Selected results on Charmonium (like) states from BESIII

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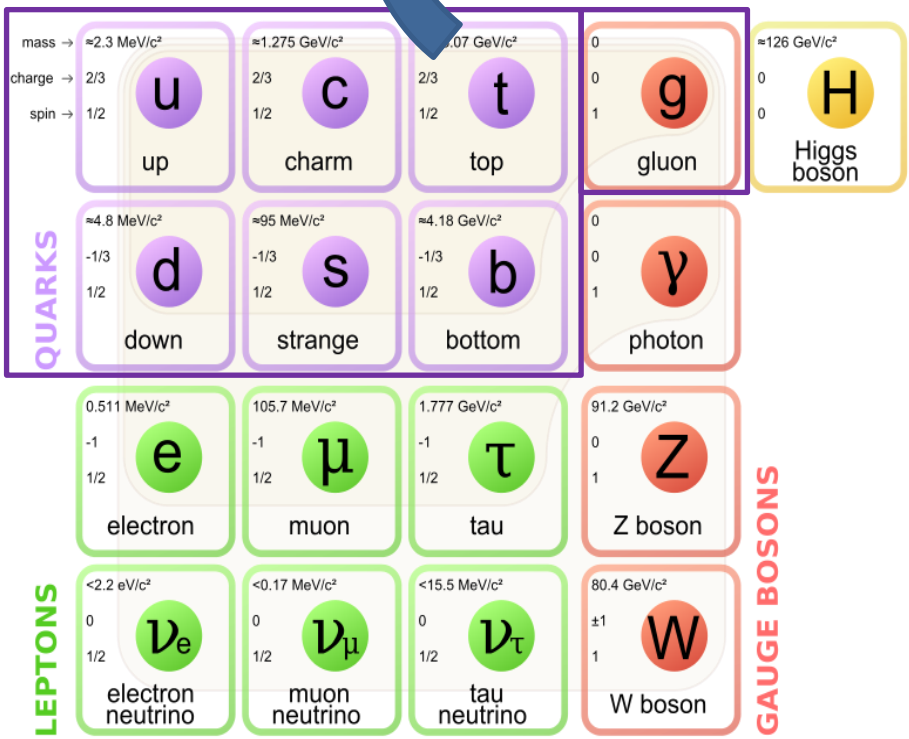
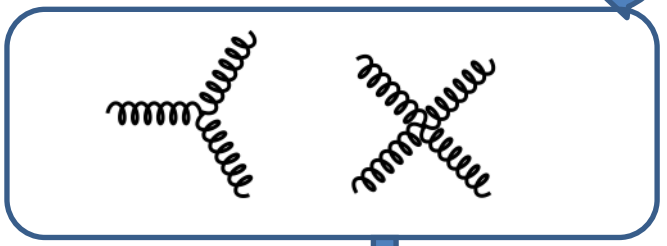
on behalf of the BESIII collaboration

XIth International Conference on
Quark Confinement and the Hadron Spectrum,
St Petersburg, Russia

The global picture

$$\mathcal{L}_{\mathrm{QCD}} = \sum_n \left(i\hbar c \bar{\psi}_n \not{D} \psi_n - m_n c^2 \bar{\psi}_n \psi_n \right) - \frac{1}{4} G^{\alpha}{}_{\mu\nu} G_{\alpha}{}^{\mu\nu}$$

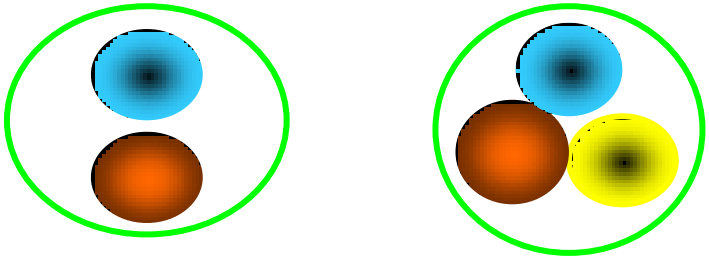




Need effective models

Hadrons：traditional & exotic

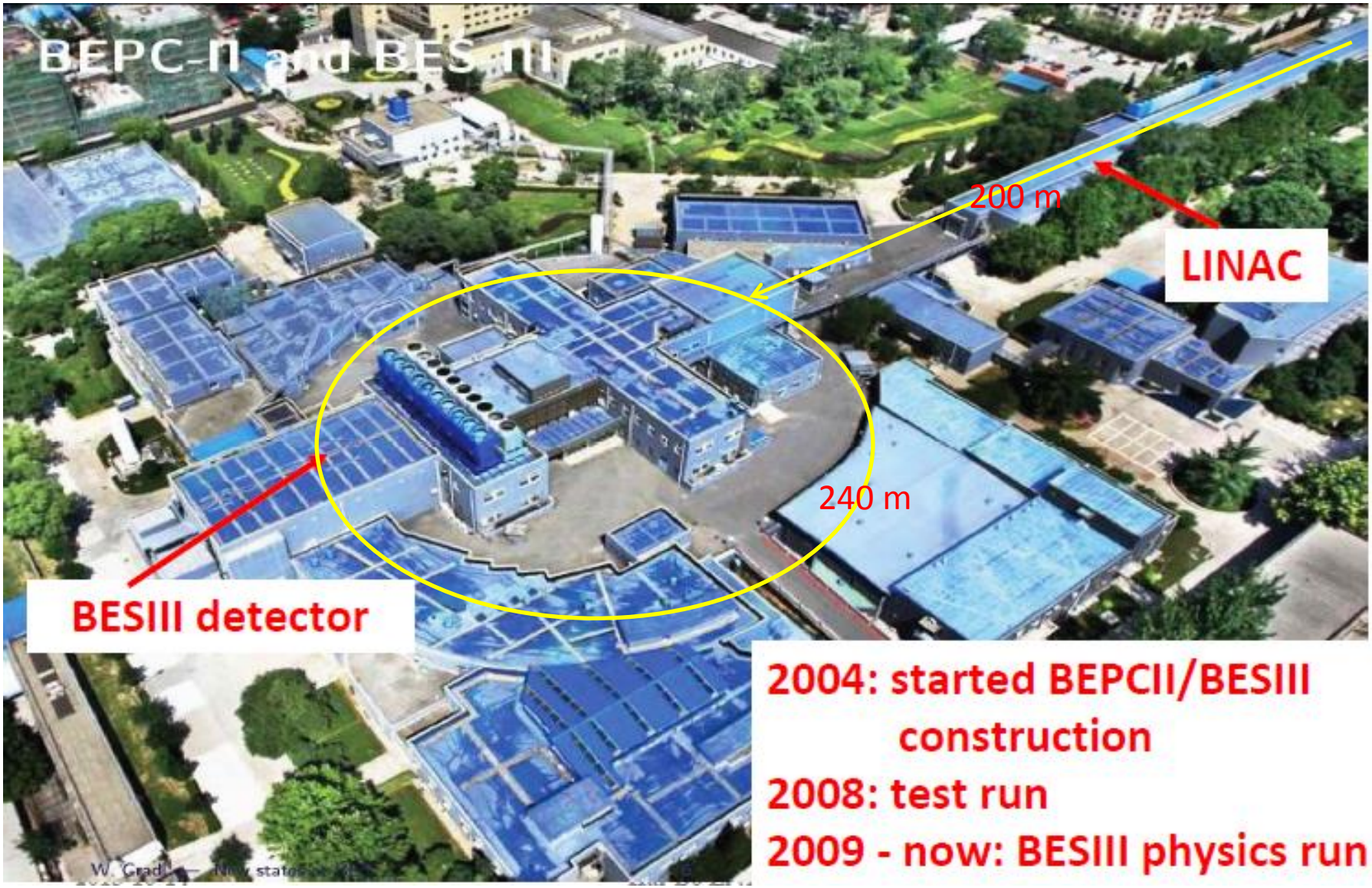
- Hadrons are composed of 2 quarks (meson) or 3 quarks (baryon) in Quark Model



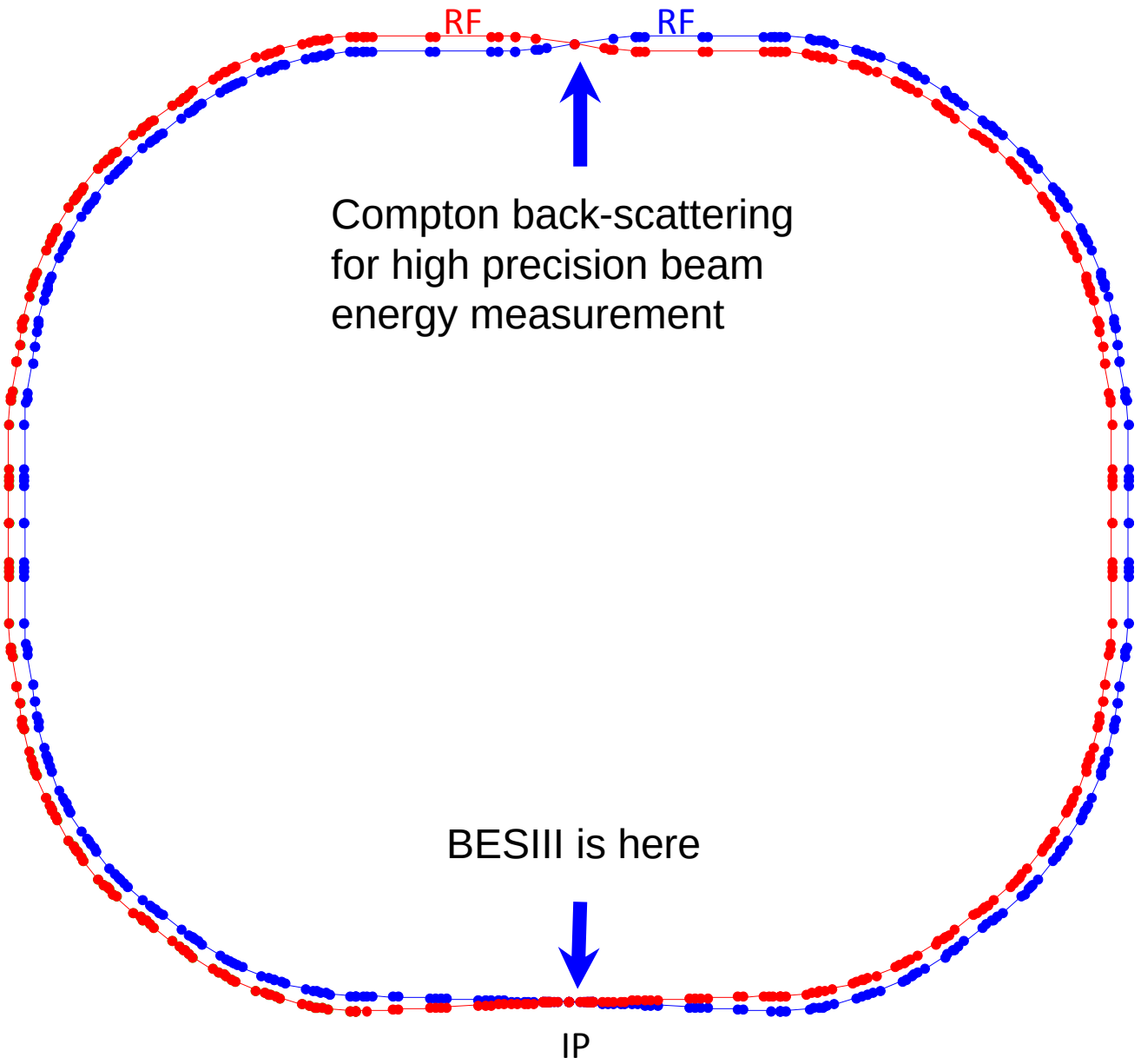
- QCD does not forbid hadrons with $N_{quarks} \neq 2, 3$
  - glueball : $N_{quarks} = 0$ (gg, ggg, …)
  - hybrid : $N_{quarks} = 2$ (or more) + excited gluon
  - multiquark state : $N_{quarks} > 3$
  - molecule : bound state of more than 2 hadrons
  - …

BESIII@BEPCII is collecting data to study this.

Beijing Electron Positron Collider II

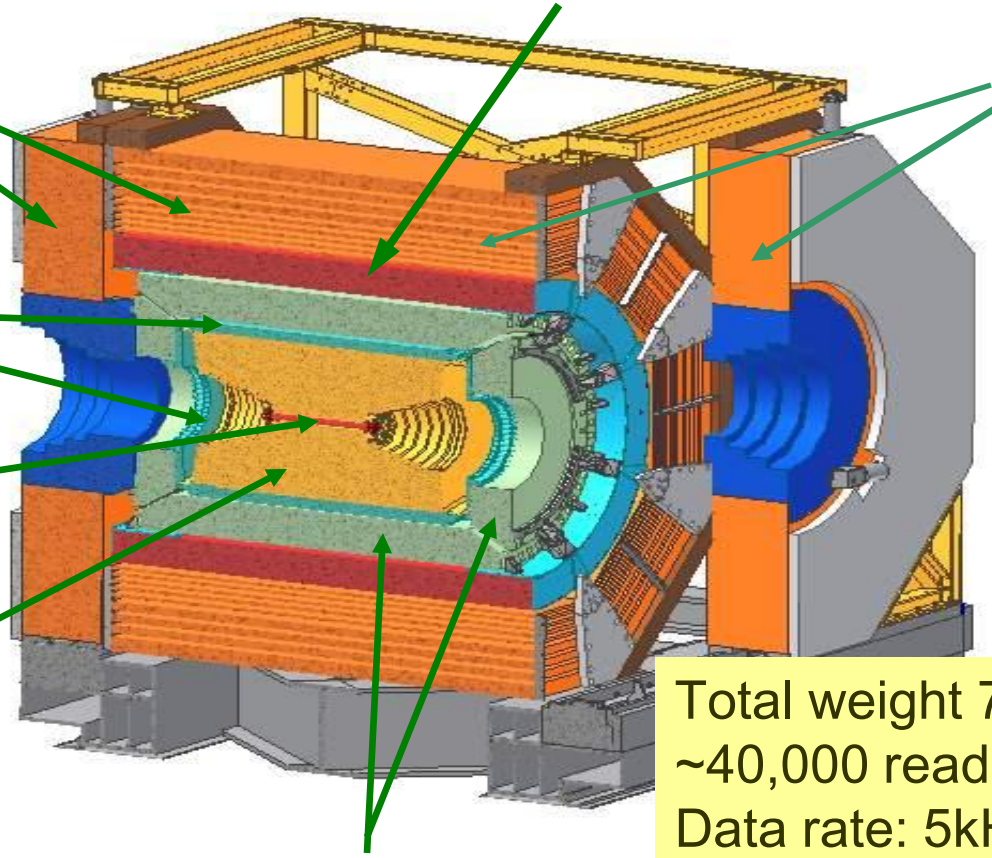


BEPC II: double-ring



Beam energy:
1-2.3 GeV
Design luminosity:
1×10^{33} $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
Energy spread:
5.16×10^{-4}
Bunch length:
1.5 cm
Total current:
0.91 A

BESIII Detector



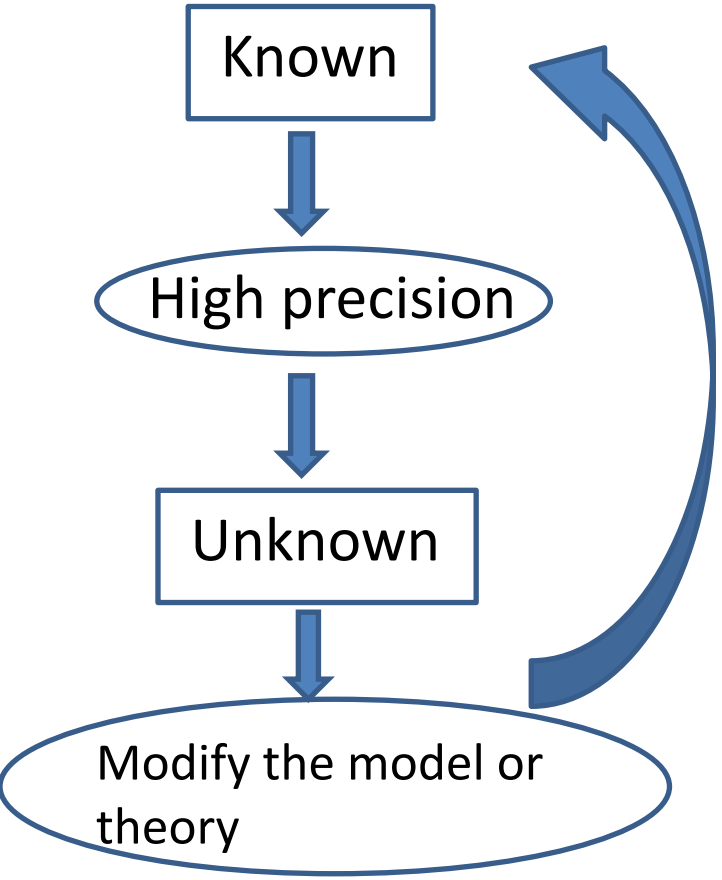

BESIII Collaboration Meeting
Jun 4-7,2014 IHEP,Beijing
I am the side band of that signal!
More than 300 members from 53 institutions in 11 countries.

Data samples collected with BESIIII detector

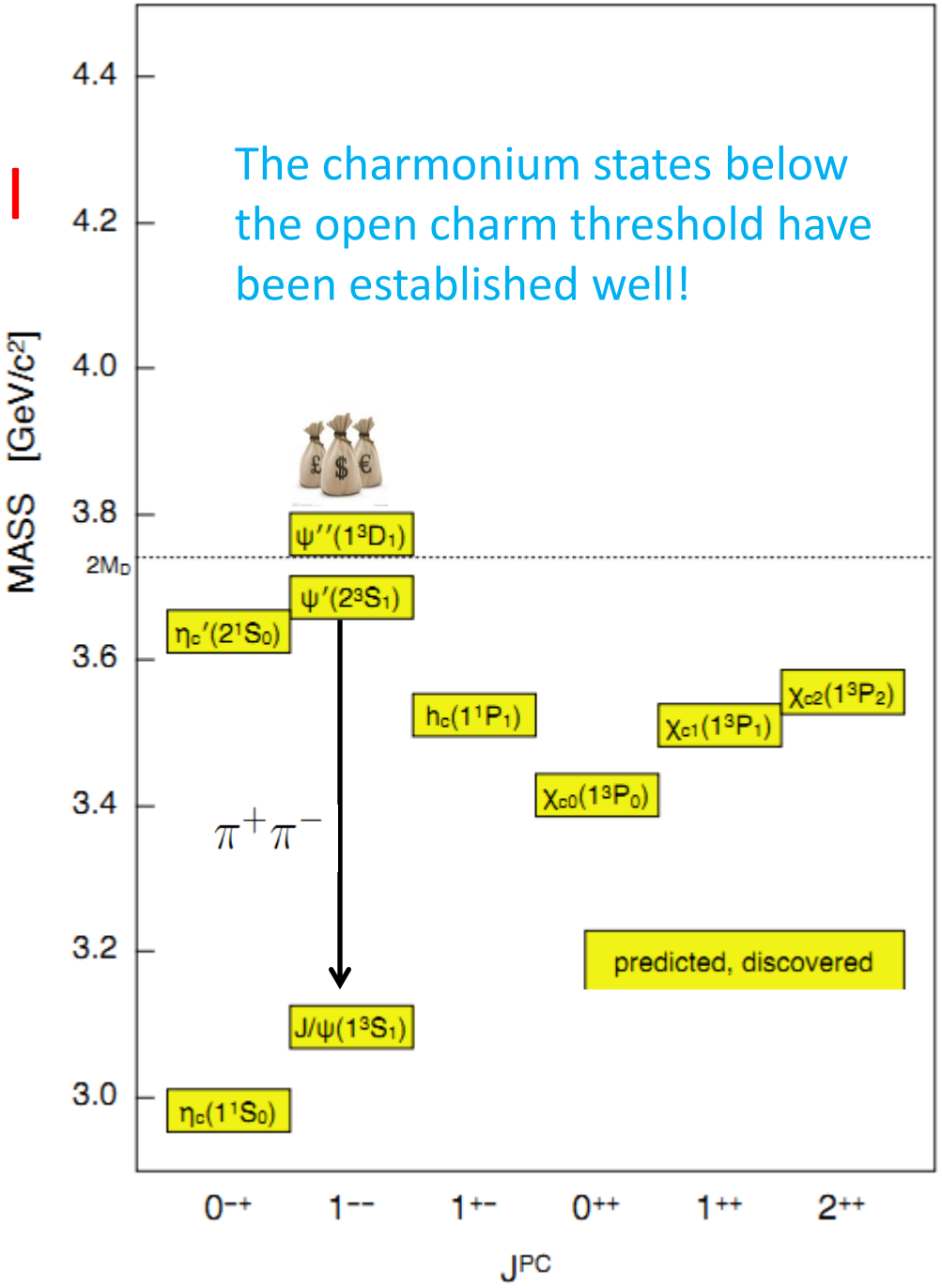
Energy point (MeV)	L or N	Main physics motivation
3097	1.3 B J/ψ	Light hadron
3554	0.024/fb	τ mass
3686	0.5 B $\psi(2S)$	Charmonium transition
3773	2.9/fb	Charm meson decays; flavor physics
4009	0.5/fb	Charmonium (like) spectroscopy
4230、4260 and coarse scan	2.3/fb	Charmonium-like spectroscopy
4360 and coarse scan	0.7/fb	Charmonium-like spectroscopy
3850-4600 fine scan	0.8/fb	R value, Charmonium spectroscopy
4420	1.0/fb	Charmonium spectroscopy
4600	0.5/fb	Charmonium spectroscopy, charmed baryon

(the result presented in this talk are based on the red data samples)

Part I:
Charmonium at BESIII



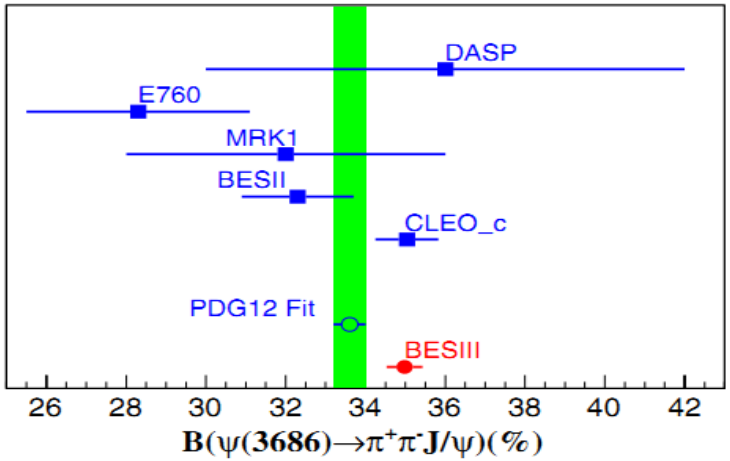
The charmonium states below the open charm threshold have been established well!

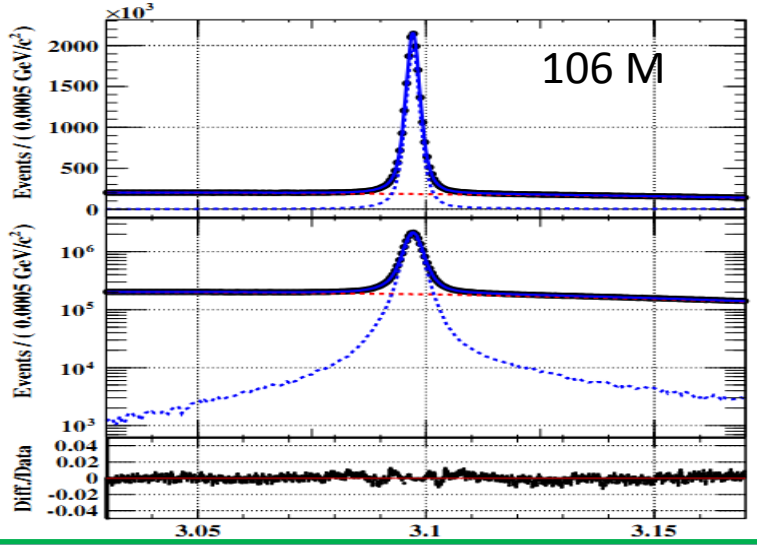


Precision measurement of $B[\psi(3686)\to\pi^+\pi^- J/\psi]$ and $B[J/\psi\to l^+l^-]$

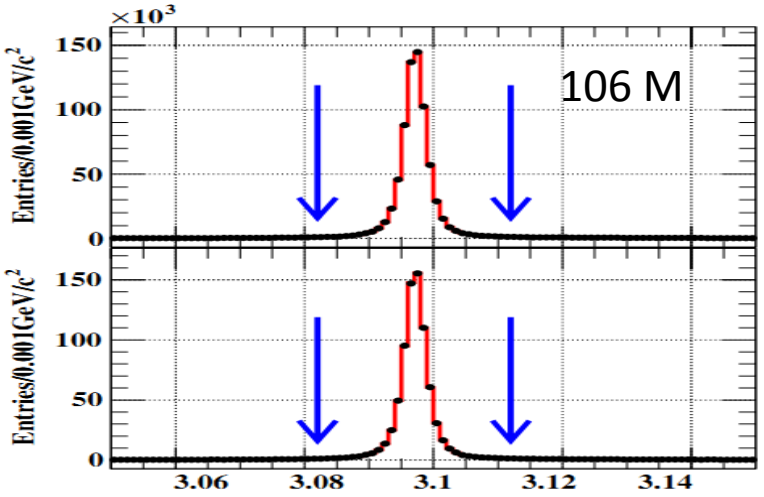
PRD 88, 032007

Channel	$B(\%)$
$\psi(3686)\to\pi^+\pi^- J/\psi$	$34.98\pm0.02\pm0.45$
$J/\psi\to l^+l^-$	$5.978\pm0.005\pm0.040$
$J/\psi\to e^+e^-$	$5.983\pm0.007\pm0.037$
$J/\psi\to\mu^+\mu^-$	$5.973\pm0.007\pm0.038$
$\frac{B[J/\psi\to e^+e^-]}{B[J/\psi\to\mu^+\mu^-]}$	$1.0017\pm0.0017\pm0.0033$





$\pi^+\pi^-$ recoil mass with $J/\psi\to$ anything



$\pi^+\pi^-$ recoil mass with $J/\psi\to e^+e^-$ (up) and $J/\psi\to\mu^+\mu^-$ (bottom)

Part II:
Exotics at BESIII

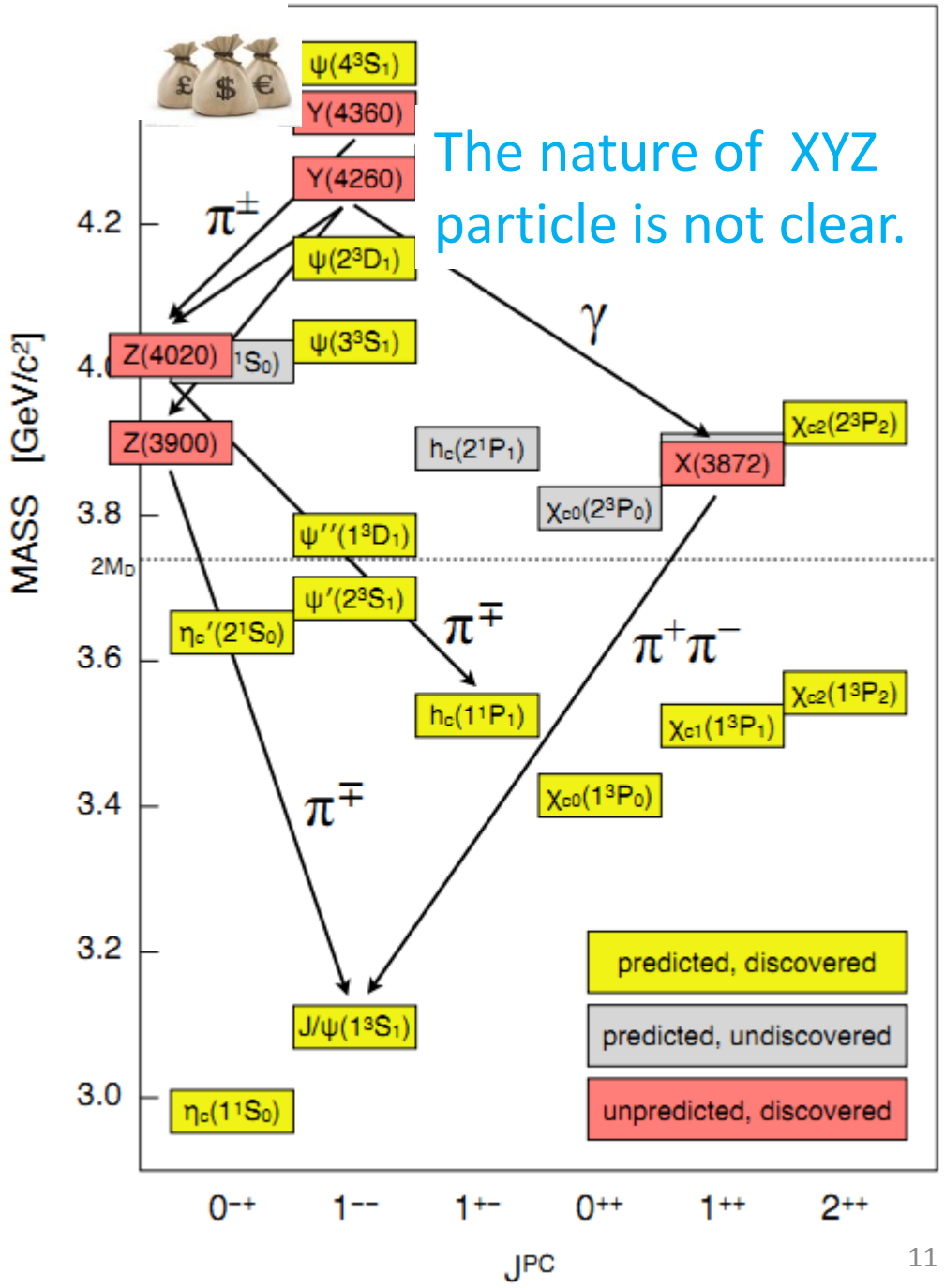
Unknown

↓

Search for the theory or model

↓

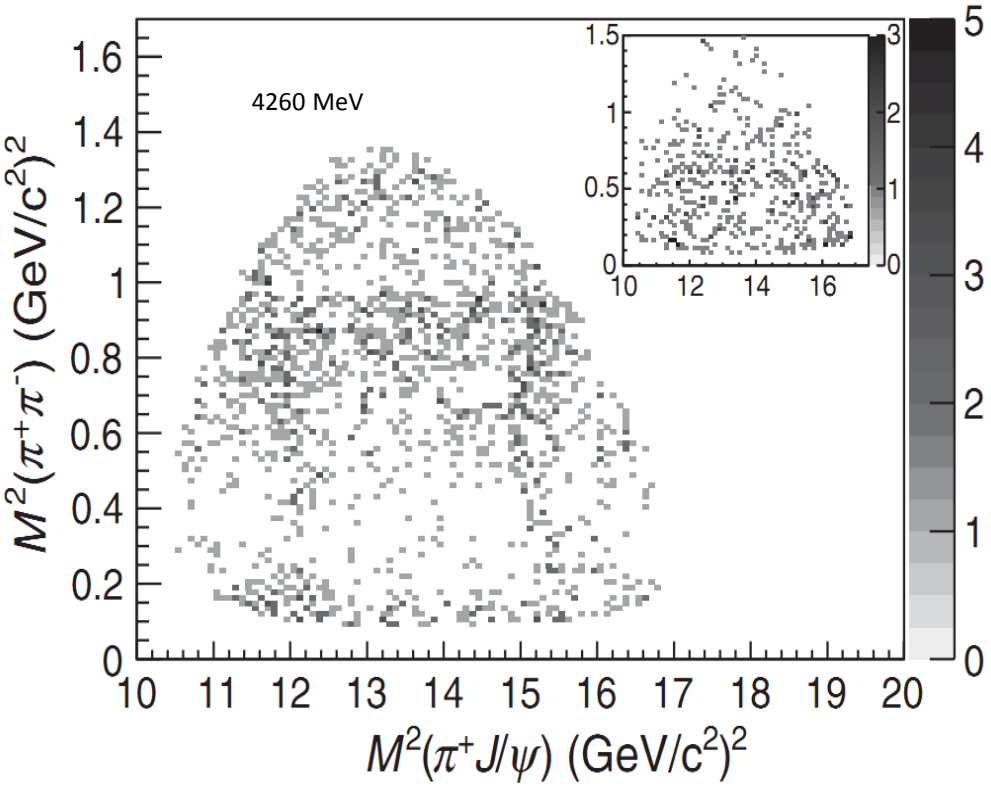
Known

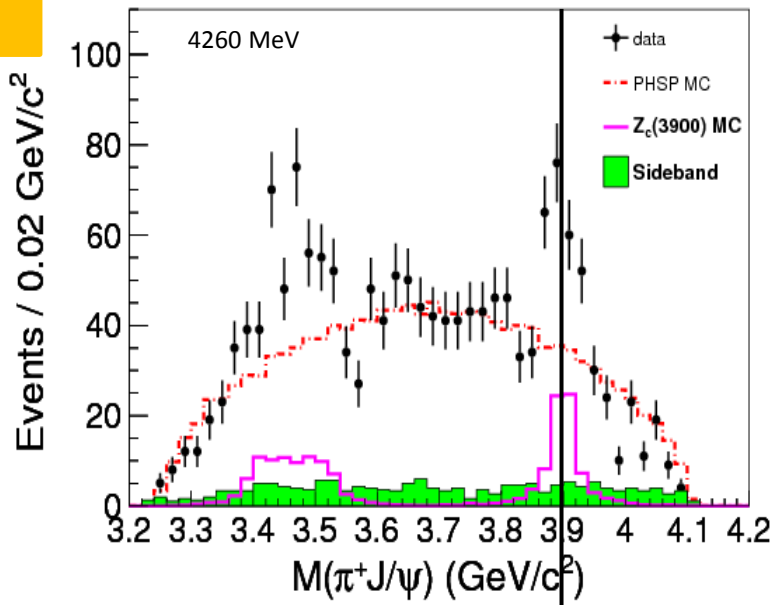


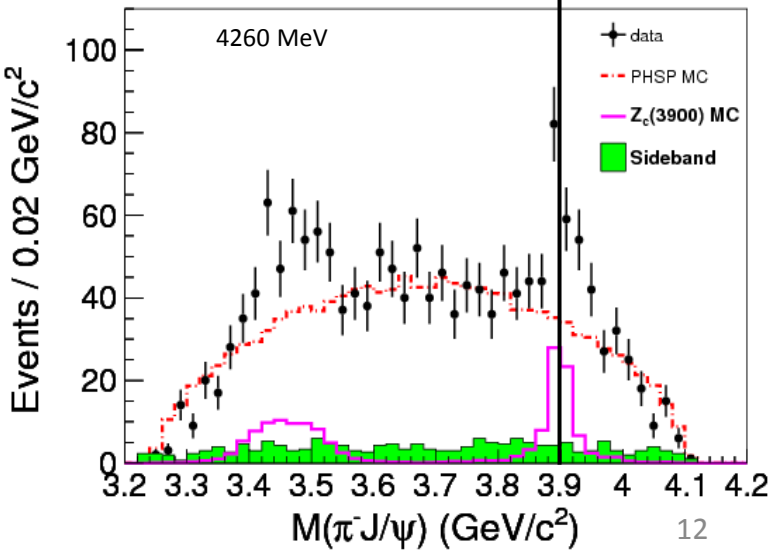
The discovery of $Z_c(3900)^{\pm}$

PRL 110, 252001

Study the $e^+e^- \to \pi^+\pi^- J/\psi$ process at 4.26 GeV, structures are there!







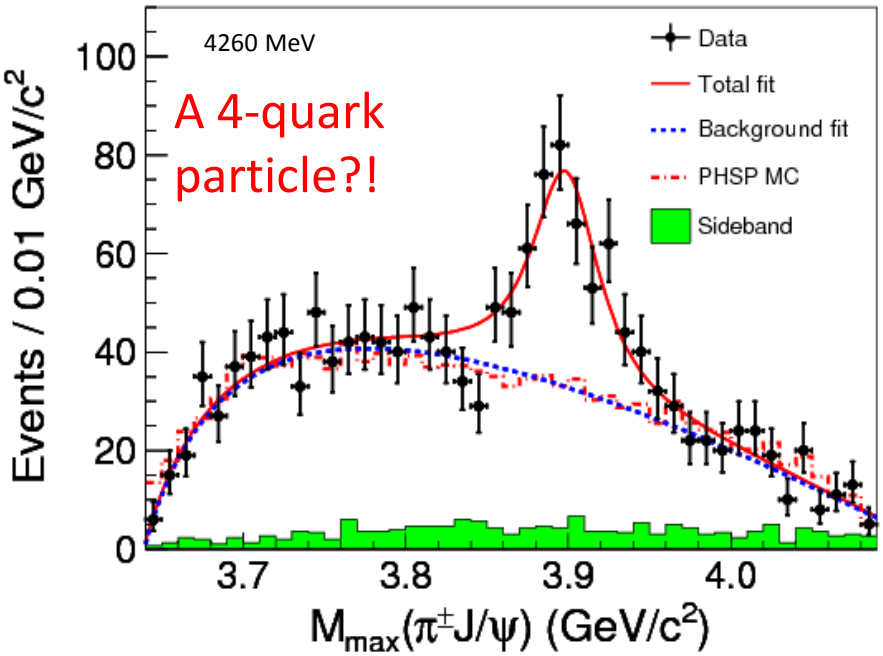
$Z_c(3900)^+$:

$$m = (3899.0 \pm 3.6 \pm 4.9)\ \mathrm{MeV}/c^2$$

$$\Gamma = (46 \pm 10 \pm 20)\ \mathrm{MeV}$$

Mass close to $D\bar{D}^*$ threshold

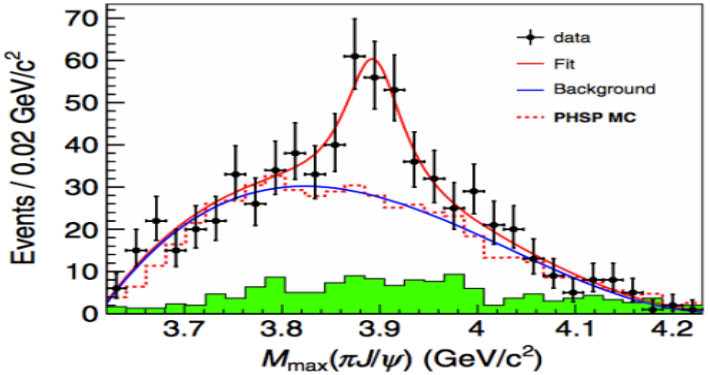
Decays to J/ψ → contains $c\bar{c}$
Electric charge → contains $u\bar{d}$



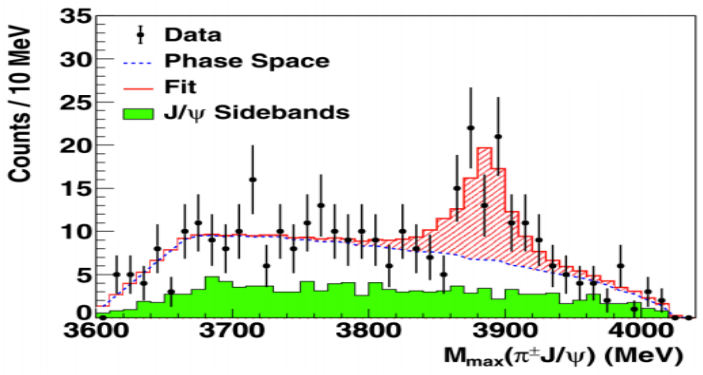
$$\sigma[e^+e^- \to \pi^+\pi^- J/\psi] = 62.9 \pm 1.9 \pm 3.7\ \mathrm{pb\ at\ 4.26\ GeV}$$

$$\frac{\sigma[e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi]}{\sigma[e^+e^- \to \pi^+\pi^- J/\psi]} = (21.5 \pm 3.3 \pm 7.5)\%\ \mathrm{at\ 4.26\ GeV}$$

Belle with ISR data (PRL 110, 252002)

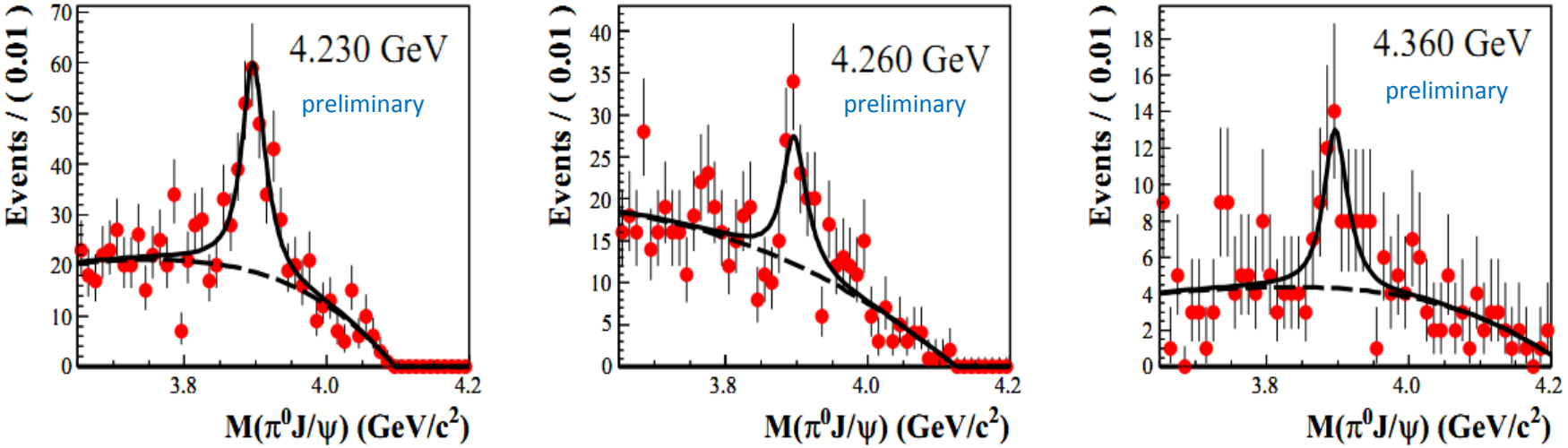


CLEOc data at 4.17 GeV (PLB 727, 366)



The neutral isospin partner: $Z_c(3900)^0$

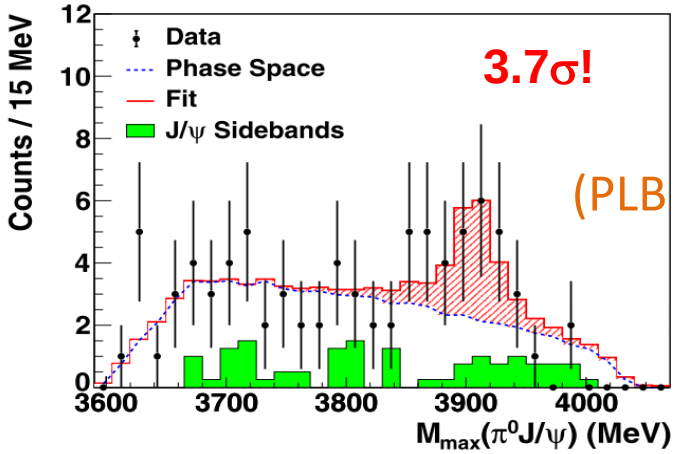
Studying the $e^+e^- \to \pi^0\pi^0 J/\psi$ process



A structure on $\pi^0 J/\psi$ invariant mass spectrum can be observed:

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

Isospin triplet is established!



(PLB 727, 366)

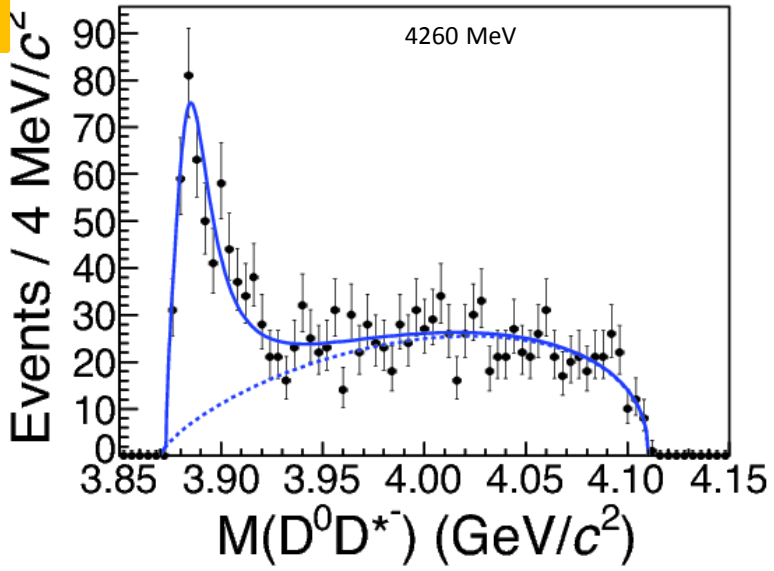
The study of $e^+e^- \to \pi^\pm(D\overline{D}^*)^\mp$ process

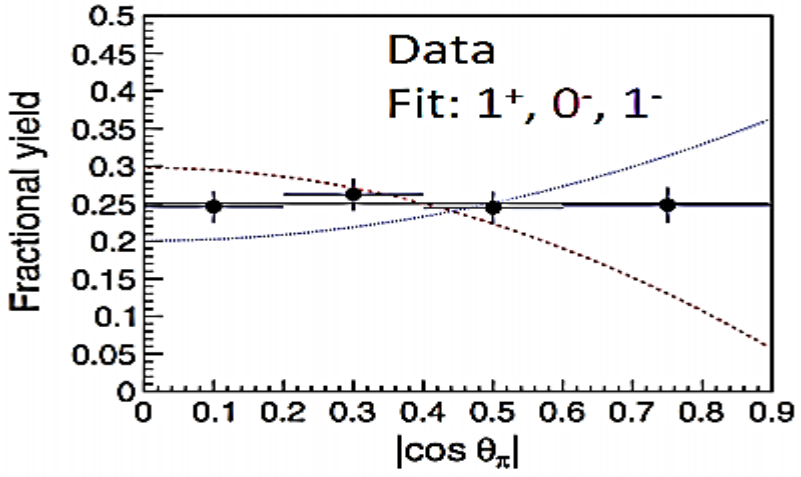
PRL 112, 022001

Reconstruct the π^+ and $D^0 \to K^-\pi^+$ and infer the D^{*-}.
(Also analyze $\pi^+D^-D^{*0}$ with the same method.)

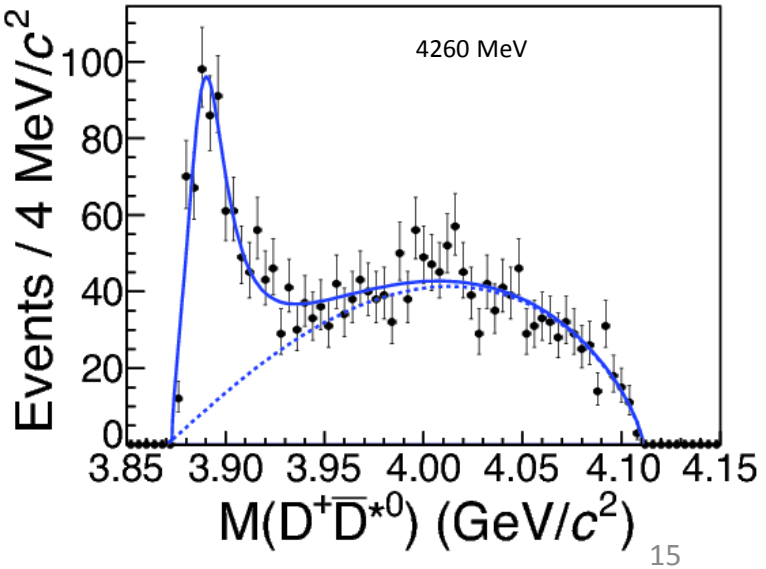
Enhancement at $D\bar{D}^*$ threshold in both channels ($Z_c(3885)^+$):

Mass = 3883.9±1.5±4.2 MeV, (fit with BW function)
Width = 24.8±3.3 ±11.0 MeV





Fit to angular distribution favors $J^P = 1^+$ over 0^- and 1^-



A comparison between Zc(3885) and Zc(3900)

	$Z_c(3885) \to D\bar{D}^*$	$Z_c(3900) \to \pi J/\psi$
Mass (MeV/c^2)	$3883.9 \pm 1.5 \pm 4.2$	$3899.0 \pm 3.6 \pm 4.9$
Γ (MeV)	$24.8 \pm 3.3 \pm 11.0$	$46 \pm 10 \pm 20$
$\sigma \times \mathcal{B}$ (pb)	$83.5 \pm 6.6 \pm 22.0$	$13.5 \pm 2.1 \pm 4.8$

- The mass and width are consistent within **2σ!**
- If this is $Z_c(3900)^+$, open charm decays are suppressed, since

$$\frac{\mathcal{B}(Z_c \to D^* \bar{D})}{\mathcal{B}(Z_c \to J/\psi \pi)} = 6.2 \pm 1.1 \pm 2.7$$

Compared to e.g.

$$\frac{\mathcal{B}(\psi(4040) \to D^{(*)} \bar{D}^{(*)})}{\mathcal{B}(\psi(4040) \to J/\psi \eta)} = 192 \pm 27$$

Different dynamics in Y(4260)-Zc(3900) system!

The study of $e^+e^- \to \pi^+\pi^- h_c$ process

PRL 111, 242001

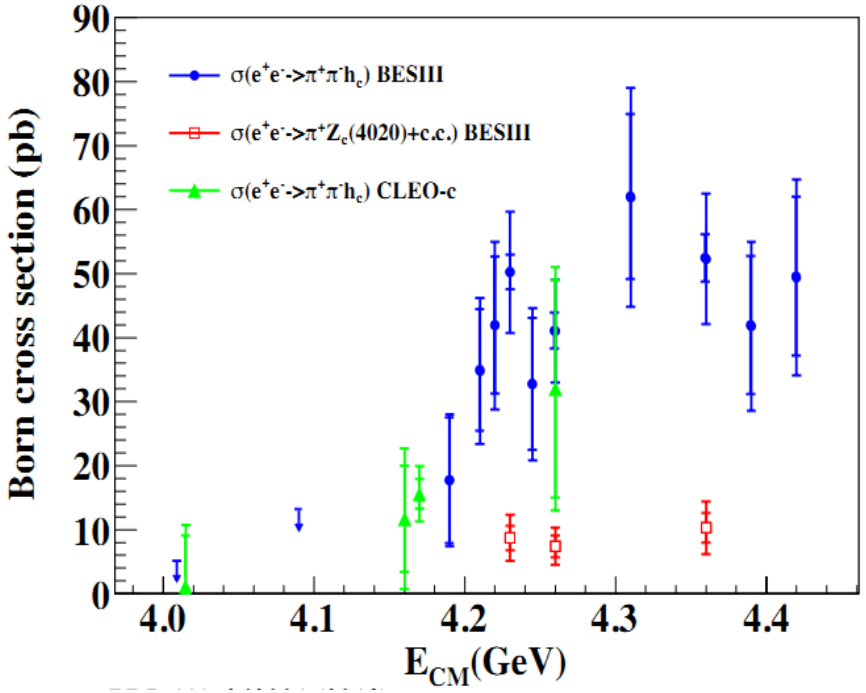
$h_c \to \gamma\eta_c$,
$\eta_c \to$16 hadronic decay modes

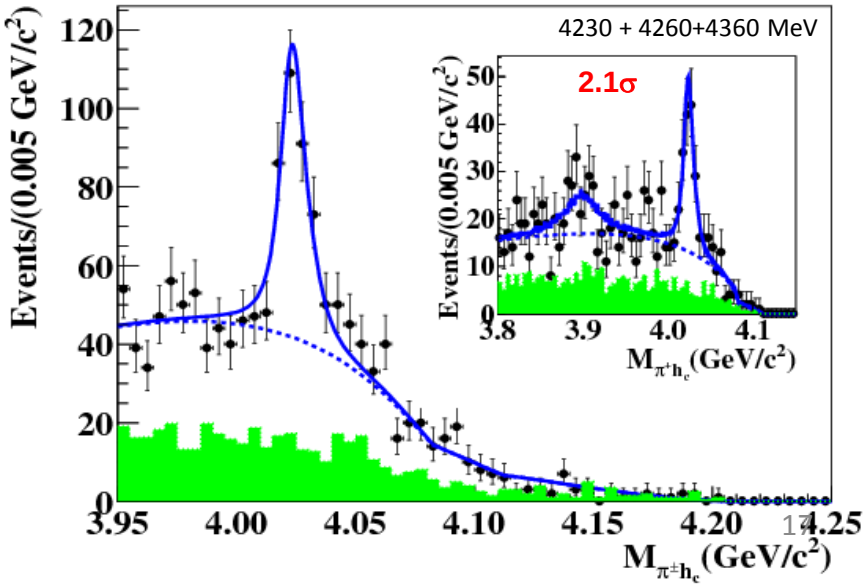
The cross section of $e^+e^- \to \pi^+\pi^- h_c$ is measured, and the shape is not trivial.

A structure, $Z_c(4020)^{\pm}$, is observed.

Mass = 4022.9±0.8 ±2.7 MeV,
Width = 7.9±2.7 ±2.6 MeV

A weak evidence for $Z_c(3900)^{\pm} \to \pi^{\pm} h_c$



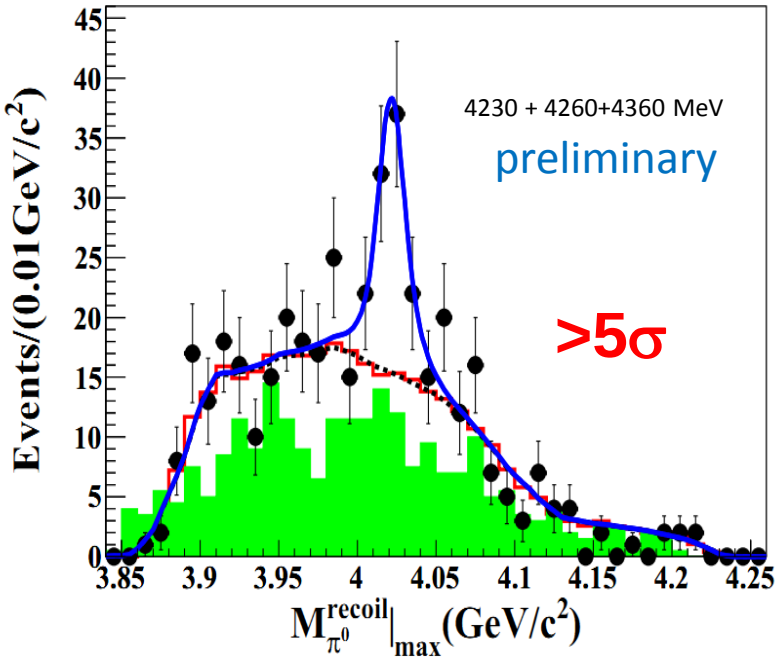


The neutral isospin partner: $Z_c(4020)^0$

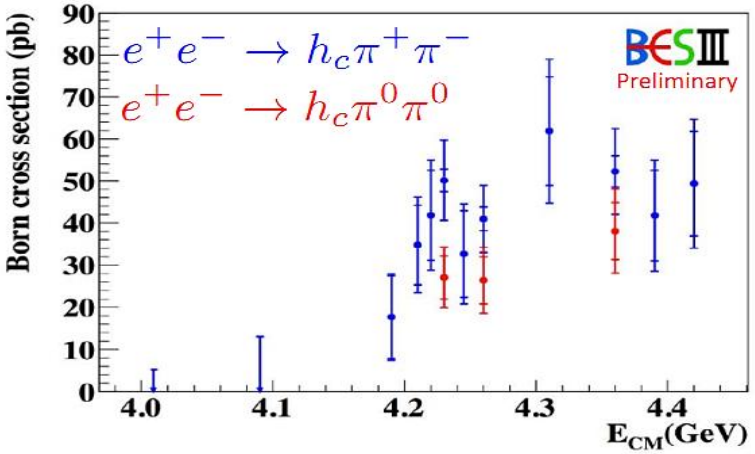
Studying the $e^+e^- \to \pi^0\pi^0 h_c$ process

A structure on π^0hc invariant mass spectrum can be observed:

Mass = 4023.9±2.2 ±3.8 MeV, Width is fixed to be same as its charged partner.



Another isospin triplet is established!



Cross sections for $e^+e^- \to h_c\pi^+\pi^-$ and $e^+e^- \to h_c\pi^0\pi^0$ are in agreement with isospin conservation

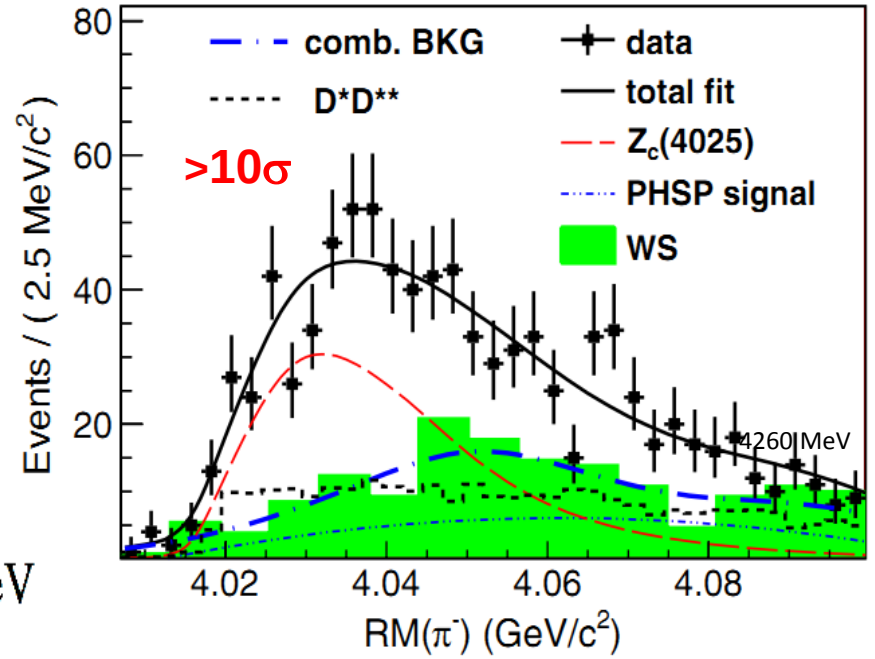
The study of $e^+e^- \to \pi^\pm (D^* \overline{D}^*)^\mp$ process

PRL 112, 132001

Tag a D^+ and a bachelor π^-, reconstruct one π^0 to suppress the background.

A structure, named as Zc(4025), can be observed in the recoil mass of the bachelor π^- .

$M(Z_c(4025)) = 4026.3 \pm 2.6 \pm 3.7$ MeV;
$\Gamma(Z_c(4025)) = 24.8 \pm 5.6 \pm 7.7$ MeV



$$\sigma[e^+e^- \to (D^*\bar{D}^*)^\pm\pi^\mp] = 137 \pm 9 \pm 15 \text{ pb at } 4.26 \text{ GeV}$$

$$\frac{\sigma[e^+e^- \to \pi^\pm Z_c(4025)^\mp \to (D^*\bar{D}^*)^\pm\pi^\mp]}{\sigma[e^+e^- \to (D^*\bar{D}^*)^\pm\pi^\mp]} = 0.65 \pm 0.09 \pm 0.06 \text{ at } 4.26 \text{ GeV}$$

Coupling to $\bar{D}^*D^*$ is much larger than to πh_c if $Z_c(4025)$ and $Z_c(4020)$ are the same state.

PRL 112, 132001

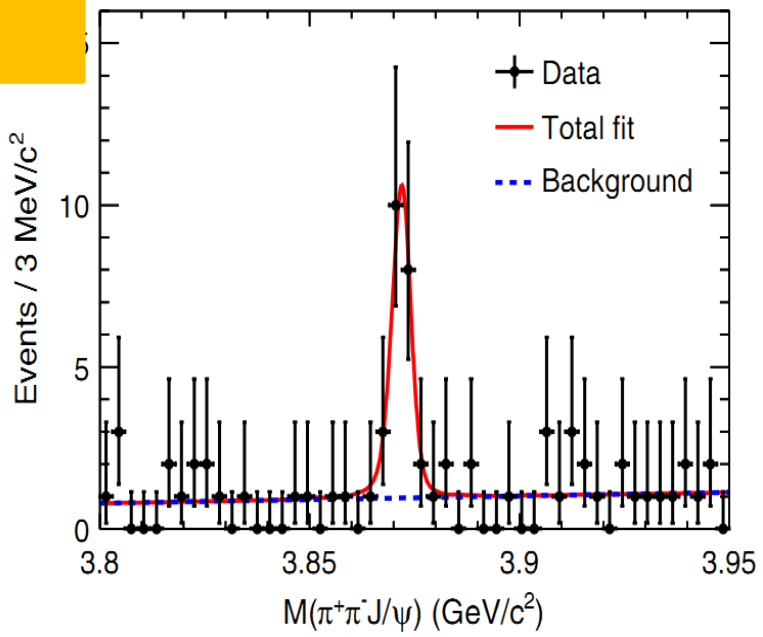
Observation of $e^+e^- \to \gamma X(3872)$ $\to \gamma \pi^+ \pi^- J/\psi$

significance = 6.3σ

N = 20.1 ± 4.5 events

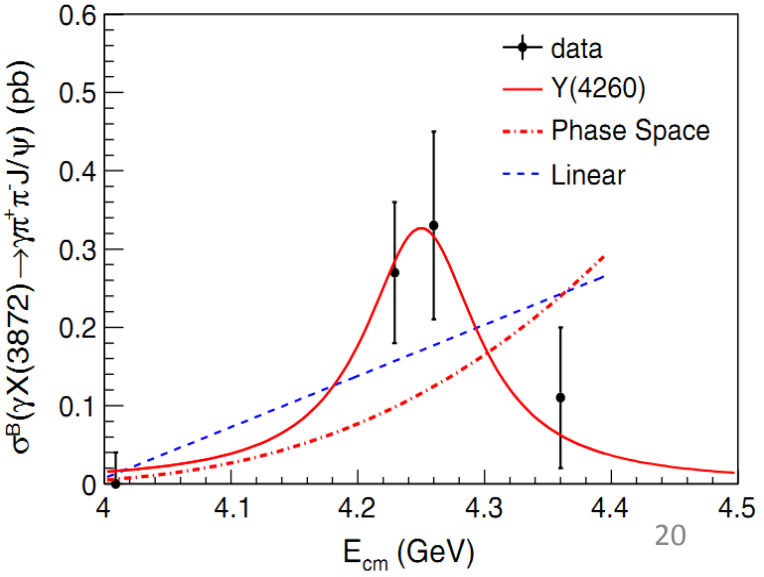
M = 3871.9 ± 0.7 ± 0.2 MeV

Γ consistent with resolution



The resonant contribution with Y(4260) line shape provides a better description of the data than either a linear continuum or a E1- transition phase space distribution.

The Y(4260)->γ X(3872) could be another previously unseen decay mode of the Y(4260) resonance.



First observation of

$e^+e^- \to \omega\chi_{c0}$ preliminary

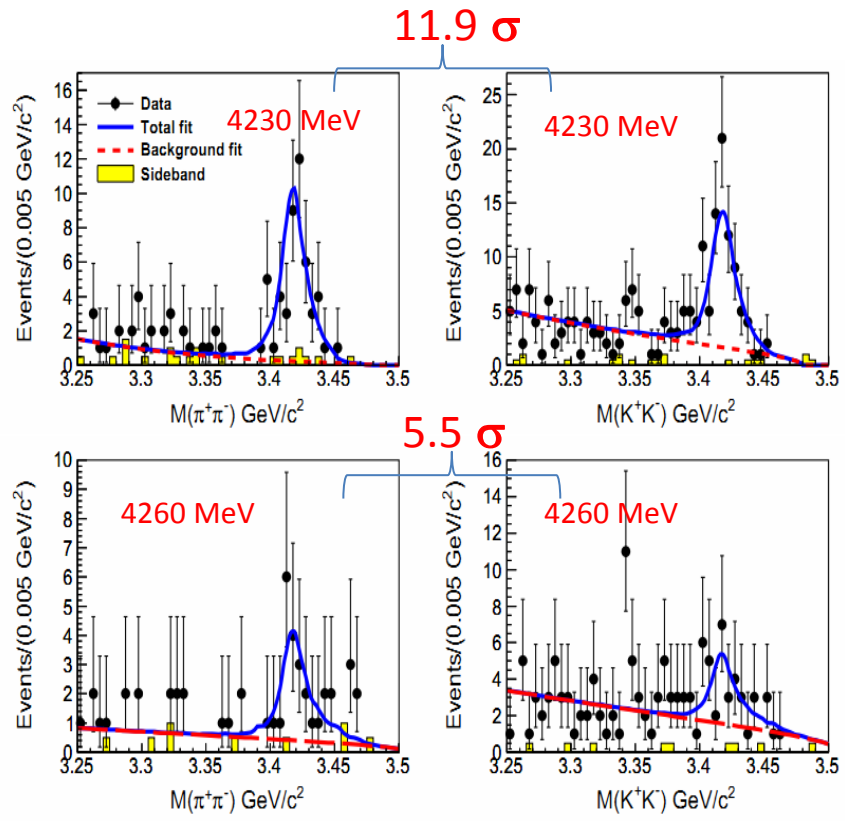
The events are reconstructed exclusively:

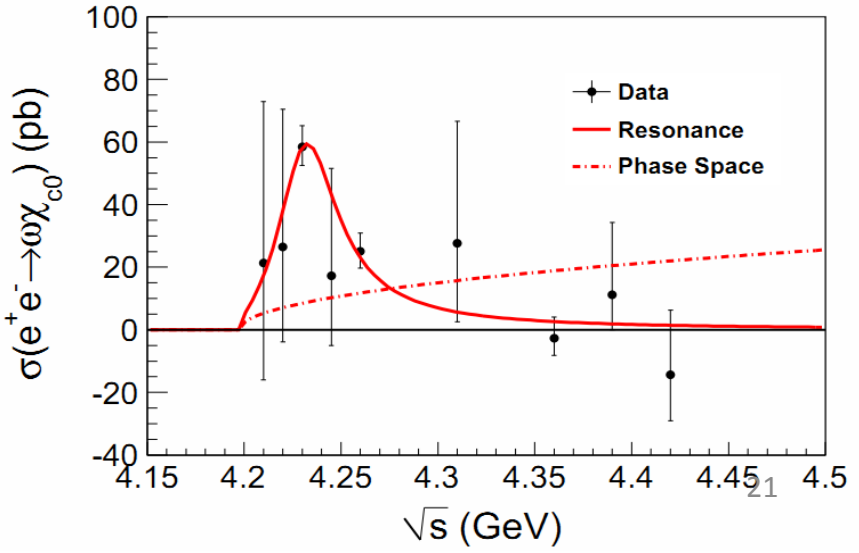
$\omega \to \pi^+\pi^-\pi^0$

$\chi_{c0} \to \pi^+\pi^-, K^+K^-$

The first observation of this process.

Fit with single Breit-Wigner yields mass lower than *Y*(4260)





Summary and outlook

- Many results on charmonium spectroscopy from BESIII experiment, especially on the charged charmonium like states, are obtained;
- The spin-parity analysis of new states is ongoing;
- More decay modes are being investigated, such as $\pi\psi'$, $\rho\eta_c$ ……

Hope we can solve the quark confinement puzzle by studying the hadron spectroscopy!

Спасибо!