

# Recent XYZ Results at BESIII

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*on behalf of the BESIII collaboration*

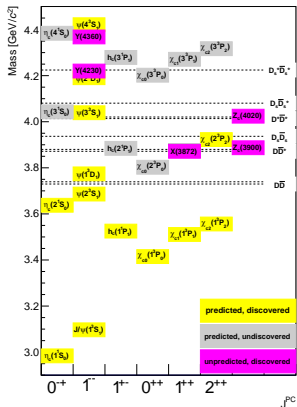
September 8, 2021

# Outline

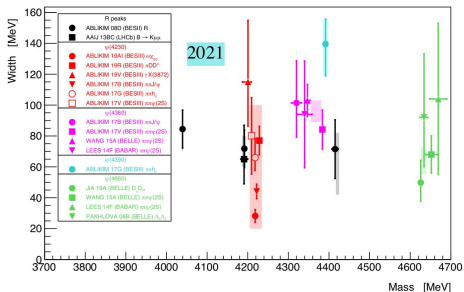
- ▶ Intro to the XYZ states
- ▶ Intro to the BESIII experiment
- ▶ Highlights of past XYZ results
- ▶ Recent searches for Y states
  - ▶ Observation of  $e^+e^- \rightarrow \eta\psi(2S)$
  - ▶ Observation of  $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$
  - ▶ Measurement of  $\sigma(e^+e^- \rightarrow \pi^+\pi^-\psi(2S))$
  - ▶ Measurements of  $\sigma(e^+e^- \rightarrow D_s^{*+}D_{sJ}^- + c.c.)$
- ▶ Recent searches for Z states
  - ▶ Measurements of  $e^+e^- \rightarrow \pi^+\pi^-\pi^-\eta_c, \pi^+\pi^-\eta_c, \gamma\pi^0\eta_c$

# Intro to the XYZ States

Phys. Rev. D 72, 054026 (2005)



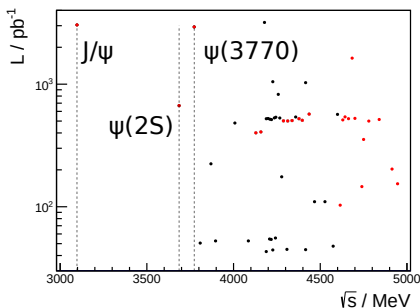
PDG 2020  $\psi$  States



Note: 2P mass predictions set by  $\chi_{c2}(2P)$  mass

- ▶  $\chi_{c1}(3872)$  (a.k.a.  $X(3872)$ ) has  $J^{PC} = 1^{++}$
- ▶ More  $\psi$  states than expected (a.k.a.  $Y$  states)
  - ▶  $Y$  states decay to hidden charm/charmonium-like final states
- ▶  $Z_c$  states are isovectors, clearly exotic nature

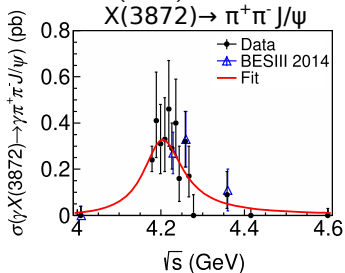
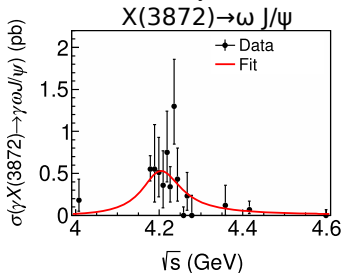
# Intro to the BESIII Experiment



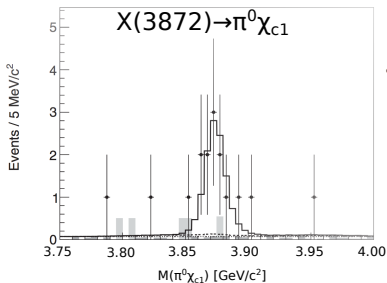
- ▶ Symmetric  $e^+e^-$  collisions between 2.0 and 5.0 GeV
- ▶ Excellent environment for XYZ physics
  - ▶ Directly produce  $1^{--}$  states like the  $Y(4230)$
  - ▶ Energy scans provide detailed cross sections
  - ▶ States are produced nearly at rest
  - ▶ Low backgrounds
  - ▶ Can reconstruct complicated decay modes of XYZ states

# Highlights of Past X(3872) Results at BESIII

Phys. Rev. Lett. 122, 232002 (2019)



Phys. Rev. Lett. 122, 202001 (2019)



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

$$\frac{B(X(3872) \rightarrow \omega J/\psi)}{B(X(3872) \rightarrow \rho^0 J/\psi)} = 1.6_{-0.3}^{+0.4} \pm 0.2$$

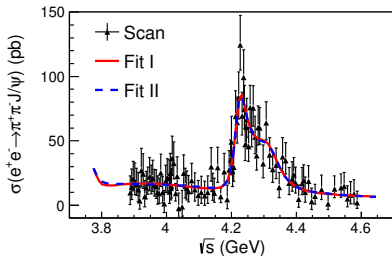
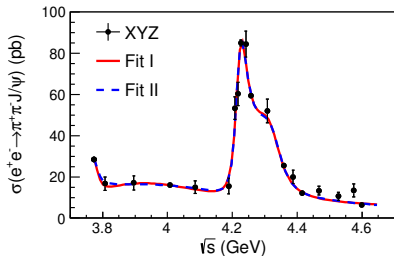
X(3872) is an isosinglet

$$\frac{B(X(3872) \rightarrow \pi^0 \chi_{c1})}{B(X(3872) \rightarrow \rho^0 J/\psi)} = 0.88_{-0.27}^{+0.33} \pm 0.10$$

Large isospin violation!

# Highlight of Past Y Results at BESIII

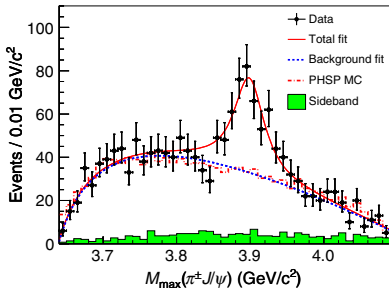
Phys. Rev. Lett. 118, 092001 (2017)



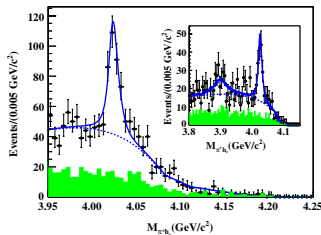
- ▶ Measure  $e^+e^- \rightarrow \pi^+\pi^- J/\psi$  cross section
- ▶ Find two resonances instead of single  $Y(4260)$ 
  - ▶  $m = (4222.0 \pm 3.1 \pm 1.4) \text{ MeV}/c^2$  and  $\Gamma = (44.1 \pm 4.3 \pm 2.0) \text{ MeV}$
  - ▶  $m = (4320.0 \pm 10.4 \pm 7.0) \text{ MeV}/c^2$  and  $\Gamma = (101.4^{+25.3}_{-19.7} \pm 10.2) \text{ MeV}$

# Highlights of Past Z Results at BESIII

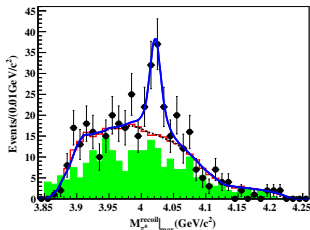
Phys. Rev. Lett. 110, 252001 (2013)



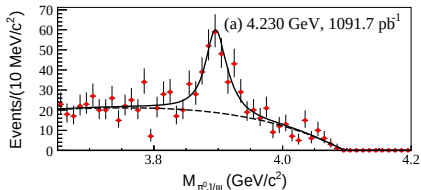
Phys. Rev. Lett. 111, 242001 (2013)



Phys. Rev. Lett. 113, 212002 (2014)



Phys. Rev. Lett. 115, 112003 (2015)



$Z_c(3900)$  in  $e^+e^- \rightarrow \pi\pi J/\psi$

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

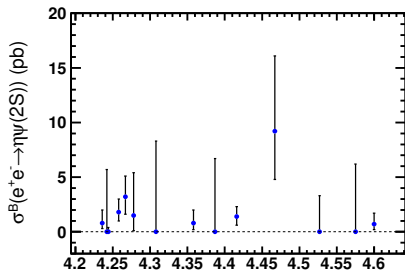
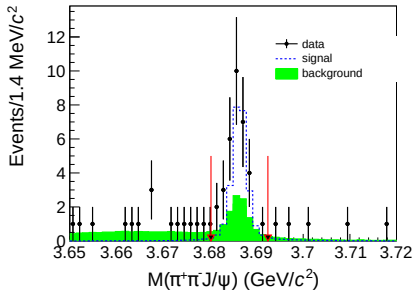
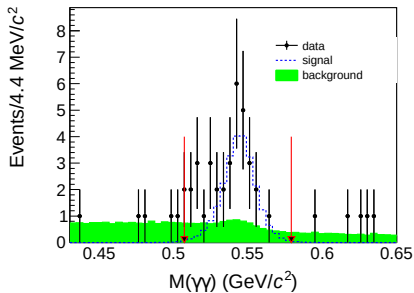
## Search for New $\Upsilon$ Decays



# Observation of $e^+e^- \rightarrow \eta\psi(2S)$

arXiv:2103.01480v2

Motivation: BESIII observes  $Y(4230)$  and  $Y(4390)$  in  $e^+e^- \rightarrow \eta J/\psi$

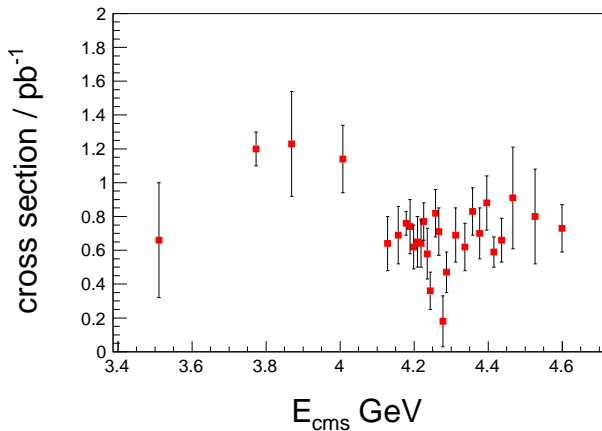


- ▶ Top row: sum of 14 energies
- ▶ Green is  $e^+e^- \rightarrow \gamma\gamma\psi(2S)$
- ▶ First observation
- ▶ Only statistical uncertainties
- ▶ Structure in  $\sigma$  unclear

# Observation of $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$

arXiv:2104.08754v2

- ▶ Motivation:  $[cs][\bar{c}\bar{s}]$  state predicted at  $4330 \pm 70 \text{ MeV}/c^2$
- ▶ If  $c\bar{c}$  annihilates, strange mesons/baryons produced
- ▶ Explains large  $f_0(980)$  in  $Y(4230) \rightarrow \pi^+\pi^- J/\psi$

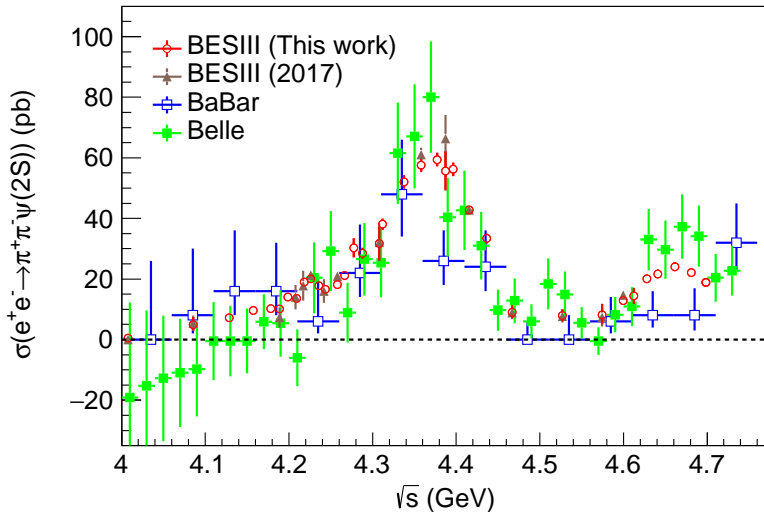


- ▶ First observation for  $3.51 < E_{\text{cm}} < 4.6 \text{ GeV}$

# Measurement of $\sigma(e^+e^- \rightarrow \pi^+\pi^-\psi(2S))$ arXiv:2107.09210

Motivation: High precision update of 2017 measurement

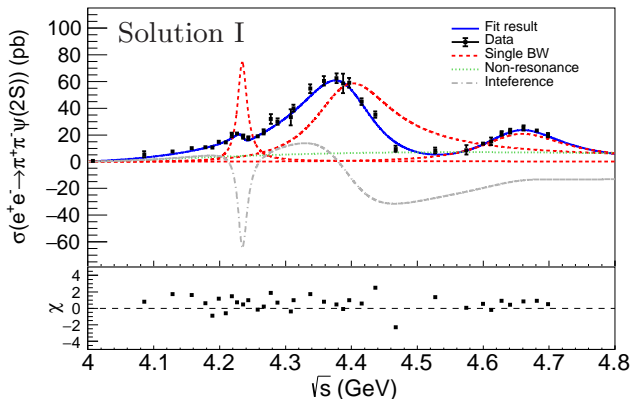
Previous result found significant  $Y(4230)$  and  $Y(4390)$



# Measurement of $\sigma(e^+e^- \rightarrow \pi^+\pi^-\psi(2S))$ arXiv:2107.09210

Motivation: High precision update of 2017 measurement

Previous result found significant  $Y(4230)$  and  $Y(4390)$



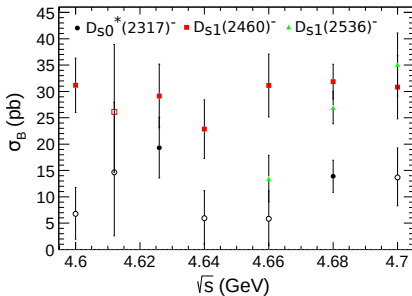
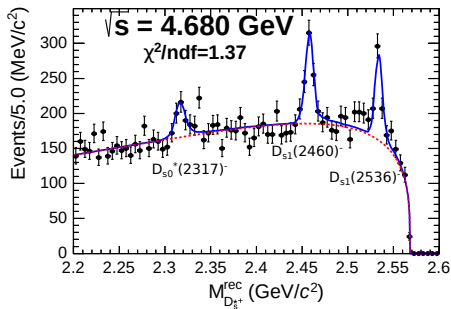
One of four fit solutions shown

Significant  $Y(4230)$  [ $4.0\sigma$ ],  $Y(4390)$  [ $16.1\sigma$ ],  $Y(4660)$  [ $8.1\sigma$ ]

First time observing  $Y(4660)$  at BESIII

# Measurement of $\sigma(e^+e^- \rightarrow D_s^{*+} D_{sJ}^-)$ 10.1103/PhysRevD.104.032012

Motivation:  $D_{s0}^*(2317)^+$  and  $D_{s1}(2460)^+$  masses below predictions  
Can search for  $Y$  states in measured cross sections



All three reactions have significant signal at  $\sqrt{s} = 4.68 \text{ GeV}$   
No structure observed

## Search for New Z Decays

$$e^+e^- \rightarrow \eta_c \pi^+ \pi^- \pi^0 \quad (1/2)$$

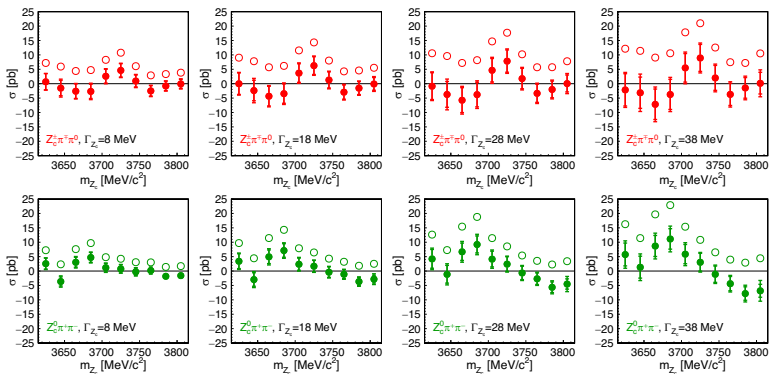
Motivation:  $Z_c$  masses near  $D\bar{D}^*$  and  $D^*\bar{D}$  thresholds

Could have new  $Z_c$  near  $D\bar{D}$  with  $J^P(D\bar{D}) = 0^+$

Hadrocharmonium predicts state near 3800 MeV

Diquark model also predicts  $J^P = 0^+$  states

10.1103/PhysRevD.103.032006

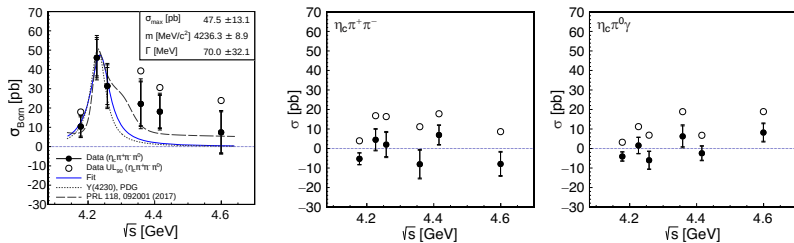


No evidence of  $Z_c$  states found

$$e^+e^- \rightarrow \eta_c(\pi^+\pi^-\pi^0)/(\pi^+\pi^-)/(\pi^0\gamma) \quad (2/2)$$

Motivation: Also can search for  $Y$  states in cross section

10.1103/PhysRevD.103.032006



Left is  $e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta_c$

Observed for first time

Cross section consistent with  $Y(4230)$  production

$\sigma(e^+e^- \rightarrow \pi^+\pi^-\eta_c)$  and  $\sigma(e^+e^- \rightarrow \gamma\pi^0\eta_c)$  consistent with zero



# Summary and Outlook

- ▶ BESIII is very active in XYZ searches
- ▶ More recent data from  $4.6 < E_{\text{cm}} < 4.95$  GeV
  - ▶ Recently observed  $Y(4660)$  for first time at BESIII
  - ▶ Recently observed  $Z_{cs}$  - see talk by Jingyi Zhao at 15:10
- ▶ Accelerator upgrade planned for 2024
  - ▶ Luminosity increase up to factor of 3 depending on energy
  - ▶ Energies up to 5.6 GeV
- ▶ More analyses are on the way

Thanks for your attention!

# Backup Slides

