



Recent exotic results at BESIII

Chengping Shen

Beihang University

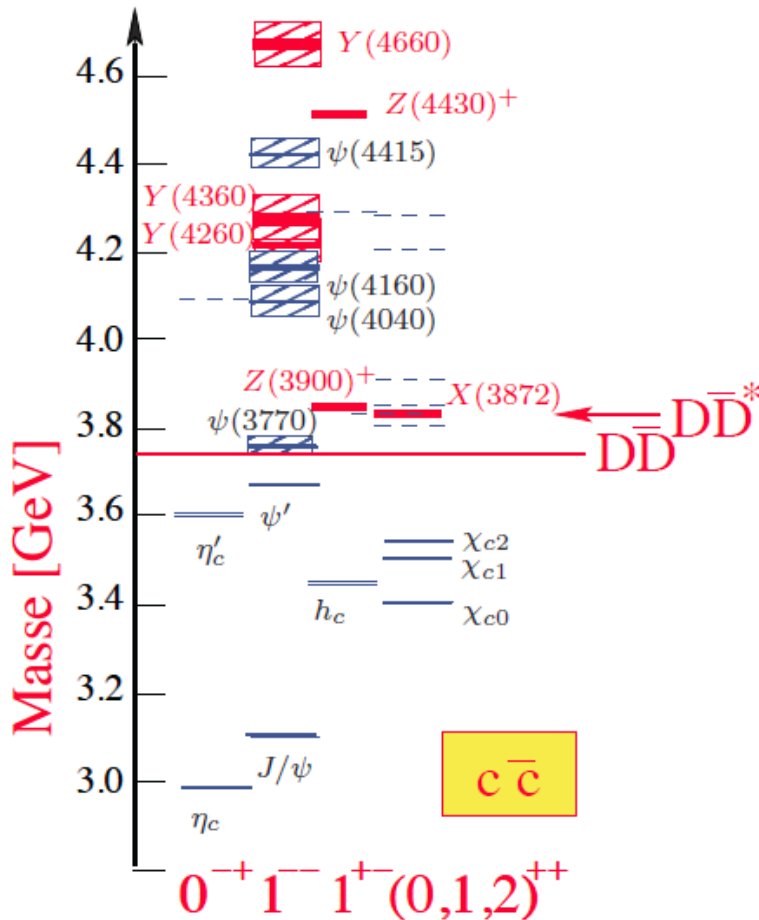
YITP, Koyto 2016.11.28



Charmonium after 2002

A new particle Zoo!

only established states shown



Quark-Model: Eichten et al. PRD 17 (1978)

→ missing low lying states found

→ Above the $\bar{D}D$ threshold:

- ▷ Many new states
- ▷ incompatible with quark model in mass and properties

What are they?



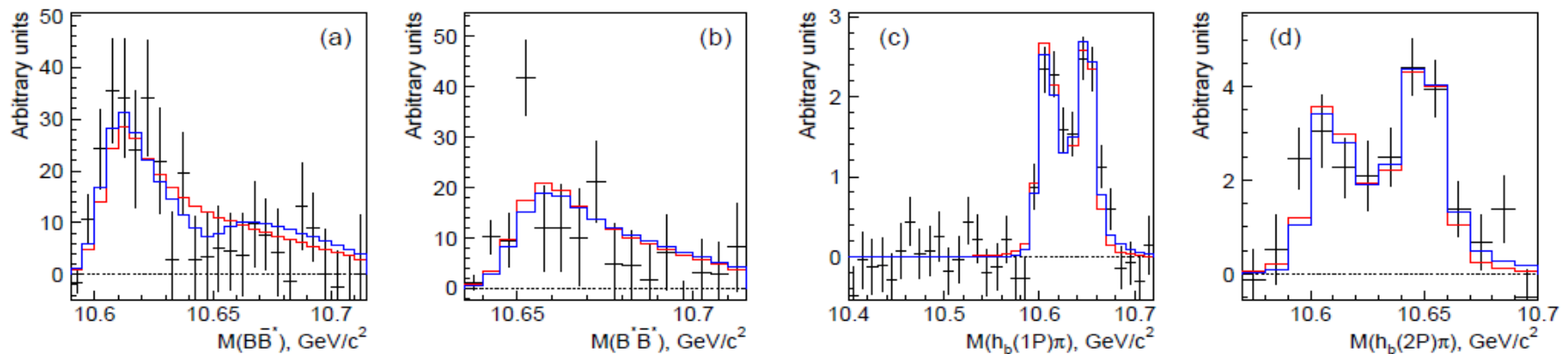
Charged states

2011: Discovery of charged states that

- have masses in the quarkonium regime;
- decay with \bar{Q} and Q in the final state

→ must contain at least 4 quarks

E.g. $Z_b(10610)^+$ and $Z_b(10650)^+$ in $e^+e^- \rightarrow \pi\pi(\bar{Q}Q)$ at $\Upsilon(5S)$

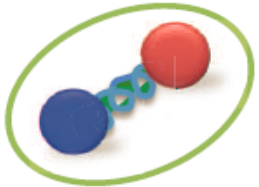


Data by Belle: A. Garmash *et al.*, arXiv:1512.07419 & A. Bondar *et al.*, PRL 108(2012)122001

Fit: F.-K. Guo *et al.*, PRD 93 (2016) no.7, 074031

more of the kind: $Z_c(3900)^+$, $Z_c(4020)^+$, $Z_c(4430)^+$, ...

Proposal



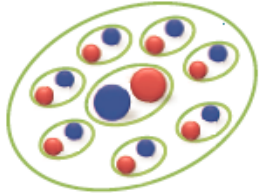
Hybrid

→ Compact with active gluons and $\bar{Q}Q$



Tetraquark

→ Compact object formed from (Qq) and $(\bar{Q}\bar{q})$



Hadro-Quarkonium

→ Compact $(\bar{Q}Q)$ surrounded by light quarks



Hadronic-Molecule

→ **Extended** object made of $(\bar{Q}q)$ and $(Q\bar{q})$

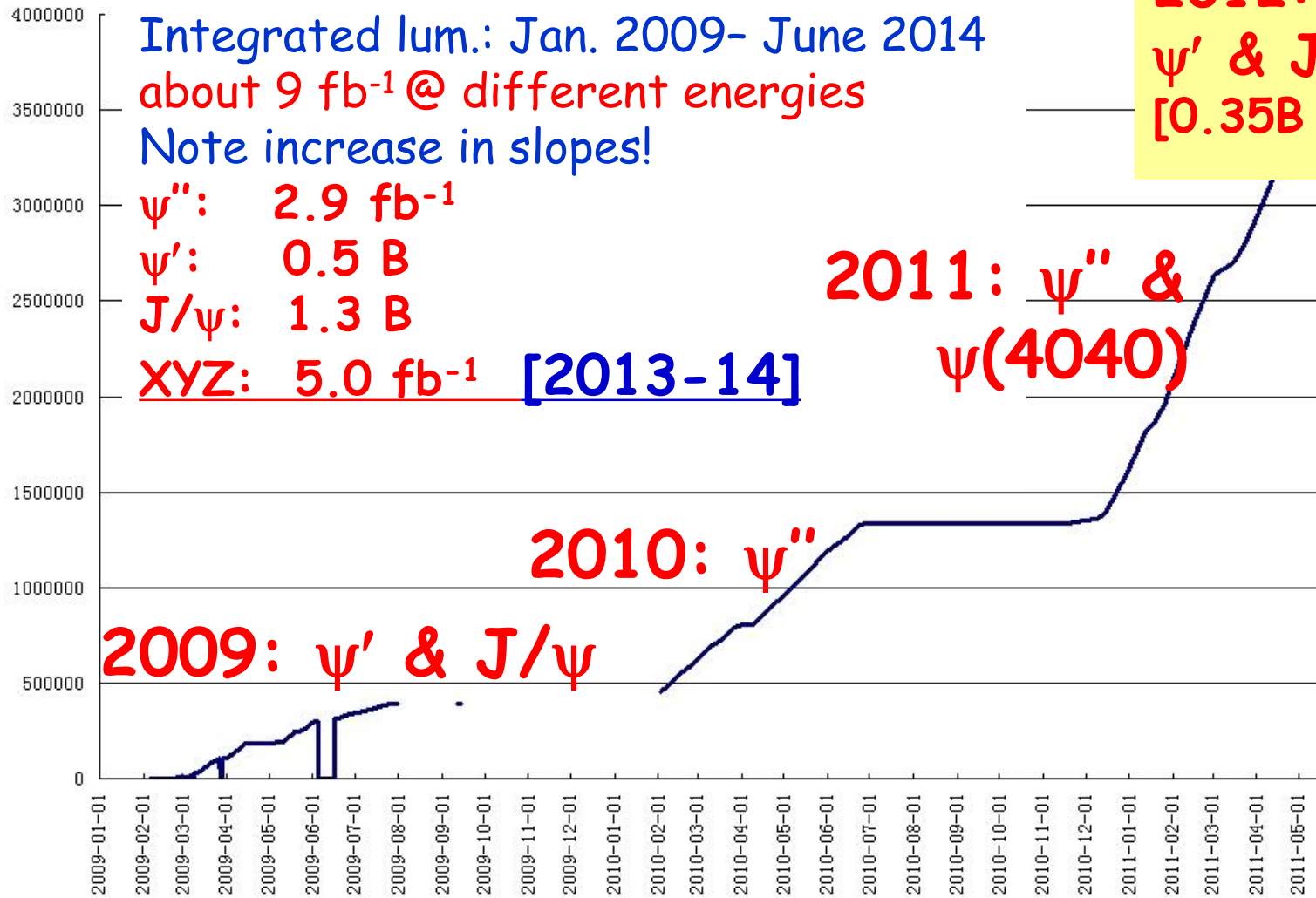
Certainly not simply a **perturbative threshold effect**

Guo et al., PRD91(2015)051504

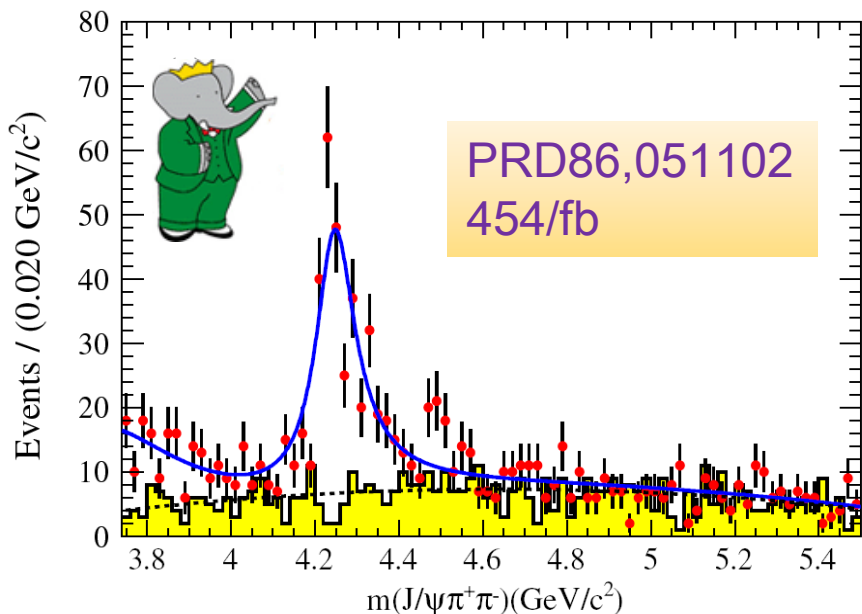
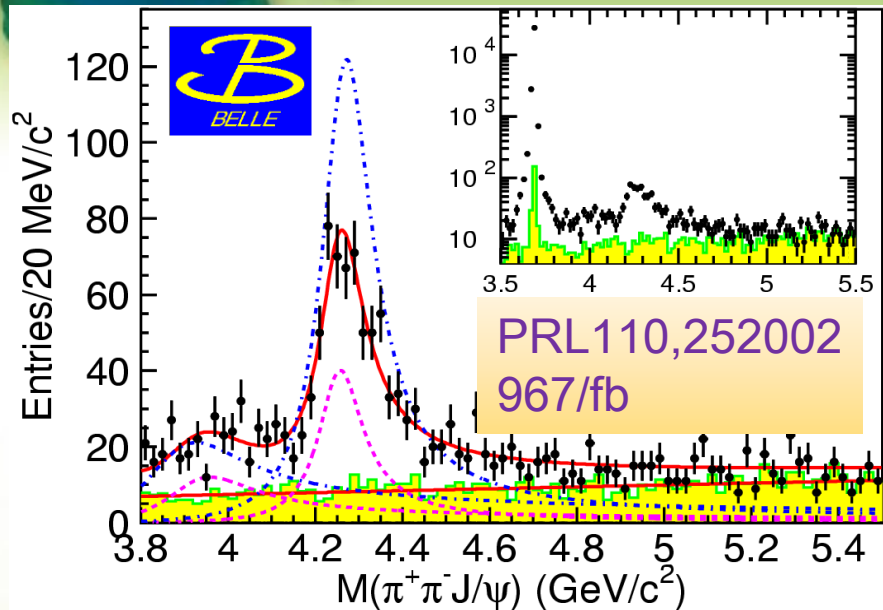
Lattice studies mostly exploratory - but progress expected soon

BESIII data samples

Note that luminosity is lower at J/ψ ,
and machine is optimal near ψ'' peak



The Y states



e^+e^- collisions near $Y(4S)$

in ISR production

$$e^+e^- \rightarrow \gamma_{\text{ISR}} J/\psi \pi^+ \pi^-$$

$$\Rightarrow J^{PC} = 1^{--}$$

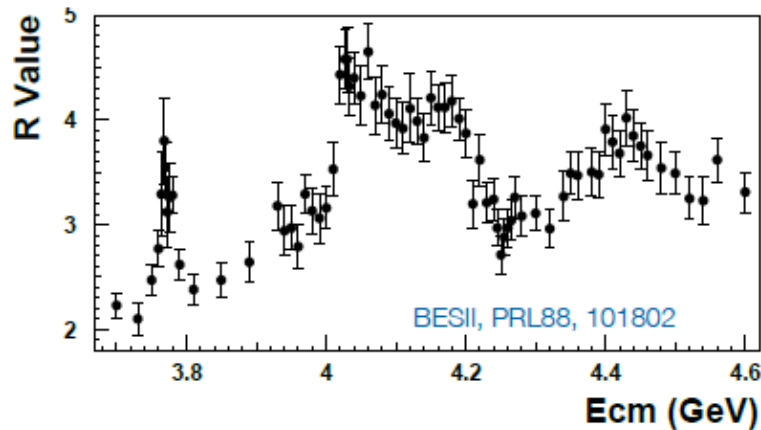
... $Y(4008) \rightarrow J/\psi \pi^+ \pi^-?$

... $Y(4260) \rightarrow J/\psi \pi^+ \pi^-$

... $Y(4360) \rightarrow \psi(2S) \pi^+ \pi^-$

... $Y(4630) \rightarrow \psi(2S) \pi^+ \pi^-$

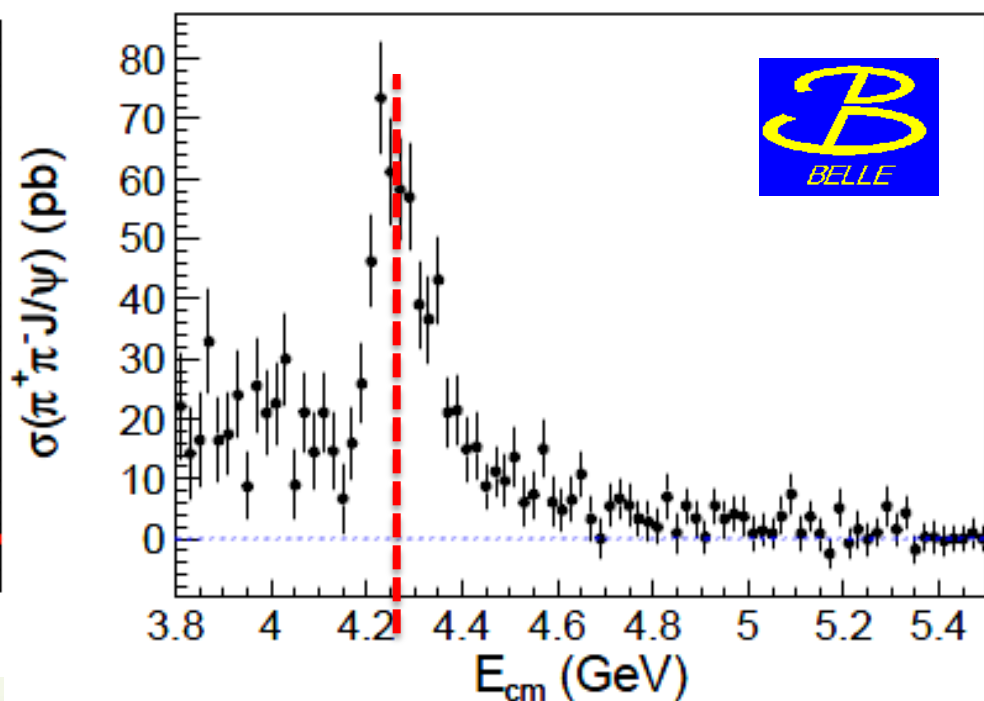
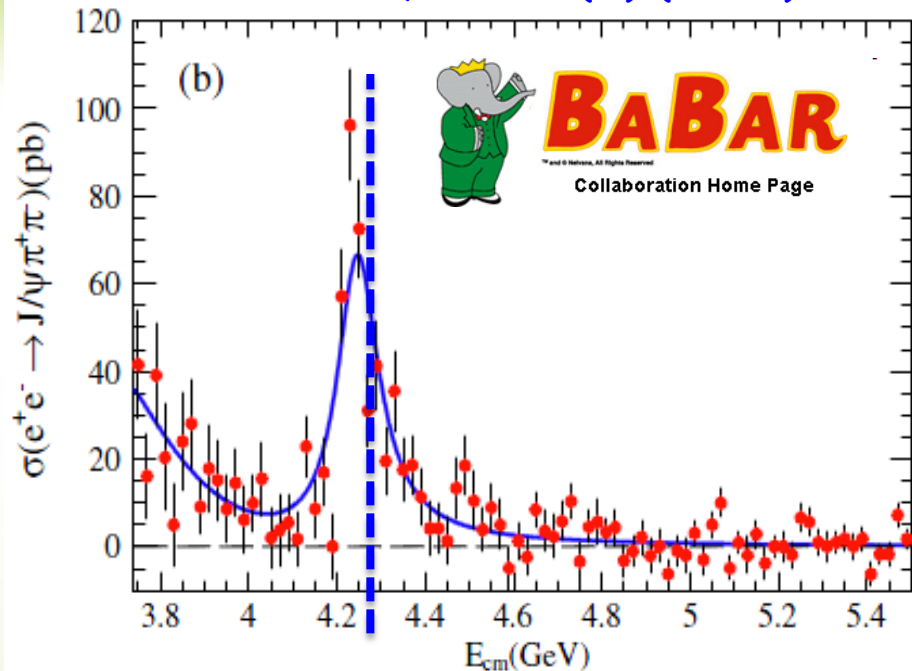
... $Y(4660) \rightarrow \Lambda_c^+ \bar{\Lambda}_c^-$



$\Upsilon(4260)$ point at BESIII

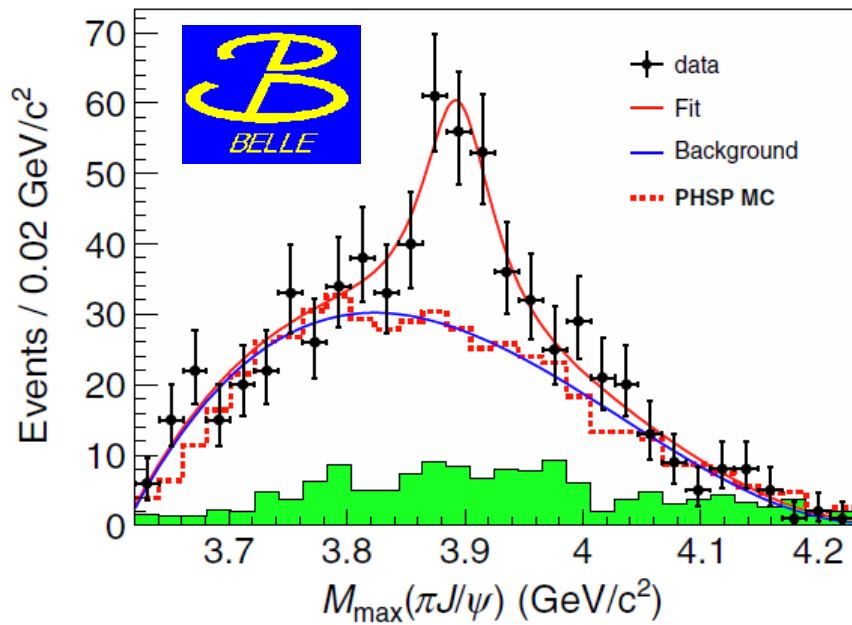
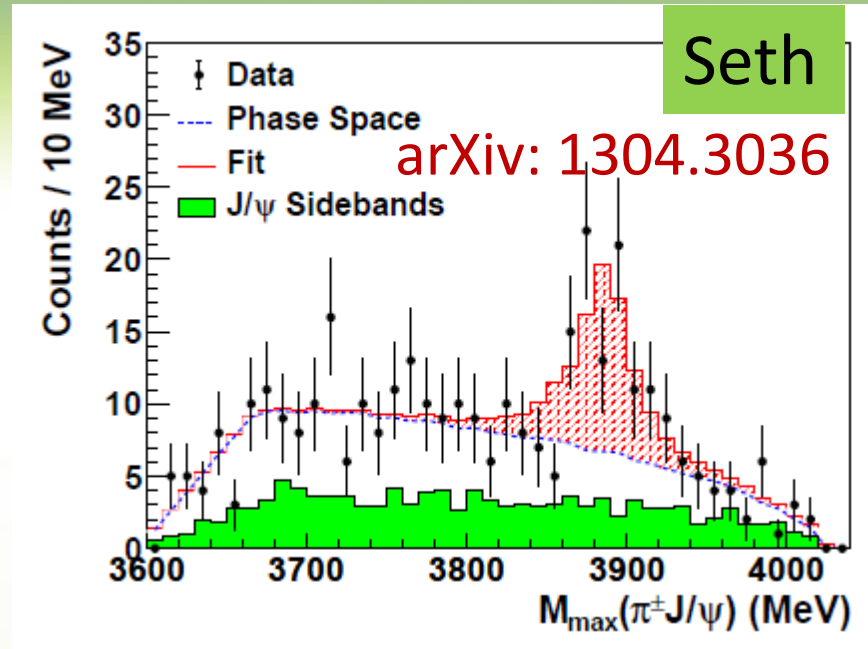
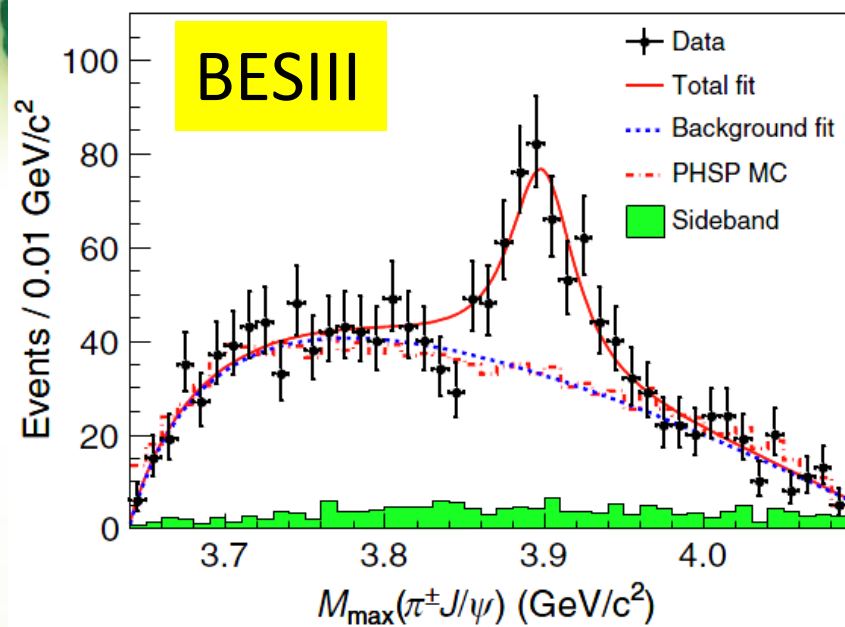
PRD **86**,051102(R) (2012).

PRL **110**,252002 (2013).



1. Dec, 2012 to Jan, 2013, BESIII accumulate 525 pb^{-1} data @ 4.26 GeV.
2. Peak position of $\Upsilon(4260) \rightarrow \pi^+\pi^-J/\psi$ cross section.
3. $N(\mu^+\mu^-) = 882 \pm 33$; $N(e^+e^-) = 595 \pm 28$; purity $\sim 90\%$.
4. Born cross section: $\sigma^B = (62.9 \pm 1.9 \pm 3.7) \text{ pb}$ at BESIII. PRL **110**, 251002
5. Good agreement with Belle and BaBar.

BESIII + Belle + CLEO's data



HEP

找到 1 笔记录

1. Observation of a Charged Charmoniumlike Structure

BESIII Collaboration (M. Ablikim (Beijing, Inst. High Energy Phys.) *et al.*).

Published in *Phys.Rev.Lett.* **110** (2013) 252001

DOI: [10.1103/PhysRevLett.110.252001](https://doi.org/10.1103/PhysRevLett.110.252001)

e-Print: [arXiv:1303.5949](https://arxiv.org/abs/1303.5949) [hep-ex] | [PDF](#)

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[ADS Abstract Service](#); [Interactions.org article](#); [Link to WIRED](#); [phys](#)

详细记录 - [Cited by 421 records](#) 250+



The nature of $Z_c(3900)$?

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...

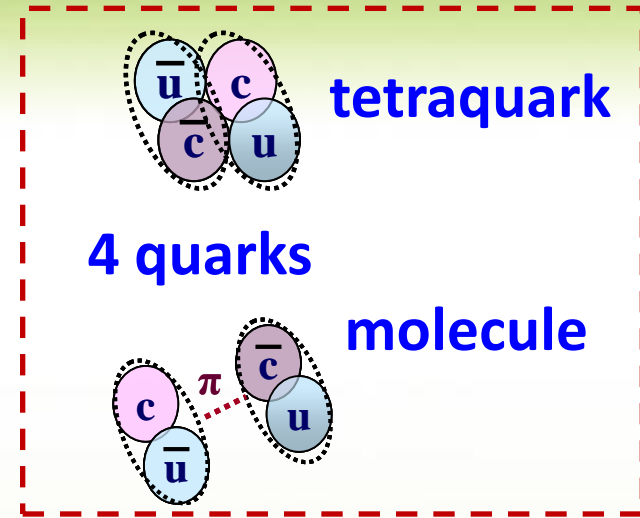
4. Meson loop

- arXiv:1303.6355
- arXiv:1304.4458...

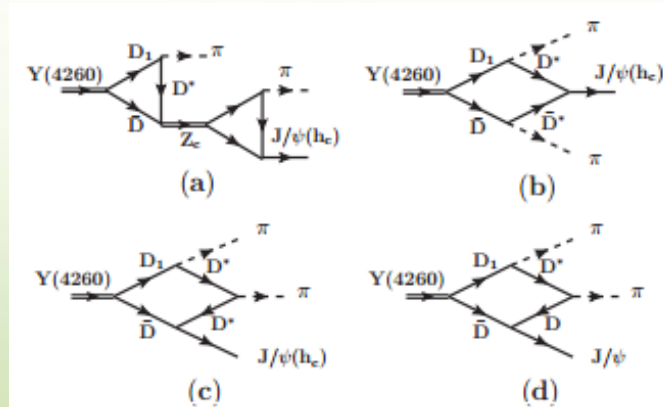
5. ISPE model

- arXiv:1303.6842...

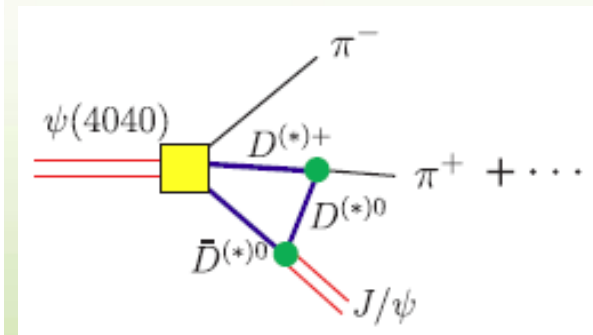
6. ...



Exotic!



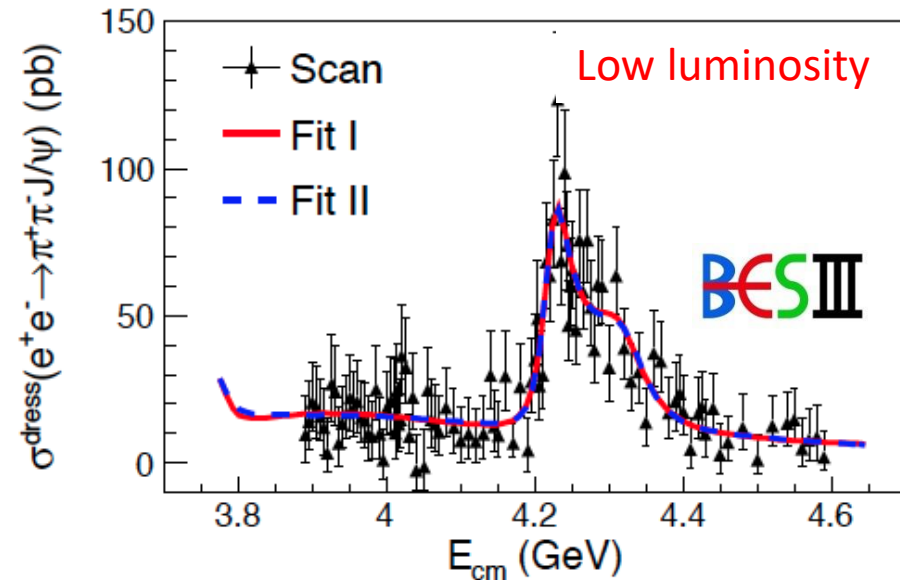
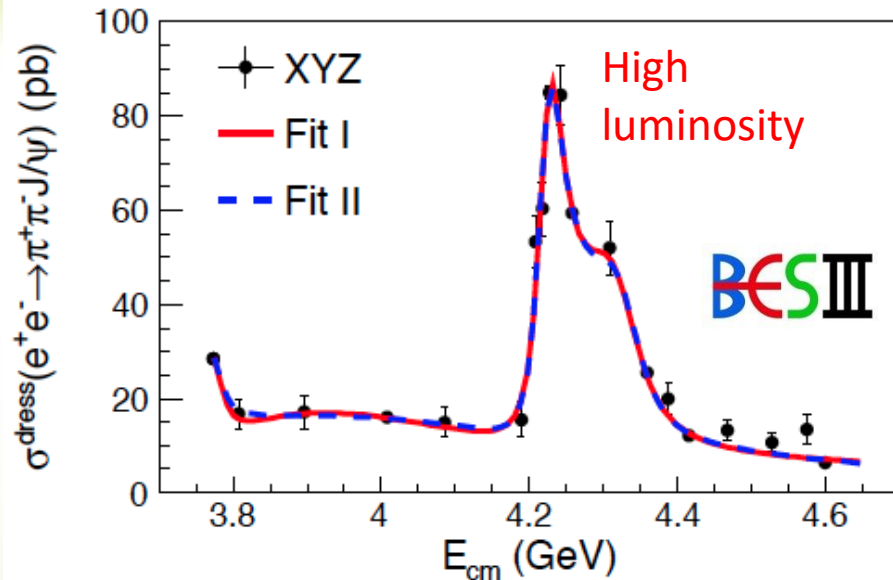
Meson loop



ISPE model

Precise cross section measurement of $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ at BESIII

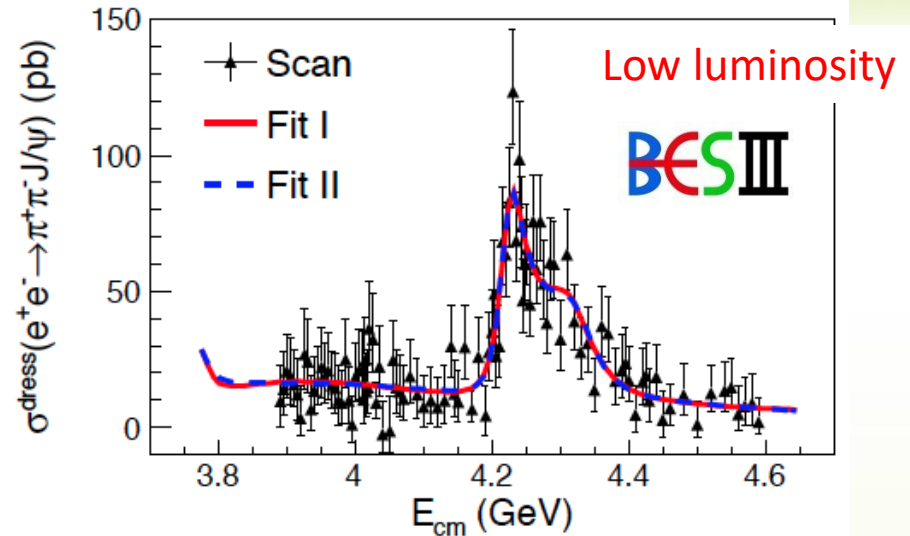
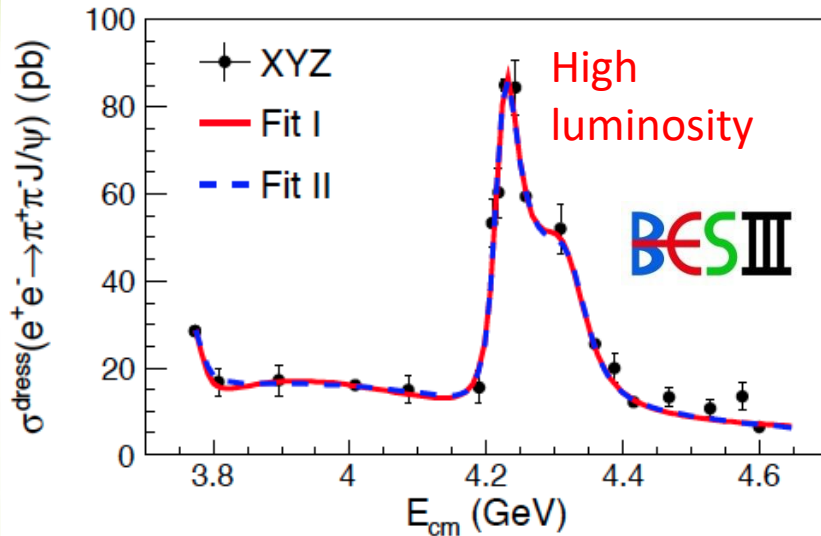
arXiv:1611.01317



- The $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ was measured with improved precision with BESIII data.
- Fit with three coherent BW resonances (Fit I); or coherent sum of an exponential and two BW resonances (Fit II).
- The 1st resonance R1 is similar to $Y(4008)$ by Belle, however can not be confirmed.
- The 2nd resonance R2 is similar to $Y(4260)$, but with lower mass & width.
- The 3rd resonance R3 have a significance $> 7.7\sigma$, nature unclear.

Precise cross section measurement of $e^+e^- \rightarrow \pi^+\pi^- J/\psi$ at BESIII

arXiv:1611.01317



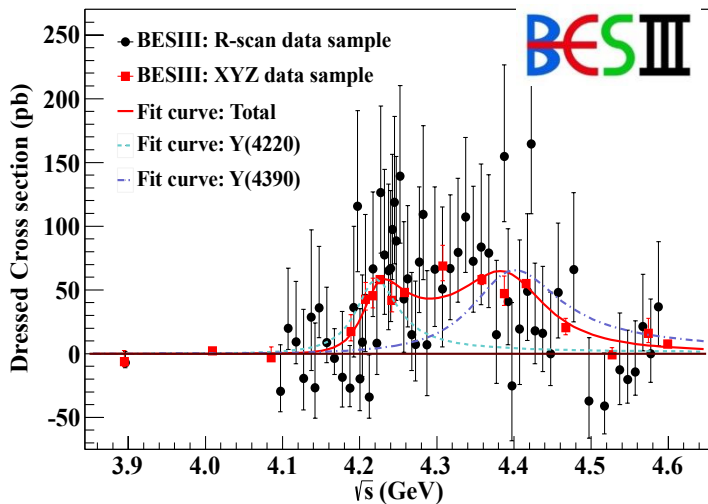
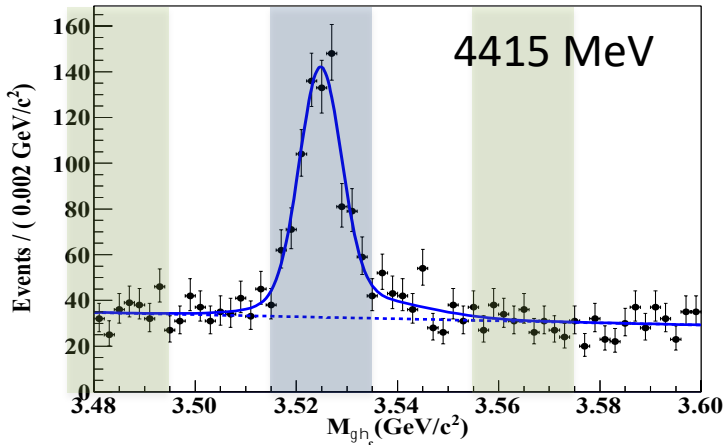
Parameter	Fit 1 / MeV	Fit 2 / MeV
$M(R_1)$	$3812.6^{+61.9}_{-96.6}$...
$\Gamma_{\text{tot}}(R_1)$	$476.9^{+78.4}_{-64.8}$...
$M(R_2)$	4222.0 ± 3.1	4220.9 ± 2.9
$\Gamma_{\text{tot}}(R_2)$	44.1 ± 4.3	44.1 ± 3.8
$M(R_3)$	4320.0 ± 10.4	4326.8 ± 10.0
$\Gamma_{\text{tot}}(R_3)$	$101.4^{+25.3}_{-19.7}$	$98.2^{+25.4}_{-19.6}$

stat. errors only

- Lineshape more complicated than just a single resonance / structure
- $Y(4008)$ not needed to describe data
- Significances for R_2 and $R_3 > 7\sigma$
- $Y(4360) \rightarrow J/\psi \pi^+ \pi^-$ seen?

Cross section measurement of $e^+e^- \rightarrow \pi^+\pi^-h_c$

arXiv:1610.07044



17 energy points from 3896 MeV to 4600 MeV ,total luminosity 5.26 fb^{-1} and 62 energy points from 4097 MeV to 4587 MeV, total luminosity: 0.51 fb^{-1}

- Decay channel: $\eta_c \rightarrow X_i$

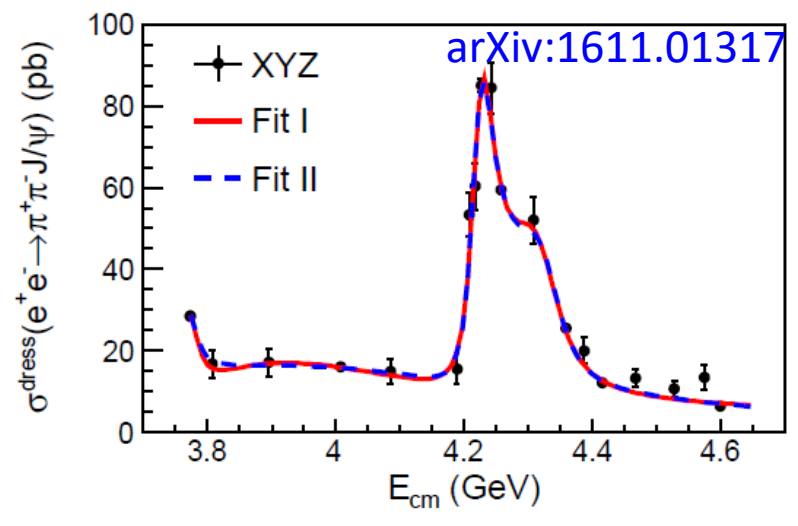
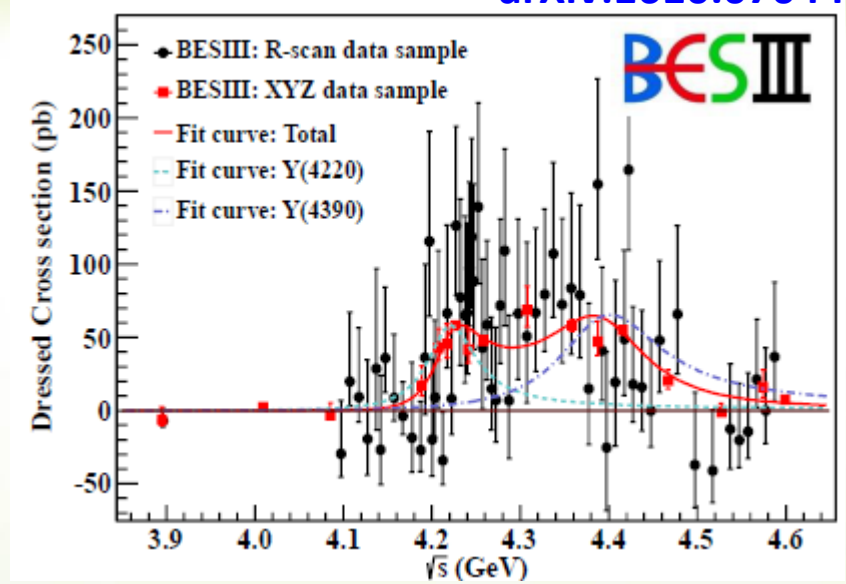
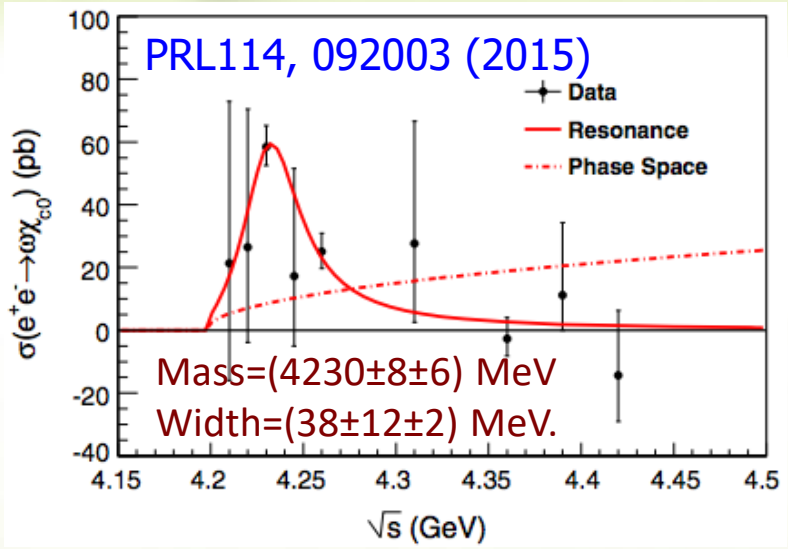
$X_i = \{pp\text{-bar}, \pi^+\pi^-K^+K^-, \pi^+\pi^-pp\text{-bar}, 2(K^+K^-), 2(\pi^+\pi^-), 3(\pi^+\pi^-), 2(\pi^+\pi^-)K^+K^-, K_S^0K^+\pi^- + \text{c.c.}, K_S^0K^+\pi^-\pi^+\pi^- + \text{c.c.}, K^+K^-\pi^0, pp\text{-bar}\pi^0, K^+K^-\eta, \pi^+\pi^-\eta, \pi^+\pi^-\pi^0\pi^0, 2(\pi^+\pi^-)\eta, 2(\pi^+\pi^-\pi^0)\}$

	M (MeV)	Γ_{tot} (MeV)	$\Gamma_{ee} \cdot \text{Br}$ (eV)	ϕ (rad)
Y(4220)	$4218.4 \pm 4.0 \pm 0.9$	$66.0 \pm 9.0 \pm 0.4$	$4.6 \pm 4.1 \pm 0.8$	--
Y(4390)	$4391.6 \pm 6.3 \pm 1.0$	$139.5 \pm 16.1 \pm 0.6$	$11.8 \pm 9.7 \pm 1.9$	$3.1 \pm 1.5 \pm 0.2$



“Y(4260)” in different channels?

arXiv:1610.07044



- In $\pi\pi J/\psi$, cross section peaks at lower than 4.26 GeV
- Possibly a narrow structure in $\omega\chi_{c0}$
 - simultaneous fit to all the modes?
 - Better model to parametrize the line shapes?



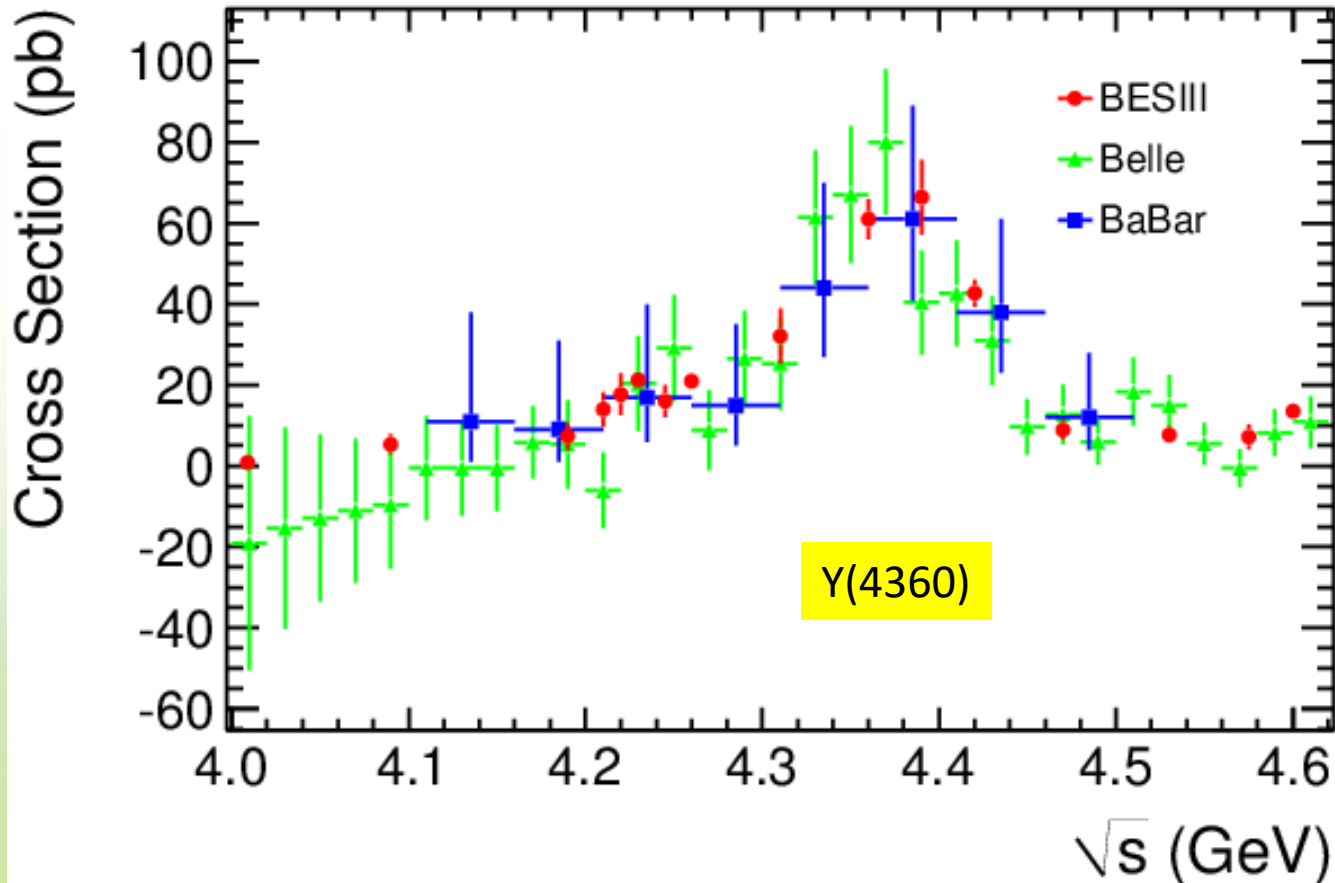
Comparison of $e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$ cross section

BESIII (16 energy points; $L_{\text{tot}}=5.1\text{fb}^{-1}$)

$\psi(2S)$ Reconstructed modes:

Mode I: $\Psi(3686) \rightarrow \pi^+\pi^-J/\psi$, $J/\psi \rightarrow l^+l^-$ ($l=e/\mu$)

Mode II: $\Psi(3686) \rightarrow \text{neutrals}+J/\psi$, $\text{neutrals}=(\pi^0\pi^0, \pi^0, \eta \text{ and } \gamma\gamma)$ $J/\psi \rightarrow l^+l^-$ ($l=e/\mu$)





Summary

- BESIII recently updated $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ cross sections. The peaking position of $Y(4260)$ shifts to lower mass obviously. More complicated structures are observed.
- BESIII recently updated $e^+e^- \rightarrow \pi^+\pi^-hc$ cross sections. Two structures, $Y(4220)$ and $Y(4390)$, were observed.
- BESIII recently updated $e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$ cross sections which are consistent with Belle results with improved precision.