Recent searches for Exotic Charmonium-like States at BESIII

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20th Lomonosov Conference on Elementary Particle Physics
19 - 25, Aug. 2021

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Outline

Introduction

Search for X(3872)

- $e^+e^- \to X(3872)\gamma$
- $e^+e^- \to \pi^0 X(3872)\gamma$

Search for Z states

- $e^+e^- \to \chi_{cJ}\pi^+\pi^-$
- $e^+e^- \to \eta_c\pi^+\pi^-\pi^0, \eta_c\pi^+\pi^-$, and $\eta_c\pi^0\gamma$
- $e^+e^- \to \eta_c\eta\pi^+\pi^-$
- $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

Search for Y states

Charmonium + light hadrons:

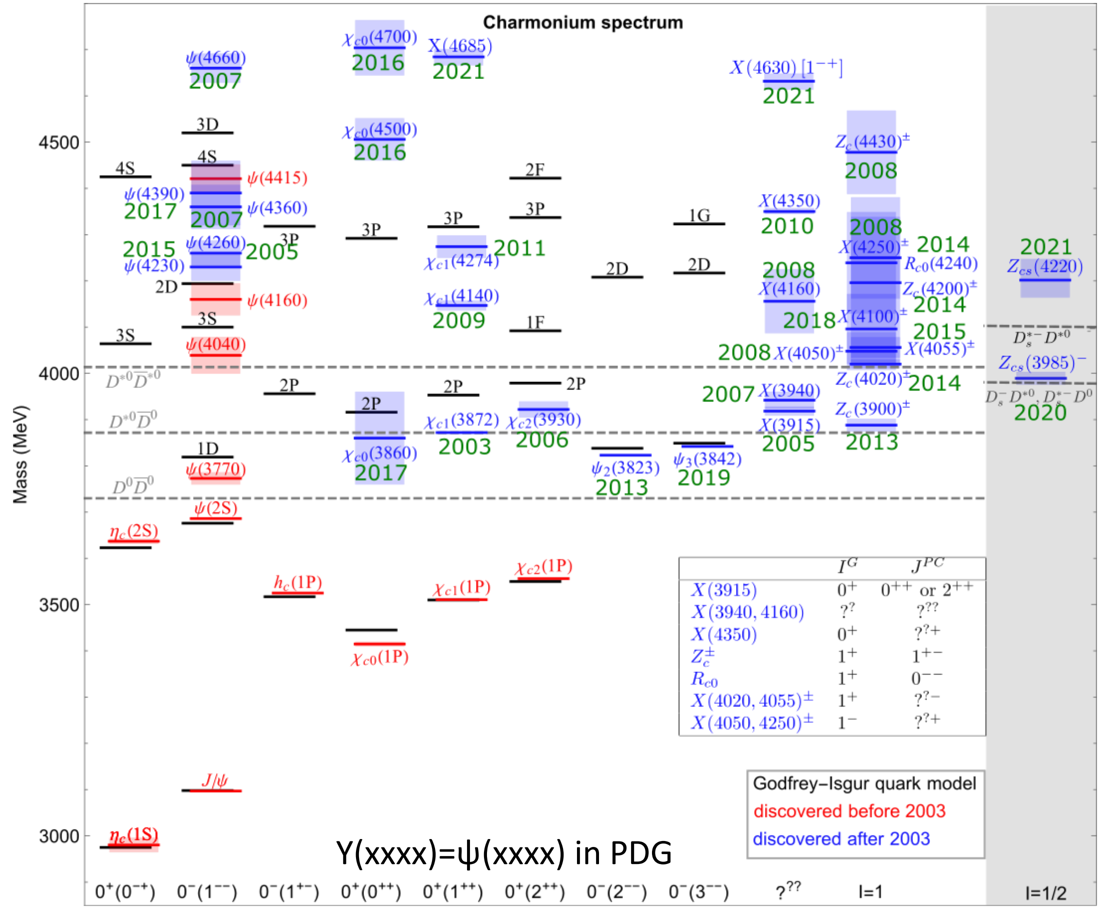
- $e^+e^- \to \pi^0\pi^0 J/\psi$
- $e^+e^- \to \eta J/\psi$
- $e^+e^- \to \eta\psi(2S)$
- $e^+e^- \to \pi^+\pi^-\psi(2S)$

Charmonium + γ :

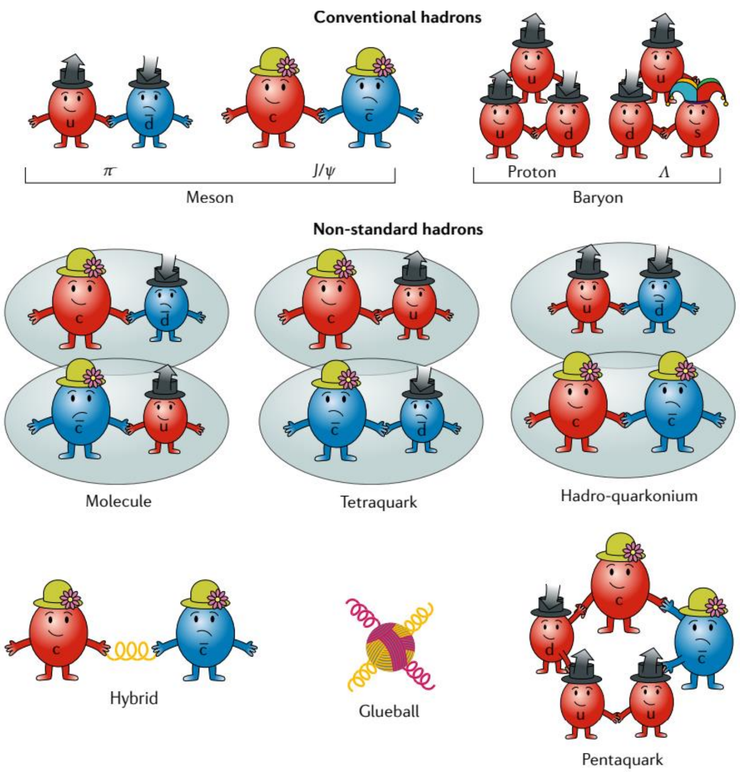
- $e^+e^- \to \gamma\chi_{c0,c1,c2}$

Summary

Charmonium-like States



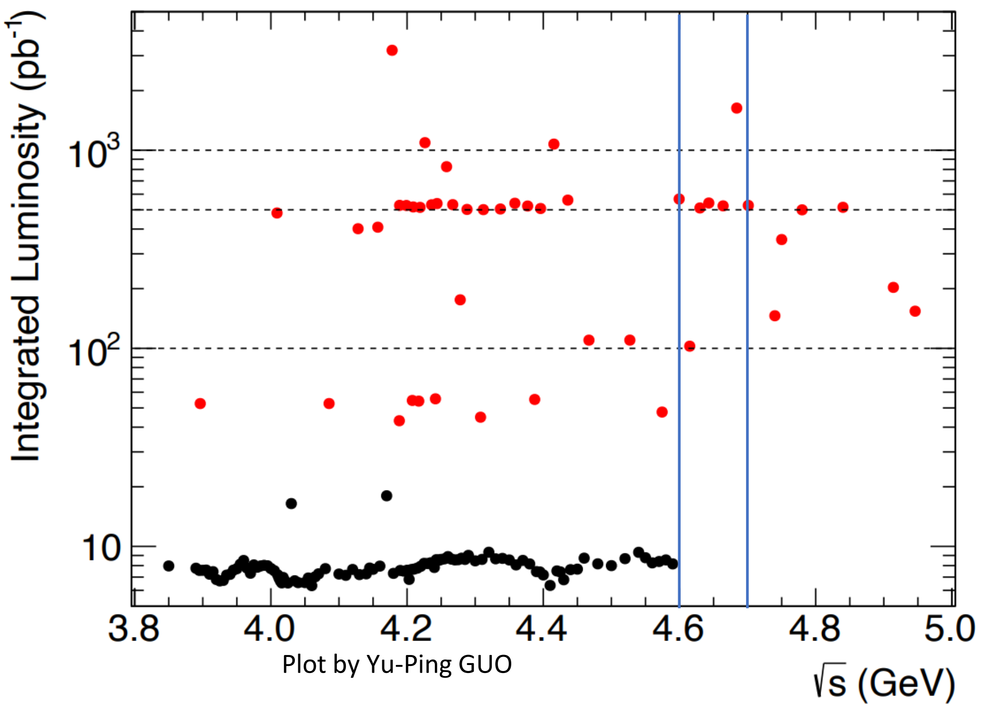
Plot from F. K. Guo on 7th XYZ meeting



Plot from C. Z Yuan and S. L. Olsen

- ✓ Many Exotic Charmonium-like(XYZ) states have been discovered in the quarkonium spectrum.
- ✓ The XYZ states show properties inconsistent with expectations from established quark models

BESIII Data for XYZ study



Plot by Yu-Ping GUO

XYZ:

- $\sqrt{s} > 3.8$ GeV : 22 fb^{-1}
- $3.8 < \sqrt{s} \leq 4.6$ GeV: 16 fb^{-1}
- $4.6 < \sqrt{s} \leq 4.7$ GeV: 3.8 fb^{-1}
- $\sqrt{s} > 4.7$ GeV: 1.9 fb^{-1}

R scan:

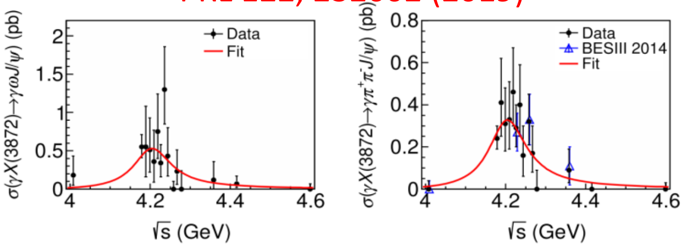
- 105 energy point
- 7~9 fb^{-1} each energy
- $3.8 < \sqrt{s} < 4.6$ GeV

Study of $X(3872) \to D^{*0}\bar{D}^0$+c.c. and γD^+D^- in $e^+e^- \to \gamma X(3872)$

PRL 124, 242001 (2020)

- The study of $e^+e^- \to \gamma X(3872)$ by BESIII support hadronic molecule interpretation for the $X(3872)$ resonance

PRL 122, 232002 (2019)



- $D^{*0} \to \gamma D^0$ and $\pi^0 D^0$
- $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^0$, and $K^-\pi^+\pi^+\pi^-$
- $D^+ \to K^-\pi^+\pi^+$ and $K^-\pi^+\pi^+\pi^0$

$4.178 \le \sqrt{s} \le 4.278$ GeV (9.0 fb^{-1})

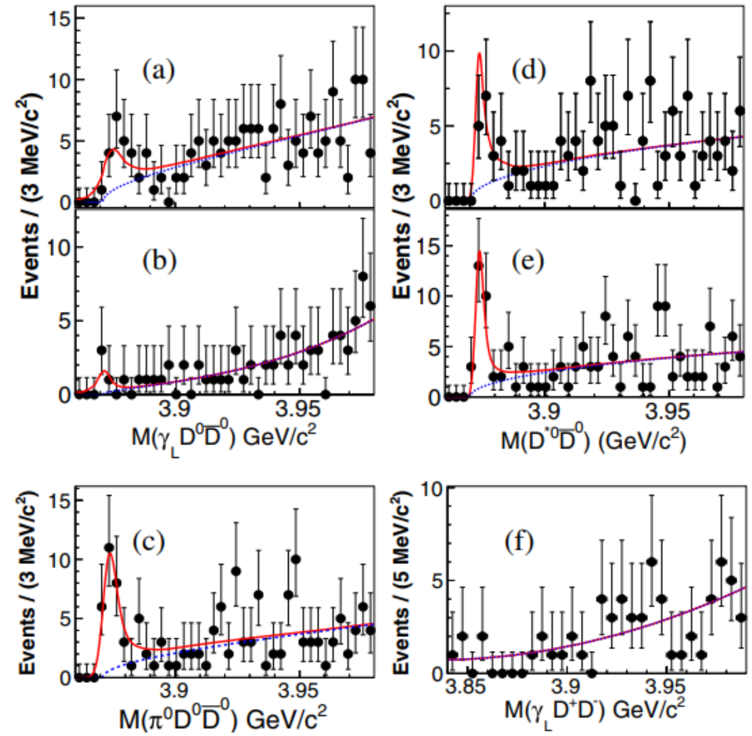


FIG. 2. $M(\gamma_L D^0\bar{D}^0)$ with $M(\gamma_L D^0)$ (a) in or (b) below the D^{*0} mass window. (c) $M(\pi^0 D^0\bar{D}^0)$ with $M(\pi^0 D^0)$ in the D^{*0} mass window. Simultaneous fit results for $X(3872)\to D^{*0}\bar{D}^0$ with (d) $D^{*0}\to\gamma D^0$ and (e) $D^{*0}\to\pi^0 D^0$ mode. (f) Fit results for $X(3872)\to\gamma_L D^+D^-$. The points with error bars are from data, the red curves are the best fit, and the blue dashed curves are the background components.

- BESIII observe $X(3872) \to D^{*0}\bar{D}^0$+c.c. with statistical significances of 7.4σ
- No evident signals for $X(3872) \to \gamma D^+D^-$, $\gamma D^0\bar{D}^0$, and $\pi^0 D^0\bar{D}^0$ are found.

Study of $X(3872) \to \gamma J/\psi$ and $\gamma\psi(2S)$ in $e^+e^- \to \gamma X(3872)$

PRL 124, 242001 (2020)

$4.178 \le \sqrt{s} \le 4.278$ GeV (9.0 fb^{-1})

- $\psi(2S) \to \pi^+\pi^- J/\psi \; and \; \mu^+\mu^-$
- $J/\psi \to e^+e^- \; or \; \mu^+\mu^-$

✓ BESIII find evidence for $X(3872) \to \gamma J/\psi$ with statistical significances of 3.5σ

✓ No evident signal for $X(3872) \to \gamma\psi(2S)$ is found.

$$R_{\gamma\psi} = \frac{B[X(3872)\to\gamma\psi(2S)]}{B[X(3872)\to\gamma J/\psi]} = 0.59 \text{ at 90\% C.L.}$$

✓ $X(3872)$ state is more likely a molecule or a mixture of molecule and charmonium, rather than a pure charmonium state

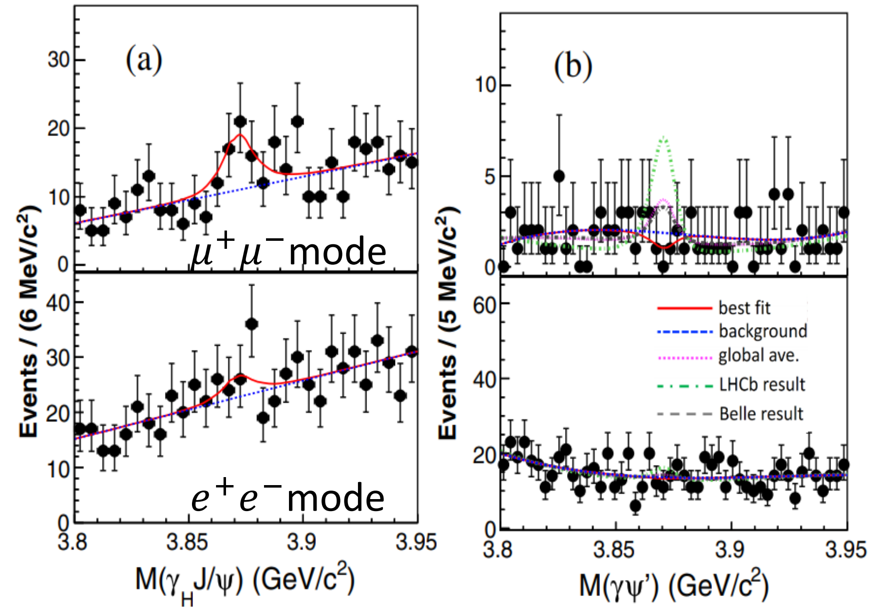


TABLE I. Relative branching ratios and UL on branching ratios compared with $X(3872) \to \pi^+\pi^- J/\psi$ [18,27], where systematic uncertainties have been taken into account.

Mode	Ratio	UL
$\gamma J/\psi$	0.79 ± 0.28	...
$\gamma\psi'$	-0.03 ± 0.22	< 0.42
$\gamma D^0\bar{D}^0$	0.54 ± 0.48	< 1.58
$\pi^0 D^0\bar{D}^0$	-0.13 ± 0.47	< 1.16
$D^{*0}\bar{D}^0$ + c.c.	11.77 ± 3.09	...
γD^+D^-	$0.00^{+0.48}_{-0.00}$	< 0.99
$\omega J/\psi$	$1.6^{+0.4}_{-0.3} \pm 0.2$ [18]	...
$\pi^0\chi_{c1}$	$0.88^{+0.33}_{-0.27} \pm 0.10$ [27]	...

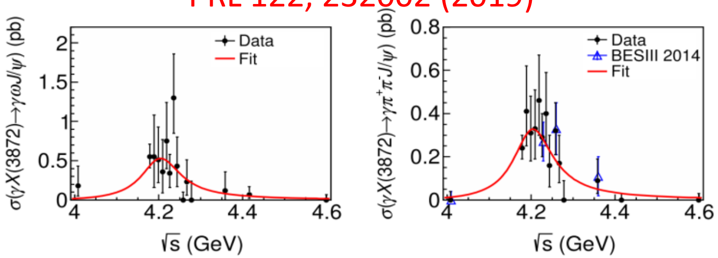
Study of $e^+e^- \to \pi^0 X(3872)\gamma$ and search for $Z_c(4020)^0 \to X(3872)\gamma$

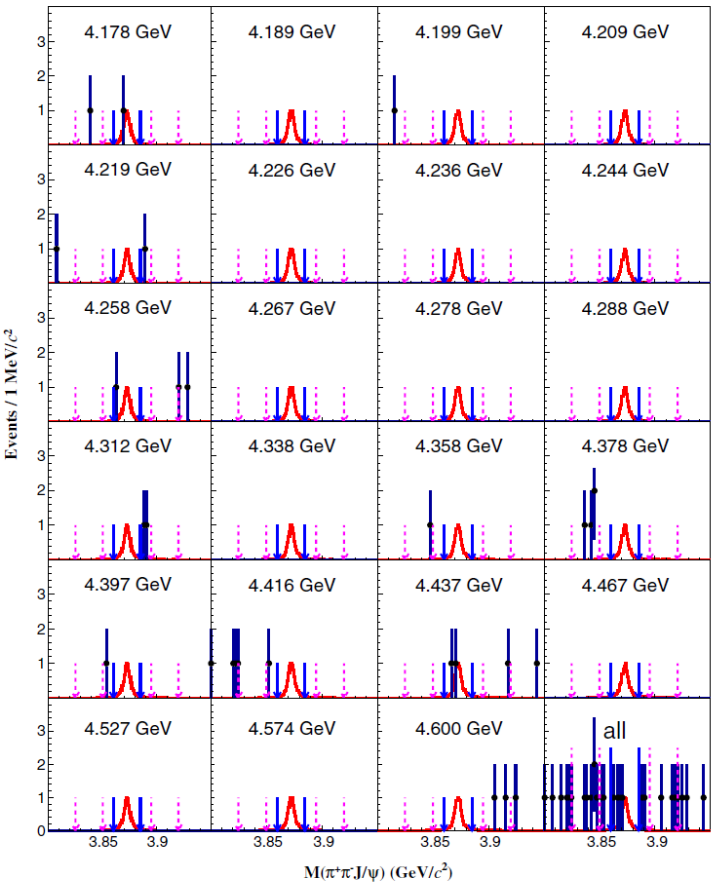
PRD 104, 012001 (2021)

$4.178 \le \sqrt{s} \le 4.600$ GeV (14.5 fb^{-1})

- Establishing connections among XYZ states may be a clue that can facilitate a better theoretical interpretation of these.

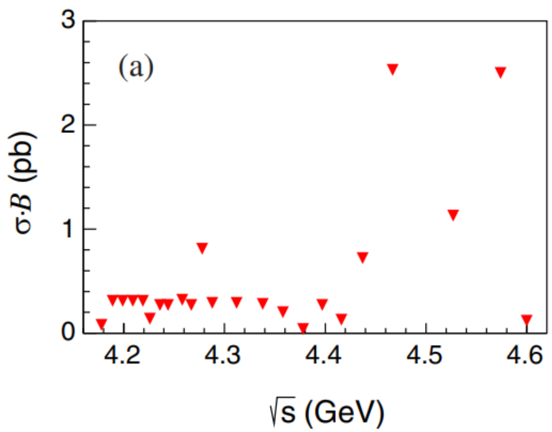
PRL 122, 232002 (2019)





■ $X(3872) \to \pi^+\pi^- J/\psi$ ■ $J/\psi \to e^+e^-$ or $\mu^+\mu^-$

- Upper limits on the number of signal events at the 90% C.L. are calculated by using Rolke method.

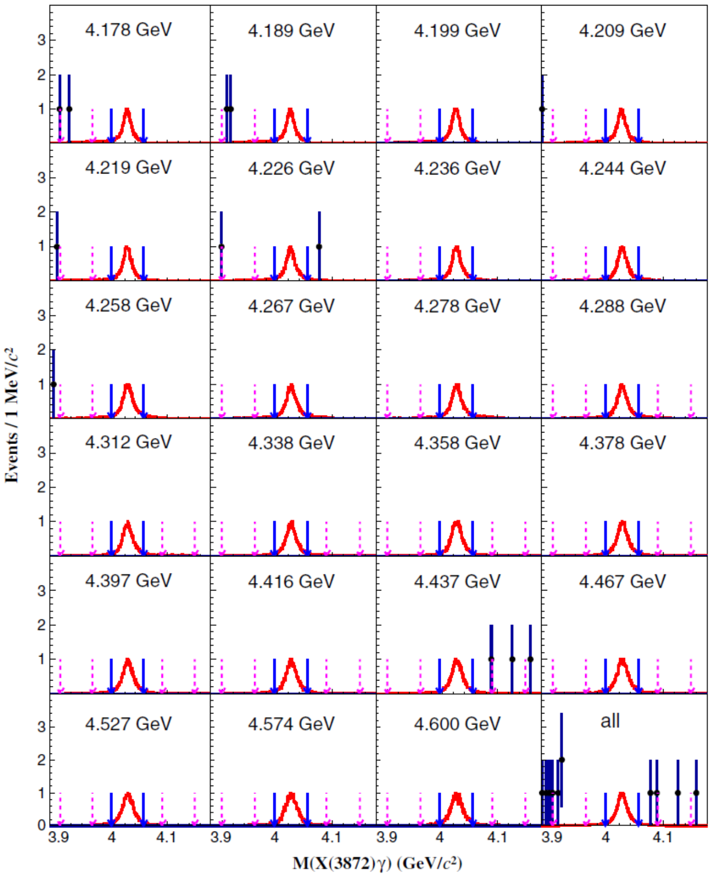


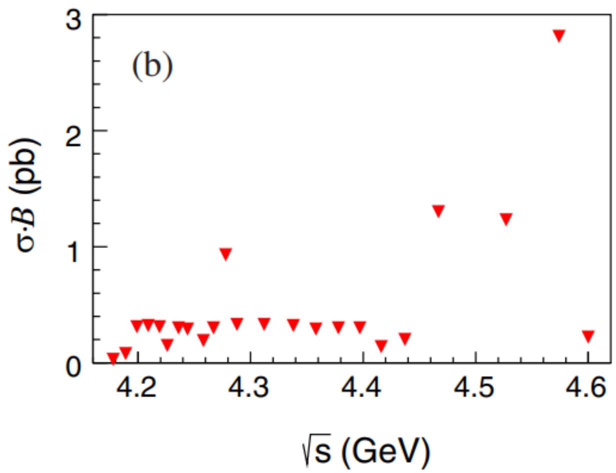
(a) $\sigma(e^+e^- \to \pi^0 X(3872)\gamma) \cdot B(X(3872) \to \pi^+\pi^- J/\psi)$

✓ The results are not in conflict with the theoretical expectation 0.1 fb [PRD 102, 114041 (2020)]

Study of $e^+e^- \to \pi^0 X(3872)\gamma$ and search for $Z_c(4020)^0 \to X(3872)\gamma$

PRD 104, 012001 (2021)





(b) $\sigma(e^+e^- \to \pi^0 Z_c(4020)^0) \cdot B(Z_c(4020)^0 \to X(3872)\gamma) \cdot B(X(3872) \to \pi^+\pi^- J/\psi)$

$$\frac{B(Z_c(4020)^0 \to X(3872)\gamma) \cdot B(X(3872) \to \pi^+\pi^- J/\psi)}{B(Z_c(4020)^0 \to (D^*\bar{D}^*)^0)} < 0.15\%$$

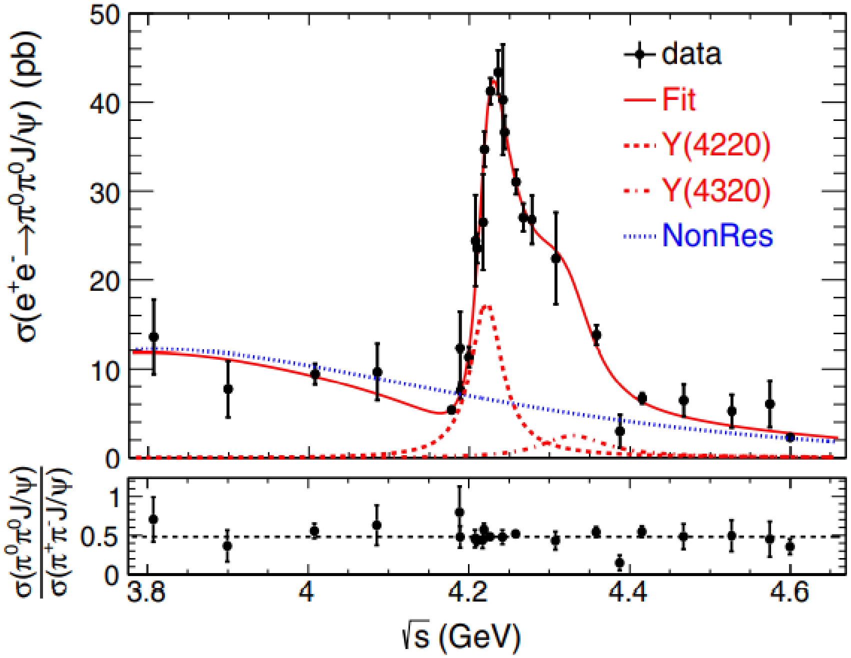
at the 90% C.L. (@4.226 and 4.258 GeV)

✓ The ratio does not contradict the prediction based on the molecular picture [PRD 99, 054028 (2019)].

Study of $e^+e^- \to \pi^0\pi^0 J/\psi$

PRD 102, 012009 (2020)

$3.81 \leq \sqrt{s} \leq 4.60$ GeV ($12.4\ fb^{-1}$)



- $\pi^0 \to \gamma\gamma, J/\psi \to e^+e^-\ or\ \mu^+\mu^-$

✓ The mass and width of the $Y(4220)$ are measured to be

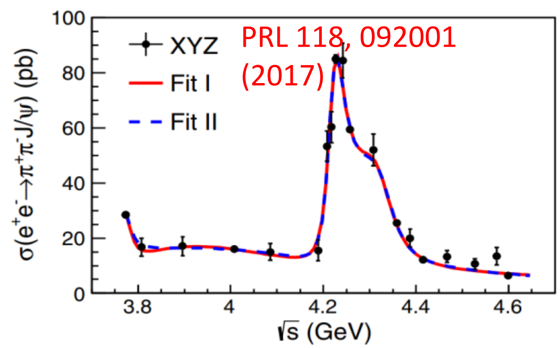
$$M(Y(4220)) = 4220.4 \pm 2.4 \pm 2.3\ \text{MeV}/c^2$$
$$\Gamma(Y(4220)) = 46.2 \pm 4.7 \pm 2.1\ \text{MeV}$$

✓ The results agree with those reported in $e^+e^- \to \pi^+\pi^- J/\psi$ and confirm the existence of the charmoniumlike state $Y(4220)$

✓ The statistical significance of $Y(4320)$ is estimated to be 4.2σ

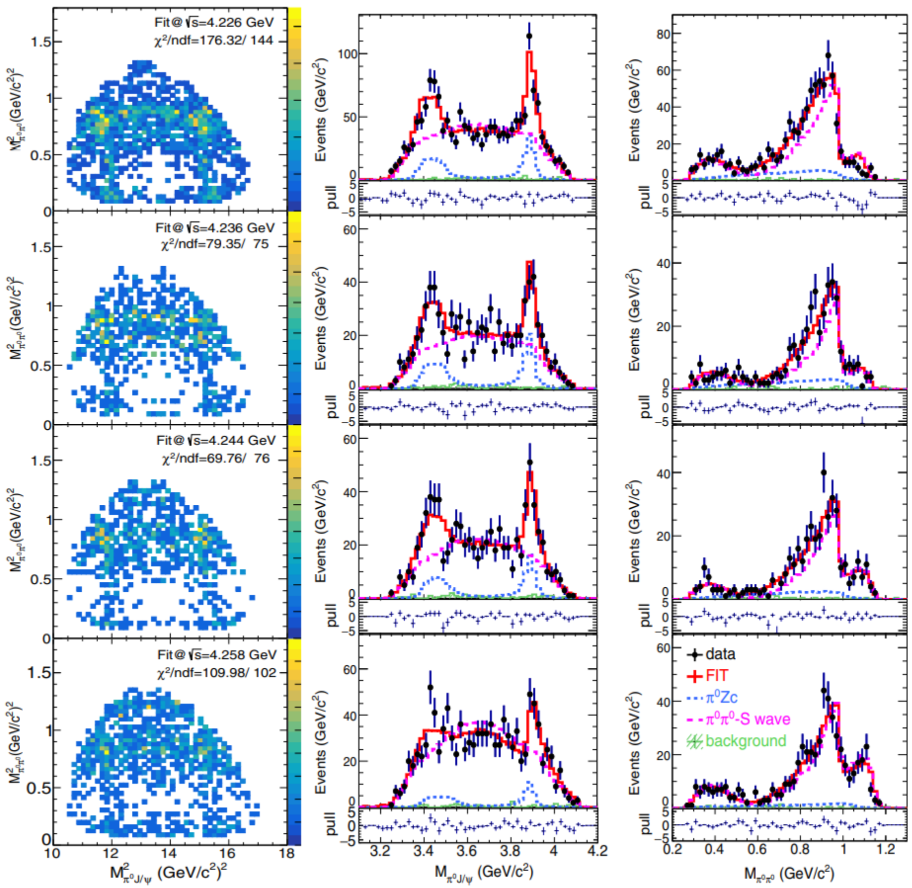
$$\frac{\sigma(\pi^0\pi^0 J/\psi)}{\sigma(\pi^+\pi^- J/\psi)} = 0.48 \pm 0.02$$

- The ratio is consistent with the prediction 0.5 based on isospin symmetry



Study of $e^+e^- \to \pi^0 Z_C(3900)^0 \to \pi^0\pi^0 J/\psi$

PRD 102, 012009 (2020)



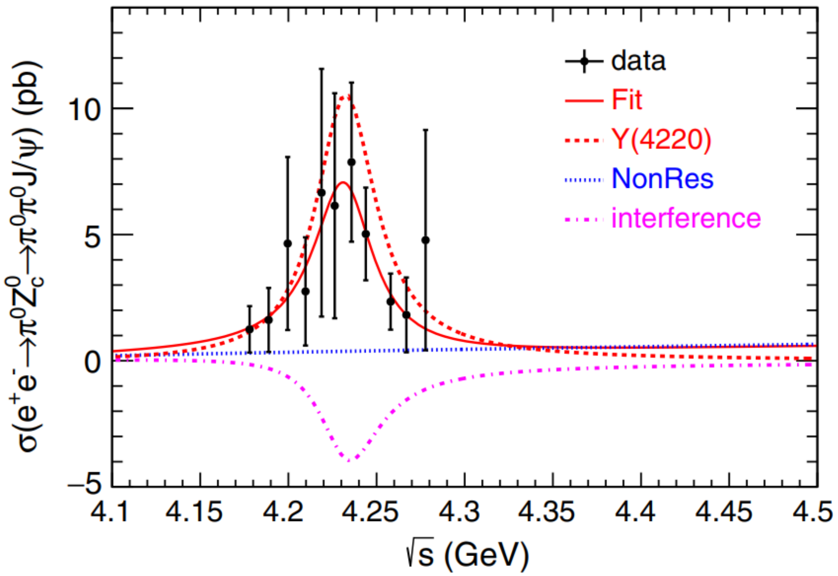
- A simultaneous PWA is performed on the four data samples

- The structures $Z_C(3900)^0$ is clearly observed.
- The spin-parity of $Z_C(3900)^0$ is determined to be $\mathrm{J^P} = 1^+$

$M(Z_C(3900)^0) = 3893.0 \pm 2.3 \pm 3.2$ MeV/c^2
$\Gamma(Z_C(3900)^0) = 44.2 \pm 5.4 \pm 8.3$ MeV

Study of $e^+e^- \to \pi^0 Z_C(3900)^0 \to \pi^0\pi^0 J/\psi$

PRD 102, 012009 (2020)



- ✓ The structures $Y(4220)$ is observed in $e^+e^- \to \pi^0 Z_C(3900)^0 \to \pi^0\pi^0 J/\psi$ cross section.
- ✓ The mass and width of the $Y(4220)$ are measured to be

$$\boxed{\begin{aligned} M(Y(4220)) &= 4231.4 \pm 5.3 \pm 4.9\ \mathrm{MeV}/c^2 \\ \Gamma(Y(4220)) &= 41.2 \pm 16.0 \pm 16.4\ \mathrm{MeV} \end{aligned}}$$

- ✓ The relationship between the two exotic states $Y(4220)$ and the $Z_C(3900)^0$ is established for the first time

Observation of the $Y(4220)$ and $Y(4390)$ in the process $e^+e^- \to \eta J/\psi$

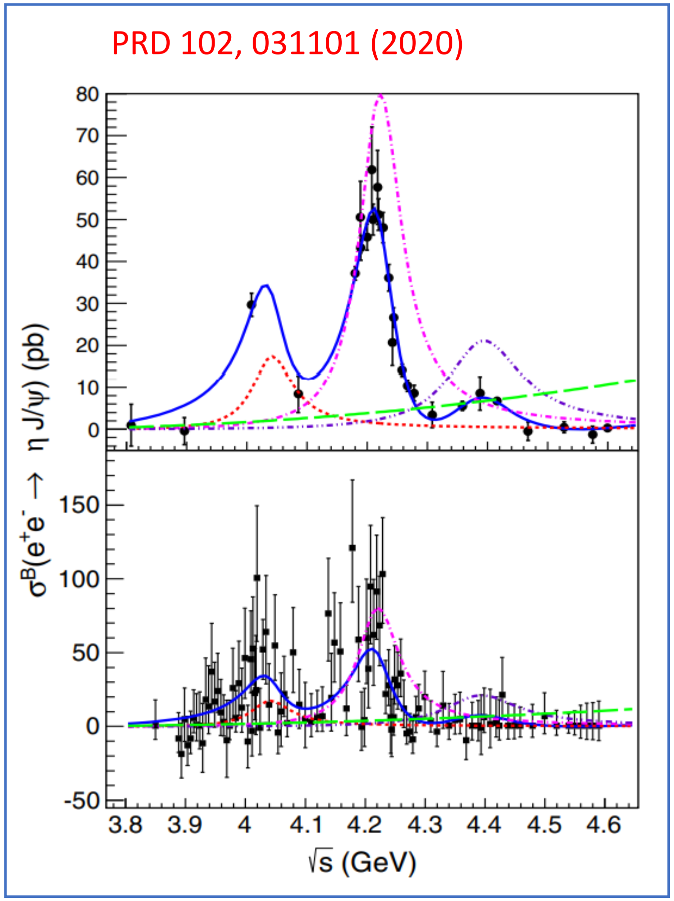
PRD 102, 031101(R) (2020)

XYZ data: $3.81 \leq \sqrt{s} \leq 4.60$ GeV (13.1 fb^{-1})
Rscan data: (0.8 fb^{-1})

- $J/\psi \to e^+e^-$ or $\mu^+\mu^-$, $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$

- A simultaneous fit is performed by considering the four processes to extract the signal yield.

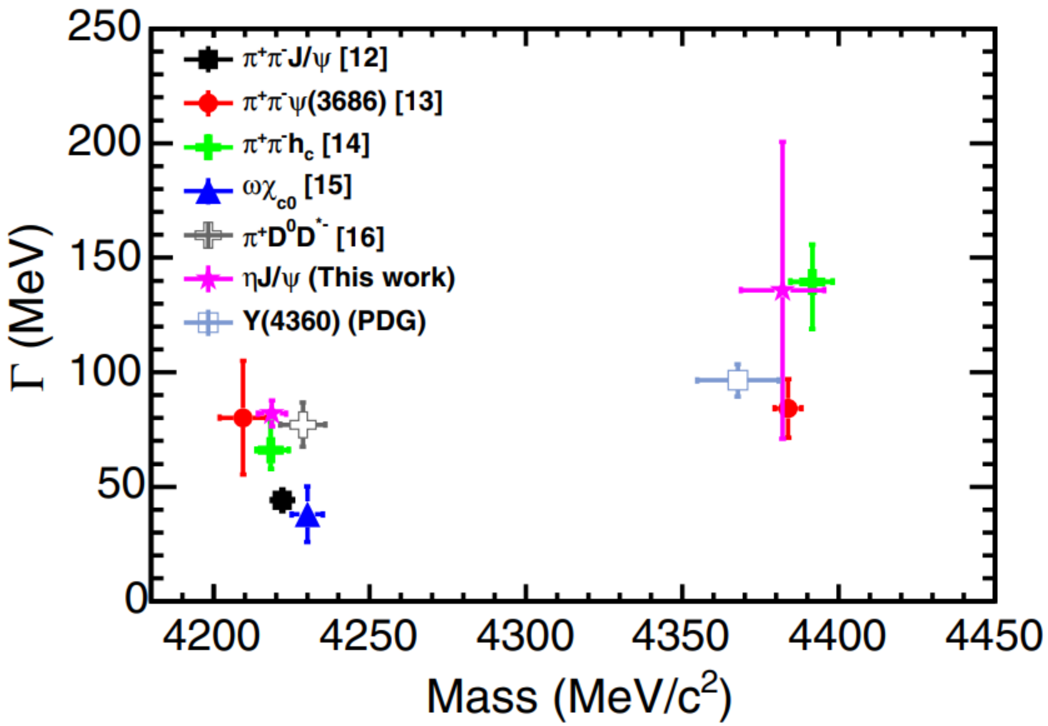
- Assuming the lowest lying one is $\psi(4040)$, $Y(4220)$ and $Y(4390)$ are observed in the process $e^+e^- \to \eta J/\psi$
- $Y(4390)$ are observed in the process $e^+e^- \to \eta J/\psi$ with significance of 6.0σ for the first time

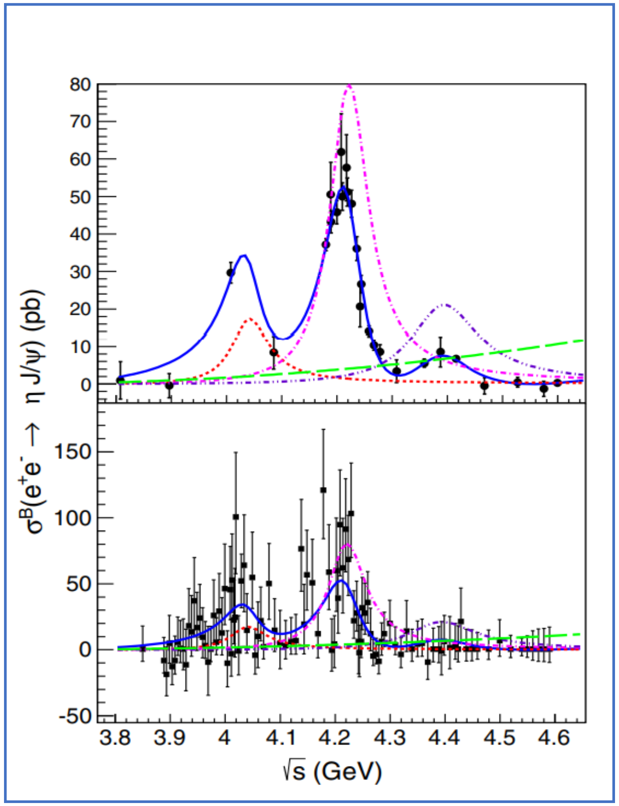


$$M(Y(4220)) = 4218.6 \pm 3.8 \pm 2.5$$
$$\Gamma(Y(4220)) = 82.0 \pm 5.7 \pm 0.4$$
$$M(Y(4390)) = 4382.0 \pm 13.3 \pm 1.7$$
$$\Gamma(Y(4390)) = 135.8 \pm 60.8 \pm 22.5$$

Observation of the $Y(4220)$ and $Y(4390)$ in the process $e^+e^- \to \eta J/\psi$

PRD 102, 031101(R) (2020)





- The masses and widths of the $Y(4220)$ and $Y(4390)$ are consistent with or close to those of previous measurements
- The intrinsic scenario for the difference on width is still unknown.

$M(Y(4220)) = 4218.6 \pm 3.8 \pm 2.5$
$\Gamma(Y(4220)) = 82.0 \pm 5.7 \pm 0.4$
$M(Y(4390)) = 4382.0 \pm 13.3 \pm 1.7$
$\Gamma(Y(4390)) = 135.8 \pm 60.8 \pm 22.5$

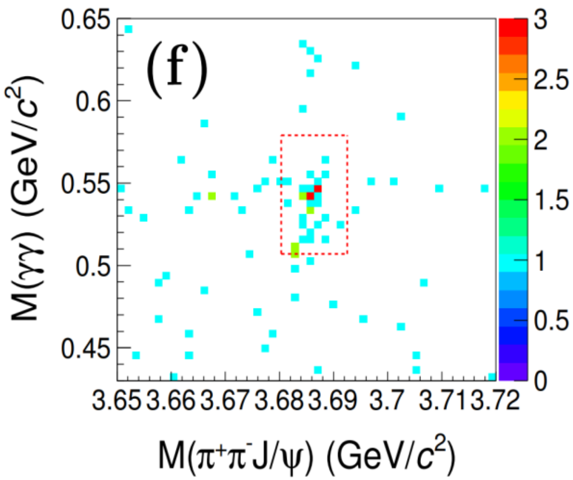
Observation of $e^+e^- \to \eta\psi(2S)$

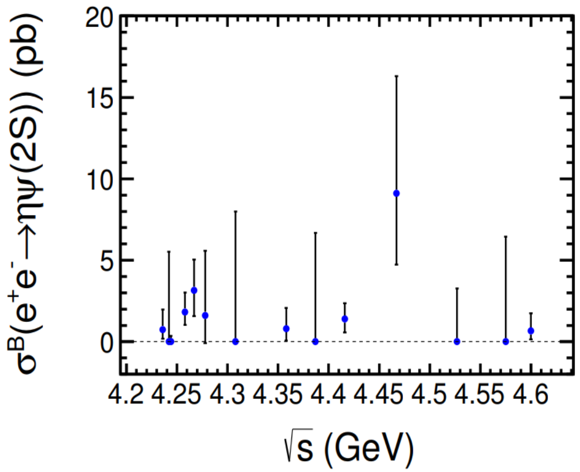
arXiv:2103.01480v2

$4.237 \leq \sqrt{s} \leq 4.600$ GeV (5.25 fb^{-1})

- $\eta \to \gamma\gamma,\ \psi(2S) \to \pi^+\pi^- J/\psi,\ J/\psi \to e^+e^-\ or\ \mu^+\mu^-$

- The signal yields are determined by Feldman-Cousins method
- The process $e^+e^- \to \eta\psi(2S)$ is observed for the first time. (S_{tot}=4.9σ)
- Upper limits on the cross section at 90% C.L. are calculated by using POLE program.
- A partial event reconstruction technique in the future may improve the detection efficiency of this process.





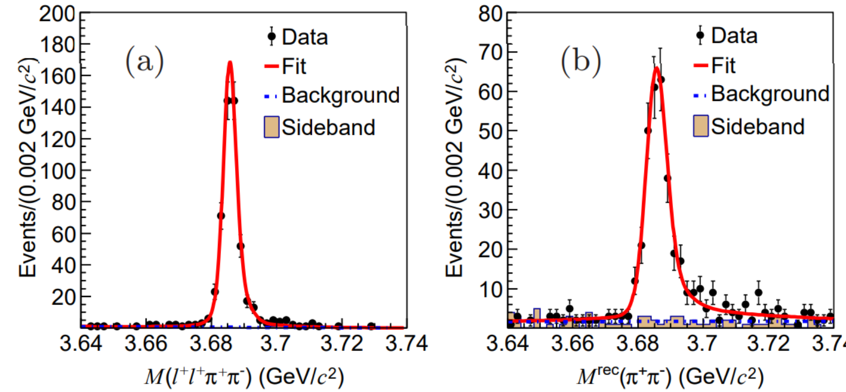
Cross section Measurement of $e^+e^- \to \pi^+\pi^-\psi(2S)$

arXiv:2107.09210

- An update of the previous BESIII result with improved precision

$4.01 \le \sqrt{s} \le 4.70$ GeV ($20.1\ fb^{-1}$)

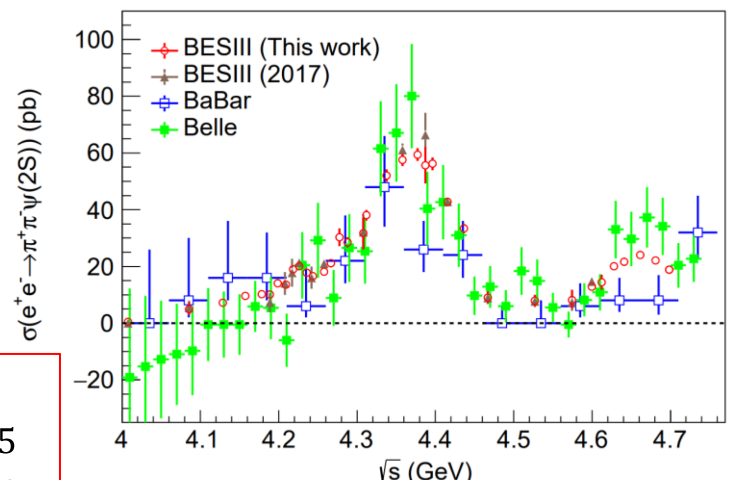
- $\psi(2S) \to \pi^+\pi^- J/\psi$ (mode I), $\psi(2S) \to$ neutrals $+ \pi^+\pi^- J/\psi$ (mode 2),
- neutrals: $\pi^0, \pi^0\pi^0, \eta$, and $\gamma\gamma$ (here $\gamma\gamma$ from $\psi(2S) \to \gamma\chi_{cJ} \to \gamma\gamma J/\psi$)
- $J/\psi \to e^+e^-$ or $\mu^+\mu^-$



- The measured cross section is obtained by performing simultaneous fit to $M(\pi^+\pi^- J/\psi)$ and $RM(\pi^+\pi^-)$ spectra.

- The line shape of $e^+e^- \to \pi^+\pi^-\psi(2S)$ can be described with $Y(4220)$, $Y(4390)$, $Y(4660)$, and continuous component.

- The statistical significances of $Y(4220)$, $Y(4390)$, and $Y(4660)$, are 4.0σ, 16.1σ, and 8.1σ, respectively.



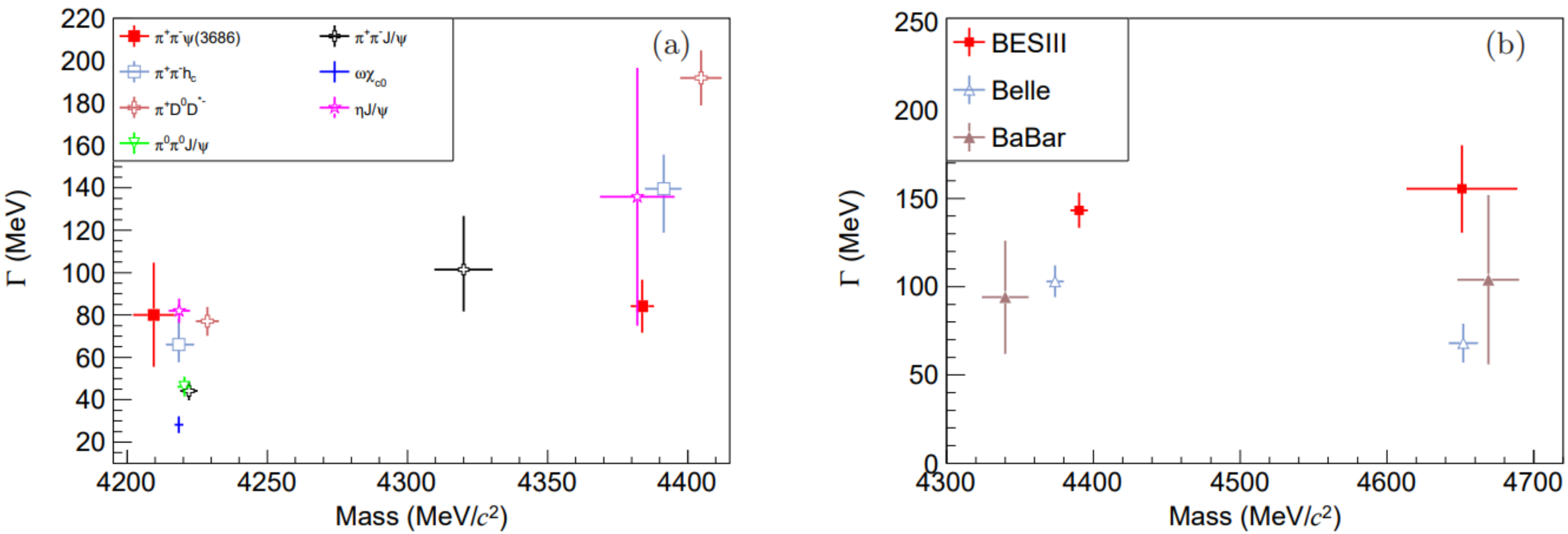
$M(Y(4220)) = 4234.4 \pm 3.2 \pm 0.2 \quad \Gamma(Y(4220)) = 17.6 \pm 8.1 \pm 0.9$

$M(Y(4390)) = 4390.3 \pm 6.0 \pm 0.7 \quad \Gamma(Y(4390)) = 143.3 \pm 10.0 \pm 0.5$

$M(Y(4660)) = 4651.0 \pm 37.8 \pm 2.1 \quad \Gamma(Y(4660)) = 155.4 \pm 24.8 \pm 0.8$

Cross section Measurement of $e^+e^- \to \pi^+\pi^-\psi(2S)$

arXiv:2107.09210



(a)For different processes investigated at the BESIII experiment:

- ✓ $Y(4390)$ states are consistent among different decay modes within uncertainties.
- ✓ The width of the Y (4220) is smaller than previous results.

(b)For the $Y(4360)$, $Y(4390)$, and $Y(4660)$ observed in $\pi^+\pi^-\psi(2S)$ process by BESIII, Belle and BaBar experiments:

- ✓ The mass of the $Y(4390)$ observed by BESIII are larger than that of the $Y(4360)$ observed by Belle and BaBar.
- ✓ But these results can still be considered as consistent results.

Measurement of $e^+e^- \to \gamma\chi_{c0,c1,c2}$ cross sections

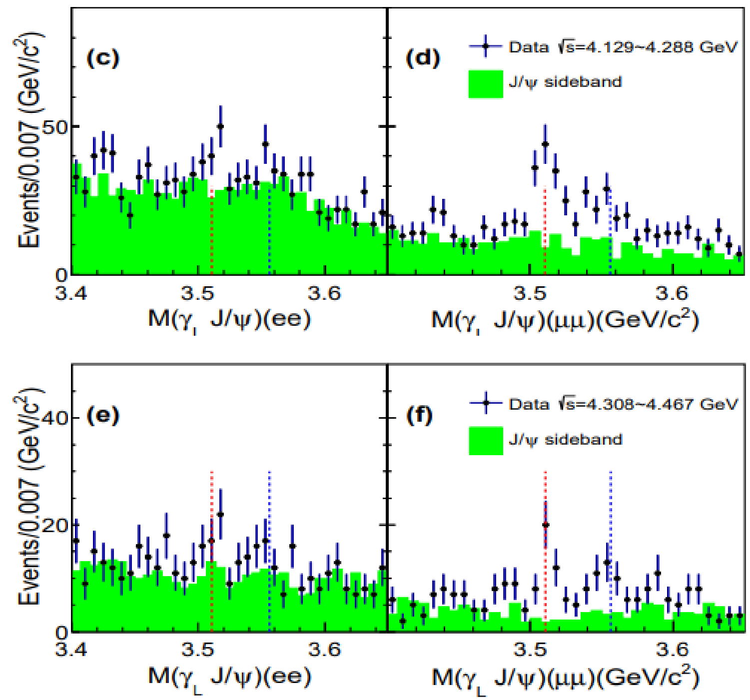
arXiv:2107.03604

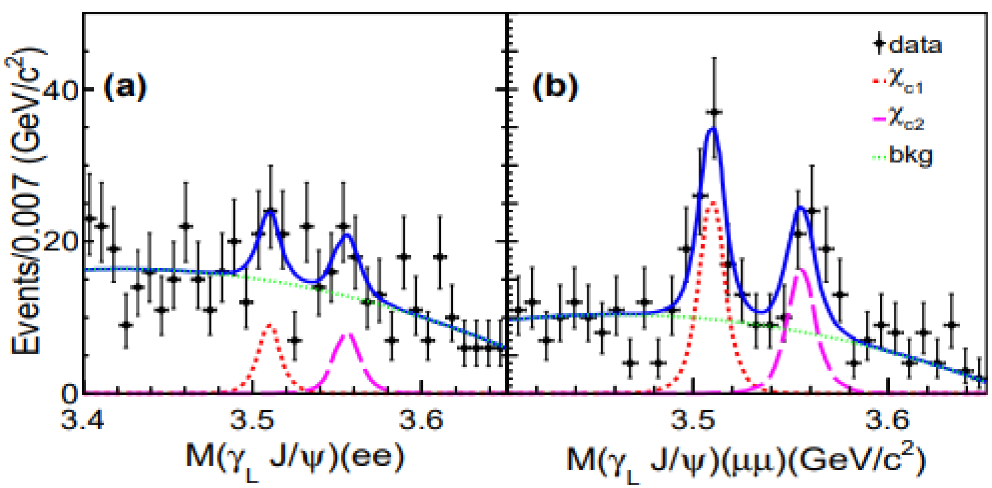
Studying the radiative transitions between vector Y-states and χ_{cJ}

$3.773 \leq \sqrt{s} \leq 4.600$ GeV (19.3 fb^{-1})

- $\chi_{c0,c1,c2} \to \gamma J/\psi, J/\psi \to e^+e^-\ or\ \mu^+\mu^-$

- To obtain the number of signal events, BESIII uses both fitting ($L_{int} > 400pb^{-1}$) and counting ($L_{int} < 200\ pb^{-1}$ and $\sqrt{s} > 4.009$ GeV) methods.



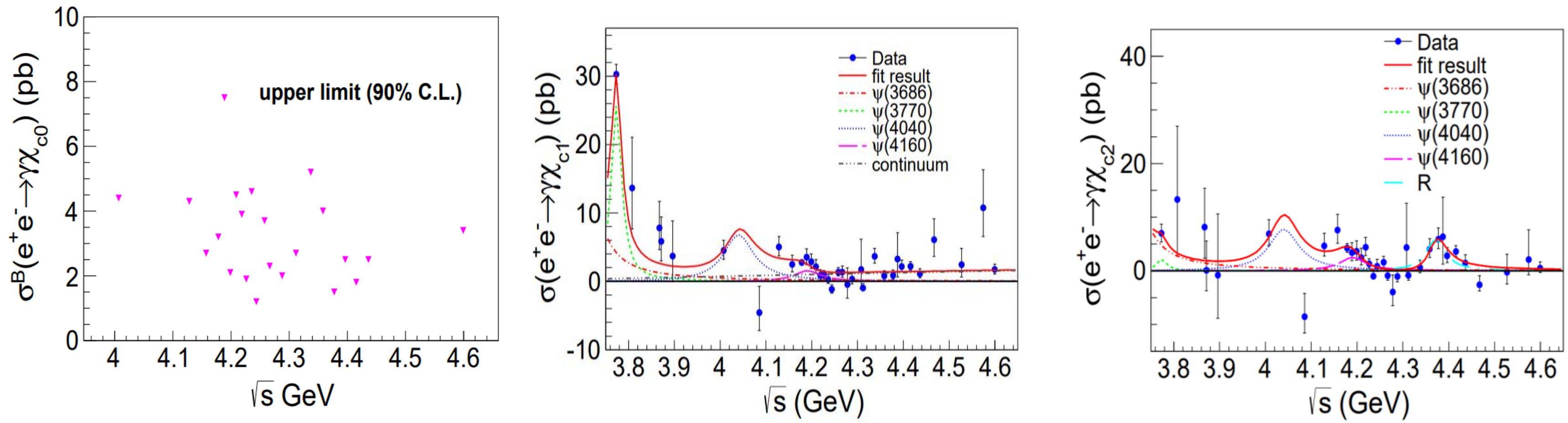


- ☐ $e^+e^- \to \gamma\chi_{c1}$ and $e^+e^- \to \gamma\chi_{c2}$ are observed for the first time.

$\gamma\chi_{c1}$ @4.178 GeV: 7.6σ
$\gamma\chi_{c2}$ @4.178 GeV: 6.0σ

Measurement of $e^+e^- \to \gamma\chi_{c0,c1,c2}$ cross sections

arXiv:2107.03604



✓ The cross section line shape of $e^+e^- \to \gamma\chi_{c1}$ can be described with ψ(3686), ψ(3770), ψ(4040) and ψ(4160) resonances.

✓ One resonance (R) with significance of 5.8σ is observed in line shape of the cross section $e^+e^- \to \gamma\chi_{c2}$,

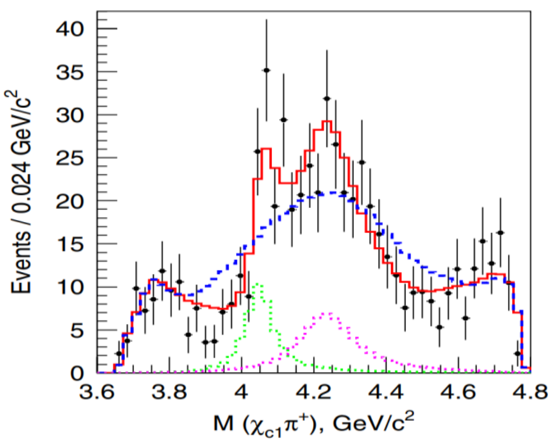
$$M(R) = 4371.7 \pm 7.5 \pm 1.8\ \mathrm{MeV}/c^2$$
$$\Gamma^{tot} = 51.1 \pm 17.6 \pm 1.9\ \mathrm{MeV}$$

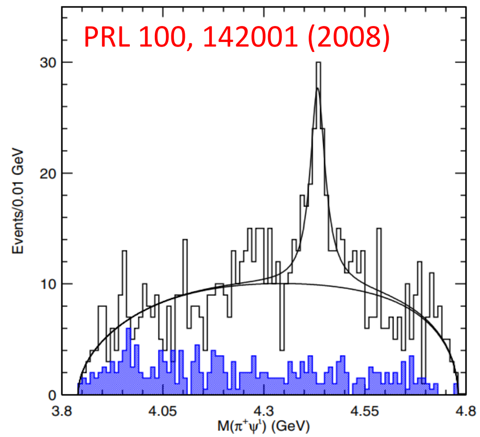
✓ The result supports the $\Upsilon(4360)/\Upsilon(4390) \to \gamma\chi_{c2}$ radiative transition.

- The measurement of $e^+e^- \to \gamma\chi_{c0,c1,c2}$ cross sections are consistent with the potential model predictions, except for B[$\psi(4160) \to \gamma\chi_{c2}$] [PRD 72, 054026 (2005)].

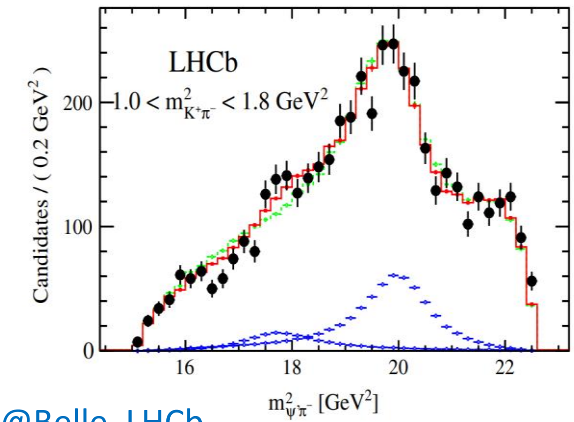
- The charged charmoniumlike structures have been observed in the $\boldsymbol{\pi}^{\pm}$+charmonium mass spectra.

PRD 78, 072004 (2008)





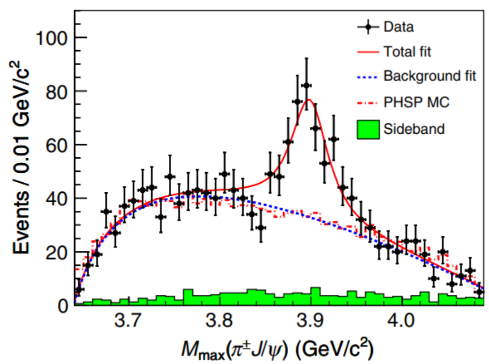
PRL 112, 222002 (2014)



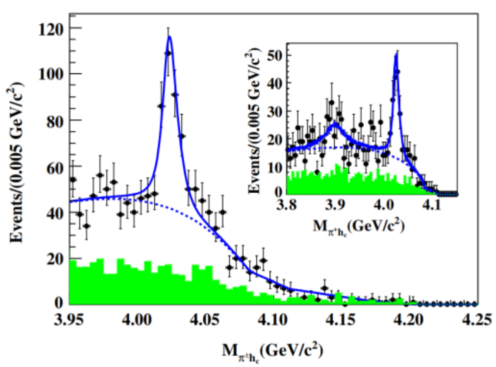
$Z_c(4050)^{\pm}, Z_c(4250)^{\pm}$@Belle

$Z_c(4430)^{\pm}$ @Belle, LHCb

PRL 110, 252001 (2013)



PRL 111, 242001 (2013)



$Z_c(3900)^{\pm}, Z_c(4020)^{\pm}$@BES3

Searching for the reaction $e^+e^- \to \chi_{cJ}\pi^+\pi^-$ and a charmoniumlike structure decaying to $\chi_{cJ}\pi^\pm$

PRD 103, 052010 (2021)

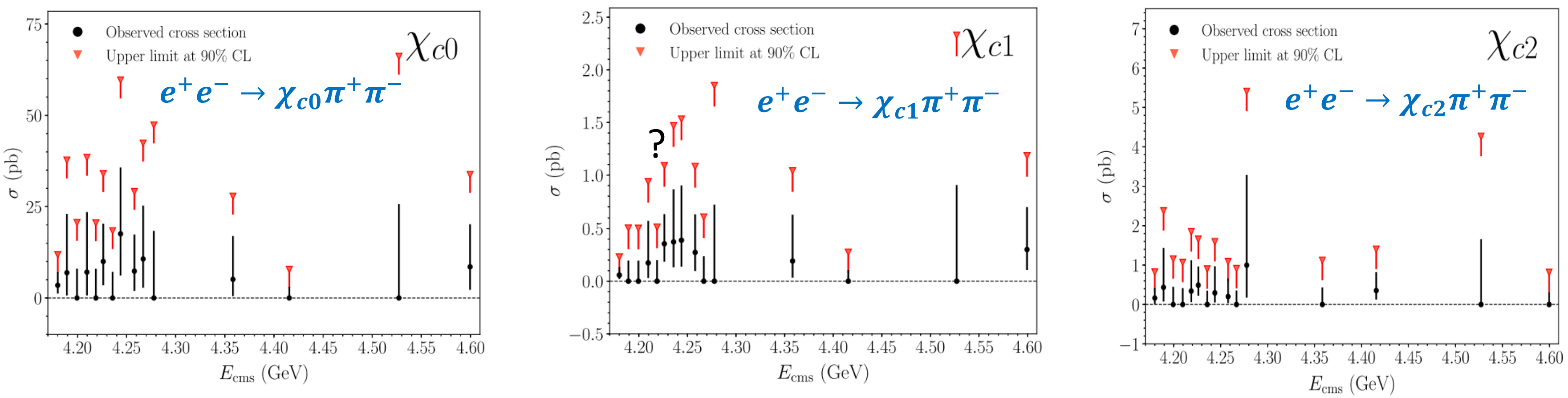
- $\chi_{cJ} \to \gamma J/\psi, J/\psi \to e^+e^-$ or $\mu^+\mu^-$

$4.178 \le \sqrt{s} \le 4.600$ GeV (11.2 fb^{-1})

✓ No significant signal has been observed,

✓ Also no charmoniumlike in the invariant mass of the $\chi_{cJ}\pi^\pm$ subsystem can be seen

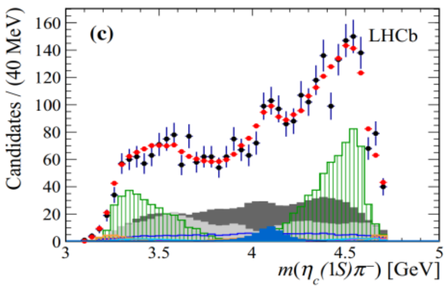
✓ A hint of an slight enhancement for $e^+e^- \to \chi_{c1}\pi^+\pi^-$



Measurements of $e^+e^- \to \eta_c\pi^+\pi^-\pi^0$, $\eta_c\pi^+\pi^-$, and $\eta_c\pi^0\gamma$, and search for $Z_c \to \eta_c\pi$

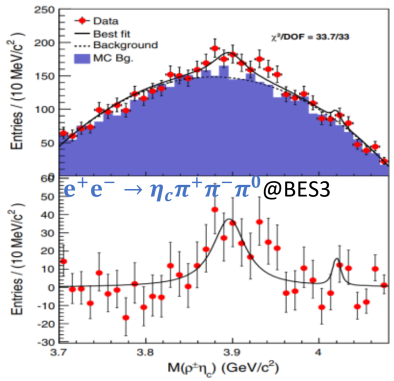
PRD 103, 032006 (2021)

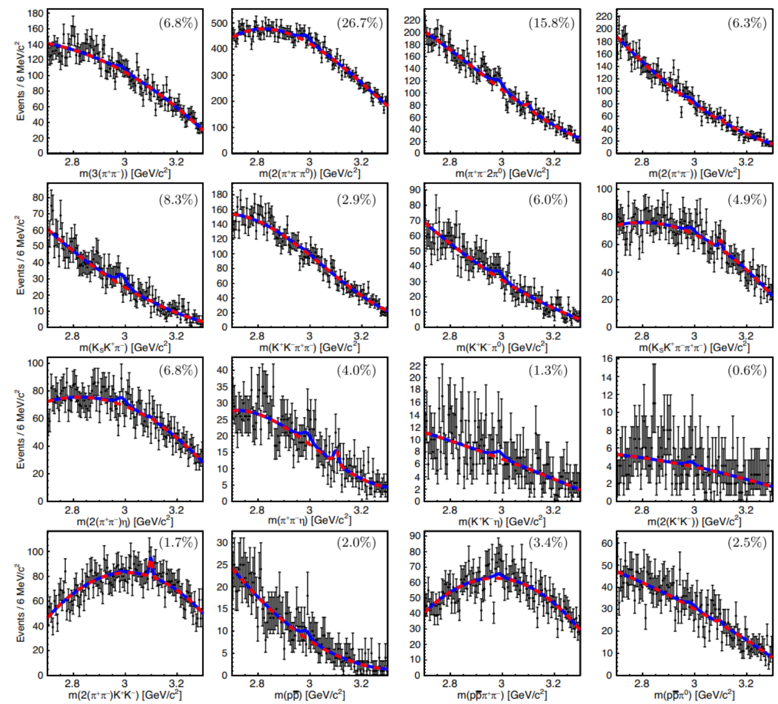
EPJC 78, 1019 (2018)



$B^0 \to K^+\eta_c\pi^-$@LHCb

PRD 100, 111102(R) (2019)





$4.178 \leq \sqrt{s} \leq 4.600$ GeV (7.3 fb^{-1})

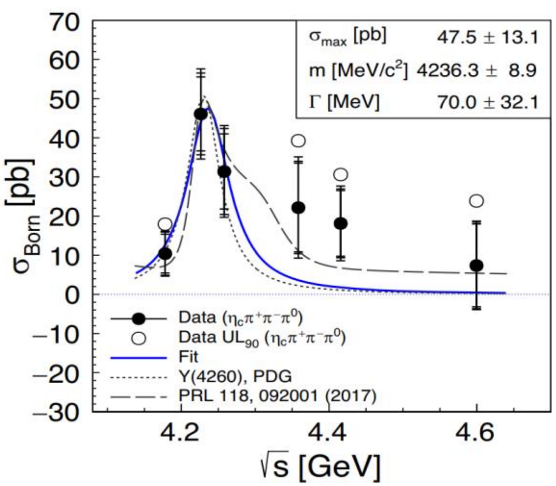
- $\eta_c \to 3(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-)$, $K_S^0 K^+\pi^-$, $\pi^+\pi^-K^+K^-$, $K^+K^-\pi^0$, $K_S^0K^+\pi^-\pi^+\pi^-$, $2(\pi^+\pi^-)\eta$, $\pi^+\pi^-\eta$, $K^+K^-\eta$, $K^+K^-K^+K^-$, $K^+K^-2(\pi^+\pi^-)$, $p\bar{p}$, $p\bar{p}\pi^0$, $p\bar{p}\pi^+\pi^-$

- A maximum-likelihood fit simultaneously for all $\boldsymbol{\eta_c}$ decay channels to determine the signal yields for each $\boldsymbol{e^+e^- \to \eta_c\pi^+\pi^-\pi^0}$, $\boldsymbol{\eta_c\pi^+\pi^-}$, and $\boldsymbol{\eta_c\pi^0\gamma}$

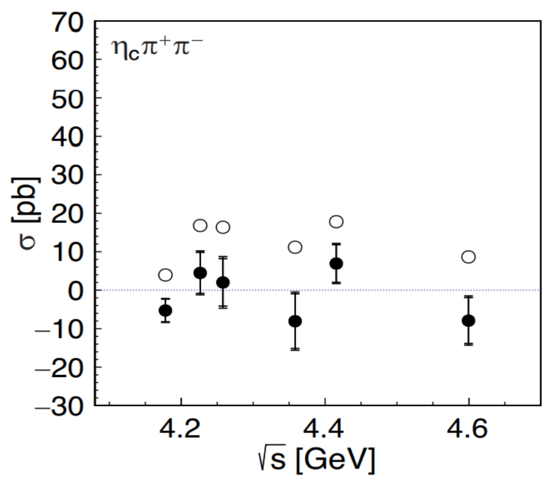
Measurements of $e^+e^- \to \eta_c\pi^+\pi^-\pi^0$, $\eta_c\pi^+\pi^-$, and $\eta_c\pi^0\gamma$, and search for $Z_c \to \eta_c\pi$

PRD 103, 032006 (2021)

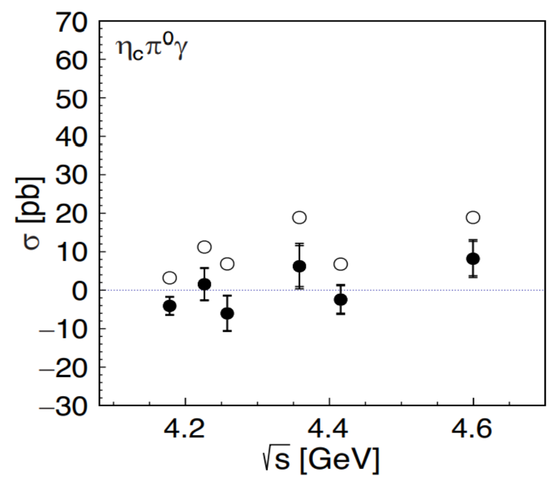
- The process $\boldsymbol{e^+e^- \to \eta_c\pi^+\pi^-\pi^0}$ is observed for the first time. (S_{stat}/S_{tot}=5.1σ/4.6σ@4.226 GeV, 5.9σ/5.2σ@Sum of all Data samples)
- The Born cross section $\boldsymbol{e^+e^- \to \eta_c\pi^+\pi^-\pi^0}$ is measured to be in agreement with the hypothesis of the production of an intermediate Y(4260) resonance decaying to the $\boldsymbol{\eta_c\pi^+\pi^-\pi^0}$ final state.
- The Born cross sections $\boldsymbol{e^+e^- \to \eta_c\pi^+\pi^-}$ and $\boldsymbol{\eta_c\pi^0\gamma}$ are found to be consistent with zero and corresponding upper limits are provided



$e^+e^- \to \eta_c\pi^+\pi^-\pi^0$



$e^+e^- \to \eta_c\pi^+\pi^-$



$e^+e^- \to \eta_c\pi^0\gamma$

Search for $Z_c \to \eta_c \pi$ in the $e^+e^- \to \eta_c \pi^+\pi^-\pi^0$ process

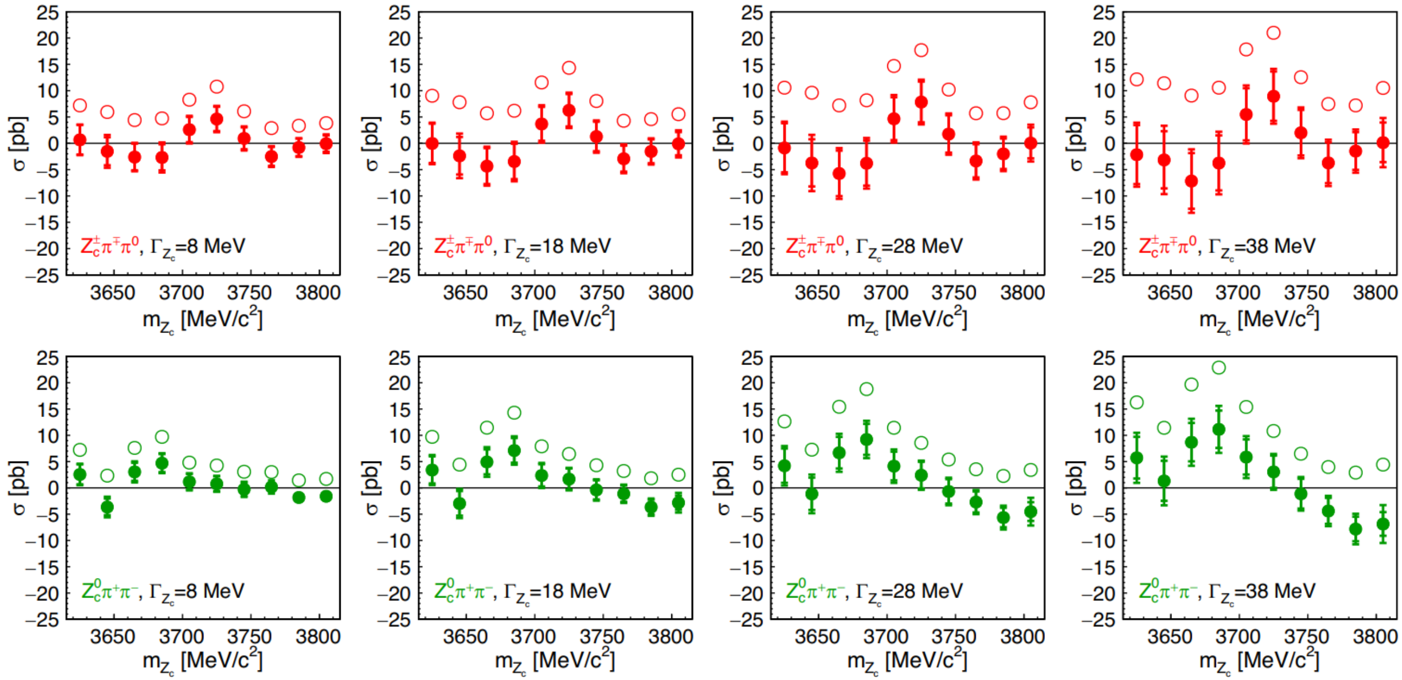
PRD 103, 032006 (2021)

@4.226 GeV (1.1 fb^{-1})

■ $e^+e^- \to Z_c^+\pi^-\pi^0 \to (\eta_c\pi^+)\pi^-\pi^0 (or\ c.c.)$ and $e^+e^- \to Z_c^0\pi^+\pi^- \to (\eta_c\pi^0)\pi^+\pi^-$

$\eta_c \to$ 16 modes

- The search is realized in terms of a mass and a width scan for Z_c, and a maximum-likelihood fit simultaneously for all $\eta_c\pi$ decay channels
- $Z_c^0 \to \eta_c\pi^0$ in $e^+e^- \to \eta_c\pi^+\pi^-\pi^0$ are found to be more significant.



Searching for the reaction channel $e^+e^- \to \eta_c\eta\pi^+\pi^-$

PRD 103, 032004 (2021)

@4.23, 4.26, 4.36, 4.42, and 4.60 GeV(4.1 fb^{-1})

■$\eta_c \to \pi^+\pi^-K^+K^-,\ 2(K^+K^-),\ 2(\pi^+\pi^-),\ 3(\pi^+\pi^-), K_S^0K^\pm\pi^\pm, K_S^0K^\pm\pi^\pm\pi^+\pi^-,$
$K^+K^-\pi^0,\ K^+K^-\eta,\ \pi^+\pi^-\eta,\ \pi^+\pi^-\pi^0\pi^0,\ 2(\pi^+\pi^-)\eta,\ 2(\pi^+\pi^-\pi^0),\ K^+K^-2(\pi^+\pi^-),$
$p\bar{p},\ p\bar{p}\pi^0,\ p\bar{p}\pi^+\pi^-$

■$\eta \to \gamma\gamma,\quad \pi^0 \to \gamma\gamma,\quad K_S^0 \to \pi^+\pi^-$

- The cross section at each center-of-mass energy is determined by a simultaneous fit to the invariant mass of the η_c meson for 16 decay modes.
- No signal is observed, the upper limits at 90% C.L. on cross sections are determined to be

$$\sigma^{\text{up}}_{4.23\text{GeV}} = 6.2\ \text{pb} \qquad \sigma^{\text{up}}_{4.26\text{GeV}} = 10.8\ \text{pb}$$
$$\sigma^{\text{up}}_{4.36\text{GeV}} = 27.6\ \text{pb} \qquad \sigma^{\text{up}}_{4.42\text{GeV}} = 22.6\ \text{pb}$$
$$\sigma^{\text{up}}_{4.60\text{GeV}} = 23.7\ \text{pb}$$

- It is not yet possible to conclude about possible resonant structures in the final-state subsystems

Observation of a Near-Threshold Structure in the K^+ Recoil-Mass Spectra in $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

PRL 126, 102001 (2021)

@4.63, 4.64, 4.66, 4.68, and 4.60 GeV(3.7 fb^{-1})

Only reconstruct the charged K^+ and D_s^-, via $D_s^- \to K^+K^-\pi^-$ and $K_S^0K^-$, $K_S^0 \to \pi^+\pi^-$

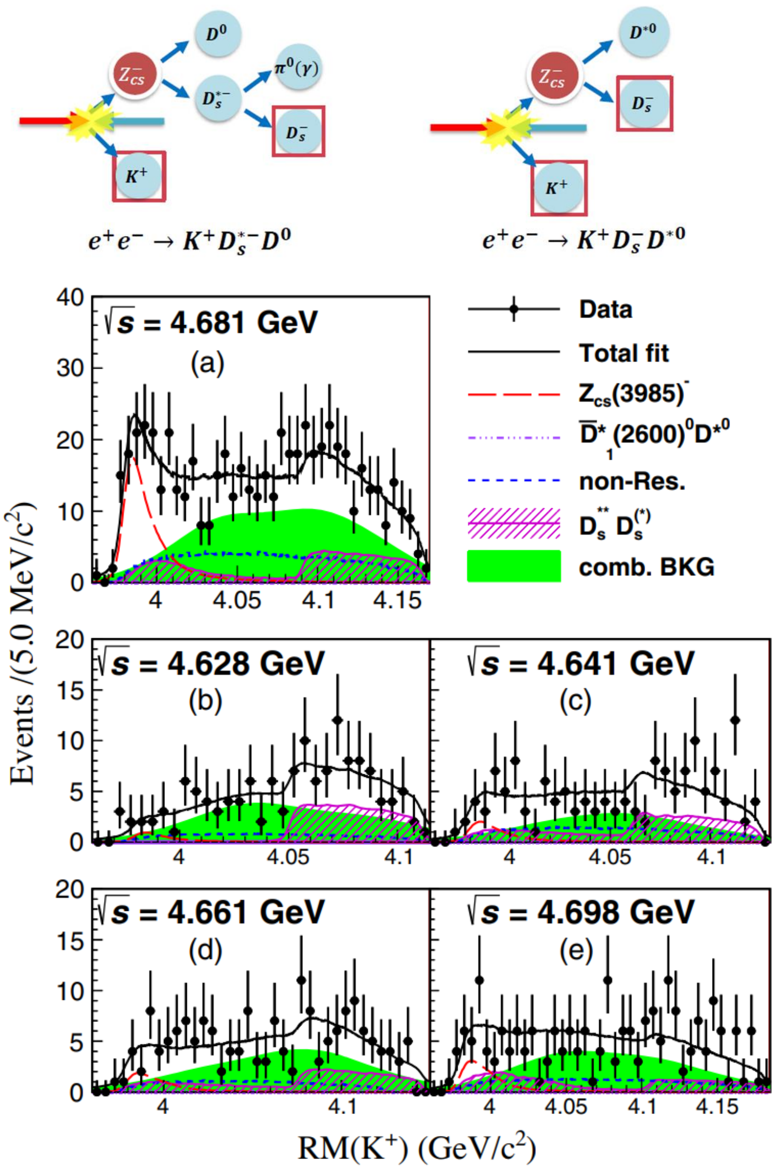
- Fit to the K^+ recoil mass spectra for five data samples

✓ The first Z_{cs} tetraquark candidate $[c\bar{c}s\bar{u}]$ with 5.3σ is observed in the near the $D_s\bar{D}^*$ and $D_s^*\bar{D}$ mass thresholds.

$$M = (3985.2^{+2.1}_{-2.0} \pm 1.7)\ \mathrm{MeV/c^2}$$
$$\Gamma = \left(13.8^{+8.1}_{-5.2} \pm 4.9\right)\ \mathrm{MeV}$$

✓ The born cross sections $\sigma^B[e^+e^- \to K^+Z_{cs}(3985)^- + c.c.]$ times the sum of the branching fractions for $Z_{cs} \to D_s^- D^{*0}$+ $D_s^{*-} D^0$ decays are measured at the five energy points.

✓ An enhancement around 4.68 GeV, $Y(4660)$?



Summary

The XYZ states are studied/searched at BESIII.

Search for X(3872)

- $e^+e^- \to X(3872)\gamma$
- $e^+e^- \to \pi^0 X(3872)\gamma$

Search for Z states

- $e^+e^- \to \chi_{cJ}\pi^+\pi^-$
- $e^+e^- \to \eta_c\pi^+\pi^-\pi^0, \eta_c\pi^+\pi^-$, and $\eta_c\pi^0\gamma$
- $e^+e^- \to \eta_c\eta\pi^+\pi^-$
- $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

Search for Y states

Charmonium + light hadrons:

- $\boldsymbol{e}^+e^- \to \pi^0\pi^0 J/\psi$
- $e^+e^- \to \eta J/\psi$
- $e^+e^- \to \eta\psi(2S)$
- $e^+e^- \to \pi^+\pi^-\psi$(2S)

Charmonium + γ :

- $e^+e^- \to \gamma\chi_{c0,c1,c2}$

More results for XYZ states at BESIII will come soon.

- Back up

XYZ: production/decay processes

XYZ	$I^G(J^{PC})$	Production processes	Decay modes
$X(3872)$	$0^+(1^{++})$	$B \to KX/K\pi X, e^+e^- \to \gamma X$, $pp/p\bar{p}$ inclusive, PbPb, $\gamma\gamma^*$	$\pi^+\pi^- J/\psi, \omega J/\psi, D^{*0}\bar{D}^0$, $\gamma J/\psi, \gamma\psi(2S)$
$X(3915)$	$0^+(0 \text{ or } 2^{++})$	$B \to KX$, $\gamma\gamma \to X$	$\omega J/\psi$
$X(4140)$	$0^+(1^{++})$	$B \to KX$, $p\bar{p}$ inclusive	$\phi J/\psi$
$X(4274)$	$0^+(1^{++})$	$B \to KX$	
$X(4500)$	$0^+(0^{++})$		
$X(4700)$	$0^+(0^{++})$		
$X(3940)$	$?^?(?^{??})$	$e^+e^- \to J/\psi + X$	$D\bar{D}^*$
$X(4160)$	$?^?(?^{??})$		$D^*\bar{D}^*$
$X(4350)$	$0^+(?^{?+})$	$\gamma\gamma \to X$	$\phi J/\psi$
$Y(4008)$	$0^-(1^{--})$	$e^+e^- \to Y$	$\pi\pi J/\psi$
$Y(4260)$	$0^-(1^{--})$	$e^+e^- \to Y$	$\pi\pi J/\psi, D\bar{D}^*\pi, \chi_{c0}\omega, h_c\pi\pi$
$Y(4360)$	$0^-(1^{--})$	$e^+e^- \to Y$	$\pi\pi\psi(2S)$
$Y(4660)$	$0^-(1^{--})$		$\pi\pi\psi(2S), \Lambda_c\bar{\Lambda}_c$
$Z_c(3900)$	$1^+(1^{+-})$	$e^+e^- \to \pi Z_c$, inclusive b-hadron decays	$\pi J/\psi, D\bar{D}^*$
$Z_c(4020)$	$1^+(?^{?-})$	$e^+e^- \to \pi Z_c$	$\pi h_c, D^*\bar{D}^*$
$Z_1(4050)$	$1^-(?^{?+})$	$B \to KZ_c$	$\pi^\pm\chi_{c1}$
$Z_2(4250)$	$1^-(?^{?+})$		
$Z_c(4200)$	$1^+(1^{+-})$	$B \to KZ_c$	$\pi^\pm J/\psi$
$Z_c(4430)$	$1^+(1^{+-})$		$\pi^\pm J/\psi, \pi^\pm\psi(2S)$
$Z_{cs}(3985)$	$\frac{1}{2}(?^?)$	$e^+e^- \to KZ_{cs}$	$\bar{D}_sD^*, \bar{D}_s^*D$

Table from F. K. Guo on 7th XYZ meeting

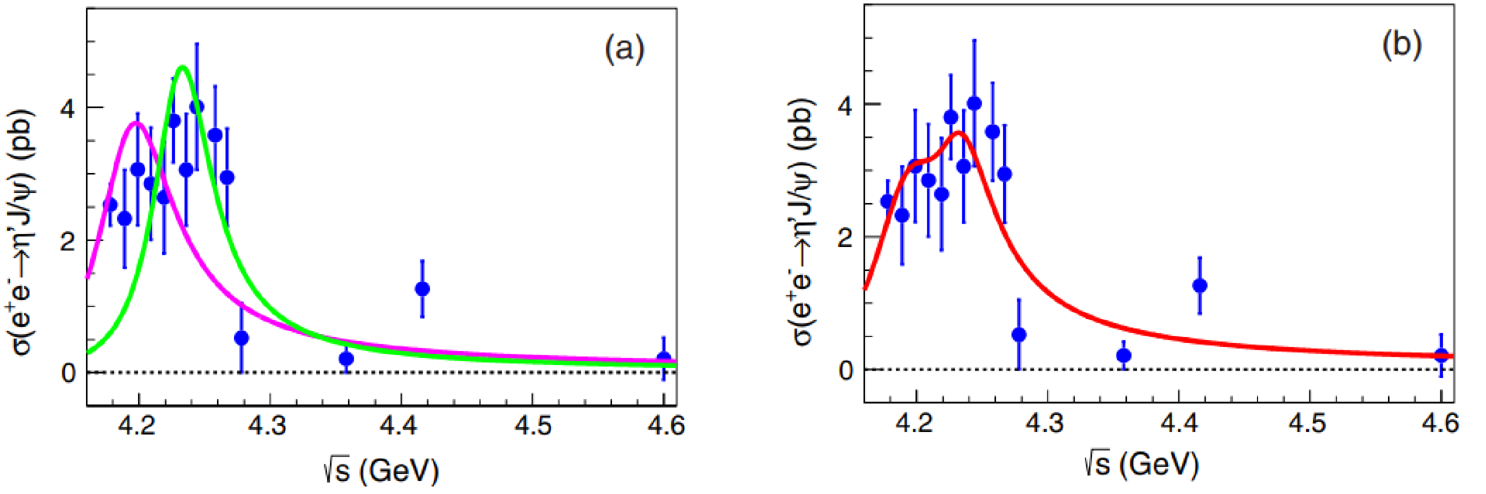
Cross section measurement of $e^+e^- \to \eta' J/\psi$

PRD 101, 012008 (2020)

$4.178 \le \sqrt{s} \le 4.600$ GeV (11 fb^{-1})

- $J/\psi \to e^+e^-$ or $\mu^+\mu^-$, $\eta' \to \gamma\pi^+\pi^-$(mode 1) and $\eta' \to \pi^+\pi^-\eta, \eta \to \gamma\gamma$(mode2)

- A simultaneous is performed for the two η' decay modes to extract the signal yield.
- $e^+e^- \to \eta' J/\psi$ cross section cannot be described by a single $\psi(4160)$ or $Y(4260)$ resonance
- A coherent sum of $\psi(4160)$ and $Y(4260)$ resonances offers a better description to $e^+e^- \to \eta' J/\psi$ cross section
- The significances for the $\psi(4160)$ and $Y(4260)$ are 6.3σ and 4.0σ



Observation of a near-threshold enhancement in the $\Lambda\bar{\Lambda}$ mass spectrum from $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$

arXiv:2104.08754

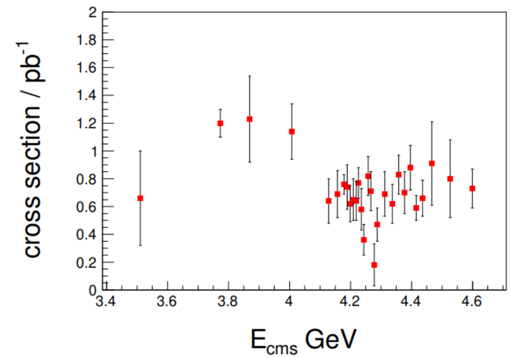
$3.51 \leq \sqrt{s} \leq 4.60$ GeV (19.5 fb^{-1})

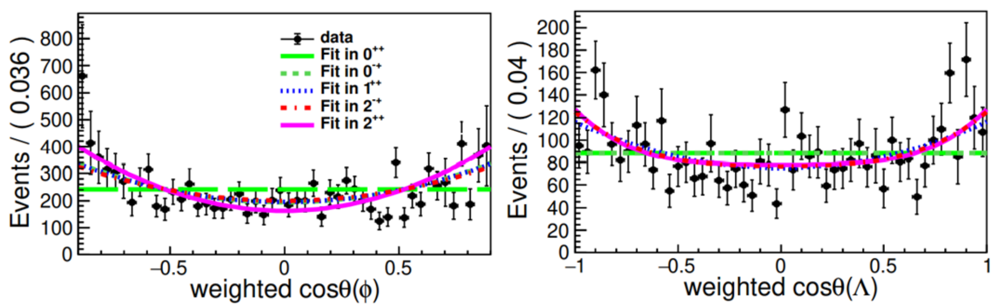
■ $\phi \rightarrow K^+K^-$, $\Lambda(\bar{\Lambda}) \rightarrow p\pi^-(\bar{p}\pi^+)$, missing $\bar{\Lambda}(\Lambda)$

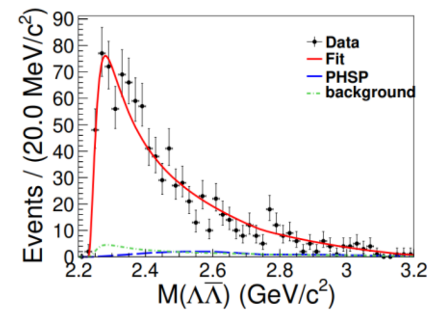
- Several light hadron decays of Y states have been searched by the BESIII, $Y(4260) \rightarrow \pi^0(\eta)p\bar{p}$, $K^+K^-\pi^0$, $\Xi\bar{\Xi}$, etc. But no significant signals.

➢ The $e^+e^- \rightarrow \phi\Lambda\bar{\Lambda}$ process has been observed for the first time

➢ Due to the limited sample sizes, cannot resolve the composition of the resonance structure







✓ A near-threshold enhancement is observed on $\Lambda\bar{\Lambda}$ mass spectrum with a significance greater than 25σ

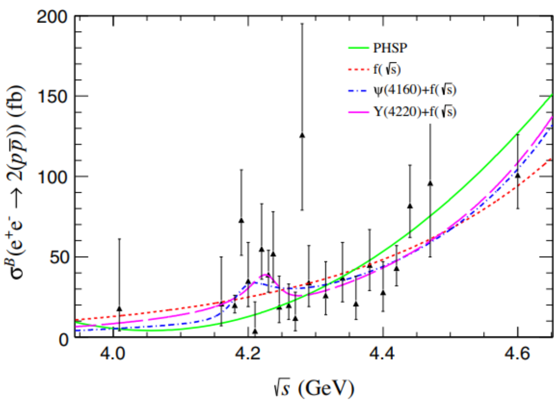
$M = 2262 \pm 4 \pm 28$ MeV/c^2 $\Gamma = 72 \pm 5 \pm 43$ MeV

$J^{PC} = 2^{++}, 2^{-+}$, or 1^{++}

✓ This enhancement could be the same thing observed in $B \rightarrow K\Lambda\bar{\Lambda}$ decays by Belle [PRD 79, 052006 (2009)]

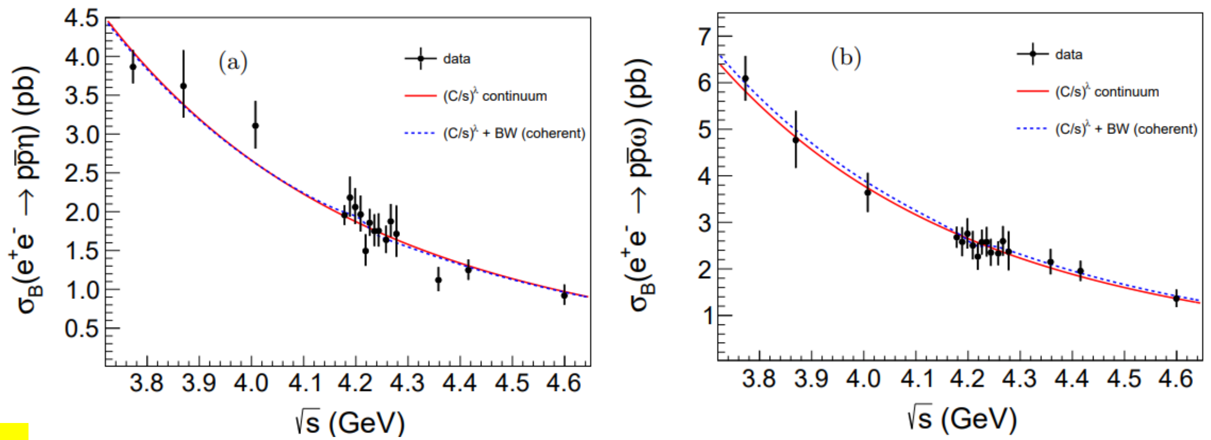
Studies of $e^+e^- \to 2(p\bar{p})$, $p\bar{p}\eta$, and $p\bar{p}\omega$

PRD 103, 052003 (2021)



$4.0 \leq \sqrt{s} \leq 4.6$ GeV (15 fb^{-1})

arXiv:2102.04268v1



$3.773 \leq \sqrt{s} \leq 4.600$ GeV (14.7 fb^{-1})

- No significant structure is observed in the lineshape of $e^+e^- \to 2(p\bar{p})$
- No evidence for a resonant contribution from a fit to the $e^+e^- \to p\bar{p}\eta$, and $p\bar{p}\omega$ lineshapes

- Upper limit at the 90% CL on cross section

7.5 pb for $\psi(4230) \to p\bar{p}\eta$

10.4 pb for $\psi(4230) \to p\bar{p}\omega$