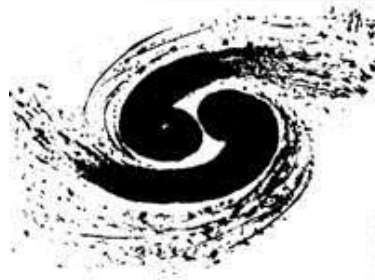


Hadron Spectroscopy at BESIII

Shuangshi Fang

(for the BESIII Collaboration)



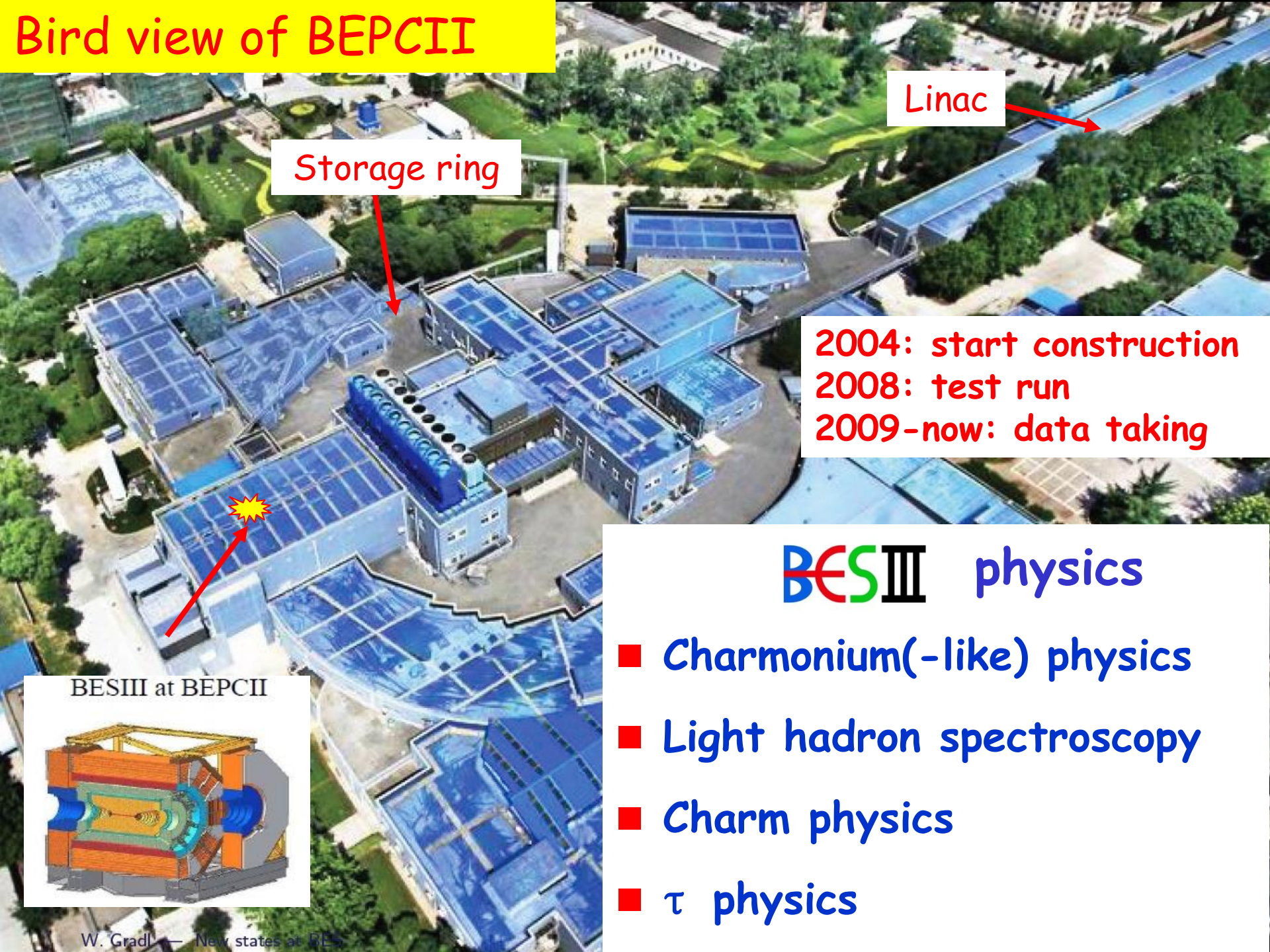
Institute of High Energy Physics, Beijing

ICHEP2014, July 2-9, Valencia, Spain

Outline

- Status of BEPCII/BESIII
- Light hadrons
- XYZ particles
- Summary

Bird view of BEPCII



Storage ring

Linac

2004: start construction
2008: test run
2009-now: data taking

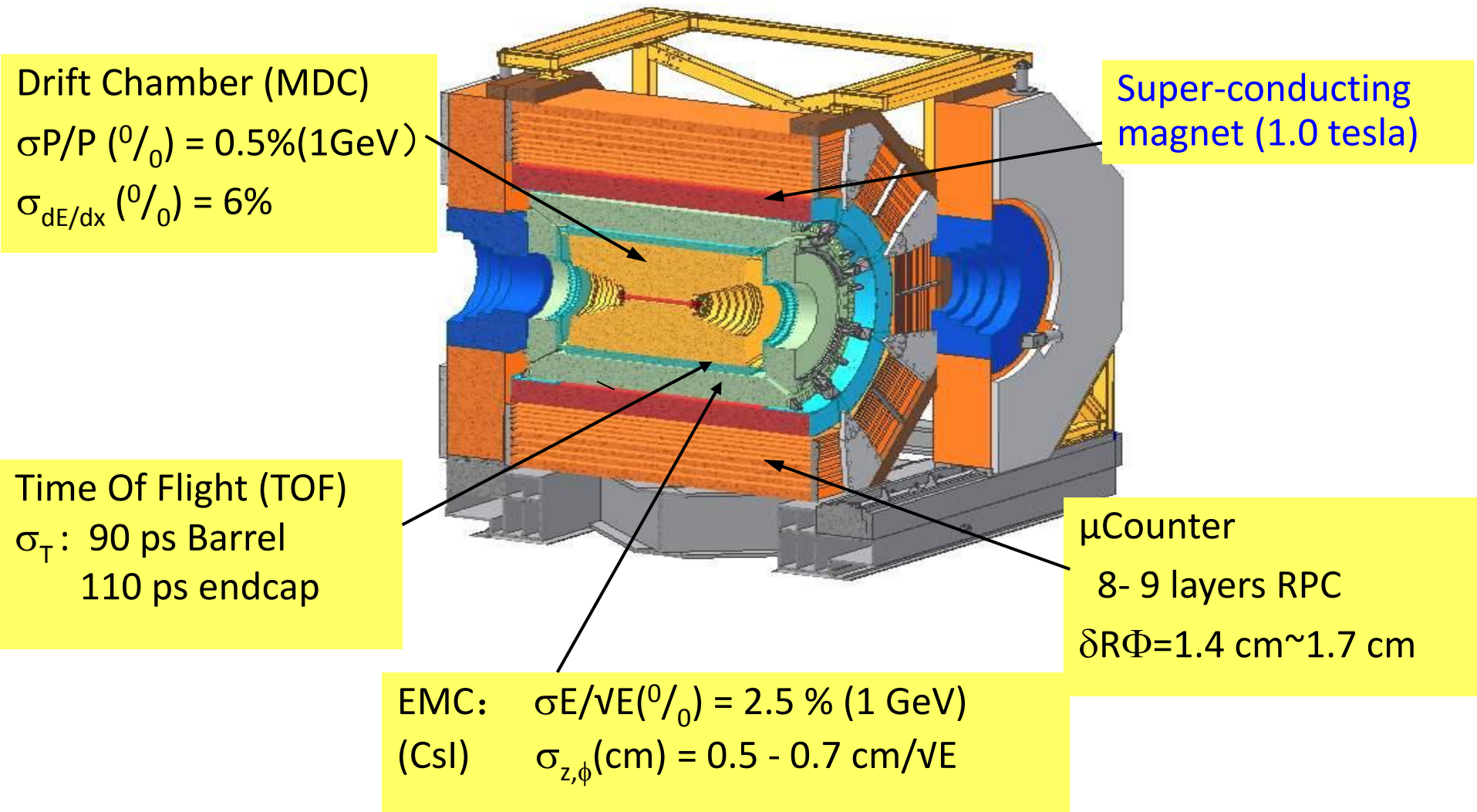


BESIII at BEPCII

BESIII physics

- Charmonium(-like) physics
- Light hadron spectroscopy
- Charm physics
- τ physics

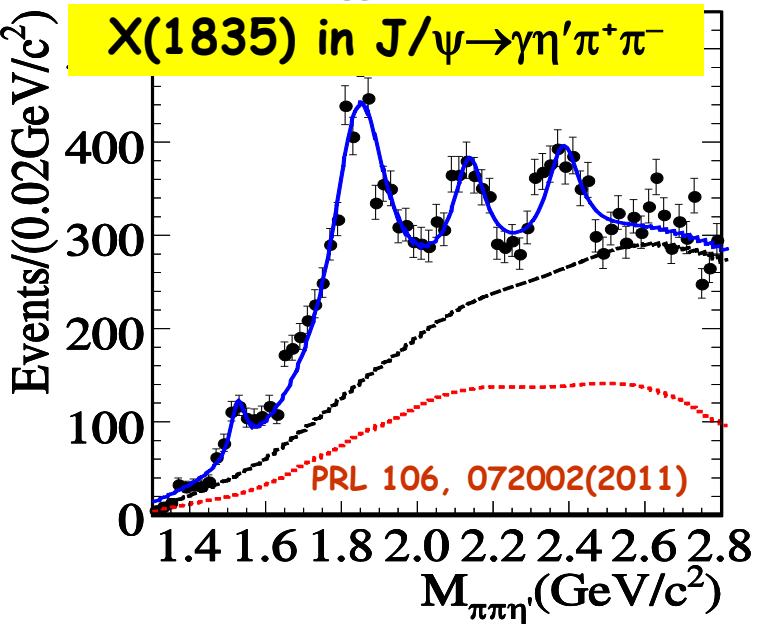
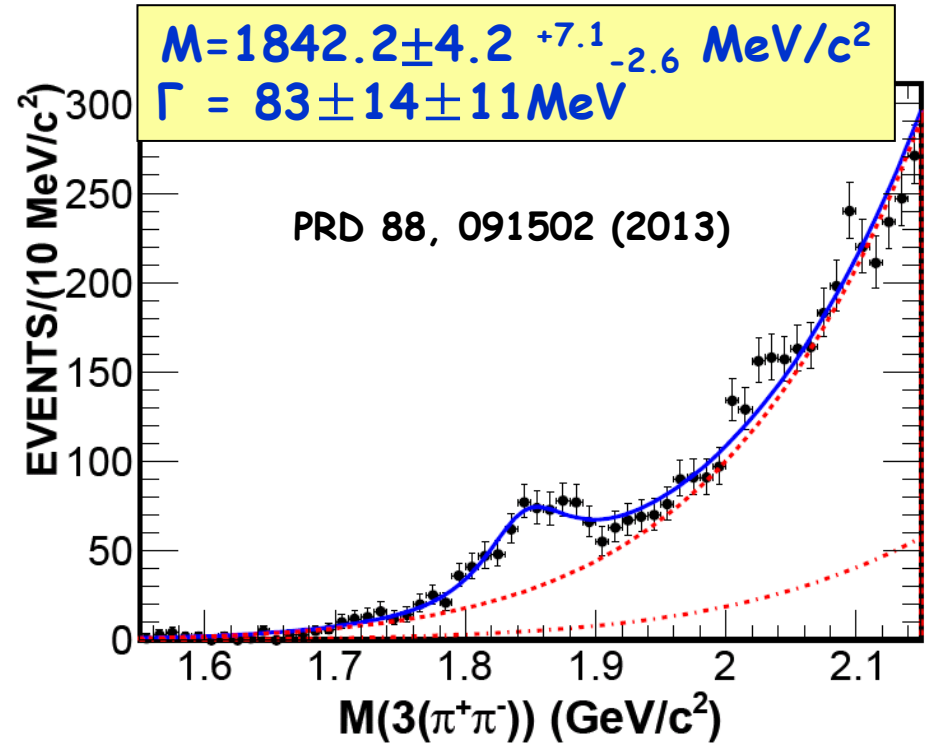
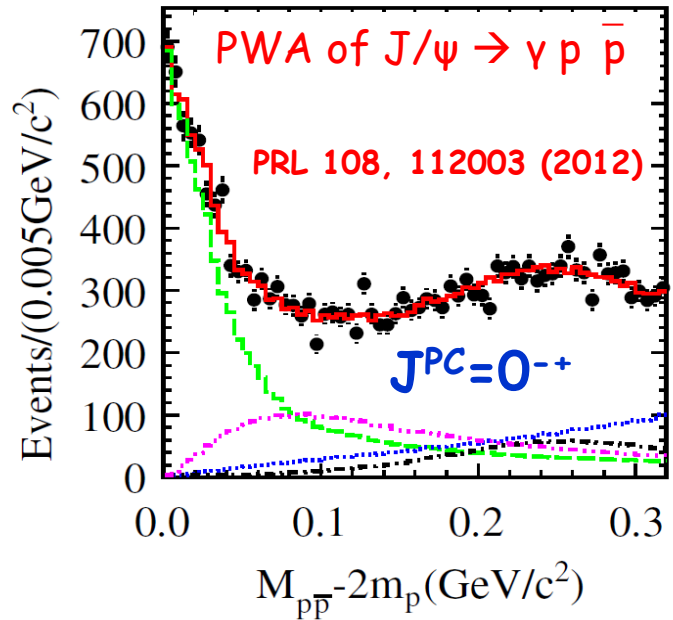
The BESIII Detector



Light hadrons

- 2009+2012 : 1.3 billion J/ψ events
0.5 billion ψ' events

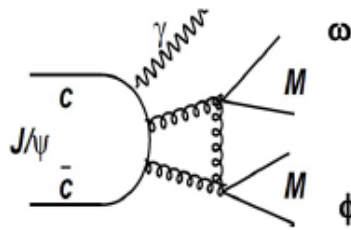
Observation of $X(1840)$ in $J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$



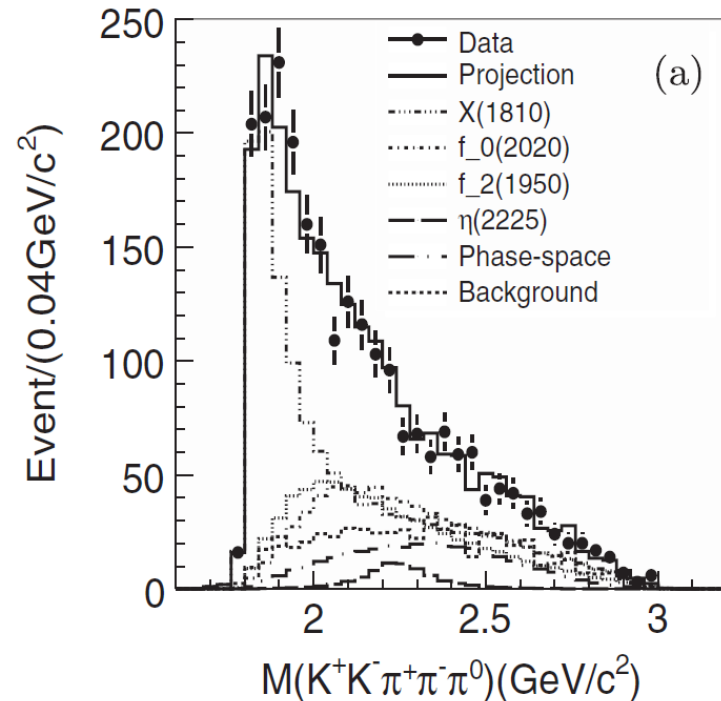
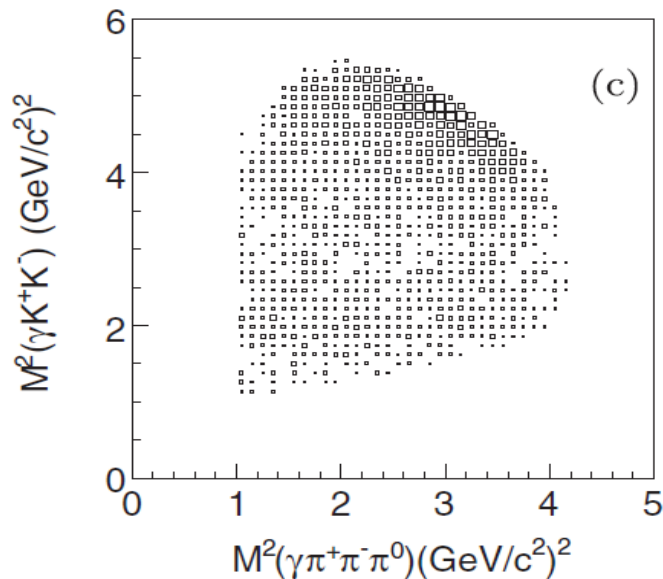
- Mass is consistent with that of $X(1835)$, but the width is much smaller than $\Gamma_{X(1835)} = 190.1 \pm 9.0 \begin{smallmatrix} +38 \\ -36 \end{smallmatrix} \text{ MeV}$
- A new decay modes of $X(1835)$?

PWA of $J/\psi \rightarrow \gamma \omega \phi$

PRD 87, 032008(2013)

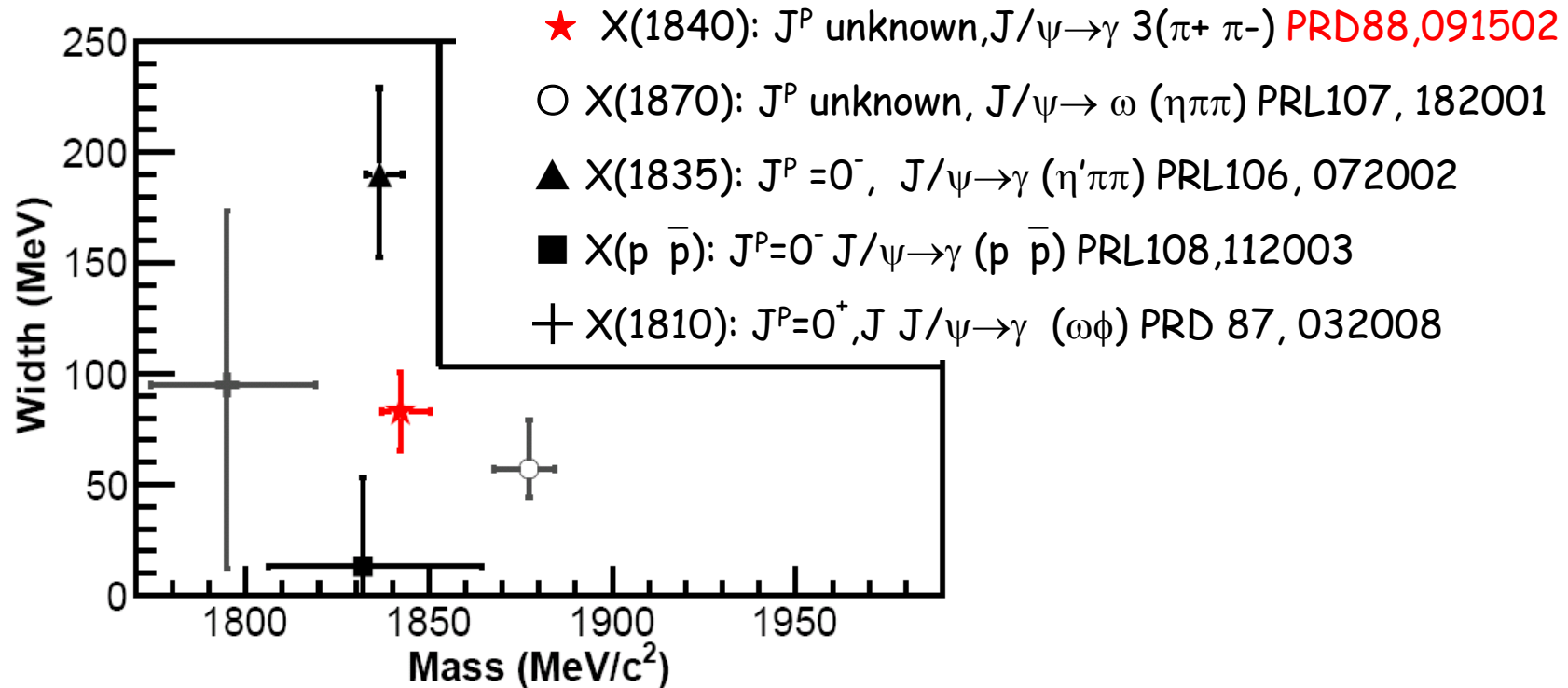


$J/\psi \rightarrow \gamma \omega \phi$ (DOZI)



- Confirmed the enhancement observed at BESII
- $M = 1795 \pm 7^{+13}_{-5} \pm 19(\text{model}) \text{ MeV}/c^2$,
- $\Gamma = 95 \pm 10^{+21}_{-34} \pm 75(\text{model}) \text{ MeV}$
- Spin-parity is determined to be 0^+
- the same as $f_0(1710)/f_0(1790)$, or a new state ?

Comparisons of the observations at BES

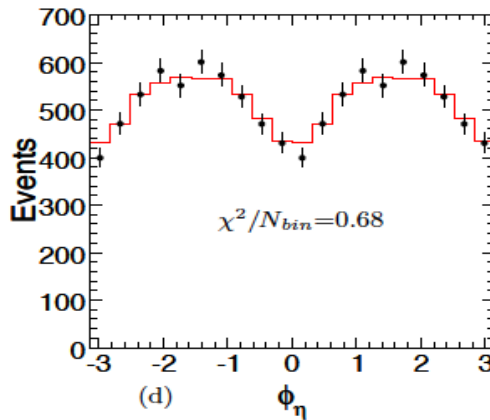
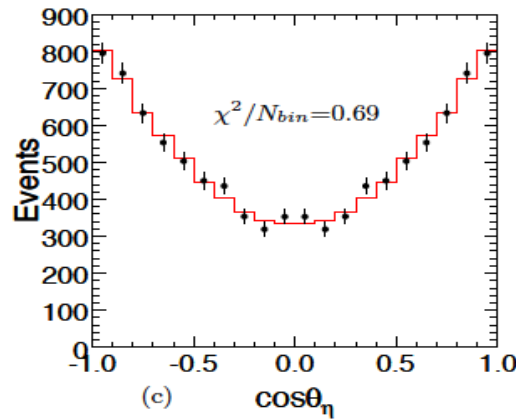
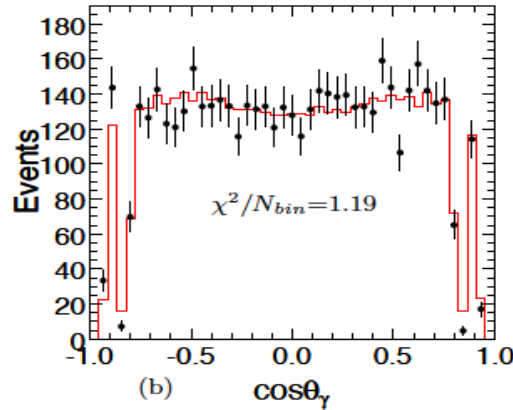
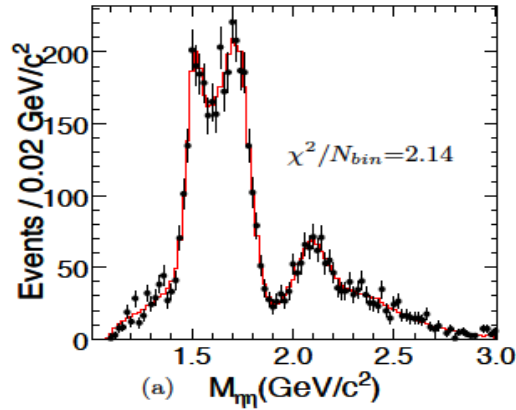


X(18??) near the threshold position of proton-antiproton

Are they the same particle? It is crucial to identify these observations.

PWA in $J/\psi \rightarrow \gamma \eta \eta$

PRD. 87, 092009 (2013)

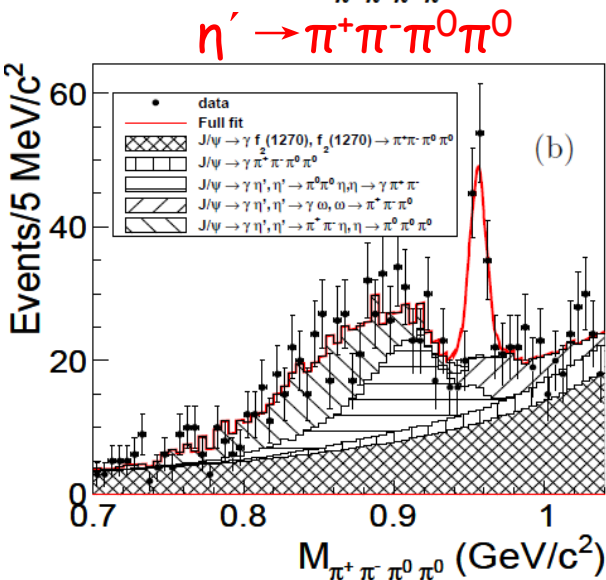
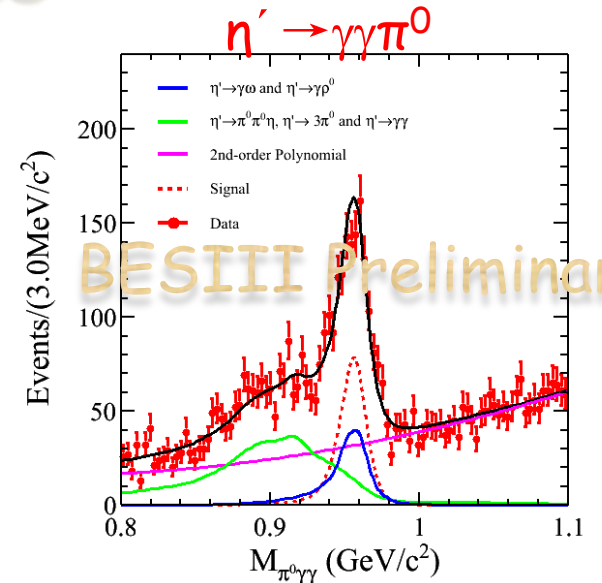
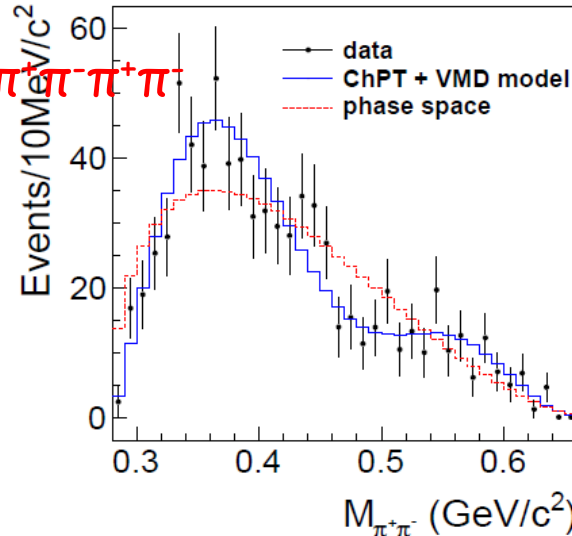
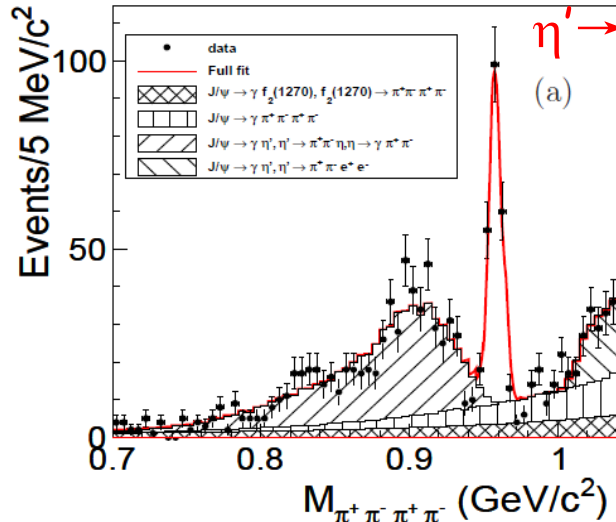


- $f_0(1710)$ and $f_0(2100)$ are dominant scalars
- $f_0(1500)$ exists (8.2σ)
- $f_2'(1525)$ is the dominant tensor
- $f_2(1810)$ and $f_2(2340)$ exist (6.4 and 7.6σ)
- No evidence for $f_j(2220)$

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

η and η' physics

PRL112,251801(2014)



$$B(\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-) = (8.63 \pm 0.69 \pm 0.64) \times 10^{-5}$$

$$B(\eta' \rightarrow \pi^+\pi^-\pi^0\pi^0) = (1.82 \pm 0.35 \pm 0.18) \times 10^{-4}$$

$$B(\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-) = (1.0 \pm 0.3) \times 10^{-4}$$

$$B(\eta' \rightarrow \pi^+\pi^-\pi^0\pi^0) = (2.4 \pm 0.7) \times 10^{-4}$$

ChPT+VMD

Phys. Rev. D 85,014014 (2012)

$$B(\eta' \rightarrow \gamma\gamma\pi^0) = [6.91 \pm 0.51 \pm 0.54 \pm 0.20(\text{PDG})] \times 10^{-4}$$

(preliminary)

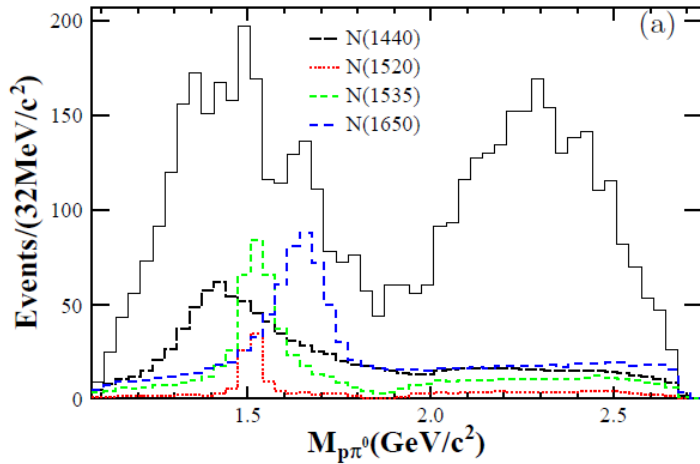
$$B(\eta' \rightarrow \gamma\gamma\pi^0): \sim 6 \times 10^{-4}$$

Nucl. Phys. Proc. Suppl. 207-208, 224 (2010)

R. Escribano, PoS QNP 2012, 079 (2012)

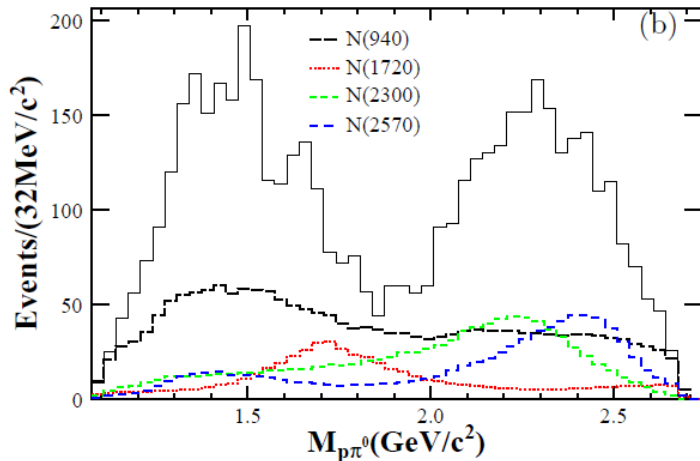
PWA results on N^* baryons in $\psi' \rightarrow \pi^0 p \bar{p}$

PRL. 110,022001(2013)



- 2-body decay:
 $\psi(2S) \rightarrow X \pi^0, X \rightarrow p \bar{p}$
 $\psi(2S) \rightarrow p \bar{N}^*, \bar{N}^* \rightarrow \bar{p} \pi^0 + \text{c.c.}$
- isospin conservation:
 Δ suppressed

Two new baryonic excited states are observed !



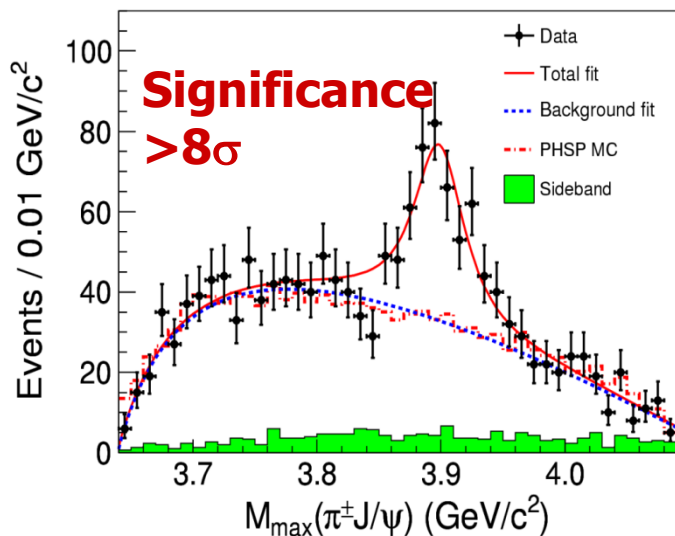
Resonance	$M(\text{MeV}/c^2)$	$\Gamma(\text{MeV}/c^2)$	ΔS	ΔN_{dof}	C.L.
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	4	12.2σ
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94-44}$	55.6	6	9.6σ
$N(2300)$	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$	120.7	4	15.0σ
$N(2570)$	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}	78.9	6	11.7σ

XYZ particles

- **2013:** ~ 1.1, 0.8, 0.5 fb⁻¹@ 4.23, 4.26, 4.36 GeV

Observation of $Z_c(3900)$ at BESIII

PRL110, 252001 (2013)

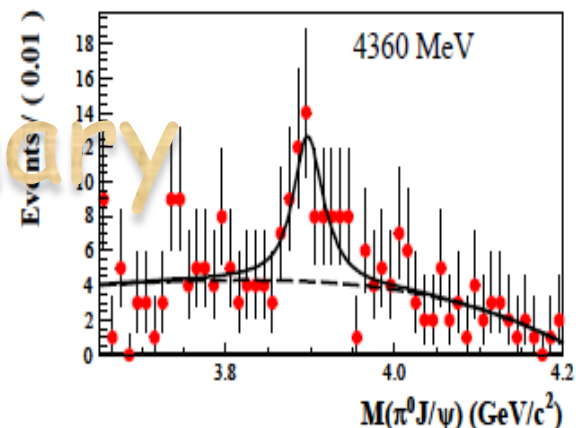
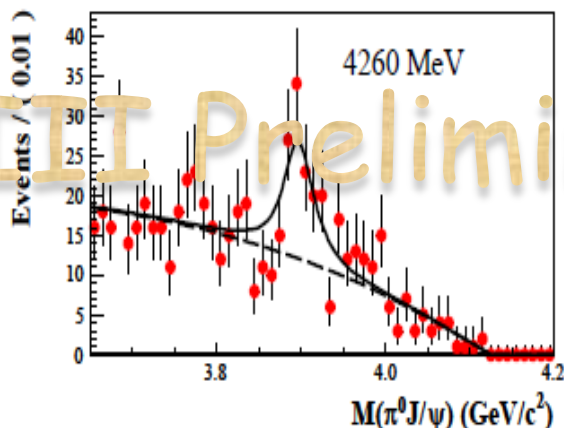
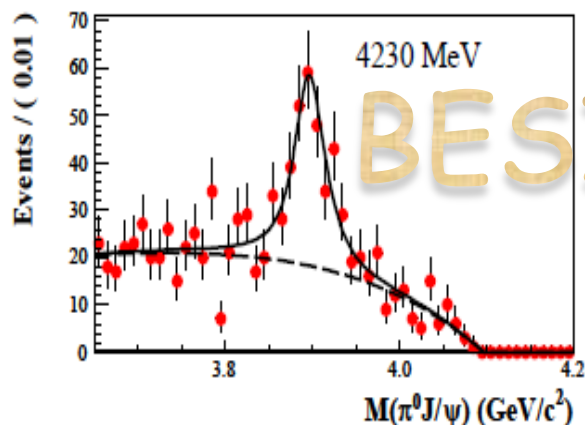


$$e^+e^- \rightarrow \pi Z_c(4020) \rightarrow \pi^+\pi^- J/\psi$$

- $M = 3899.0 \pm 3.6 \pm 4.9 \text{ MeV}/c^2$
- $\Gamma = 46 \pm 10 \pm 20 \text{ MeV}$

$$e^+e^- \rightarrow \pi Z_c(4020) \rightarrow \pi^0\pi^0 J/\psi$$

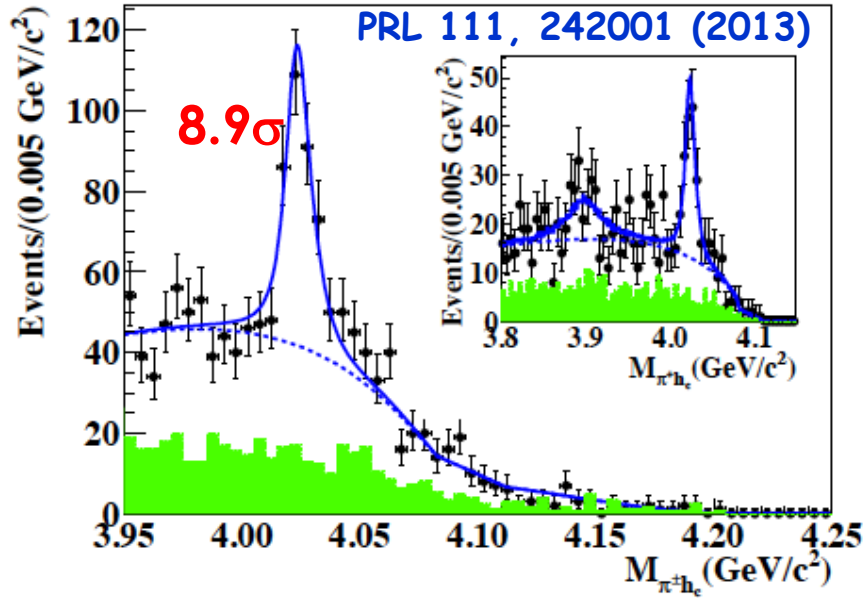
- $M = 3894.8 \pm 2.3 \text{ MeV}/c^2$
- $\Gamma = 29.6 \pm 8.2 \text{ MeV}$



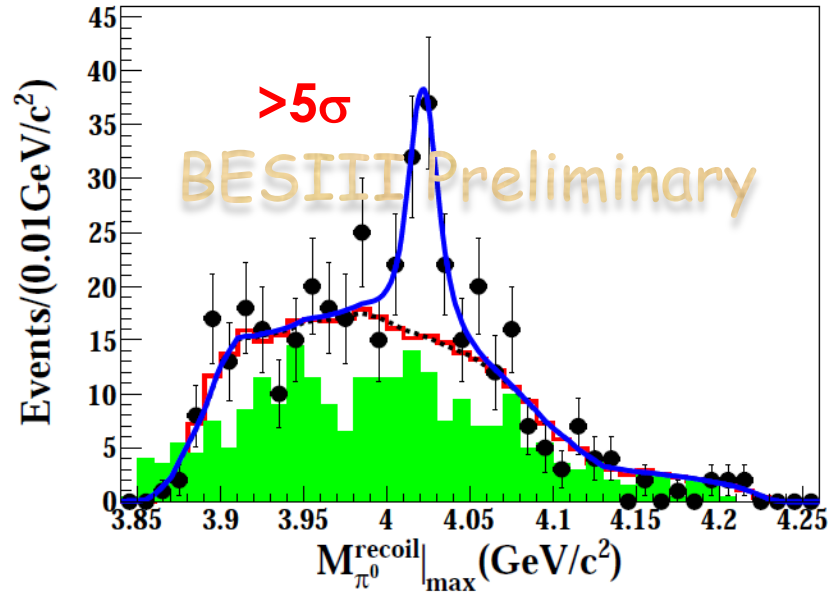
BESIII Preliminary

Observation of $Z_c(4020)$ in $e^+e^- \rightarrow \pi\pi h_c$

$e^+e^- \rightarrow \pi^+\pi^-h_c$



$e^+e^- \rightarrow \pi^0\pi^0h_c$



No significant: $Z_c(3900)$ (2.1σ)

$$M = 4022.9 \pm 0.8 \pm 2.7 \text{ MeV}/c^2$$

$$\Gamma = 7.9 \pm 2.7 \pm 2.6 \text{ MeV}$$

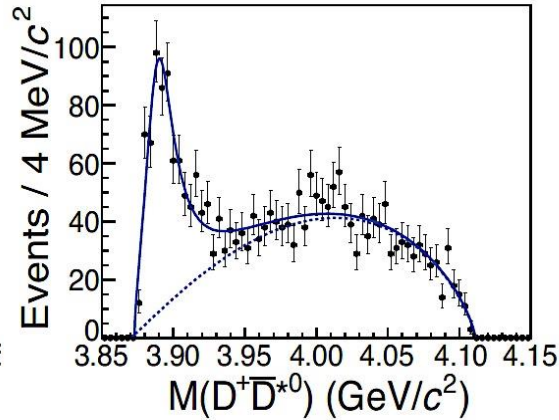
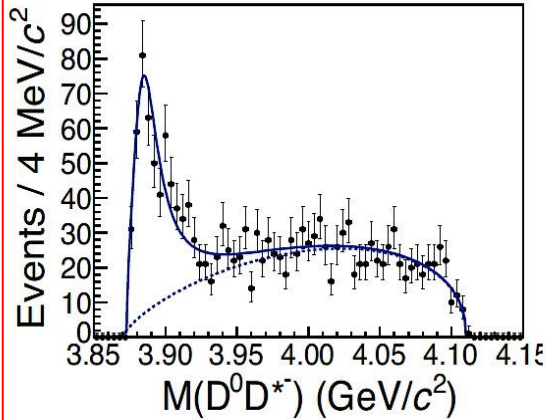
$$\frac{\sigma(e^+e^- \rightarrow \pi^0 Z_c(4020)^0 \rightarrow \pi^0 \pi^0 h_c)}{\sigma(e^+e^- \rightarrow \pi^\pm Z_c(4020)^\mp \rightarrow \pi^\pm \pi^\mp h_c)}$$

$$M = 4023.6 \pm 2.3 \pm 3.9 \text{ MeV}/c^2$$

\sqrt{s} (GeV)	$R_{\pi Z_c(4020)}$
4.230	$0.79 \pm 0.30 \pm 0.26$
4.260	$1.18 \pm 0.46 \pm 0.37$
4.360	$0.99 \pm 0.47 \pm 0.32$

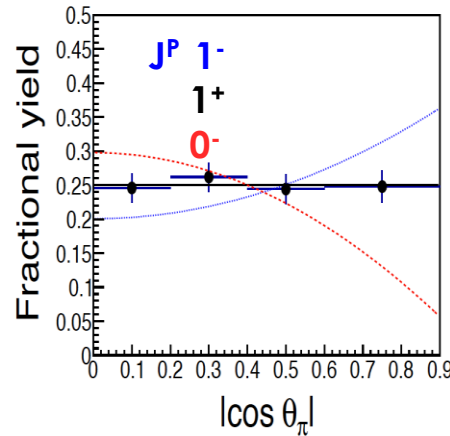
Observation of $Z_c(3885)$ and $Z_c(4025)$

$$e^+e^- \rightarrow \pi^- (D^* \bar{D})^+$$



$$M = 3883.9 \pm 1.5 \pm 4.2 \text{ MeV}/c^2$$

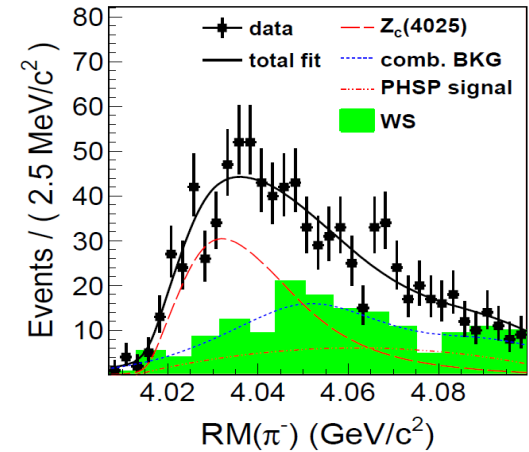
$$\Gamma = 24.8 \pm 3.3 \pm 11.0 \text{ MeV}$$



- fits favor 1^+ distribution assumption

PRL 112, 022001 (2014)

$$e^+e^- \rightarrow \pi^- (D^* \bar{D}^*)^+$$



$$M = 4026.3 \pm 2.6 \pm 3.7 \text{ MeV}/c^2$$

$$\Gamma = 24.8 \pm 5.6 \pm 7.7 \text{ MeV}$$

PRL 112, 132001 (2014)

the Z_c states at BESIII

Channel	Mass (MeV/c ²)	Width (MeV)
$\pi J/\psi$	$3899.0 \pm 3.6 \pm 4.9$ 3894.8 ± 2.3 (Prel.)	$46 \pm 10 \pm 20$ 29.6 ± 8.2 (Prel.)
$(D \bar{D}^*)^\pm$	$3883.9 \pm 1.5 \pm 4.2$	$24.8 \pm 3.3 \pm 11.0$
	2σ difference	1σ difference
πh_c	$4022.9 \pm 0.8 \pm 2.7$ $4022.9 \pm 0.8 \pm 2.7$ (Prel.)	$7.9 \pm 2.7 \pm 2.6$
$(D^* \bar{D}^*)^\pm$	$4026.3 \pm 2.6 \pm 3.7$	$24.8 \pm 5.6 \pm 7.7$
	1σ difference	2σ difference

Close to $D \bar{D}^*$
threshold (3875 MeV)

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

- At least 4-quarks; Near threshold;
- Isospin: $I=1$, hint of a new spectroscopy ?
- Whether they are two states need further understanding (couple channel analysis? quantum number determination? interference?)

Summary

- BESIII is successfully operating since 2008
 - World largest data samples at J/ψ , ψ' , $\psi(3770)$, $\psi(4040)$, $Y(4260)$ already collected, more data in future coming soon
- Hadron spectroscopy
 - Observation of $X(1840)$
 - PWA of $J/\psi \rightarrow \gamma \eta \eta, \gamma \omega \phi$
 - η/η' physics
 - Observation of Z_c states, hint of a new spectroscopy !
- Expect more results from BESIII in the future !

Many thanks
for your attention !