

# XYZ studies at BESIII

Z. Q. Liu (劉智青)  
IHEP, Beijing

*On behalf of BESIII Collaboration*

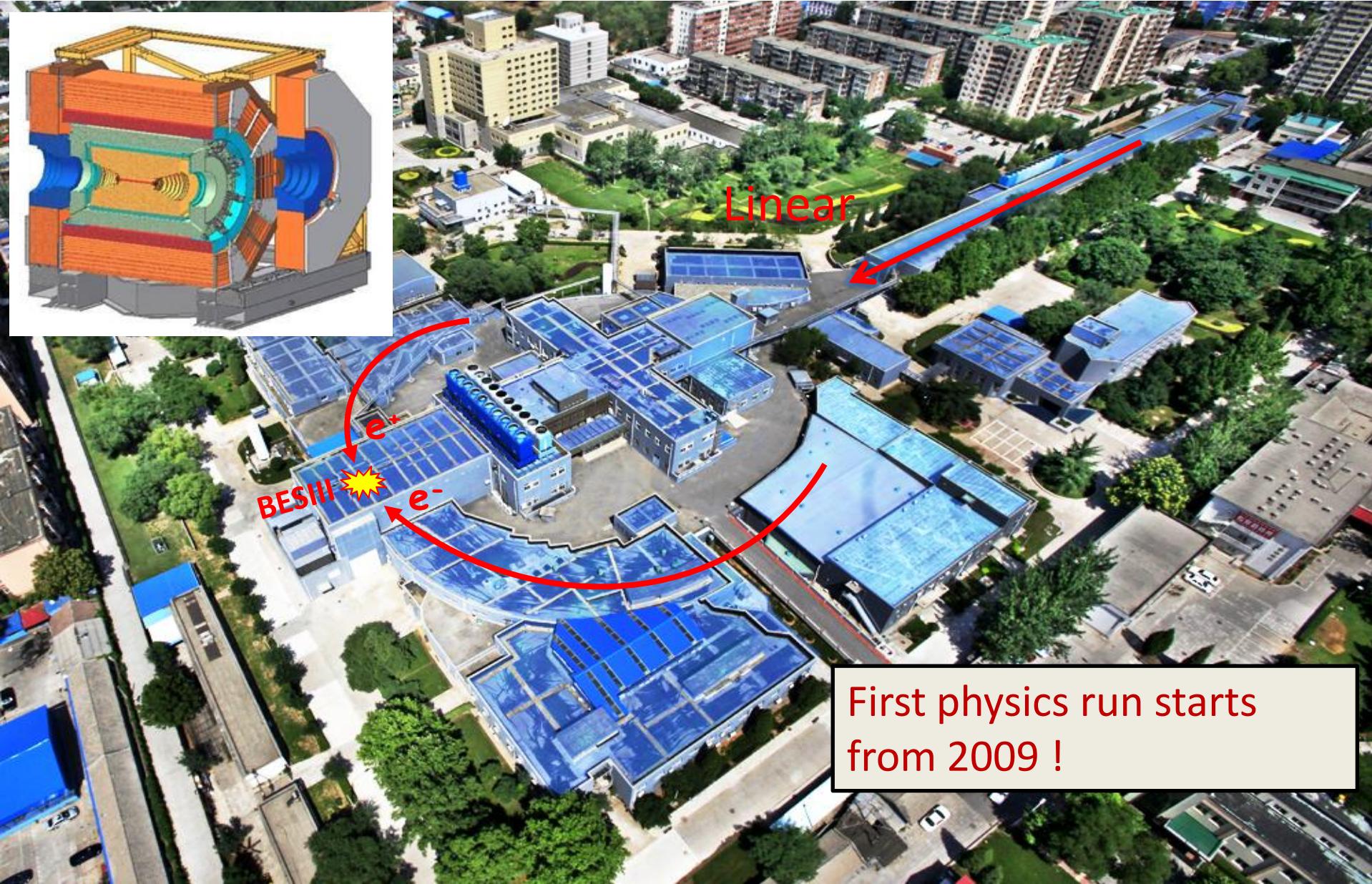
[zqliu@ihep.ac.cn](mailto:zqliu@ihep.ac.cn)

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)



# BEPC II storage ring

Double ring:  
symmetric collider  
CMS energy:

2.0 - 4.6 GeV

Design Luminosity @  $\psi(3770)$ :  
(70% achieved, ~20/pb per day)  
 $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

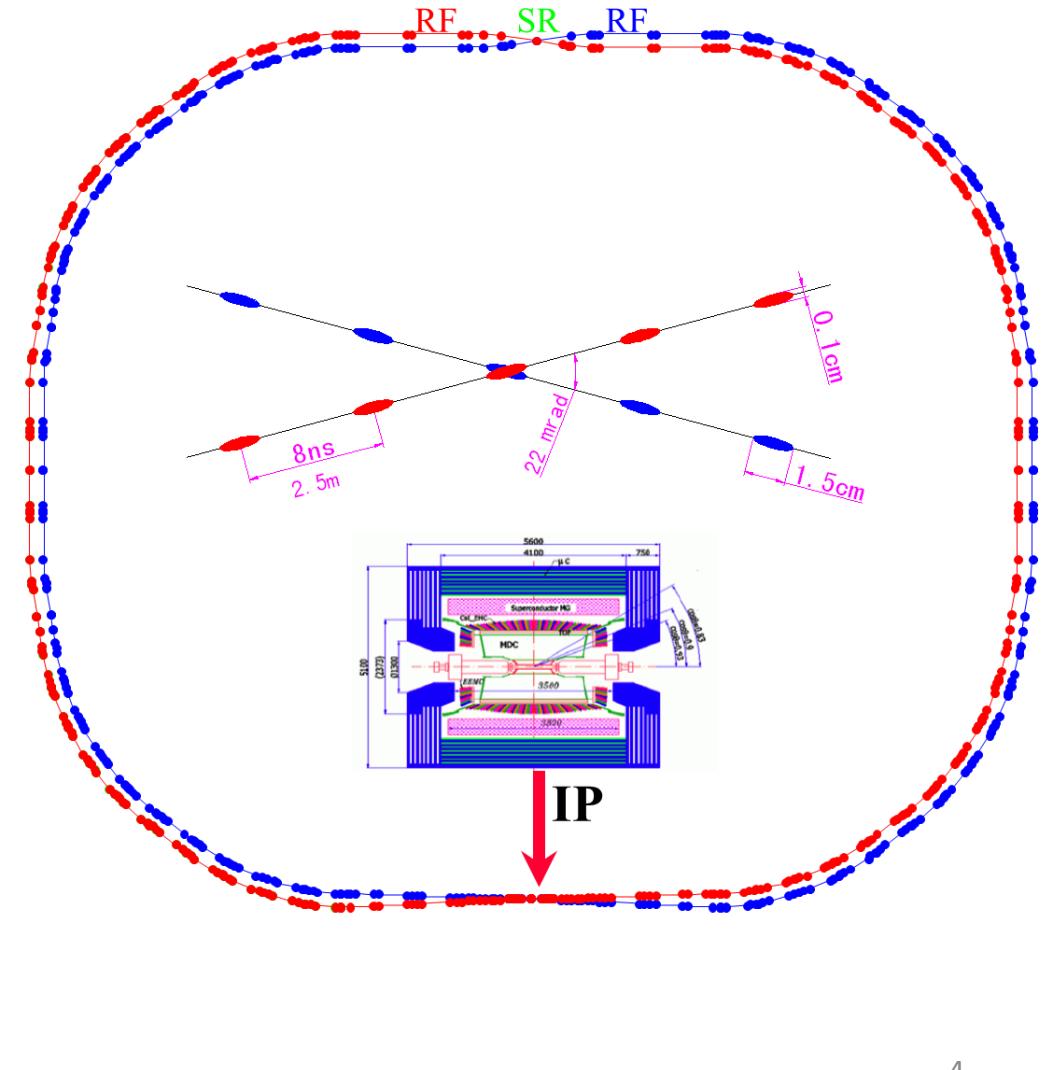
Energy spread:  
1.1 MeV @ 3.686 GeV

No. of bunches:  
93

Bunch length:  
1.5 cm

Total current:  
0.91 A

Circumference :  
237 m



# The BESIII Collaboration

Political Map of the World, June 1999

US (6)

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

~360 members

52 institutions from 11 countries

Europe (12)

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

Netherland: KVI/Univ. of Groningen

Sweden: Uppsala Univ.

Turkey: Turkey Accelerator Center

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Pakistan (2) China(30)

Univ. of Punjab  
COMSAT CIIT

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.

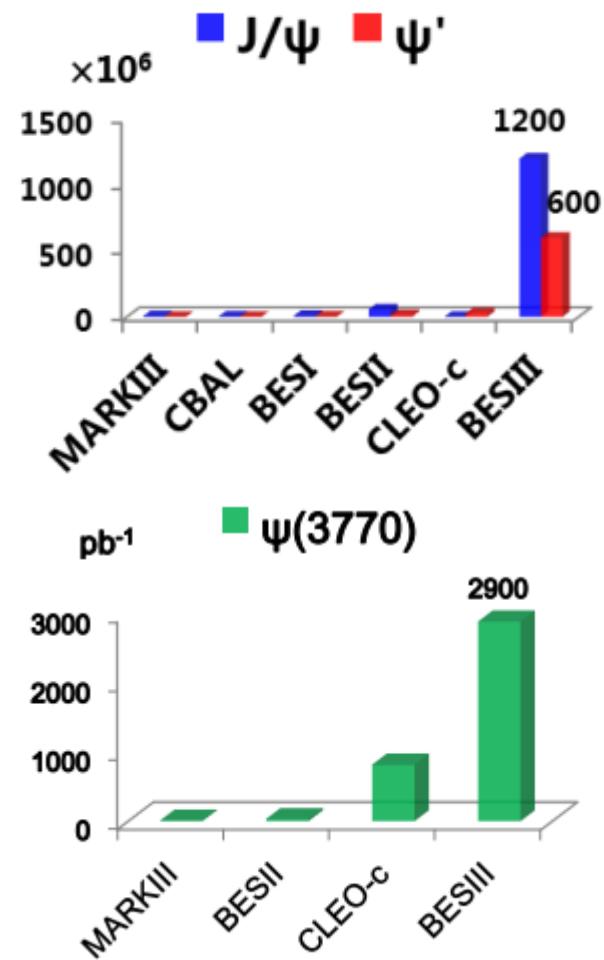
Lanzhou Univ., Henan Sci. and Tech. Univ.

Hong Kong Univ., Hong Kong Chinese Univ.

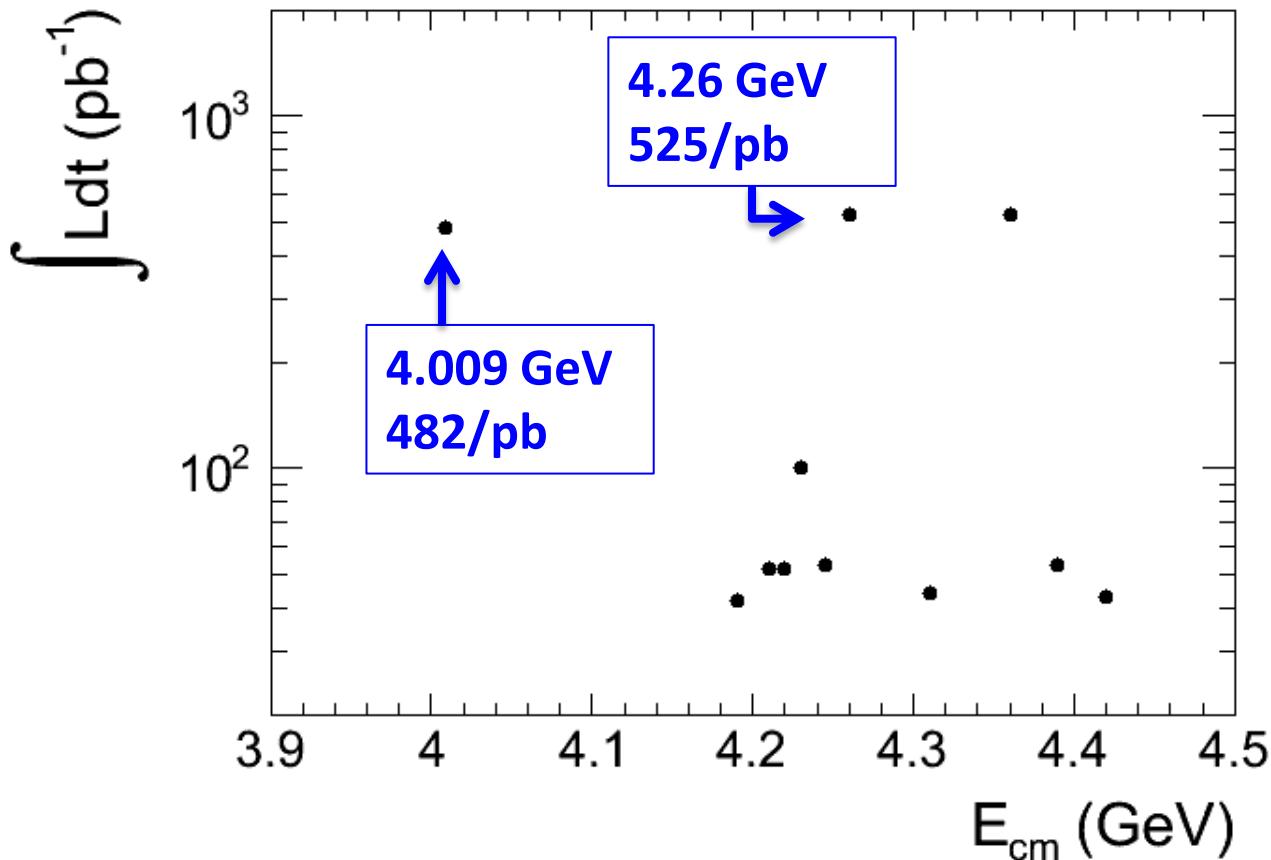
# What can we do at BESIII?

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

NOT the whole story!



# XYZ programs at BESIII

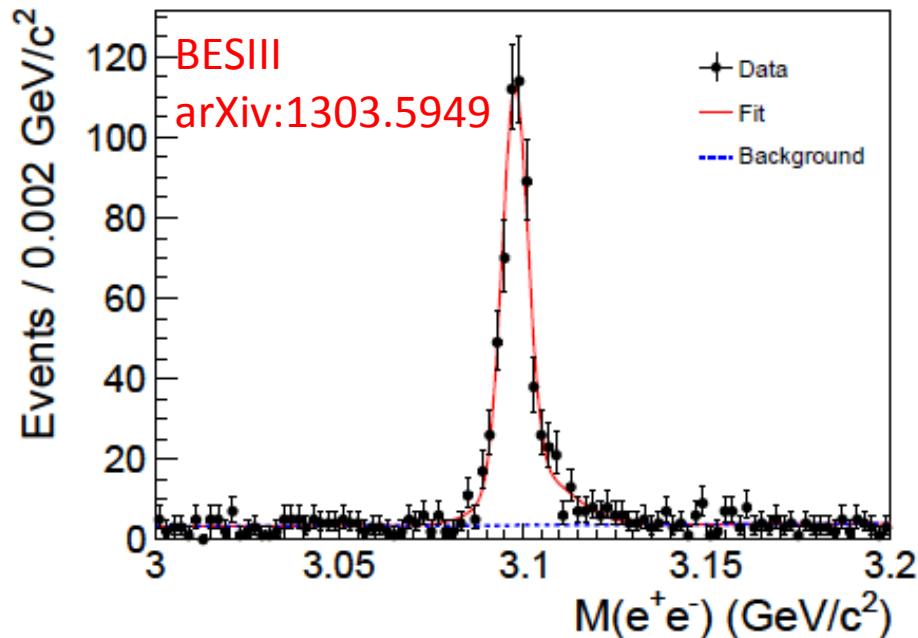
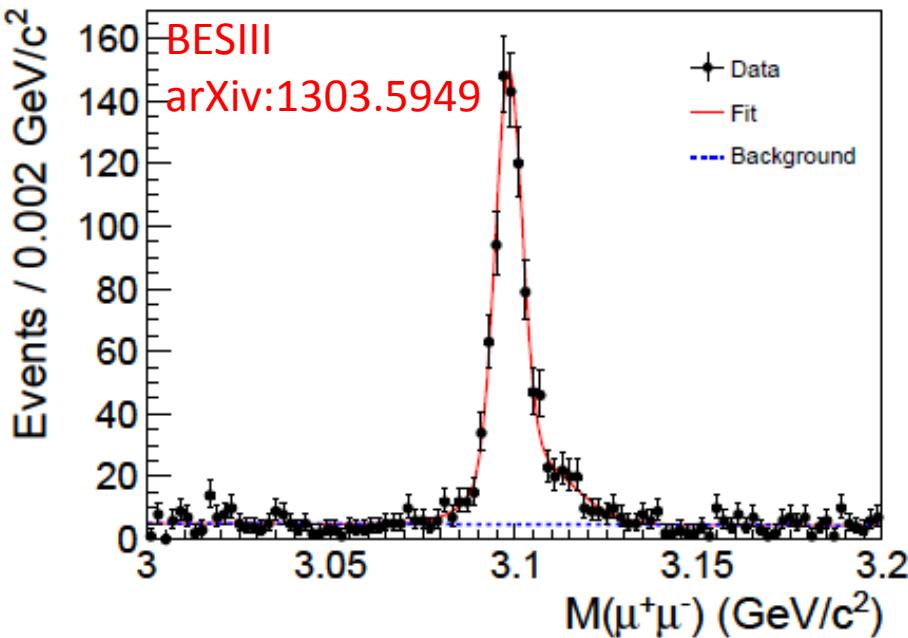


- More in the future
- 2/fb near  $\Upsilon(4260)$  peak by this June!
- 2/fb on  $\psi(4160)$
- Scan over  $3.8 - 4.6$  GeV
- ...

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

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

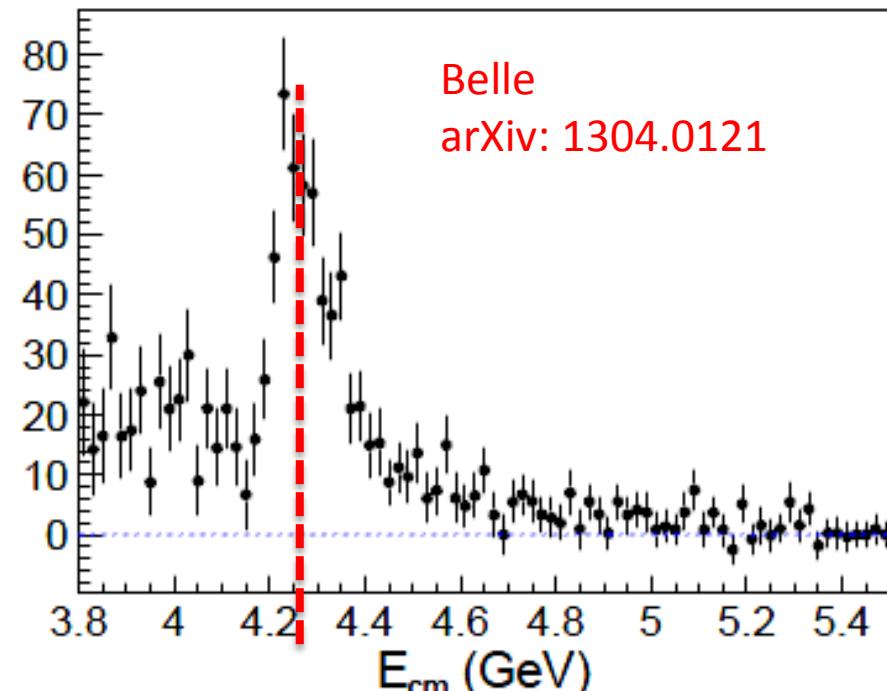
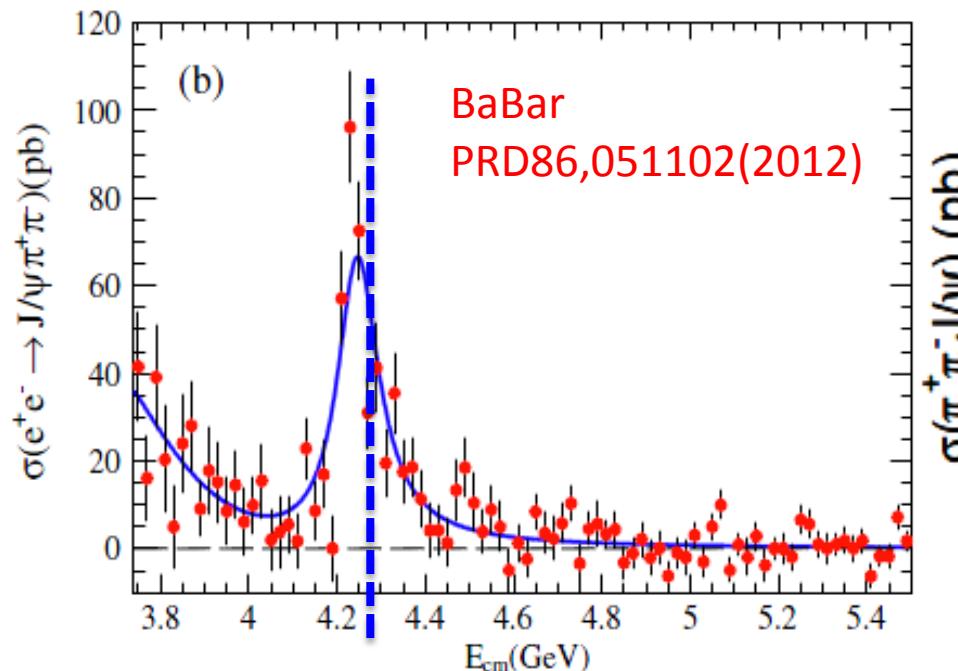
- Dec, 2012 to Jan, 2013, BESIII accumulate 525/pb data @ 4.26 GeV
- Study  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$  exclusive process.



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 $Z_c(3900)$

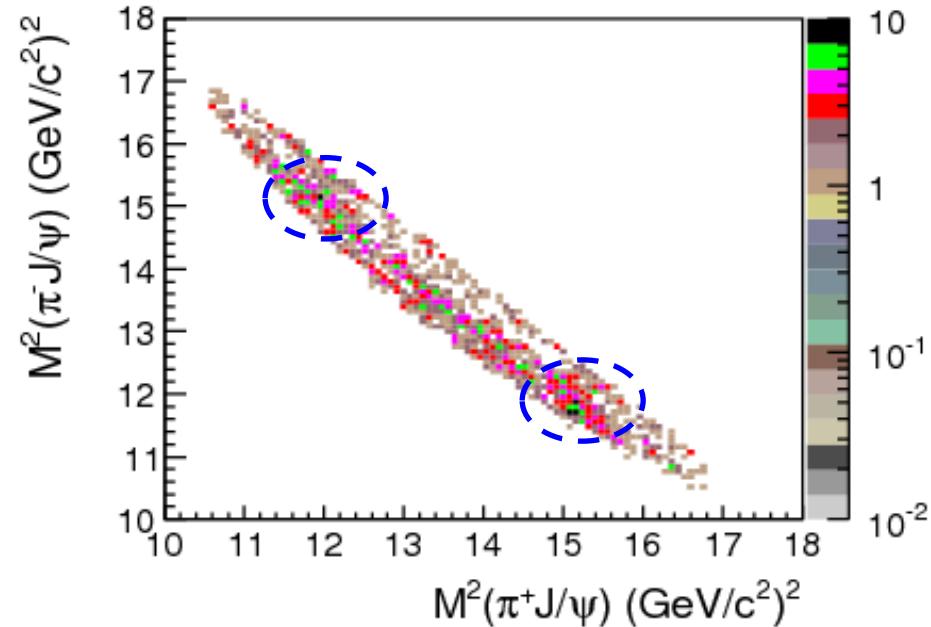
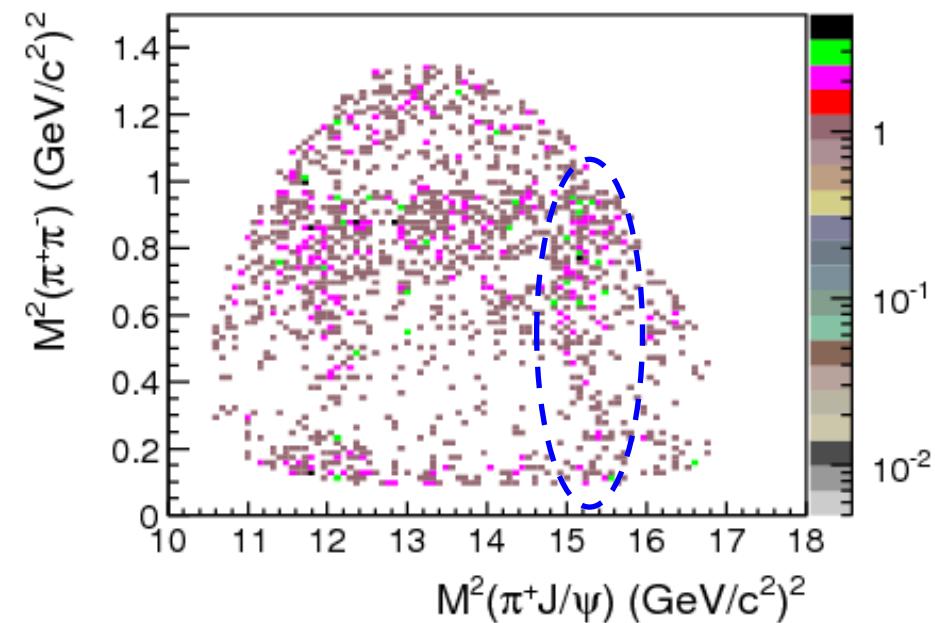
- Dec, 2012 to Jan, 2013, BESIII accumulate 525/pb data @ 4.26 GeV
- Study  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$  exclusive process.



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 $Z_c(3900)$

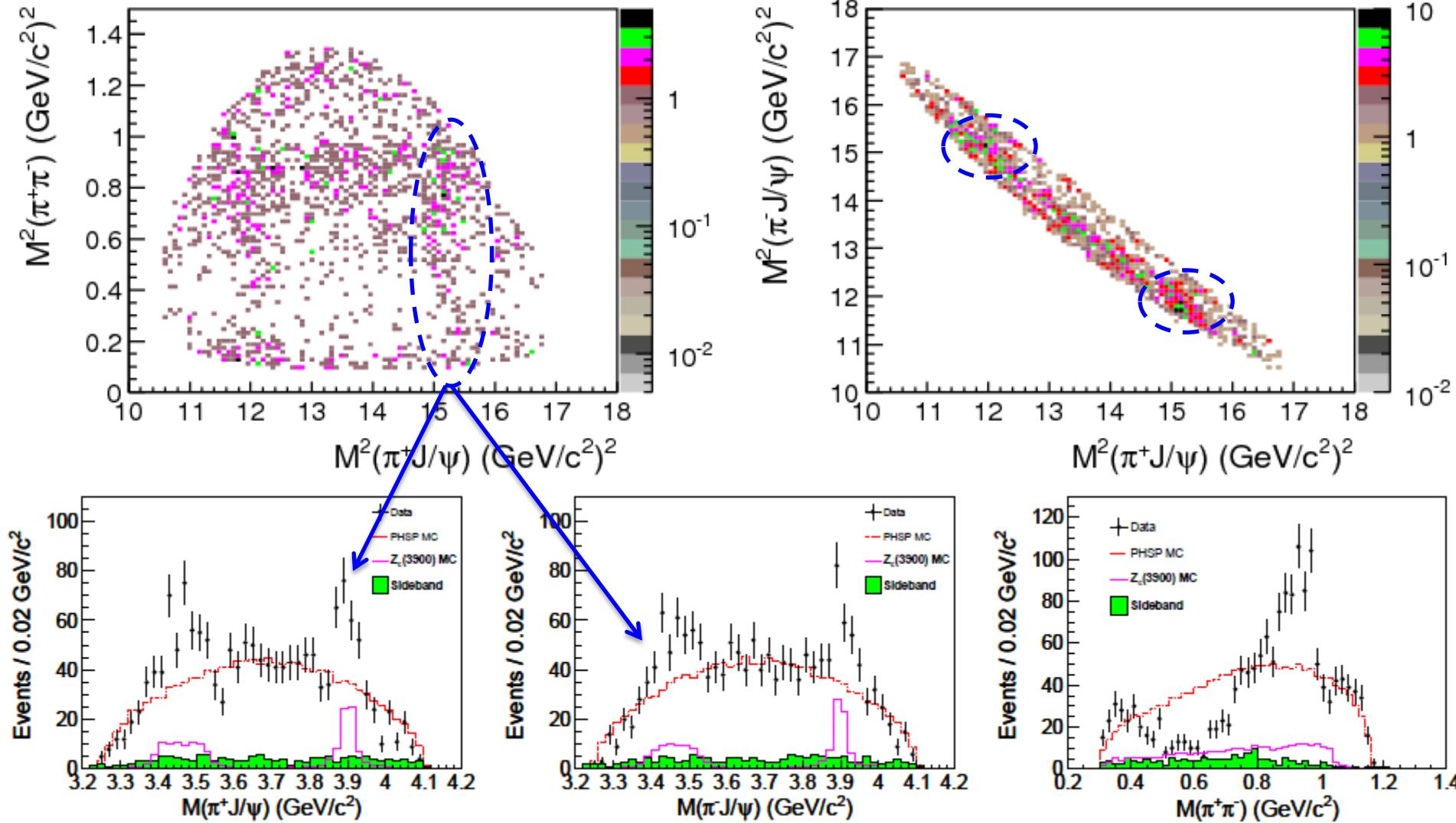
- Requiring  $J/\psi$  mass window:  $[3.08, 3.12]$  GeV, we have 1595 events.
- $J/\psi$  sidebands:  $[3.00, 3.06]$  &  $[3.14, 3.20]$  GeV, 3 times of signal region.



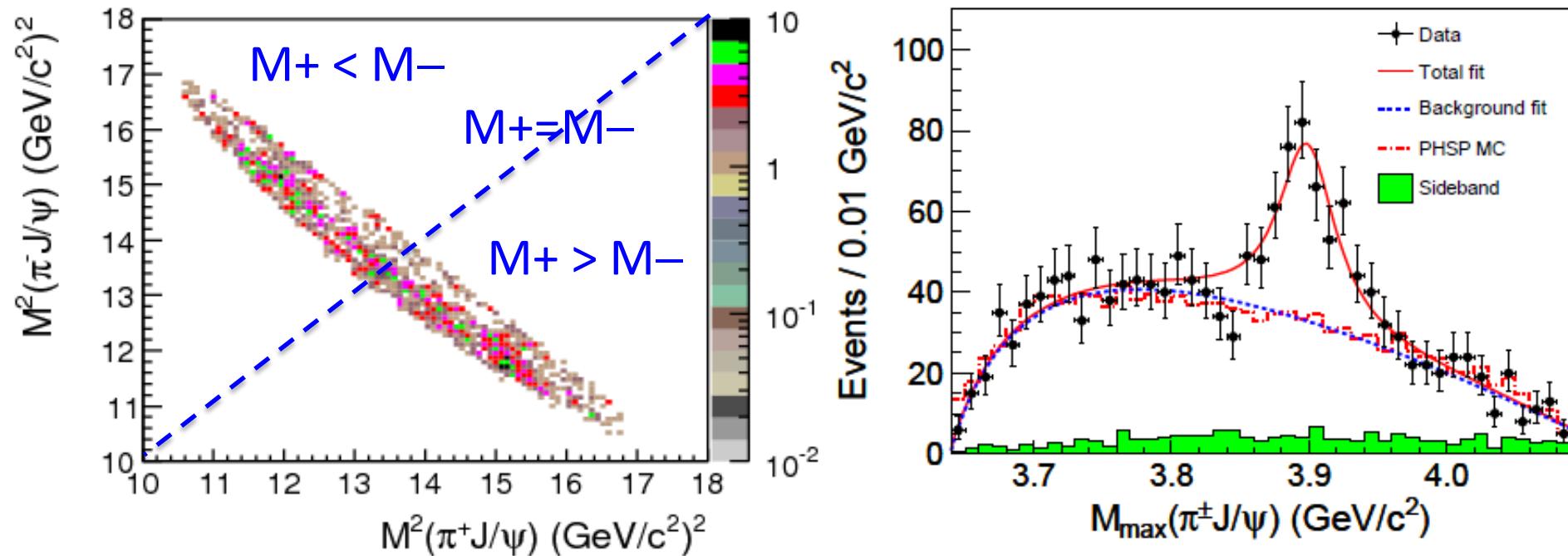
1. Structure both in  $M(\pi\pi)$  mass distribution and  $M(\pi J/\psi)$  mass distribution.
2. Phase space reflection effect.

# 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  $M_{\max}(\pi^\pm J/\psi)$  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

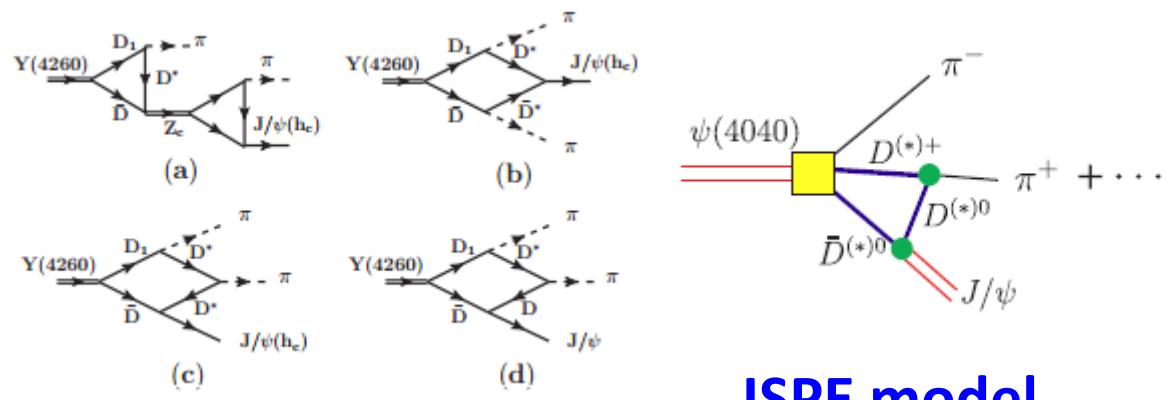
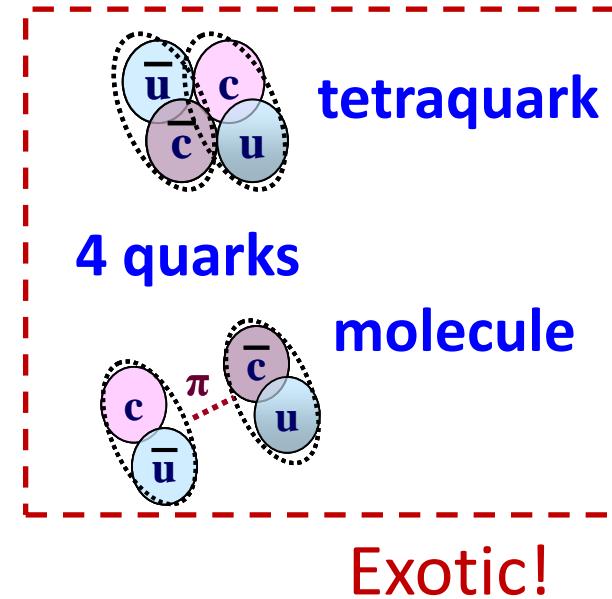
## 4. Meson loop

- arXiv:1303.6355
- arXiv:1304.4458

## 5. ISPE model

- arXiv:1303.6842

## 6. ...

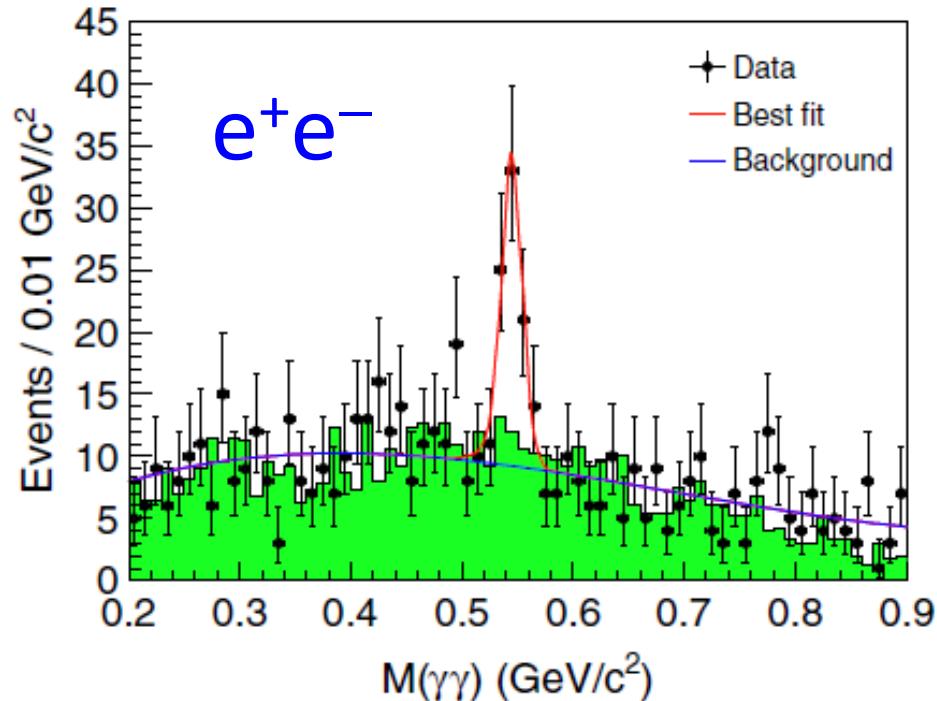
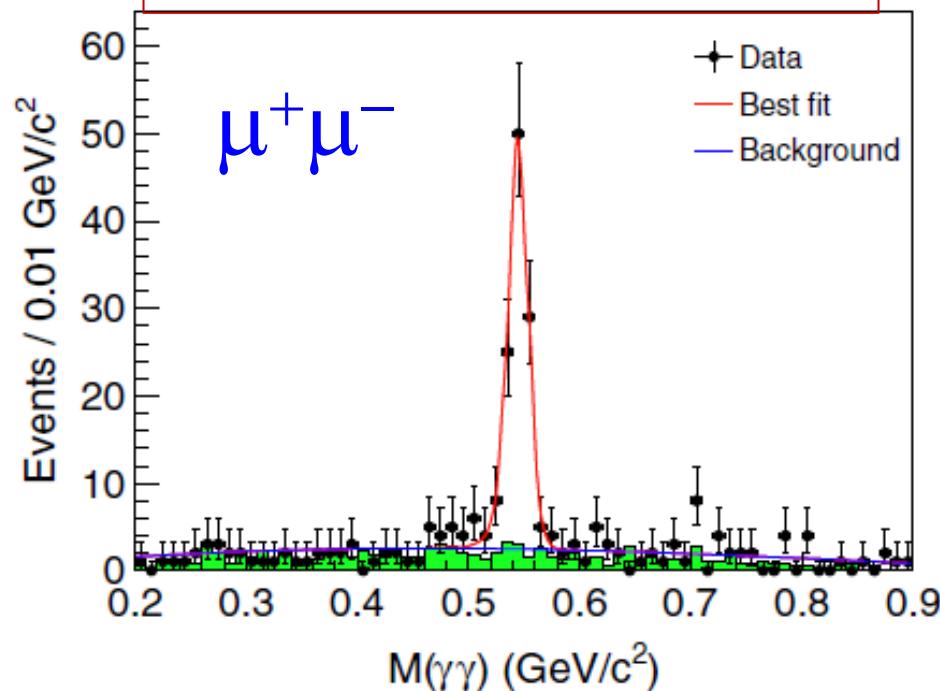


Meson loop

ISPE model

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

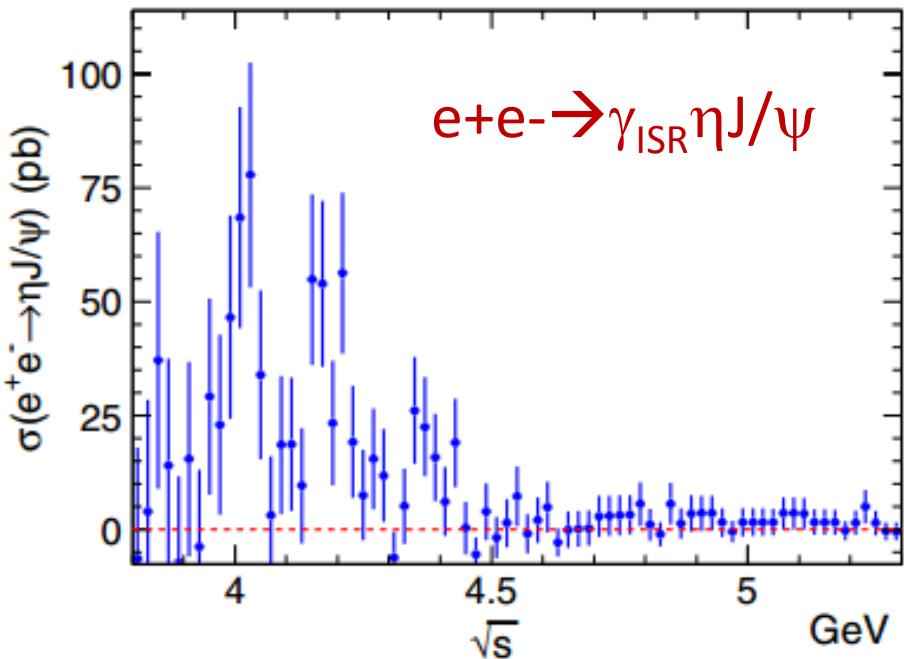
BESIII PRD86,071101(R)(2012).



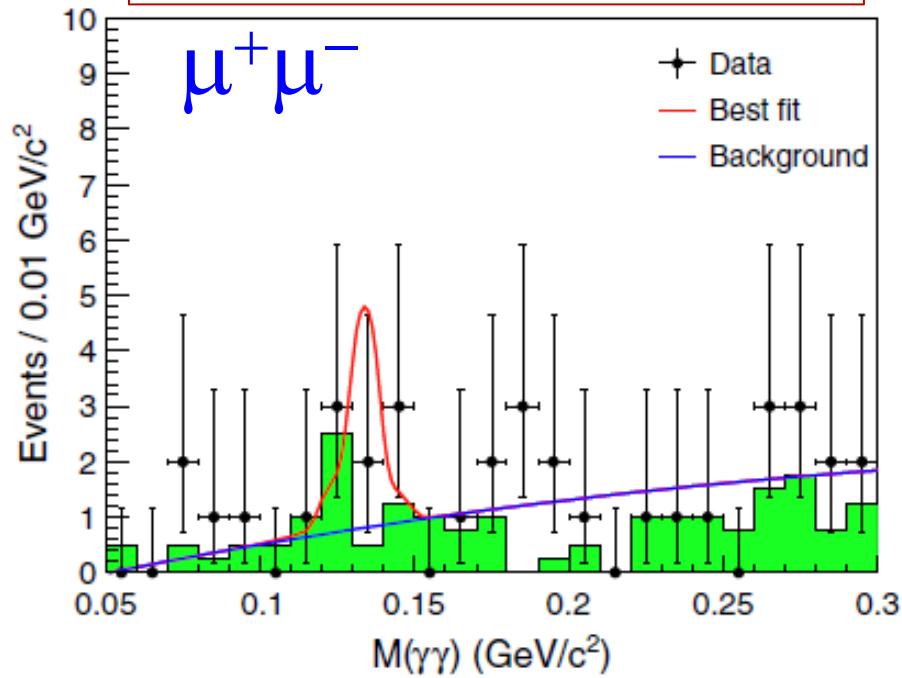
1. Using 482/pb data at  $E_{cm}=4.009$  GeV,  $J/\psi \rightarrow l+l-$  &  $\eta \rightarrow \gamma\gamma$
2.  $N(\mu\mu)=111.4 \pm 11.0$ ;  $N(ee)= 61.4 \pm 10.5$ ; significance  $> 10\sigma$ .
3.  $\sigma(\eta J/\psi)=(32.1 \pm 2.8 \pm 1.3)$  pb.
4. Partial width: 400 keV level,  $2 \times \sigma(\pi+\pi-J/\psi)$
5. Similar with  $\Upsilon(4S)$ : 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  $E_{cm}=4.009$  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  $\sim 2/fb$  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:
  - $\pi^+ \pi^- h_c$
  - $D\bar{D}^* \pi$
  - $D^* \bar{D}^* \pi$
  - $\pi^+ \pi^- \psi(2S)$
  - Search for  $h_c(2P)$
  - ...

# Future XYZ plans at BESIII

Using the scan data samples above open charm threshold:

- Line Shape measurements

1.  $\Upsilon(4260) \rightarrow \pi^+ \pi^- J/\psi$
2.  $\Upsilon(4360) \rightarrow \pi^+ \pi^- \psi(2S)$
3.  $\psi(4040) \& \psi(4160) \rightarrow \eta J/\psi$
4.  $\pi^+ \pi^- h_c$
5.  $D\bar{D}^* \pi$
6.  $D^* \bar{D}^* \pi$

# 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 !**