

## $\Upsilon$ decays to charmonium at BESIII

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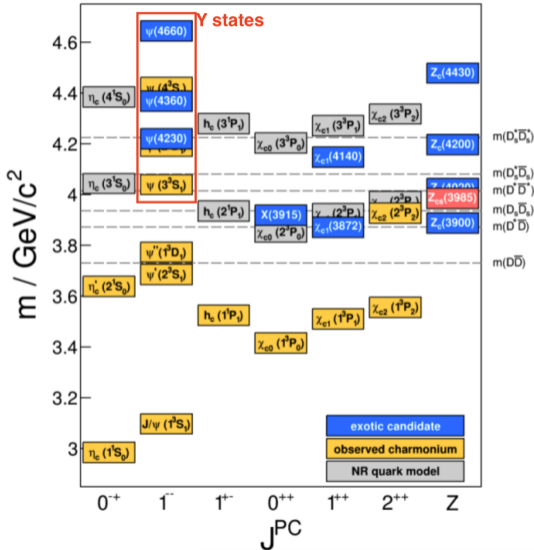
<sup>1</sup> Ruhr University Bochum, Germany

QWG 2022 at 26-30 September



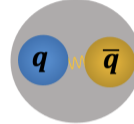
QWG 2022 - The 15th International  
Workshop on Heavy Quarkonium

# Conventional and Exotic Hadrons

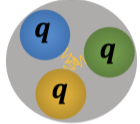


## Conventional hadrons

### Meson

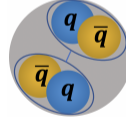


### Baryon

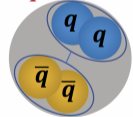


## Exotic hadrons

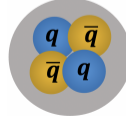
### Molecule



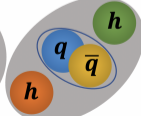
### Diquarkonium



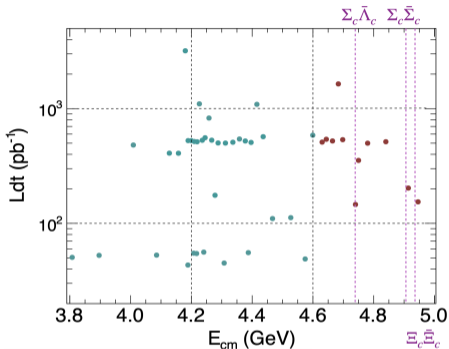
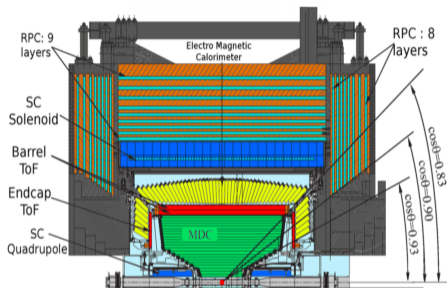
### Tetraquark



### Hadroquarkonium

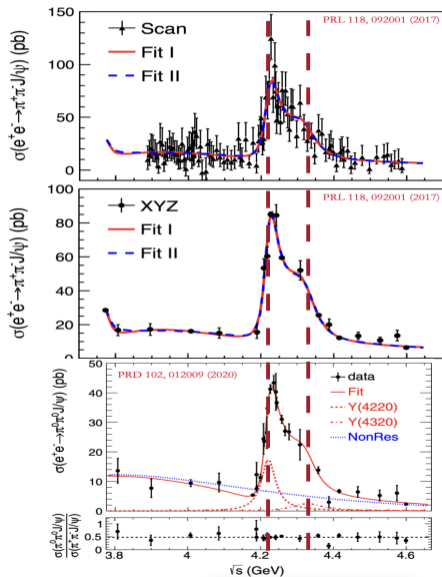


# BESIII Data



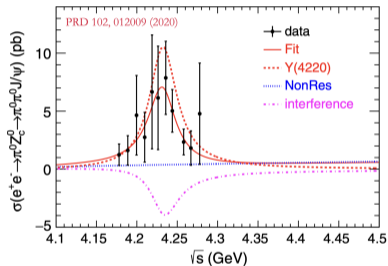
- ▶ BESIII collected data samples at  $\sqrt{s} \in (2.00, 4.95)$  GeV
- ▶ Able to measure the decay final states with high precision
- ▶ Largest scan data samples in the charmonium-like region
- ▶ Able to study  $Y$  states via cross sections

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



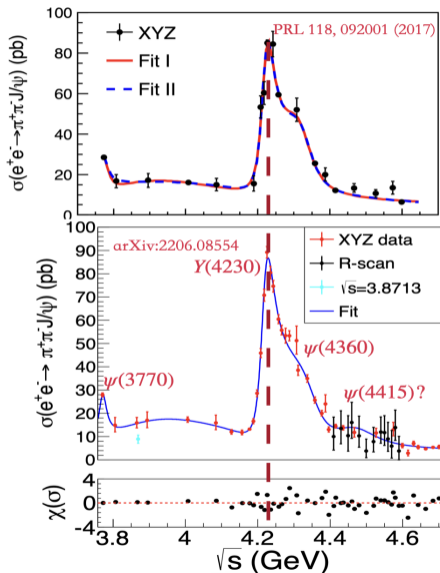
▶ Two resonances  $Y(4230)$  and  $Y(4360)$

▶ Intermediate states



▶ More detailed studies are ongoing with more data sets and new thresholds

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



► Revisit  $\pi^+\pi^- J/\psi$  study

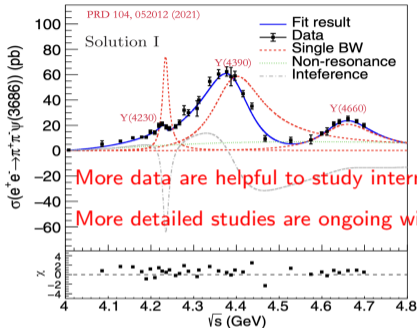
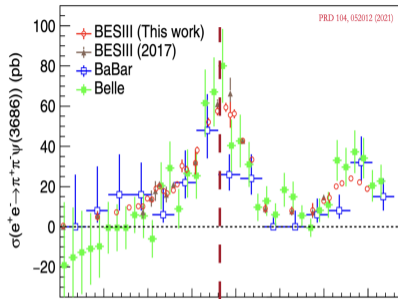
- ✓ More data sets
- ✓ More energy points
- ✓ New threshold

►  $Y(4230)$  and  $Y(4360)$  ( $> 10\sigma$  significance)

- ✓  $M(4230) = 4221.4 \pm 1.5 \pm 2.0$  MeV/ $c^2$
- ✓  $\Gamma = 41.8 \pm 2.9 \pm 2.7$  MeV
- ✓  $M(4360) = 4298 \pm 12 \pm 26$  MeV/ $c^2$
- ✓  $\Gamma(4360) = 127 \pm 17 \pm 10$  MeV

► A structure around 4.4 GeV ( $\sim 3\sigma$  significance)

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



Four solutions

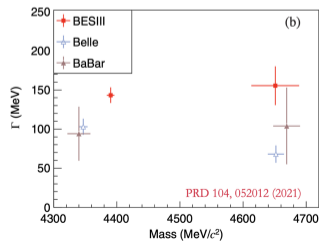
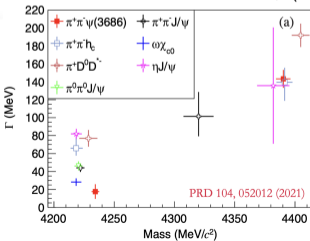
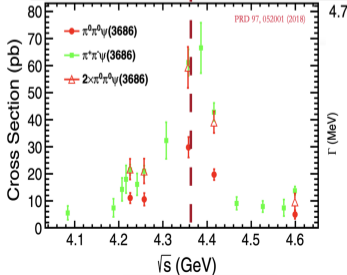
Narrow Y(4230)

Significant Y(4390)

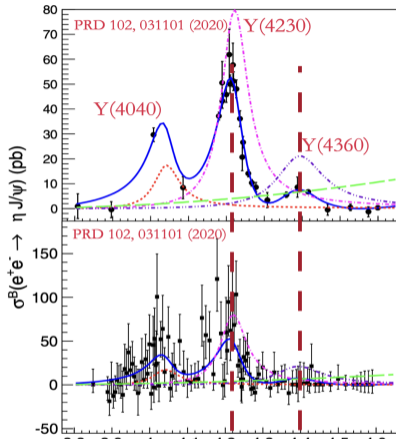
Significant Y(4660)

More data are helpful to study intermediate states

More detailed studies are ongoing with new thresholds

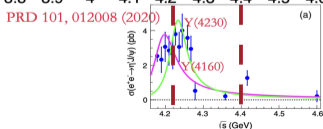
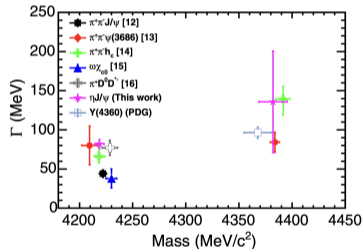


# $e^+e^- \rightarrow \eta J/\psi, \eta' J/\psi$



## ► $\eta J/\psi$

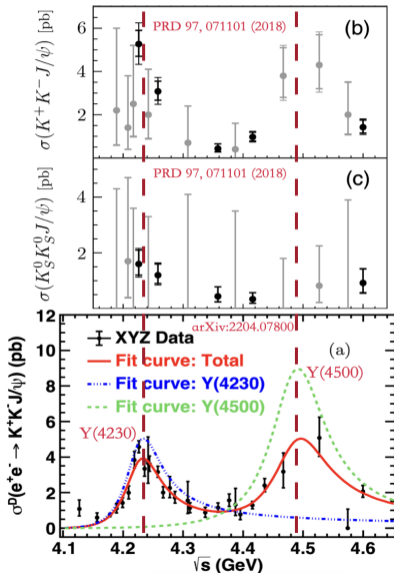
- ✓ Fixed Y(4040)
- ✓  $M(4230) = 4218.6 \pm 3.8 \pm 2.5 \text{ MeV}/c^2$   
 $\Gamma = 82.0 \pm 5.7 \pm 0.4 \text{ MeV}$
- ✓  $M(4360) = 4382.0 \pm 13.3 \pm 1.7 \text{ MeV}/c^2$   
 $\Gamma(4360) = 135.8 \pm 60.8 \pm 22.5 \text{ MeV}$



## ► $\eta' J/\psi$

- ✓ Can't describe by Y(4160) and Y(4230)
- ✓ Y(4360) exists? (Need more data and further analysis)

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



► Y(4230)

- ✓  $M = 4225.3 \pm 2.3 \pm 21.5 \text{ MeV}/c^2$
- ✓  $\Gamma = 72.9 \pm 6.1 \pm 30.8 \text{ MeV}$

► Claim a structure Y(4500)

- ✓ Statistical significance:  $> 8\sigma$
- ✓  $M = 4484.7 \pm 13.3 \pm 24.1 \text{ MeV}/c^2$
- ✓  $\Gamma = 111.1 \pm 30.1 \pm 15.2 \text{ MeV}$

Mass prediction

- \* Conventional  $c\bar{c}$ : 4489-4529 MeV
- \* Heavy-antiheavy hadronic molecule: 4483-4503 MeV
- \* Exotic  $c\bar{c}s\bar{s}$ : 4350-4550 MeV

**Waiting for theoretical interpretation for its nature**



# Summary and Outlook

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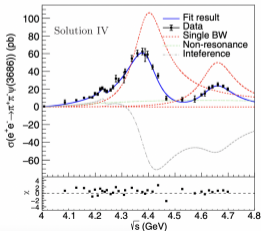
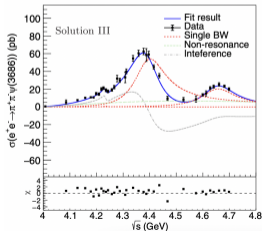
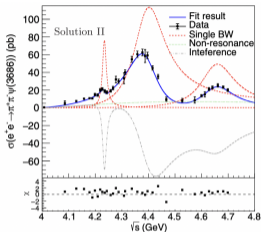
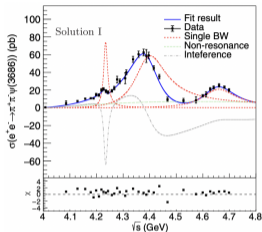
- ▶ BESIII has the largest scan data samples in the charmonium(-like) region, which support us study exotic states with higher precision
- ▶ Some new vectors are found (waiting for theoretical interpretation)
  - ✓  $Y(4500)$  in the  $e^+e^- \rightarrow K^+K^- J/\psi$
- ▶ BESIII plans to operate for up to 10 more years,
  - ✓ Increase center of mass energy up to 5.6 GeV (access new thresholds)
  - ✓ Increase luminosity by a factor of 3 (better statistics)
- ▶ Several analyses were introduced briefly in this report, and more analyses are ongoing.

**Thanks for your attention**

**BACKUP**

# $e^+e^- \rightarrow \pi^+\pi^-\psi(3686)$ at $\sqrt{s} \in [4.008, 4.700]$ GeV

[PRD 104 (2021) 5, 052012]



Y(4230)

- ✓  $M = 4234.4 \pm 3.2 \pm 0.2 \text{ MeV}/c^2$
- ✓  $\Gamma = 17.6 \pm 8.1 \pm 0.9 \text{ MeV}$

Y(4390)

- ✓  $M = 4390.3 \pm 6.0 \pm 0.7 \text{ MeV}/c^2$
- ✓  $\Gamma = 143.3 \pm 10.0 \pm 0.5 \text{ MeV}$

Y(4660)

- ✓  $M = 4651.0 \pm 37.8 \pm 2.1 \text{ MeV}/c^2$
- ✓  $\Gamma = 155.4 \pm 24.8 \pm 0.8 \text{ MeV}$