

# XYZ studies at BESIII

Z. Q. Liu (劉智青)  
IHEP, Beijing

*On behalf of BESIII Collaboration*

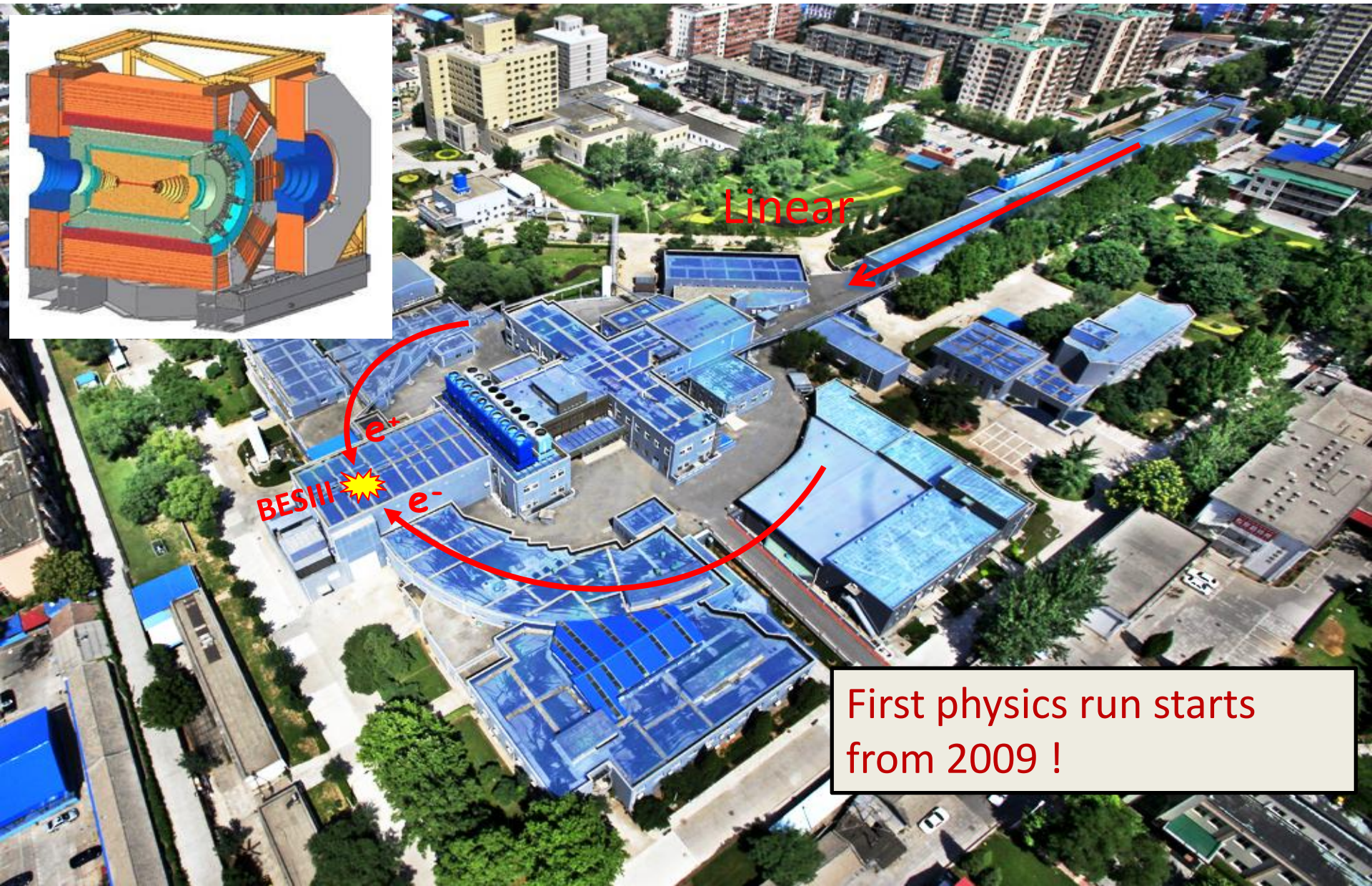
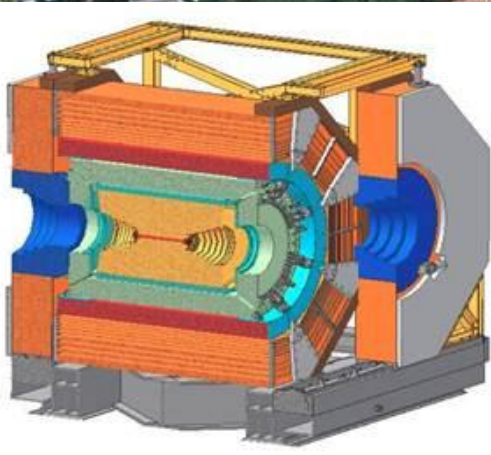
[zqliu@ihep.ac.cn](mailto:zqliu@ihep.ac.cn)

QWG2013, IHEP, Beijing

# Outline

1. Introduction.
2. XYZ programs at BESIII.
3. First results: Discovery of  $Z_c(3900)$ .
4. Future XYZ plans.
5. Summary

# Beijing Electron Positron Collider (BEPC II)



First physics run starts from 2009 !



# BEPC II storage ring

Double ring:

symmetric collider

CMS energy:

2.0 - 4.6 GeV

Design Luminosity @  $\psi(3770)$ :

(70% achieved,  $\sim 20/\text{pb}$  per day)

$1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

Energy spread:

1.1 MeV @ 3.686 GeV

No. of bunches:

93

Bunch length:

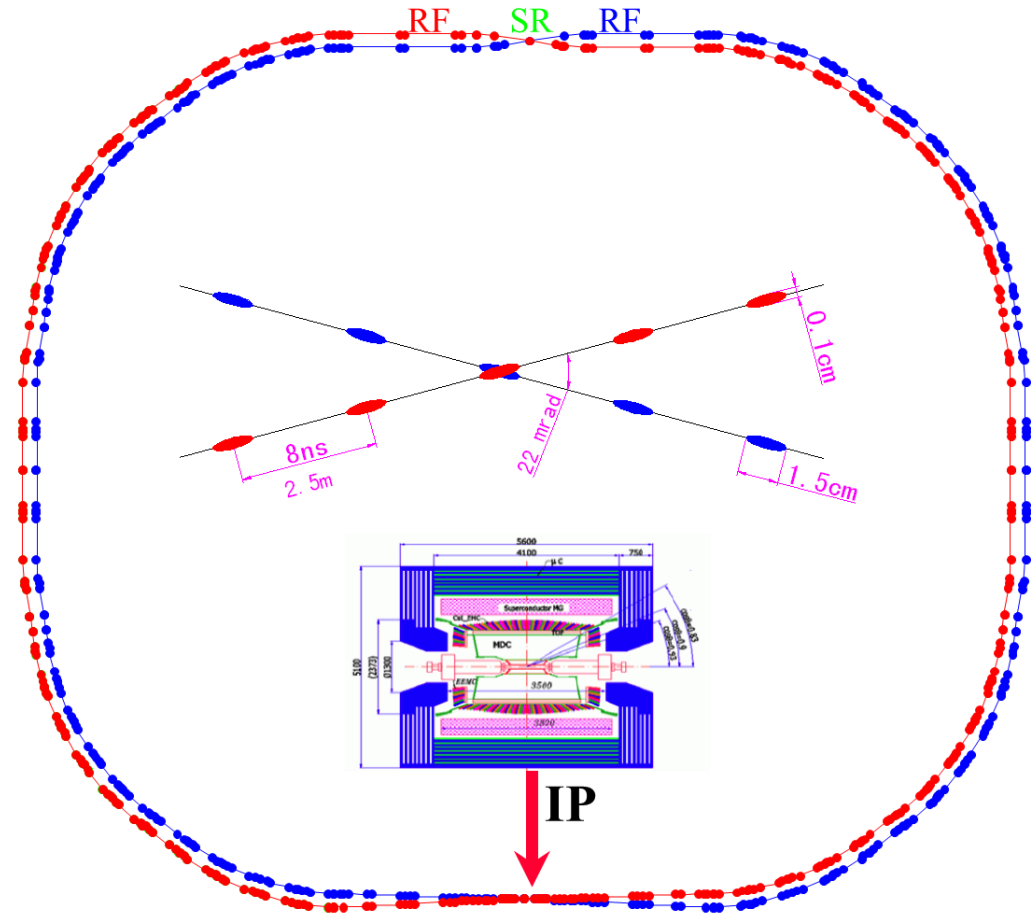
1.5 cm

Total current:

0.91 A

Circumference :

237 m



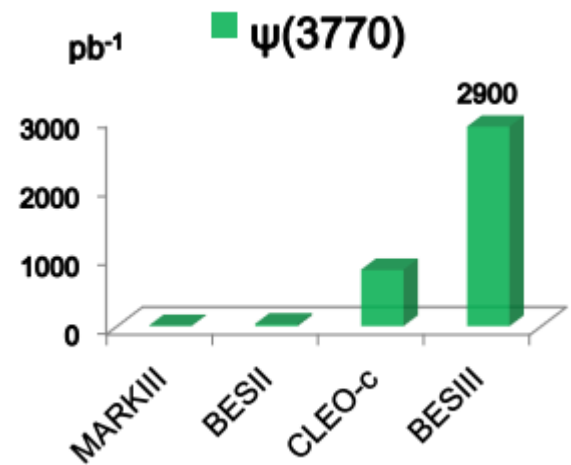
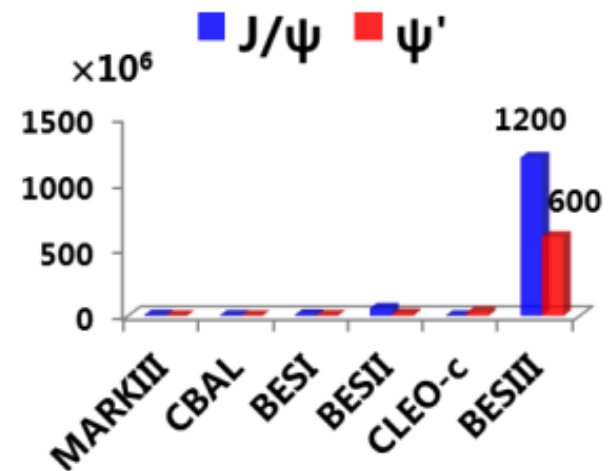
# The BESIII Collaboration



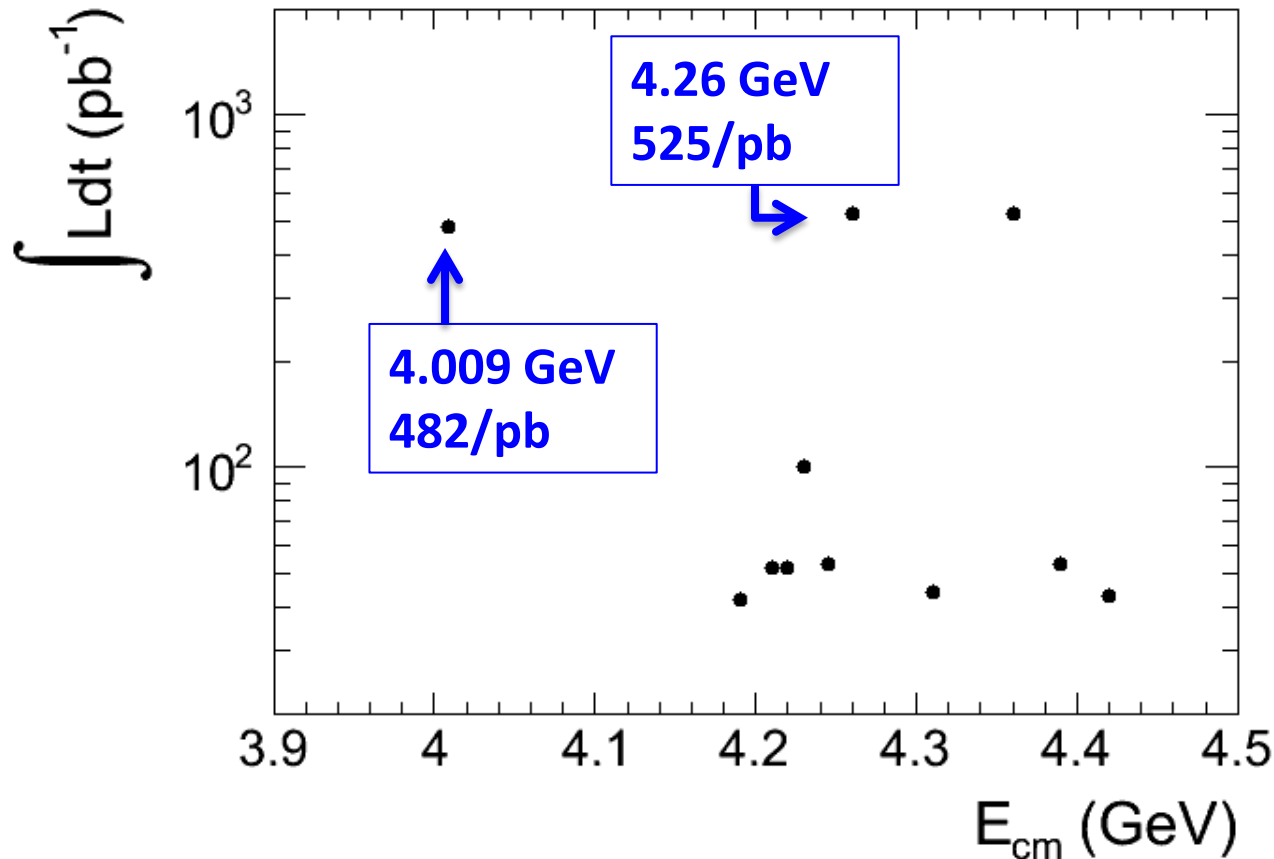
# What can we do at BESIII?

- We have collected world's largest charmonium data sample!
- $\sim 225\text{M} + 1000\text{M}$   $J/\psi$  events.
- $\sim 106\text{M} + 500\text{M}$   $\psi(2S)$  events.
- $\sim 2.9/\text{fb}$   $\psi(3770)$  data.

**NOT the whole story!**



# XYZ programs at BESIII

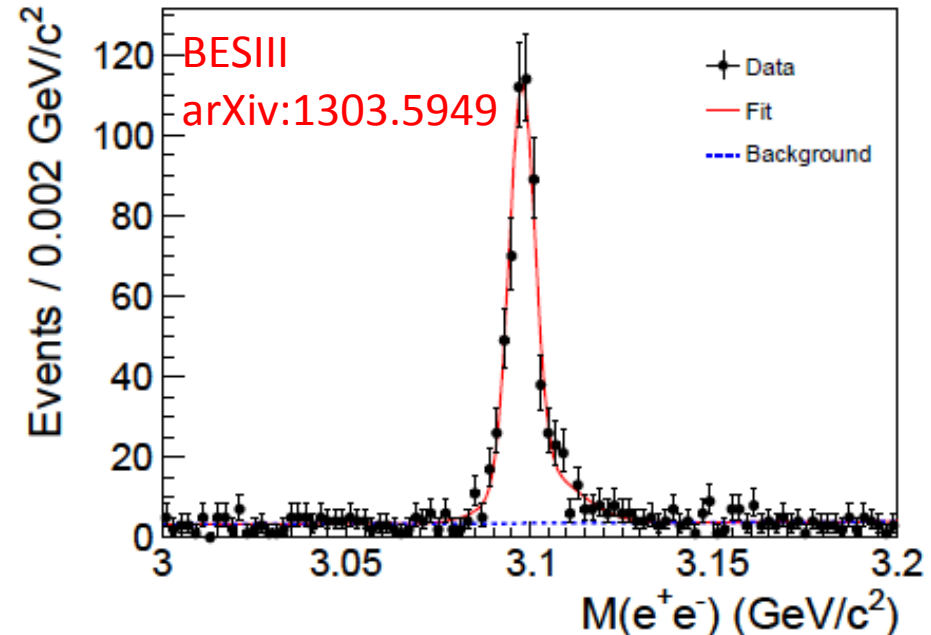
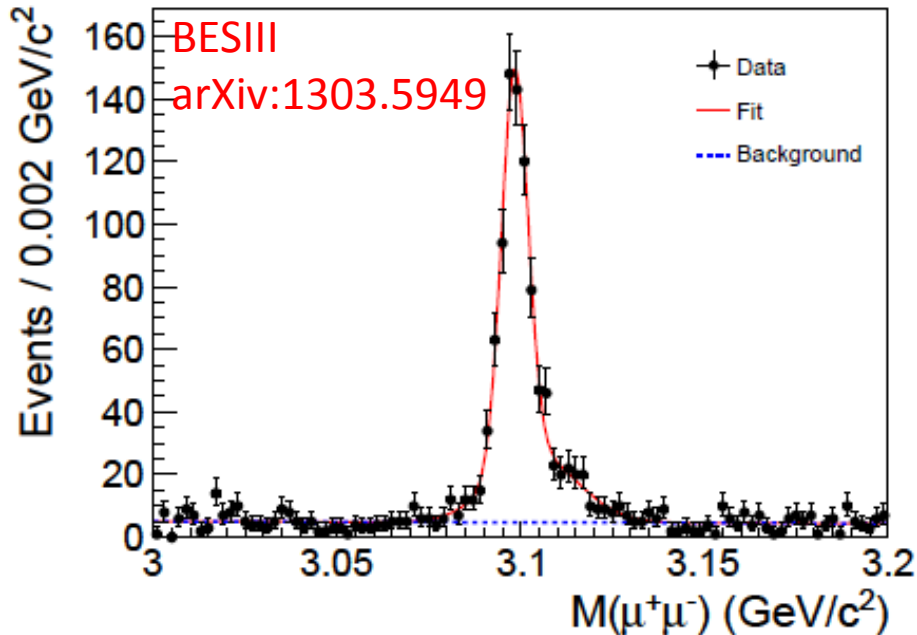


- More in the future
- 2/fb near  $Y(4260)$  peak by this June!
- 2/fb on  $\psi(4160)$
- Scan over 3.8 – 4.6 GeV
- ...

Energy	Luminosity ( $\text{pb}^{-1}$ )
$E_{\text{cm}} = 4.009$ GeV	482
$E_{\text{cm}} = 4.26$ GeV	525

# First results: Discovery of $Z_c(3900)$

- Dec, 2012 to Jan, 2013, BESIII accumulate 525/pb data @ 4.26 GeV
- Study  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$  exclusive process.

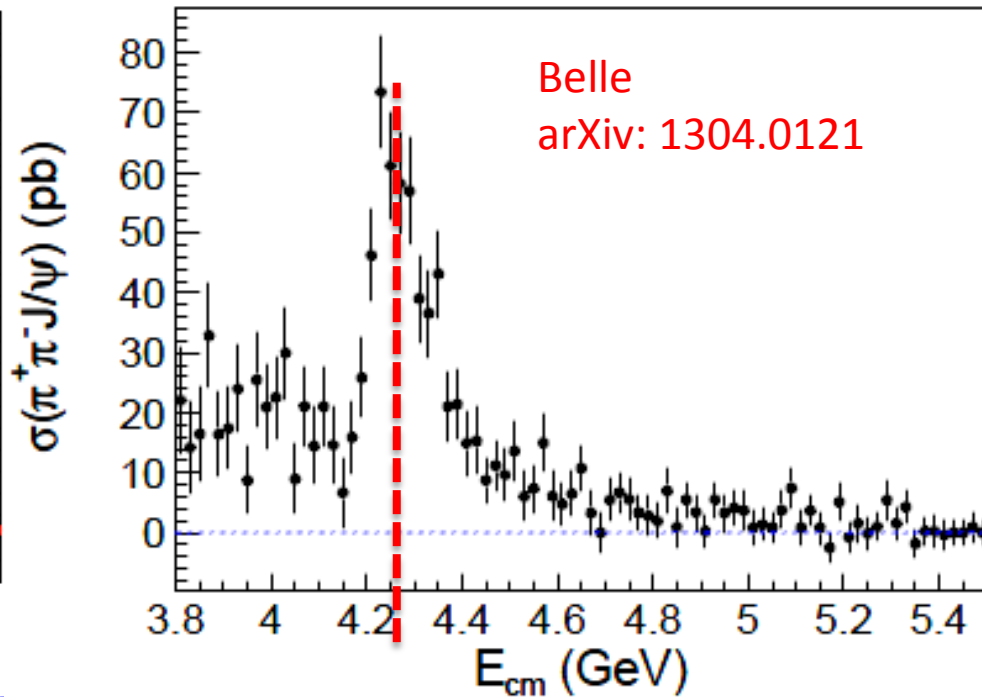
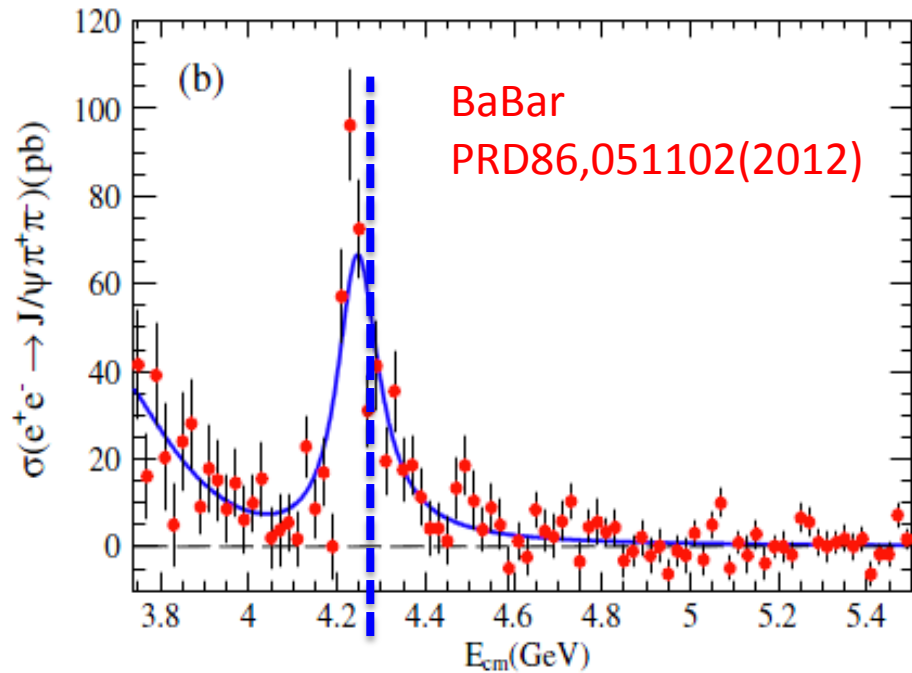


1. Fit with two Gaussian functions and linear background.
2.  $N(\mu\mu)=882 \pm 33$ ;  $N(ee)=595 \pm 28$ .



# First results: Discovery of $Z_c(3900)$

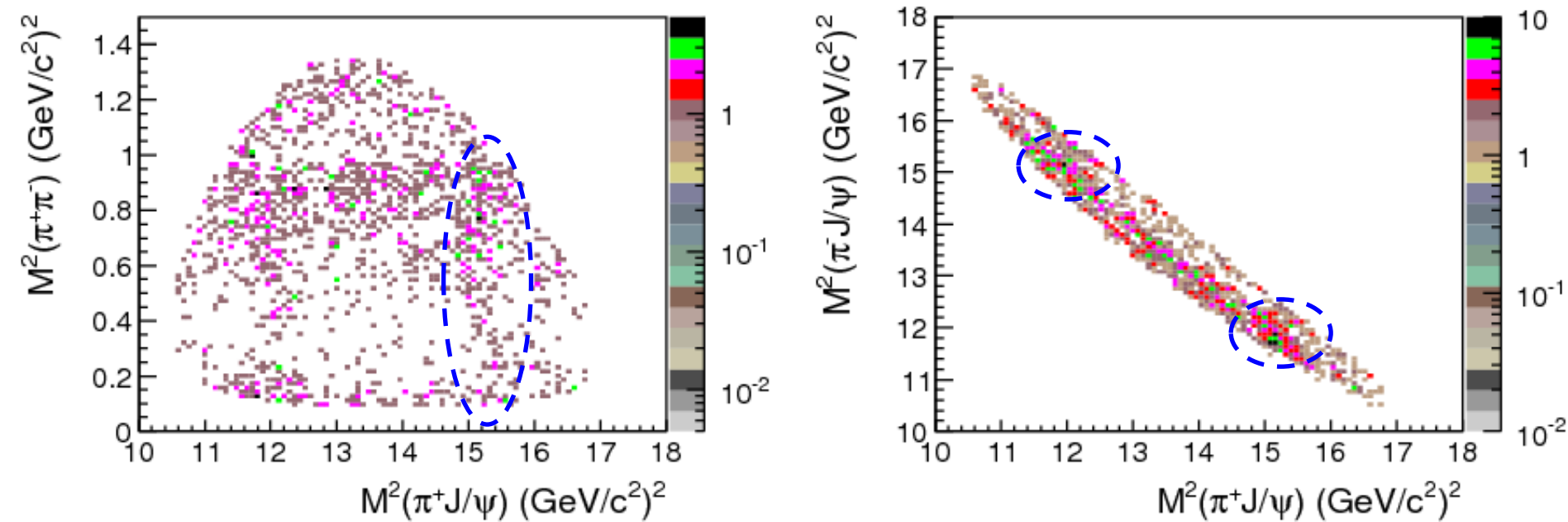
- Dec, 2012 to Jan, 2013, BESIII accumulate 525/pb data @ 4.26 GeV
- Study  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$  exclusive process.



1. Fit with two Gaussian functions and linear background.
2.  $N(\mu\mu)=882 \pm 33$ ;  $N(ee)=595 \pm 28$ .
3.  $\sigma^B=(62.9 \pm 1.9 \pm 3.7)$  pb at BESIII, good agreement with Belle and BaBar.

# First results: Discovery of $Z_c(3900)$

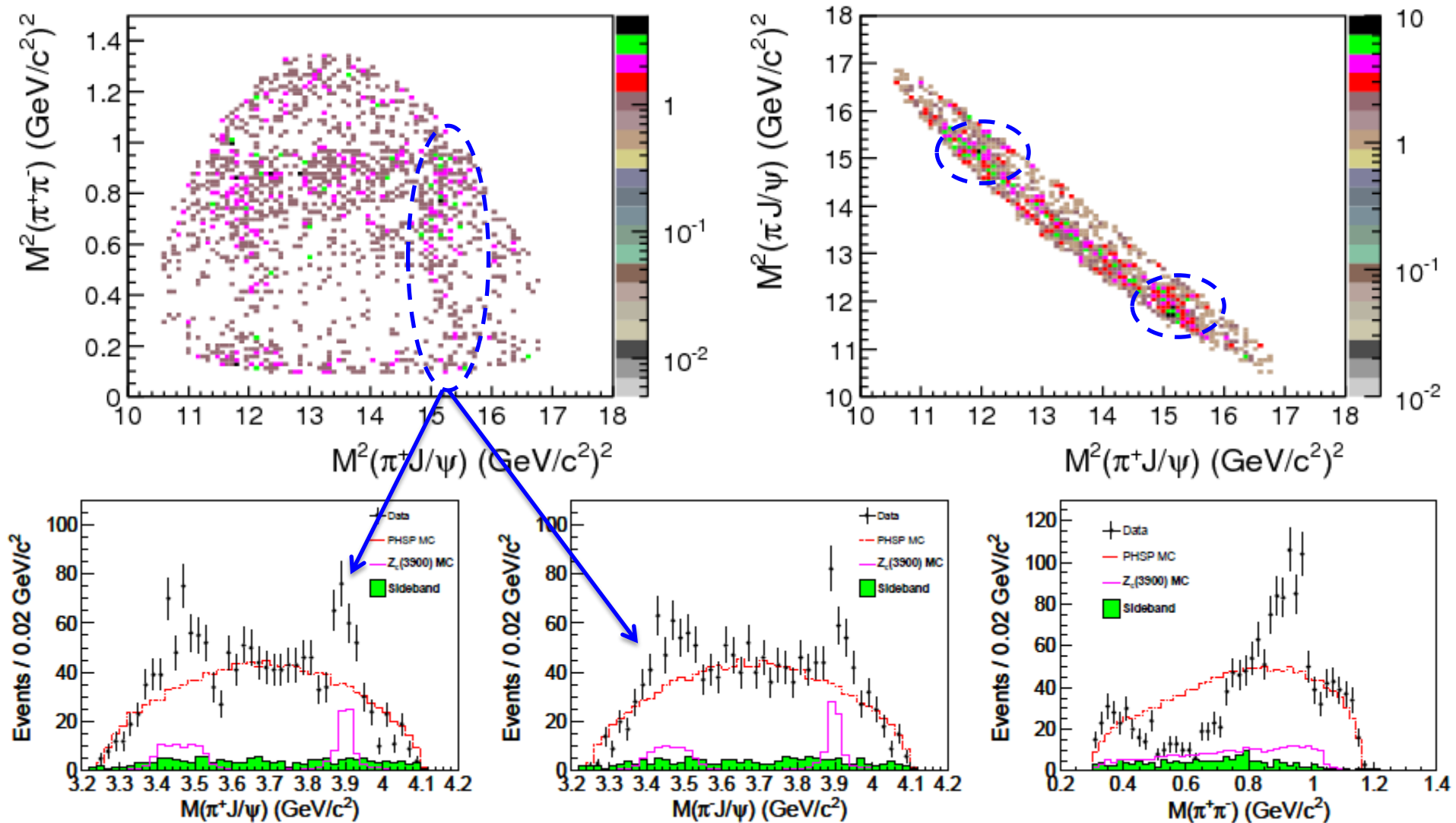
- Requiring  $J/\psi$  mass window:  $[3.08, 3.12]$  GeV, we have 1595 events.
- $J/\psi$  sidebands:  $[3.00, 3.06]$  &  $[3.14, 3.20]$  GeV, 3 times of signal region.



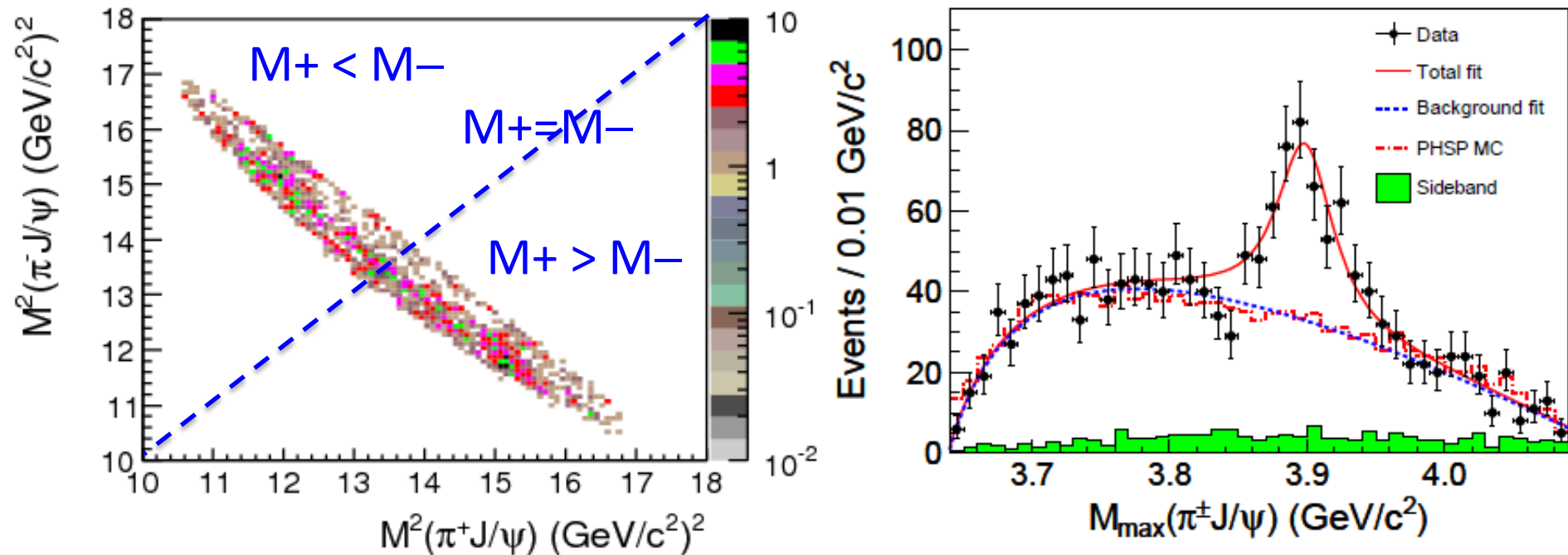
1. Structure both in  $M(\pi\pi)$  mass distribution and  $M(\pi J/\psi)$  mass distribution.
2. Phase space reflection effect.

# First results: Discovery of $Z_c(3900)$

- Requiring  $J/\psi$  mass window:  $[3.08, 3.12]$  GeV, we have 1595 events.
- $J/\psi$  sidebands:  $[3.00, 3.06]$  &  $[3.14, 3.20]$  GeV, 3 times of signal region.



# First results: Discovery of $Z_c(3900)$



1. 1D fit to extract resonant parameters.
2. Divided by diagonal line; Fit  $M_{\text{max}}(\pi^\pm J/\psi)$  mass distribution.
3. S-Wave Breit Wigner;  $p^*q$  phase space factor; efficiency applied.
4.  $M=(3899.0 \pm 3.6 \pm 4.9)\text{MeV}$ ;  $\Gamma=(46 \pm 10 \pm 20)\text{MeV}$ .
5. Statistical significance:  $>8\sigma$ , discovery!



# The nature of $Z_c(3900)$ ?

From SPIRE HEP Database (21st, Apr):

## 1. Tetraquarks

- arXiv:1110.1333, 1303.6857
- arXiv:1304.0345, 1304.1301

## 2. Hadronic molecules

- arXiv:1303.6608, 1304.2882, 1304.1850

## 3. Four quark state (1 or 2)

- arXiv:1304.0380

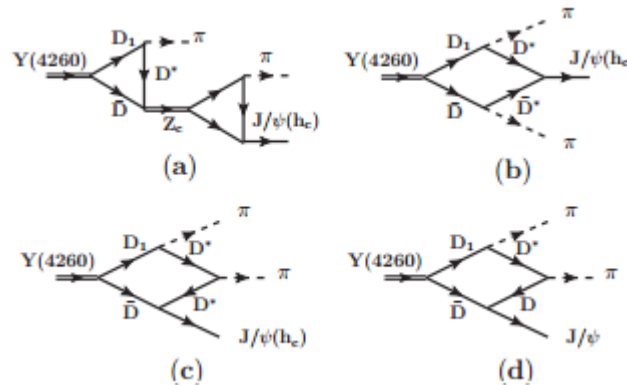
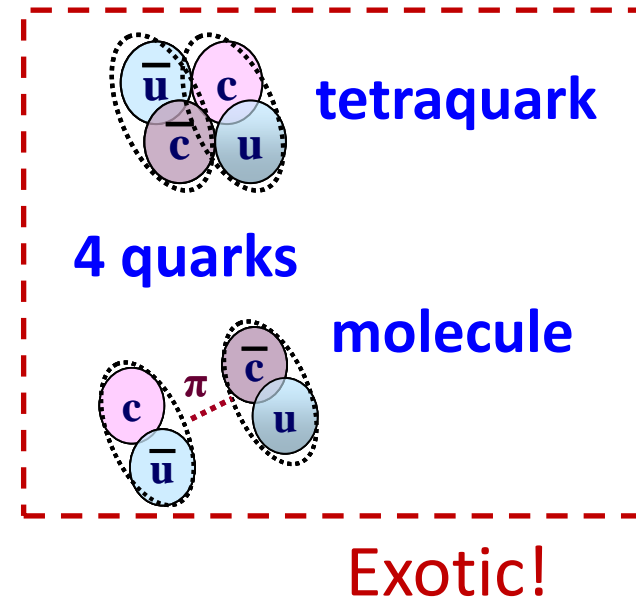
## 4. Meson loop

- arXiv:1303.6355
- arXiv:1304.4458

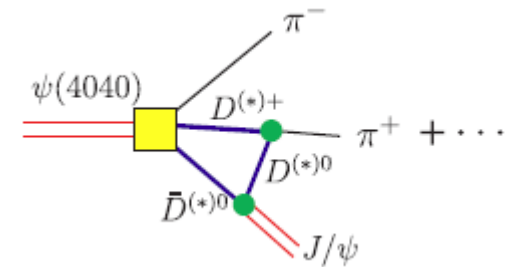
## 5. ISPE model

- arXiv:1303.6842

## 6. ...



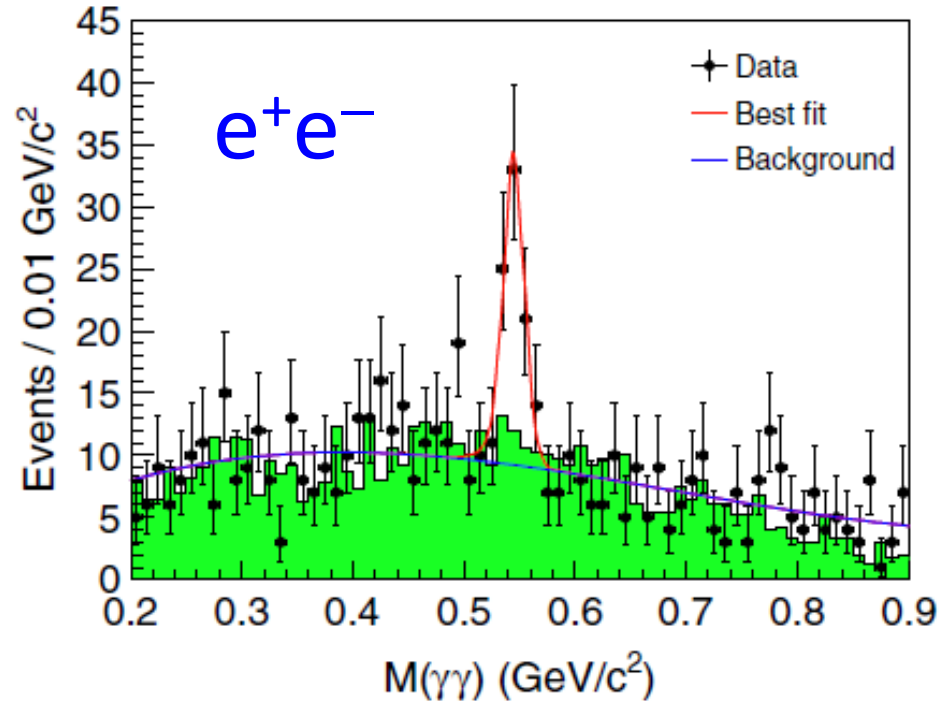
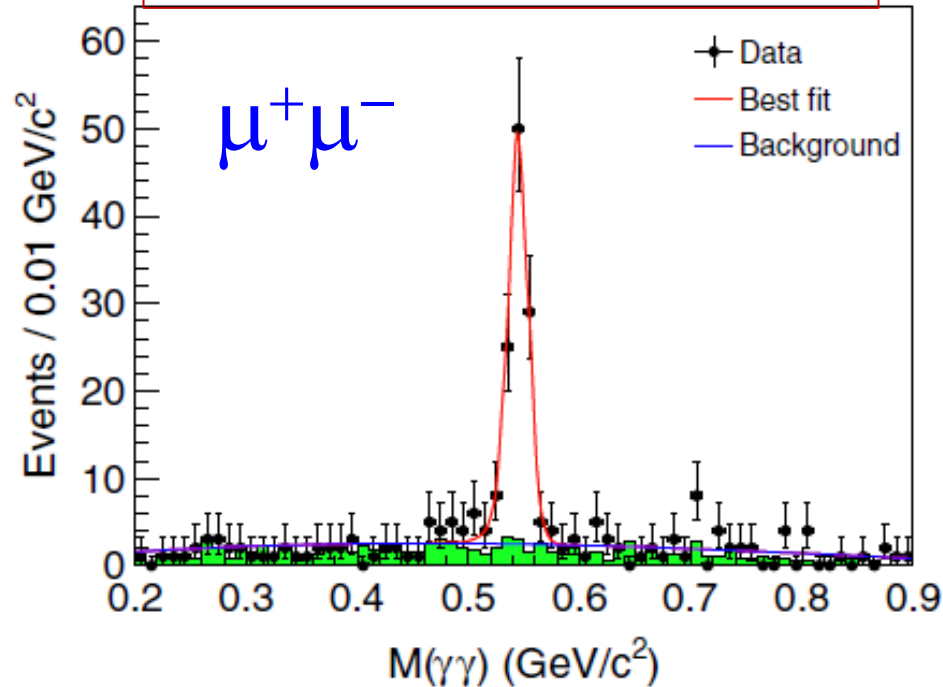
Meson loop



ISPE model

# First observation of $\psi(4040) \rightarrow \eta J/\psi$ transition

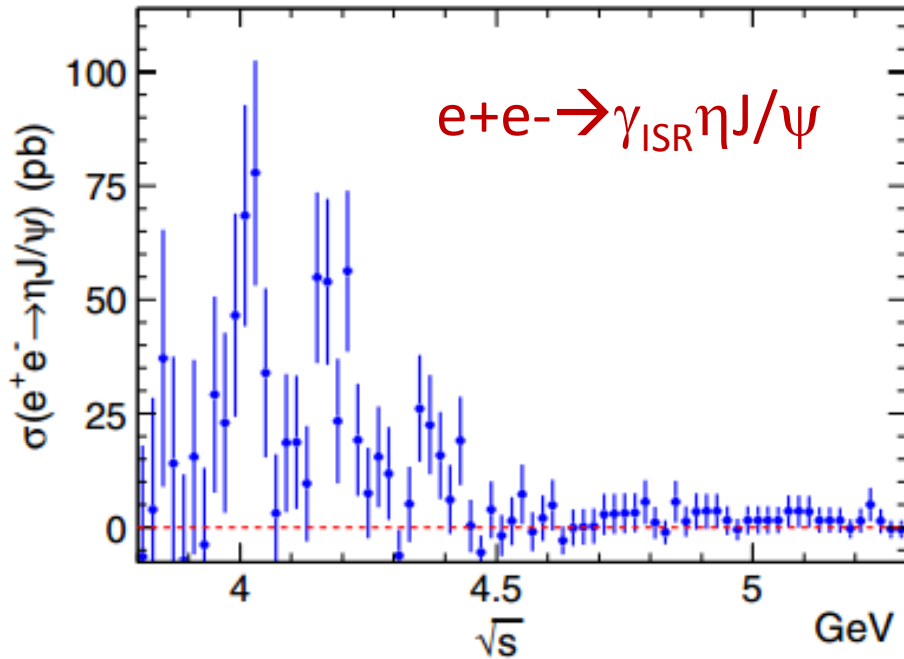
BESIII PRD86,071101(R)(2012).



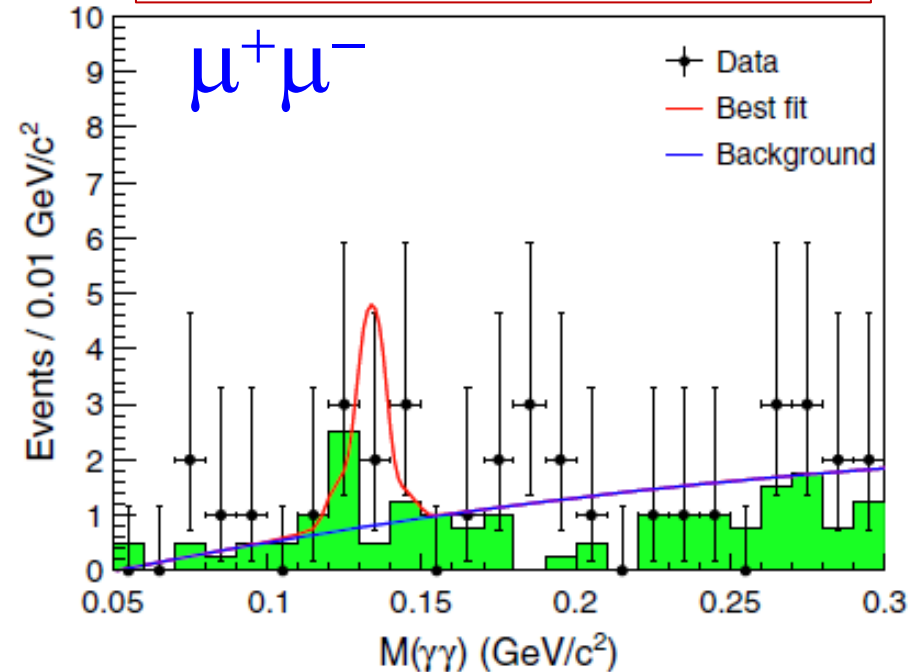
1. Using 482/pb data at  $E_{\text{cm}}=4.009$  GeV,  $J/\psi \rightarrow l+l^-$  &  $\eta \rightarrow \gamma\gamma$
2.  $N(\mu\mu)=111.4 \pm 11.0$ ;  $N(ee)=61.4 \pm 10.5$ ; significance  $>10\sigma$ .
3.  $\sigma(\eta J/\psi)=(32.1 \pm 2.8 \pm 1.3)$  pb.
4. Partial width: 400 keV level,  $2 \times \sigma(\pi^+\pi^- J/\psi)$
5. Similar with  $Y(4S)$ : admixture of four quark state?

# First observation of $\psi(4040) \rightarrow \eta J/\psi$ transition

Belle PRD87,051101(R)(2013).



BESIII PRD86,071101(R)(2012).



1. Using 482/pb data at  $E_{\text{cm}} = 4.009$  GeV,  $J/\psi \rightarrow l+l^-$  &  $\eta \rightarrow \gamma\gamma$
2. Conventional  $\psi(4040)$  &  $\psi(4160) \rightarrow \eta J/\psi$ .
3.  $e^+e^- \rightarrow \pi^0 J/\psi$  in  $\mu\mu$  mode.
4.  $N(\mu\mu) < 11.7$  @ 90% C.L
5.  $\sigma(\pi^0 J/\psi) < 1.6$  pb @ 90% C.L

# Future XYZ plans at BESIII

Using  $\sim 2/\text{fb}$  data sample around 4.26 GeV:

- $Z_c(3900)$
- PWA analysis to determine  $J^P$
- Precise mass, width and branching ratio measurements.
- potential topics ongoing:
  - $\pi^+\pi^-h_c$
  - $DD^*\pi$
  - $D^*D^*\pi$
  - $\pi^+\pi^-\psi(2S)$
  - Search for  $h_c(2P)$
  - ...



# Future XYZ plans at BESIII

Using the scan data samples above open charm threshold:

- Line Shape measurements

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

2.  $Y(4360) \rightarrow \pi^+ \pi^- \psi(2S)$

3.  $\psi(4040) \text{ \& } \psi(4160) \rightarrow \eta J/\psi$

4.  $\pi^+ \pi^- h_c$

5.  $DD^* \pi$

6.  $D^* D^* \pi$

# Summary

1. Discover a charged charmoniumlike state  $Z_c(3900)$ .
2. First observation of  $\psi(4040) \rightarrow \eta J/\psi$  hadronic transition.
3. Lots of exciting ongoing topics.
4. BESIII brings us to a *NEW XYZ stage* !

**Thank you !**