



XYZ states at BESIII

Liu Jingyi(刘晶译)

Institute of High Energy Physics

On behalf of BESIII collaboration

Outline

- *Introduction*
- *Probe X family*
- *Probe Y family*
- *Probe Z family*
- *Summary and outlook*

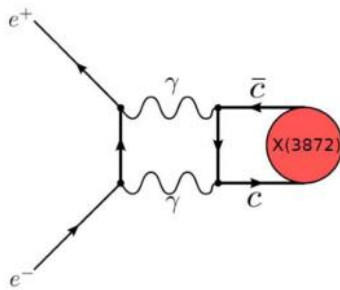
Introduction

- XYZ states
 - Masses are mainly above 3.8 GeV, but cannot be fully described by the prediction in charmonium spectroscopy by potential model
 - Also called charmonium-like states or charmonium exotics
- Nature of XYZ states
 - Molecular? Hybrid? $q\bar{q}$ glue-ball? Tetra-quark?
- Data at BESIII
 - $\sim 12 \text{ fb}^{-1}$ between center-of-mass energy 3.8 and 4.6 GeV
 - Fined energy scan

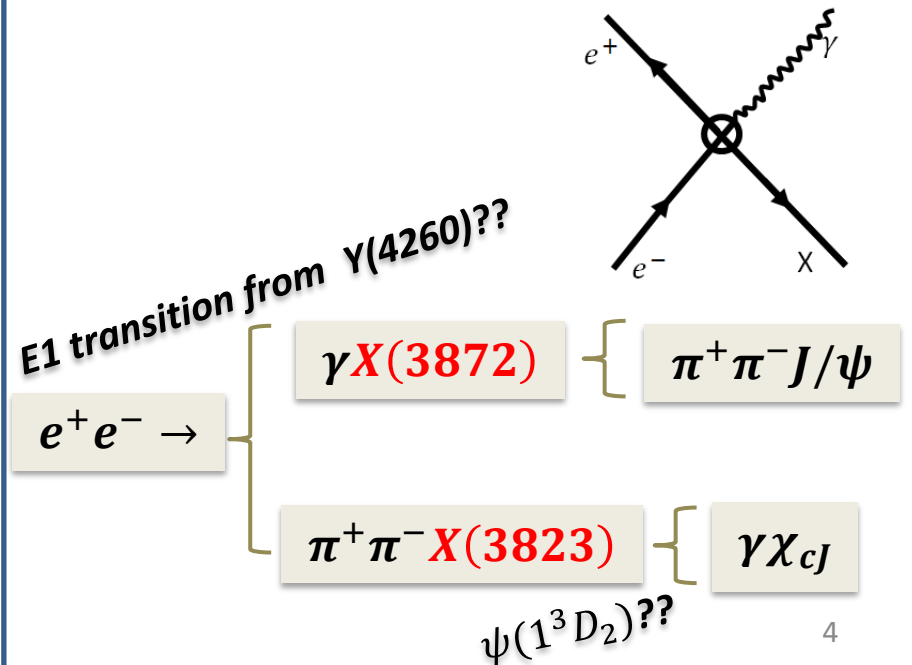
Probe X family

- Mainly represent 1^+ charmonium-like states
- Two probe methods at BESIII

directly

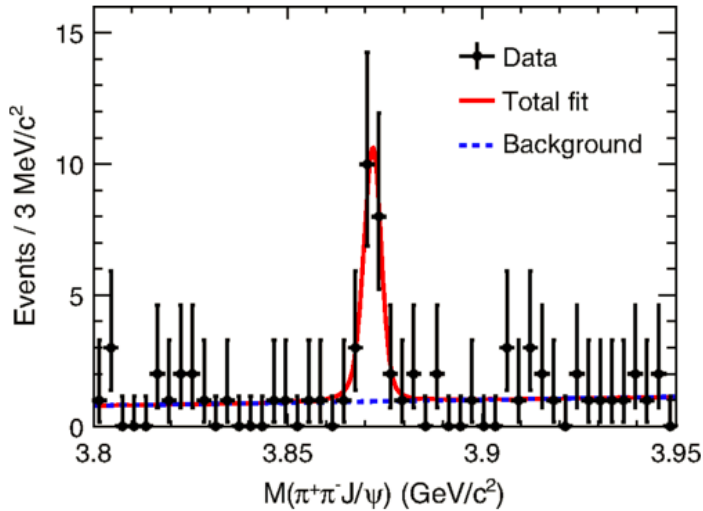


through transition from 1^{--} states

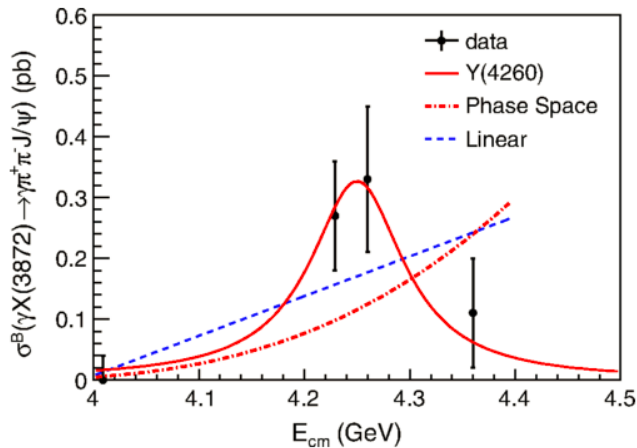


$$e^+e^- \rightarrow \gamma X(3872)$$

PRL 112, 092001(2014)



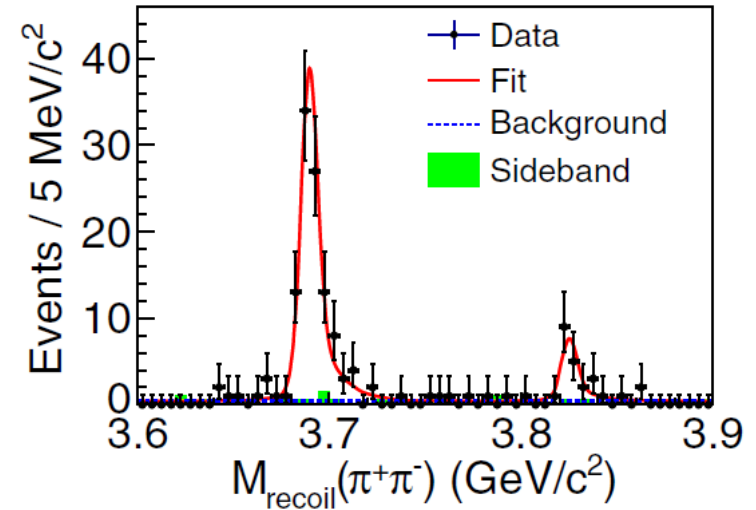
- $X(3872) \rightarrow \pi^+\pi^- J/\psi$
- Fit with $Y(4260)$



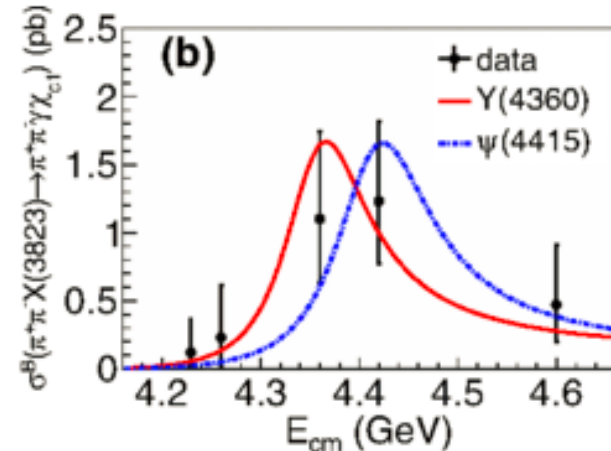
$$e^+e^- \rightarrow \pi^+\pi^- X(3823)$$

XYZ

PRL 115, 011803(2015)



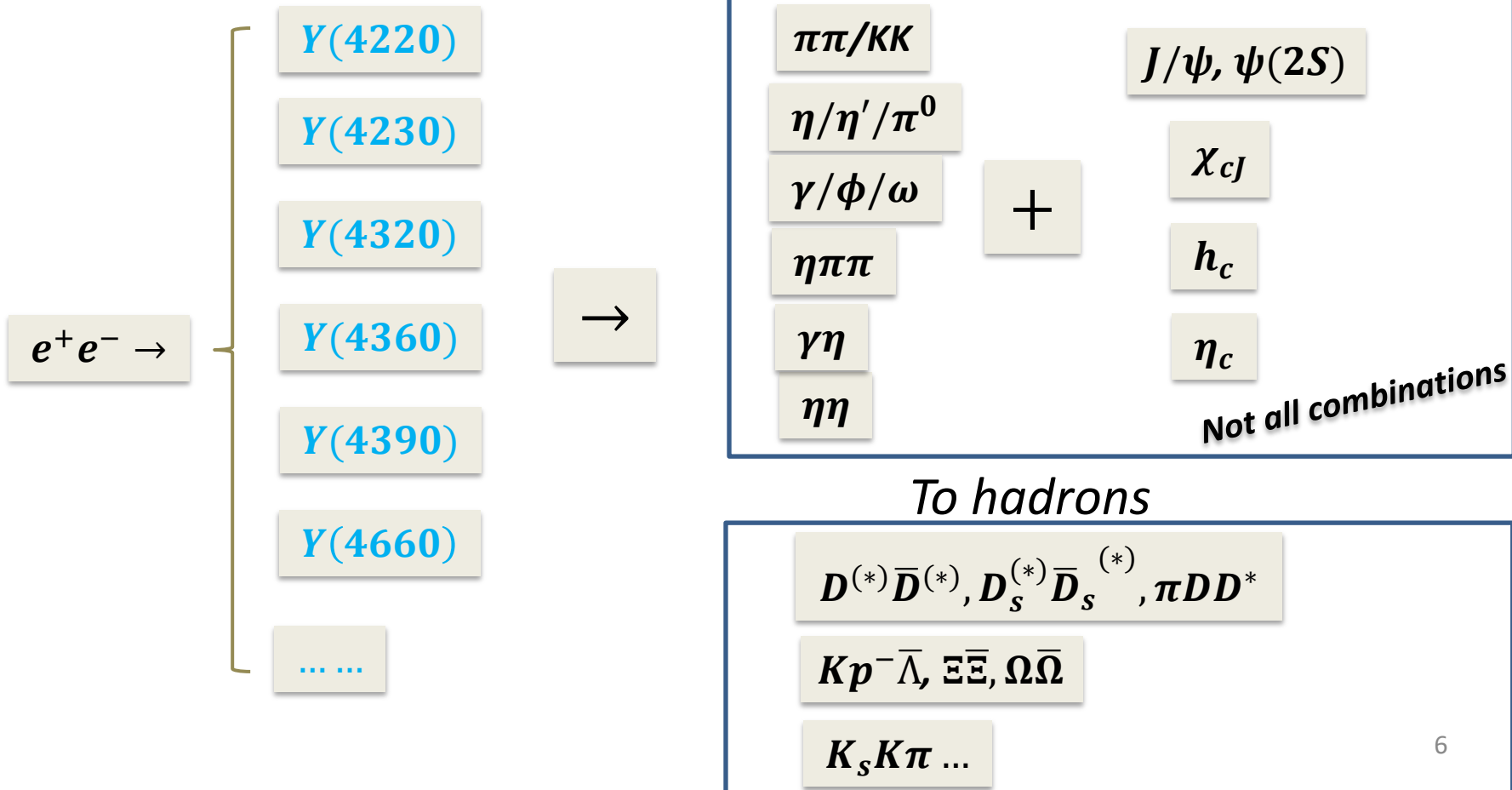
- $X(3823) \rightarrow \gamma \chi_{c1/2}$
- With statistical significance of 6.2σ
- Good candidate of $\psi(1^3D_2)$



Probe Y family

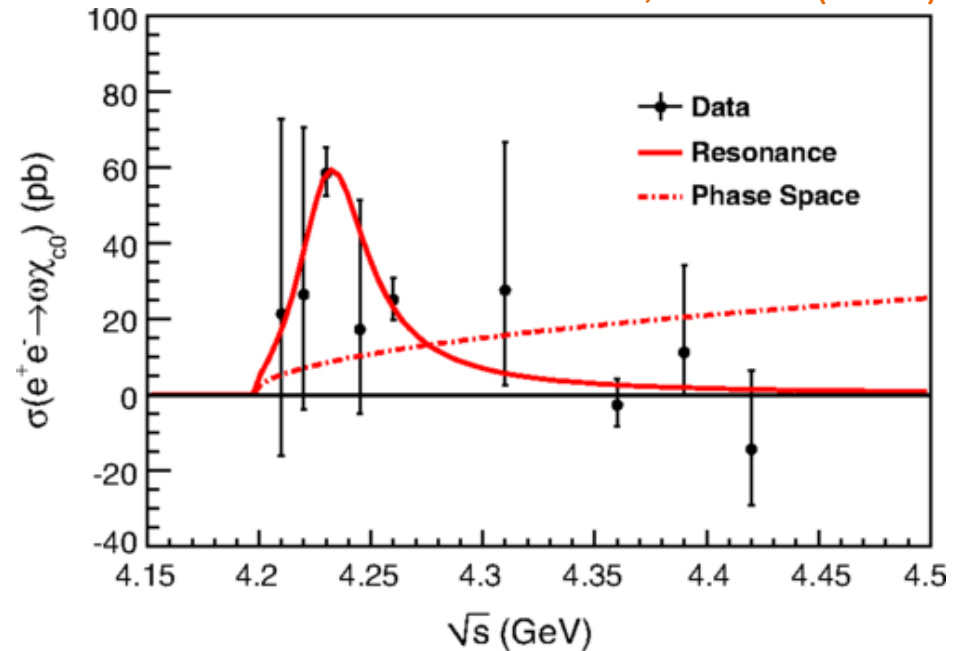
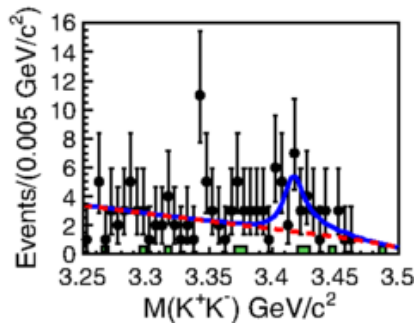
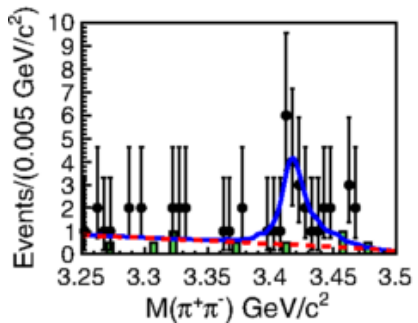
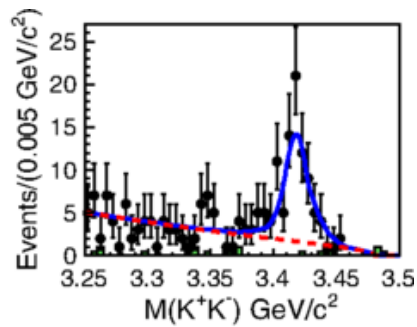
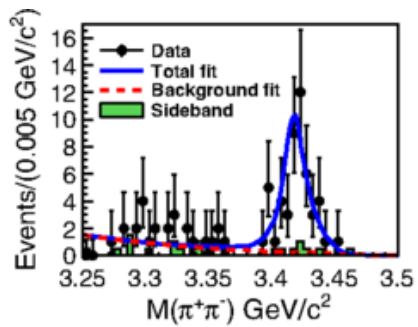
- Represent 1^{--} charmonium-like states
- mainly by e^+e^- cross sections measurements

Transition to charmonium states



$$e^+e^- \rightarrow \omega\chi_{c0}$$

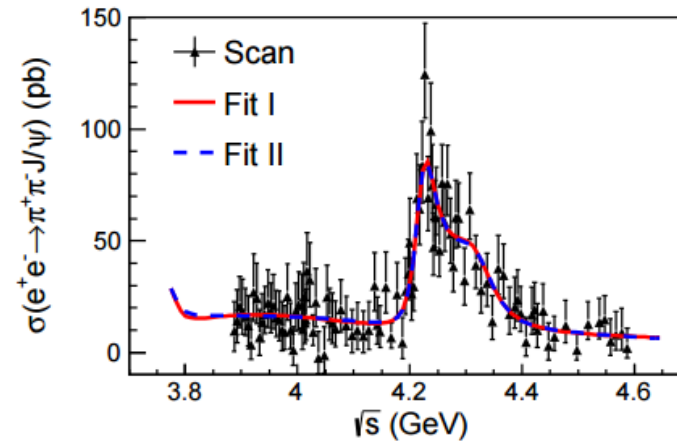
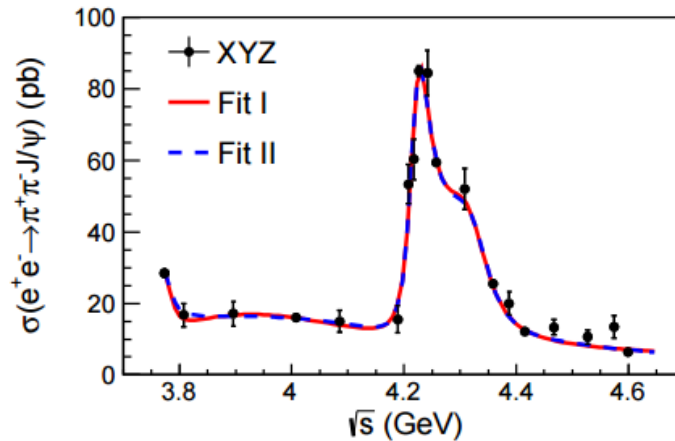
PRL 114, 092003(2015)



- More than 9σ
- Fit with $Y(4260)$
- Mass and width to be $(4230 \pm 8 \pm 6)$ MeV/c² and $(38 \pm 12 \pm 2)$ MeV

$$e^+e^- \rightarrow \pi^+\pi^-J/\psi$$

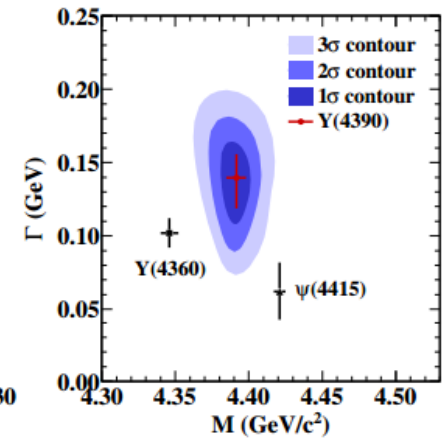
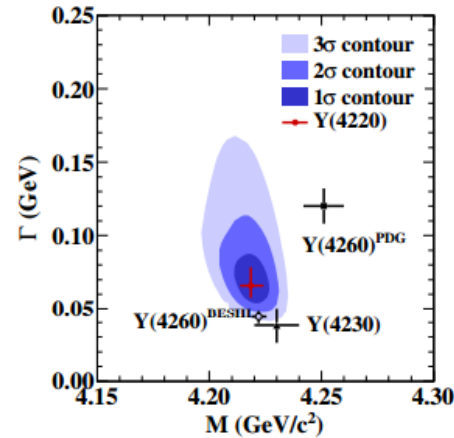
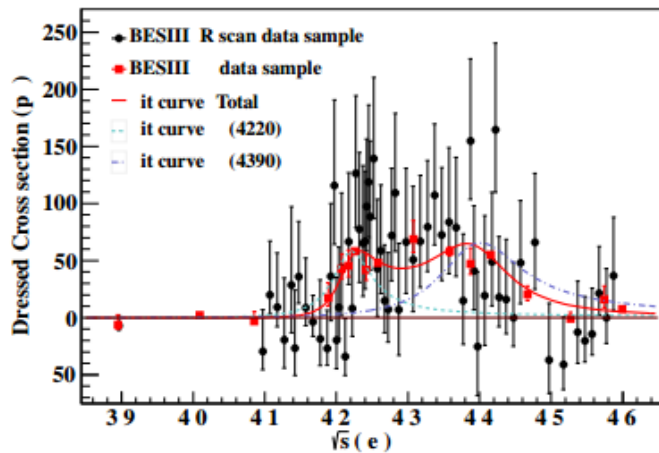
PRL 118, 092001(2017)



- Two structures
- $M_1 = 4222.0 \pm 3.1 \pm 1.4$ MeV, $\Gamma_1 = 44.1 \pm 4.3 \pm 2.0$ MeV
 - Agrees with $Y(4260)$
- $M_2 = 4320.0 \pm 10.4 \pm 7.0$ MeV, $\Gamma_2 = 101.4^{+25.3}_{-19.7} \pm 10.2$ MeV
 - Agrees with $Y(4360)$ within errors
 - This resonances is observed with $> 7.6 \sigma$

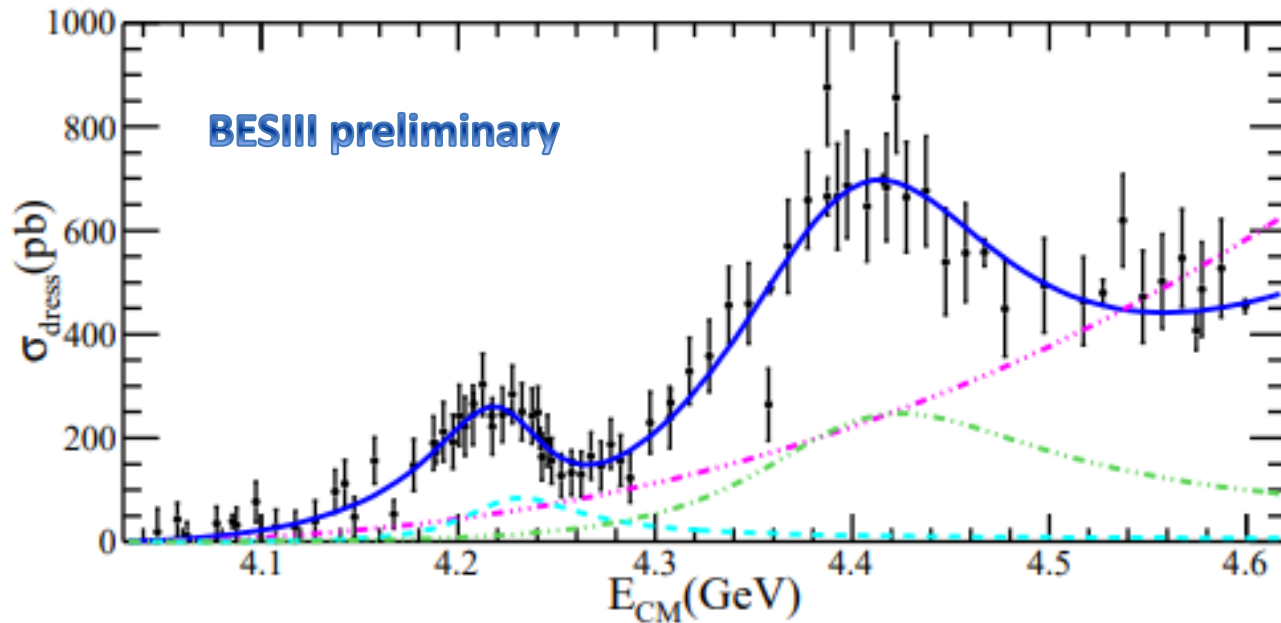
$$e^+e^- \rightarrow \pi^+\pi^-h_c$$

PRL 118, 092002(2017)



- Two structures' significance is 10σ
- Y(4220) and Y(4290)
- $M_1 = 4218.4^{+5.5}_{-4.5} \pm 0.9$ MeV, $\Gamma_1 = 66.0^{+16.2}_{-20.6} \pm 0.4$ MeV
- $M_2 = 4391.5^{+6.3}_{-4.5} \pm 0.9$ MeV, $\Gamma_2 = 139.5^{+16.2}_{-20.6} \pm 0.4$ MeV

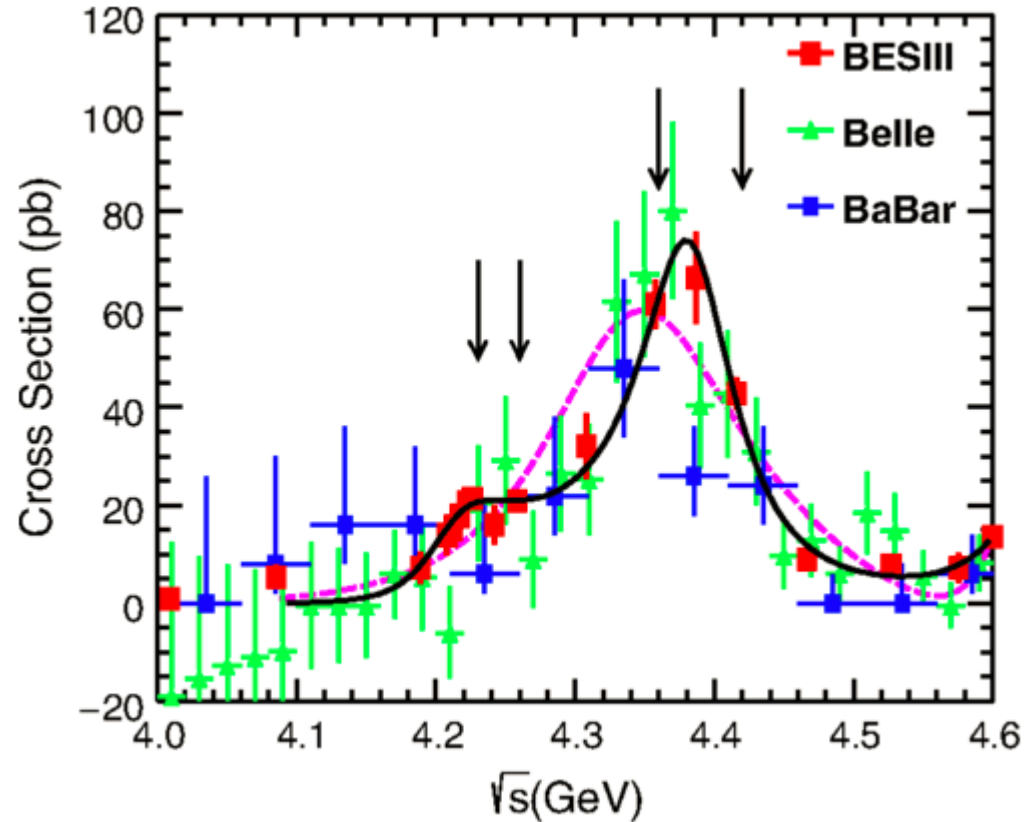
$$e^+e^- \rightarrow \pi^+ D^0 D^{*-}$$



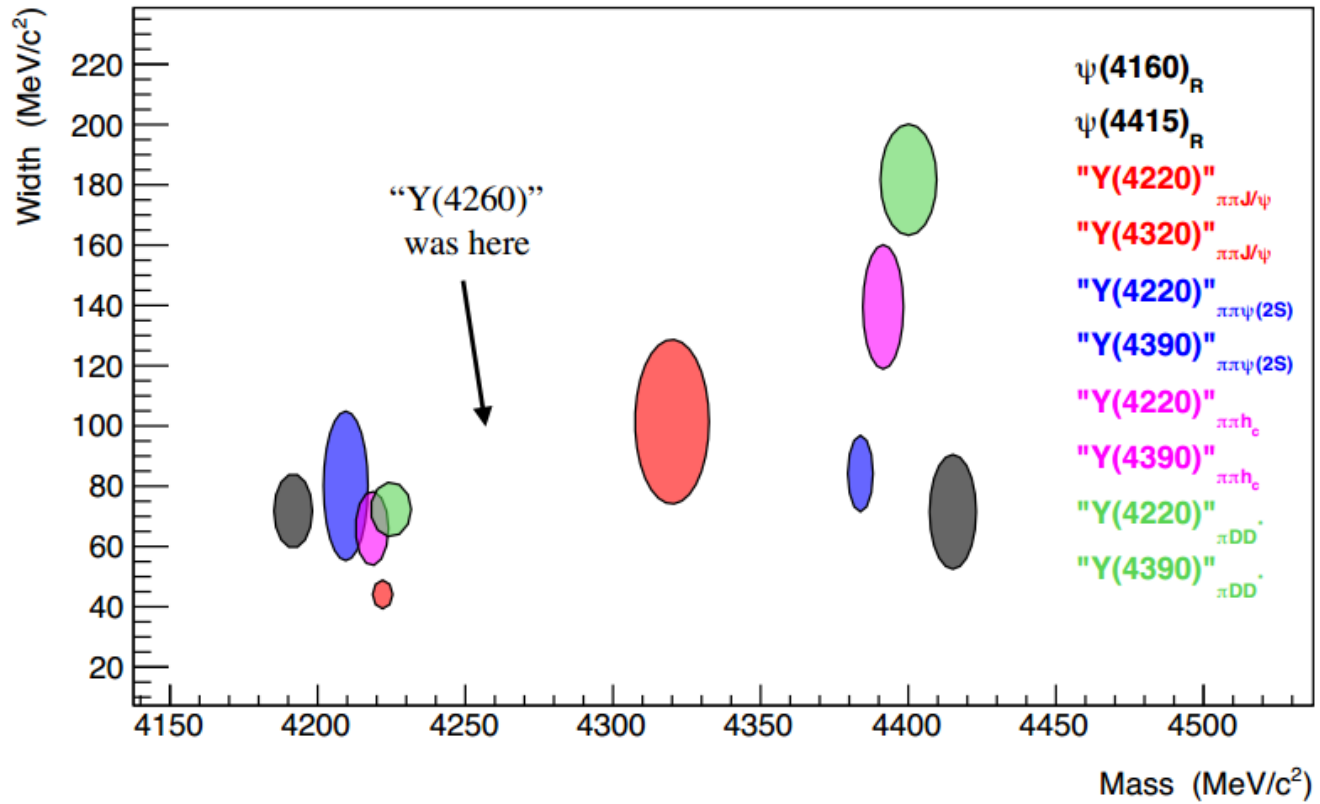
- $M1 = 4228.6 \pm 4.1 \pm 5.9 \text{ MeV}/c^2$, $\Gamma1 = 77.1 \pm 6.8 \pm 6.9 \text{ MeV}$
- $M2 = 4404.6 \pm 7.4 \pm 5.5 \text{ MeV}/c^2$, $\Gamma2 = 191.7 \pm 13.0 \pm 17.1 \text{ MeV}$
- Consistent with $Y(4220)$ and $Y(4390)$ of $\pi\pi h_c$

$$e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$$

PRD 96,032004(2017)



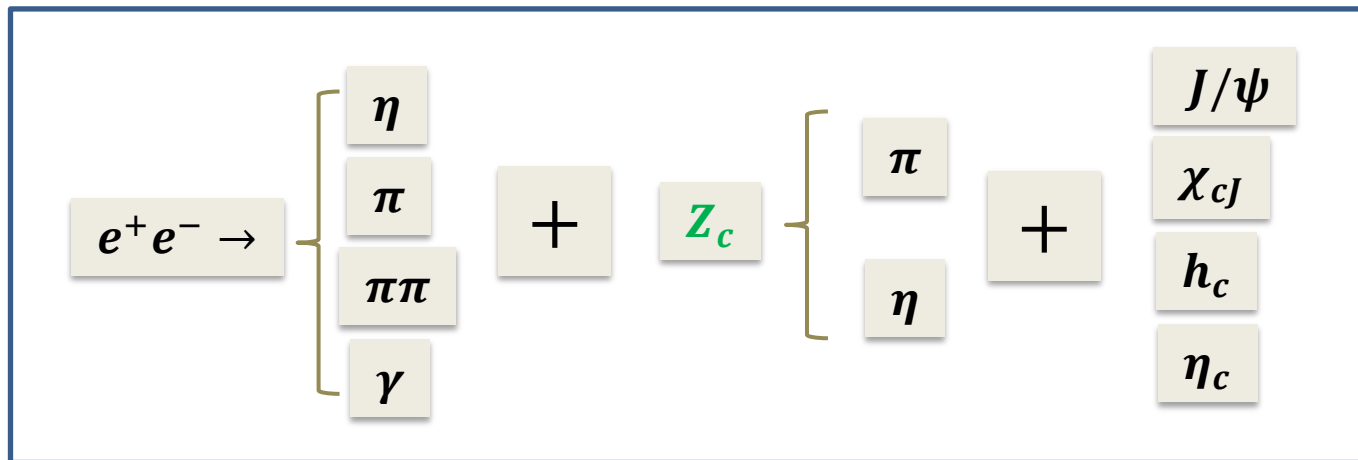
- $M1 = 4209.5 \pm 7.4 \pm 1.4$ MeV/c² and $\Gamma1 = 80.1 \pm 24.6 \pm 2.9$ MeV
 - Significance is 5.8σ
- $M2 = 4383.8 \pm 4.2 \pm 0.8$ MeV/c² and $\Gamma2 = 84.2 \pm 12.5 \pm 2.1$ MeV



Probe Z family

- Represent non-zero iso-spin charmonium-like states
- Transition to Z at BESIII

1-- transition to Z through light hadrons

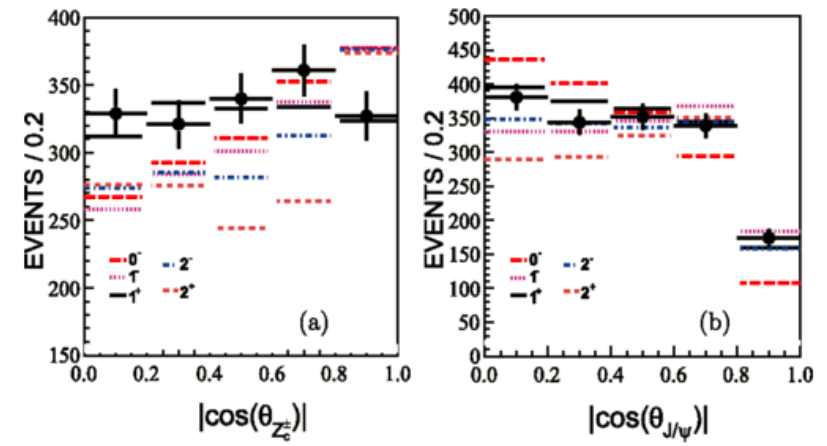
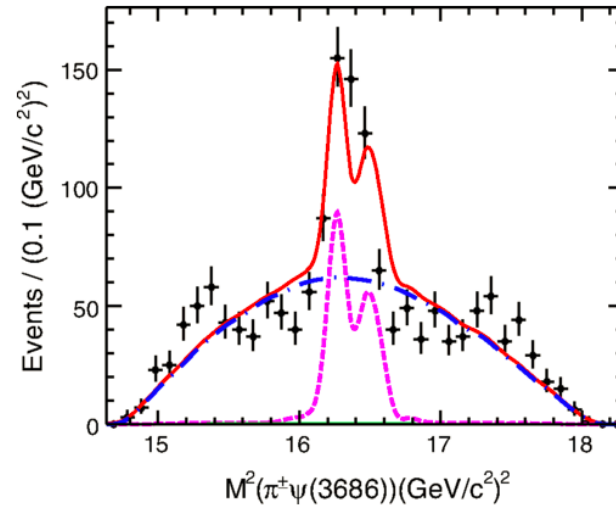
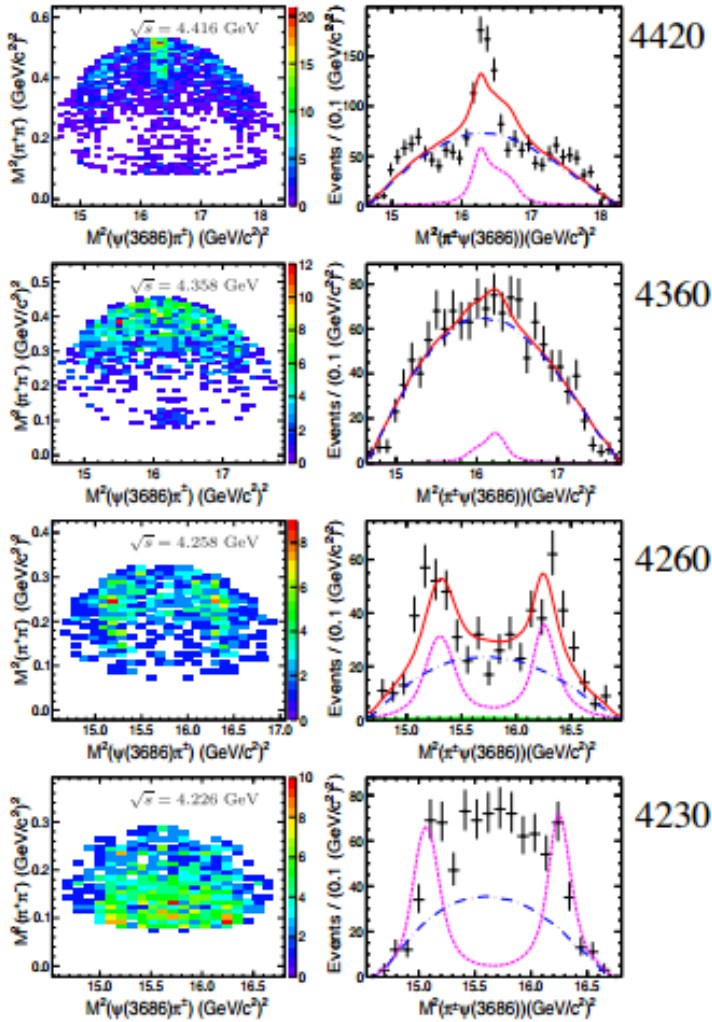


- **Study of Z at BESIII**
 - Spin and parity determination
 - Amplitude analysis

- **Abundant Z states**

Name	Channel	mass(MeV/c ²)	width(MeV)	σ^{Born} at 4.26 GeV (pb)
$Z_c(3900)$	$\pi^\pm J/\psi$	$3899.0 \pm 3.6 \pm 4.9$	$46 \pm 10 \pm 20$	13.5 ± 5.2
	$\pi^0 J/\psi$	$3894.8 \pm 2.3 \pm 2.7$	$29.6 \pm 8.2 \pm 8.2$	4.0 ± 0.9
$Z_c(3885)$	$(D\bar{D}^*)^\pm$	$3881.7 \pm 1.6 \pm 1.6$	$26.6 \pm 2.0 \pm 2.1$	$108.4 \pm 6.9 \pm 8.8$
	$(D\bar{D}^*)^0$	$3885.7^{+4.3}_{-5.7} \pm 8.4$	$35^{+11}_{-12} \pm 15$	$47 \pm 9 \pm 10 \pm 0.9$
$Z_c(4020)$	$\pi^\pm h_c$	$4022.9 \pm 0.8 \pm 2.7$	$7.9 \pm 2.7 \pm 2.6$	$7.4 \pm 1.7 \pm 2.1 \pm 1.2$
	$\pi^0 h_c$	$4023.9 \pm 2.2 \pm 3.8$	Fixed	$8.5 \pm 2.9 \pm 1.1 \pm 1.3$
$Z_c(4025)$	$(D^*\bar{D}^*)^\pm$	$4026.3 \pm 2.6 \pm 3.7$	$24.8 \pm 5.6 \pm 7.7$	89.0 ± 18.7
	$(D^*\bar{D}^*)^0$	$4025.5^{+2.0}_{-4.7} \pm 3.1$	$23.0 \pm 6.0 \pm 1.0$	$43.4 \pm 8.0 \pm 5.4$
$Z_c(4030)$	$\pi^\pm \psi'$	4032.1 ± 2.4	26.1 ± 5.3	-
	$\pi^0 \psi'$	4038.7 ± 6.5		-

$\pi^+\pi^-\psi(2S)$



Hypothesis	$\Delta(-2 \ln L)$	$\Delta(\text{ndf})$	Significance
1^+ over 0^-	94.0	13	7.6σ
1^+ over 1^-	158.3	13	10.8σ
1^+ over 2^-	151.9	13	10.5σ
1^+ over 2^+	96.0	13	7.7σ

J^P for $Z_c(3900)$, 1^+ is favored. PRL 119, 072002(2017)

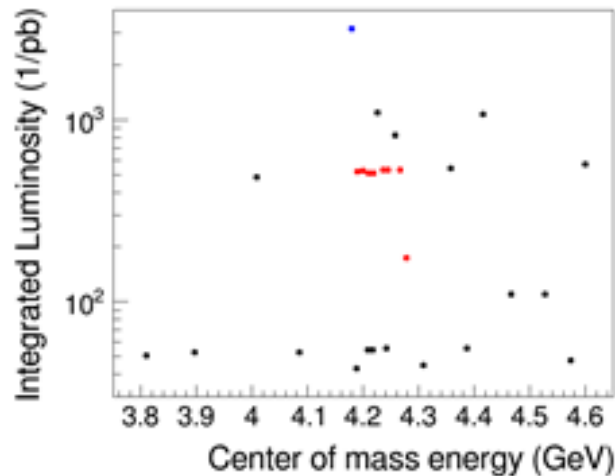
Summary and Outlook

- BESIII has performed scientific XYZ studies with large data samples collected at this energy region
 - New XYZ states
 - New decay modes for existed XYZ states
 - Resonant parameters study
- More measurements are needed!

Thanks for your attention !

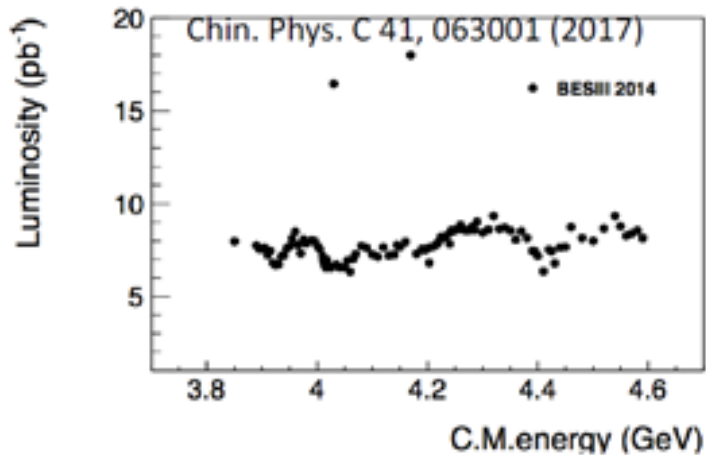
Back up

BESIII dataset for XYZ study



■ XYZ data

- $\sim 12 \text{ fb}^{-1}$ total
- Massive sample collected around 4.260 GeV



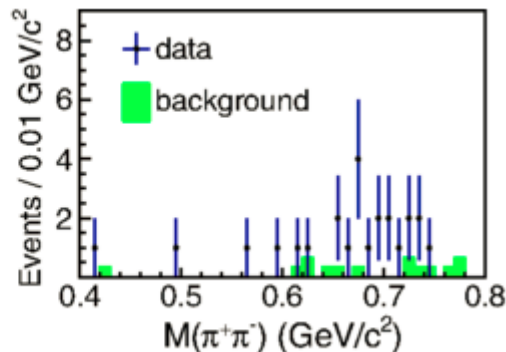
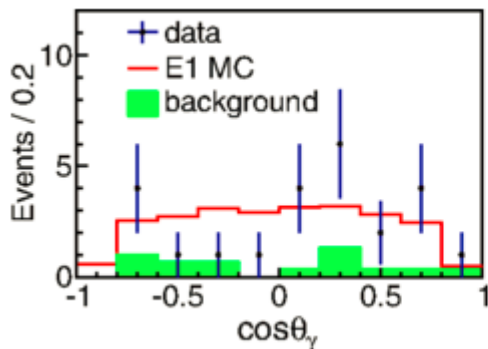
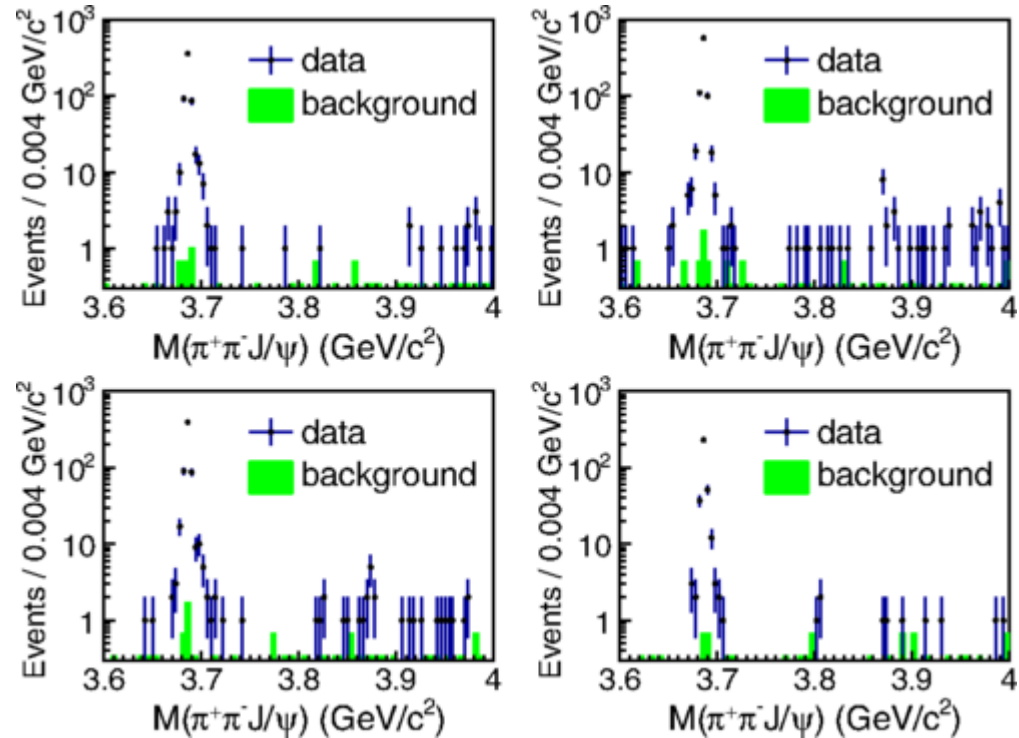
■ R Scan data

- 3.85 – 4.59 GeV.
- 104 points, $\sim 8 \text{ pb}^{-1}$ each.

$$e^+e^- \rightarrow \gamma X(3872) \rightarrow \gamma(\pi^+\pi^-J/\psi)$$

$$M = (3871.9 \pm 0.7_{\text{stat.}} \pm 0.2_{\text{sys.}}) \text{ MeV}/c^2$$

$$\Gamma < 2.4 \text{ MeV (90\% C. L.)}$$



$$e^+e^- \rightarrow \pi^+\pi^-X(3823) \rightarrow \pi^+\pi^-\gamma\chi_{c1/2}$$

- $M = (3821.7 \pm 1.3 \pm 0.7) \text{ MeV}/c^2$
- $\Gamma < 16 \text{ MeV}$ (90% C. L.)

