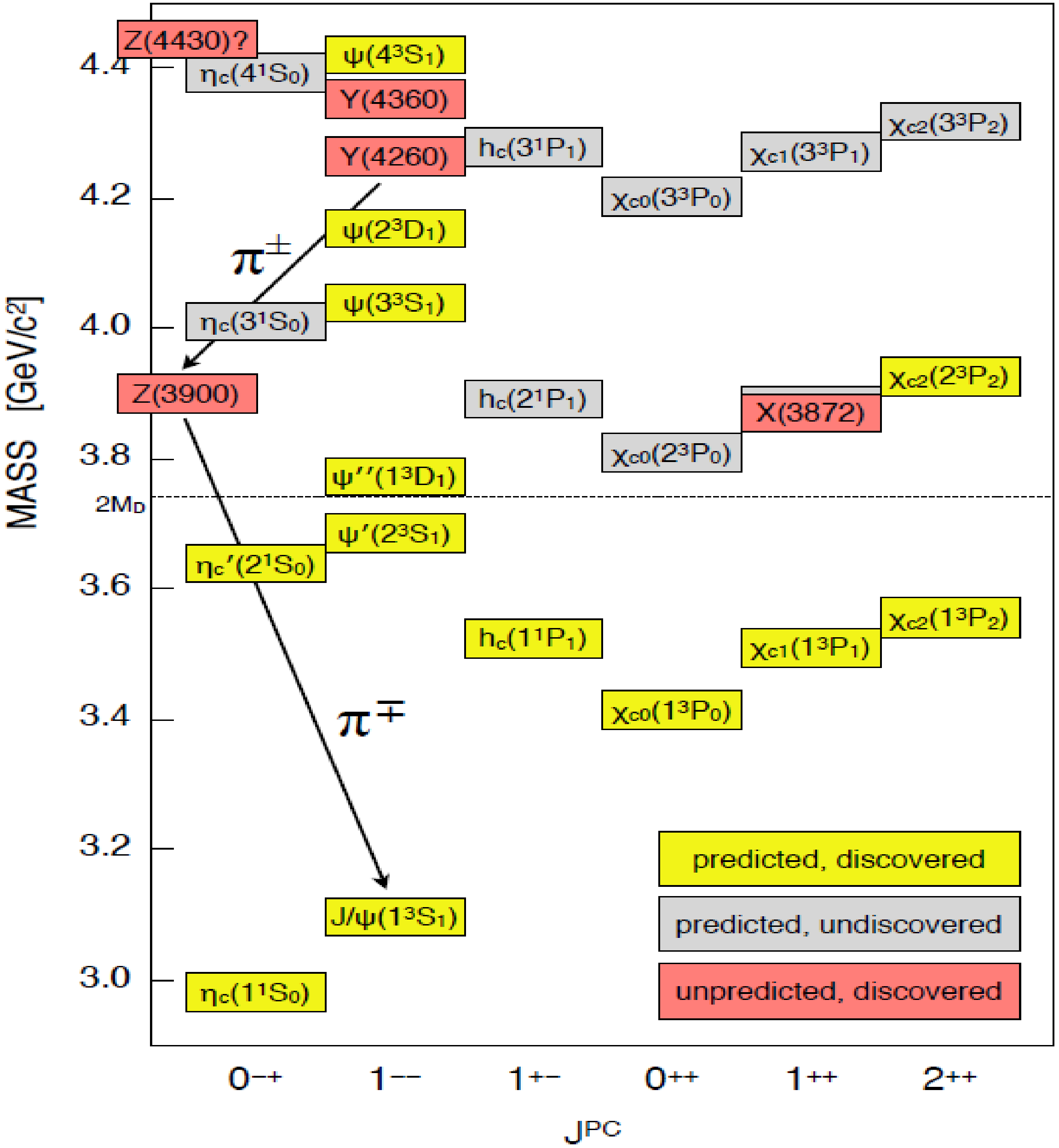
(II) But the *"XYZ"* states point beyond the quark model. $(c\bar{c}q,\ c\bar{q}q\bar{c},\ (c\bar{q})(q\bar{c}),\ c\bar{c}\pi\pi)$

Red:Lightest Hybrid

Blue: First excited Hybrid



JHEP 1207, 126(2012)



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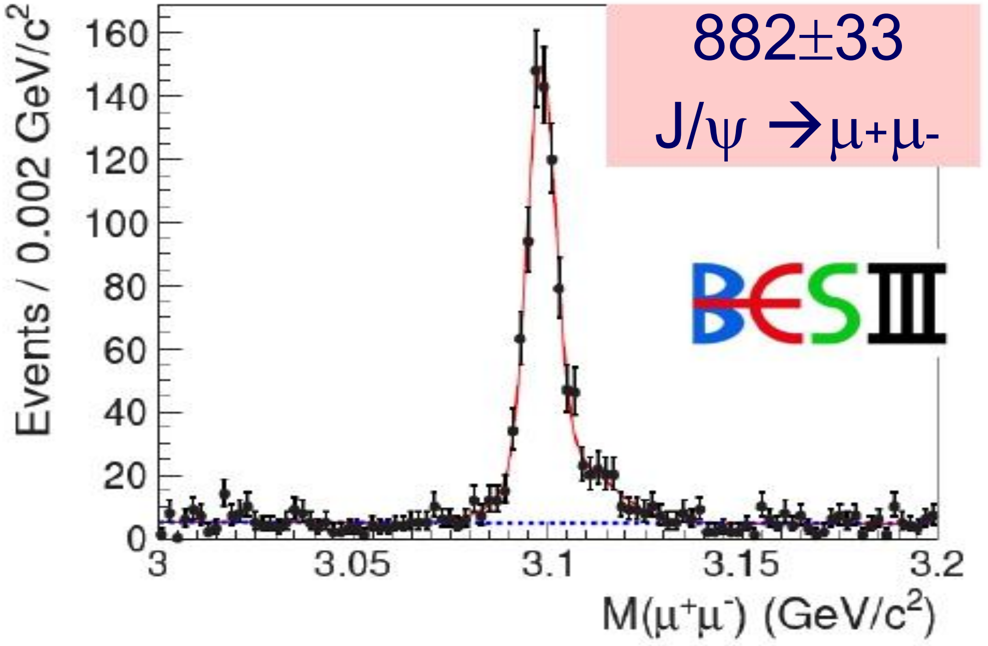
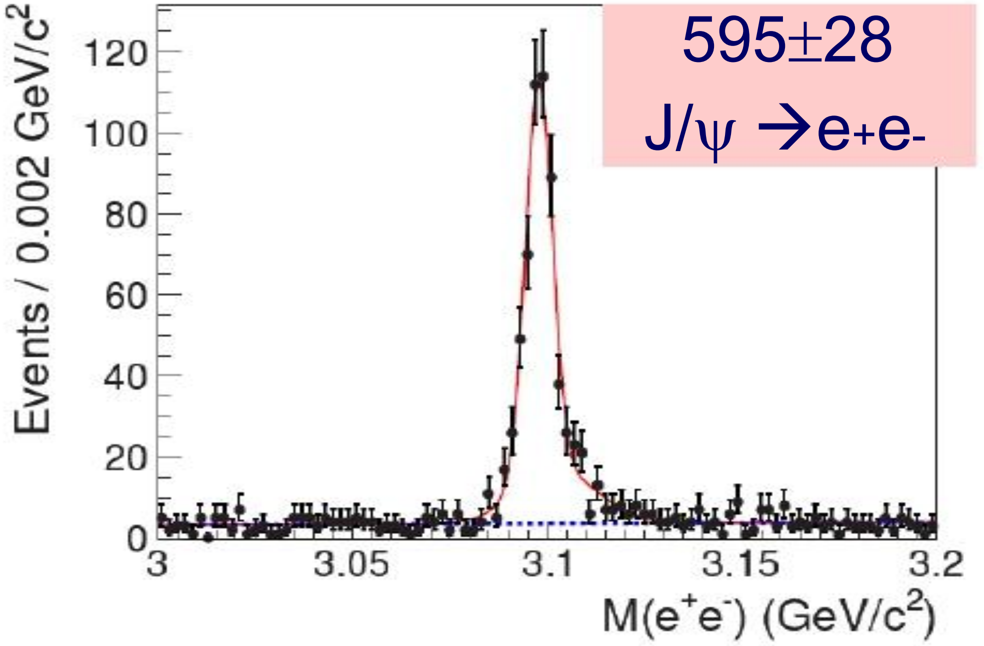
(III) Most of the XYZ states were discovered by Belle and BaBar.

(IV) But BESIII can directly produce the **Y(4260)** and **Y(4360)** in e^+e^- annihilation.

(V) BESIII has observed "charged charmoniumlike structures" — the **Z_c(3900)** …

BESIII: Cross scetion of e+e-→ π+π-J/ψ at 4.26 GeV



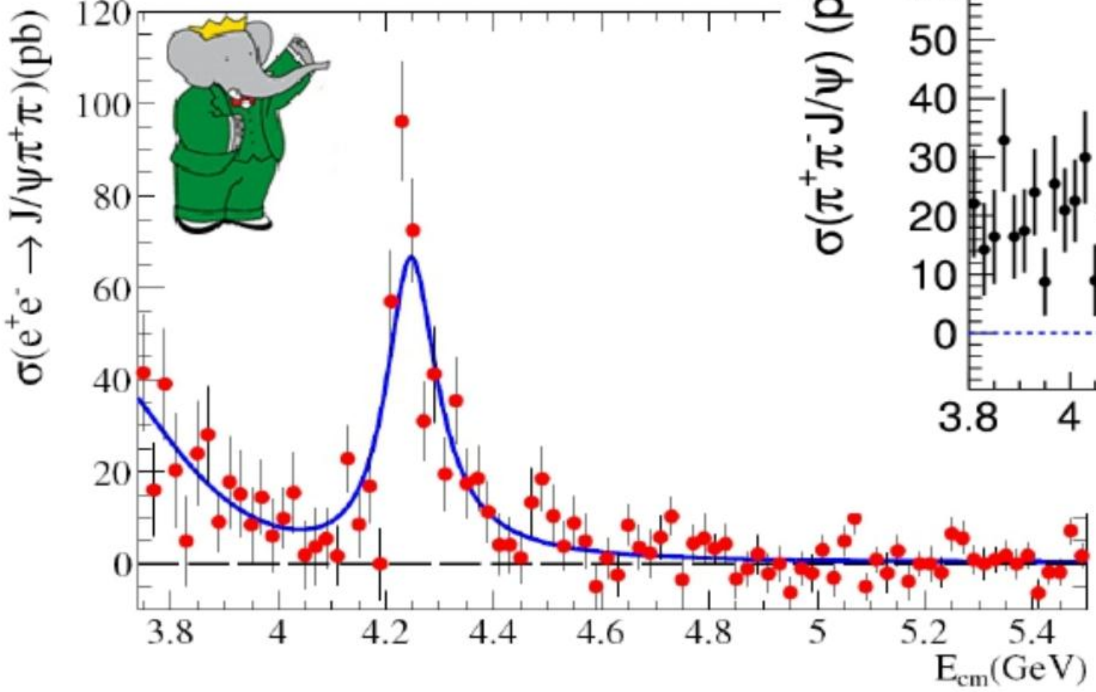


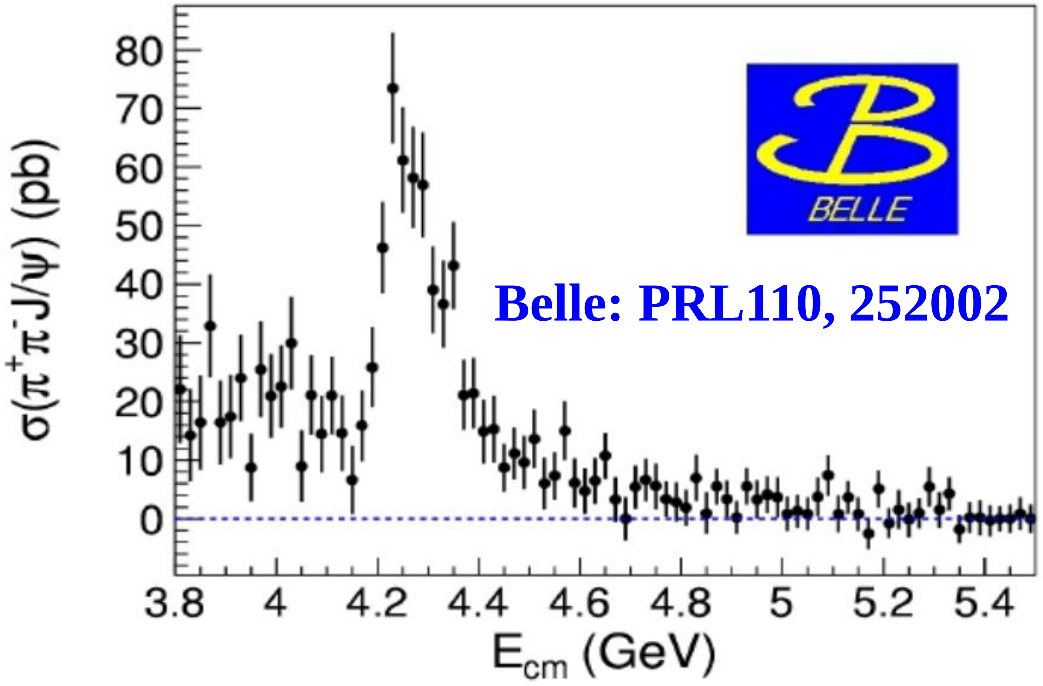
- Select 4 charged tracks and reconstruct J/ψ with lepton pair
- Very clean sample, very high efficiency (~45%)
- $\sigma(e^+e^- \to \pi^+\pi^- J/\psi) = (62.9 \pm 1.9 \pm 3.7)$ pb

PRL110, 252001

e+e- ⟶ π+π-J/ψ – cross sections @ 4.260 GeV

BaBar: PRD86, 051102 (2012)





Belle: PRL110, 252002

BESIII: $\sigma_B(e^+e^- \to \pi^+\pi^- J/\psi)$ = **(62.9±1.9±3.7) pb**

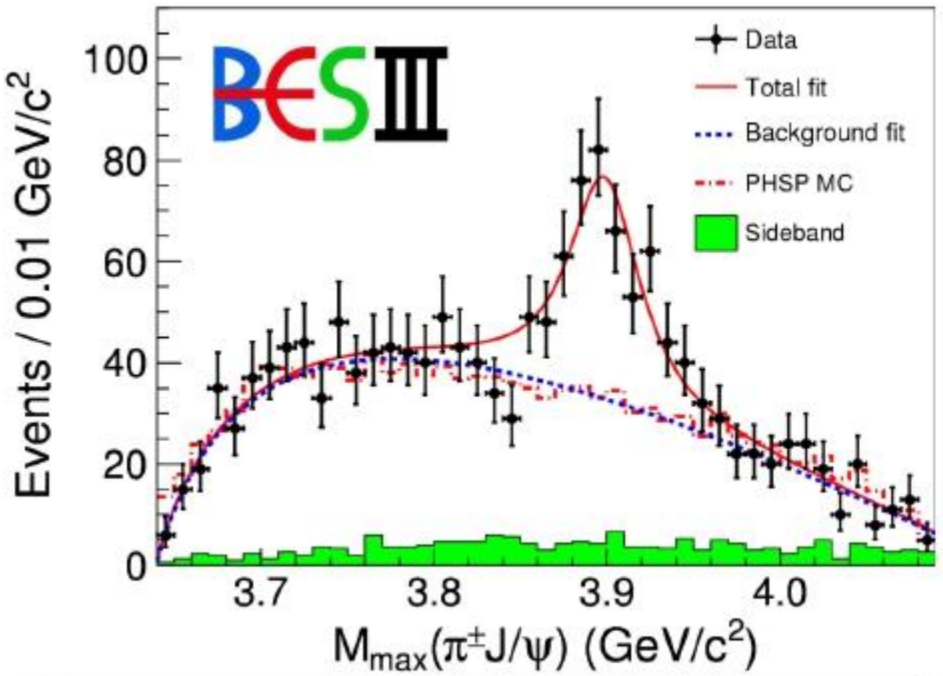
- agreement with BaBar & Belle

BESIII cross sections:

- **best precision**
- **more energy points**
- **more data!**

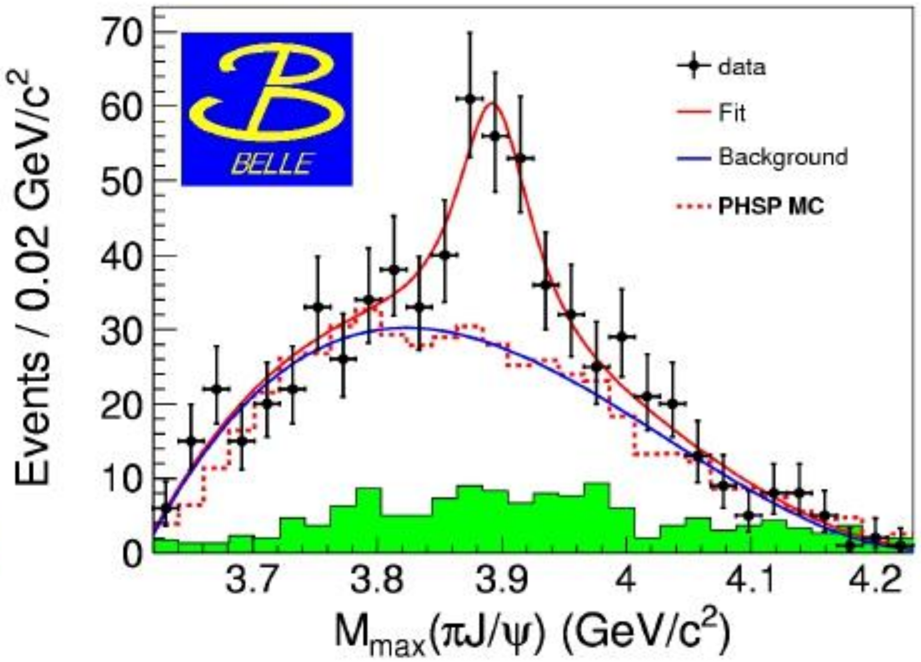
Z_c(3900) observed in two experiments!

BESIII at 4.26 GeV: PRL110, 252001



- M = 3899.0±3.6±4.9 MeV
- Γ = 46±10±20 MeV
- 307 ± 48 events
- >8σ

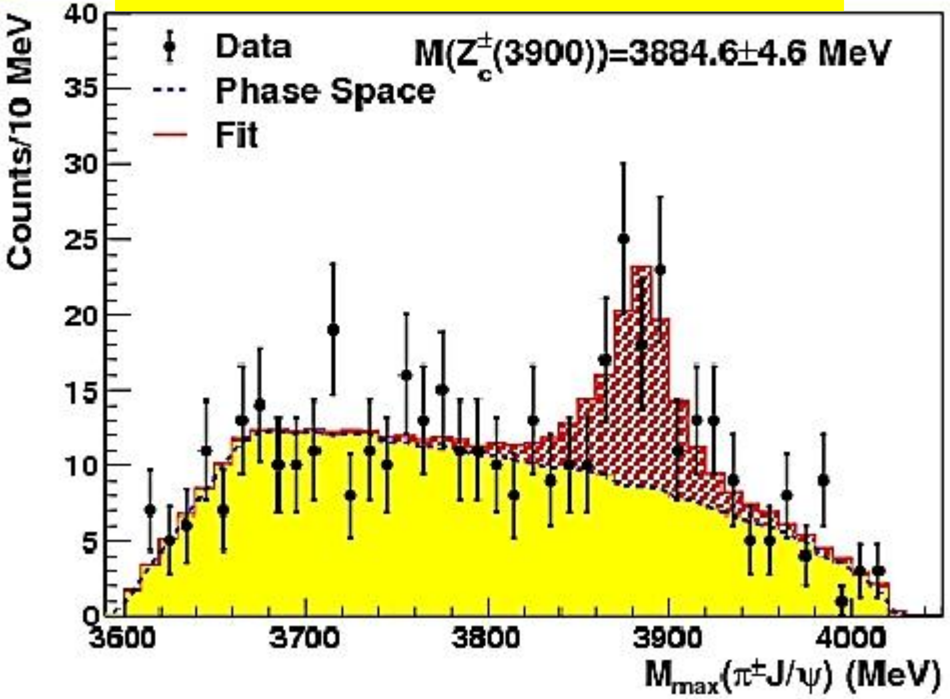
Belle with ISR: PRL110,252002

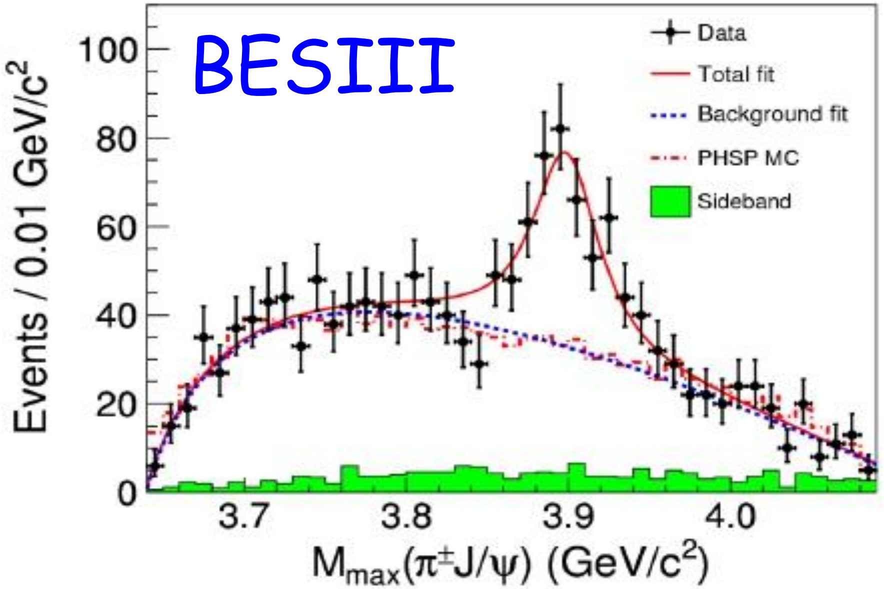


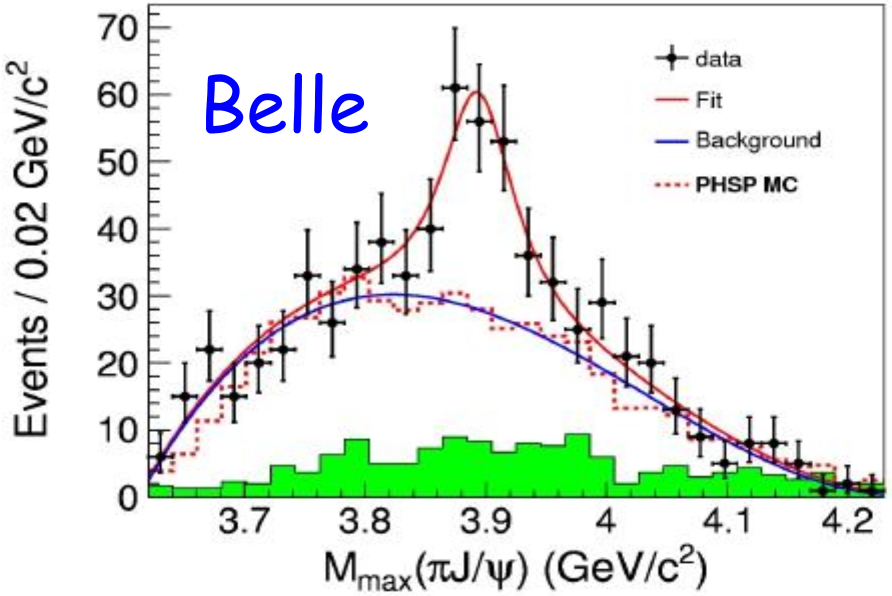
- M = 3894.5±6.6±4.5 MeV
- Γ = 63±24±26 MeV
- 159 ± 49 events

Confirmed with CLEOc data!

CLEOc data at 4.17 GeV:
PLB 727, 366



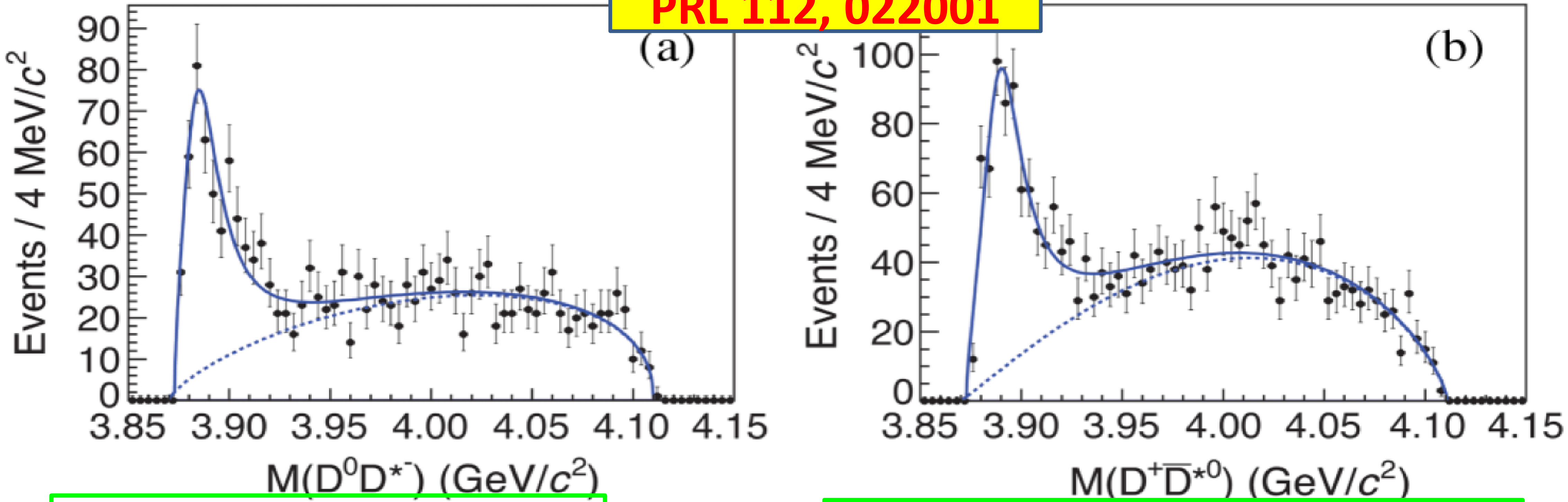




- **M = 3885±5±1 MeV**
- **Γ = 34±12±4 MeV**
- **81 ± 20 events**
- 6.1σ

BESIII: e+e-⟶ πZc(3885) → $\pi^-(D\overline{D^*})^+$+c.c. @ 4.260 GeV

PRL 112, 022001

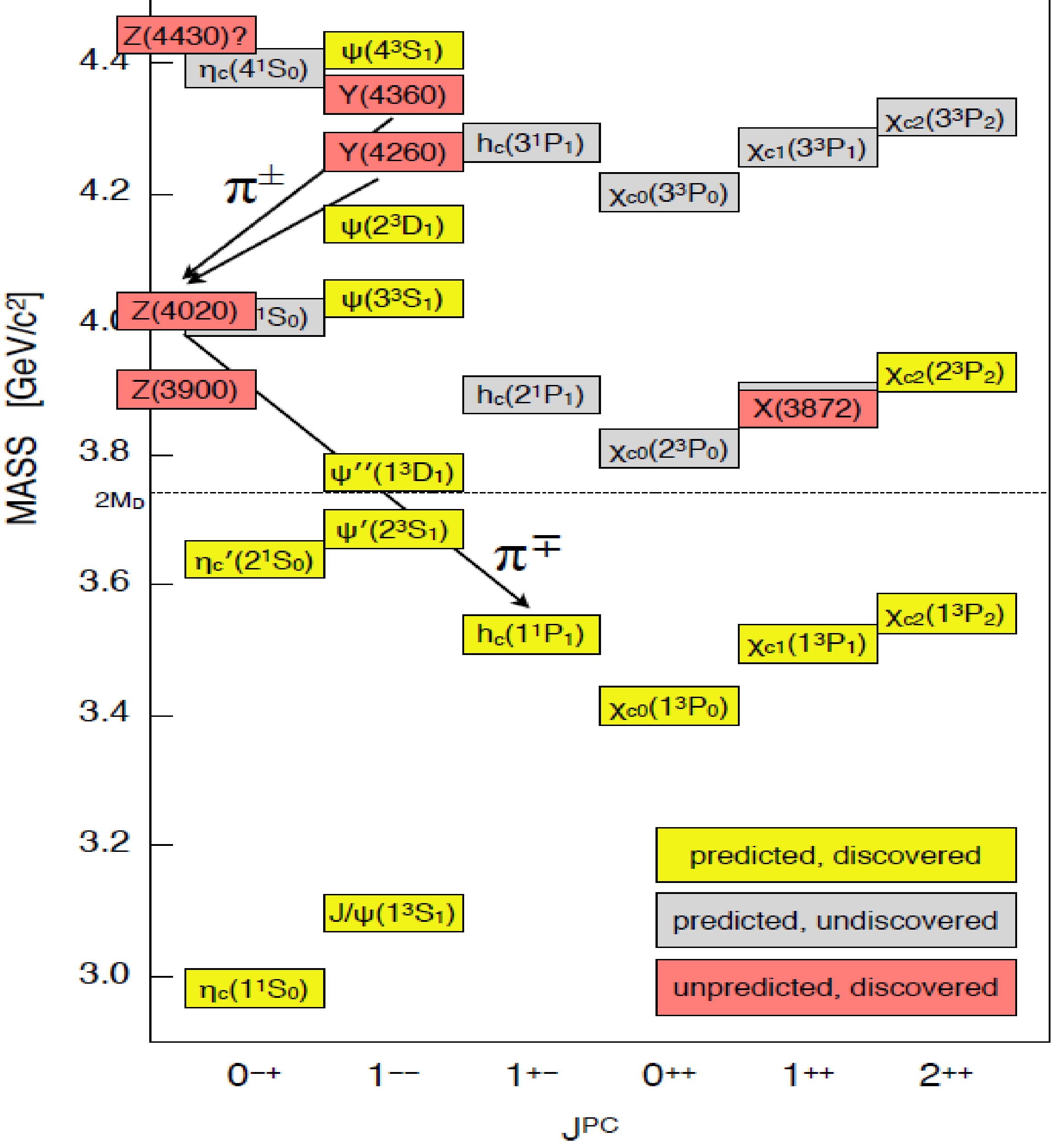


- M = (3883.9 ± 1.5 ± 4.2) MeV
- Γ = (24.8 ± 3.3 ± 11.0) MeV
- >18σ

πZc(3885) ang. dist. favours $J^P = 1^+$
disfavours 1^- or 0^-

σ(e+e-⟶ π-Zc(3885)+ × Zc(3885)+⟶ (DD*)+ +c.c.) = (83.5 ± 6.6 ± 22.0) pb

$$R=\frac{\Gamma(Z_c(3885)\to D\overline{D^*})}{\Gamma(Z_c(3900)\to \pi J/\psi)} = (6.2\pm1.1\pm2.7)\%$$



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(IV) But BESIII can directly produce the **Y(4260)** and **Y(4360)** in e^+e^- annihilation.

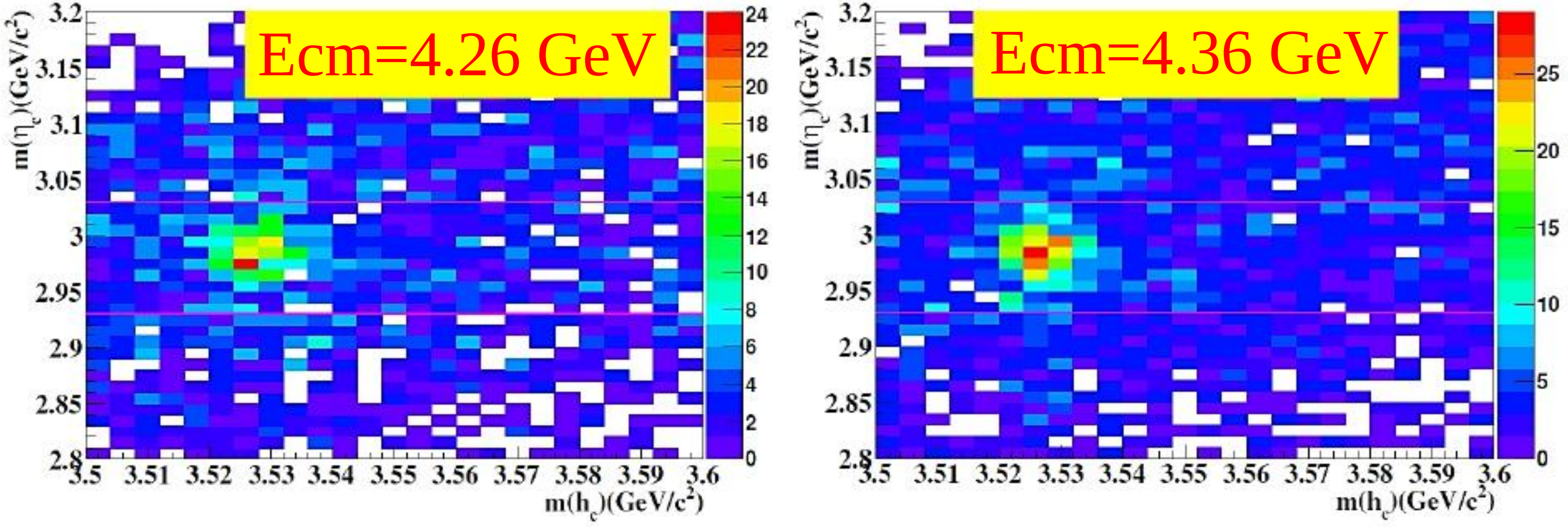
(V) BESIII has observed "charged charmoniumlike structures" — the **$Z_c(3900)$** and the **$Z_c'(4020)$**.

BESIII: $e^+e^- \to \pi^+\pi^- h_c(1P)$

PRL 111, 242001

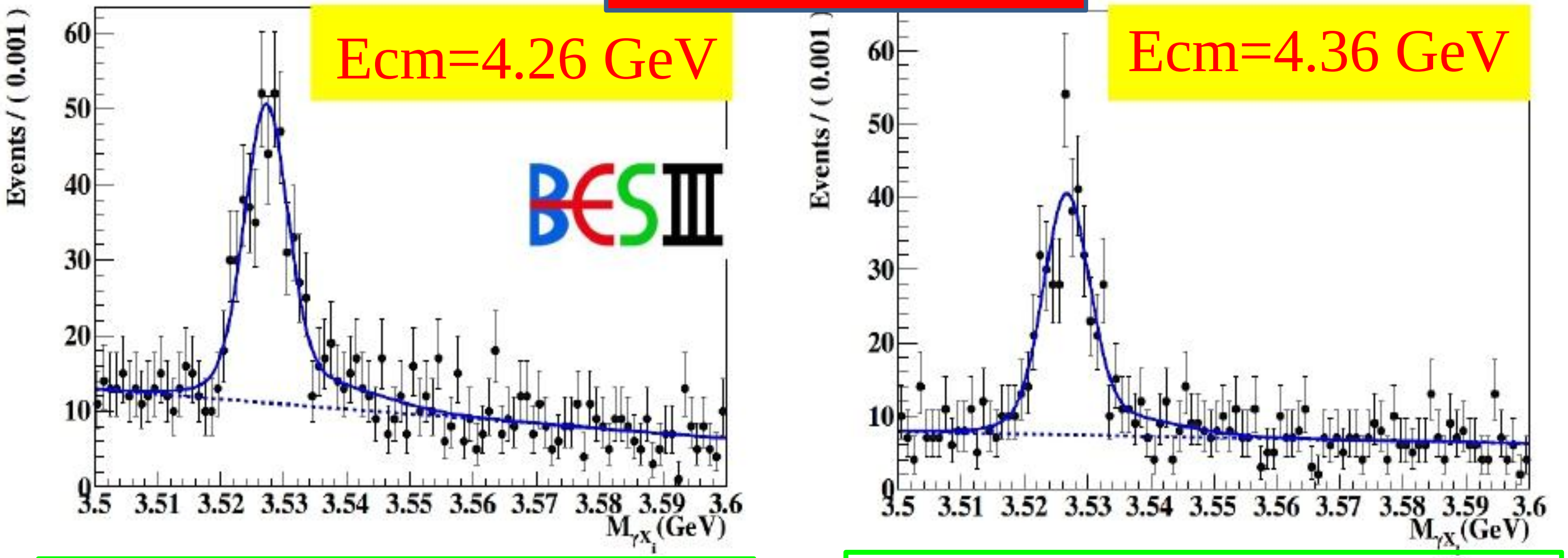
$h_c \to \gamma\eta_c$, $\eta_c \to$ hadrons [16 exclusive decay modes]

- $p\bar{p}$, $\pi^+\pi^-K^+K^-$, $\pi^+\pi^-p\bar{p}$, $2(K^+K^-)$, $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$
- $2(\pi^+\pi^-)K^+K^-$, $K_S^0K^+\pi^-$+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: Cross section of e+e-$\rightarrow$ π+π-h_c(1P)

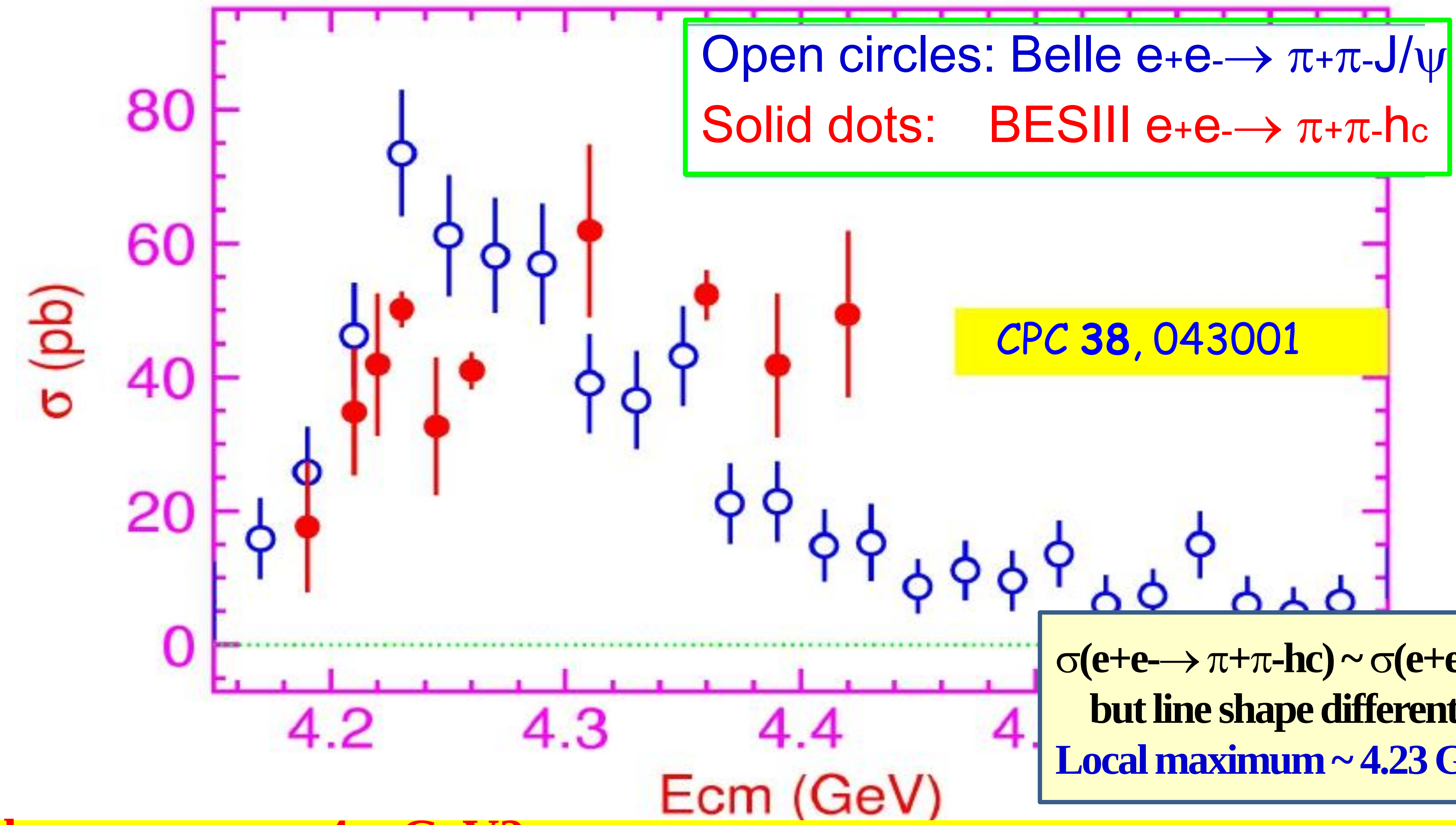
PRL 111, 242001



- N(hc)=416±28
- Lum=827/pb
- σ_B= 41.0±2.8±7.4 pb

- N(hc)=357±25
- Lum=544/pb
- σ_B= 52.3±3.7±9.2 pb

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

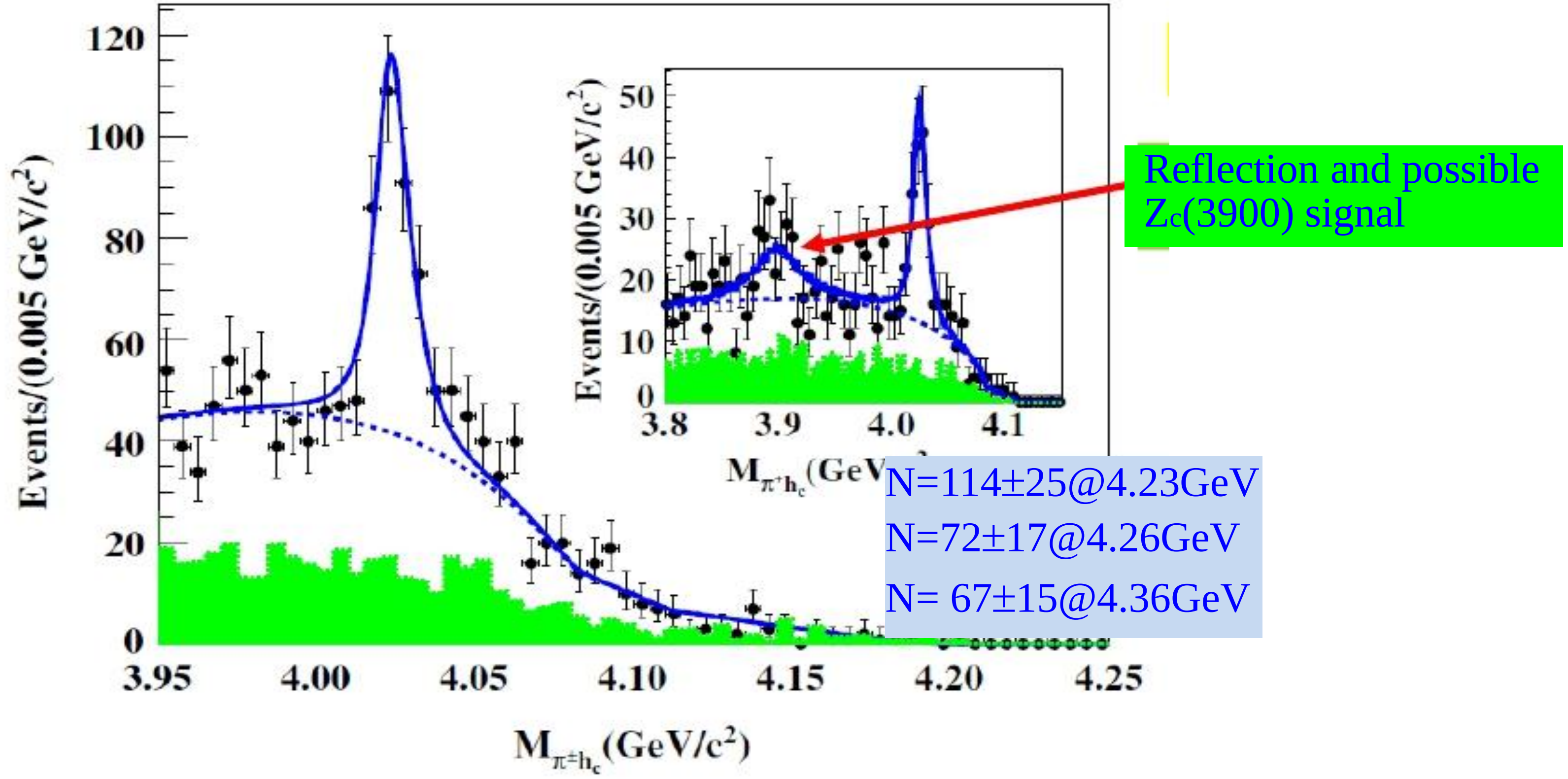


$\sigma(e^+e^- \to \pi^+\pi^- h_c) \sim \sigma(e^+e^- \to \pi^+\pi^- J/\psi)$
but line shape different
Local maximum ~ 4.23 GeV

Broad structure at ~4.x GeV?
Need more data at high energies to complete the line shape measurement

BESIII: $e^+e^- \to \pi Z_c(4020) \to \pi^+\pi^- h_c(1P)$

PRL 111, 242001

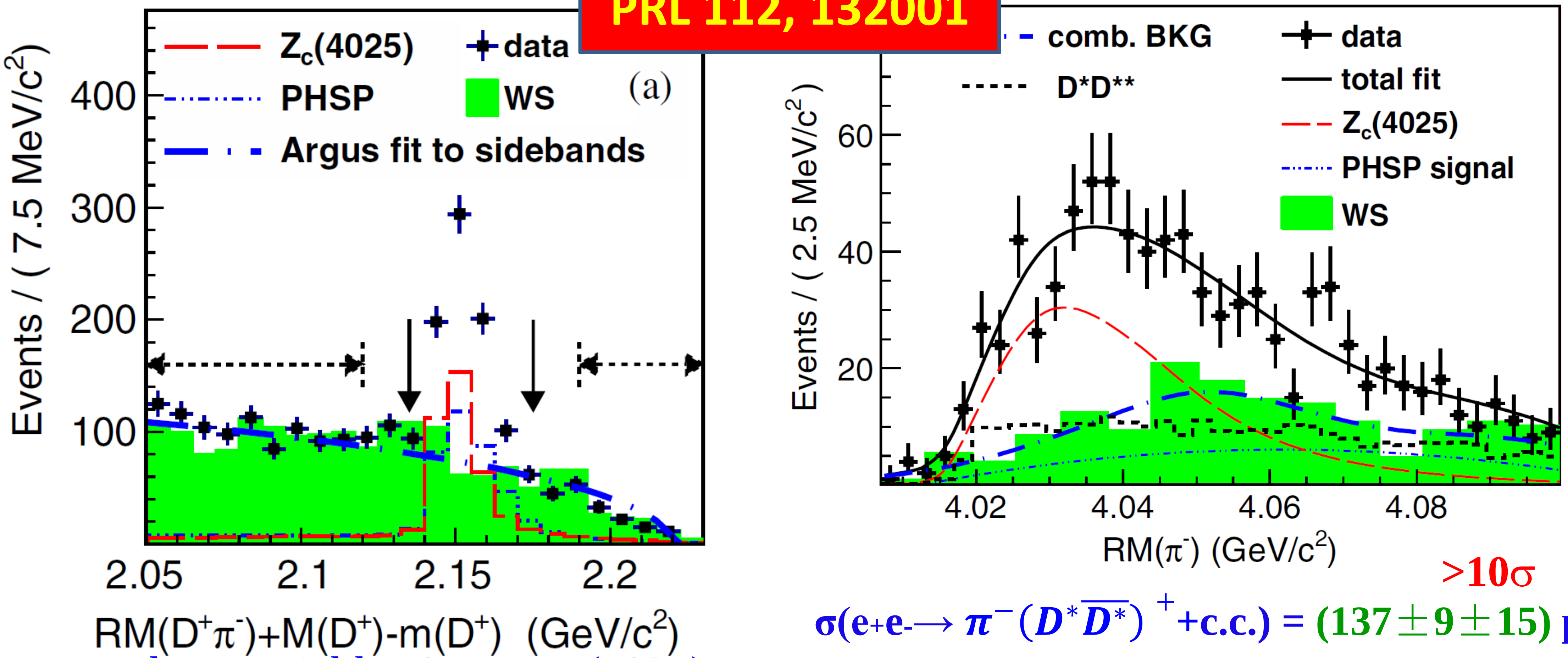


Simultaneous fit to **4.23/4.26/4.36 GeV** data and **16 η_c** decay modes: **8.9σ**

$M(Z_c(4020)) = 4022.9 \pm 0.8 \pm 2.7$ MeV; $\Gamma(Z_c(4020)) = 7.9 \pm 2.7 \pm 2.6$ MeV

BESIII: e+e-→ πZc(4025) → $\pi^-(D^*\overline{D^*})^+$+c.c. @ 4.260 GeV

PRL 112, 132001



>10σ

$\sigma(e+e- \to \pi^-(D^*\overline{D^*})^+$+c.c.) = (137 ± 9 ± 15) pb

Fit to π± recoil mass yields 401±47 Zc(4025) events

M(Zc(4025)) = 4026.3±2.6±3.7 MeV;

Γ(Zc(4025)) = 24.8±5.6±7.7 MeV

$$\frac{\sigma(e^+e^-\to\pi^-Z_c^+\to\pi^-(D^*\overline{D^*})^+ + c.c.)}{\sigma(e^+e^-\to\pi^-(D^*\overline{D^*})^+ + c.c.)} = (65 \pm 9 \pm 6)\%$$

Summary of Z states

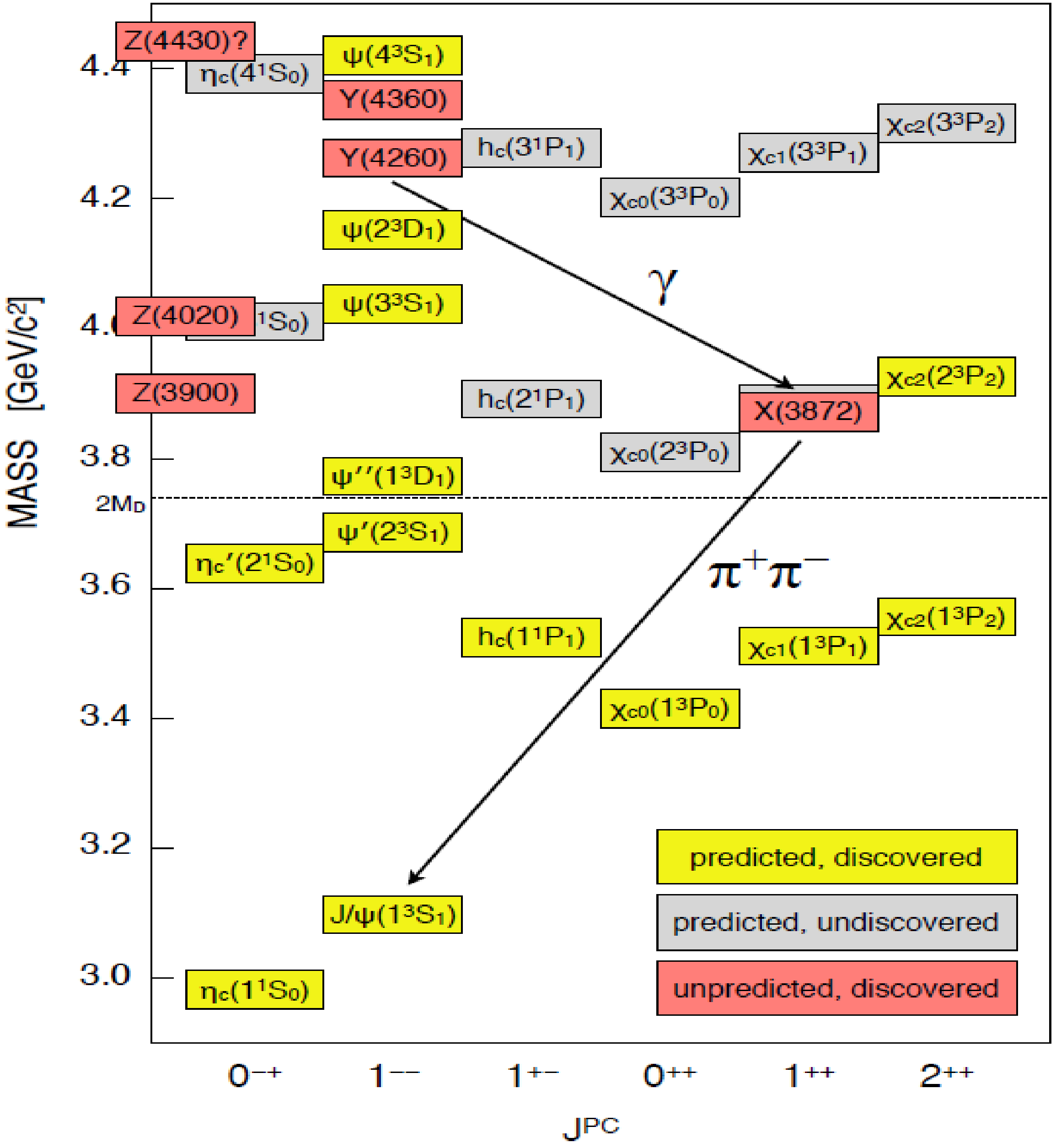
Channel	Mass [MeV/c^2]	Width [MeV]
$J/\psi\,\pi^+$	$3899.0 \pm 3.6 \pm 4.9$	$46 \pm 10 \pm 20$
$(D\bar{D}^*)^+$	$3883.9 \pm 1.5 \pm 4.2$	$24.8 \pm 3.3 \pm 11.0$
$h_c\pi^+$	$4022.9 \pm 0.8 \pm 2.7$	$7.9 \pm 2.7 \pm 2.6$
$(D^*\bar{D}^*)^+$	$4026.3 \pm 2.6 \pm 3.7$	$24. \pm 5.6 \pm 7.7$

Close to DD* threshold=3875 MeV

Close to D*D* threshold=4017 MeV

Nature of these states?

- Tetraquark L. Maiani, A. Ali et al.
- Hadronic molecule U.-G. Meissner, F.K. Guo et al.
- Hadro-charmonium M. B. Voloshin
- Meson loop Q. Zhao et al.
- ISPE model X. Liu et al.
- …



(I) The quark model describes most of charmonium remarkably well. $(c\bar{c})$

(II) But the "*XYZ*" states point beyond the quark model. $(c\bar{c}g,\ c\bar{q}q\bar{c},\ (c\bar{q})(q\bar{c}),\ c\bar{c}\pi\pi)$

(III) Most of the XYZ states were discovered by Belle and BaBar.

(IV) But BESIII can directly produce the **Y(4260)** and **Y(4360)** in e^+e^- annihilation.

(V) BESIII has observed "charged charmoniumlike structures" — the **Z_c(3900)** and the **Z_c'(4020)**.

(VI) BESIII has also observed a transition to the **X(3872)**.

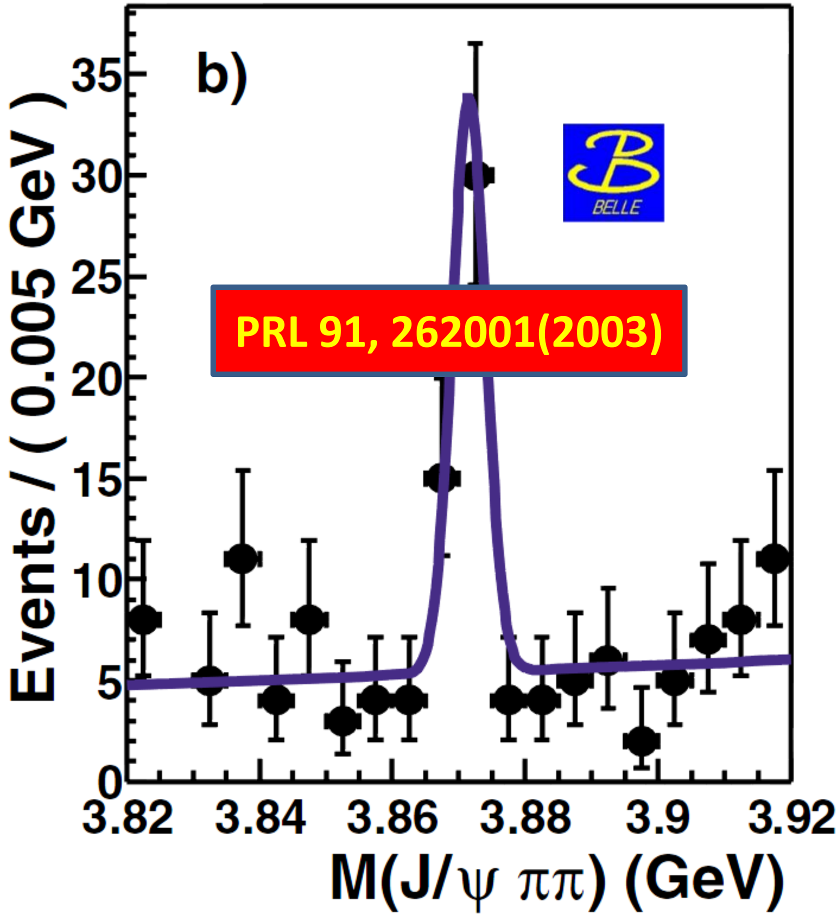
X(3872)

- First observed in Belle:

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

- Theoretical predicted: The production rate of **X(3872) will be strongly enhanced in Y(4260) decays** compared to that of ψ(4040,4415) and ψ(4160) decays

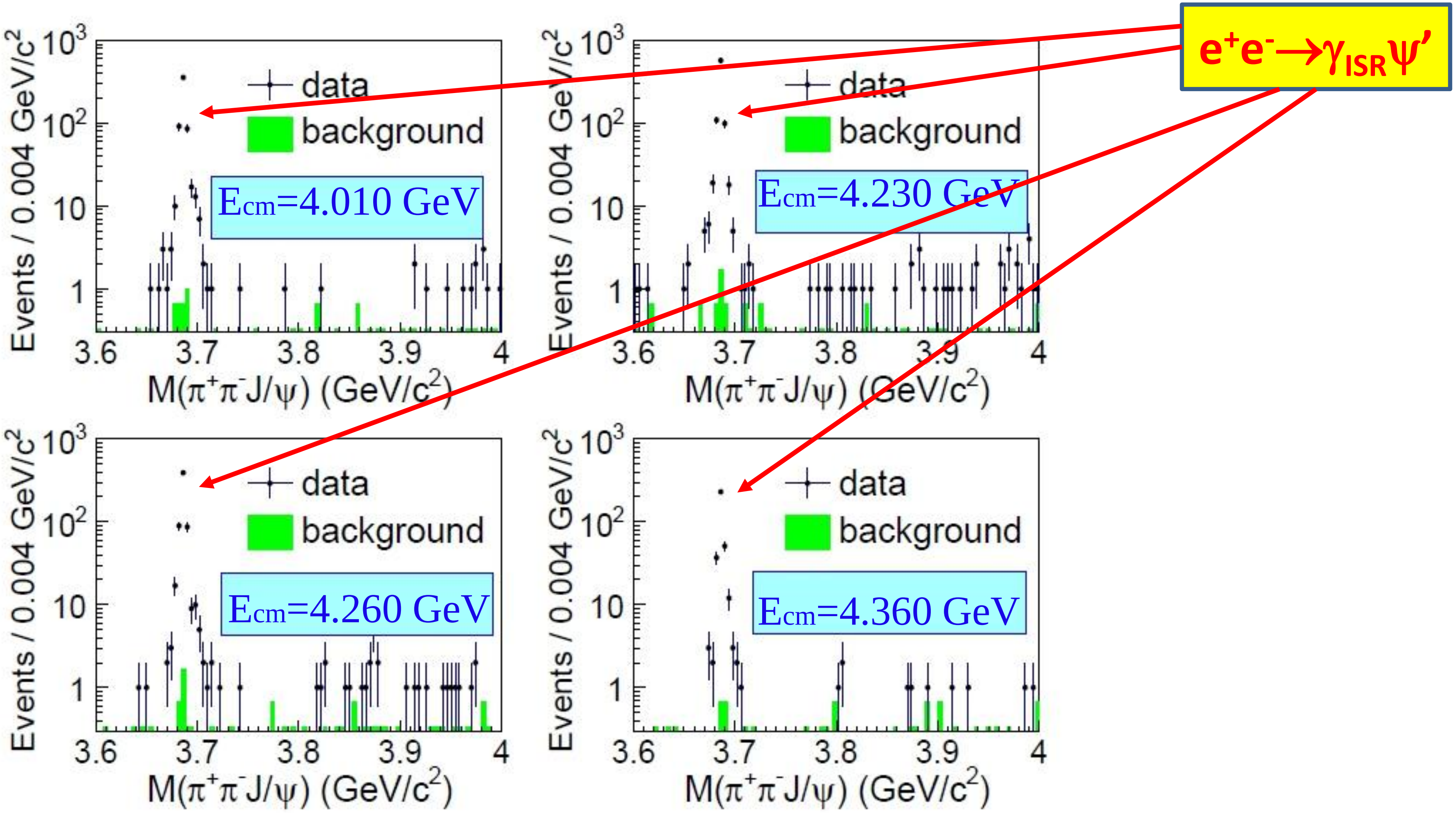
F.K. Guo et al, PLB 725,127(2013)



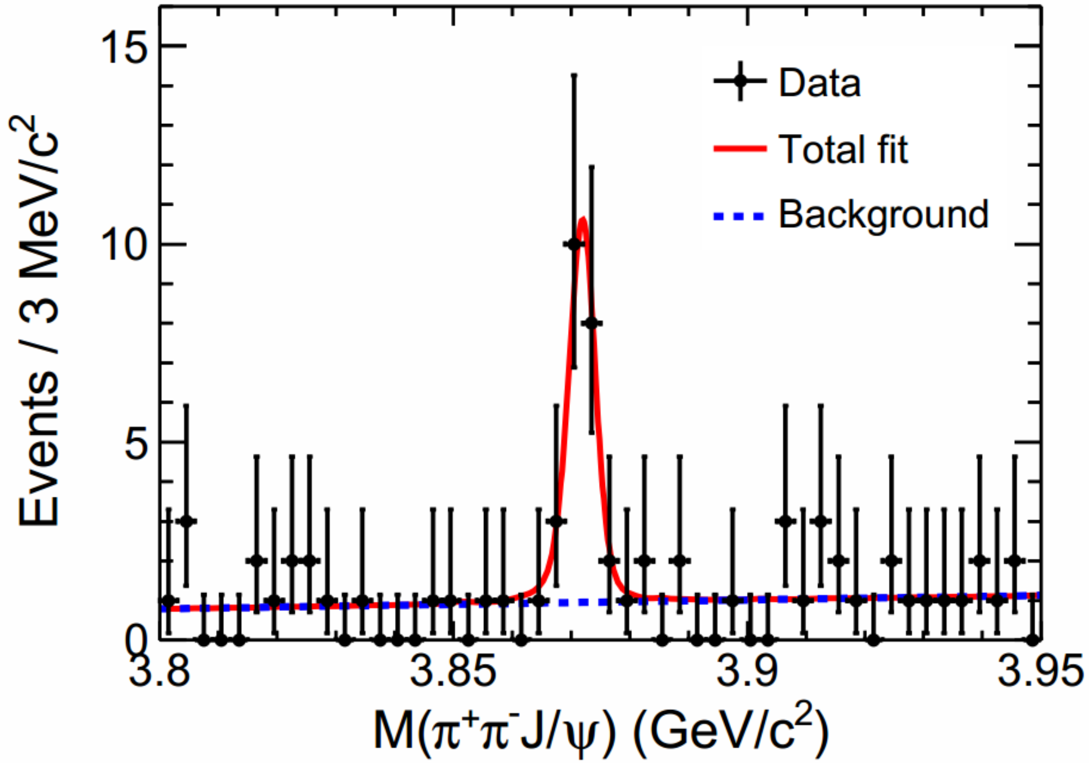
hep-ex:1310.4101

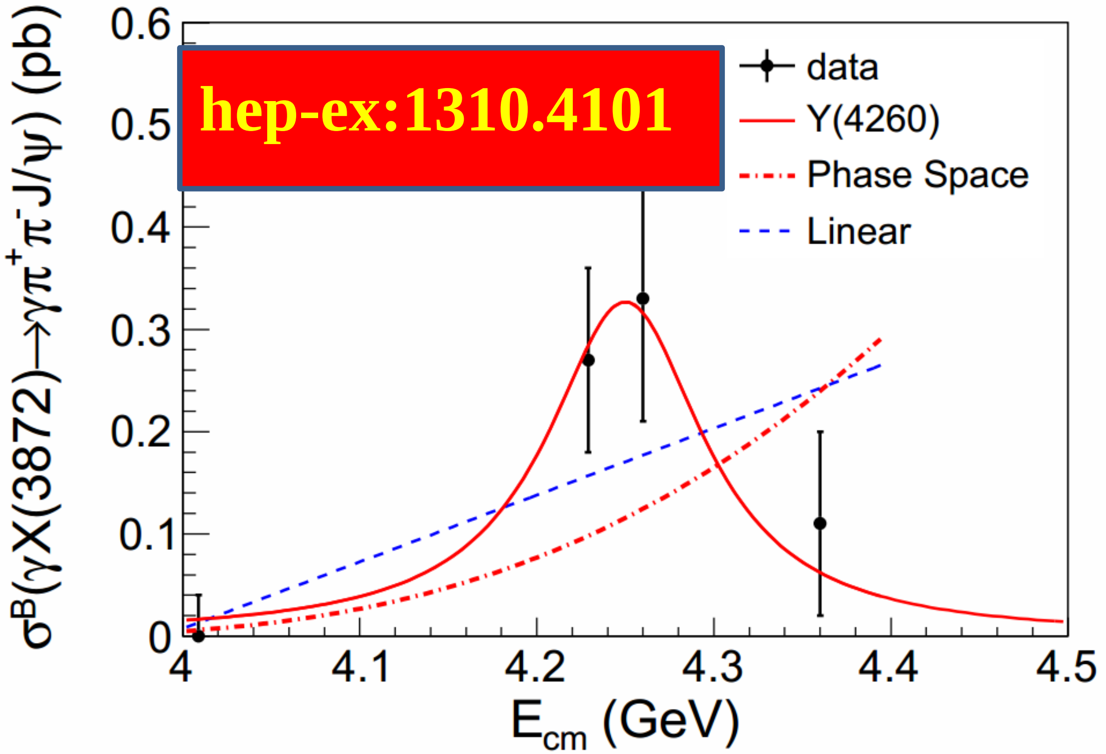
BESIII: $e^+e^- \rightarrow \gamma X(3872) \rightarrow \gamma\pi^+\pi^- J/\psi$

X(3872) signal at around 4.230-4.260 GeV



BESIII: e+e- → γX(3872) → γπ+π-J/ψ





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

$\mu_{\psi(3686)}$ = - (0.34±0.04) MeV/c2; σ_M= (1.14±0.07) MeV

N(X(3872)) = 20.1±4.5

M = (3871.9±0.7±0.2) MeV/c2

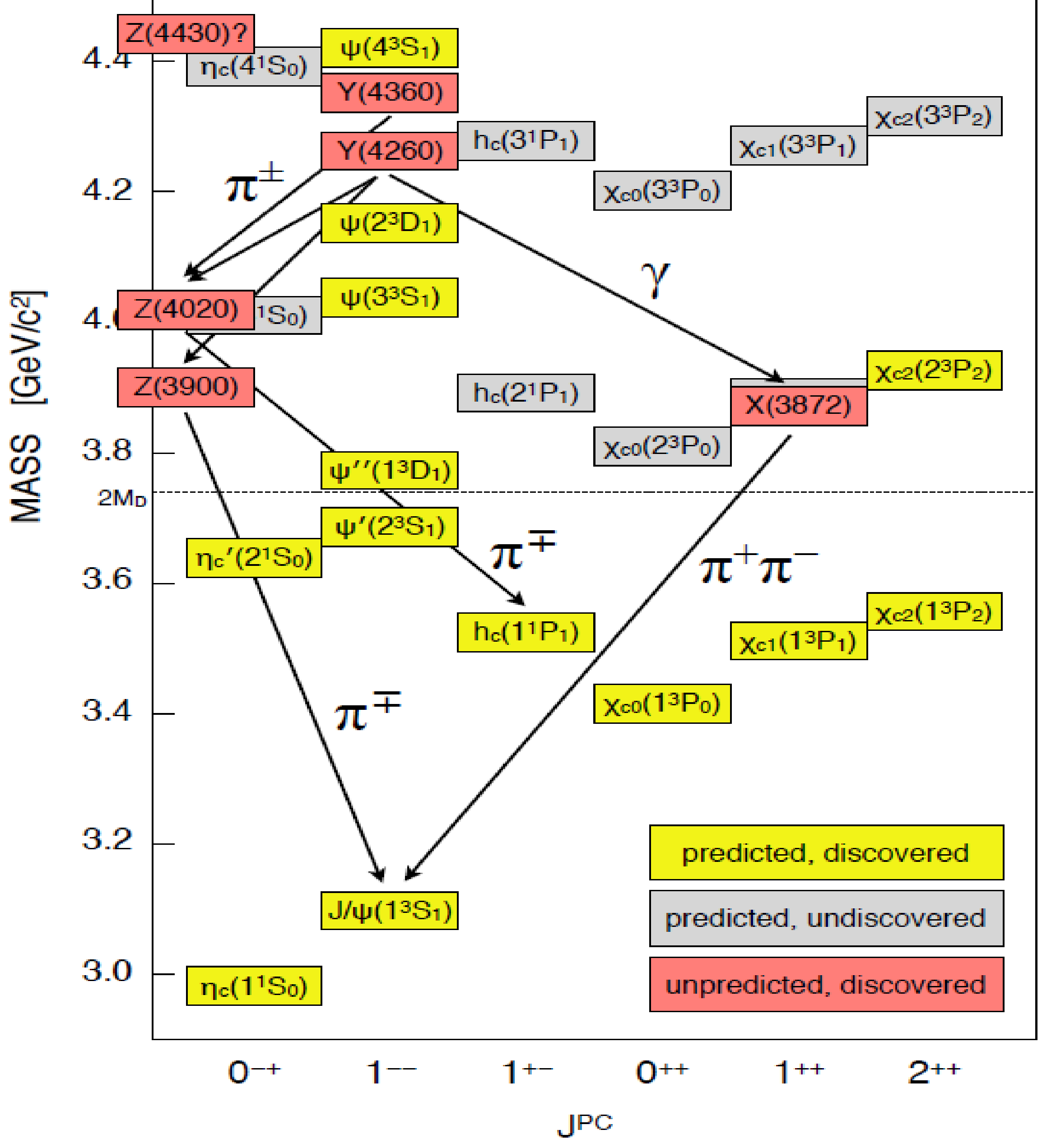
Γ = consistent with σ_M

>6.3σ

[PDG: 3871.68±0.17 MeV]

Could be a Y(4260) → γX(3872)!

Consist with Guo's (PLB725,127(2013))prediction!



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(VI) BESIII has also observed a transition to the **X(3872)**.

(VII) We are building connections.

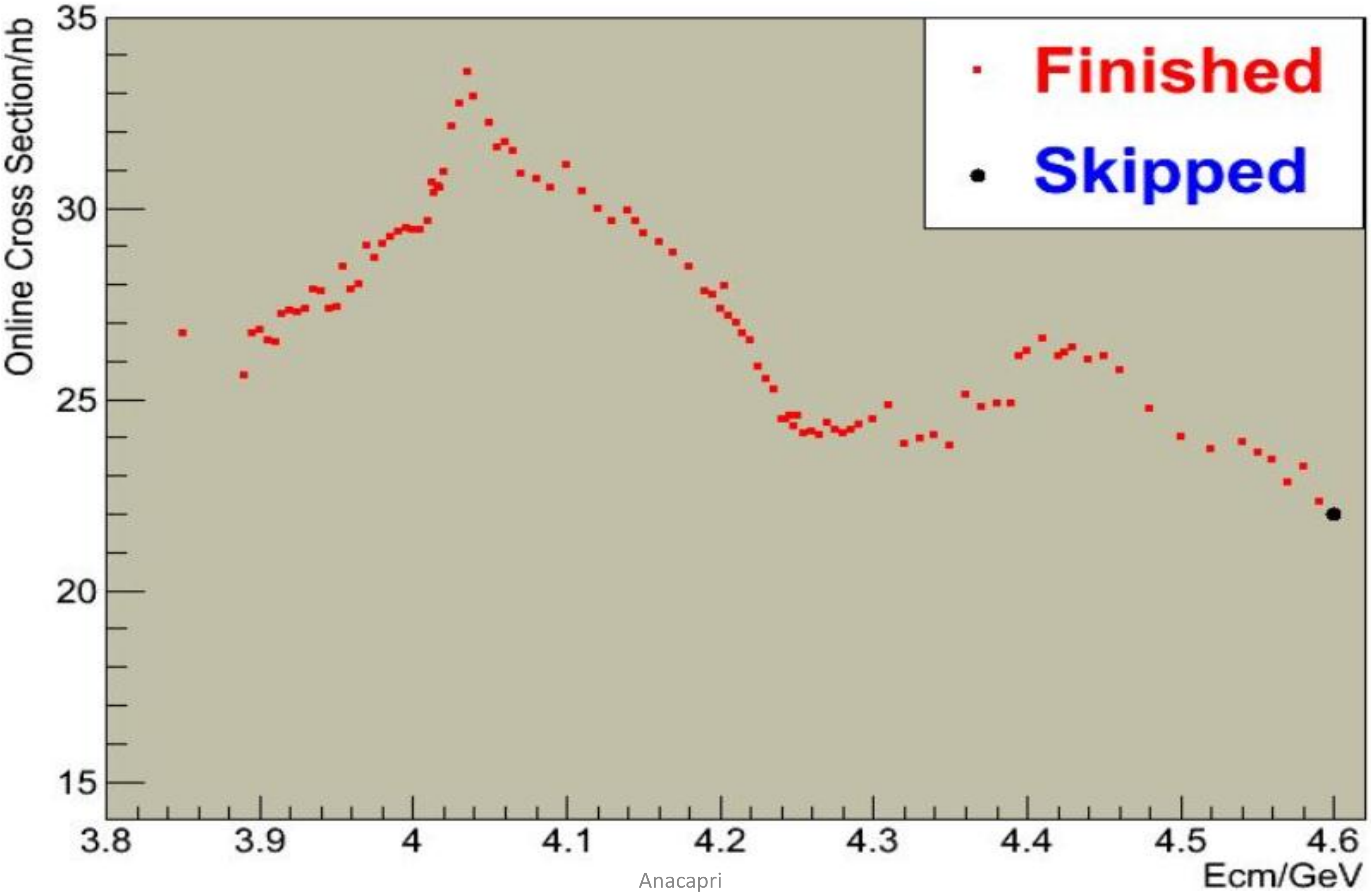
Summary

BESIII started data taking for physics since 2009

- World largest data samples at J/ψ, ψ',$\psi(3770)$, $\psi(4040)$, Y(4260) already collected, more data in future coming soon
- BESIII is in her golden age, more results will appear: charm meson, form factors, tau physics, two-photon, rare processes …
- BESIII is playing leading role on hadron spectroscopy
- Observation of X(3872), Zc(3900),Zc(4025),…
- Expect more results from BESIII in the future !

Thanks!

Online cross sections



BESIII: $e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.260 GeV

PRL 110, 252001