Recent results on X from BESIII

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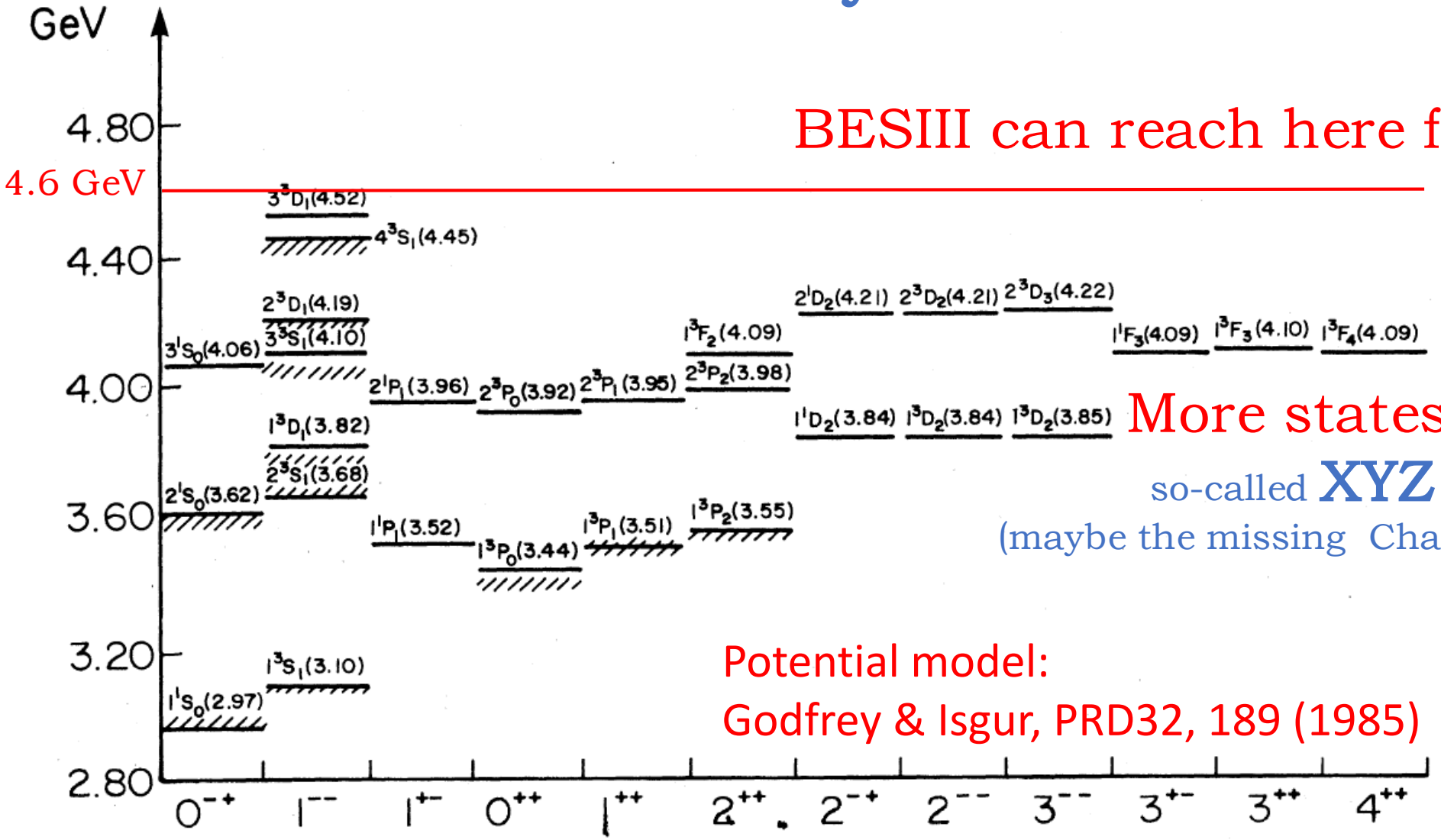
Outline:

- What we can study at BESIII
- Recent results on X

  - Observation of $X(3823)$ $(\psi(1^3D_2))$ (arXiv:1503.08203)
  - Observation of the $e^+e^- \to \gamma X(3872)$ (PRL 112,092001)
  - Improved limit for Γ_{ee} of $X(3872)$ via ISR (arXiv:1505.02559)
  - Search for $Y(4140)$ via $e^+e^- \to \gamma\phi J/\psi$ (PRD 91,032002)

- Summary

What we can study at BESIII



BESIII can reach here for now

More states?

so-called **XYZ**

(maybe the missing Charmonium)

Potential model:

Godfrey & Isgur, PRD32, 189 (1985)

XYZ states

conventional quarkonium $(c\bar{c})$, meson molecule $(c\bar{q}+\bar{c}q)$, tetraquark $(c\bar{c}q\bar{q})$, hybrid state $(c\bar{c}+g\ldots)$ et.al.

X: 1^{++}, et.al

Y: $J^{PC}=1^{--}$

Z: isospin triplet

radiative or hadronic transition from Y

e^+e^- annihilation

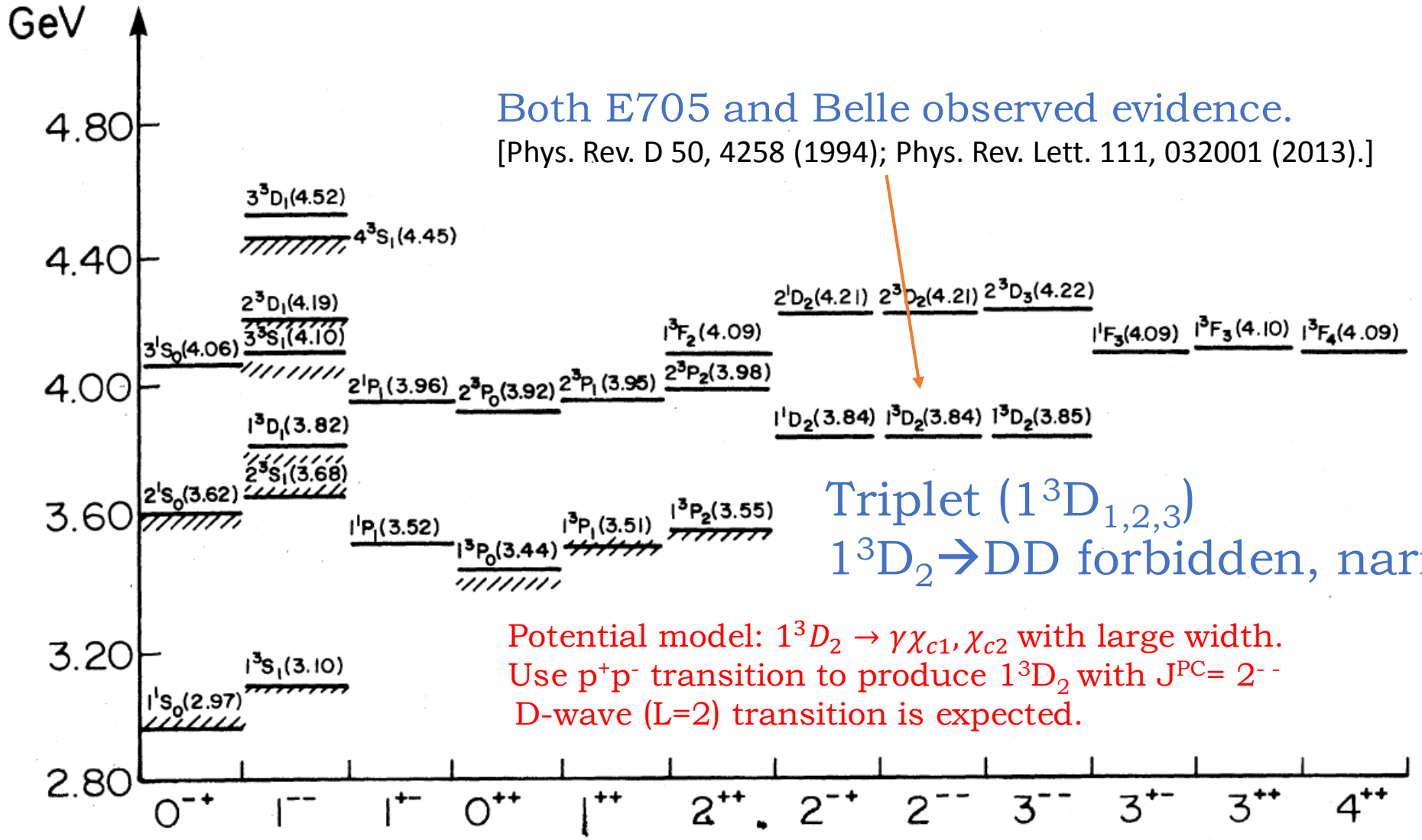
Hadronic transition from Y

$Y\rightarrow\gamma X(3872)$

$Y(4260)\rightarrow\pi Z_c$

Largest data sample around $Y(4260)$ at BESIII,
We can study the relations between X and Y.

Observation of $X(3823)$ $(\psi(1^3D_2))$



Both E705 and Belle observed evidence.

[Phys. Rev. D 50, 4258 (1994); Phys. Rev. Lett. 111, 032001 (2013).]

Triplet ($1^3D_{1,2,3}$)

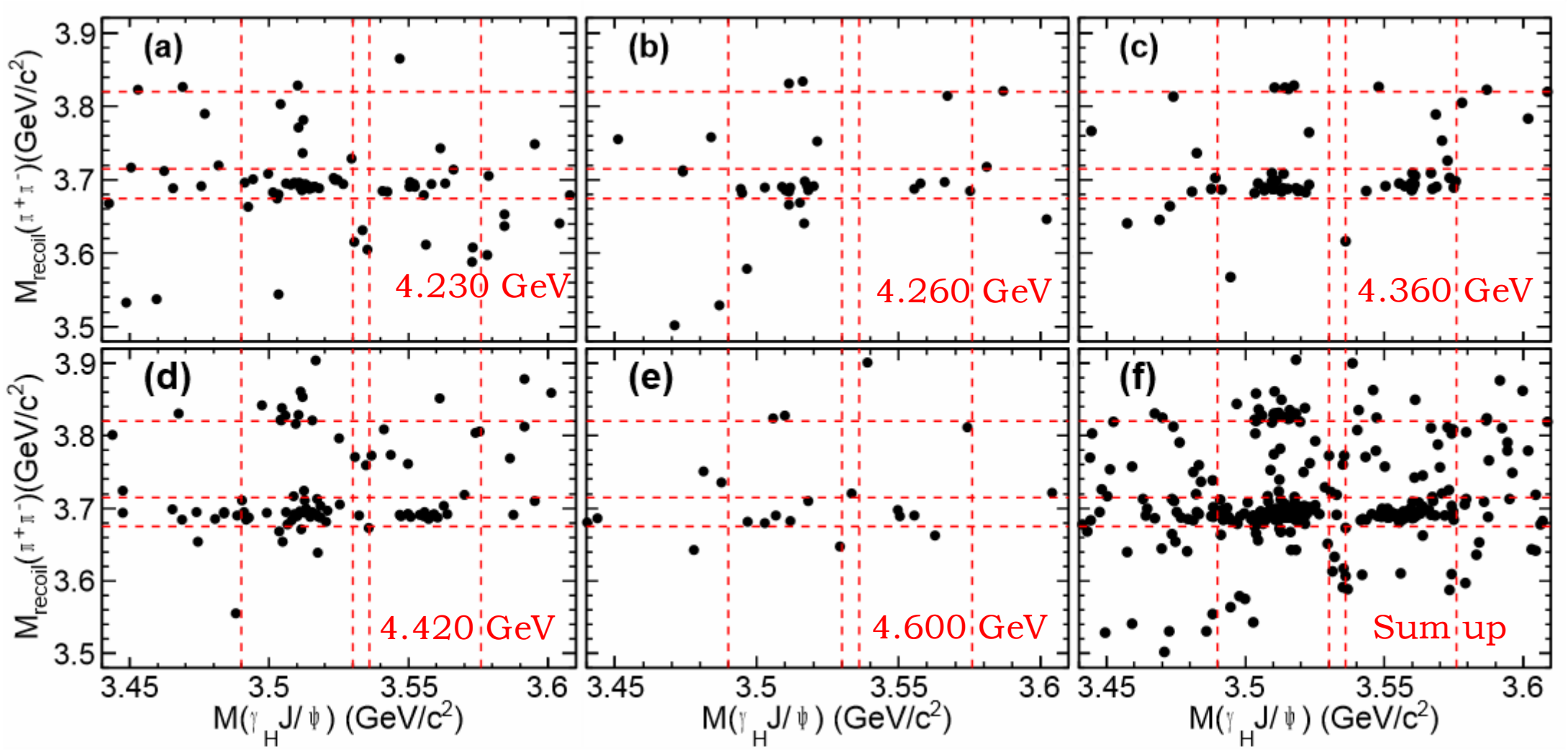
1^3D_2→DD forbidden, narrow

Potential model: $1^3D_2 \rightarrow \gamma\chi_{c1}, \chi_{c2}$ with large width.

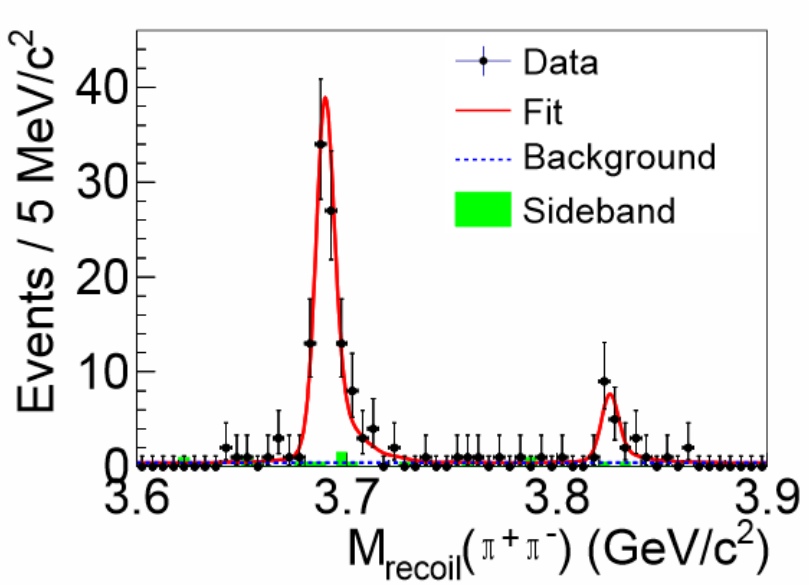
Use p^+p^- transition to produce 1^3D_2 with $J^{PC}= 2^{--}$

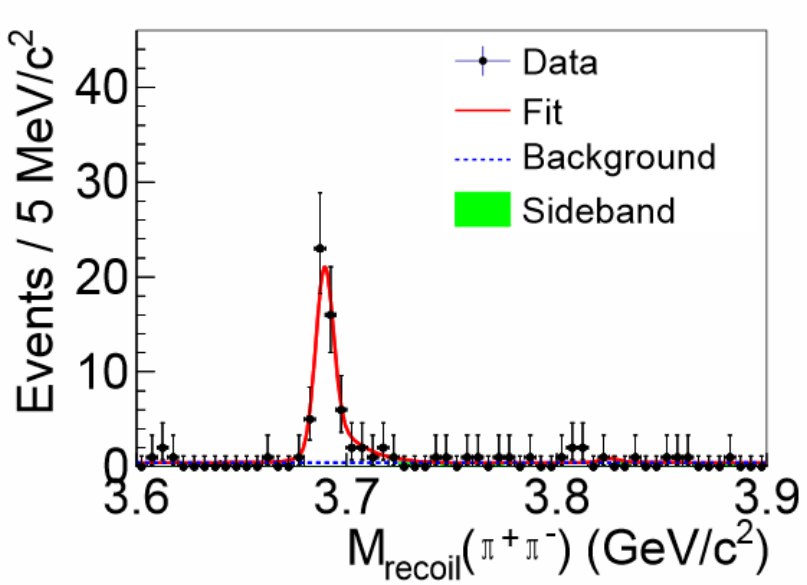
D-wave (L=2) transition is expected.

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



arXiv:1503.08203

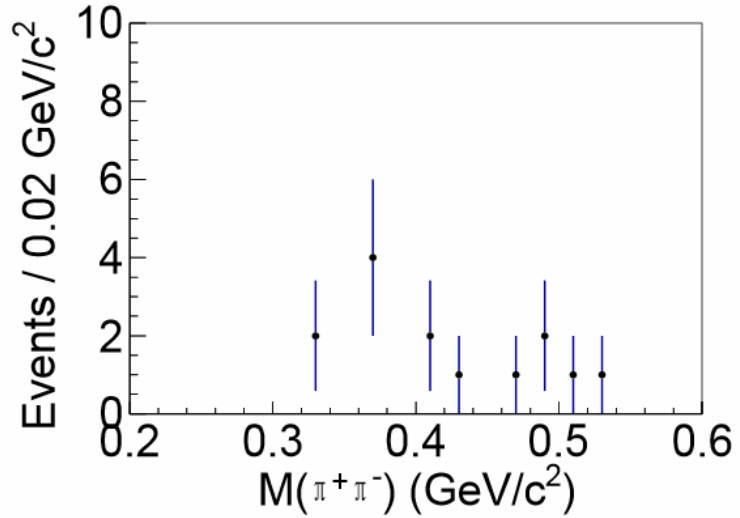


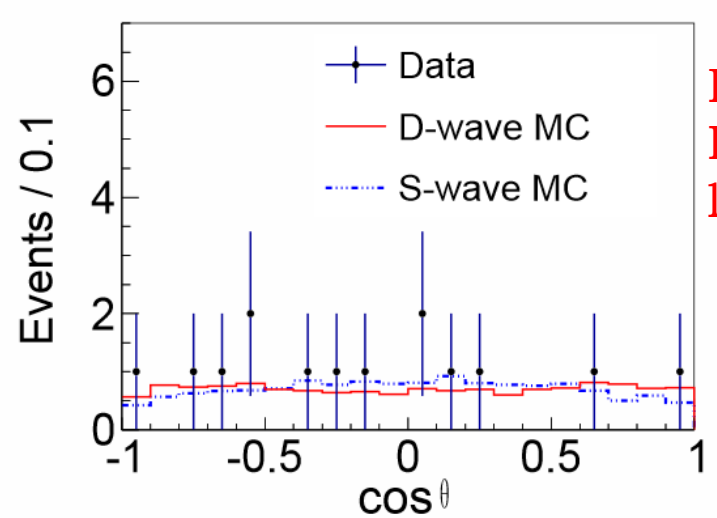


Simultaneous fit of $\gamma\chi_{c1}$ (left) and $\gamma\chi_{c2}$ (right) events

$M\big(X(3823)\big) = (3821.7 \pm 1.3(stat) \pm 0.7(syst))\ \mathrm{MeV}/c^2$

$\Gamma\big(X(3823)\big) < 16\ \mathrm{MeV}$ at 90% C. L. consist with Belle





D-wave is expected.
Limited statistics
limited informations

Born cross section $\sigma[e^+e^- \to \pi^+\pi^- X(3823)] \cdot \mathcal{B}(X(3823) \to \gamma\chi_{c1})$

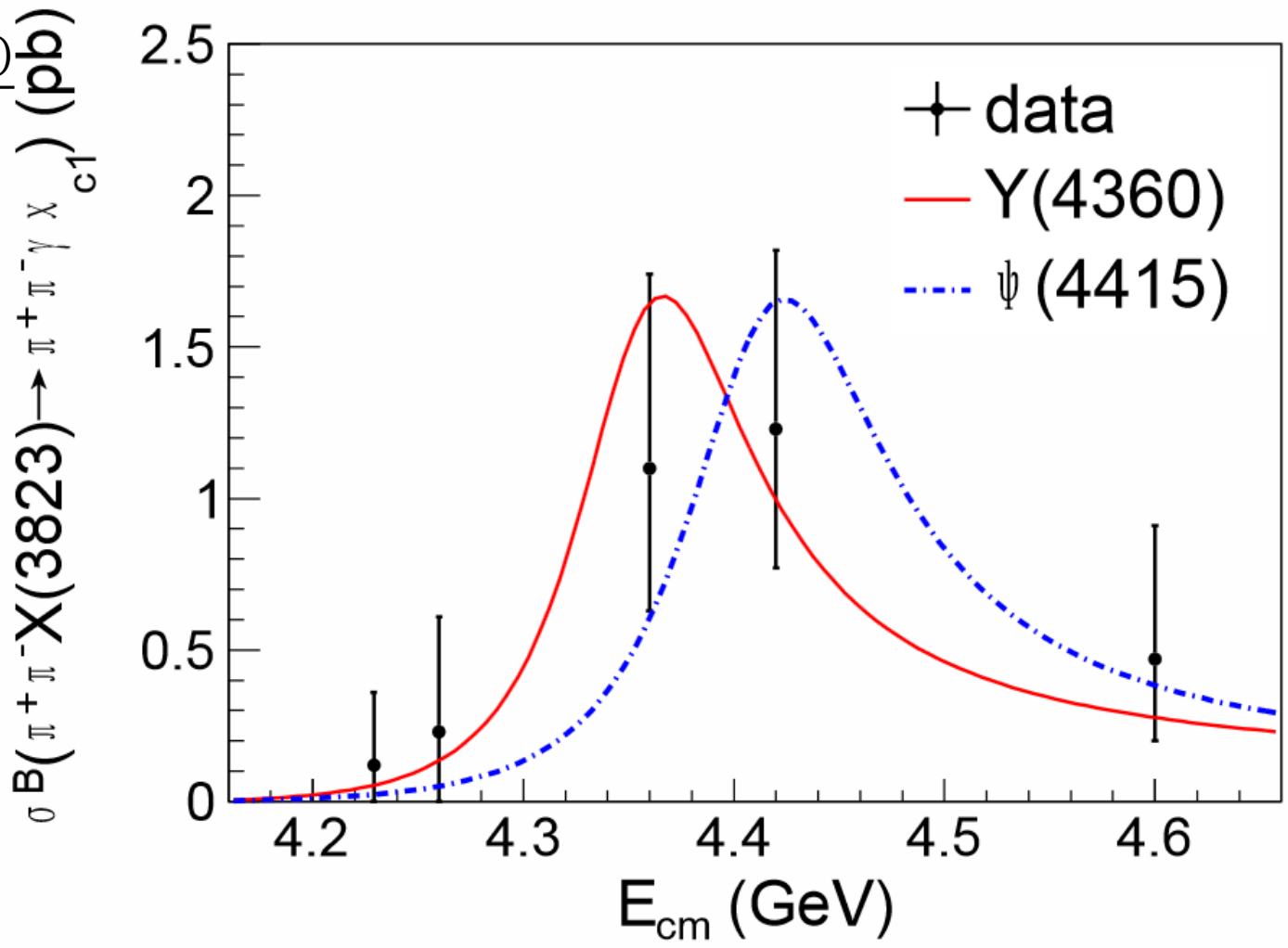
$$\frac{\sigma[e^+e^- \to \pi^+\pi^- X(3823)] \cdot \mathcal{B}(X(3823) \to \gamma\chi_{c1})}{\sigma[e^+e^- \to \pi^+\pi^-\psi'] \cdot \mathcal{B}(\psi' \to \gamma\chi_{c1})}$$

$=0.20^{+0.13}_{-0.10}$ (4.36 GeV)
$=0.39^{+0.21}_{-0.17}$ (4.42 GeV)

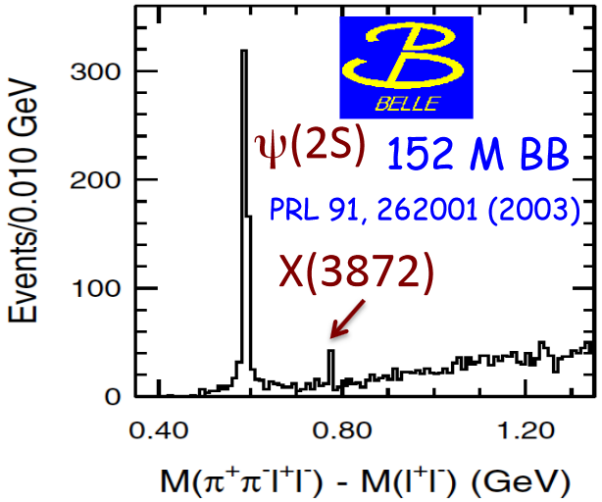
$$\frac{\mathcal{B}(X(3823) \to \gamma\chi_{c2})}{\mathcal{B}(X(3823) \to \gamma\chi_{c1})}$$

< 0.42 at 90% C.L.

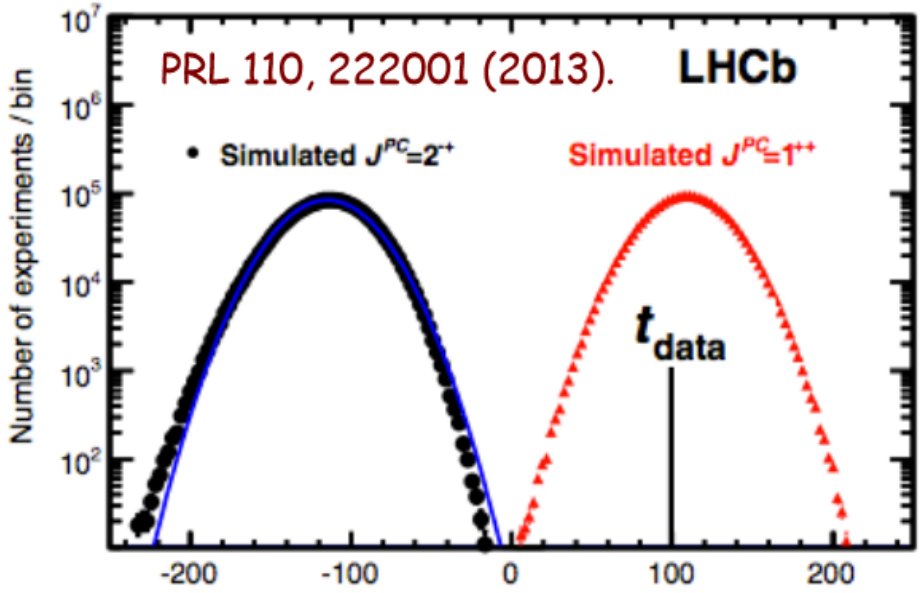
≈ 0.24 (PRD 55,4001)

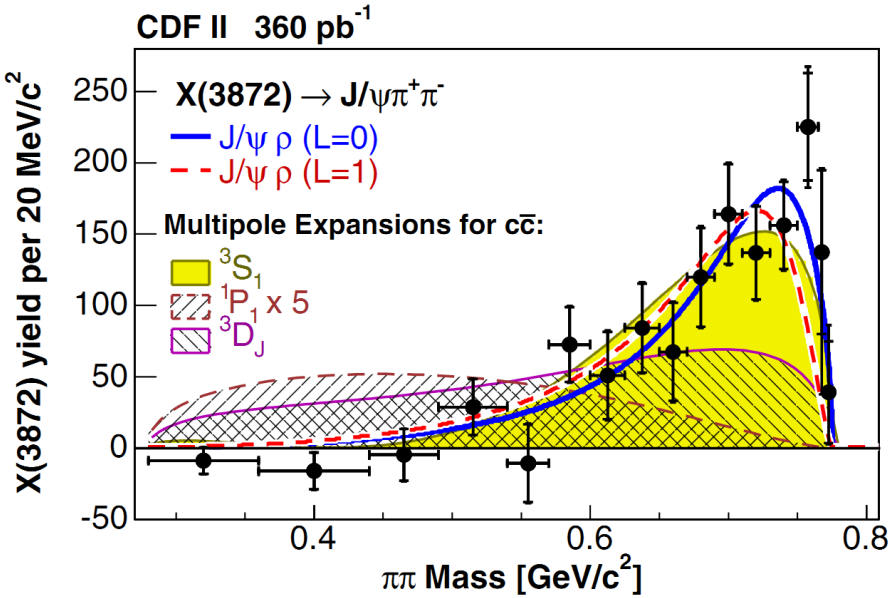


Observation of the $e^+e^- \to \gamma X(3872)$

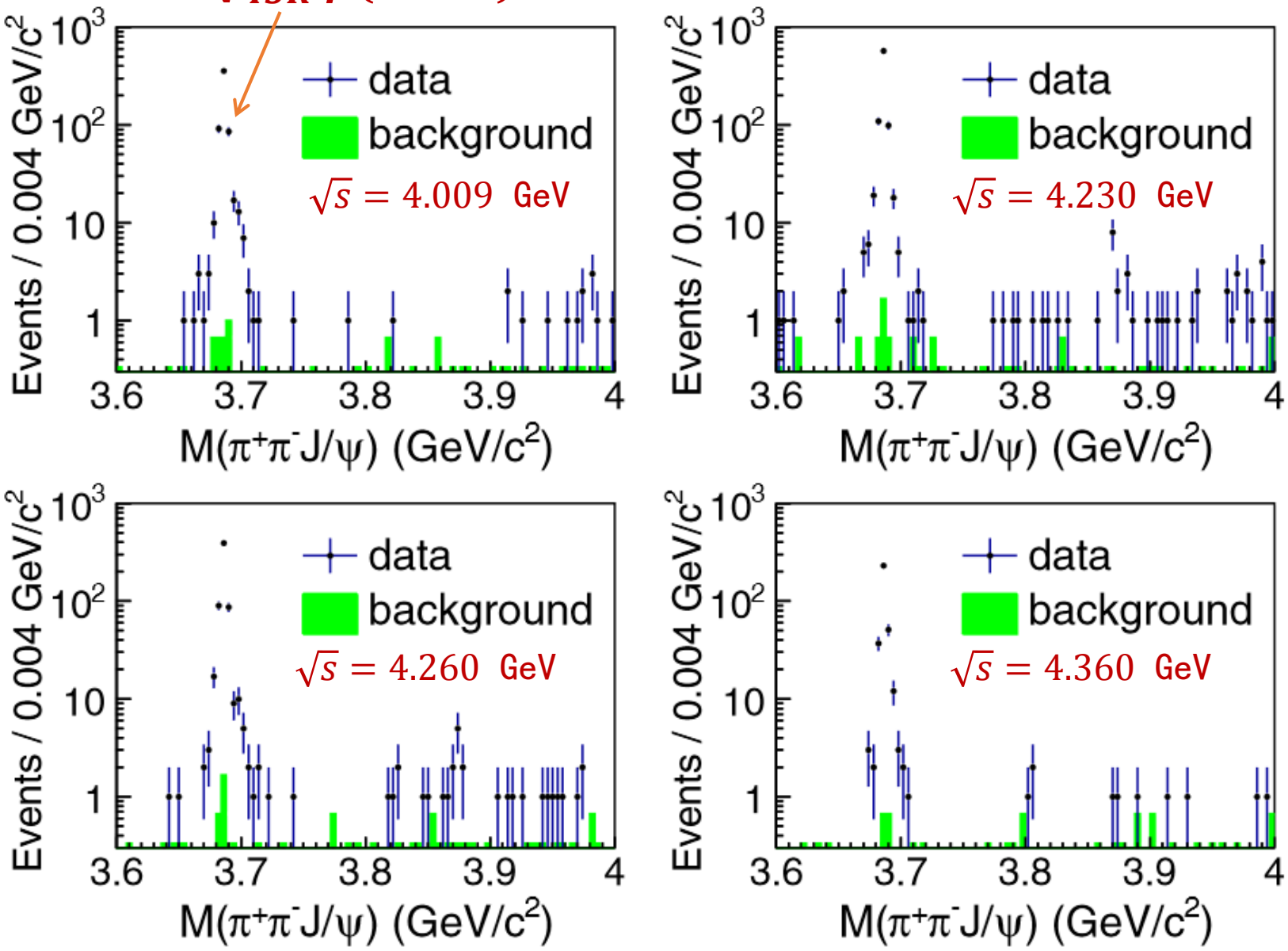


- Observed by Belle, Babar, CDF, LHCb only from B decays and $p\bar{p}$ collision,
- Mass 3871.69±0.17 MeV
- very narrow (< 1.2 MeV)
- close to $D^{*0}D^0$ threshold (~3871.8)
- $J^{PC} = 1^{++}$ (LHCb)
- Hunt it through radiative transition





$\gamma_{ISR}\psi(3686)$, as validation

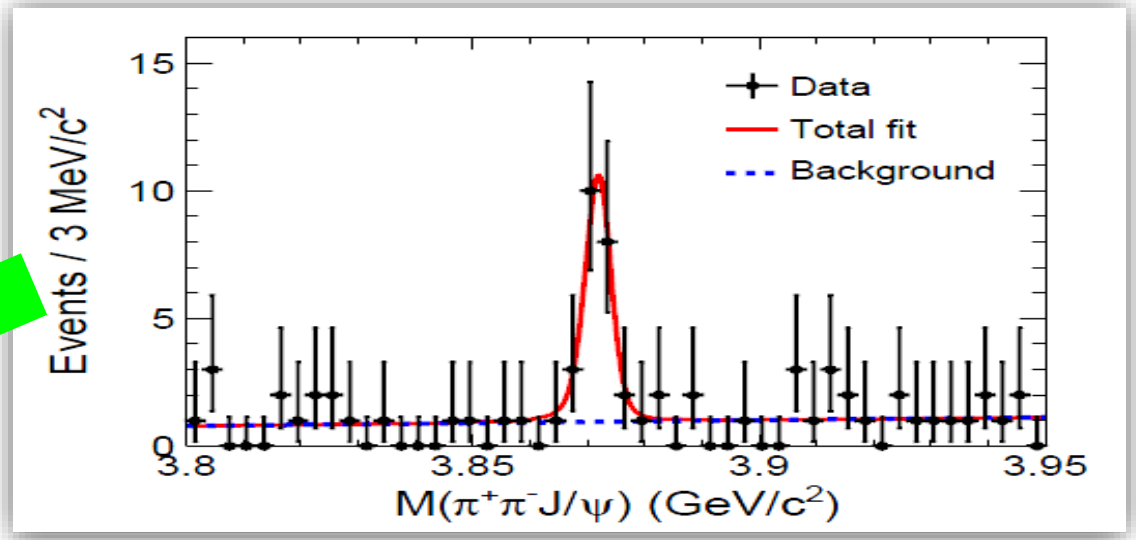


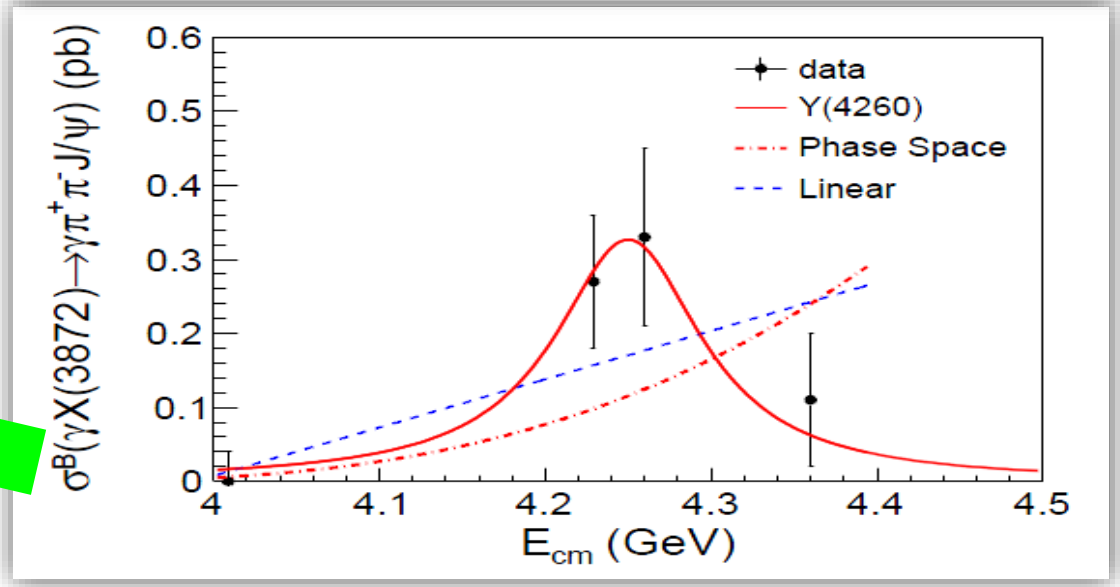
Observation of the $e^+e^- \to \gamma X(3872)$

- M=3871.9±0.7 ± 0.2 MeV
- Summed over all data X(3872) significance = 6.3 s
- Production in Y(4260) decay suggestive,

$\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$=5% (arXiv:0910.3138)

$$R = \frac{\mathcal{B}(Y(4260) \to \gamma X(3872))}{\mathcal{B}(Y(4260) \to \pi^+\pi^- J/\psi)} = 0.1$$





[BESIII RPL112,092001]

Where are they come from?

$Y(4260)$ or narrow structure in $\pi^+\pi^- h_c$

γ

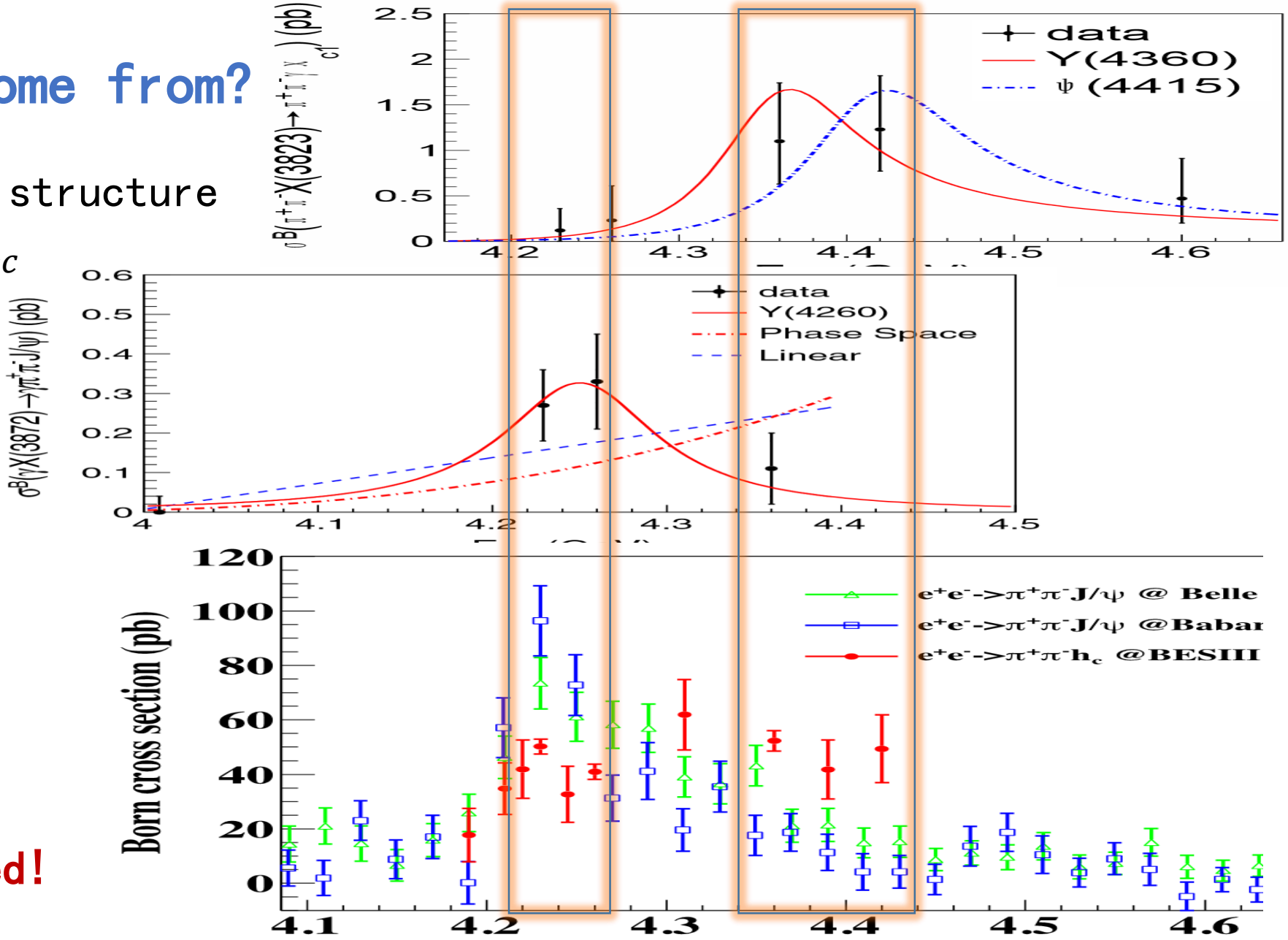
$X(3872)$

$Y(4360)/\psi(4415)$, or broad structure in $\pi^+\pi^- h_c$

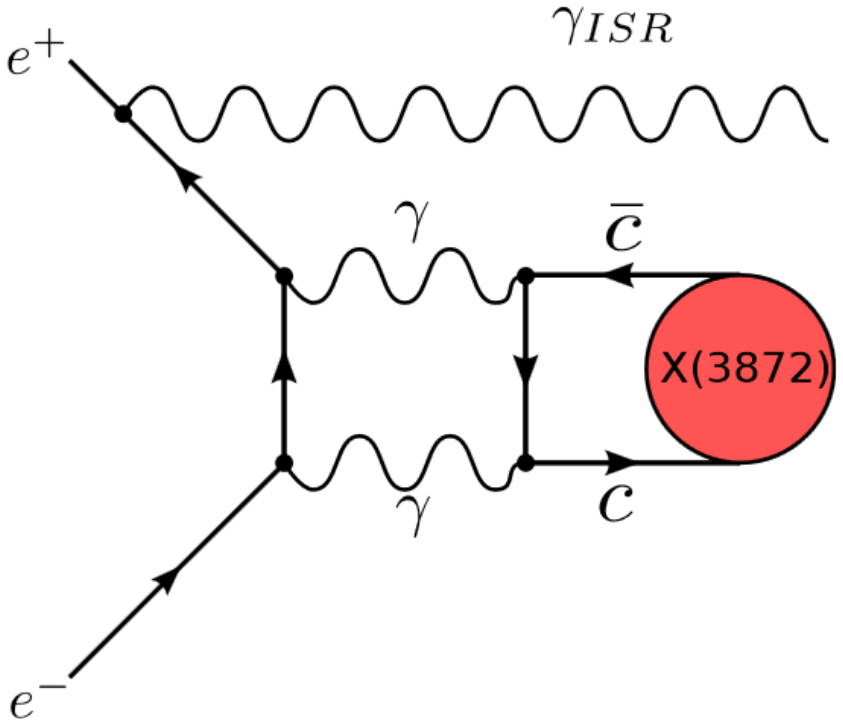
$\pi^+\pi^-$

$X(3823)$

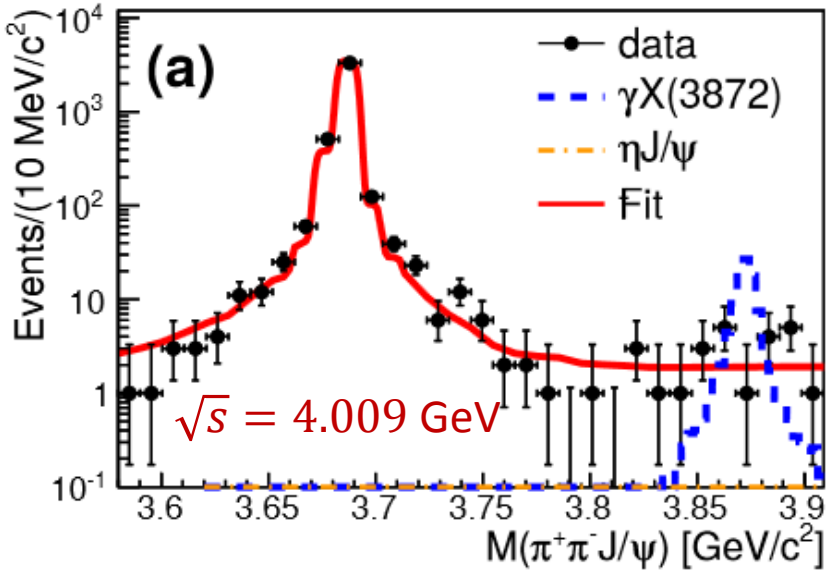
X and Y are related!

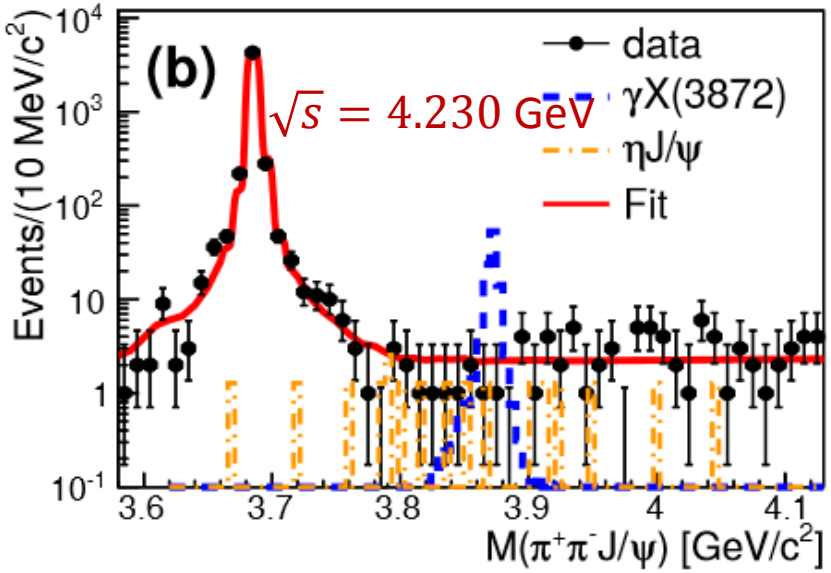


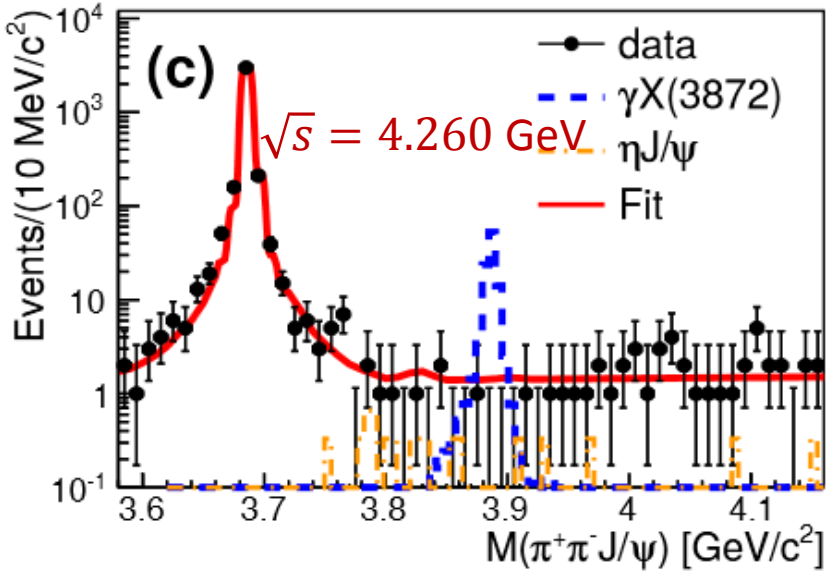
Improved limit for Γ_{ee} of $X(3872)$ via ISR

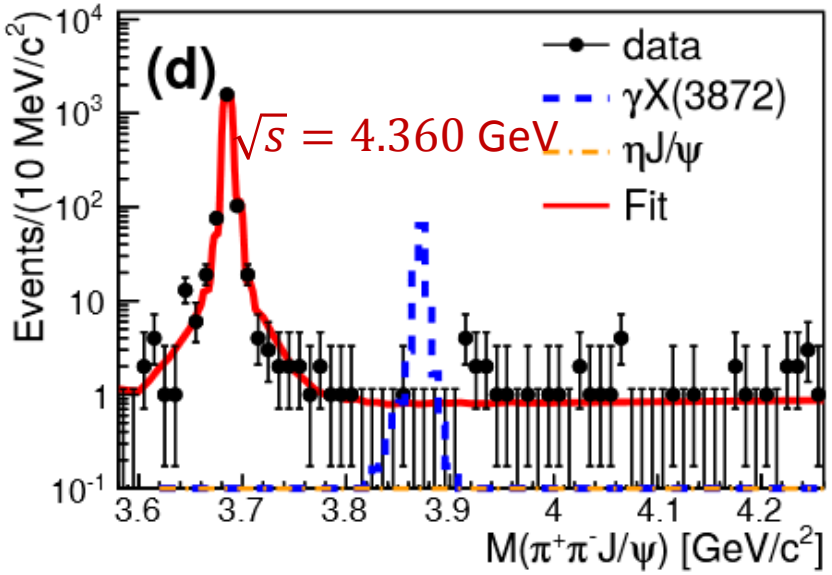


- Many explanations (molecule, tetraquark,$\chi_{c1}(2P)$ et.al)
- Γ_{ee} may help to understand the nature of $X(3872)$
- $J^{PC} = 1^{++}$, can not be produced via single photon but allowed by box diagram
- $\Gamma_{ee}^{X(3872)} \sim 0.03$ eV from VMD model
- $\Gamma_{ee}^{X(3872)} < 280$ eV (current measurement) (PLB 579,74)
- Never been observed directly in e^+e^- anaihilation









Untagged ISR measurement

No obvious signal

$\Gamma_{ee}^{X(3872)}\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$

<0.13 eV at 90% C.L.

Assuming

$\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$ >3%

$\Gamma_{ee}^{X(3872)}$<4.3 eV

Now can reach eV level.

With more data, we can do better.

Search for Y(4140) via $e^+e^- \to \gamma\phi J/\psi$

Exist

CDF (3.8σ) $B^+ \to \phi J/\psi K^+$

CDFII (>5 σ) $B^+ \to \phi J/\psi K^+$
6.0 fb^{-1} at $\sqrt{s} = 1.96$ TeV

CMS $B^+ \to \phi J/\psi K^+$
5.2 fb^{-1} at $\sqrt{s} = 7$ TeV

D0 (3.1σ) $B^+ \to \phi J/\psi K^+$
10.4 fb^{-1} at $\sqrt{s} = 1.96$ TeV

V.S.

or not?

Belle $\gamma\gamma \to \phi J/\psi$
825 fb^{-1} e^+e^- collider

Belle $B^+ \to \phi J/\psi K^+$ 772× 10^6 $\bar{B}B$

LHCb$B^+ \to \phi J/\psi K^+$
0.37 fb^{-1} at $\sqrt{s} = 7$ TeV
(2.4σ) disagreement with CDF

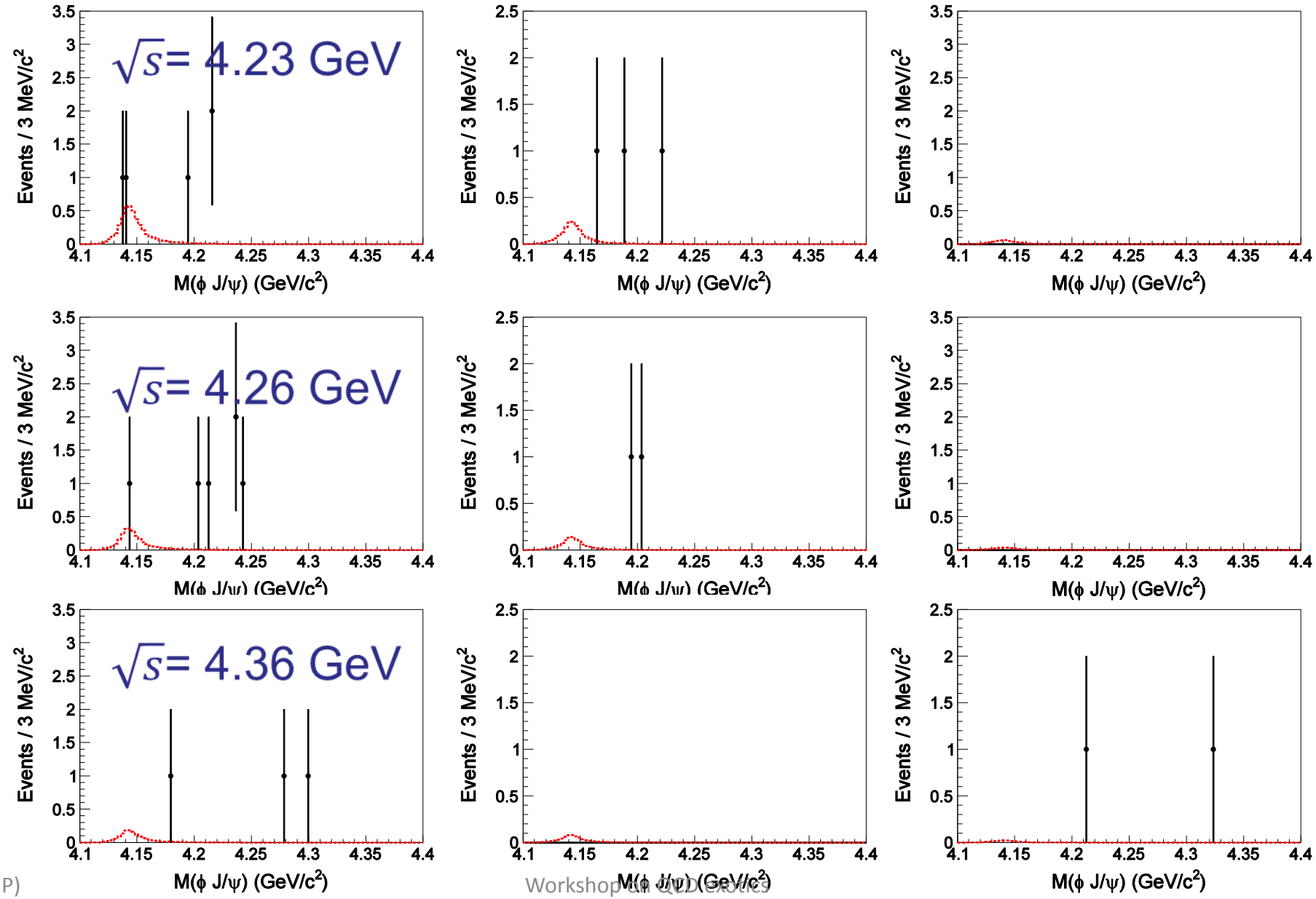
BABAR$B^+ \to \phi J/\psi K^+$ 469× 10^6 $\bar{B}B$

A good candidate for $D_s^*\overline{D_s^*}$ molecular.

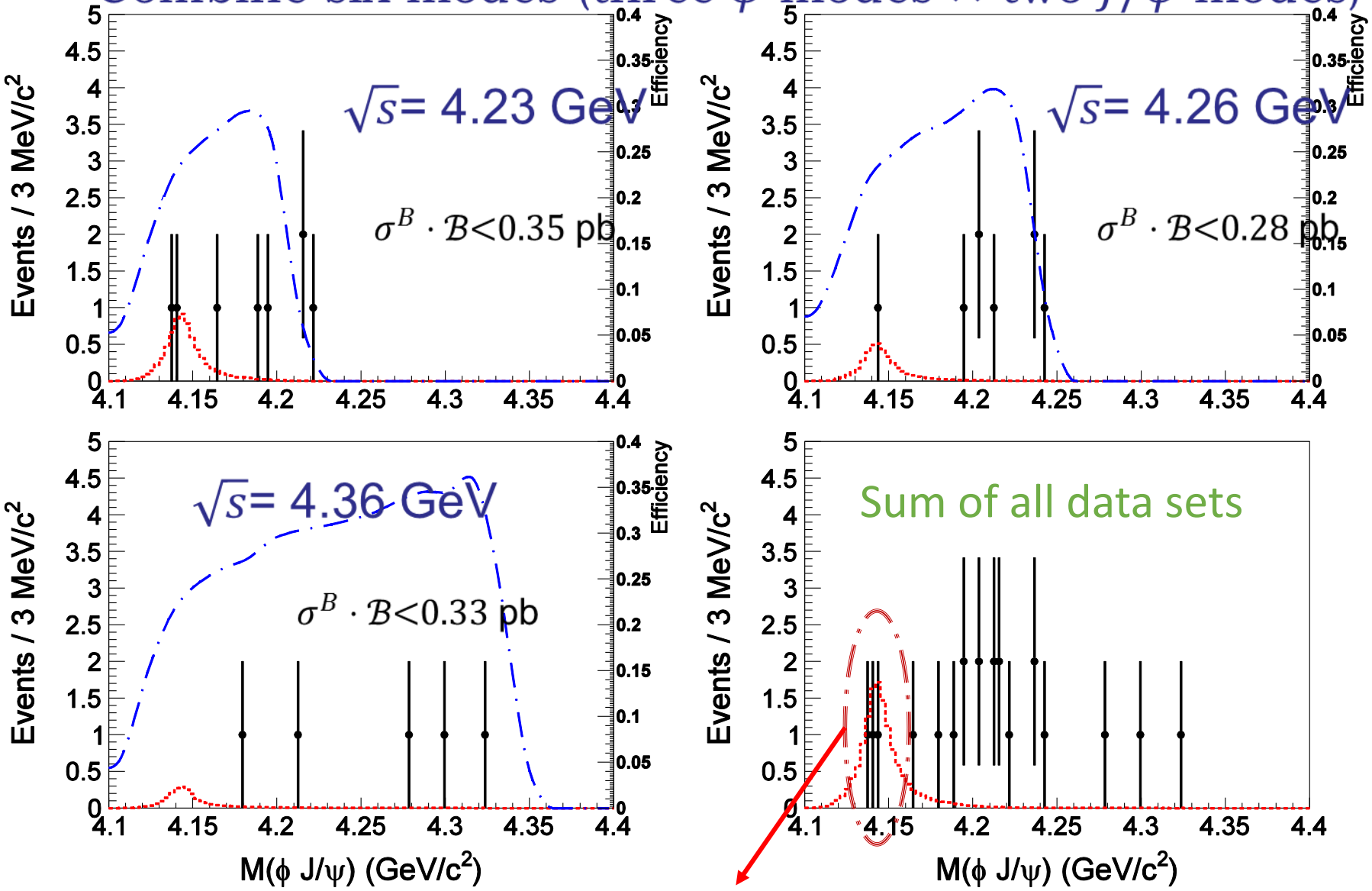
Positive C-parity,
radiative transition of 1^{--} charmonium (-like) states at BESIII?

$e^+e^- \to \gamma\phi J/\psi$, $J/\psi \to e^+e^-/\mu^+\mu^-$
with $\phi \to K^+K^-$ (one Kaon can be missing), $\phi \to K_SK_L$ (K_L is missing) and $\phi \to \pi^+\pi^-\pi^0$

$\phi \to K^+K^-$ $\phi \to K_S^0 K_L^0$ $\phi \to \pi^+\pi^-\pi^0$



Combine six modes (three ϕ modes × two J/ψ modes)



Three events seems like Y(4140).
No background from MC studies

No significant $Y(4140)$ signal.

Upper limit at the 90% C.L. for $\sigma^B \cdot \mathcal{B} = \sigma^B\left(e^+e^- \to \gamma Y(4140)\right) \cdot \mathcal{B}(Y(4140) \to \phi J/\psi)$

$\sqrt{s}$ (GeV/c^2)	Luminosity (pb^{-1})	$(1+\delta)$	n^{prod}	$\sigma^B \cdot \mathcal{B}$ (pb)
4.23	1094	0.840	<339	<0.35
4.26	827	0.847	<207	<0.28
4.36	545	0.944	<179	<0.33

Systematic uncertainty is considered.

Compared with $X(3872)$ production. PRL 112, 092001

$$\sigma^B\left(e^+e^- \to \gamma X(3872)\right) \cdot \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$$

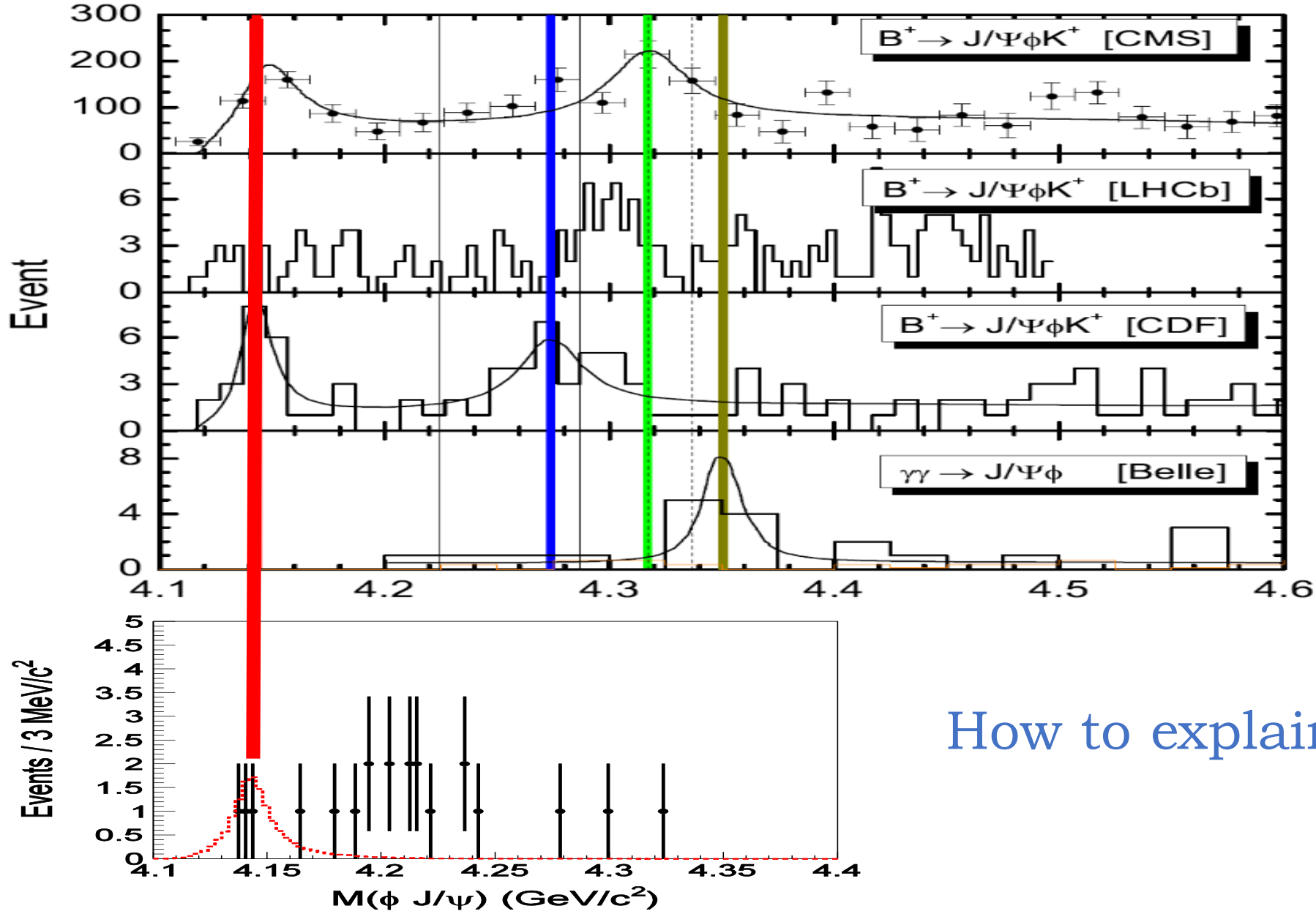
$= 0.27 \pm 0.09(\text{stat}) \pm 0.02(\text{syst})$ pb at $\sqrt{s} = 4.23$ GeV,

$= 0.33 \pm 0.12(\text{stat}) \pm 0.02(\text{syst})$ pb at $\sqrt{s} = 4.26$ GeV.

Take $\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)$ = 5%. arXiv: 0910.3138

And $\mathcal{B}(Y(4140) \to \phi J/\psi)$ = 30%, molecular calculation, PRD 80, 054019.

$$\frac{\sigma^B(e^+e^- \to \gamma Y(4140))}{\sigma^B\left(e^+e^- \to \gamma X(3872)\right)} \leqslant 0.1 \text{ at } \sqrt{s} = 4.23 \text{ and } 4.26 \text{ GeV}.$$



How to explain?

Summary

- The $X(3823)$ $(\psi(1^3D_2))$ is observed with significance 6.2σ via $e^+e^- \to \pi^+\pi^-\gamma\chi_{c1}$.
- The $X(3872)$ is observed with significance 6.3σ via $e^+e^- \to \gamma X(3872)$.
- The $\Gamma_{ee}^{X(3872)}$ is estimated as <4.3 eV at 90% C.L..
- The Y(4140) is searched via $e^+e^- \to \gamma\phi J/\psi$, no obvious signal (three events).

The sources of $X(3823)$ and $X(3872)$ are not clear,
candidates are $Y(4360)/\psi(4415)$ for $X(3823)$ and $Y(4260)$ for $X(3872)$,
or the two structures in $\pi^+\pi^- h_c$.

With more data above 4.0 GeV at BESIII, more informations of XYZ particles will be uncovered. Hopefully we may understand the natures of them.

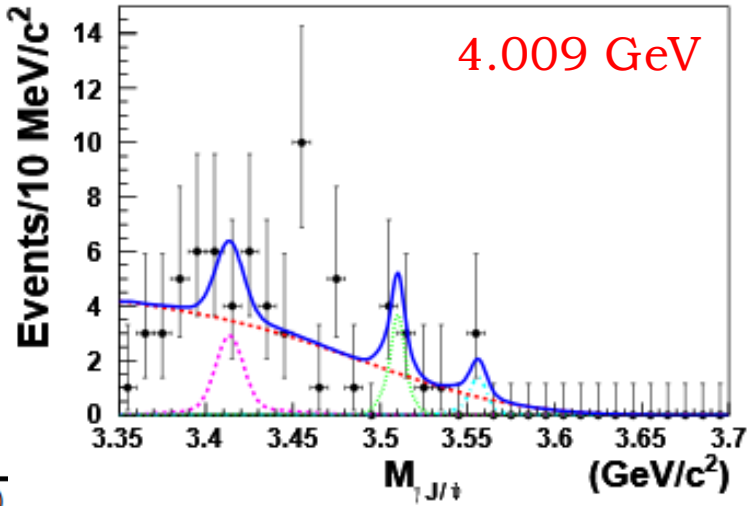
Thanks for your attention.

Back up

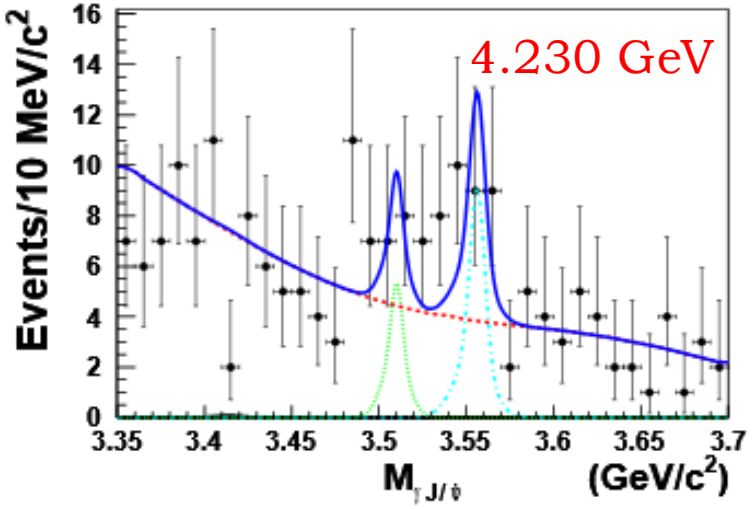
Search for $e^+e^- \to \gamma\chi_{cJ}$ from 4.009 to 4.360 GeV

Invariant mass of $\gamma J/\psi$

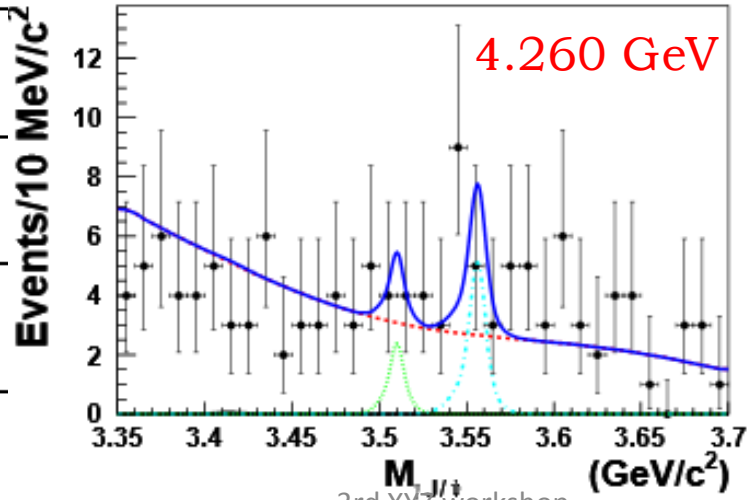
$\sqrt{s}$/GeV		$N^{\rm obs}$	significance (σ)
4.009	χ_{c0}	7.0±6.6	1.6
	χ_{c1}	4.4±2.6	2.2
	χ_{c2}	1.8±1.7	1.5
4.230	χ_{c0}	0.2±2.3	0.0
	χ_{c1}	6.7±4.3	1.9
	χ_{c2}	13.3±5.2	2.9
4.260	χ_{c0}	0.1±1.9	0.0
	χ_{c1}	3.0±3.0	1.1
	χ_{c2}	7.5±3.9	2.3
4.360	χ_{c0}	0.1±0.7	0.0
	χ_{c1}	5.2±4.9	2.4
	χ_{c2}	4.4±4.5	2.0

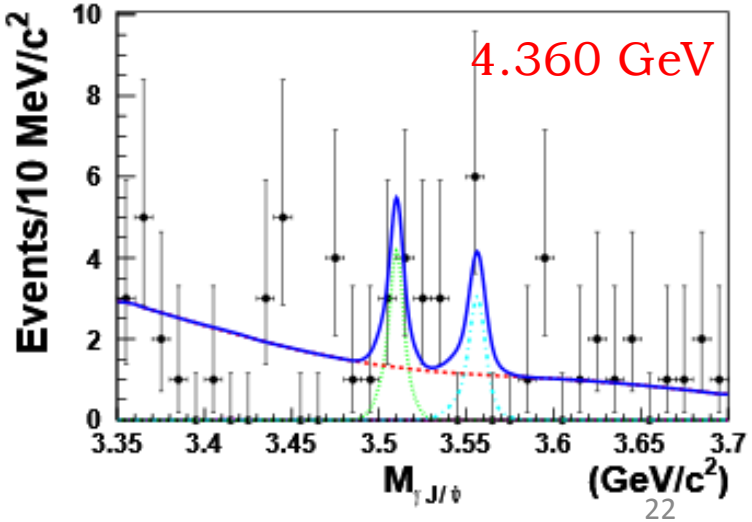


(a)



(b)





Combine all the data sets.

Evidence for

$e^+e^- \to \gamma\chi_{c1}$ (3.0σ)

$e^+e^- \to \gamma\chi_{c2}$ (3.4σ)

$\sqrt{s}$ (GeV)		$\sigma^{\rm UP}$ (pb)	σ^B (pb)
4.009	χ_{c0}	188	65.1±61.3±7.2
	χ_{c1}	5.2	2.3±1.4±0.2
	χ_{c2}	18	4.8±4.5±0.5
4.230	χ_{c0}	27	0.7±8.0±0.1
	χ_{c1}	1.7	0.7±0.5±0.1
	χ_{c2}	5.0	2.7±1.1±0.3
4.260	χ_{c0}	26	0.5±8.9±0.1
	χ_{c1}	1.2	0.4±0.4±0.1
	χ_{c2}	4.2	2.0±1.1±0.2
4.360	χ_{c0}	24	0.7±5.0±0.1
	χ_{c1}	3.0	1.4±1.3±0.1
	χ_{c2}	5.0	2.2±2.3±0.2