



New results from $Y(4260)$ decays at BESIII

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on behalf of BESIII collaboration

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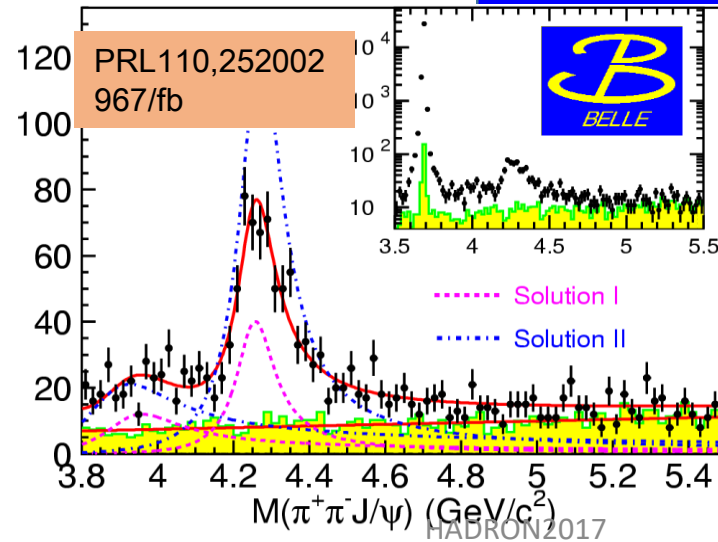
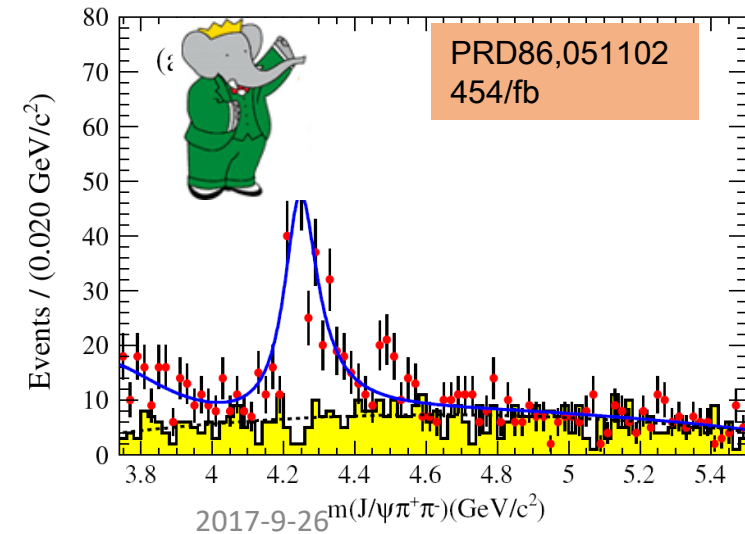
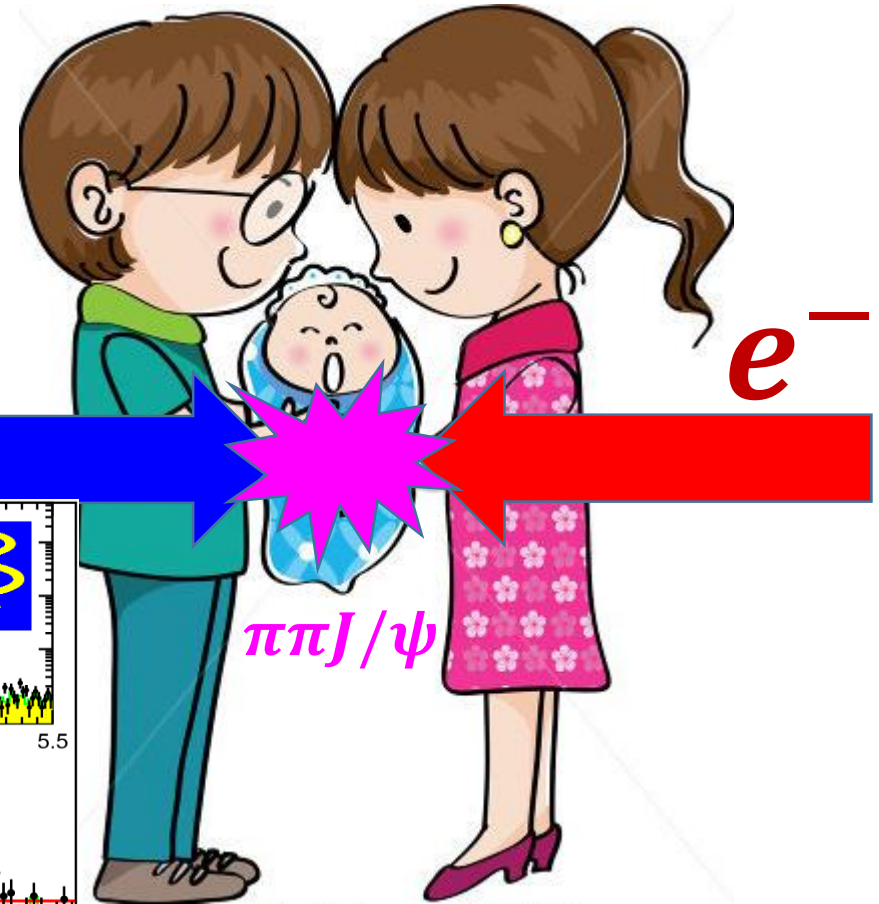
The birth of $Y(4260)$

BaBar and Belle observed an enhancement around 4.26 GeV from ISR $\pi^+\pi^-J/\psi$

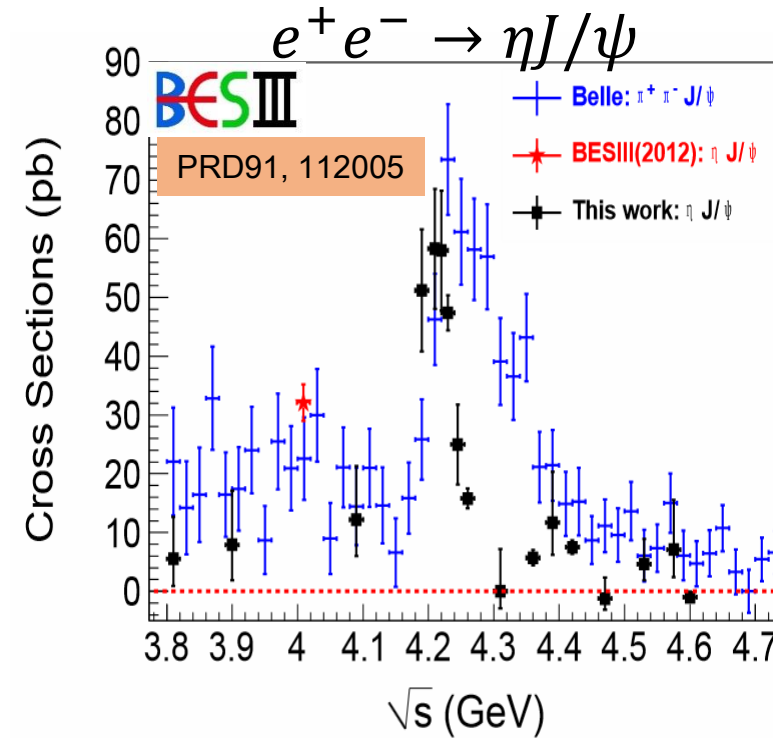
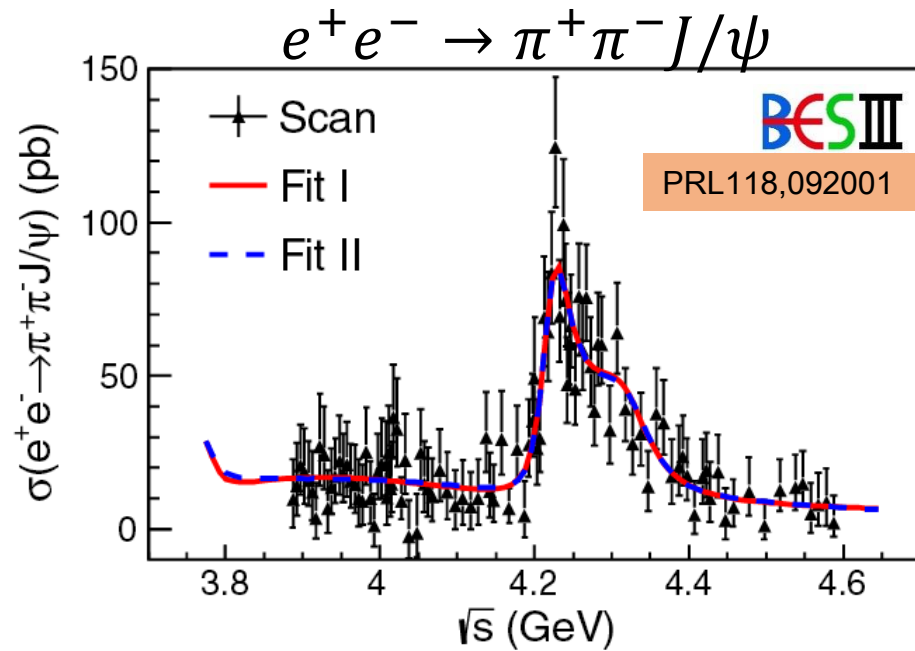
Intrinsic question: **why(4260)?**

- unusual position
- unusual line-shape
- unusual decay

Born to be different

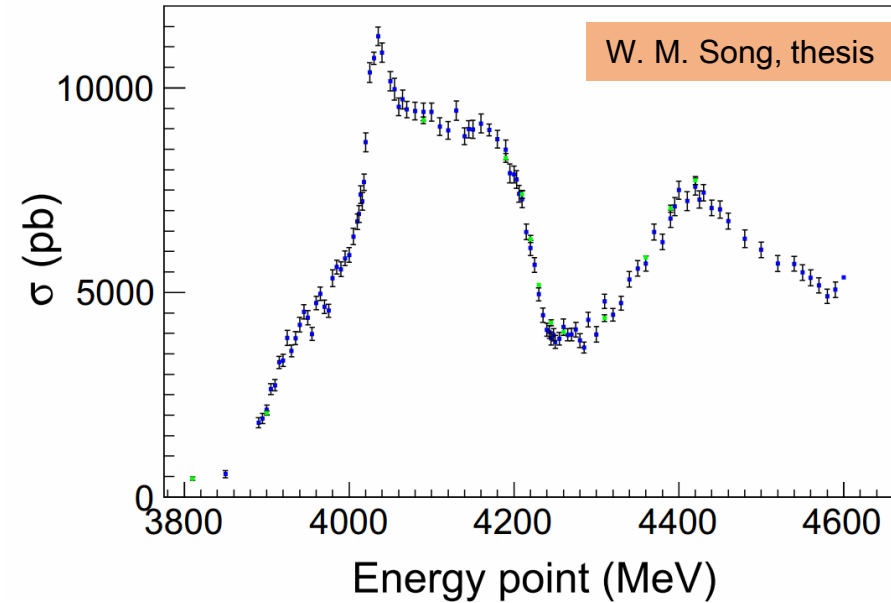
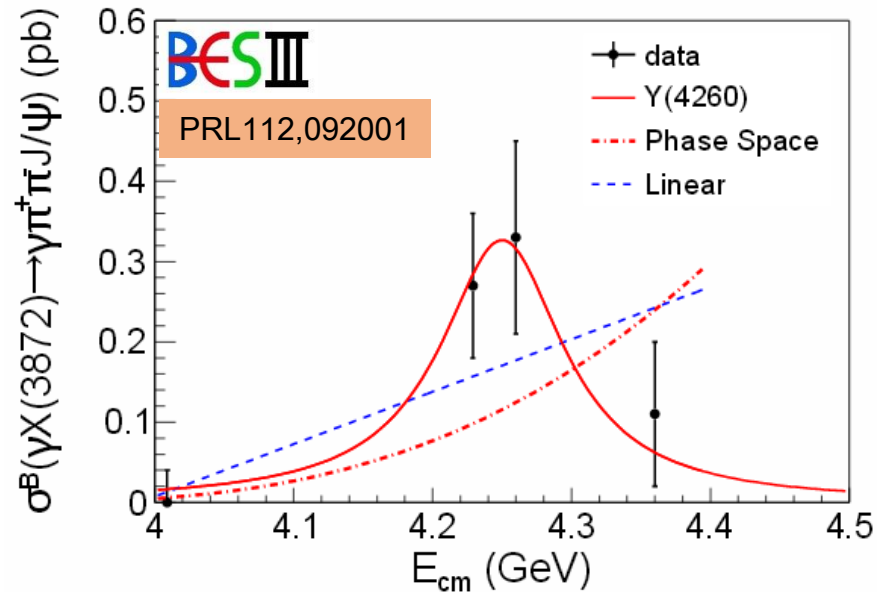


unusual line-shape



- Not asymmetric,
- parameters are different in different channels

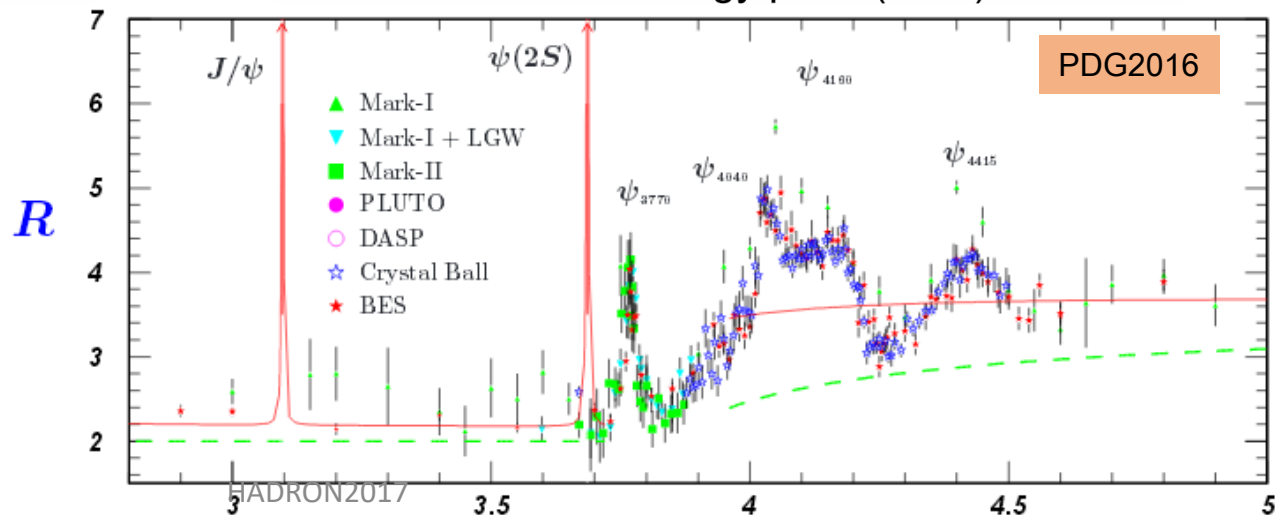
unusual decay



Known possible decay:

- $\pi\pi J/\psi$,
- πZ_c
- $\gamma X(3872)$
- $\omega \chi_{c0}$

No significant in R and R_c distributions

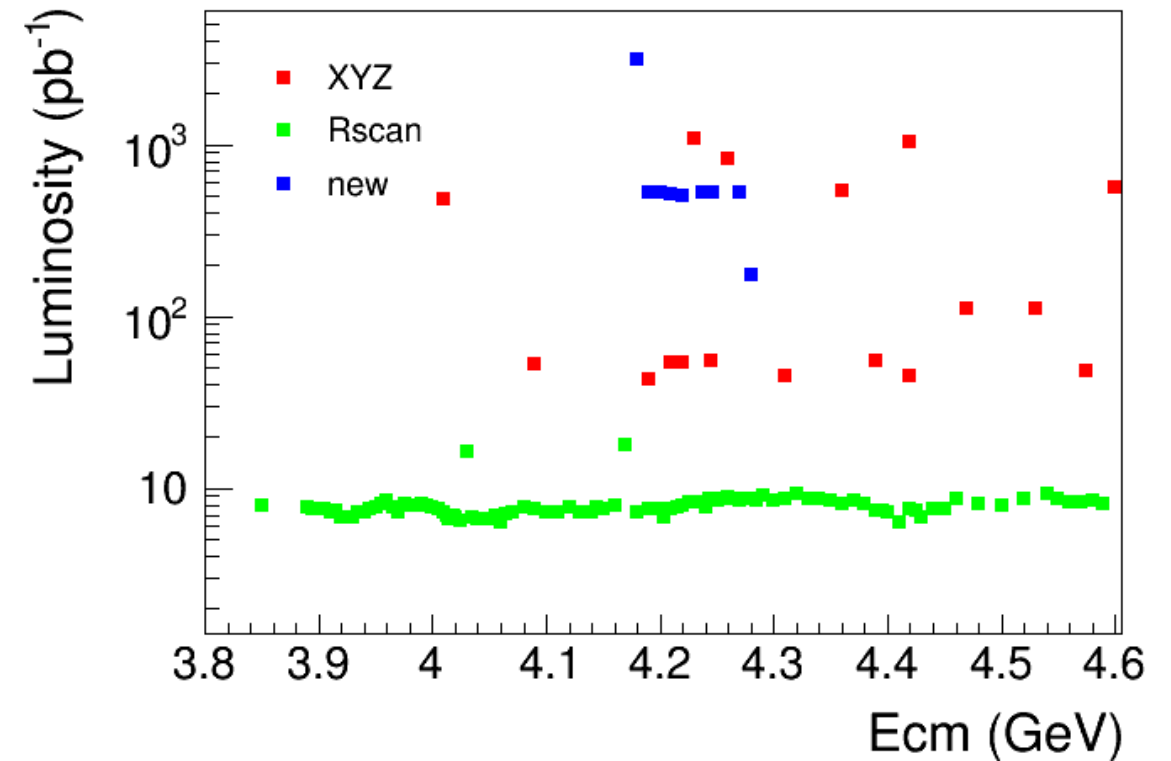


Grow into a baby, but more puzzles came.



BESIII is the ideal place to study and answer why(4260)

Only be produced by e^+e^- annihilation



Recent studies of $Y(4260)$ at BESIII

Hadronic transition

- $\pi^+\pi^-J/\psi$
- $\pi^+\pi^-h_c$
- $\pi^+\pi^-\psi(3686)$
- K^+K^-J/ψ
- ηh_c

Open-charm

- $\pi D^* D$

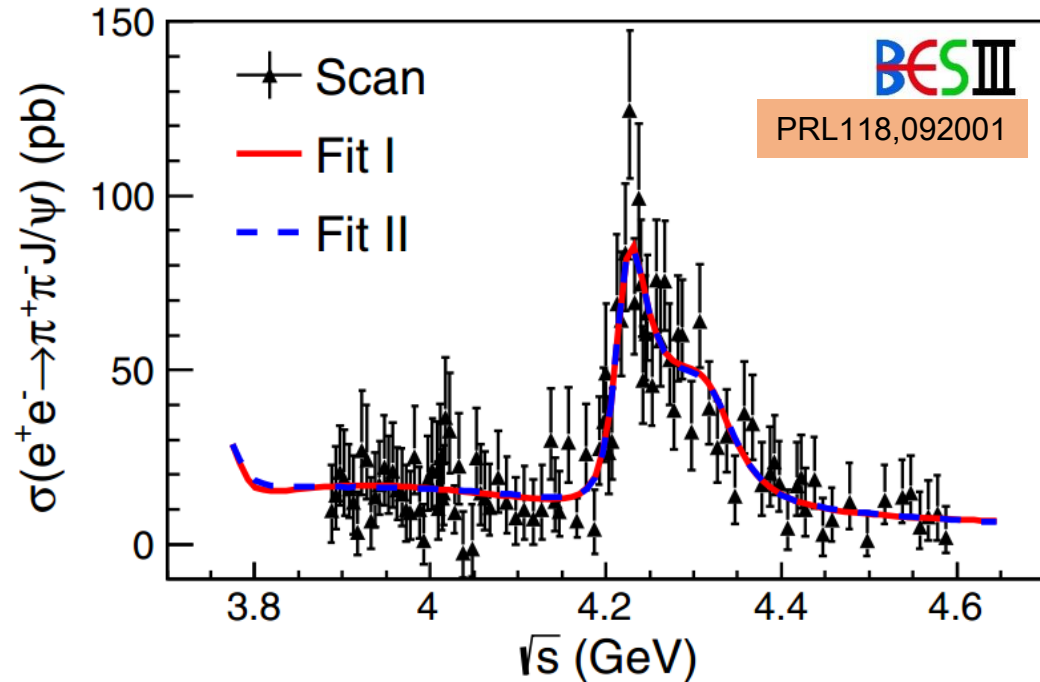
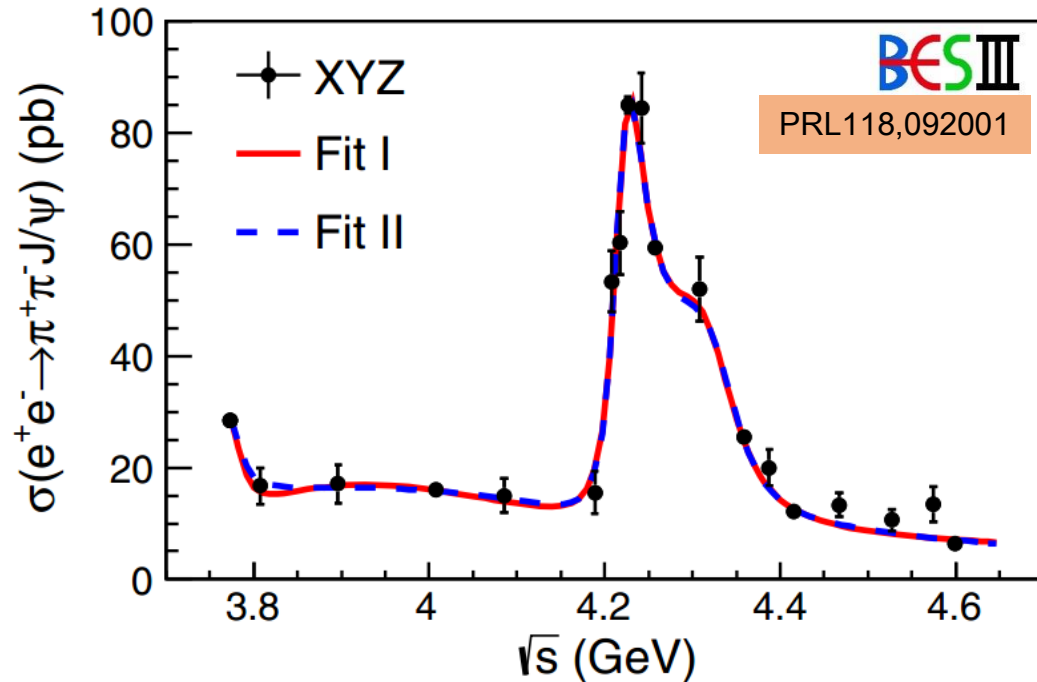
Radiation transition

- $\gamma\eta_c$

Light hadrons

- $p\bar{p}\pi^0, \phi\phi\phi, \phi\phi\omega, \eta Y(2175)$

Cross section measurements of $e^+e^- \rightarrow \pi^+\pi^-J/\psi$



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

Cross section:

$$\sigma(\sqrt{s}) = \frac{N^{\text{sig}}}{\mathcal{L}_{\text{int}}(1 + \delta)\epsilon\mathcal{B}}$$

- The cross section of $e^+e^- \rightarrow \pi^+\pi^-J/\psi$ is measured precisely.
- A shoulder around 4.3 GeV is observed, indicate another state. Breit-Wigner is used to parameterize Y states. Three coherent BW, and an incoherent $\psi(3770)$

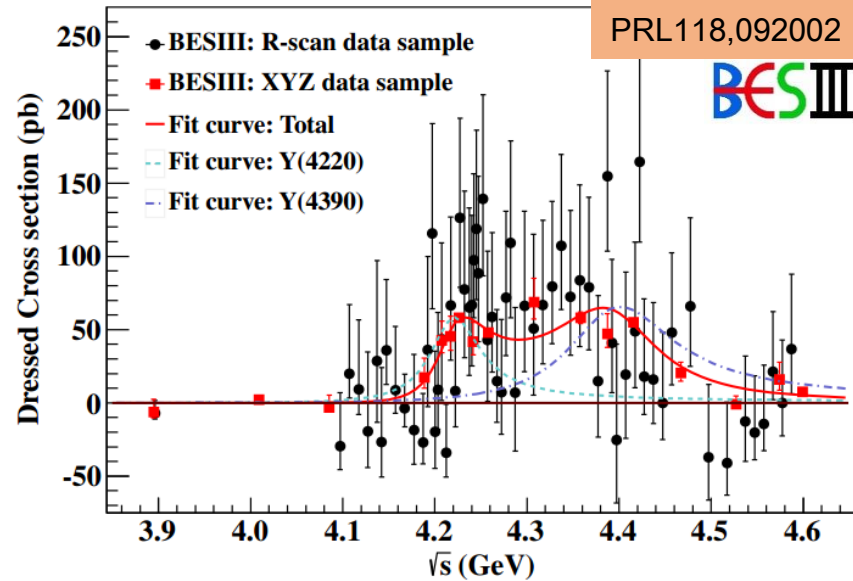
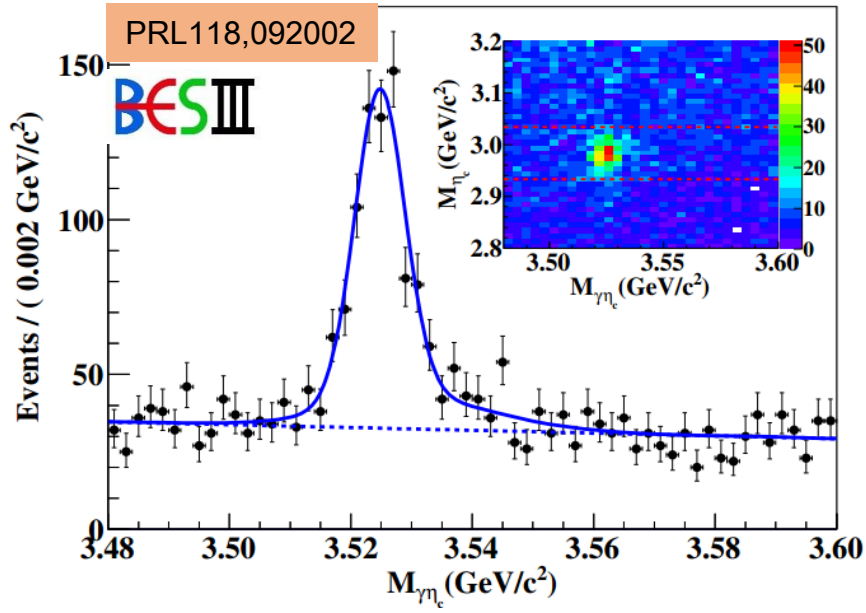
Cross section measurements of $e^+e^- \rightarrow \pi^+\pi^- J/\psi$

Parameters	Fit result
$M(R_1)$	$3812.6_{-96.6}^{+61.9} (\dots)$
$\Gamma_{\text{tot}}(R_1)$	$476.9_{-64.8}^{+78.4} (\dots)$
$M(R_2)$	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)
$\Gamma_{\text{tot}}(R_3)$	$101.4_{-19.7}^{+25.3}$ ($98.2_{-19.6}^{+25.4}$)

- R_1 : not significant, cannot confirm $Y(4008)$
- R_2 : $Y(4260)$, much narrower than previous results
- R_3 : significance 7.9σ , parameters consist with $Y(4360)$
- Fit model from previous results are ruled out with C.L. more than 5.4σ

With more data, the previous $Y(4260)$ split into two states with masses 4220 and 4320 MeV.

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



Decay channel: $e^+e^- \rightarrow \pi^+\pi^-h_c, h_c \rightarrow \gamma\eta_c, \eta_c \rightarrow :$

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

$$\sigma^{\text{dressed}} = \frac{N^{\text{obs}}}{\mathcal{L}(1 + \delta) \sum_{i=1}^{16} \epsilon_i \mathcal{B}(\eta_c \rightarrow X_i) \mathcal{B}(h_c \rightarrow \gamma\eta_c)}$$

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

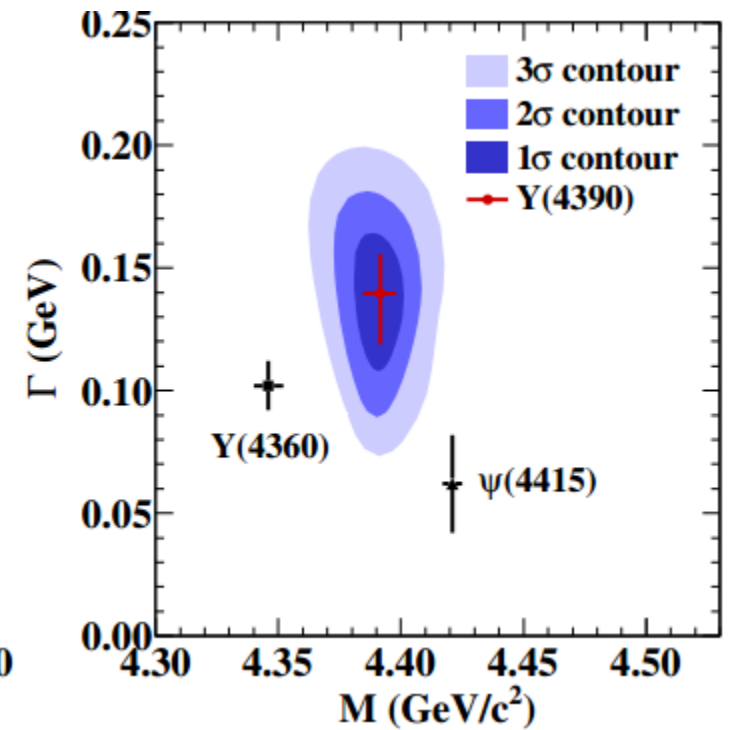
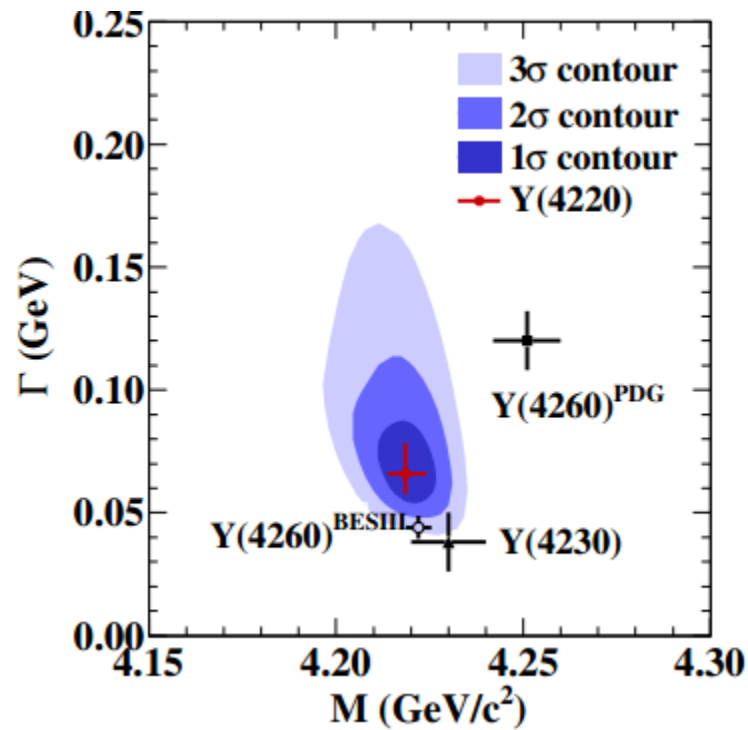
$$\sigma(m) = \left| B_1(m) \sqrt{\frac{P(m)}{P(M_1)}} + e^{i\phi} B_2(m) \sqrt{\frac{P(m)}{P(M_2)}} \right|^2$$

$B_i(m)$: constant width Breit-Wigner function

$P(m)$: 3-body phase space factor

ϕ : relative phase between two resonances

significance of two structures
assumption over one structure
> 10σ



	M (MeV)	Γ_{tot} (MeV)	$\Gamma_{ee} \cdot B$ (eV)	ϕ (rad)
Y(4220)	$4218.4^{+5.5}_{-4.5} \pm 0.9$	$66.0^{+12.3}_{-8.3} \pm 0.4$	$4.6^{+2.9}_{-1.4} \pm 0.8$	--
Y(4390)	$4391.5^{+6.3}_{-6.8} \pm 1.0$	$139.5^{+16.2}_{-20.6} \pm 0.6$	$11.6^{+5.0}_{-4.4} \pm 1.9$	$3.1^{+0.7}_{-0.9} \pm 0.2$

Cross section measurements of $e^+e^- \rightarrow \pi^+\pi^-\psi(3686)$

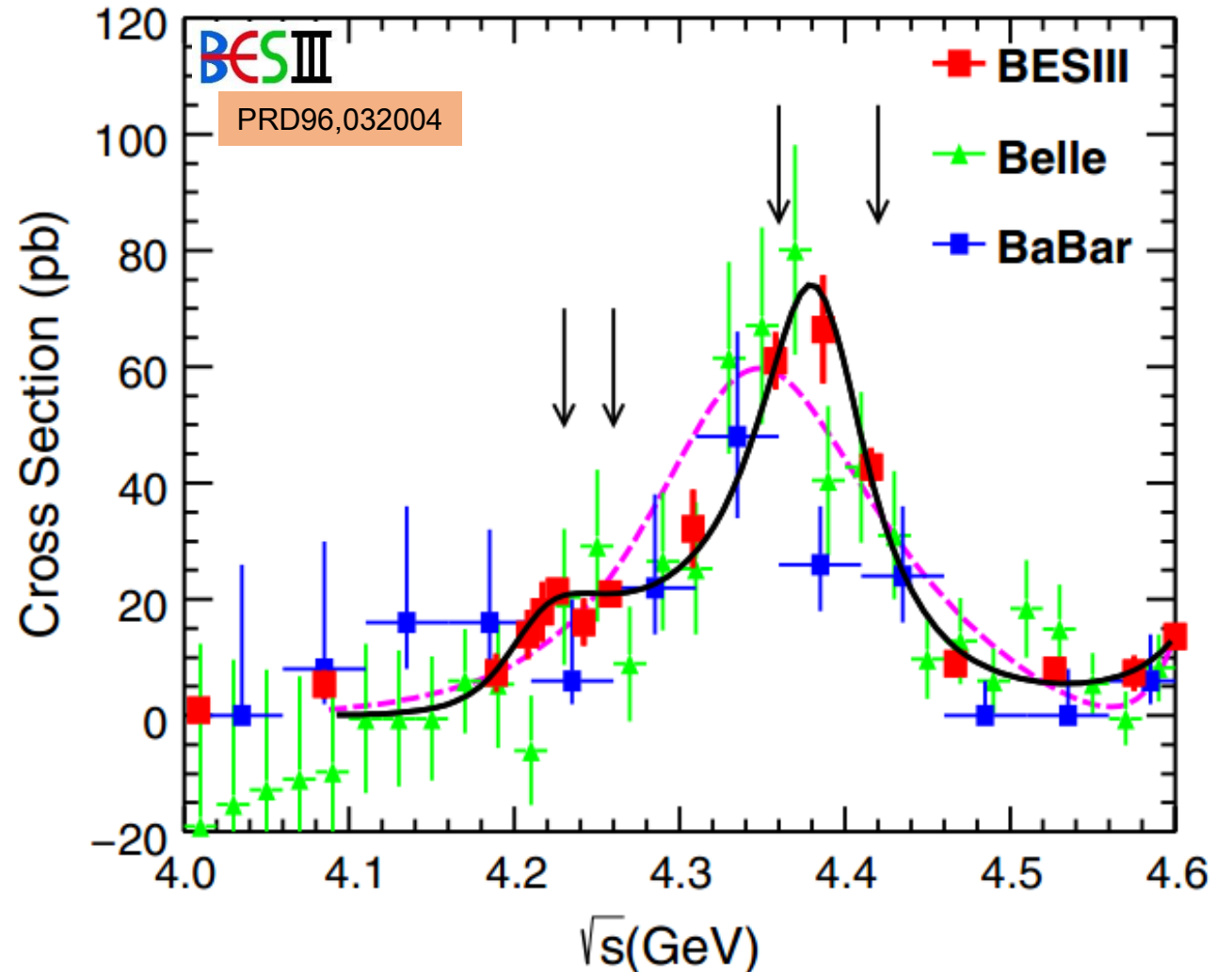
$$\psi(3686) \rightarrow \pi^+\pi^-J/\psi$$

$$\psi(3686) \rightarrow \pi^0\pi^0(\pi^0, \eta, \gamma\gamma)J/\psi$$

- Precision is improved.
- Enhancement at 4.22 GeV,
- Goes higher at 4.6 GeV.

Indicate three states:

$$\mathcal{A} = f_1 e^{i\phi_1} + f_2 + f_3 e^{i\phi_2}$$

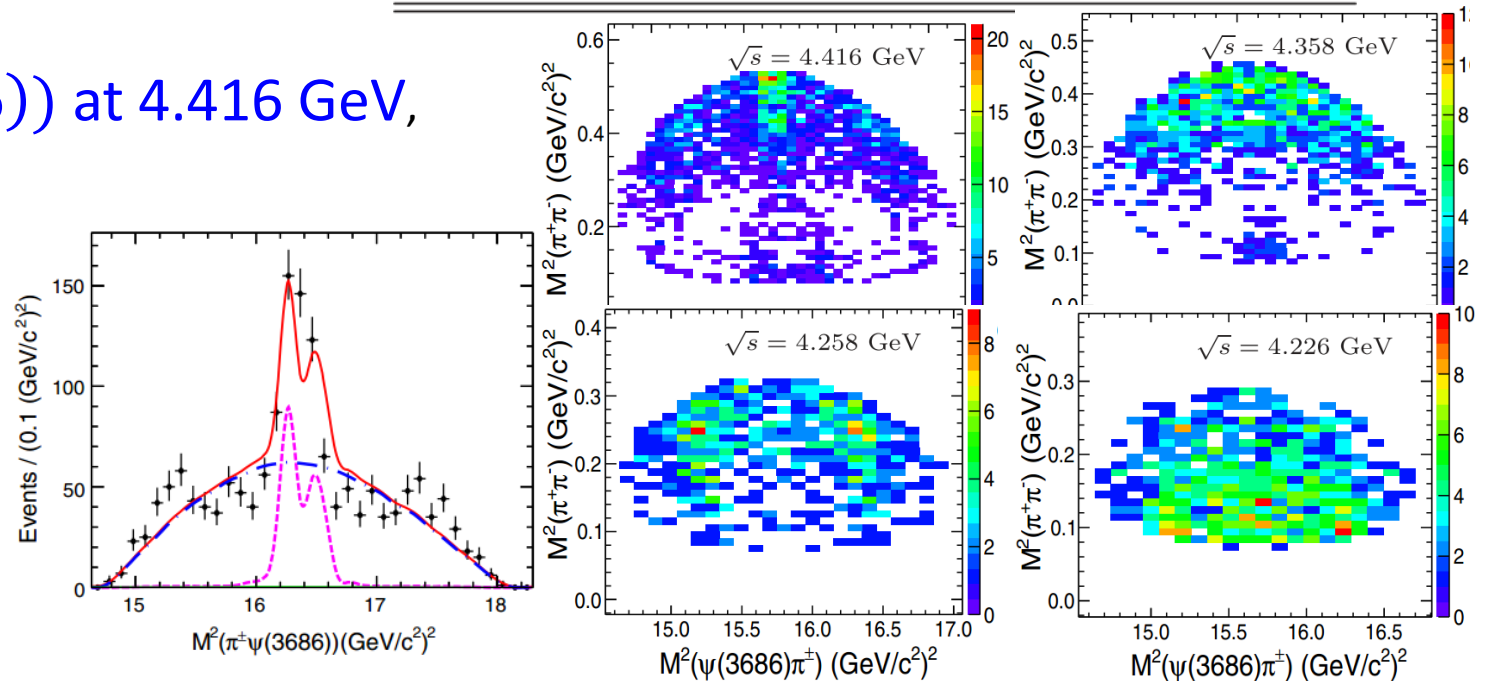


Cross section measurements of $e^+e^- \rightarrow \pi^+\pi^-\psi(3686)$

- $Y(4220)$, significance 5.8σ ,
- both $Y(4220)$ and $Y(4390)$ are consistent with results in $\pi^+\pi^-h_c$

Parameters	Solution I	Solution II
$M(Y4220)$ (MeV/ c^2)	4209.5 ± 7.4	
$\Gamma(Y(4220))$ (MeV)	80.1 ± 24.6	
$\mathcal{B}\Gamma^{e^+e^-}(Y(4220))$ (eV)	0.8 ± 0.7	0.4 ± 0.3
$M(Y4390)$ (MeV/ c^2)	4383.8 ± 4.2	
$\Gamma(Y(4390))$ (MeV)	84.2 ± 12.5	
$\mathcal{B}\Gamma^{e^+e^-}(Y(4390))$ (eV)	3.6 ± 1.5	2.7 ± 1.0
ϕ_1 (rad)	3.3 ± 1.0	2.8 ± 0.4
ϕ_2 (rad)	0.8 ± 0.9	4.7 ± 0.1

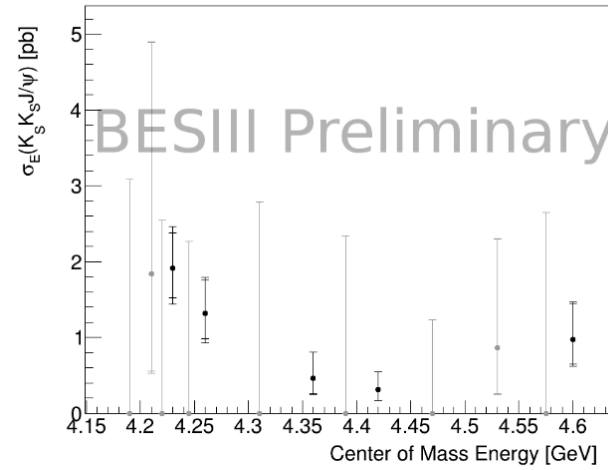
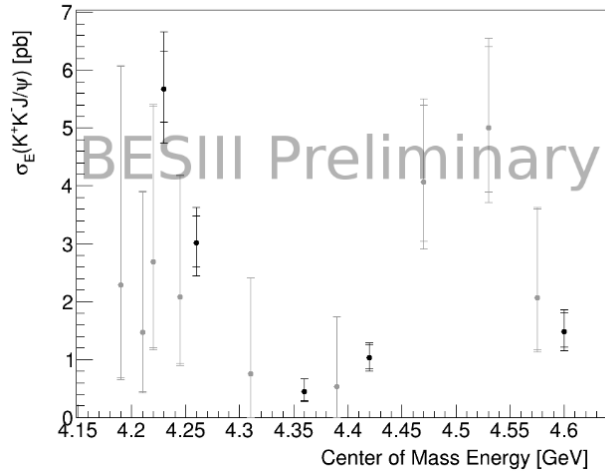
Charge structure in $M(\pi^\pm\psi(3686))$ at 4.416 GeV,
 The 1^+ state is difficult to explain data.
 No evidence from other data samples.



Cross section measurements of $e^+e^- \rightarrow K^+K^-J/\psi$

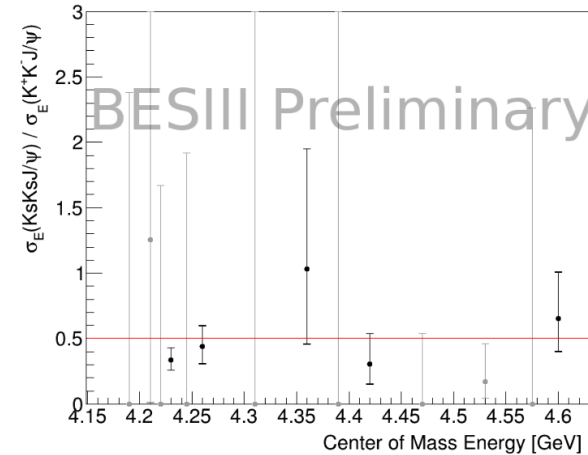
$e^+e^- \rightarrow K^+K^- J/\psi$

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

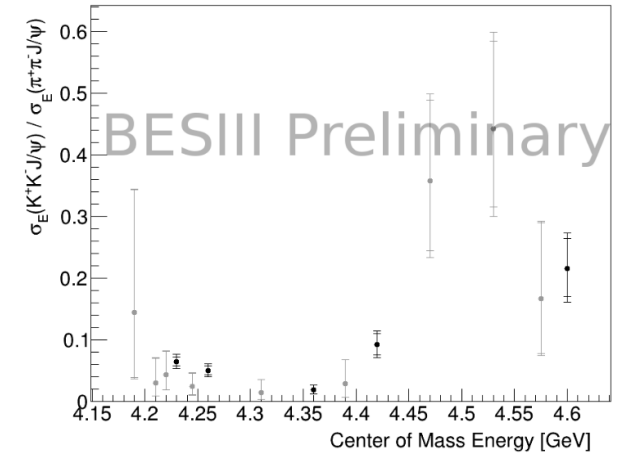


Cross section for K^+K^-J/ψ and $K_S K_S J/\psi$

Energy [GeV]	$\sigma_E(K^+K^- J/\psi)$ [pb]	$\sigma_E(K_S K_S J/\psi)$ [pb]	$\frac{\sigma_E(K_S K_S J/\psi)}{\sigma_E(K^+K^- J/\psi)}$	$\frac{\sigma_E(K^+K^- J/\psi)}{\sigma_E(\pi^+\pi^- J/\psi)}$
4.189	$2.3^{+3.8}_{-1.6} \pm 0.3$	< 5.1	< 2.4	$0.14^{+0.20}_{-0.11} \pm 0.02$
4.208	$1.5^{+2.4}_{-1.0} \pm 0.2$	$1.8^{+3.0}_{-1.3} \pm 0.3$	$1.3^{+2.9}_{-1.2} \pm 0.1$	$0.030^{+0.040}_{-0.021} \pm 0.004$
4.217	$2.7^{+2.7}_{-1.5} \pm 0.4$	< 4.2	< 1.7	$0.043^{+0.038}_{-0.024} \pm 0.006$
4.226	$5.64^{+0.63}_{-0.57} \pm 0.75$	$1.9^{+0.5}_{-0.4} \pm 0.3$	$0.306^{+0.087}_{-0.072} \pm 0.024$	$0.0644^{+0.0072}_{-0.0067} \pm 0.0094$
4.241	$2.1^{+2.1}_{-1.1} \pm 0.3$	< 3.8	< 1.9	$0.024^{+0.022}_{-0.014} \pm 0.004$
4.258	$2.99^{+0.47}_{-0.41} \pm 0.40$	$1.3^{+0.4}_{-0.3} \pm 0.2$	$0.47^{+0.17}_{-0.14} \pm 0.04$	$0.0499^{+0.0076}_{-0.0070} \pm 0.0073$
4.308	$0.7^{+1.7}_{-0.7} \pm 0.1$	< 4.7	< 6.6	$0.015^{+0.020}_{-0.011} \pm 0.002$
4.358	$0.44^{+0.22}_{-0.15} \pm 0.06$	$0.46^{+0.34}_{-0.20} \pm 0.07$	$1.03^{+0.92}_{-0.57} \pm 0.08$	$0.0185^{+0.0080}_{-0.0063} \pm 0.0027$
4.387	$0.5^{+1.2}_{-0.5} \pm 0.1$	< 3.9	< 5.7	$0.028^{+0.039}_{-0.022} \pm 0.004$
4.416	$1.14^{+0.22}_{-0.19} \pm 0.14$	$0.32^{+0.23}_{-0.15} \pm 0.05$	$0.31^{+0.23}_{-0.15} \pm 0.02$	$0.091^{+0.018}_{-0.016} \pm 0.013$
4.467	$4.0^{+1.3}_{-1.0} \pm 0.5$	< 2.1	< 0.5	$0.36^{+0.13}_{-0.11} \pm 0.05$
4.527	$4.3^{+1.4}_{-1.1} \pm 0.7$	$0.86^{+1.43}_{-0.60} \pm 0.13$	$0.17^{+0.29}_{-0.13} \pm 0.01$	$0.44^{+0.14}_{-0.13} \pm 0.06$
4.575	$2.1^{+1.5}_{-0.9} \pm 0.3$	< 4.4	< 2.3	$0.17^{+0.12}_{-0.09} \pm 0.02$
4.600	$1.53^{+0.33}_{-0.27} \pm 0.20$	$1.12^{+0.50}_{-0.35} \pm 0.14$	$0.65^{+0.35}_{-0.25} \pm 0.05$	$0.215^{+0.049}_{-0.045} \pm 0.031$

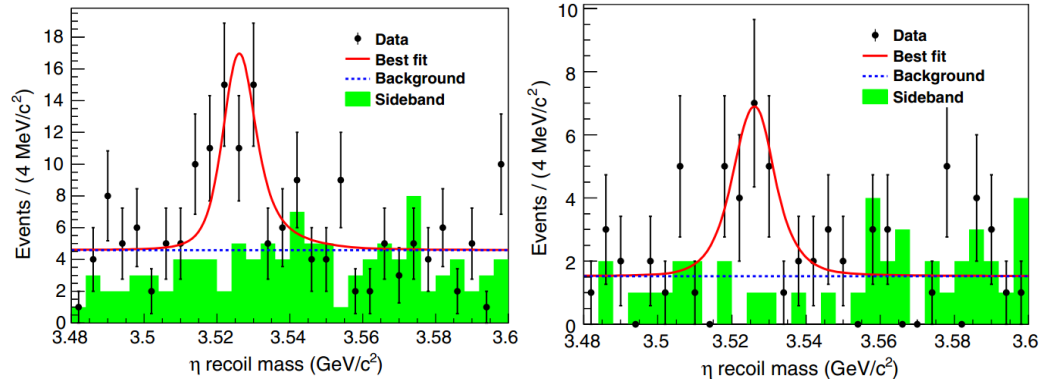


consist with prediction
by isospin symmetry



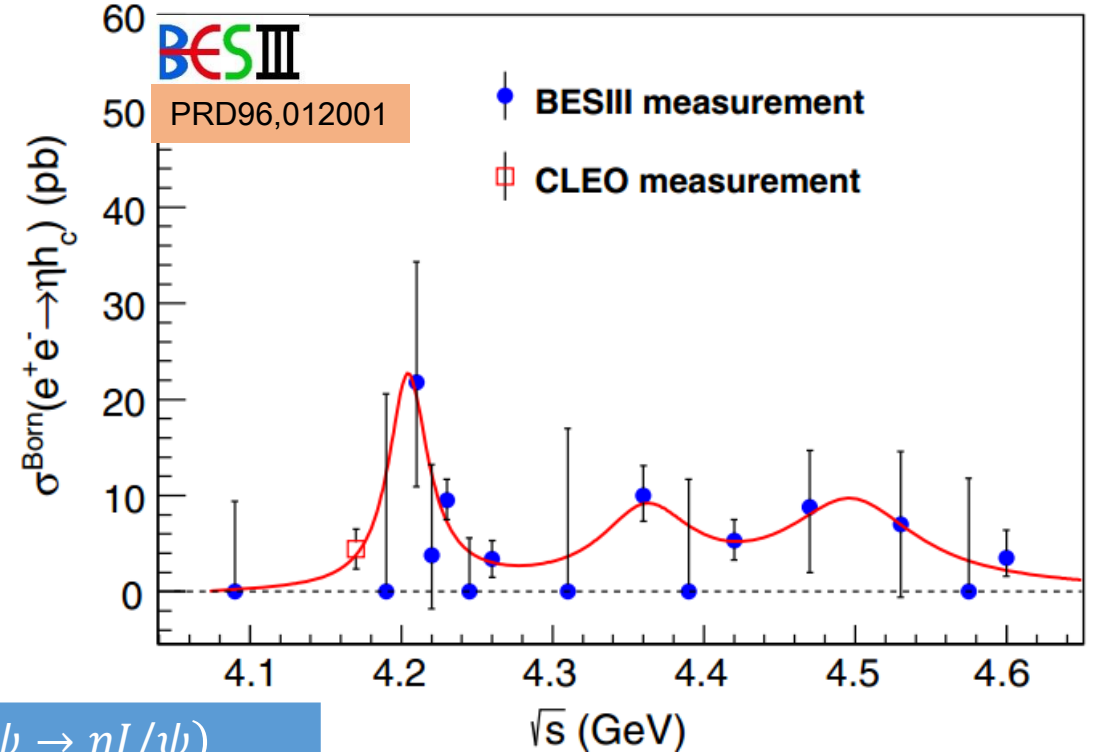
inconsistent with flat ratio.
More complex structure.

Cross section measurements of $e^+e^- \rightarrow \eta h_c$



$\eta \rightarrow \gamma\gamma,$

$h_c \rightarrow \gamma\eta_c, \eta_c \rightarrow 16$ channels



\sqrt{s} (GeV)	$\sigma(e^+e^- \rightarrow \eta h_c)$ (pb)	$\Gamma(\psi \rightarrow \eta h_c)/\Gamma(\psi \rightarrow \eta J/\psi)$
4.226	$9.5^{+2.2}_{-2.0} \pm 2.7$	0.20 ± 0.07
4.358	$10.0^{+3.1}_{-2.7} \pm 2.6$	1.79 ± 0.84

ratio $\Gamma(\psi \rightarrow \eta h_c)/\Gamma(\psi \rightarrow \eta J/\psi)$ are larger than theoretical expectation 0.07887(0.06736) for $\psi(2D)(4S)$ PRD95,114031

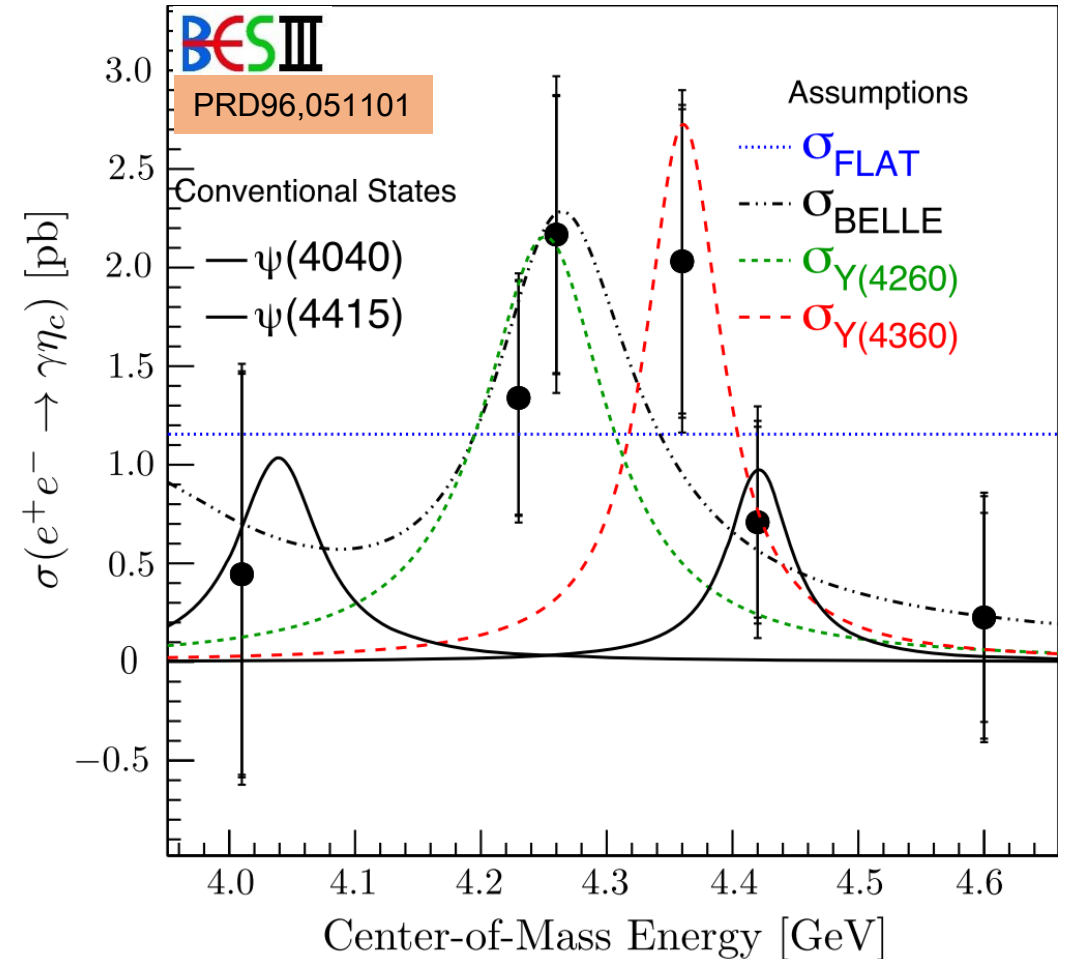
Radiation transition $\gamma\eta_c$

E_{CM} (GeV)	$\sigma(e^+e^- \rightarrow \gamma\eta_c)$ (pb)	sig. (σ)	U.L. (pb)
4.01	$0.44 \pm 1.02 \pm 0.32$	0.4	2.4
4.23	$1.34 \pm 0.59 \pm 0.22$	2.2	2.2
4.26	$2.17 \pm 0.70 \pm 0.39$	3.0	3.2
4.36	$2.03 \pm 0.77 \pm 0.40$	2.7	3.2
4.42	$0.71 \pm 0.48 \pm 0.33$	1.4	1.6
4.60	$0.23 \pm 0.53 \pm 0.35$	0.4	1.4

Better explained by $Y(4260)$ than by other conventional charmonium states.

$$\sigma_{\text{peak}}(e^+e^- \rightarrow \gamma\chi_{c0}) / \sigma_{\text{peak}}(\gamma\eta_c) < 2.8.$$

Decay to $\gamma\eta_c$ will be enhanced relative to $\gamma\chi_{c0}$ if $Y(4260)$ is a hybrid meson. PLB625,212; 628,215.

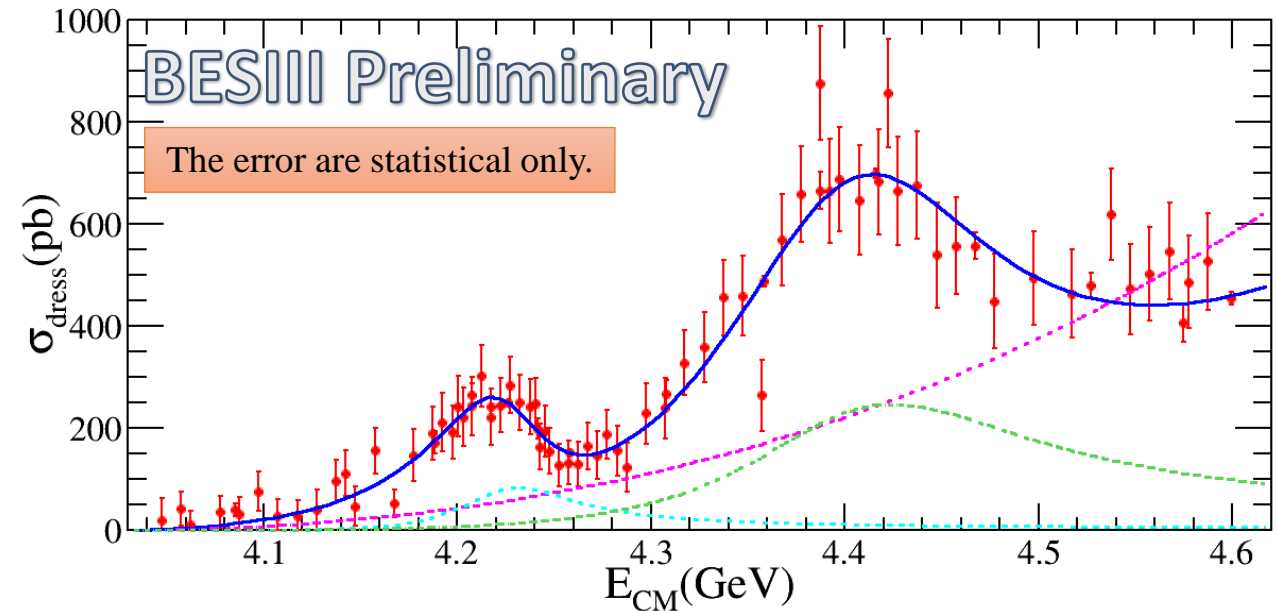


Cross section measurements of $e^+e^- \rightarrow \pi^+ D^0 D^{*-}$

Tag π^+ and $D^0 \rightarrow K^-\pi^+$ of $e^+e^- \rightarrow \pi^+ D^0 D^{*-}$

Parameters	SolutionI	SolutionII	SolutionIII	SolutionIV
c (10^{-4})		5.5 ± 0.6		
M_1 (MeV/ c^2)		4224.8 ± 5.6		
Γ_1 (MeV)		72.3 ± 9.1		
M_2 (MeV/ c^2)		4400.1 ± 9.3		
Γ_2 (MeV)		181.7 ± 16.9		
Γ_1^{el} (eV)	62.9 ± 11.5	7.2 ± 1.8	81.6 ± 15.9	9.3 ± 2.7
Γ_2^{el} (eV)	88.5 ± 15.8	55.3 ± 8.7	551.9 ± 85.3	344.9 ± 70.6
ϕ_1	-2.1 ± 0.1	2.8 ± 0.3	-0.9 ± 0.1	-2.3 ± 0.2
ϕ_2	1.9 ± 0.3	2.3 ± 0.2	2.3 ± 0.1	-1.9 ± 0.1

BESIII
Preliminary

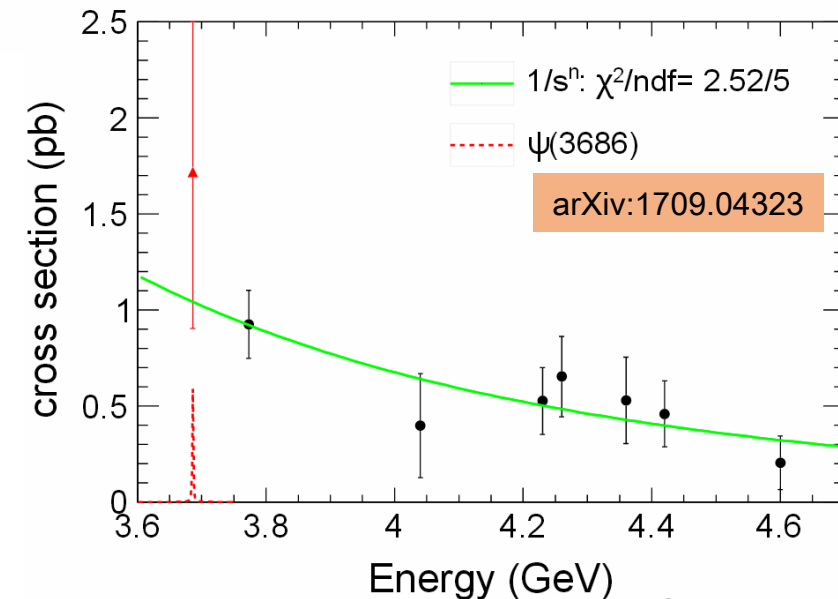
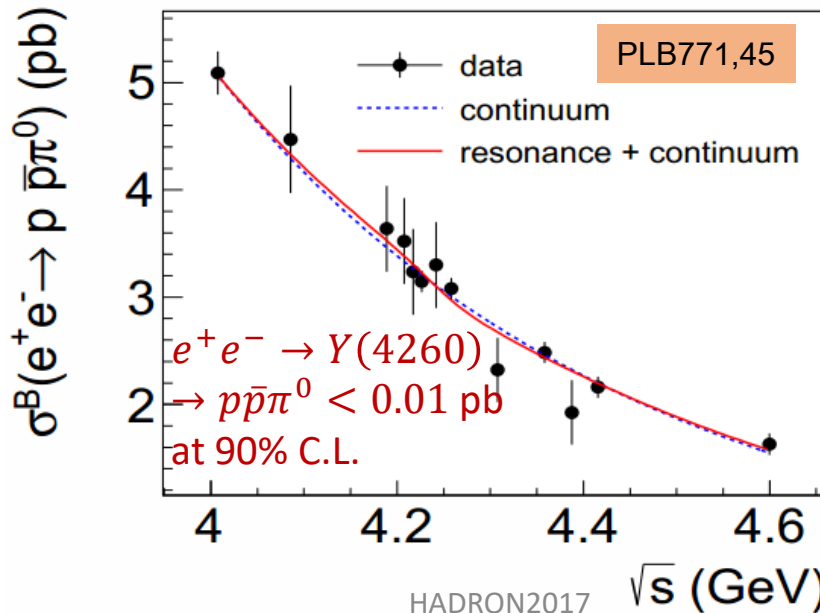
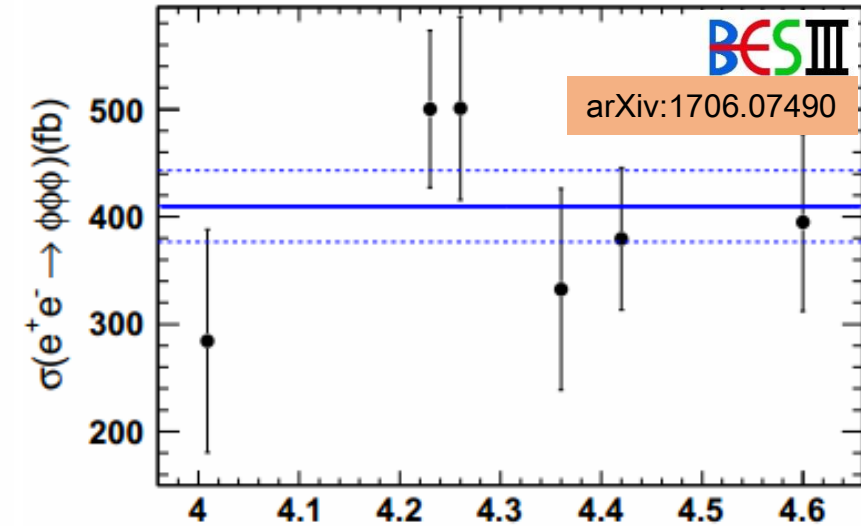
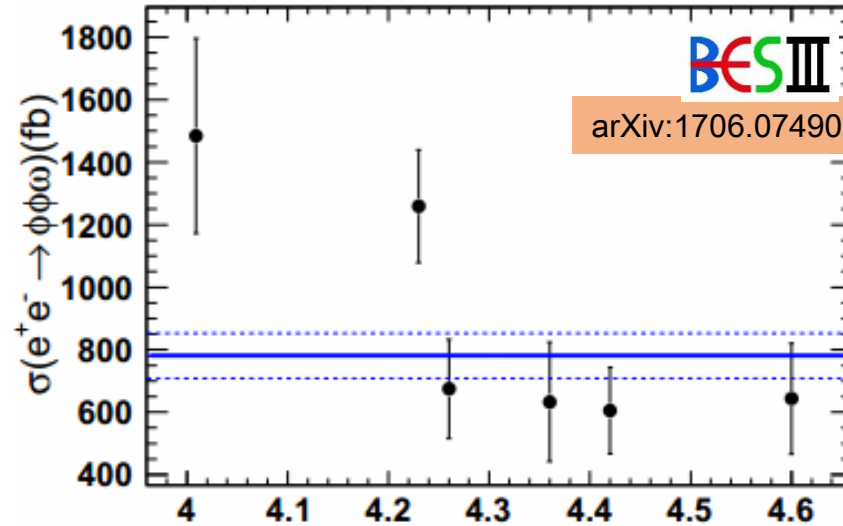


- The statistical significance of two resonances assumption over one is greater than 10σ .
- The resonant parameters of $Y(4220)$ and $Y(4390)$ states are consistent with the structures observed in $e^+e^- \rightarrow \pi^+\pi^-h_c$. The resonant parameters of $Y(4220)$ are also consistent with those of the resonance observed in $e^+e^- \rightarrow \omega\chi_{c0}$ and $e^+e^- \rightarrow \pi^+\pi^-J/\psi$.

Investigate light hadron channels

- several light hadron channels are studied,
- no obvious Y state

- $e^+e^- \rightarrow \phi\phi\omega$ (top left)
- $e^+e^- \rightarrow \phi\phi\phi$ (top right)
- $e^+e^- \rightarrow p\bar{p}\pi^0$ (bottom left)
- $e^+e^- \rightarrow \eta Y(2175)$ (bottom right)

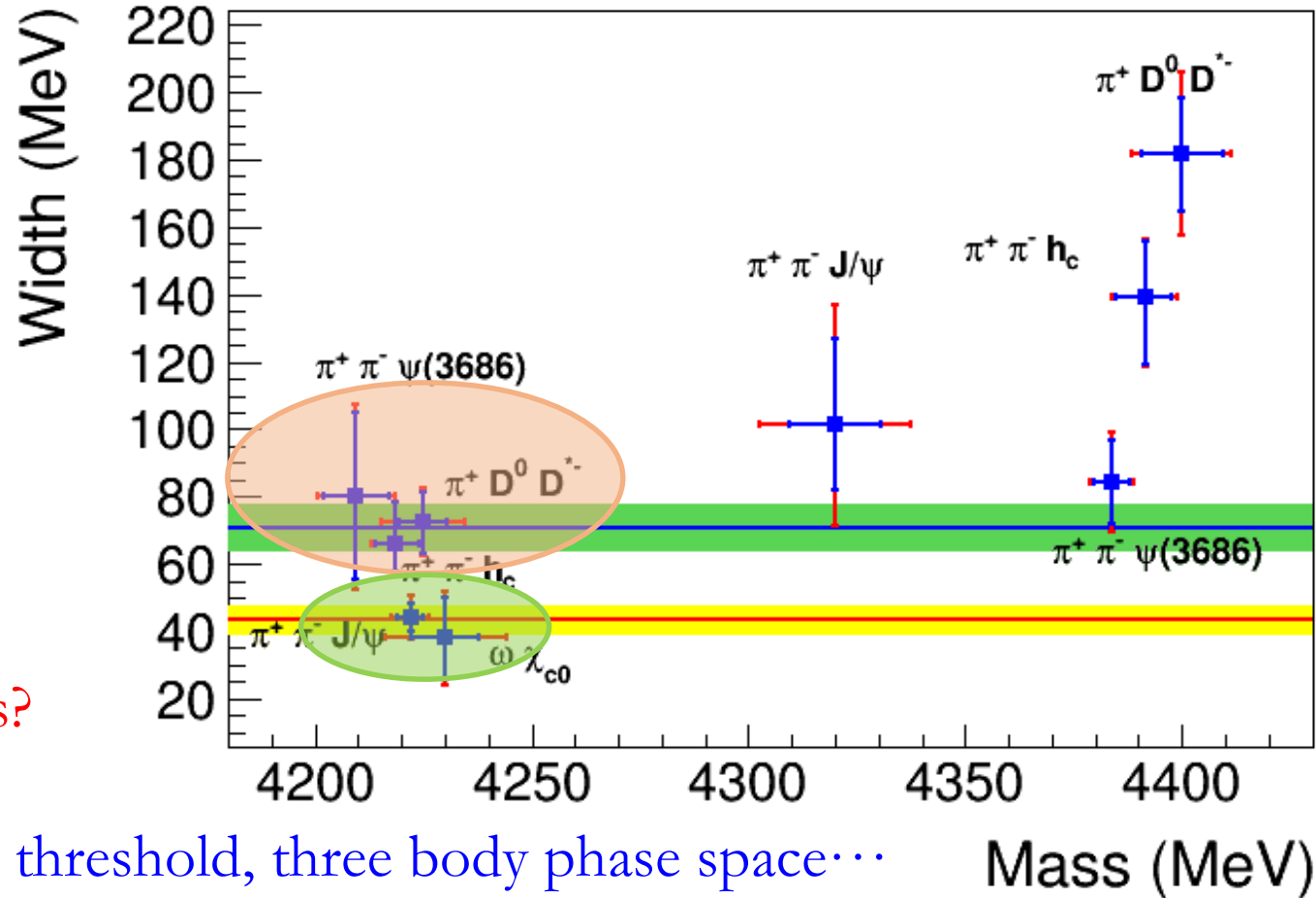




One or two state around
4220 MeV?

If one, why the widths
have so much differences?
 3σ difference.

open-charm($DD_1, D_S^* D_S^*$) threshold, three body phase space...



	$\pi^+ \pi^- J/\psi, \omega \chi_{c0}$	$\pi^+ \pi^- h_c, (\psi(3686)), \pi^+ D^0 D^{*-}$	total
width (MeV)	43.3 ± 4.4	70.9 ± 7.0	52.6 ± 3.6
χ^2/ndf	0.16/1	0.28/2	9.9/4

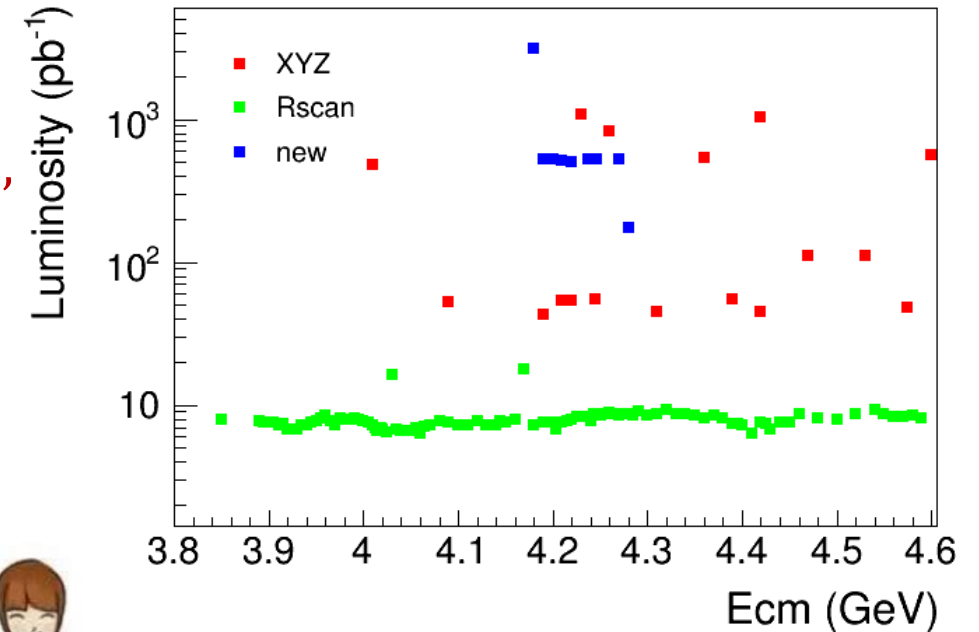
Summary

$Y(4260) \longrightarrow Y(4220)$

- $\omega\chi_{c0}, \pi^+\pi^-h_c, \pi^+\pi^-(K^+K^-)J/\psi, \pi^+\pi^-\psi(3686), \eta h_c, \eta'J/\psi,$ and $\pi^+D^0D^{*-}$ have similar structure around 4220 MeV, could be one state, or two.
- No evidence for $Y \rightarrow \text{light hadron}$.
- More data around 4220 MeV at BESIII, more results will come.

We will know better and better.

Thanks for your attention.



Back-up