Latest results from BESIII

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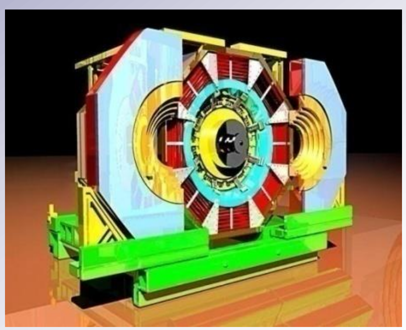
on behalf of the BESIII Collaboration



Selected Problems In Quantum Field Theory

Seminar devoted to the memory of Prof. E.A. Kuraev

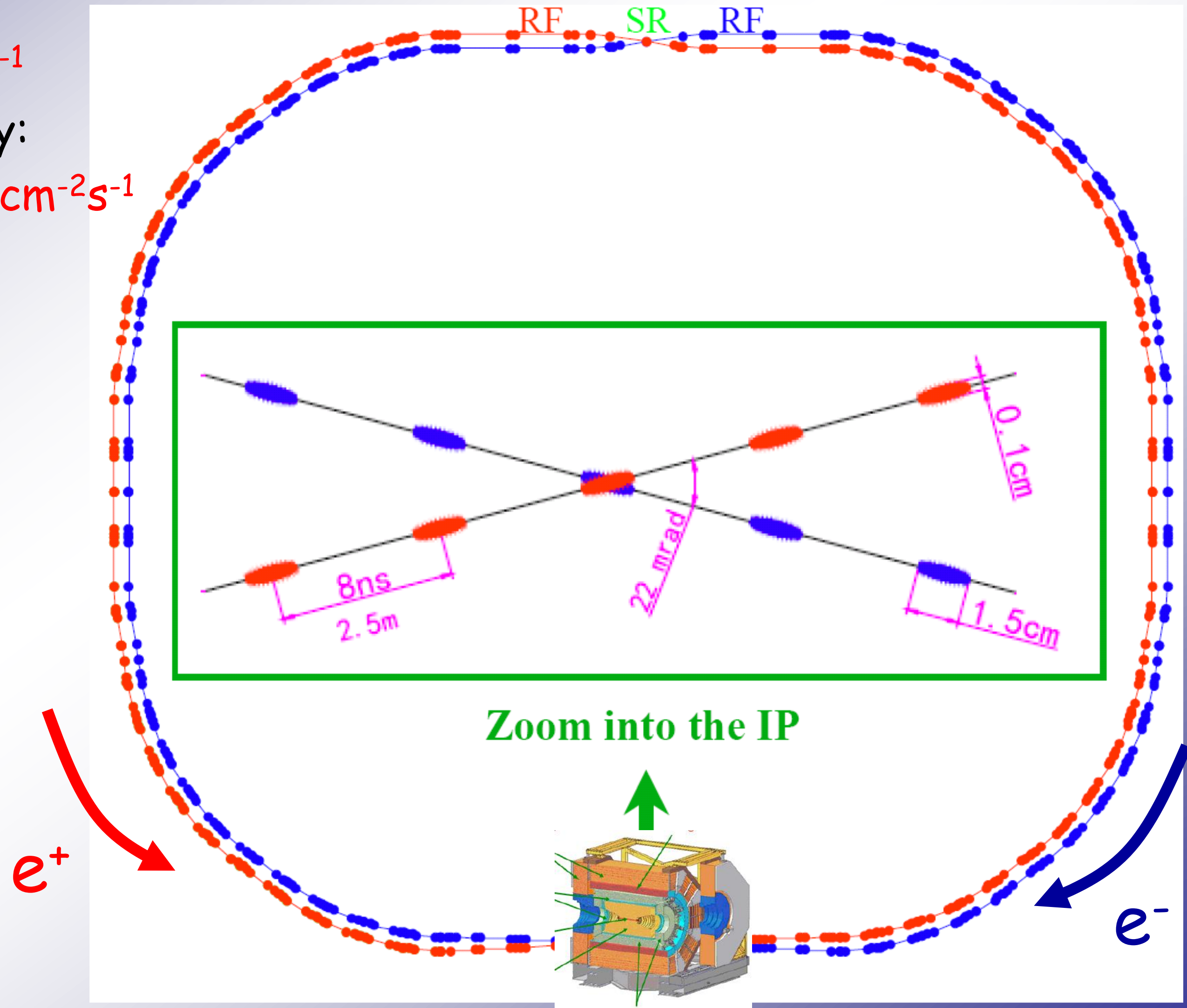
JINR, Dubna, Russia

April 6-8, 2015

BEPCII Storage Rings

Beijing Electron-Positron Collider II

- Beam energy:
  1.0-2.3 GeV
- Design Luminosity:
  1×10^{33} $cm^{-2}s^{-1}$
- Achieved Luminosity:
  $\sim 0.85 \times 10^{33}$ $cm^{-2}s^{-1}$
- 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
- Circumference:
  237m

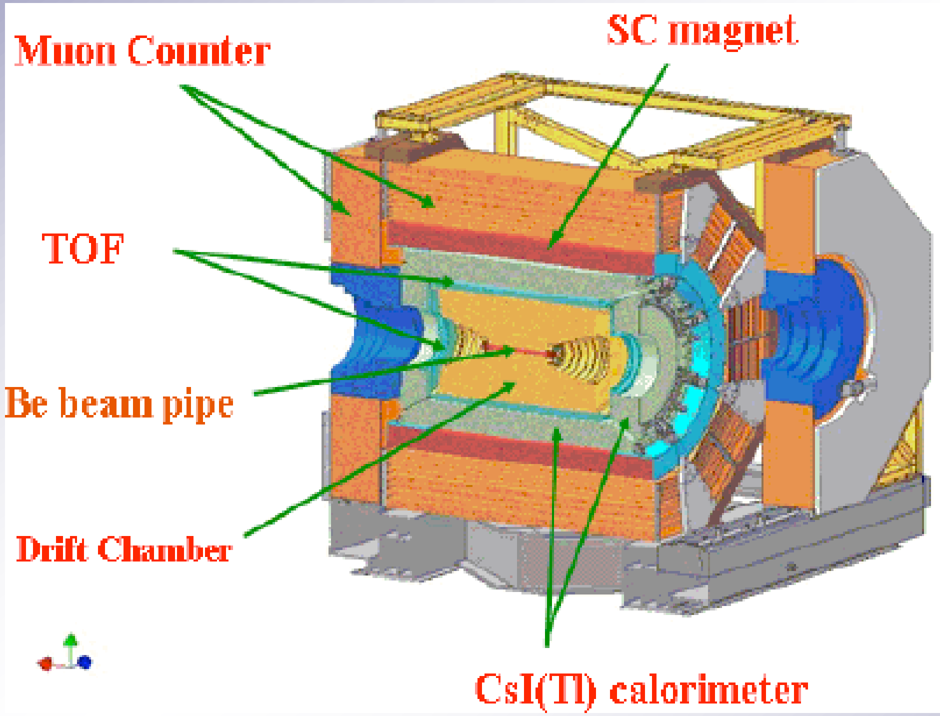


The BESIII Spectrometer @ IHEP

BEijing Spectrometer III

e^+e^- collisions

$\sqrt{S}$ tuned depending on energy

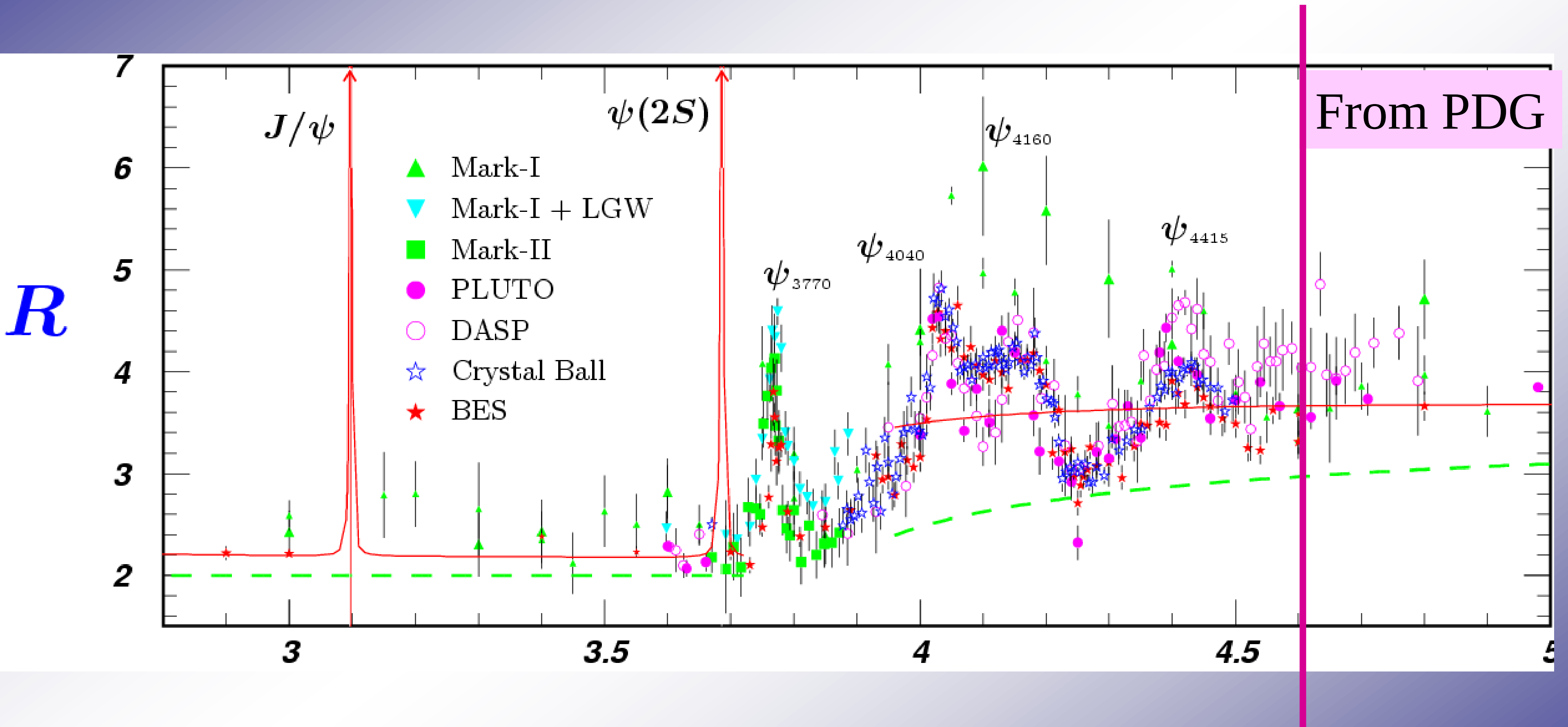


Physics program

- Charmonium Physics
- D-Physics
- Light Hadron Spectroscopy
- τ-Physics
- ...

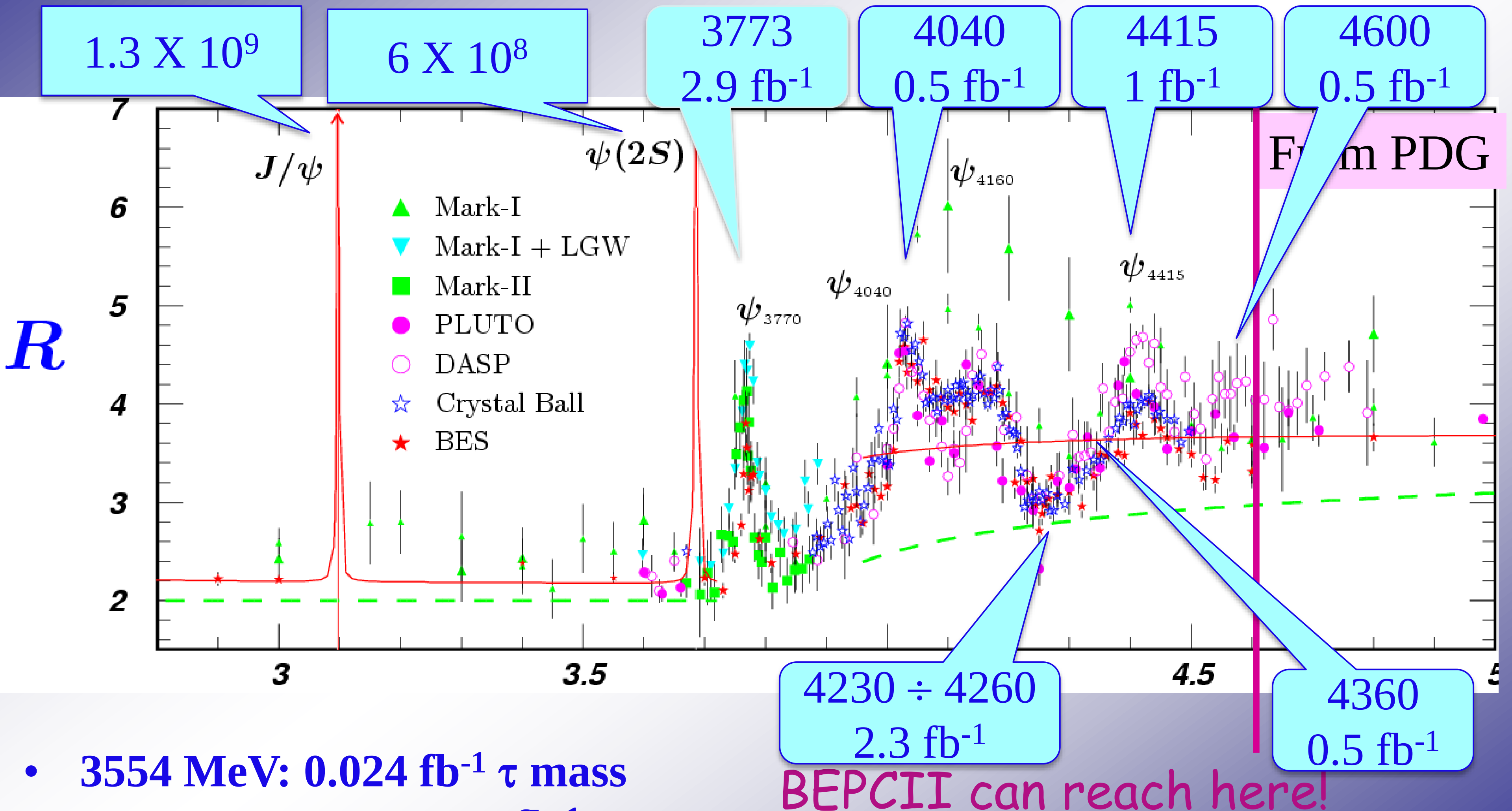
D.M. Asner et al, Physics at BES-III, arXiv:0809.1869v1 [hep-ex] (2008)

BESIII Production of Charmonium(like) states



BEPCII can reach here!

BESIII Production of Charmonium(like) states



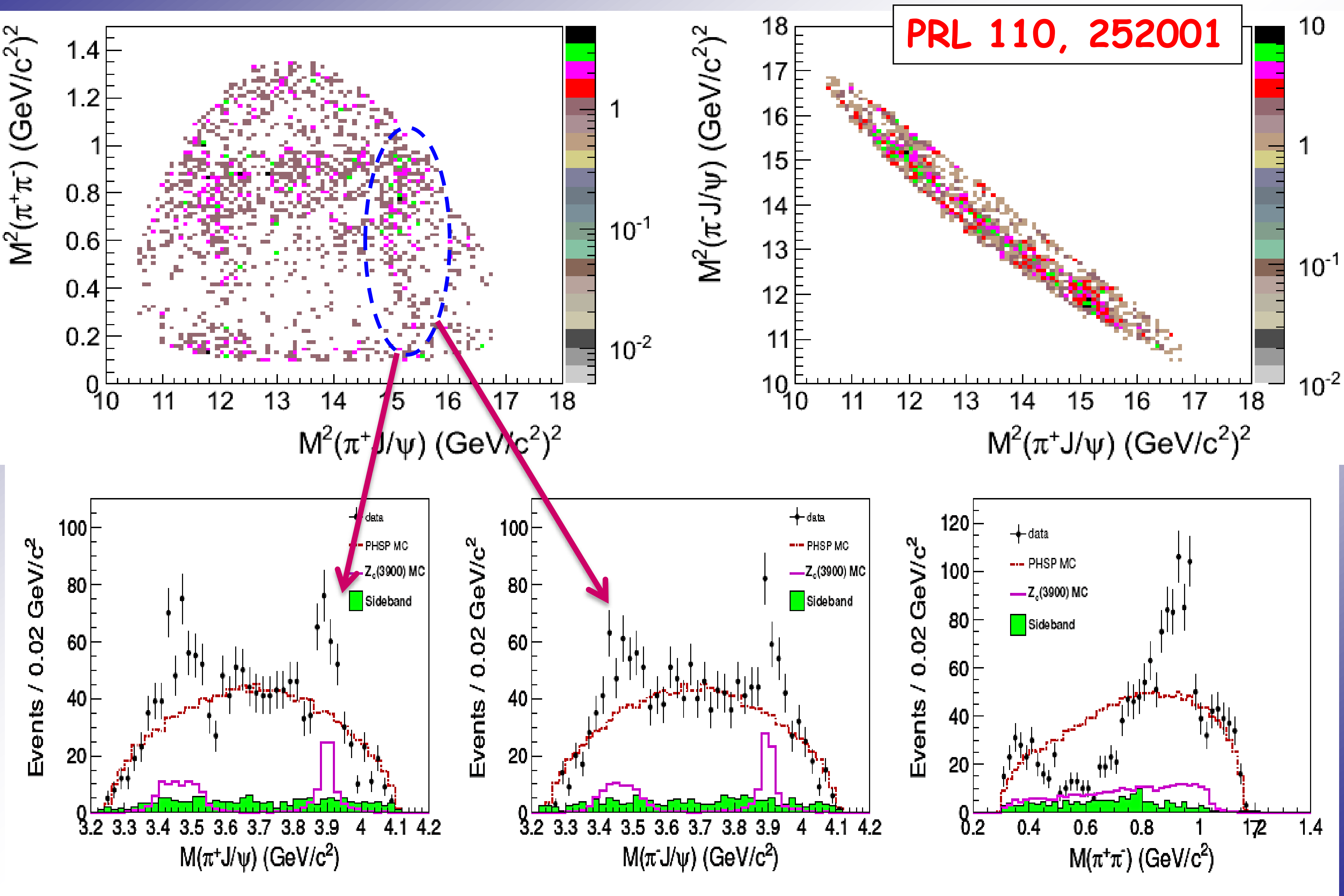
- 3554 MeV: 0.024 fb^{-1} τ mass
- 4100 ÷ 4400 MeV: 0.5 fb^{-1} coarse scan
- 3850 ÷ 4590 MeV: 0.5 fb^{-1} fine scan

Observation of a charmonium like structure: $Z_c(3900)^{\pm}$

PRL 110, 252001

- 2013: 515 pb^{-1} @ 4260 MeV
- $e^+e^- \rightarrow \pi^+\pi^- J/\psi$
- Dominant background $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$
- J/ψ signal: [3.08,3.12] GeV
- J/ψ sideband: [3.0,3.06] GeV or [3.14,3.20] GeV
- Structure seen: $Z_c(3900)^{\pm}$ -> $\pi^{\pm}$ J/ψ

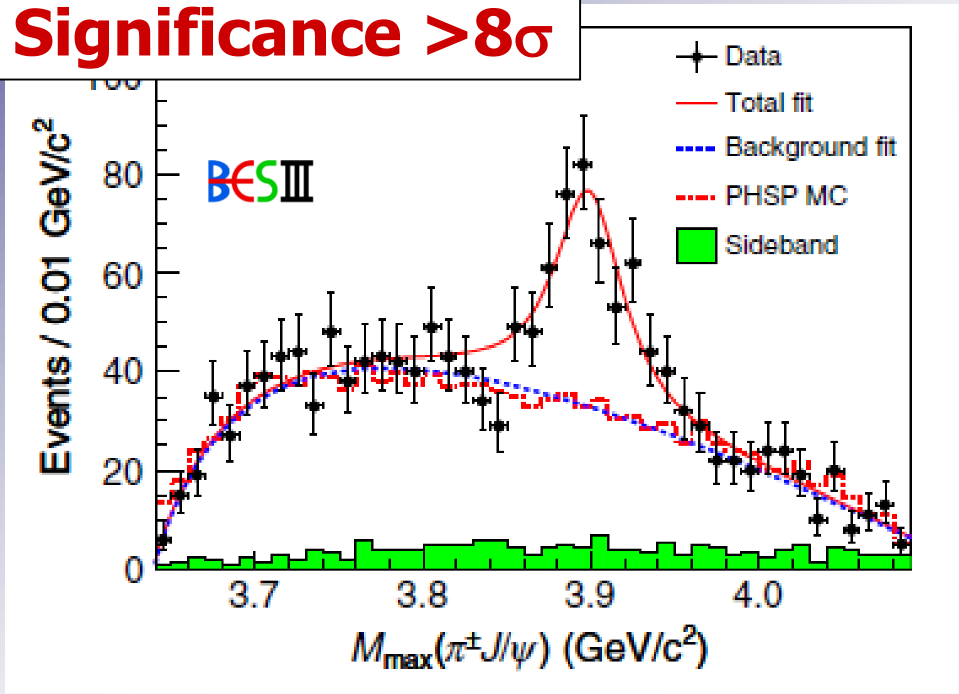
Dalitz Plots and 1D Projections



BESIII: $e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV

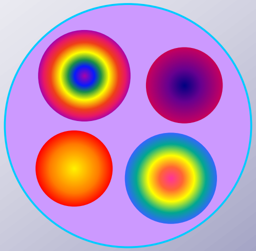
PRL 110, 252001

Significance >8σ



$Z_c(3900)^\pm$

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

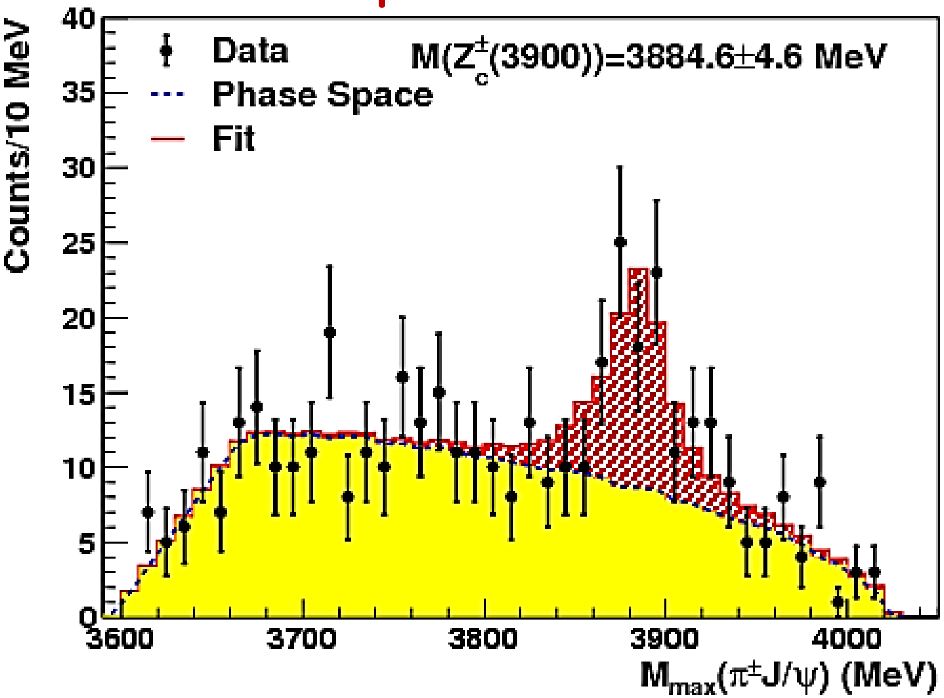


- S-wave Breit-Wigner with efficiency correction
- Mass = (3899.0±3.6±4.9) MeV
- Width = (46±10±20) MeV
- Fraction = (21.5±3.3±7.5)%

BESIII: $e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV

K. Seth & co. @ 4.170 GeV

hep-ex:1304.3036

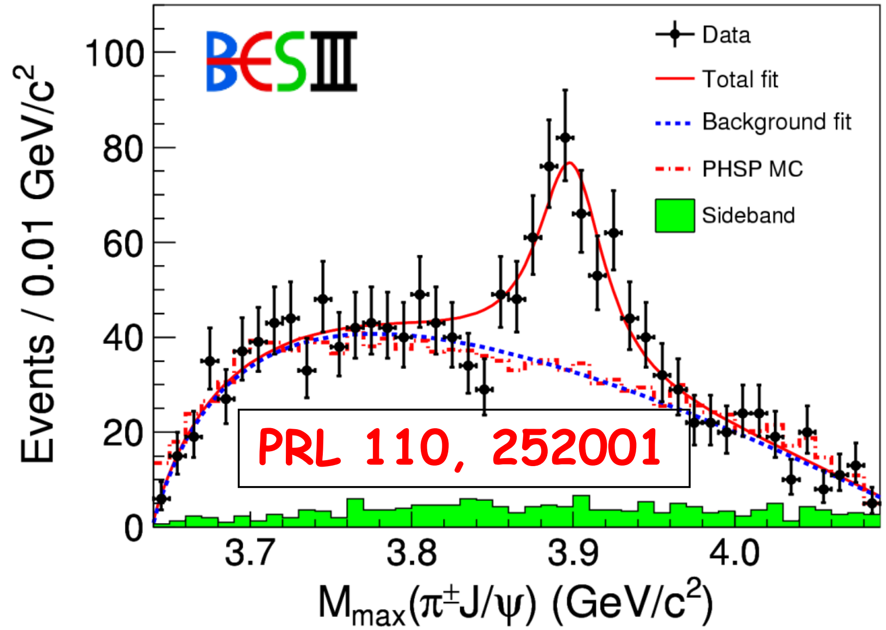


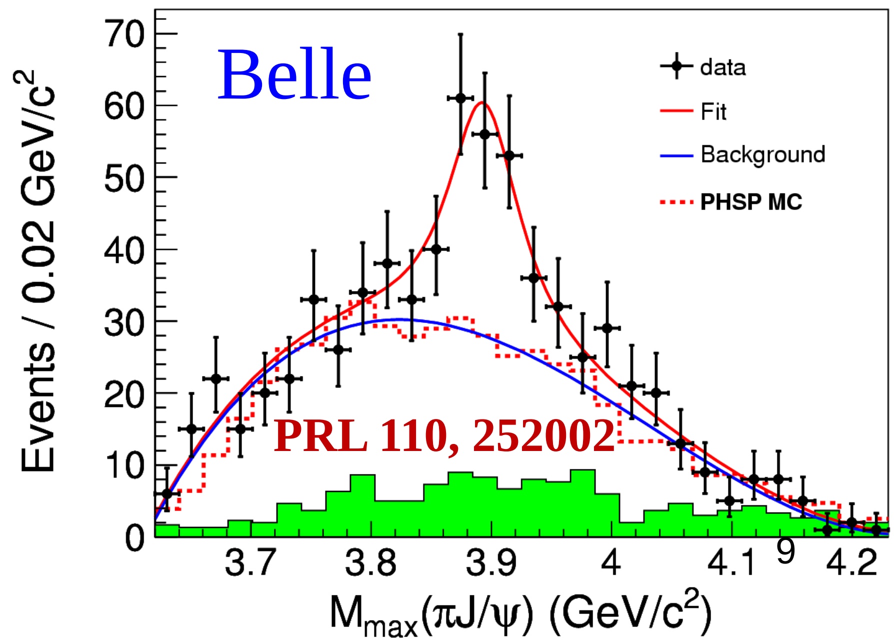
$M = (3885 \pm 5 \pm 1)$ MeV/c^2

$\Gamma = (34 \pm 12 \pm 4)$ MeV/c^2

81±20 events

6.1σ

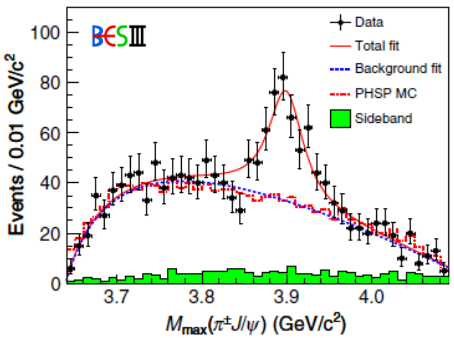




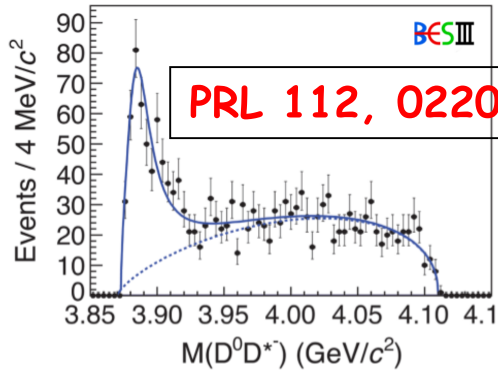
BESIII: Z_c Results

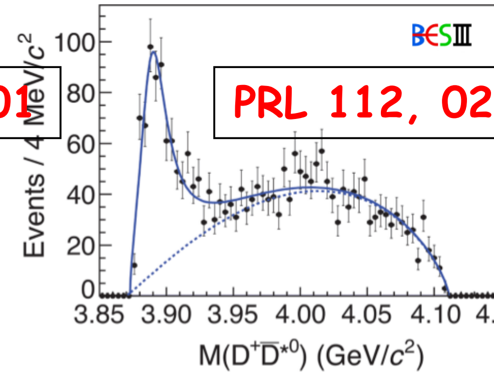
PRL 110, 252001

$e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV



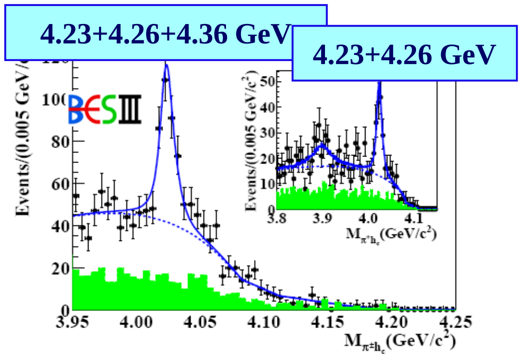
$e^+e^- \to \pi^-(D\overline{D}^*)^+$+c.c. @ 4.26 GeV





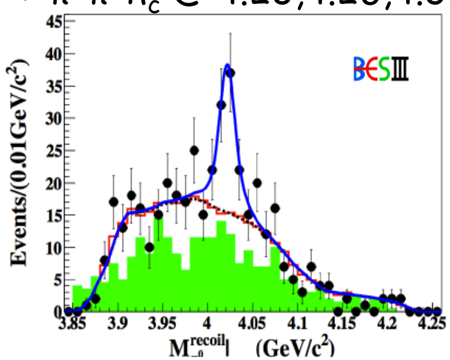
PRL 111, 242001

$e^+e^- \to \pi^+\pi^- h_c$ @ 4.23,4.26,4.36 GeV



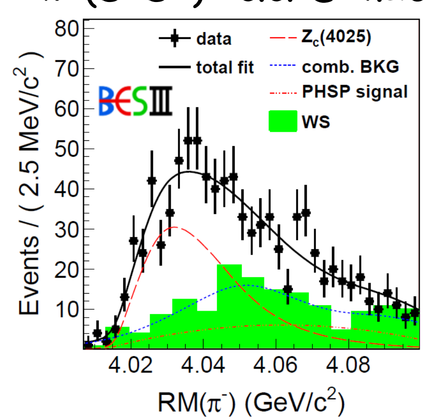
PRL 113, 212002

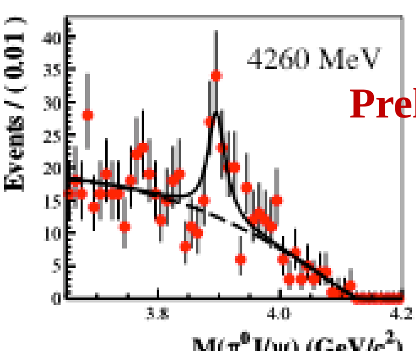
$e^+e^- \to \pi^0\pi^0 h_c$ @ 4.23,4.26,4.36 GeV

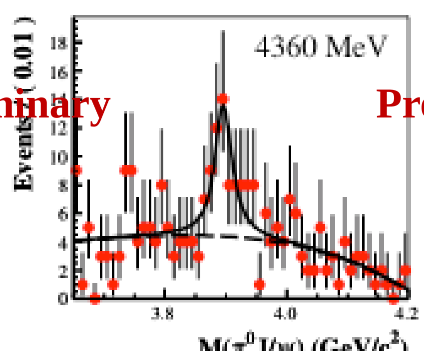


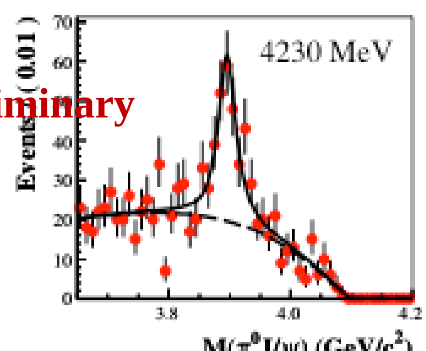
PRL 112, 132001

$e^+e^- \to \pi^{-+}(D^*\overline{D}^*)^\pm$+c.c. @ 4.26 GeV









$e^+e^- \to \pi^0\pi^0 J/\psi$
@ 4.23,4.26,4.36 GeV

Above 4 GeV

- The observed charmonium-like states Y(4260), Y(4360), and Y(4660) can not interpreted as conventional charmoniums.
- New decay modes searching and the line shape measurement is useful for understanding the nature of these Y-states.
- Hadronic transitions (by an η or π^0) to lower charmonia like J/ψ are regarded as sensitive probes to study the properties of these Y-states.
- Nature of these Y-states:

  hybrids ?

  tetraquarks?

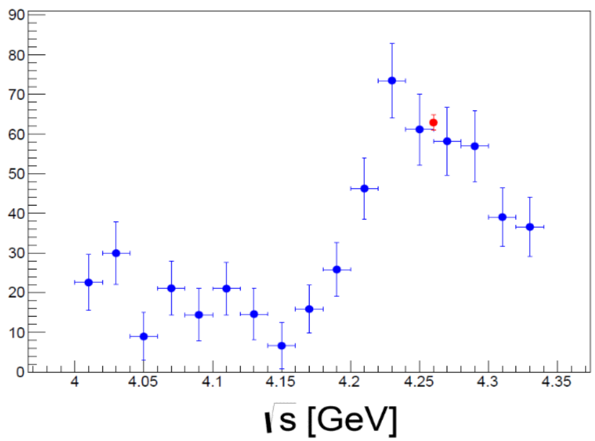
  hadro-charmonium?

  hadronic molecule?

BESIII: Cross Sections Results

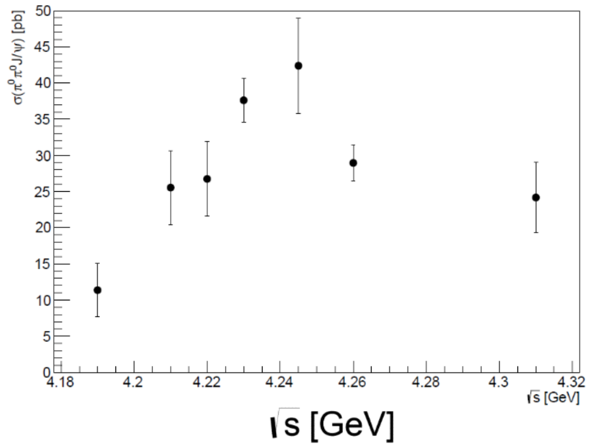
PRL 110, 252001

$e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV



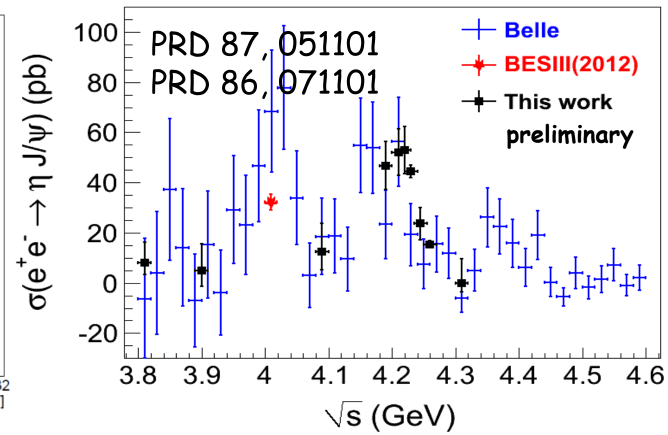
BESIII Preliminary!

$e^+e^- \to \pi^0\pi^0 J/\psi$ @ 4.19-4.31 GeV

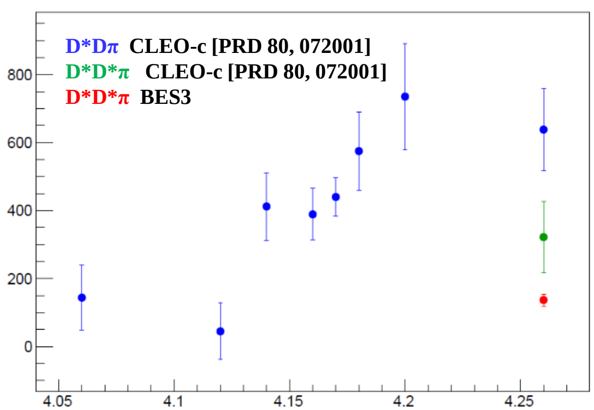


BESIII Preliminary!

$e^+e^- \to \eta J/\psi$ @ 3.81-4.31 GeV

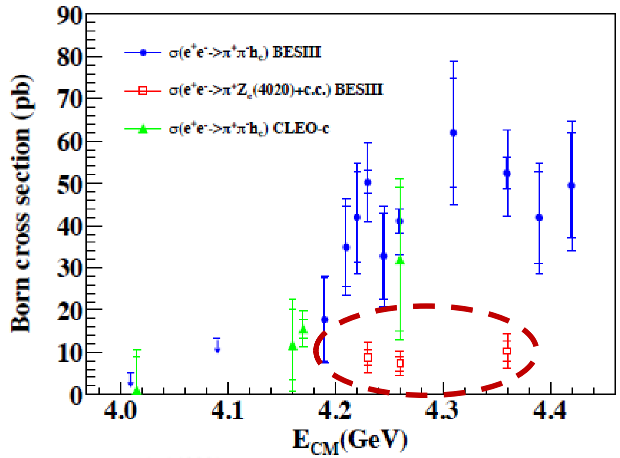


PRL 112, 132001



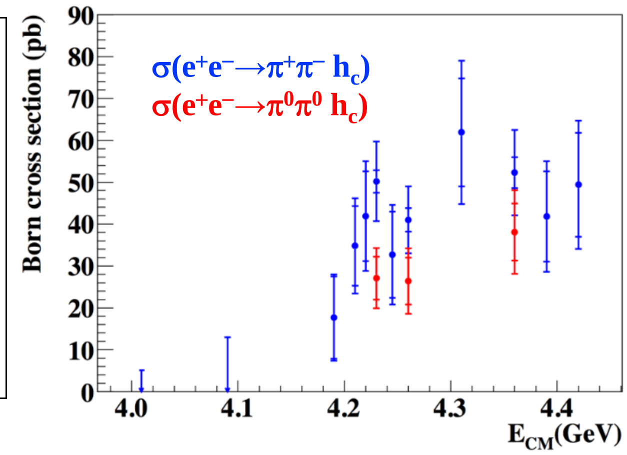
$e^+e^- \to \pi^{-+}(D^*\bar{D}^*)^{\pm}$+c.c. @ 4.26 GeV

PRL 111, 242001



$e^+e^- \to \pi^+\pi^- h_c$ @ 4.23,4.26,4.36 GeV

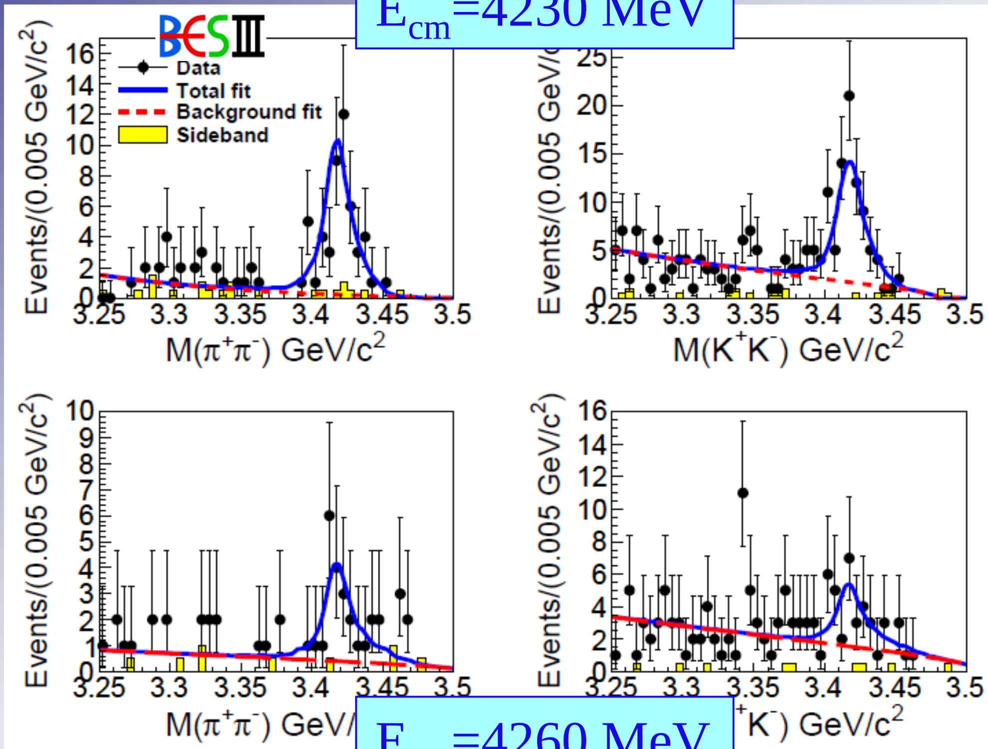
BESIII Preliminary!



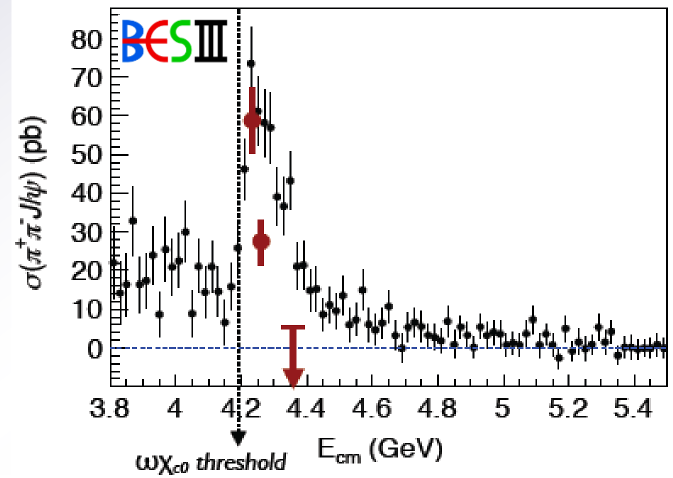
BESIII: $e^+e^- \to \omega\chi_{cJ}$ @ 4.21-4.42 GeV

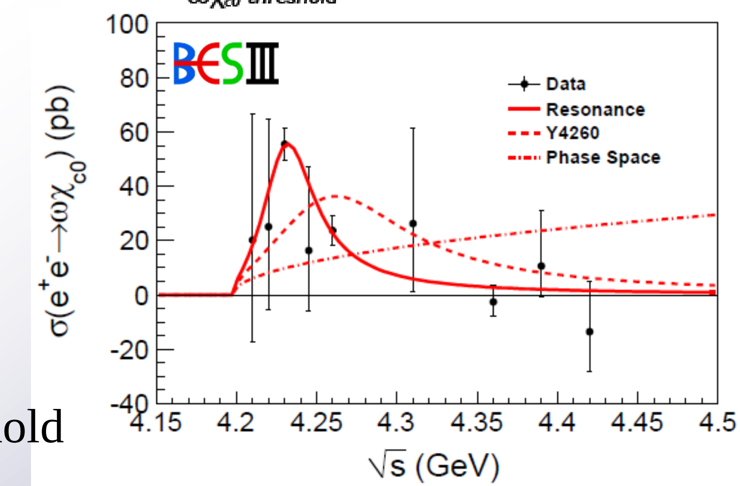
PRL 114 (2015) 9, 092003

E_{cm}=4230 MeV



E_{cm}=4260 MeV





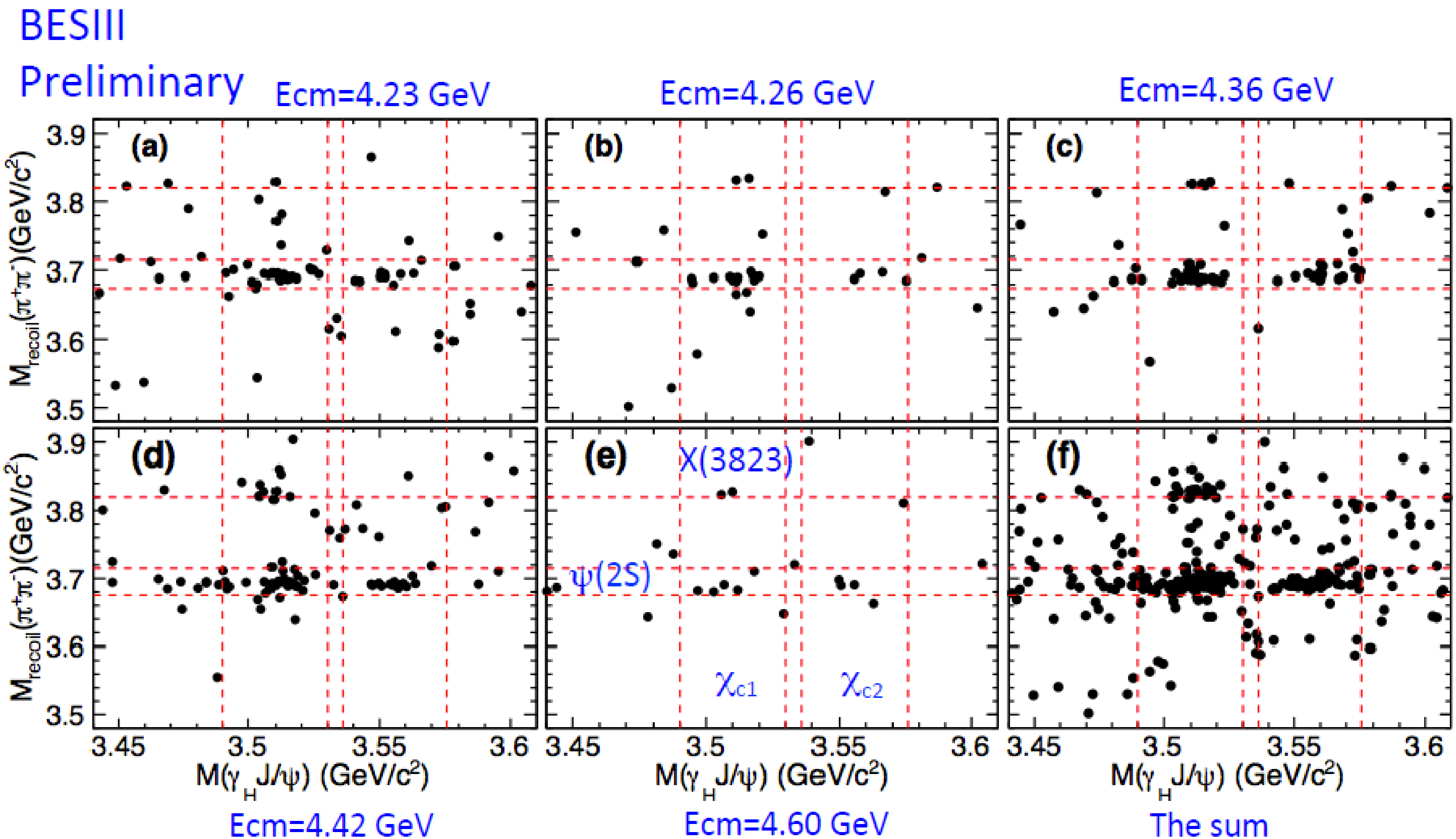
- The mass of Y(4260) is very close to $\omega\chi_{cJ}$ mass threshold
- Observation of $\omega\chi_{c0}$ at 4230, 4260 MeV data
- No evidence at 4360MeV
- Line shape seems inconsistent with Y(4260)
- BW fitting: a narrow structure around 4230MeV.

A fine structure at 4230MeV?

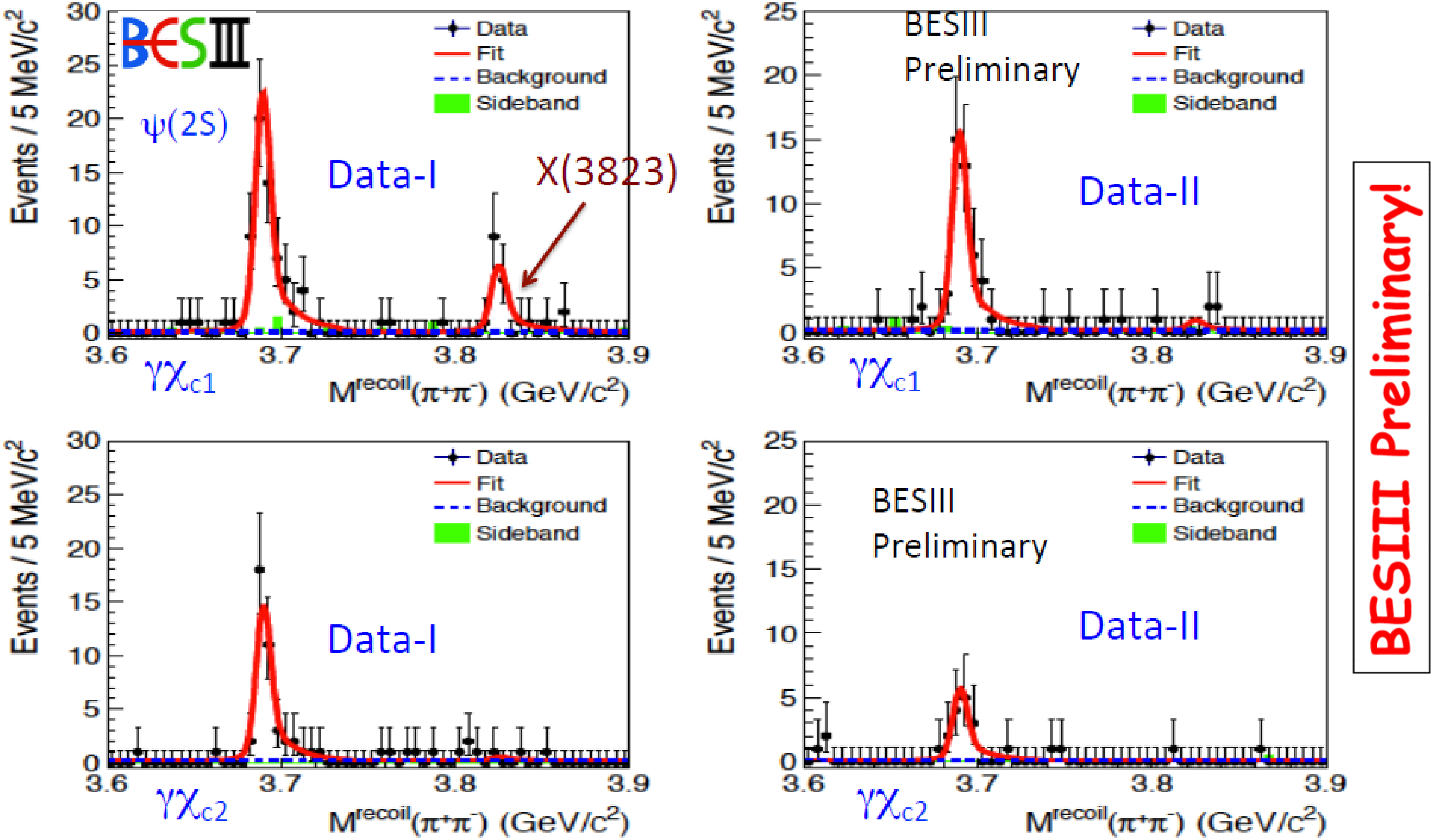
$$M = (4229 \pm 11 \pm 6)\ \text{MeV}/c^2$$
$$\Gamma = (40 \pm 14 \pm 2)\ \text{MeV}/c^2$$

BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{c1,2}$ @ 4.19-4.60 GeV

BESIII Preliminary!



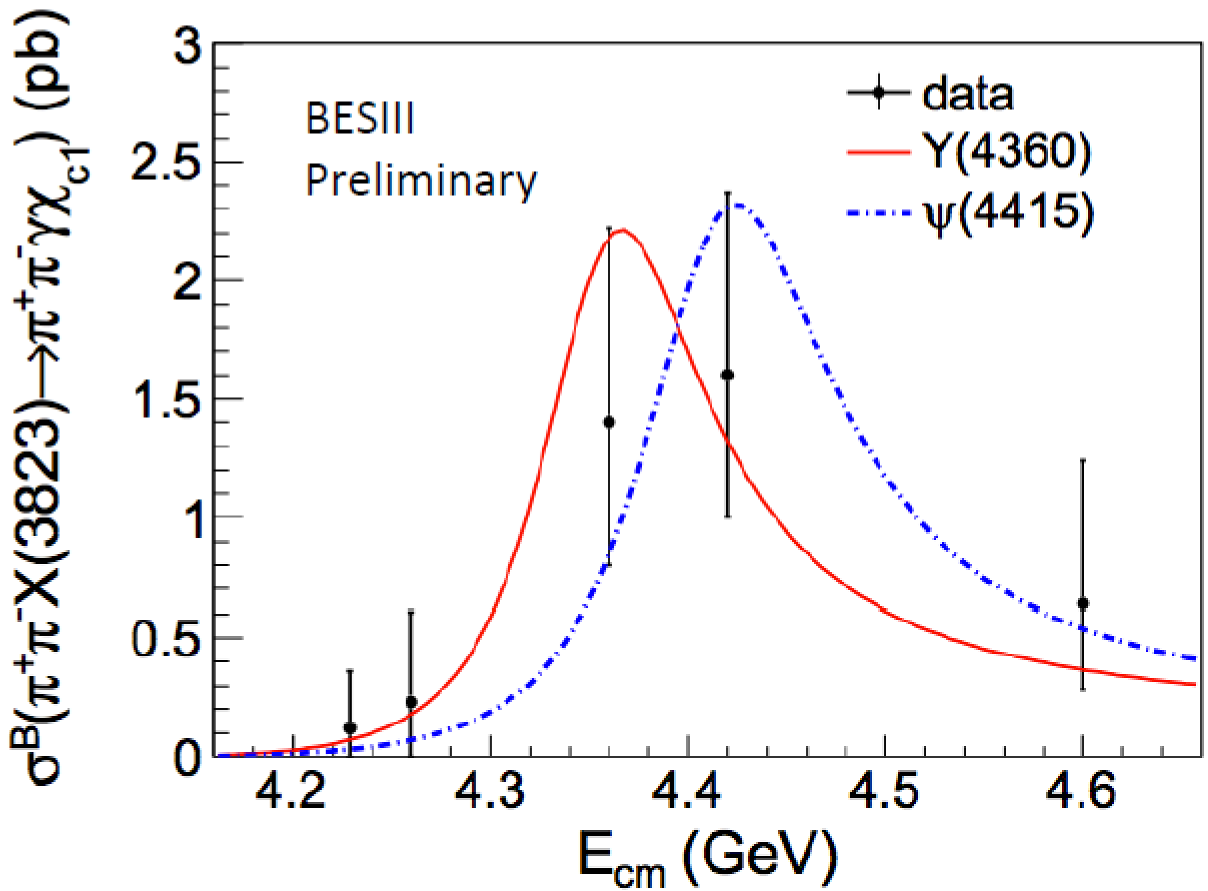
BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{c1,2}$ @ 4.19-4.60 GeV



- Simultaneous fit: data-I (4.36, 4.42, 4.60 GeV) & data-II (4.23, 4.26 GeV)
- Signal: MC simulated shape + Background: linear
- M=3821.7±1.3±0.7 MeV; Significance: 6.7σ, observation !

BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{C1,2}$ @ 4.19-4.60 GeV

BESIII Preliminary!



1. Energy dependent cross section of $e^+e^- \to \pi^+\pi^- X(3823)$.
2. Both Y(4360) and $\psi(4415)$ line shape give reasonable description.

J/ψ Strong and Electromagnetic Decay Amplitudes

Resonant contributions

$\Gamma_{J/\psi} \sim 93\text{KeV} \rightarrow \text{pQCD}$

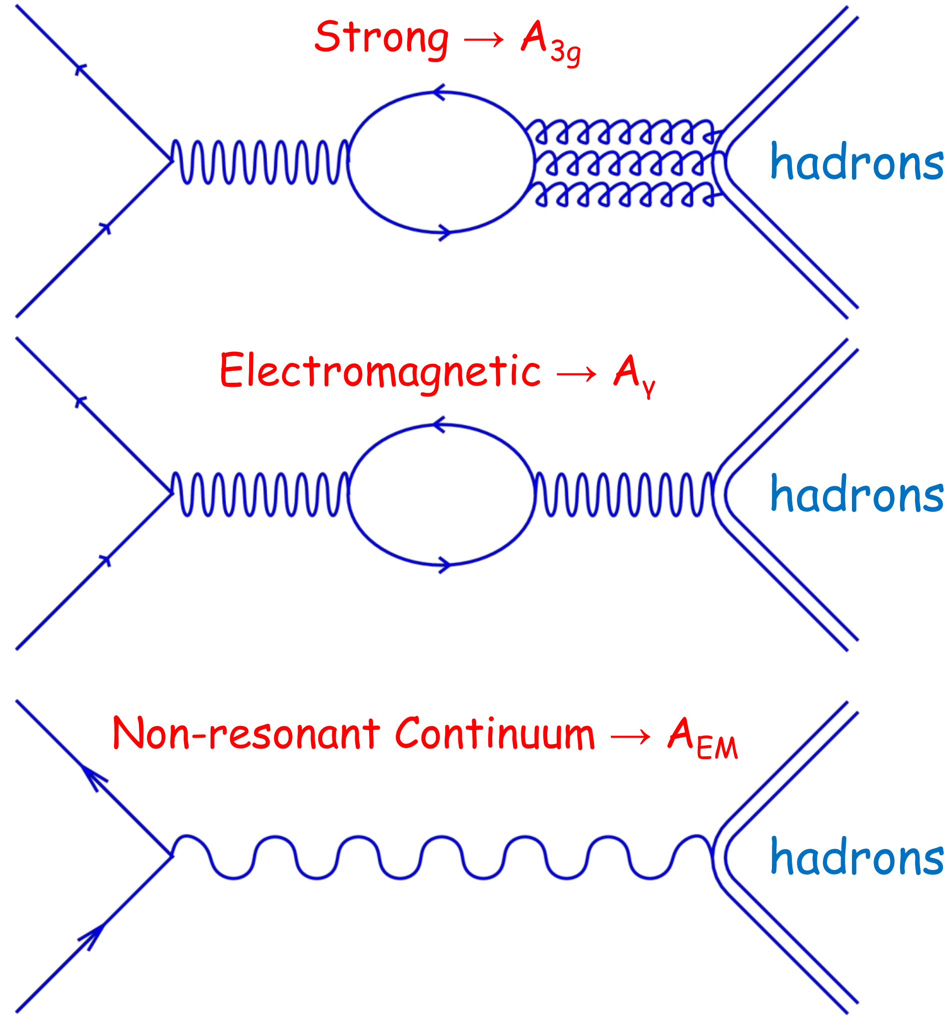
pQCD: all amplitudes almost real [1,2]

QCD -> $\Phi_p \sim 10^\circ$ [1]

Non-resonant continuum

pQCD regime

$A_{EM} \in \Re$



[1] J. Bolz and P. Kroll, WU B 95-35.
[2] S.J. Brodsky, G.P. Lepage, S.F. Tuan, Phys. Rev. Lett. 59, 621 (1987).

J/ψ Strong and Electromagnetic Decay Amplitudes

- If both real, they must interfere ($\Phi_p \sim 0°/180°$)
- On the contrary $\Phi_p \sim 90° \rightarrow$ No interference

$J/\psi \rightarrow N\bar{N}$ ($\frac{1}{2}^+\frac{1}{2}^-$) $\Phi_p = 89° \pm 15°$ [1]; $89° \pm 9°$[2]

$J/\psi \rightarrow$ VP (1^-0^-) $\Phi_p = 106° \pm 10°$ [3]

$J/\psi \rightarrow$ PP (0^-0^-) $\Phi_p = 89.6° \pm 9.9°$ [4]

$J/\psi \rightarrow$ VV (1^-1^-) $\Phi_p = 138° \pm 37°$ [4]

- Results are model dependent
- Model independent test:

interference with the non resonant continuum

[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997); R. Baldini et al., Phys. Lett. B444, 111 (1998)
[2] J.M. Bian et al., J/ψ -> ppbar and J/ψ -> nnbar measurement by BESIII, to be published on PRD
[3] L. Kopke and N. Wermes, Phys. Rep. 174, 67 (1989); J. Jousset et al., Phys. Rev. D41,1389 (1990)
[4] M. Suzuki et al., Phys. Rev. D60, 051501 (1999).

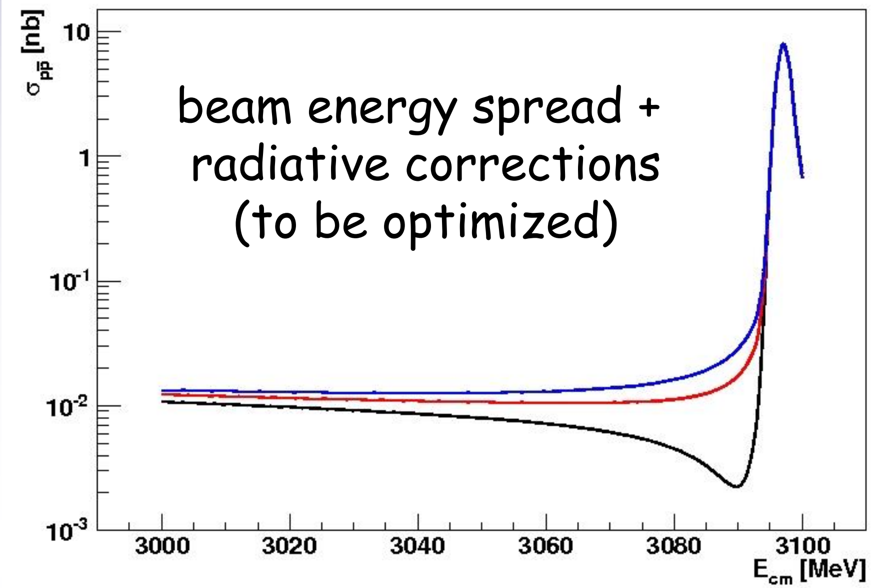
Simulated Yields for $e^+e^- \to p\bar{p}$

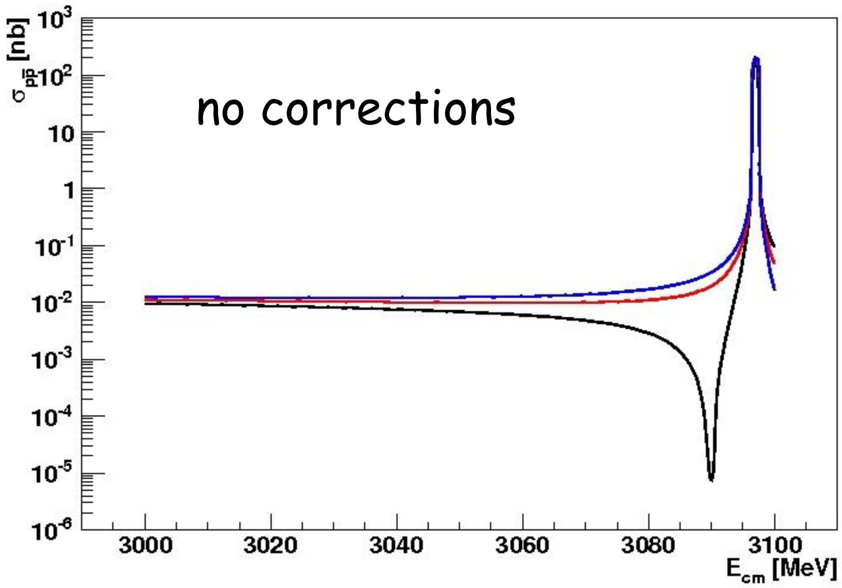
— $\Delta\varphi = 0°$

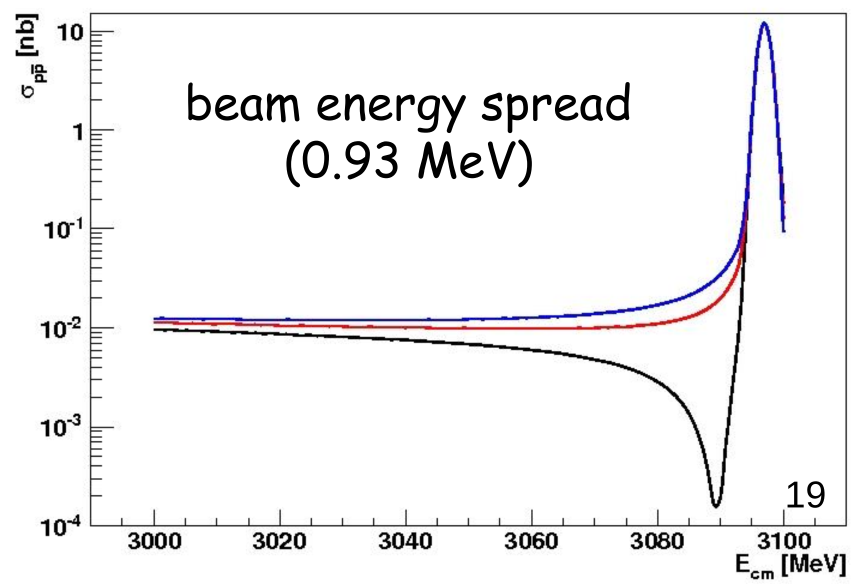
— $\Delta\varphi = 90°$

— $\Delta\varphi = 180°$

continuum reference
$\sigma \sim 11$ pb







Summary

- Studies on X, Y, and Z states are ongoing
- Many new results from experimental data
- Extremely good precision

Next plans

- Collect data at higher energies to complete scans
- Higher luminosity expected from BEPCII
- Many analysis are ongoing

Stay tuned

- Many new exciting results on their way

Backup Slides

BESIII Detector

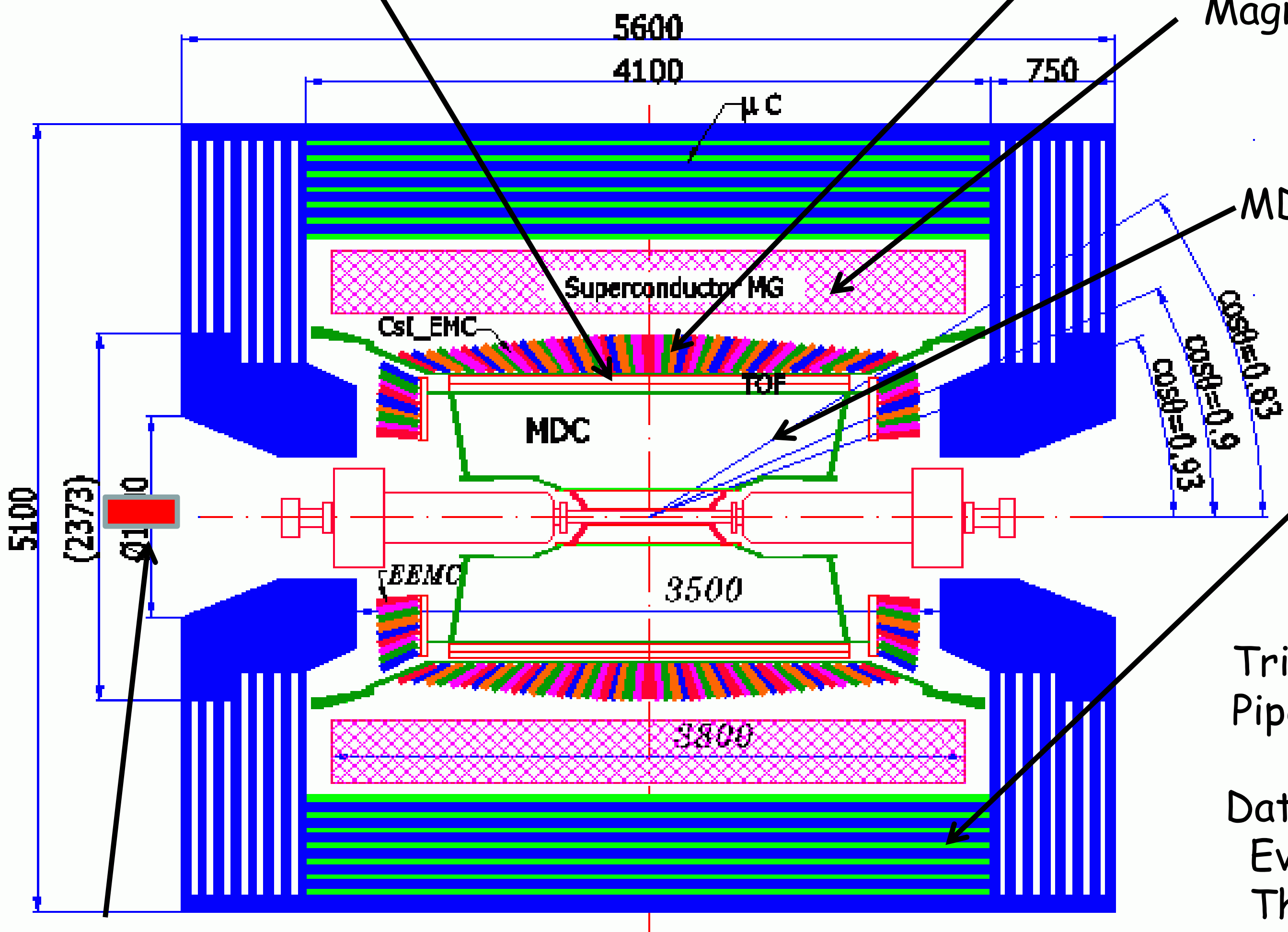
TOF:
σ_T = 80 ps Barrel
110 ps Endcap

EMC: CsI crystals, 28 cm
$\Delta E/E$ = 2.5% @1 GeV
σ_z = 0.6 cm/$\sqrt{E}$

Magnet: 1T Superconducting

MDC: small cell & He gas
σ_{xy}= 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Muon: 9 layer RPC

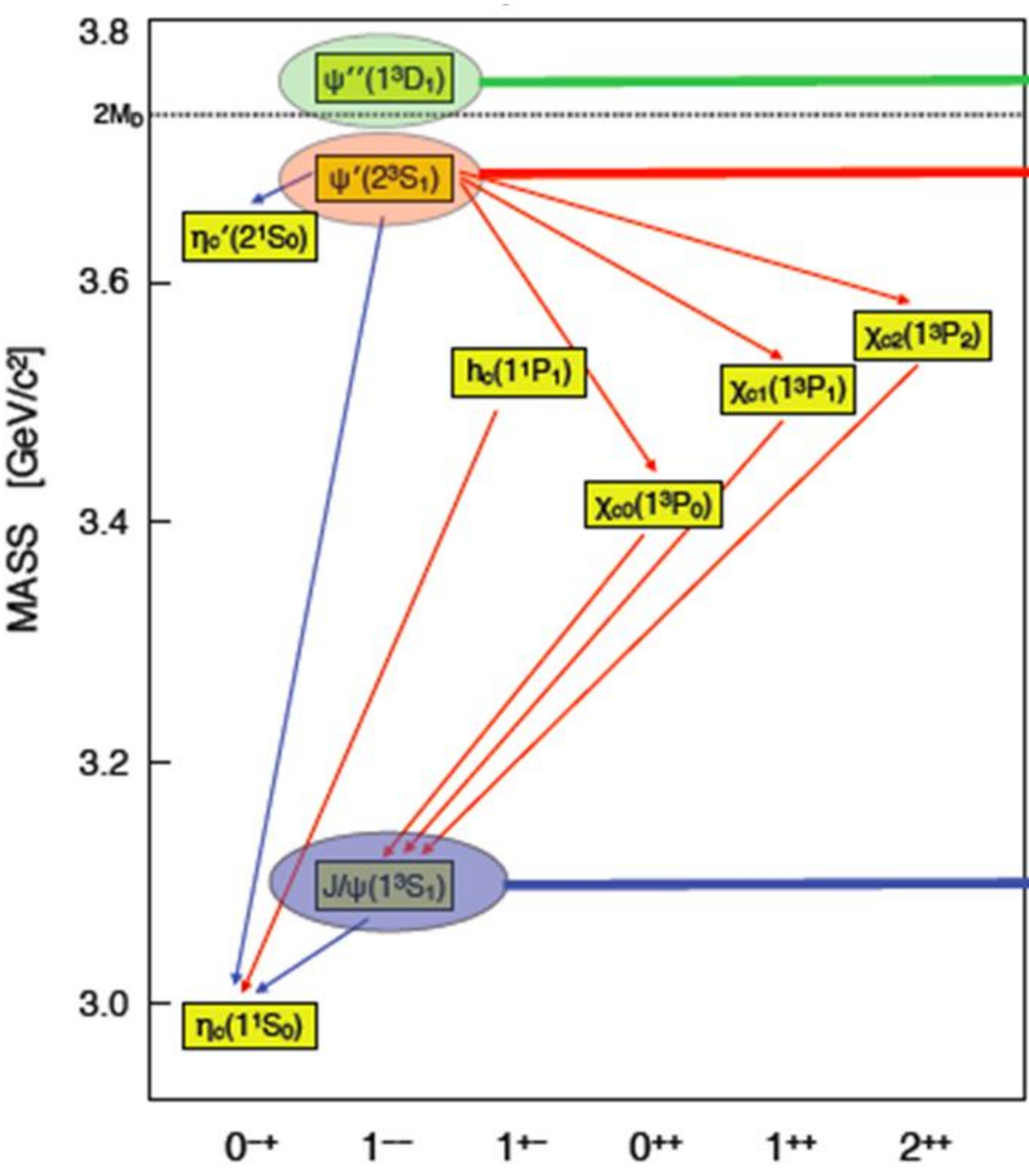


Trigger: Tracks & Showers
Pipelined; Latency = 2.4 ms

Data Acquisition:
Event rate = 3 kHz
Thruput ~ 50 MB/s

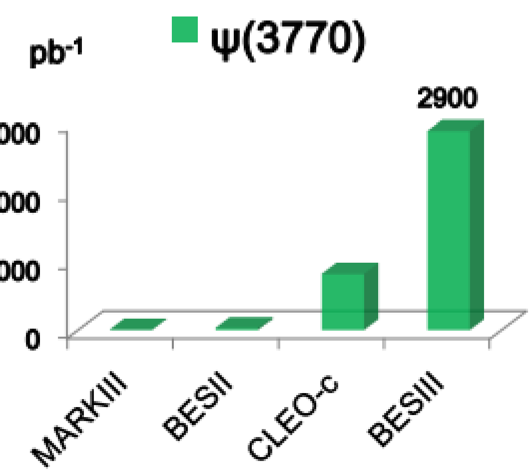
Zero Degree Detector (ISR)

BESIII Data Set

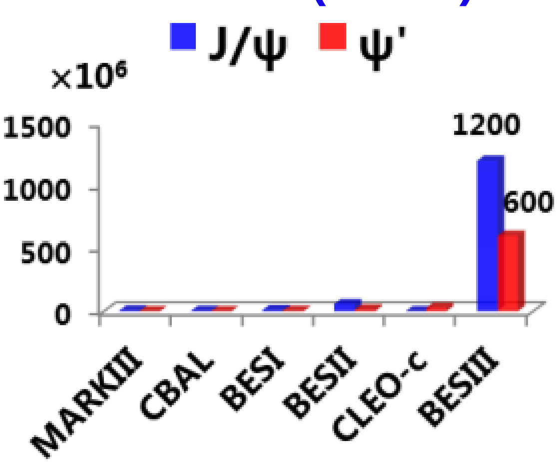


2.9 fb^{-1} / 20 fb^{-1}

0.6 B / 3 B (106 M)



1.3 B / 10 B (225 M)



BESIII Data Taking

E_{cm} (MeV)	run	luminosity (pb^{-1})
4190	30372–30437	43.09
4210	31983–32045	54.55
4220	32046–32140	54.13
4230	32239–33484 and 30438–30491	1091.74
4245	32141–32226	55.59
4260	29677–30367 and 31561–31981	825.67
4310	30492–30557	44.90
4360	30616–31279	539.84
4390	31281–31325	55.18
4420	31327–31390	44.67
Total		2809.36

BESIII Data Taking

1.3×10^9	J/Ψ @ 3.097 GeV	2009 (0.225×10^9) + 2012
0.4×10^9	Ψ' @ 3.686 GeV	2009 (0.106×10^9) + 2012
2.9 fb^{-1}	$\Psi(3770)$ @ 3.773 GeV	2010 + 2011
0.5 fb^{-1}	$\Psi(4040)$ @ 4.009 GeV	2011
0.024 fb^{-1}	τ mass scan at around 3.554 GeV	2011
1.9 fb^{-1}	Y(4260) @ 4.23 and 4.26 GeV	2013
0.5 fb^{-1}	Y(4360) @ 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
1.0 fb^{-1}	@ 4.42 GeV	2014
0.1 fb^{-1}	@ 4.47 GeV	2014
0.1 fb^{-1}	@ 4.53 GeV	2014
0.04 fb^{-1}	@ 4.575 GeV	2014
0.5 fb^{-1}	@ 4.60 GeV	2014

The $Z_c(3900)$ signal

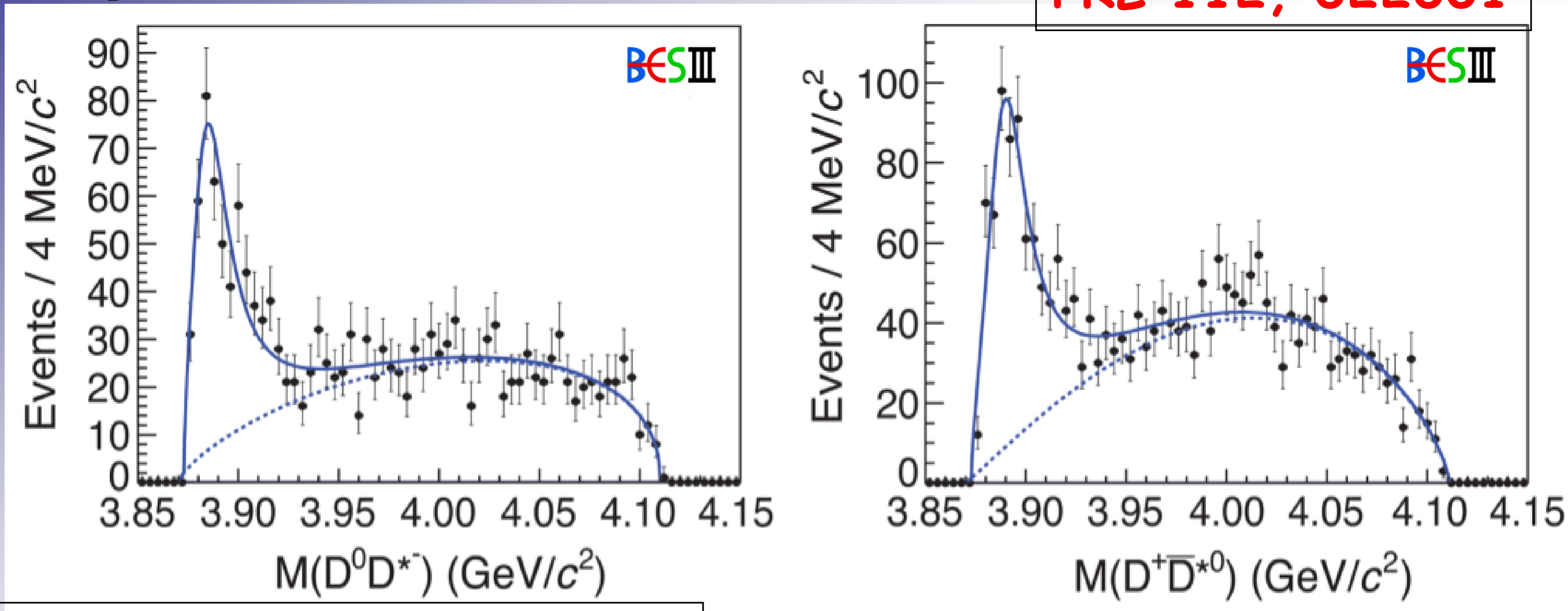
TABLE I: Summary of the systematic errors (%) in the cross section measurement.

Source	$\mu^+\mu^-$	e^+e^-
Luminosity	1.0	1.0
MC Statistics	0.5	0.7
Tracking	4.0	4.0
Background shape	0.5	3.4
$Y(4260)$ line-shape	0.6	0.6
Kinematic fit	2.2	2.3
Branching ratios	1.0	1.0
Decay model	3.1	3.1
Others	1.0	1.0
Total	5.9	6.8

BESIII: $e^+e^- \to \pi Z_c(3885) \to \pi^-(D\bar{D}^*)^+ + c.c.$ @ 4.260 GeV

525 pb^{-1} data @ 4260 MeV

PRL 112, 022001



M = (3883.9±1.5±4.2) MeV/c^2
Γ = (24.8±3.3±11.0) MeV/c^2
>18σ

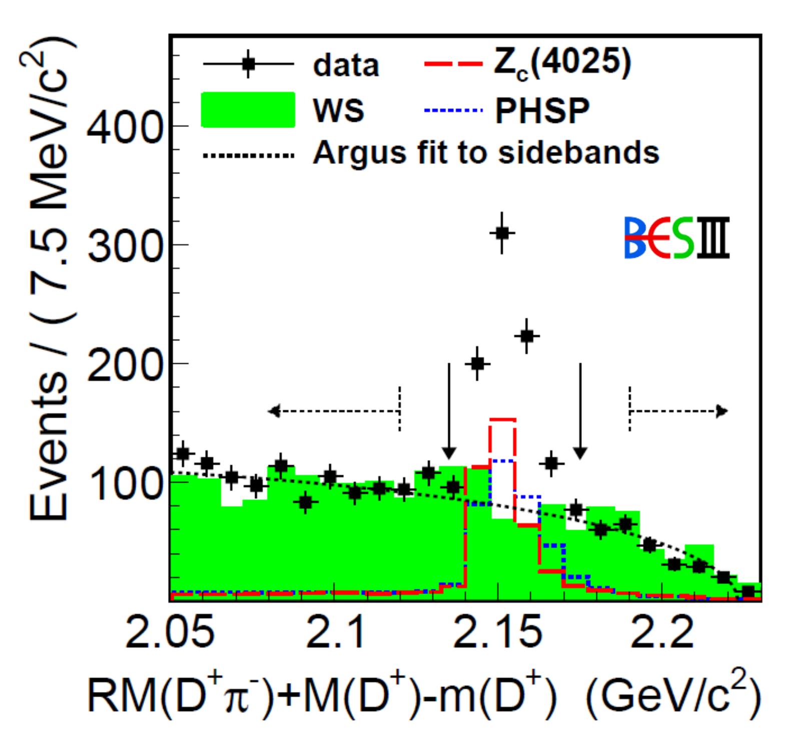
$\pi Z_c(3885)$ ang. dist. favours $J^P = 1^+$
disfavours 1^- e 0^-

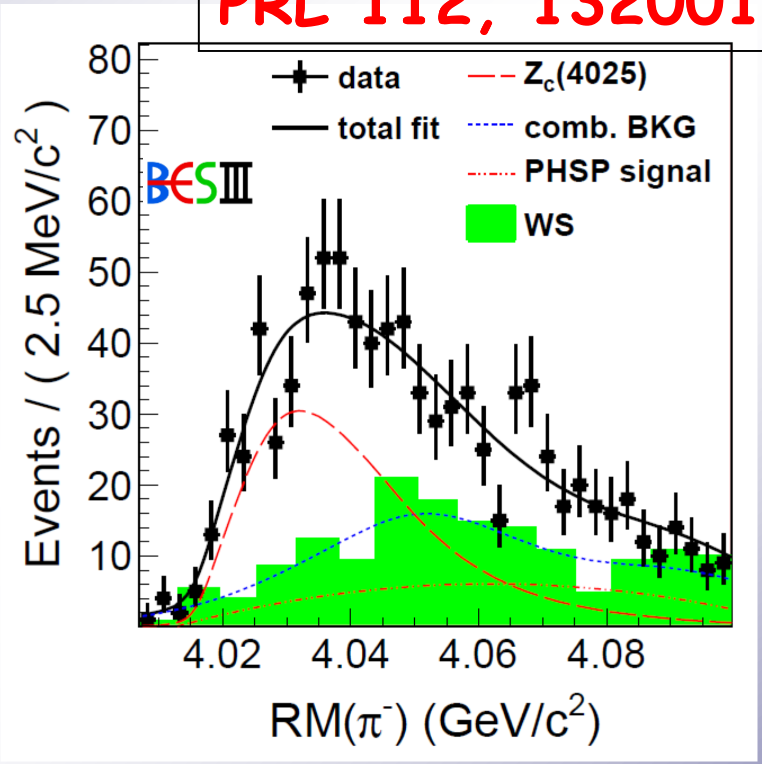
$\sigma(e^+e^- \to \pi^- Z_c(3885)^+ \times Z_c(3885)^+ \to (D\bar{D}^*)^+ + c.c.) = (83.5 \pm 6.6 \pm 22.0)$ pb

$$R = \frac{\Gamma(Z_c(3885) \to D^*\bar{D}^*)}{\Gamma(Z_c(3900) \to \pi J/\psi)} = (6.2 \pm 1.1 \pm 2.7)$$

BESIII: $e^+e^- \to \pi Z_c(4025) \to \pi^-(D^*\bar{D}^*)^+$+c.c. @ 4.260 GeV

PRL 112, 132001





M = (4026.3±2.6±3.7) MeV/c^2

Γ = (24.8±5.7±7.7) MeV/c^2

>10σ

$$\sigma(e^+e^- \to \pi^-(D^*\bar{D}^*)^+ + c.c.) = (137\pm9\pm15)\ \text{pb}$$

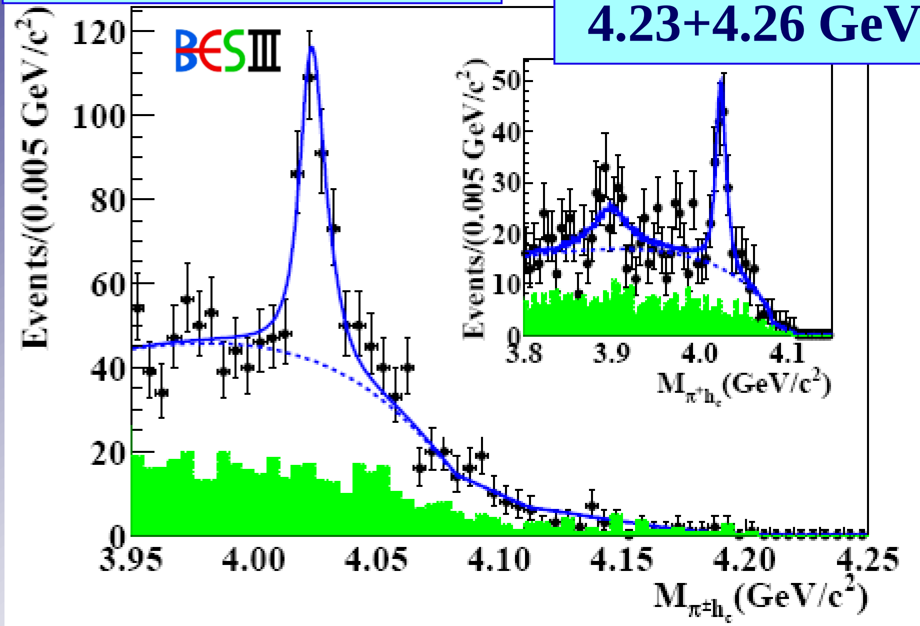
$$R = \frac{\sigma(e^+e^- \to \pi^- Z_c^+ \to \pi^-(D^*\bar{D}^*)^+ + c.c.)}{\sigma(e^+e^- \to \pi^-(D^*\bar{D}^*)^+ + c.c.)} = (65\pm9\pm6)\%$$

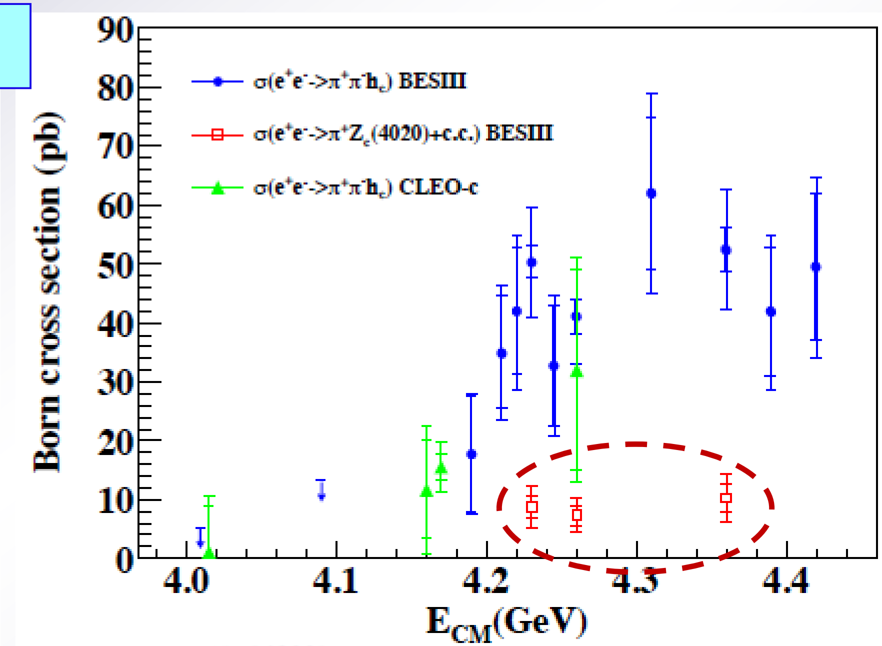
BESIII: $e^+e^- \to \pi Z_c(4020) \to \pi^+\pi^- h_c$ @ 4.23/4.26/4.36 GeV

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

4.23+4.26+4.36 GeV

4.23+4.26 GeV





$M = (4022.9 \pm 0.8 \pm 2.7)$ MeV/c^2

$\Gamma = (7.9 \pm 2.7 \pm 2.6)$ MeV/c^2

$>8.9\sigma$

$\sigma(e^+e^- \to \pi Z_c(4020) \to \pi^+\pi^- h_c)$

$\sigma(4.23\text{ GeV}) = (8.7 \pm 1.9 \pm 2.8 \pm 1.4)$ pb

$\sigma(4.26\text{ GeV}) = (7.4 \pm 1.7 \pm 2.1 \pm 1.2)$ pb

$\sigma(4.36\text{ GeV}) = (10.3 \pm 2.3 \pm 3.1 \pm 1.6)$ pb

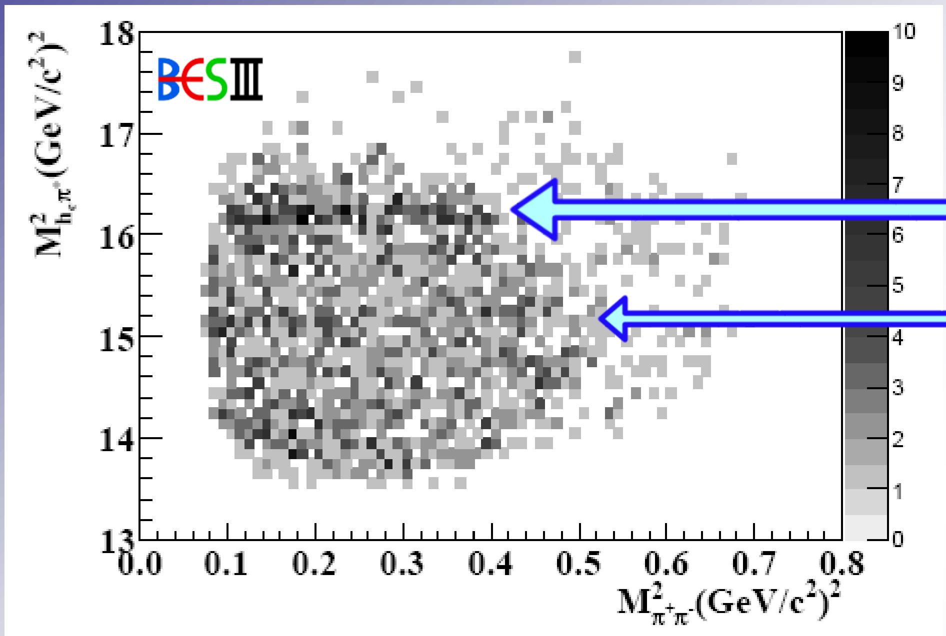
$B((h_c \to \gamma\eta_c)$

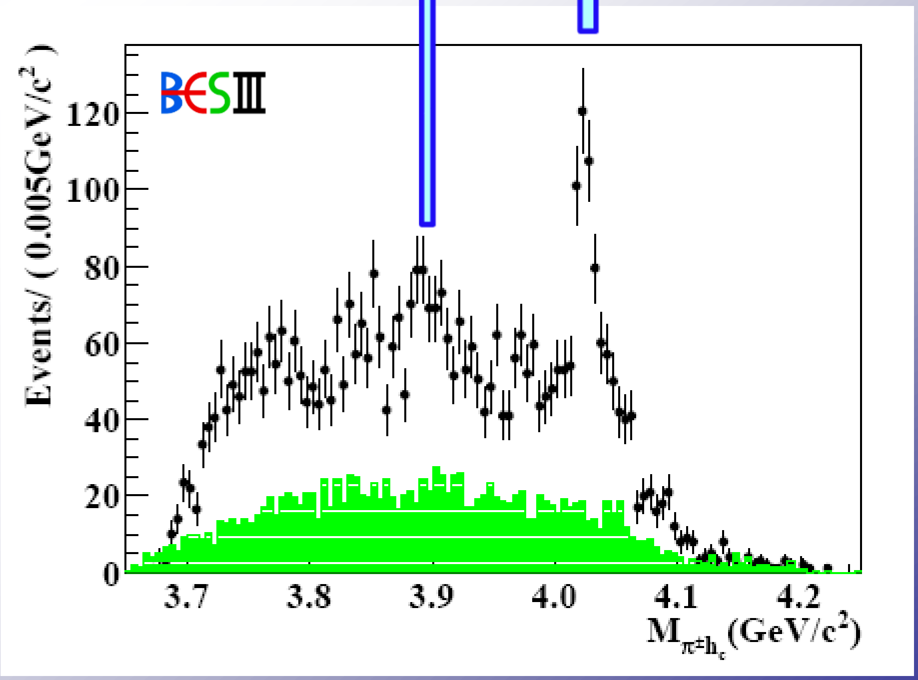
4.26 GeV:

$\sigma(e^+e^- \to \pi Z_c(3900)^+ \pi^- \to \pi^+\pi^- h_c) = < 11$ pb (90% C.L.)

PRL 111, 242001

BESIII: $e^+e^- \to \pi Z_c(4020) \to \pi^+\pi^- h_c$ @ 4.23/4.26/4.36 GeV



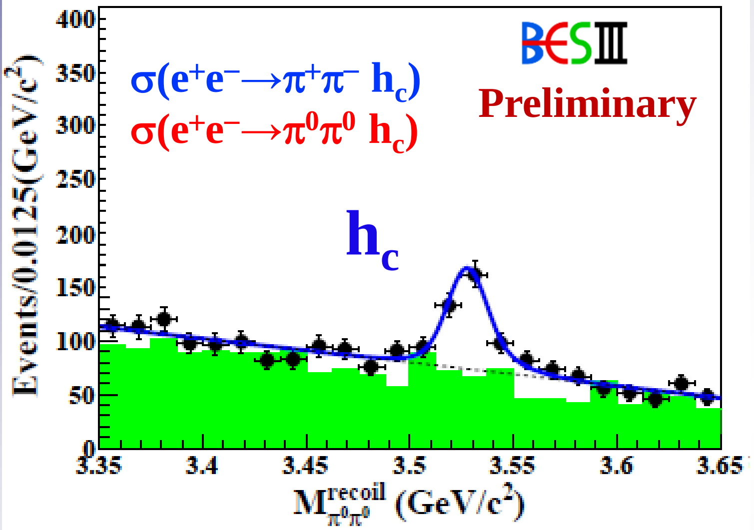


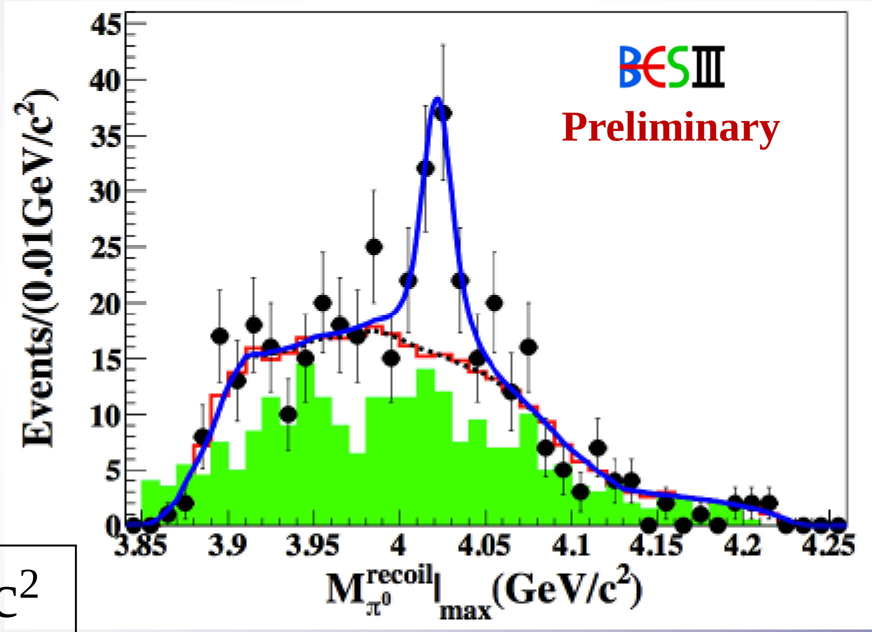
- **all collected energies**
  [3.900 ÷ 4.420 GeV]
- **$h_c \to \gamma\eta_c$, $\eta_c \to$ hadrons**
  [16 exclusive decay modes]

BESIII: $e^+e^- \to \pi Z_c(4020)^0 \to \pi^0\pi^0 h_c$ @ 4.23/4.26/4.36 GeV

BESIII Preliminary!

- 2.8fb^{-1} data at 10 energy points from 4230~4420 MeV
- $Z_c(4020)^0$ is observed clearly at: E_{cm}=4230, 4260, 4360MeV





$M_{Z_c(4020)^0}$ = (4023.6±2.2±3.9) MeV/c^2

$M_{Z_c(4020)^\pm}$ = (4022.9±0.8±2.7) MeV/c^2

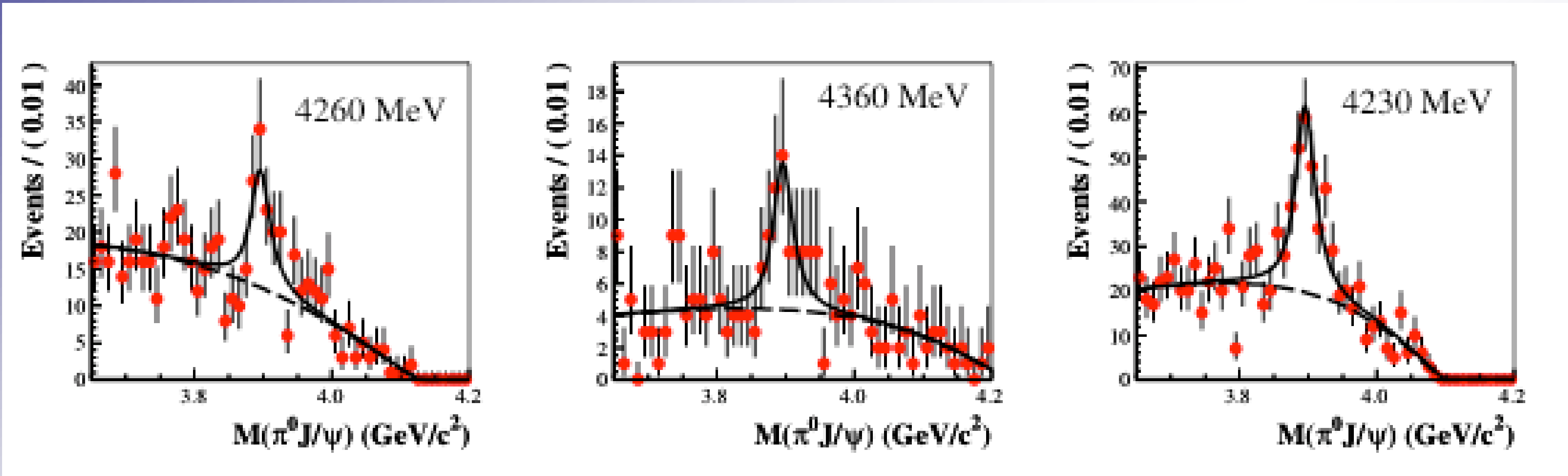
$\Gamma_{Z_c(4020)^0}$ fixed @ $\Gamma_{Z_c(4020)^\pm}$

>5σ

An isospin triplet for $Z_c(3900)$ has also been observed

BESIII: $e^+e^- \to \pi^0 Z_c^0(3900) \to \pi^0\pi^0 J/\psi$ @ 4.19-4.42 GeV

BESIII Preliminary!



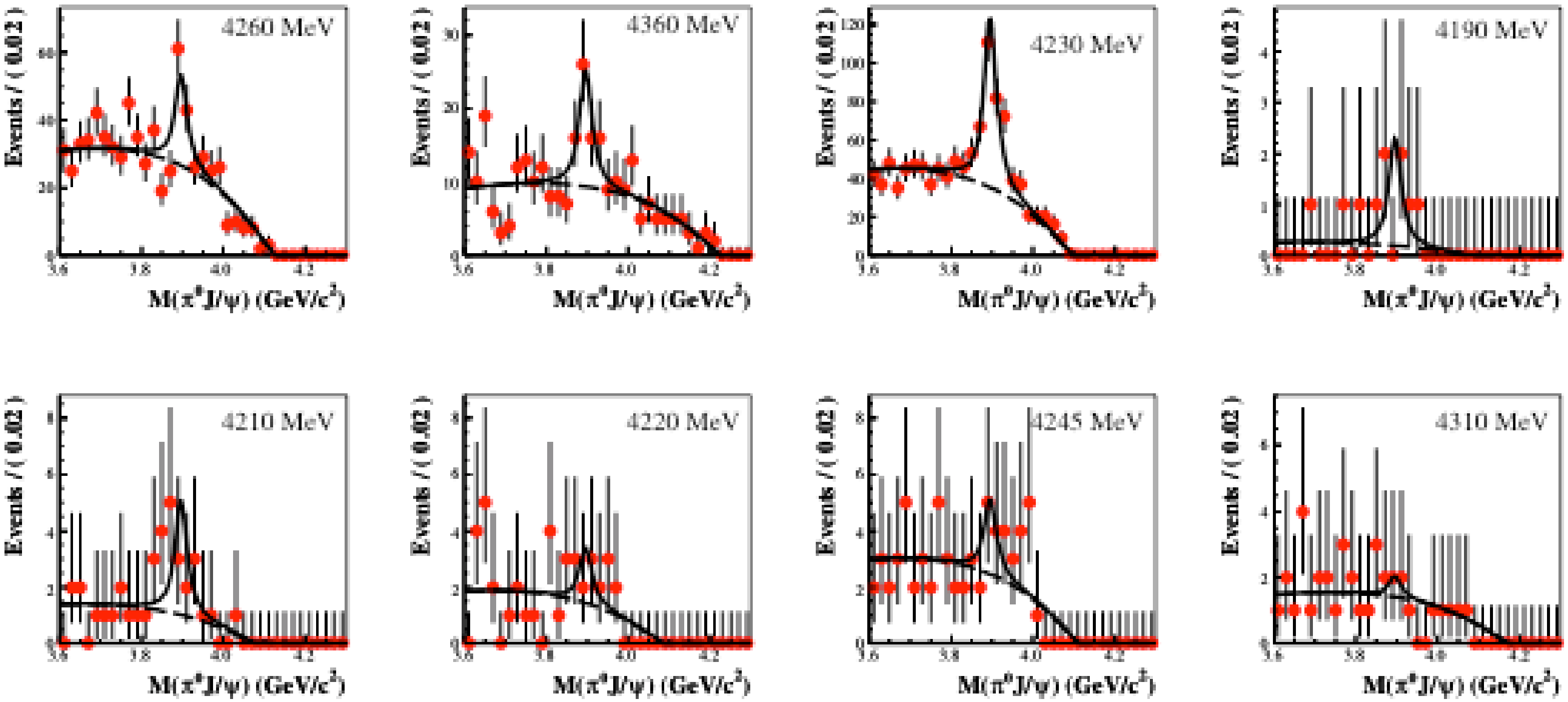
We extract the $Z_c^0(3900)$ parameters and yield by performing a simultaneous fit to the π0J/ψ invariant mass distributions for three subsamples: 4230 MeV, 4260 MeV and 4360 MeV.

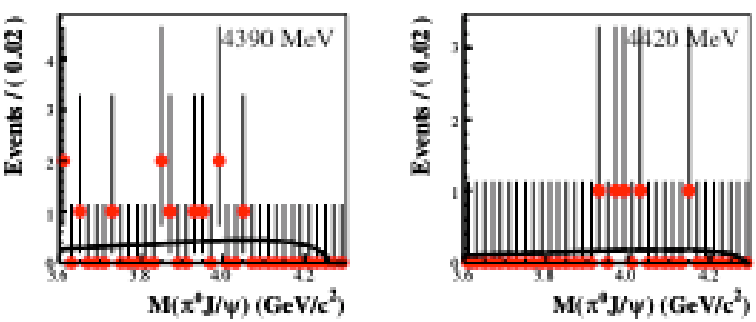
Signal: BW convolved with 3-Gaussian
Bg: Argus, float all parameters except m0

Mass = 3894.8±2.3 MeV
Width = 29.6±8.2 MeV
Significance = 10.4 σ

BESIII: $e^+e^- \to \pi^0 Z_c^0(3900) \to \pi^0\pi^0 J/\psi$ @ 4.19-4.42 GeV

BESIII Preliminary!





To determine the yields of $Z_c^0(3900)$, at 10 energy points a simultaneous fit is performed to the π0J/ψ spectra for each of the ten energy points.

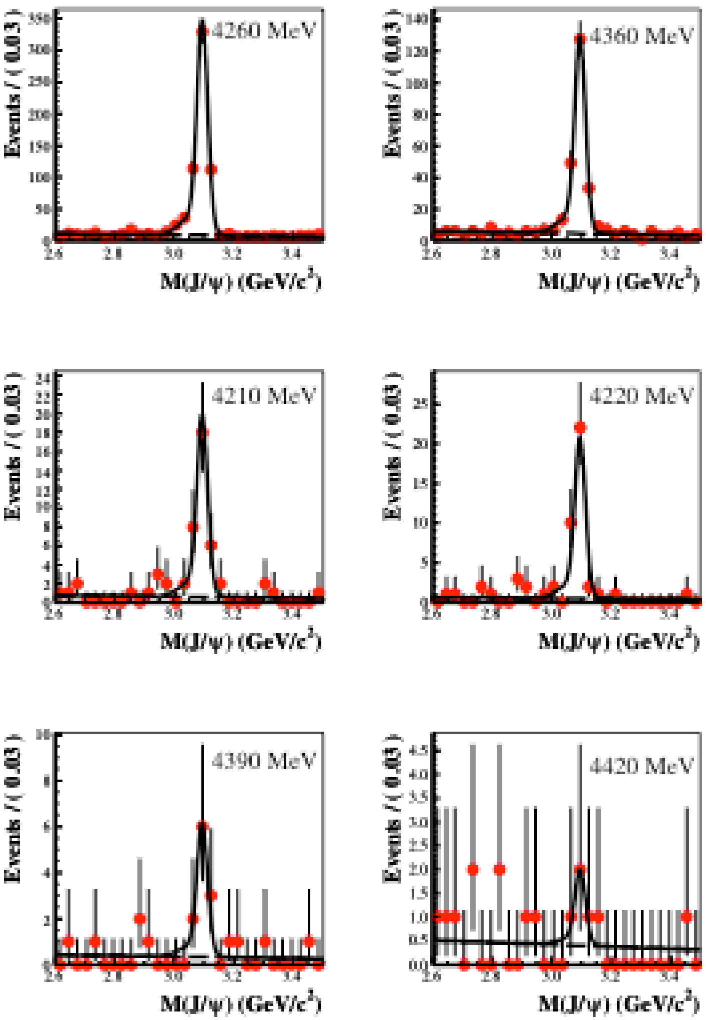
Signal: BW convolved with 3-Gaussian, parameters are fixed to the overall fit.

Bg: Argus, m_0 are fixed based on beam energy. The slope and power are floated, but the same for all points.

33

BESIII: $e^+e^- \to \pi^0 Z_c^0(3900) \to \pi^0\pi^0 J/\psi$ @ 4.19-4.42 GeV

BESIII Preliminary!



To obtain the yields of π0π0J/ψ, a simultaneous fit is made to the J/ψ spectra at all ten energy points.

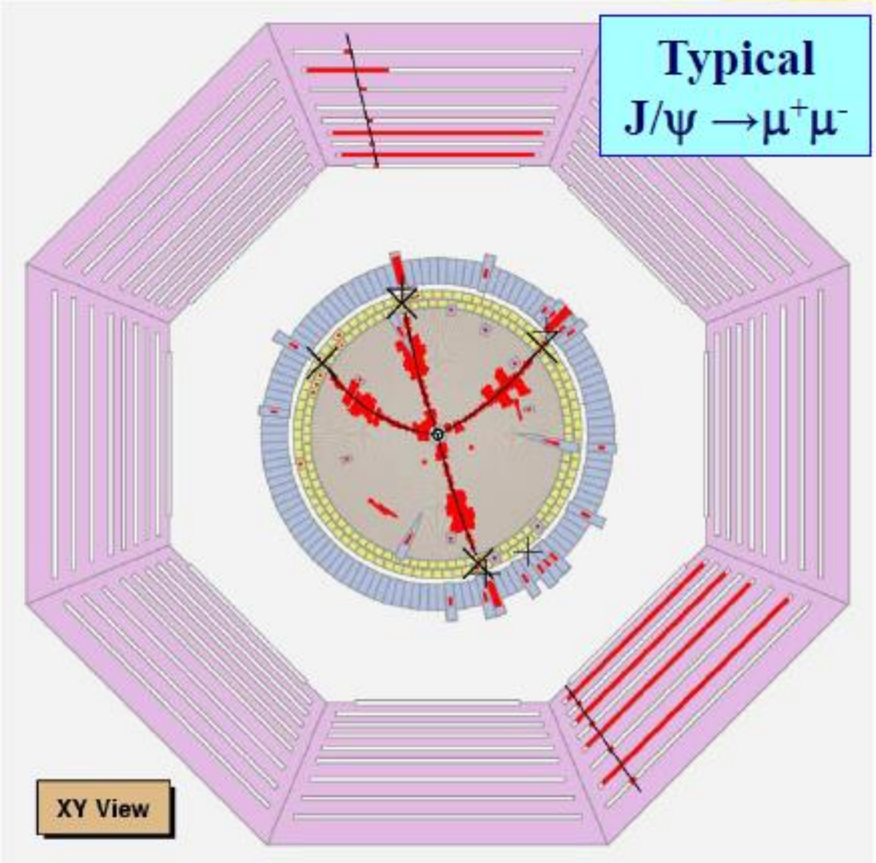
Signal: BW convolved with D-Gaussian instrument resolution (same for all energy points)
Bg: 1st ordered poly.
(same for all energy points)

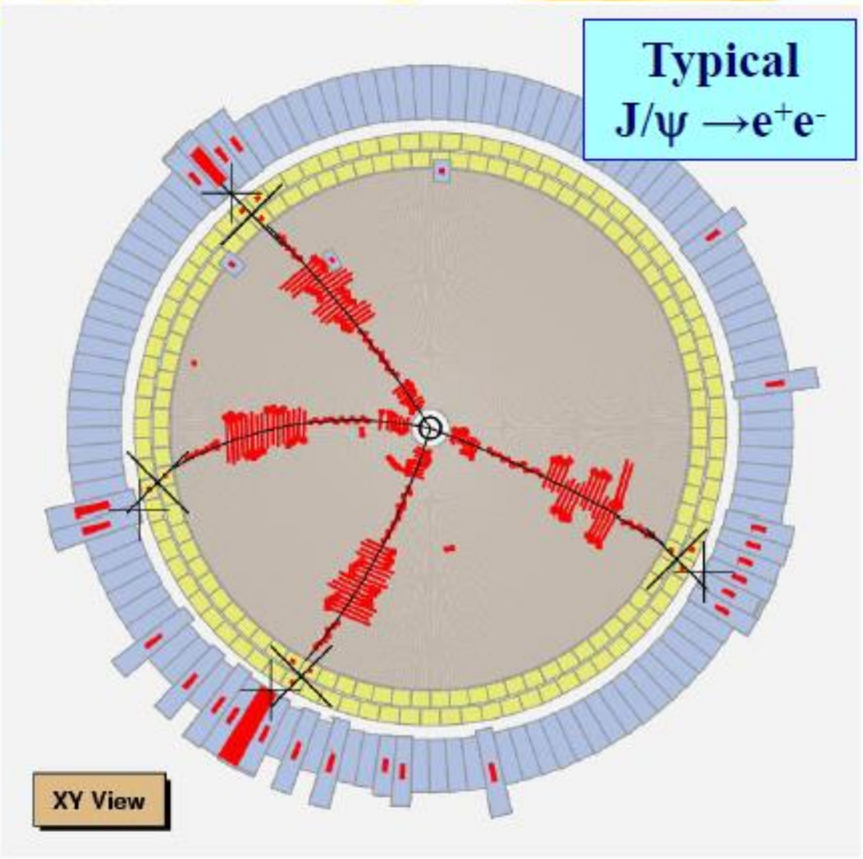
BESIII: $e^+e^- \to \pi^0 Z_c^0(3900) \to \pi^0\pi^0 J/\psi$ @ 4.19-4.31 GeV

BESIII Preliminary!

E_{cm} GeV	$R(Z_c/\pi^0\pi^0 J/\psi)$	Obs. Xsec (pb)	Born Xsec (pb)
4.260	$0.14 \pm 0.03 \pm 0.01$	$23.68 \pm 1.04 \pm 1.75$	$28.95 \pm 1.27 \pm 2.14$
4.360	$0.21 \pm 0.06 \pm 0.01$	$15.00 \pm 1.10 \pm 1.11$	$14.57 \pm 1.07 \pm 1.08$
4.230	$0.27 \pm 0.03 \pm 0.01$	$30.28 \pm 1.02 \pm 2.24$	$37.61 \pm 1.27 \pm 2.78$
4.190	< 1.00	$9.45 \pm 3.00 \pm 0.70$	$11.37 \pm 3.61 \pm 0.84$
4.210	< 0.65	$20.79 \pm 3.85 \pm 1.54$	$25.54 \pm 4.73 \pm 1.89$
4.220	< 0.41	$21.60 \pm 3.82 \pm 1.60$	$26.74 \pm 4.73 \pm 1.98$
4.245	< 0.30	$34.24 \pm 4.69 \pm 2.53$	$42.38 \pm 5.80 \pm 3.14$
4.310	< 0.30	$22.04 \pm 4.16 \pm 1.63$	$24.17 \pm 4.56 \pm 1.79$
4.390	< 0.55	$7.56 \pm 2.53 \pm 0.56$	$6.93 \pm 2.32 \pm 0.51$
4.420	< 1.00	$2.87 \pm 2.13 \pm 0.21$	$2.52 \pm 1.87 \pm 0.19$

BESIII: $e^+e^- \to \pi^+\pi^- J/\psi$ events



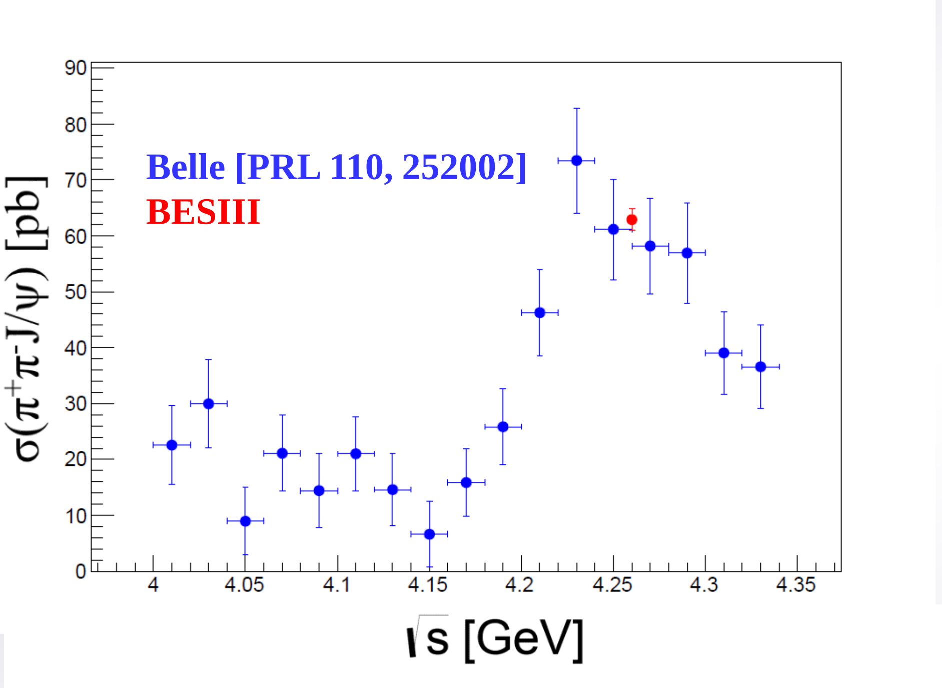


- 4 charged tracks, J/ψ reconstruct via lepton pairs
- very clean sample, very high efficiency, kinematic fit used
- only use MDC & EMC information, MC simulation reliable

BESIII: Cross Sections Results

PRL 110, 252001

$e^+e^- \to \pi^+\pi^- J/\psi$ @ 4.26 GeV



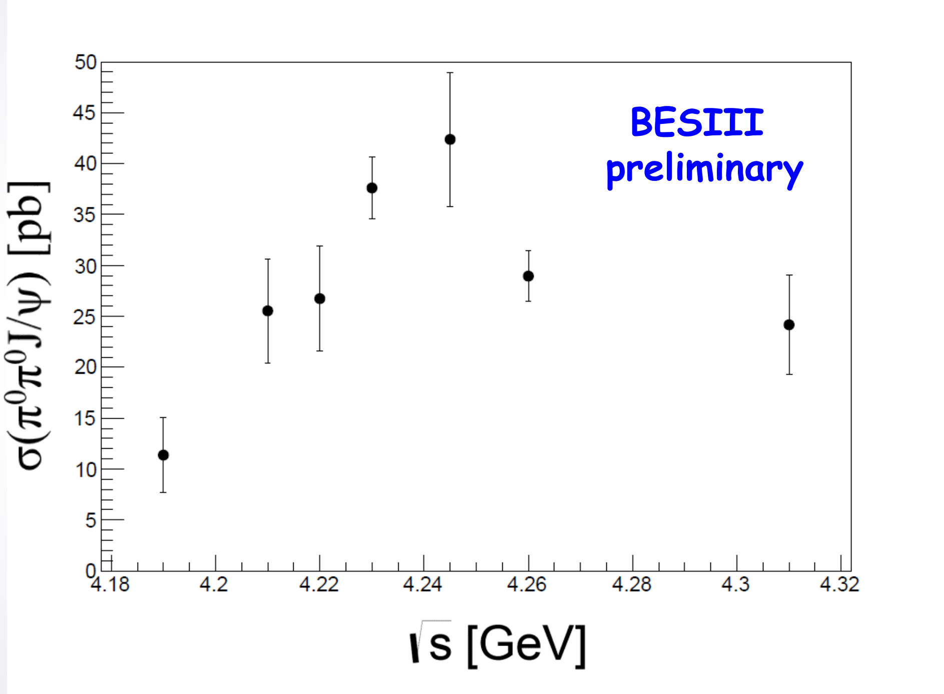
$\sigma(\pi+\pi-J/\psi) = (62.9 \pm 1.9 \pm 3.7)$ pb

$\sigma(\pi+\pi-J/\psi) = (61.17 \pm 8.98 \pm \sim 7.5\%)$ pb

Z_c R = (21.5±3.3±7.5)%

BESIII Preliminary!

$e^+e^- \to \pi^0\pi^0 J/\psi$ @ 4.19-4.31 GeV



7 energy points

$Z_{c0}/Z_{c\pm}$ R = (21.5±3.3±7.5)%

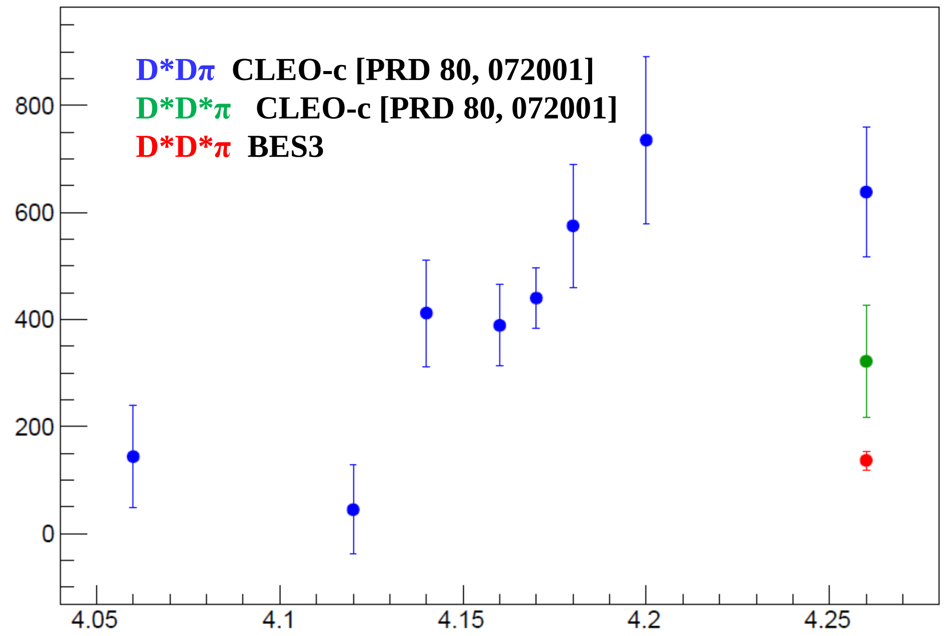
BESIII: DDbar Results

PRL 112, 022001

$e^+e^- \to \pi^-(D\bar{D}^*)^+$+c.c. @ 4.26 GeV

PRL 112, 132001

$e^+e^- \to \pi^-(D^*\bar{D}^*)^+$+c.c. @ 4.26 GeV



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

$\sigma(e^+e^- \to \pi^- (D^*\bar{D}^*)^+ + c.c.) = (332 \pm 67 \pm 80)$ pb

$\sigma(e^+e^- \to \pi^- Z_c(3885)^+ \times Z_c(3885)^+ \to (D\bar{D}^*)^+ + c.c.) = (83.5 \pm 6.6 \pm 22.0)$ pb

$$R = \frac{\sigma(e^+e^- \to \pi^- Z_c^+ \to \pi^- (D^*\bar{D}^*)^+ + c.c.)}{\sigma(e^+e^- \to \pi^- (D^*\bar{D}^*)^+ + c.c.)}$$

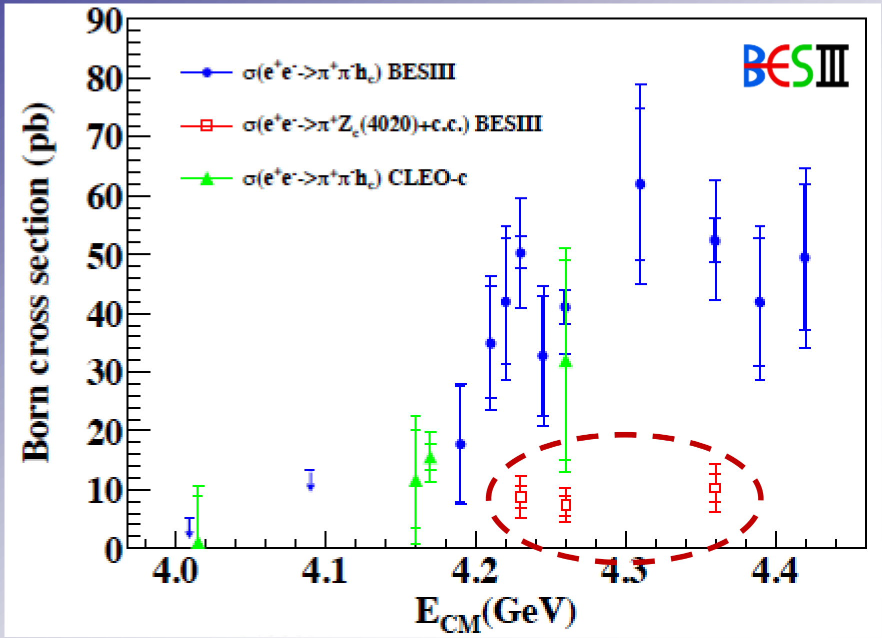
$$= (65 \pm 9 \pm 6)\%$$

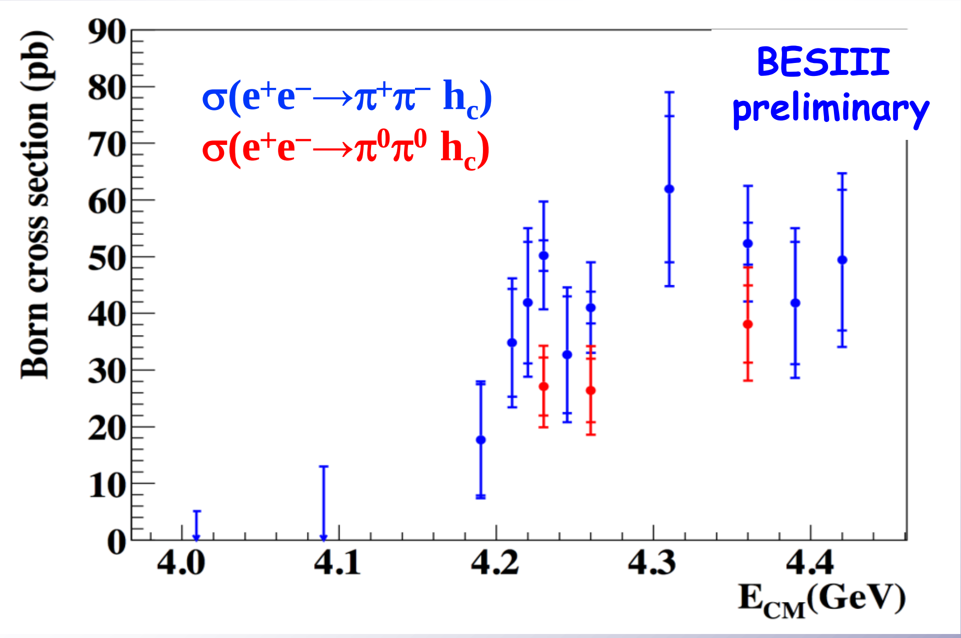
$$R = \frac{\Gamma(Z_c(3885) \to D\bar{D}^*)}{\Gamma(Z_c(3900) \to \pi J/\psi)} = (6.2 \pm 1.1 \pm 2.7)$$

BESIII: h_c Results

PRL 111, 242001

BESIII Preliminary!





13 energy points

$\sigma(e^+e^- \to \pi Z_c(4020)^\pm \to \pi^+\pi^- h_c)$

σ(4.23 GeV) = (8.7±1.9±2.8±1.4) pb

σ(4.26 GeV) = (7.4±1.7±2.1±1.2) pb

σ(4.36 GeV) = (10.3±2.3±3.1±1.6) pb

$\sigma(e^+e^- \to \pi Z_c(3900) \to \pi^+\pi^- h_c)$

σ(4.26 GeV) = < 11 pb (90% C.L.)

10 energy points

$\sigma(e^+e^- \to \pi Z_c(4020)^0 \to \pi^0\pi^0 h_c)$

σ(4.23 GeV) = (6.5±2.2±0.7±1.0) pb

σ(4.26 GeV) = (8.5±2.9±1.1±1.3) pb

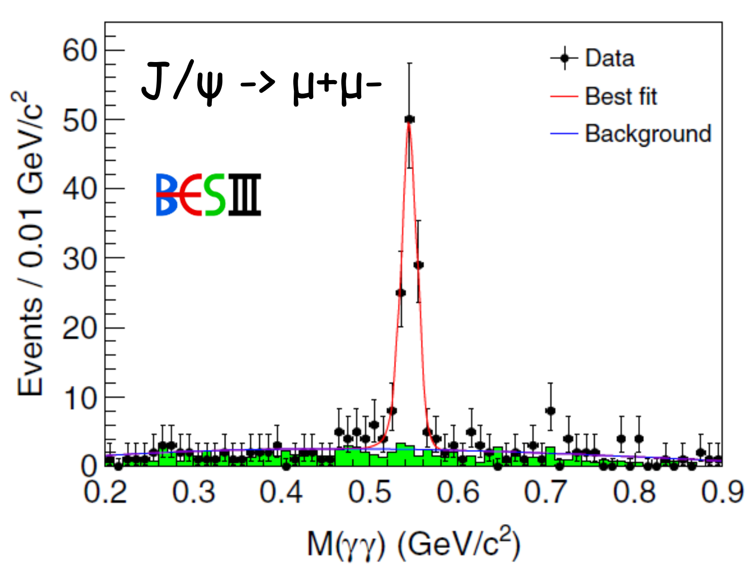
σ(4.36 GeV) = (9.9±4.1±1.3±1.5) pb

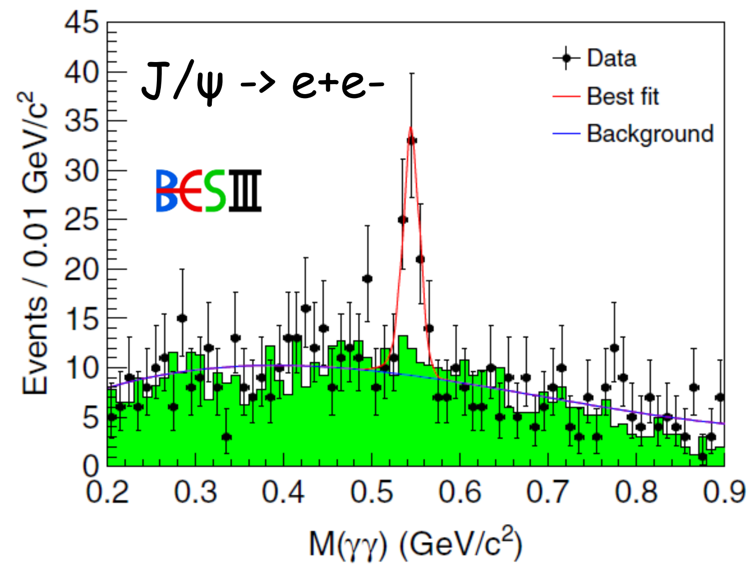
BESIII: e^+e^- -> $\eta J/\psi$, $\pi^0 J/\psi$ @ 4.009 GeV

PRD 86, 071101

J/ψ -> l^+l^-

η/π^0 -> $\gamma\gamma$





Statistical significance:

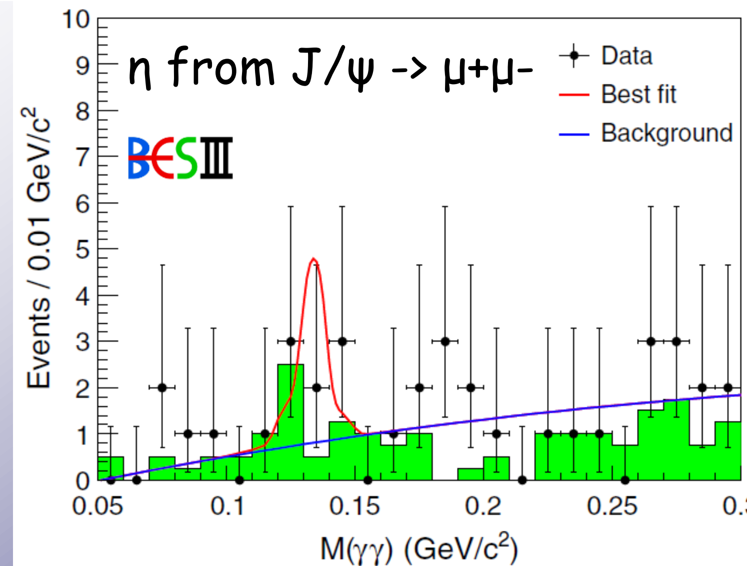
η ~ 10 σ

π^0 ~ 1.1 σ

Cross sections:

σ (e^+e^- -> $\eta J/\psi$) = (32.1 ± 2.8 ± 1.3) pb

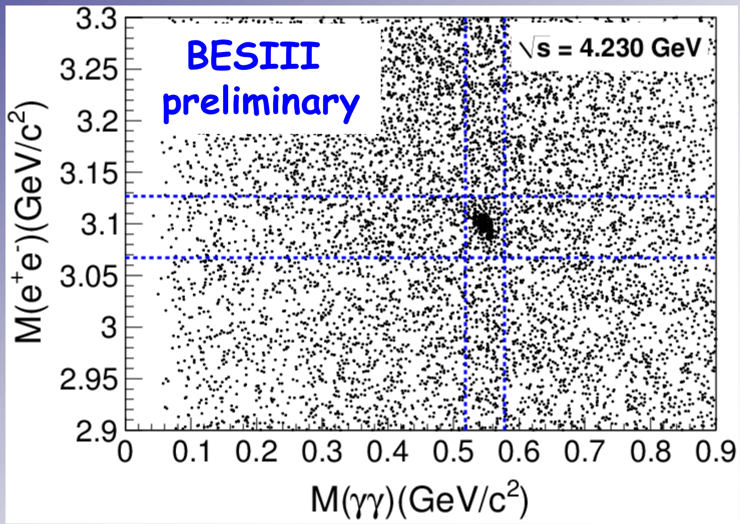
σ (e^+e^- -> $\pi^0 J/\psi$) = 1.6 pb (90% CL) upper limit

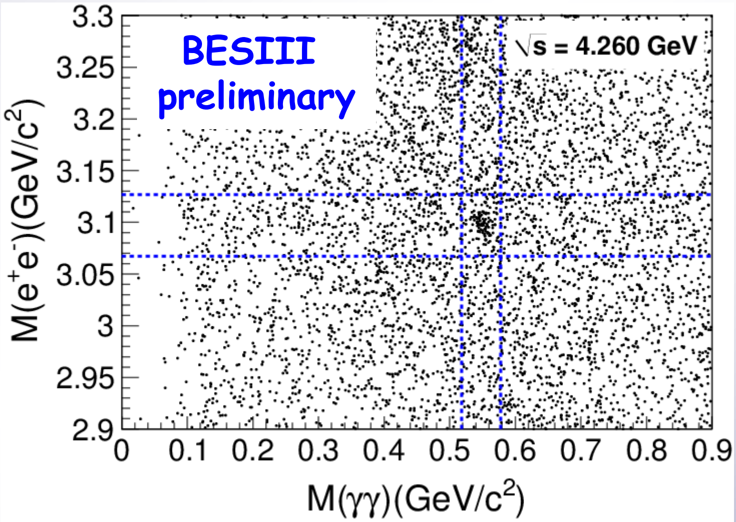


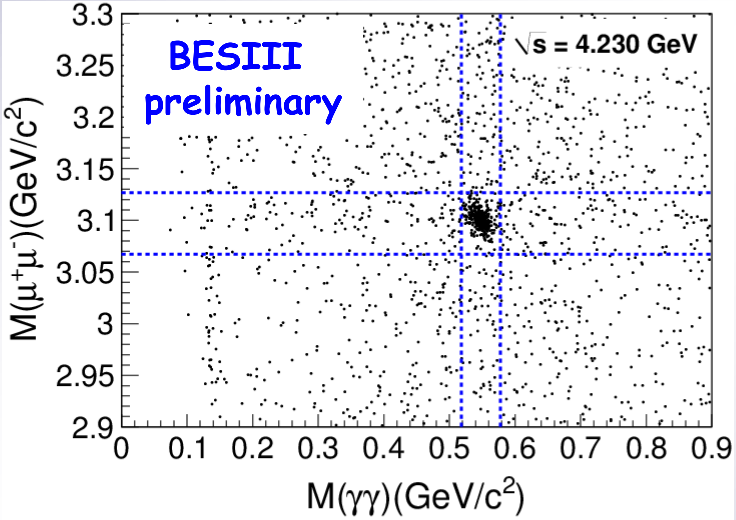
CLEO not contraddicted (PRL 96, 162003)

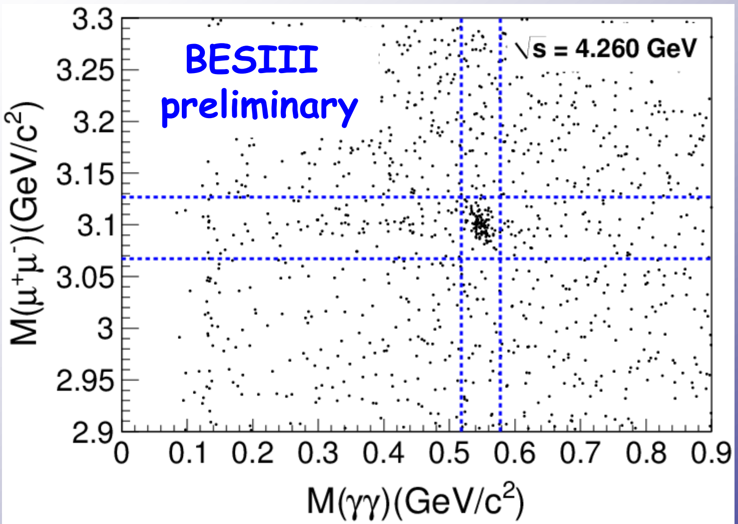
BESIII: $e^+e^- \to \eta J/\psi$ @ 3.81-4.31 GeV

BESIII Preliminary!



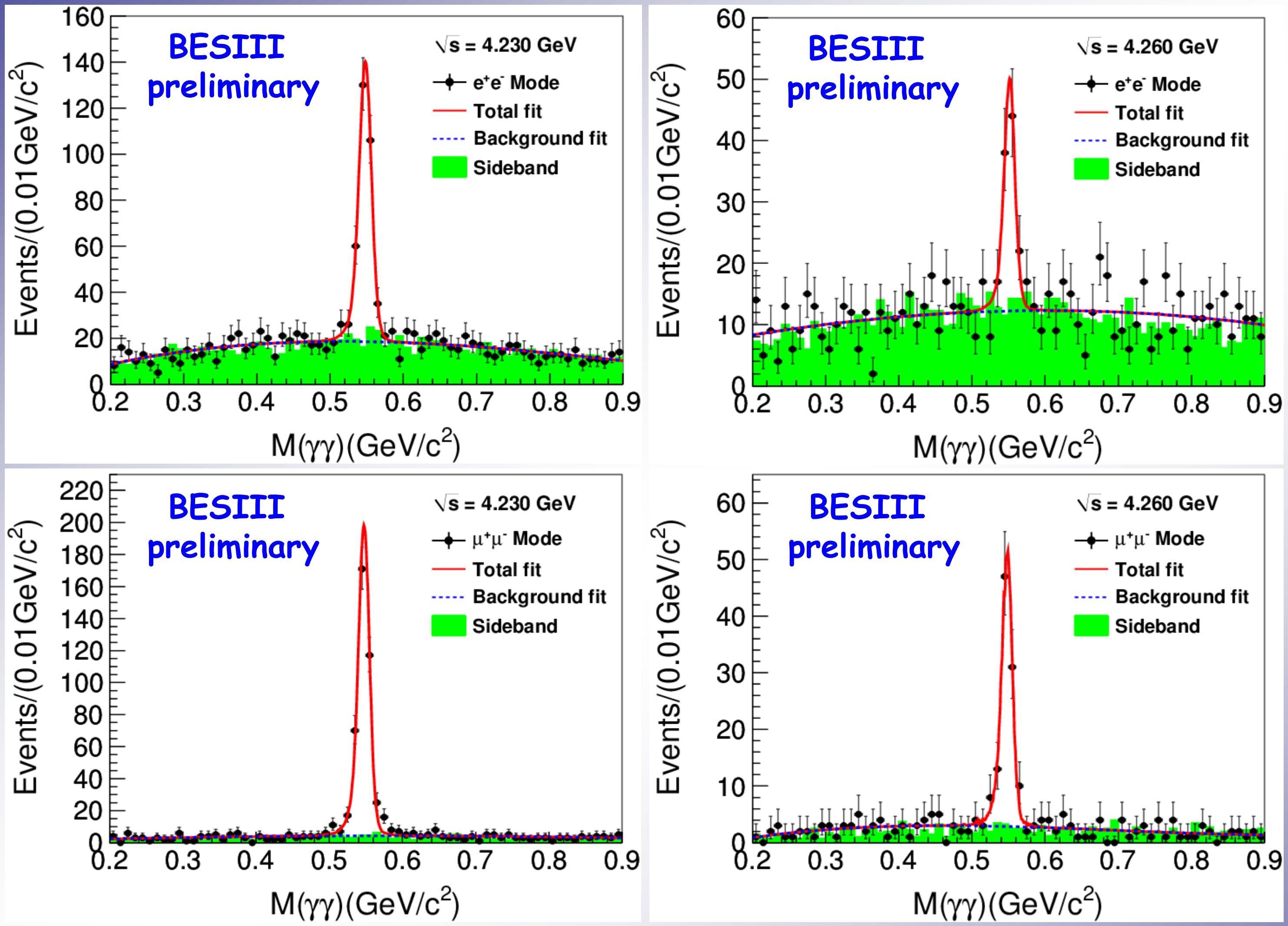






BESIII: $e^+e^- \to \eta J/\psi$ @ 3.81-4.31 GeV

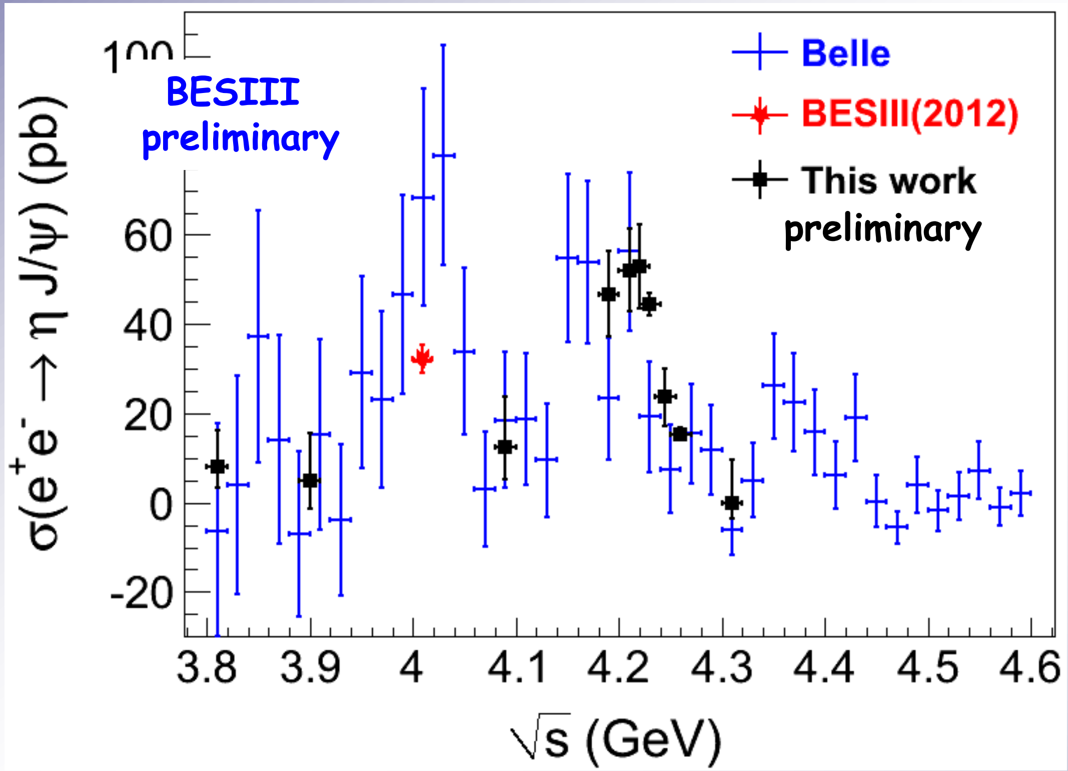
BESIII Preliminary!



- Signal:
  MC simulated shape.
- Background:
  Polynominal fuction.

BESIII: $e^+e^- \to \eta J/\psi$ @ 3.81-4.31 GeV

BESIII Preliminary!



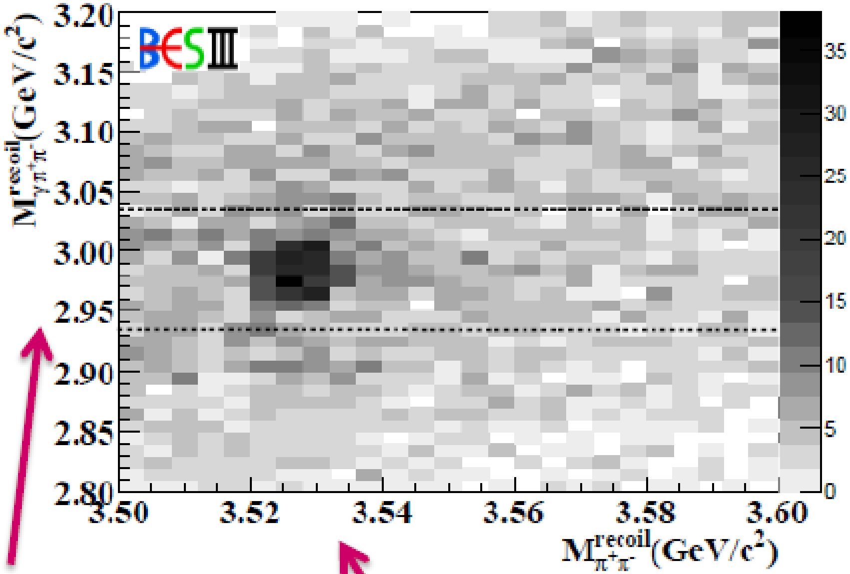
PRD 87, 051101
PRD 86, 071101

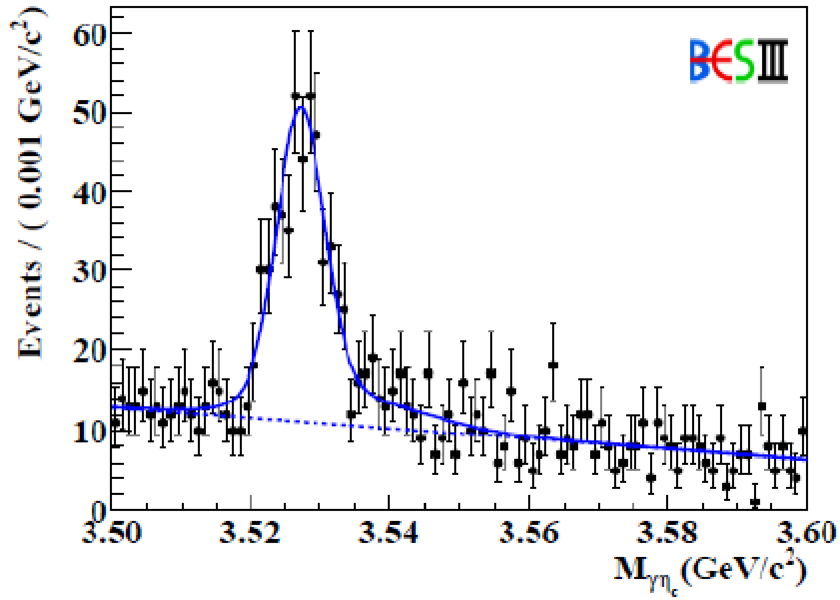
- The measured $\sigma(e^+e^- \to \eta J/\psi)$ agree with previous results but with improved accuracy.
- The cross section peaks around 4.2 GeV.

BESIII: $e^+e^- \to \pi^+\pi^- h_c(1P)$ @ 4.260 GeV

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., $K^+K^-\pi^0$
  - $p\bar{p}\pi^0$, $K^+K^-\eta$, $\pi^+\pi^-\eta$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-)\eta$, $2(\pi^+\pi^-\pi^0)$



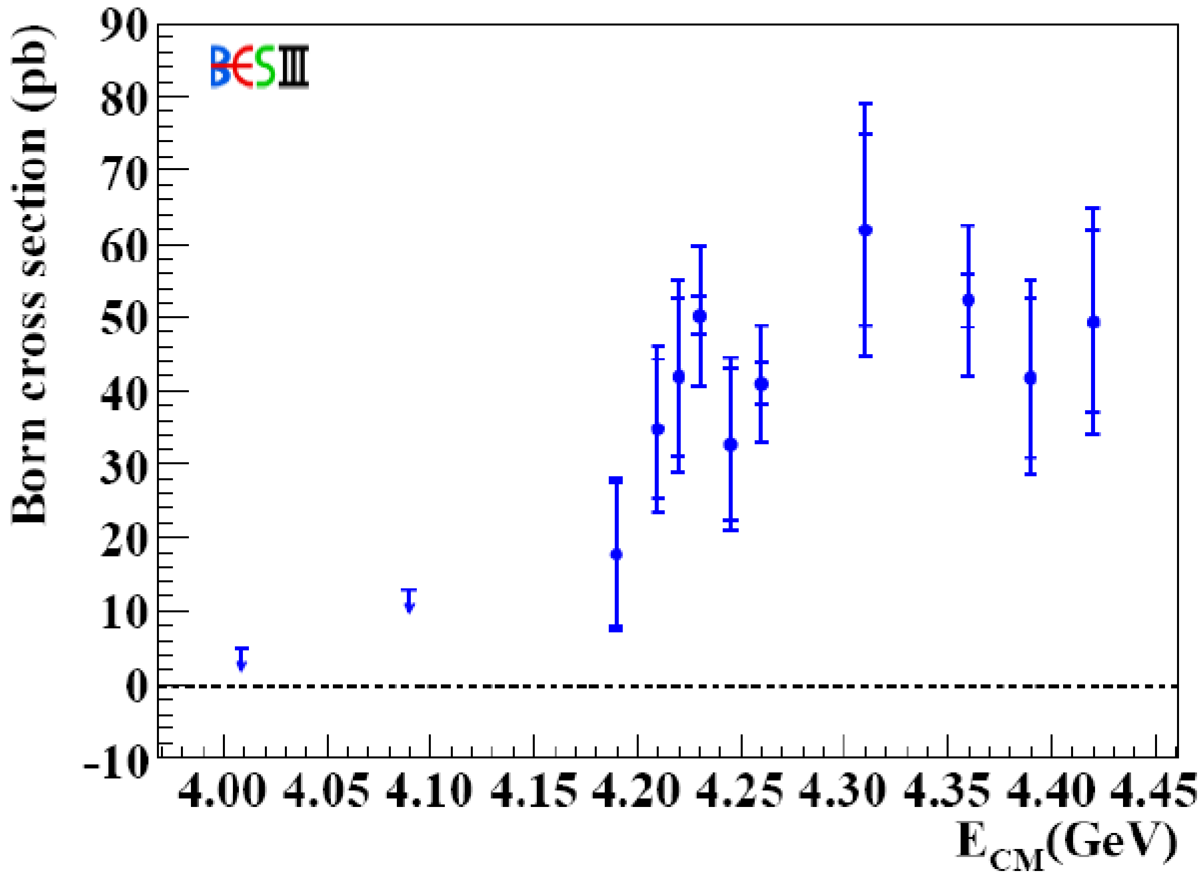


η_c **candidate**

h_c **candidate**

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

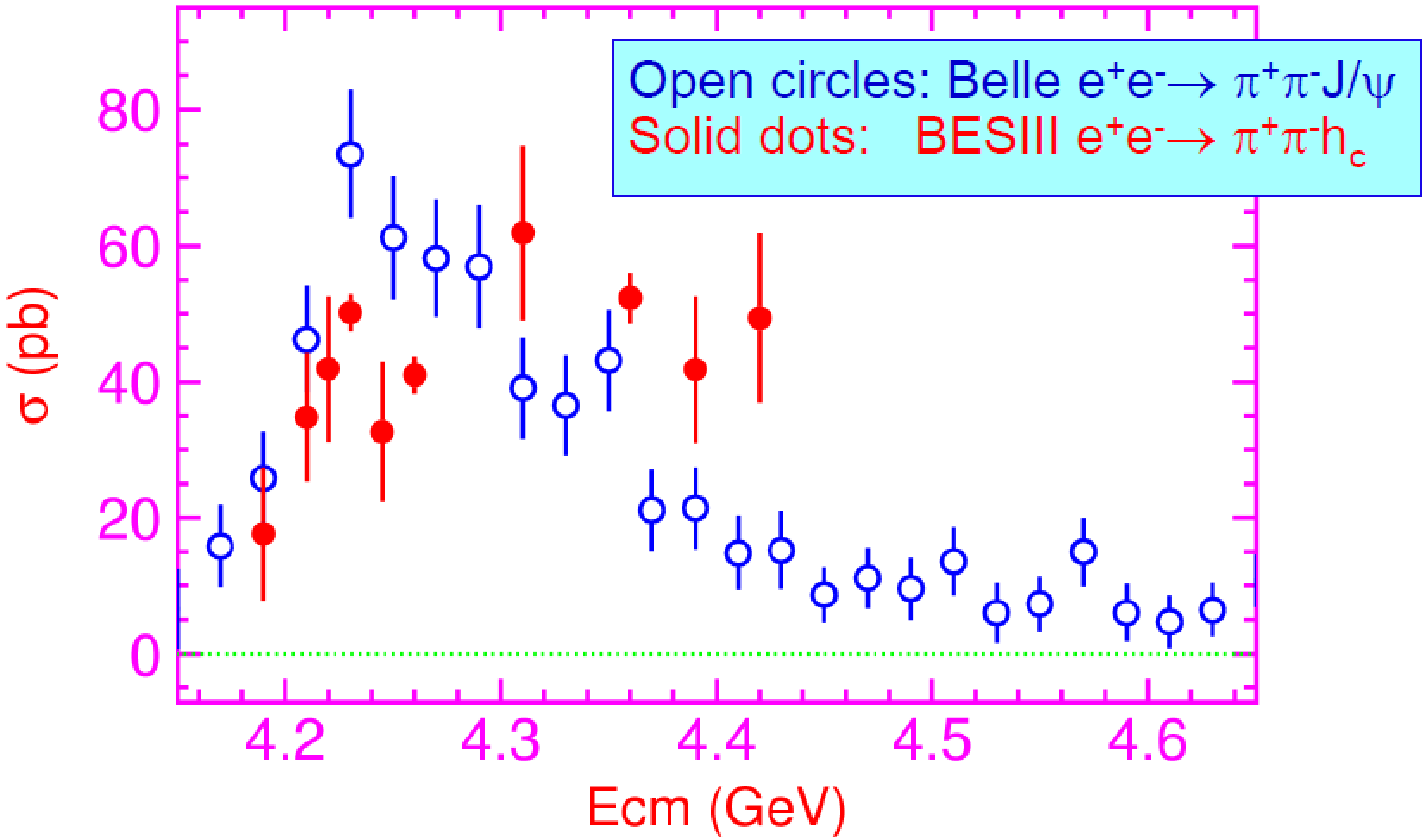
PRL 111, 242001



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

$e^+e^- \rightarrow \pi^+\pi^- h_c(1P)$ vs $e^+e^- \rightarrow \pi^+\pi^- J/\psi$

PRL 111, 242001

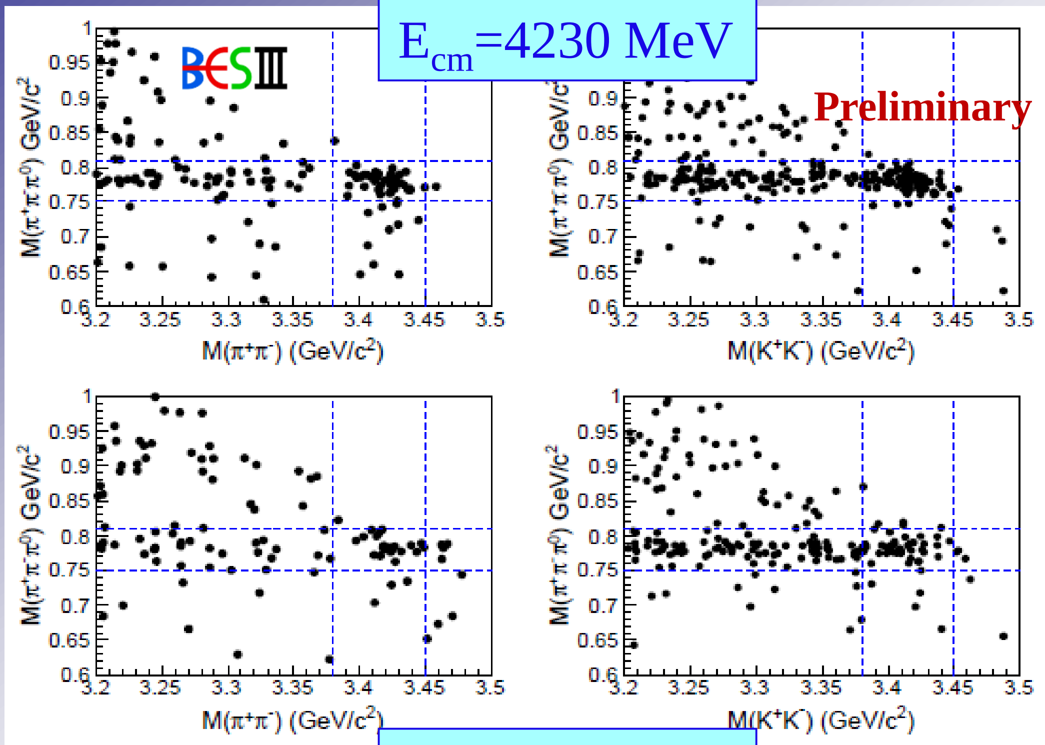


More data at higher energies needed to complete line shape measurement

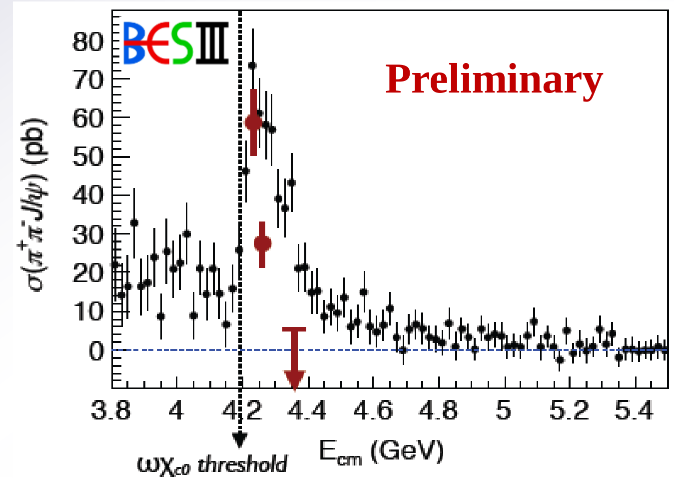
BESIII: e+e--> ωχCJ @ 4.21-4.42 GeV

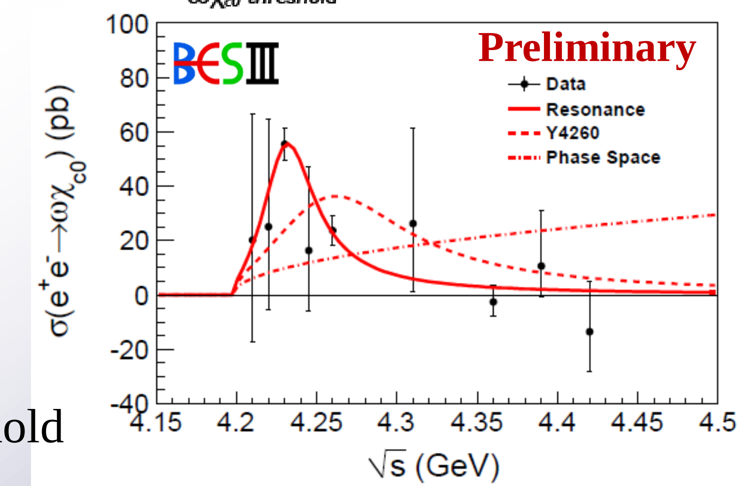
BESIII Preliminary!

E_{cm}=4230 MeV



E_{cm}=4260 MeV





A fine structure at 4230MeV?

- The mass of Y(4260) is very close to $\omega\chi_{cJ}$ mass threshold
- Observation of $\omega\chi_{c0}$ at 4230, 4260 MeV data
- No evidence at 4360MeV
- Line shape seems inconsistent with Y(4260)
- BW fitting: a narrow structure around 4230MeV.

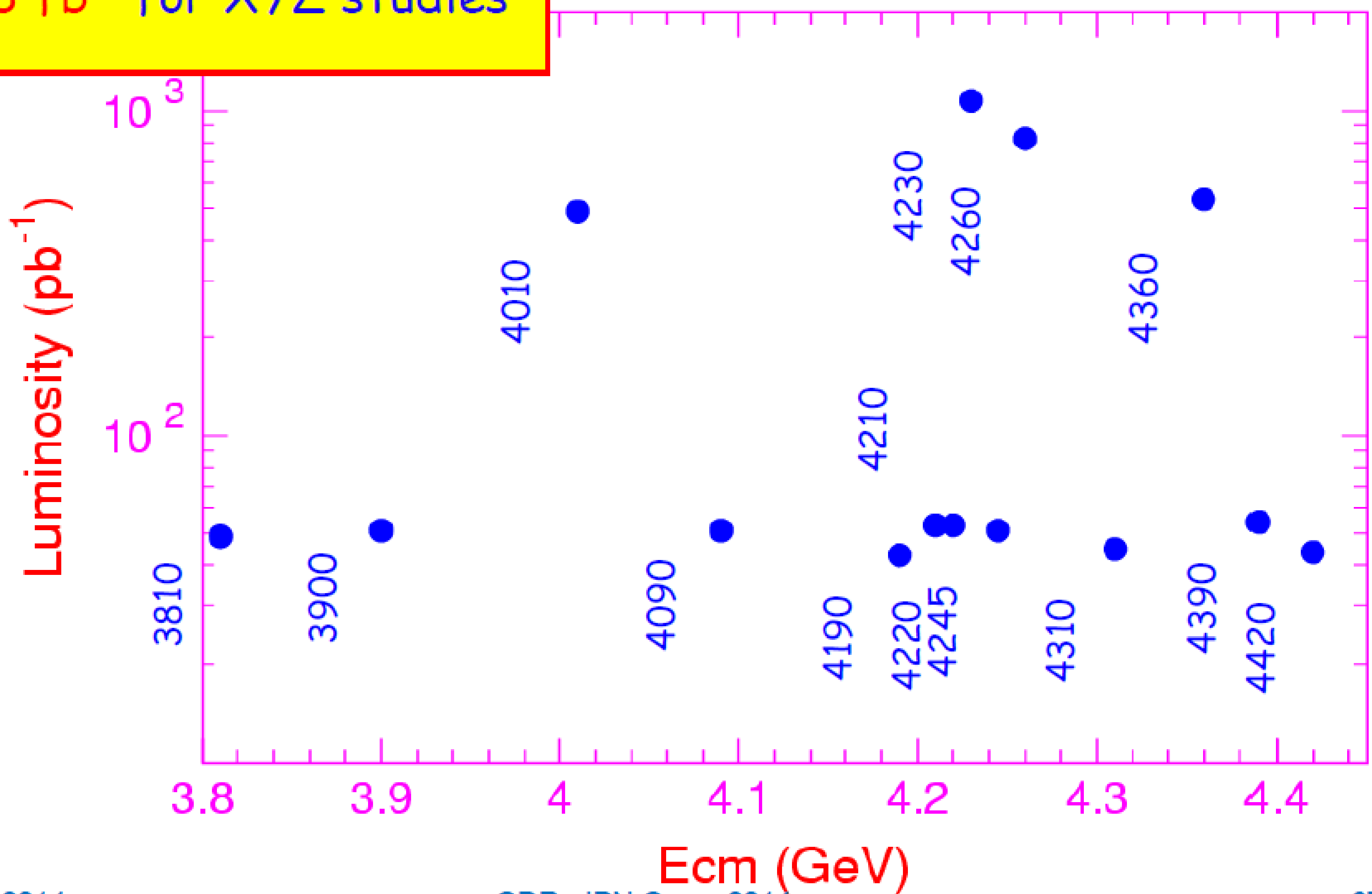
Preliminary

$M = (4229 \pm 11 \pm 6)\ \mathrm{MeV}/c^2$

$\Gamma = (40 \pm 14 \pm 2)\ \mathrm{MeV}/c^2$

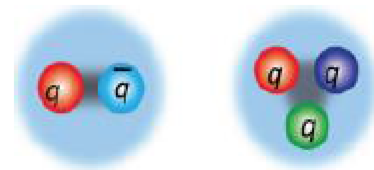
BESIII data set

3.3 fb^{-1} for XYZ studies

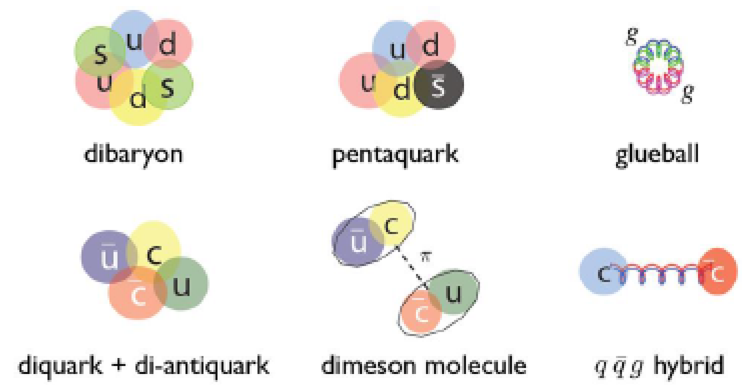


Hadronic exotic states

- **Experiments :**
  - Hadrons are composed of 2 (meson) or 3 (baryon) quarks
  - Described very well in quark model (QM)



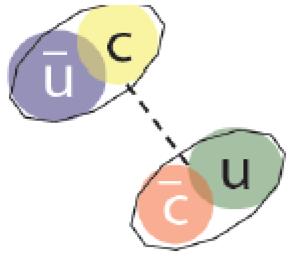
- **QCD suggests:**
  - Confinement : stable hadrons need to be colorless
  - Gluon-gluon interactions : hadron with gluons (hybrids and glueballs) could exist
  - Allow hadrons with $N_{quarks} \neq 2, 3$ (multi-quarks)



Can we find evidence for these interesting exotic hadrons?

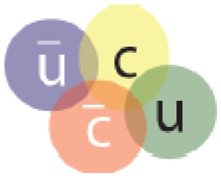
A long history of searching for the exotic hadron,
no solid conclusion was reached in past a few decades,
some hints on charmomium-like and bottomnium-like particles, recently.

Exotic Meson (Charmonium-Like)



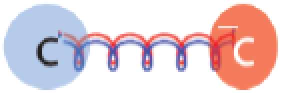
Molecular states:

- Loosely bound states of a pair of mesons,
- bound by the long-range color-singlet pion exchange,
- weakly bound, mesons tend to decay as if they were free.



Tetraquarks:

- bound states of four quarks,
- bound by colored-force between quarks,
- decay through rearrangement,
- many states with the same multiplet, some are with non-zero charge, or strangeness



Hybrids:

- bound states with a pair of quarks and one excited gluon
- Lattice and model predictions for lowest lying charmonium hybrid m~4200 MeV

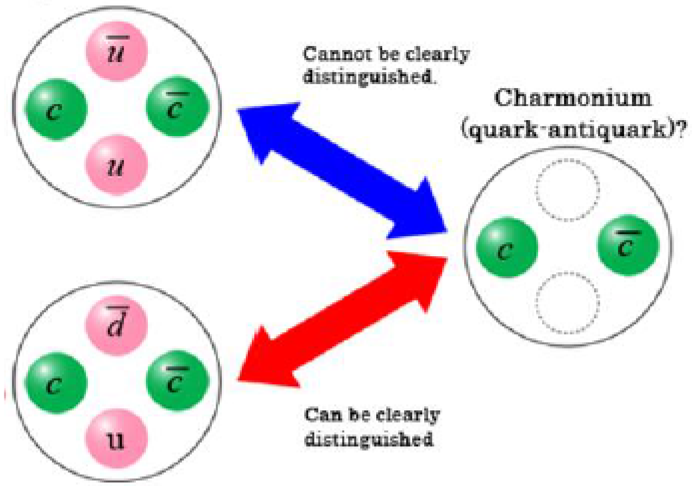
Z_c states

The most promising way to searching for the exotic hadrons

- Decay into a charmonium or $D^{(*)}\overline{D^{(*)}}$ pair
  - thus contains hidden-$c\bar{c}$ pair
- Have electric charge,
  - thus has two more light quarks

At least 4 quarks, not a conventional meson

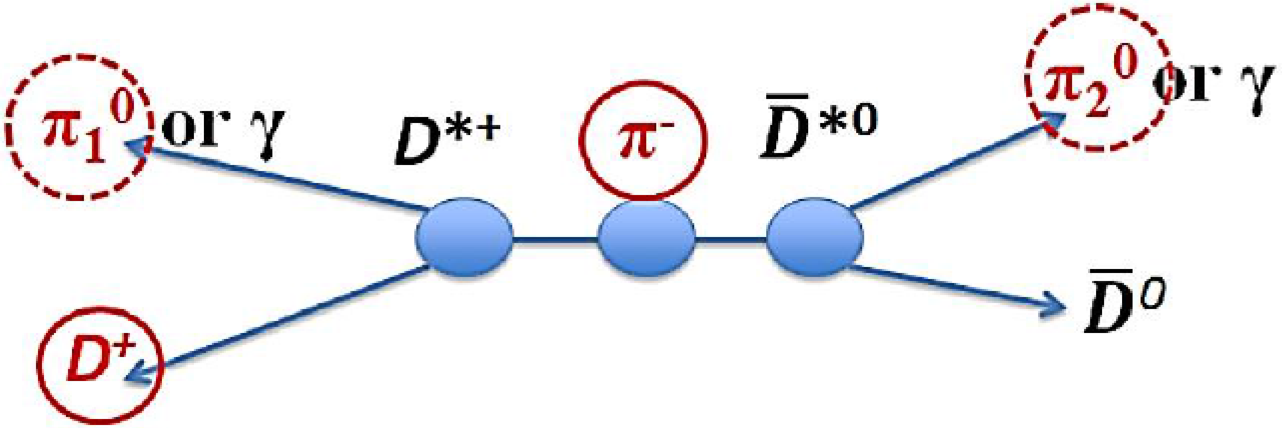
- Observed in final states :
  - $\pi^{\pm}J/\psi$, $\pi^{\pm}\psi(2S)$, $\pi^{\pm}h_c$, $\pi^{\pm}\chi_{cJ}$, $(D^{(*)}\overline{D^{(*)}})^{\pm}$,…
- Experimental search:
  - BESIII/CLEO-c : $e^+e^- \to \pi^{\pm}$ +Exotics, ….
  - Belle/BaBar : $e^+e^- \to (\gamma_{ISR})\pi^{\pm}$+Exotics, ….
  - Belle/BaBar/LHCb: $B \to K^{\pm}$+Exotics, …



BESIII: $e^+e^- \to \pi Z_c(4025) \to \pi^- (D^*D^*)^+ + c.c.$ @ 4.260 GeV

hep-ex:1308.2760

- **827 pb^{-1}** data at E_{CM}=4.260 GeV
- Tag a D^+ and a bachelor π^-, reconstruct one π^0 to suppress the background.

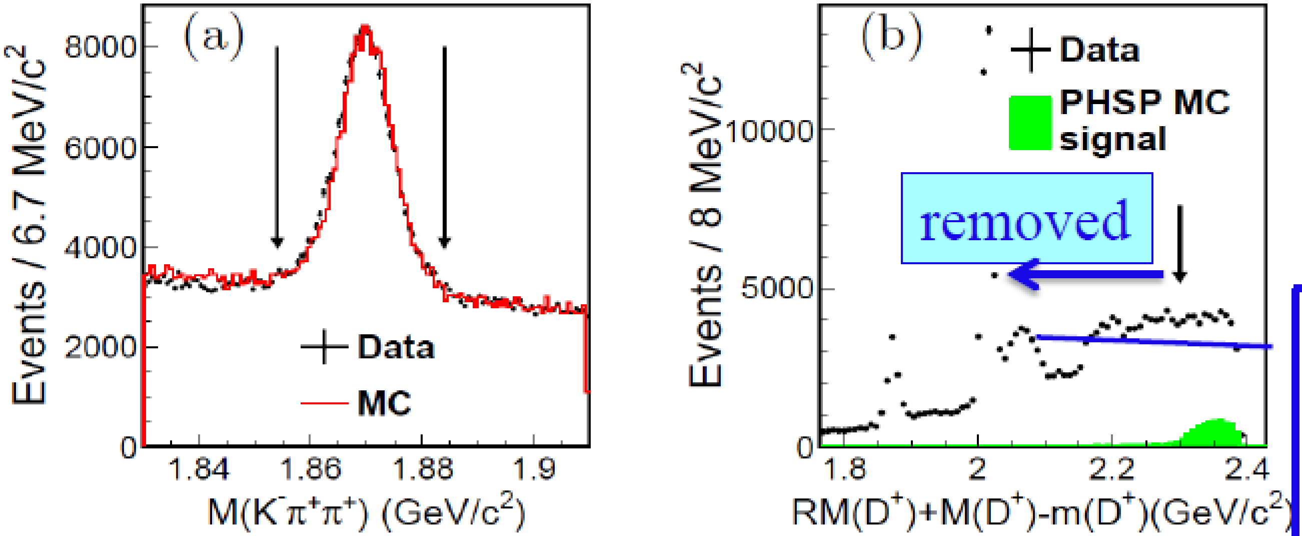


Topology of the decays of the signal process:

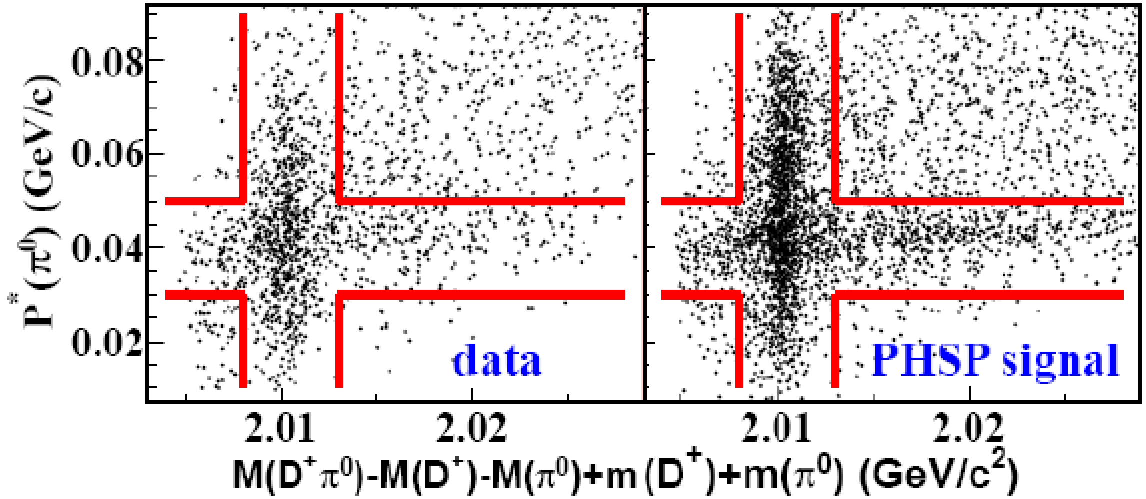
- thick line circled: D^+ and π^- detected in the final states
- dashed line circled: at least of π_1^0 or π_2^0 tagged

BESIII: $e^+e^- \rightarrow \pi Z_c(4025) \rightarrow \pi^- (D^*D^*)^+$+c.c. @ 4.260 GeV

hep-ex:1308.2760

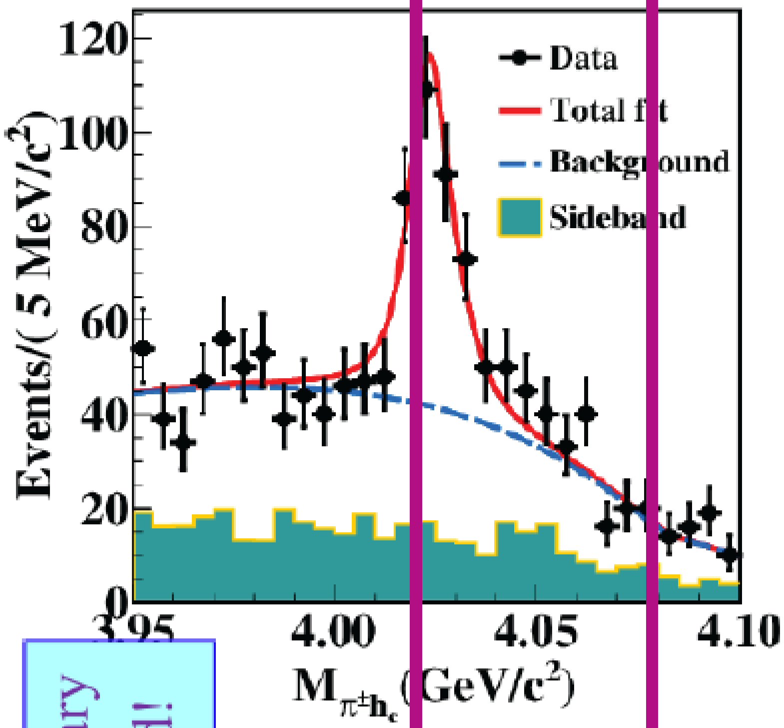


Remove DD, DD*, D*D*, DsDs, …

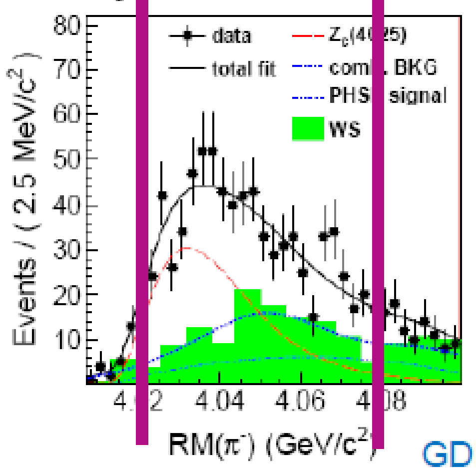


BESIII: $Z_c(4020)=Z_c(4025)$?

PRL 111, 242001
hep-ex:1308.2760



BESIII preliminary
The Zc' is found!



$M(4020) = (4021.8 \pm 1.0 \pm 2.5)$ MeV

$M(4025) = (4026.3 \pm 2.6 \pm 3.7)$ MeV

$\Gamma(4020) = (5.7 \pm 3.4 \pm 1.1)$ MeV

$\Gamma(4025) = (24.8 \pm 5.7 \pm 7.7)$ MeV

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

Mass consistent with each other but.. width ~2σ difference

Interference with other amplitudes may change the results

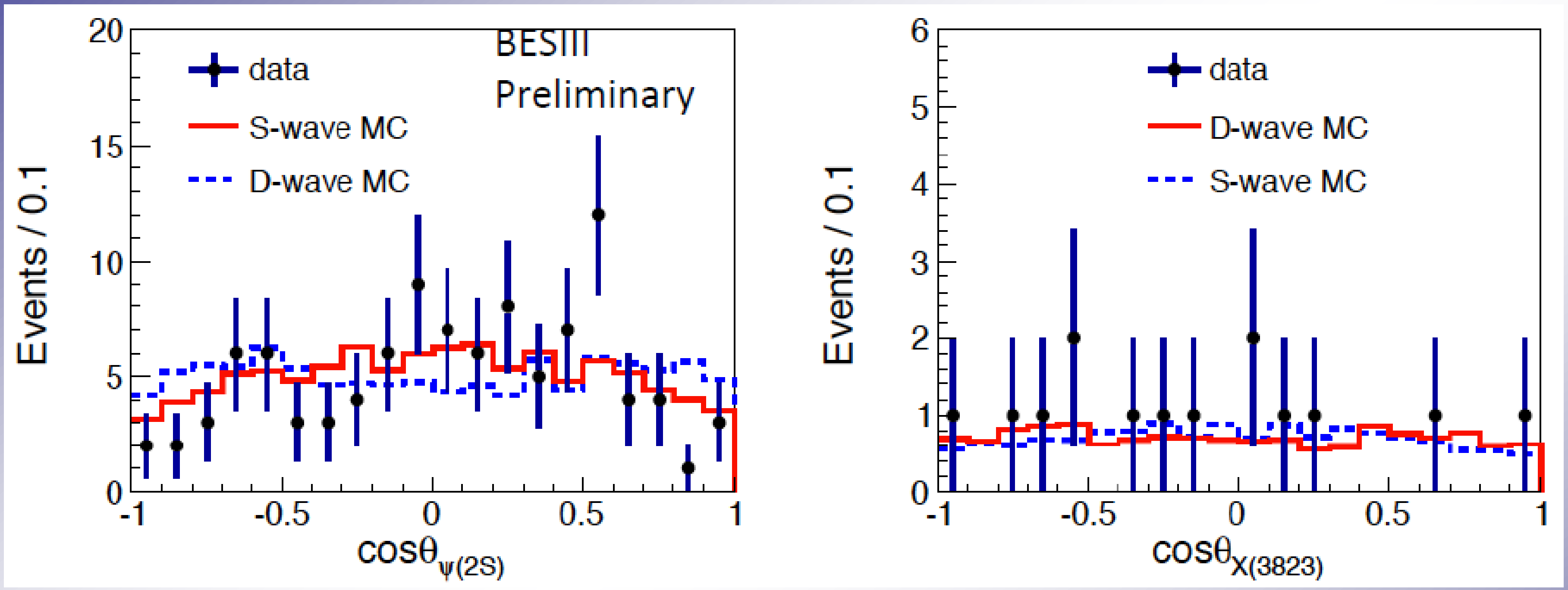
Coupling to $\bar{D}^*D^*$ is much larger than to πh_c if they are the same state

Will fit with Flatte formula

BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{c1,2}$ @ 4.19-4.60 GeV

$\psi(1^3D_2)$ candidate

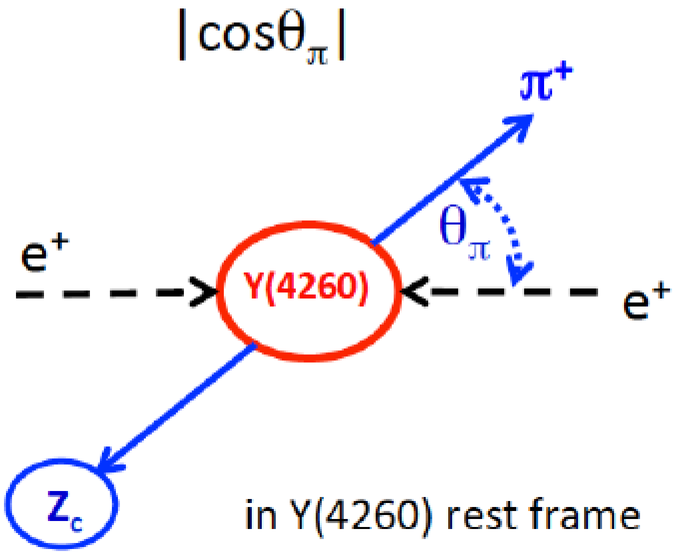
BESIII Preliminary!

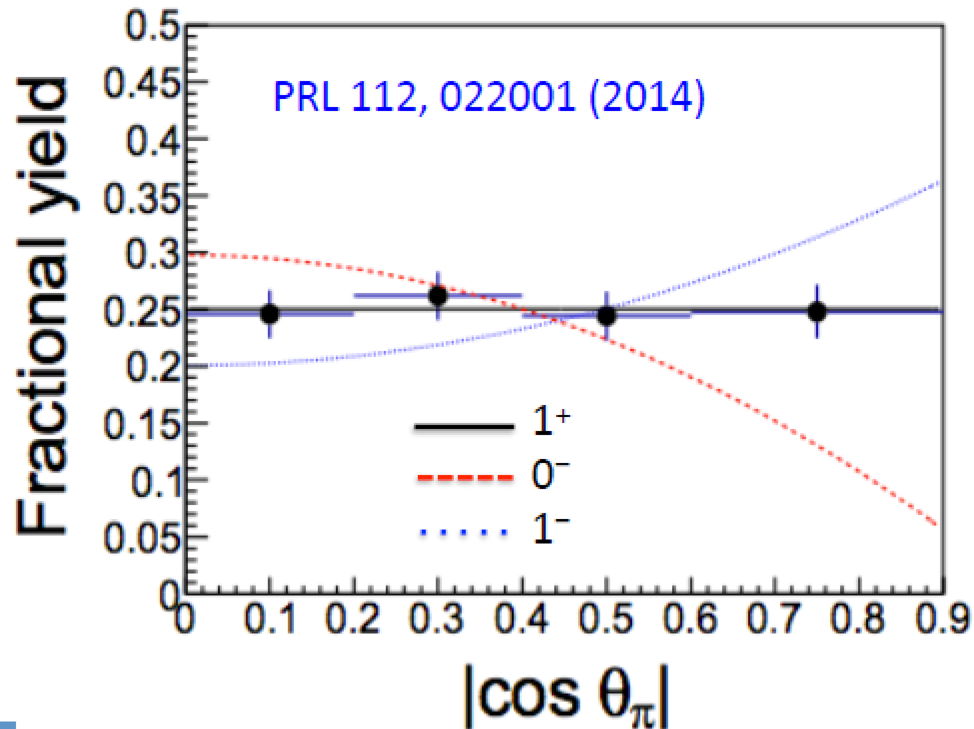


- Assume ππ system is dominant by f0(500)
- Many new exciting results on their way

BESIII: $e^+e^- \to \pi Z_c(3885) \to \pi^-(DD^*)^+ + c.c.$ @ 4.260 GeV

BESIII Preliminary!





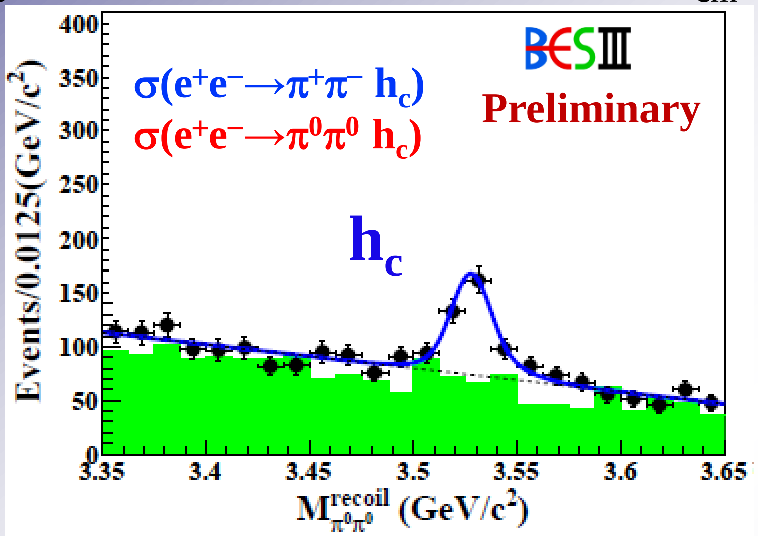
J^P	L	$dN/d\|\cos\theta_\pi\|$
1^+	S-wave	flat
0^-	P-wave	$\sin^2\theta_\pi$
1^-	P-wave	$1+\cos^2\theta_\pi$

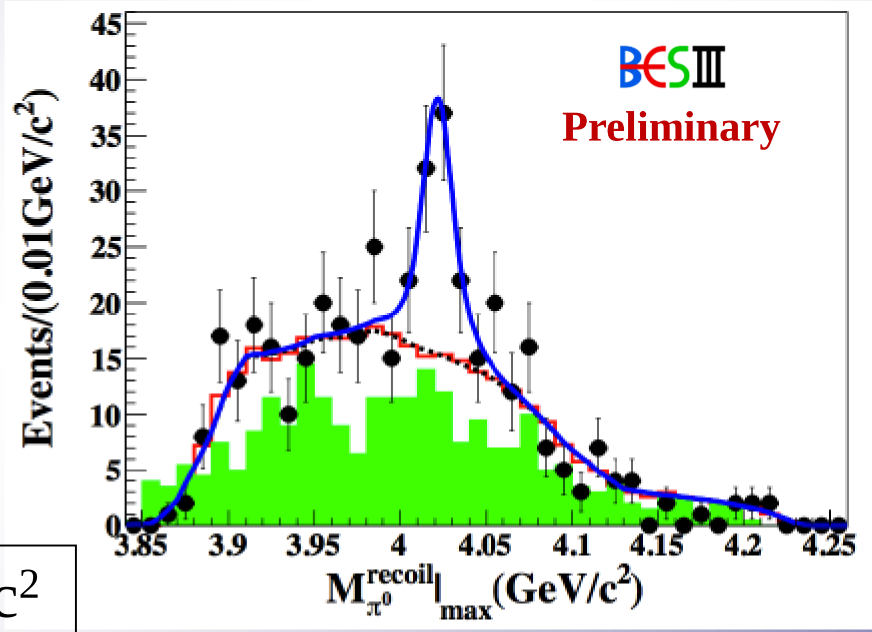
Favor $J^P=1^+$

BESIII: $e^+e^- \to \pi Z_c(4020)^0 \to \pi^0\pi^0 h_c$ @ 4.23/4.26/4.36 GeV

BESIII Preliminary!

- 2.8fb^{-1} data at 10 energy points from 4230~4420 MeV
- $Z_c(4020)^0$ is observed clearly at: E_{cm}=4230, 4260, 4360MeV





$M_{Z_c(4020)^0}$ = (4023.6±2.2±3.9) MeV/c^2

$M_{Z_c(4020)^\pm}$ = (4022.9±0.8±2.7) MeV/c^2

$\Gamma_{Z_c(4020)^0}$ fixed @ $\Gamma_{Z_c(4020)^\pm}$

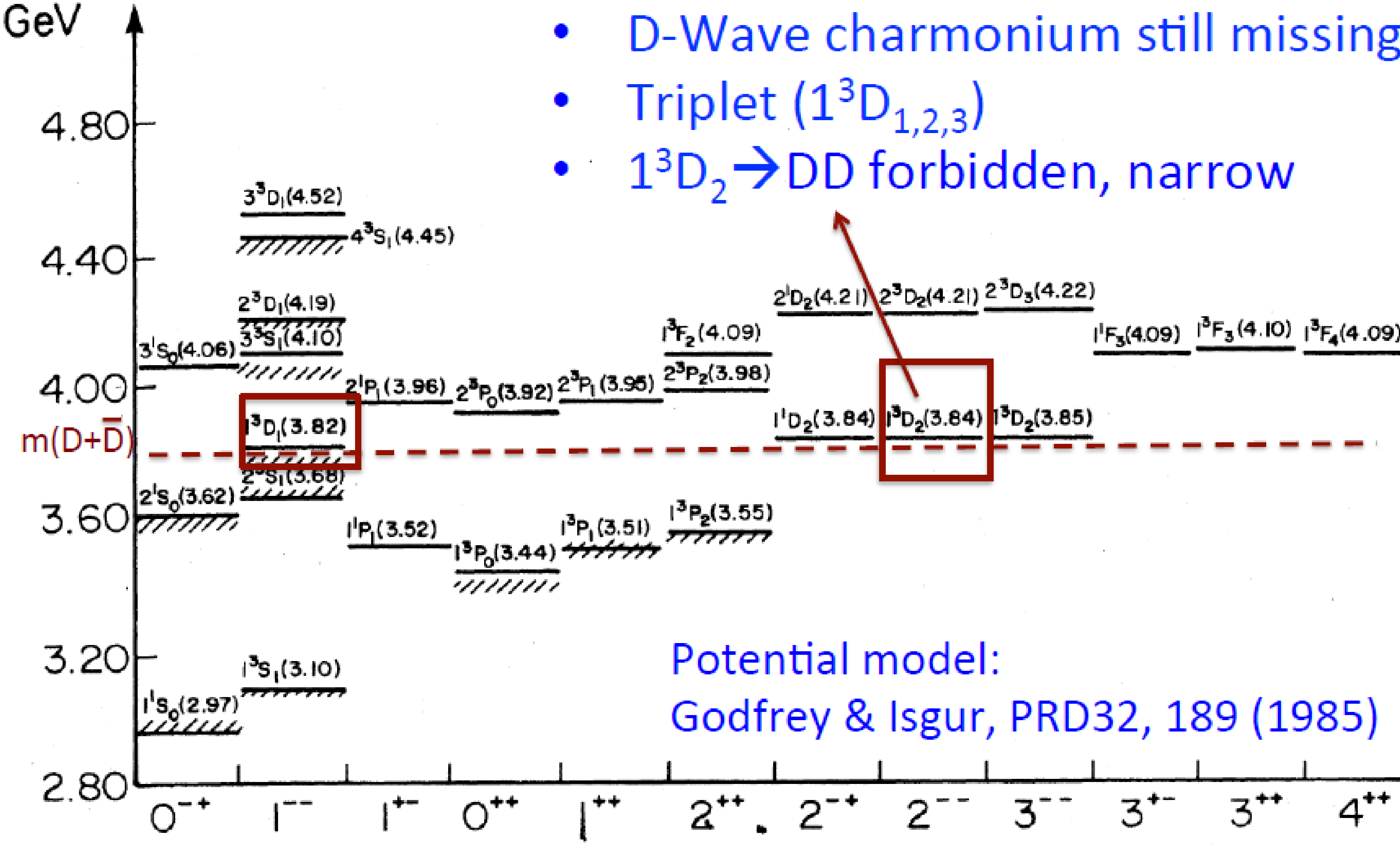
$>5\sigma$

An isospin triplet for $Z_c(3900)$ has also been observed

BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{C1,2}$ @ 4.19-4.60 GeV

BESIII Preliminary!

- D-Wave charmonium still missing
- Triplet ($1^3D_{1,2,3}$)
- $1^3D_2 \to DD$ forbidden, narrow

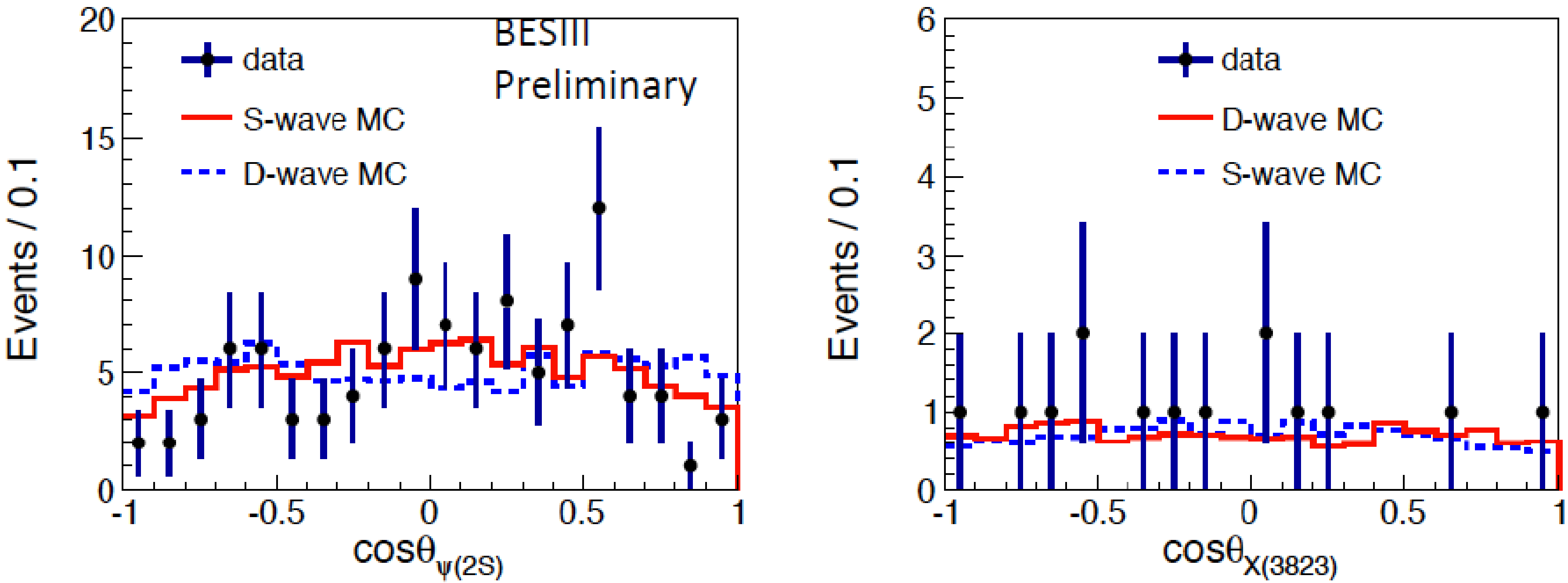


Potential model:
Godfrey & Isgur, PRD32, 189 (1985)

BESIII: $e^+e^- \to \pi^+\pi^- X(3823) \to \gamma\chi_{c1,2}$ @ 4.19-4.60 GeV

$\psi(1^3D_2)$ candidate

BESIII Preliminary!



1. Assume $\pi\pi$ system is dominant by $f_0(500)$
2. Scattering angle distribution of $\psi(2S)$ and X(3823) in e+e- CM frame.
3. Kolmogorov-Smirnov test p-value is given.
4. (Left) $\pi+\pi-\psi(2S)$: S-wave (p=0.791), D-wave (p=0.451)→S-wave seems to be better.
5. (right) $\pi+\pi-$X(3823): S (p=0.928), D (p=0.978)→Can't distinguish

Investigated Processes

- Exclusive scenario: could see interference effects

• e^+e^+ -> J/ψ -> $p\bar{p}$, $n\bar{n}$ $N\bar{N}$

BR ~ 2.17×10^{-3} σ_{cont}~ 11 pb

• e^+e^- -> J/ψ -> $\rho\pi$ VP

BR ~ 1.69% σ_{cont}~ 20 pb

• e^+e^- -> J/ψ -> $2(\pi^+\pi^-)\pi^0$

BR ~ 5.5% σ_{cont}~ 500 pb