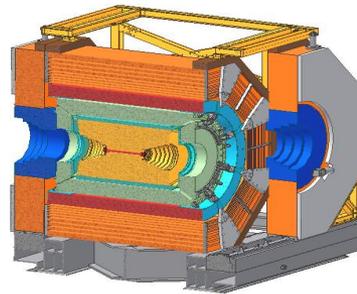# News of X(3872) from BESIII

Zhiqing Liu

Shandong University
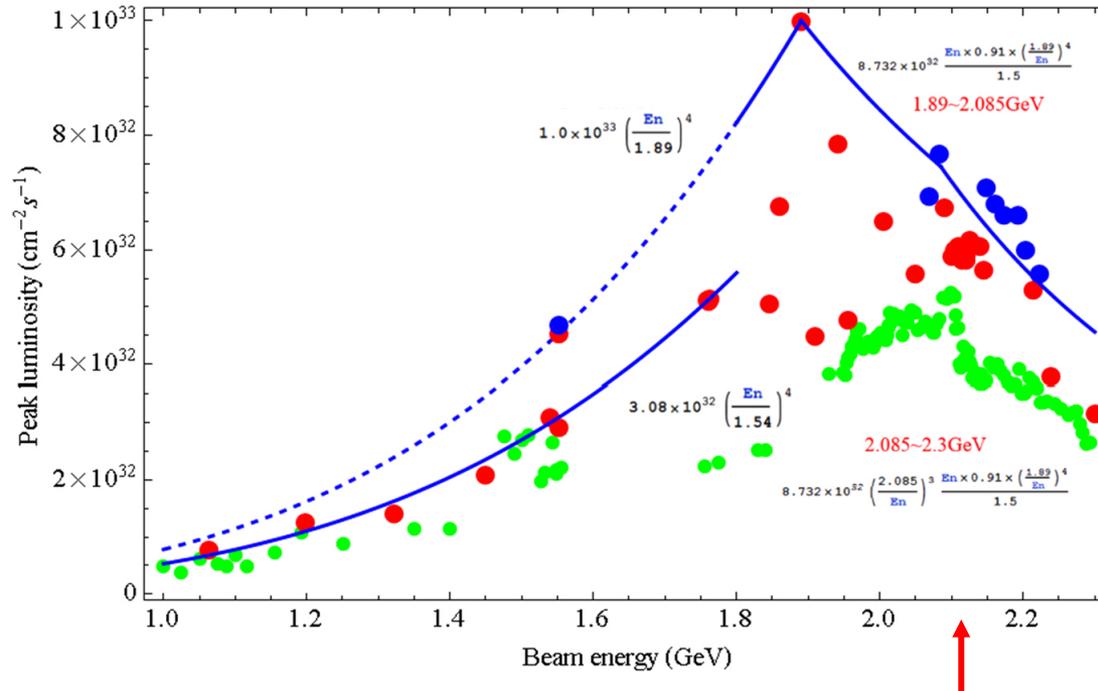
March 16, UC Davis

Outline

➤ Introduction of the BESIII experiment

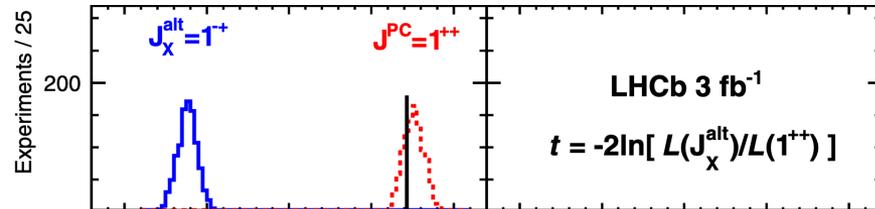➤ Production of X(3872) at BESIII
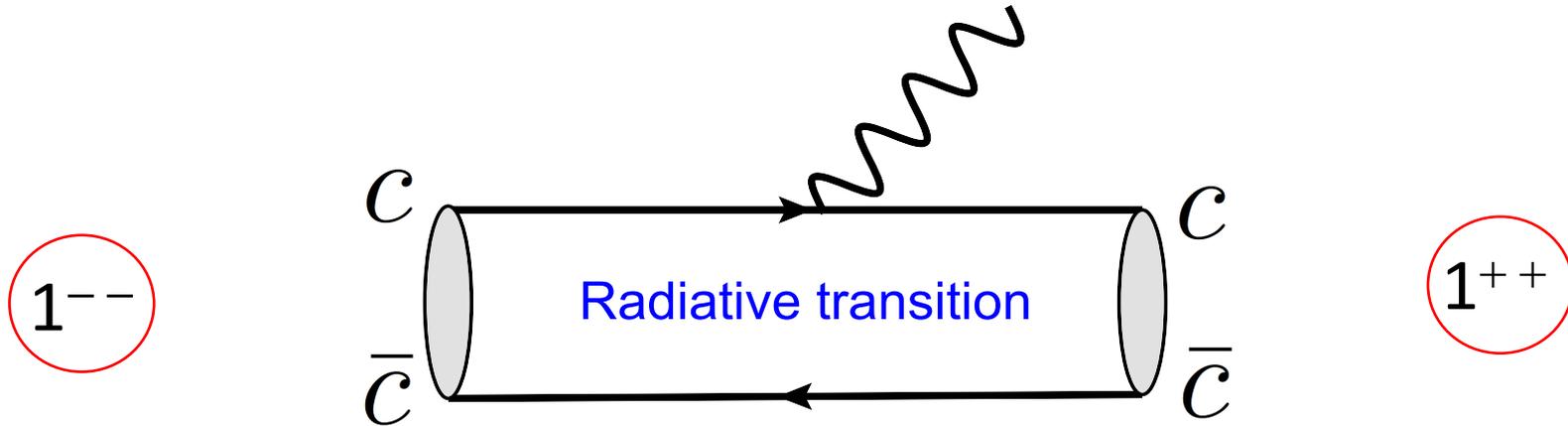
➤ Decay of X(3872) at BESIII

➤ Summary

BEPCII Luminosity

- ➤ Center-of-Mass energy: 2.0 - 4.936 GeV
- ➤ Design Luminosity @ ψ(3770): 1×10^{33} cm^{-2}s^{-1} (achieved in 2016)
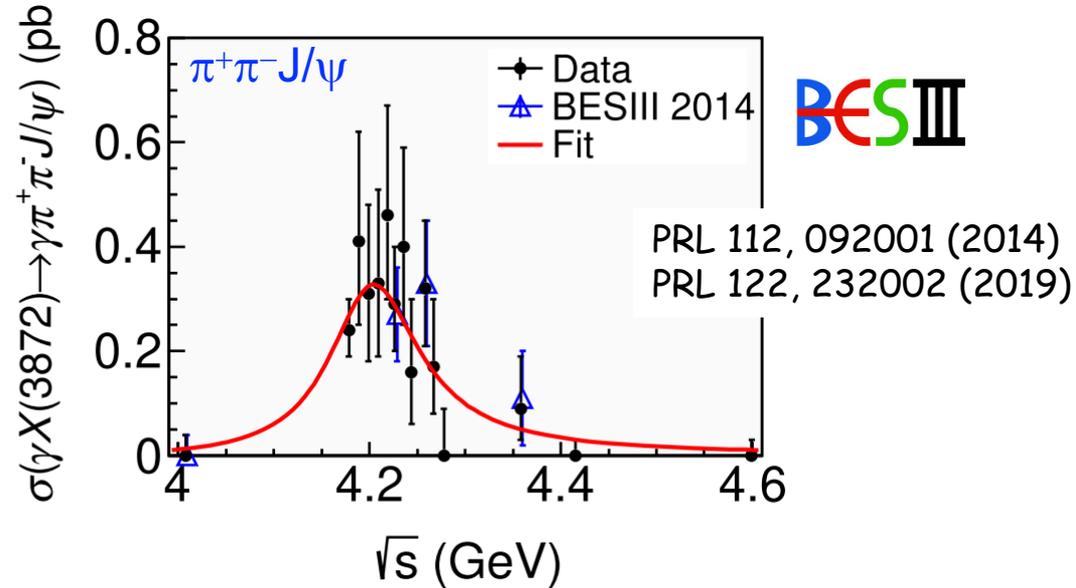- ➤ Energy spread: 1.1 MeV @ 3.686 GeV

How to produce X(3872)?

Excited state → Ground state

c c

Radiative transition

$\bar{c}$ $\bar{c}$

1^{--} 1^{++}

Experiments / 25

$J_X^{alt}=1^+$ $J^{PC}=1^{++}$

200

LHCb 3 fb^{-1}

$t = -2\ln[\, L(J_X^{alt})/L(1^{++})\,]$

PRD 92, 011102(R) (2015)

➤ X(3872) spin-parity $J^{PC}=1^{++}$

➤ Produced with a photon in e+e- machine

Cross section of e⁺e⁻→γX(3872)

$\omega J/\psi$ — σ(γX(3872)→γωJ/ψ) (pb) vs √s (GeV)

$\pi^+\pi^- J/\psi$ — σ(γX(3872)→γπ⁺π⁻J/ψ) (pb) vs √s (GeV)

PRL 112, 092001 (2014)
PRL 122, 232002 (2019)
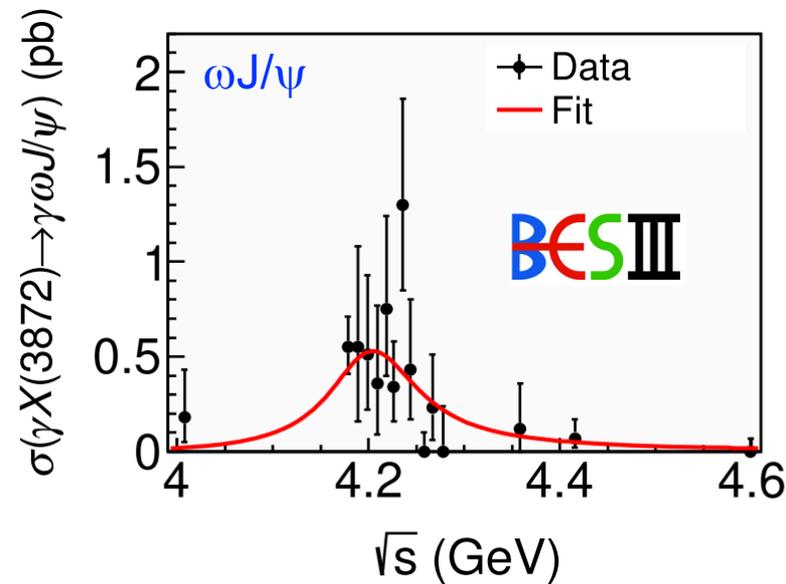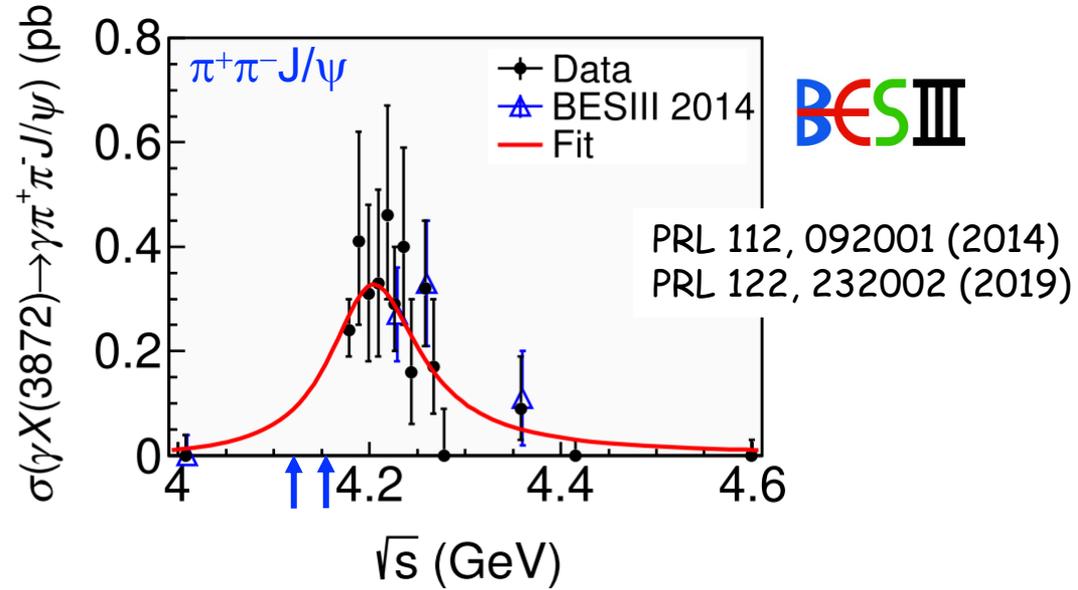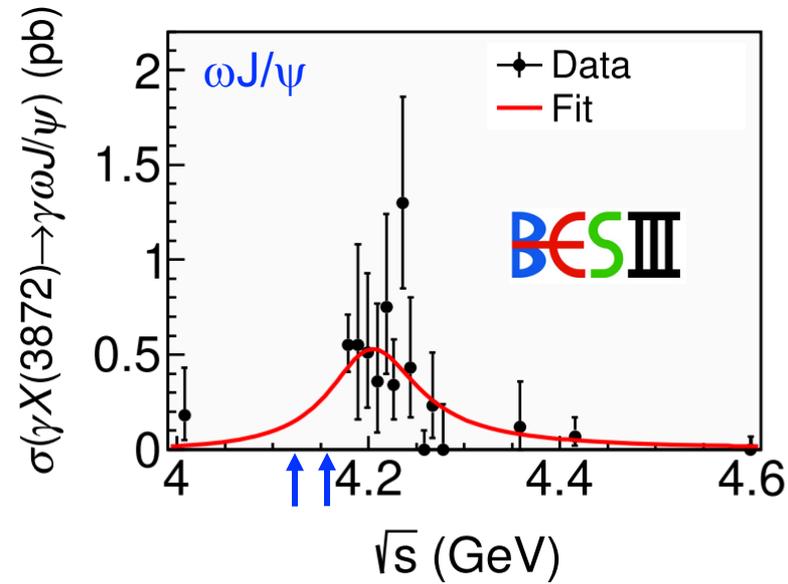
➢ Production cross section ~ 0.3 pb @ 4.2 GeV with $\pi^+\pi^-$J/ψ channel

Phys. Rev. Lett. **124**, 152001

➢According to BaBar's measurement Br[X(3872)→$\pi^+\pi^-$J/ψ]=(4.1±1.3)%

➢ σ[e+e-→γX(3872)]~7.3 pb level; Daily luminosity L=25 pb⁻¹ at BESIII →
BESIII will produce ~180 events per day ("super mini-factory")

Y(4260)→γX(3872)

- ➤ e⁺e⁻→γX(3872) cross section line shape by BESIII

- ➤ M=4200.6$^{+7.9}_{-13.3}$ ± 3.0 MeV, Γ=115$^{+38}_{-26}$ ± 12 MeV

- ➤ Unique at BESIII, Br[Y(4260)→γX(3872)]/Br[Y→π⁺π⁻J/ψ]~9%

Strongly suggest the Y(4260)→γX(3872) transition → *Commonality between Y(4260) & X(3872)…*

Rev. Mod. Phys. 90, 015003 (2018)

Decay of X(3872) at BESIII

X(3872)→π⁺π⁻J/ψ
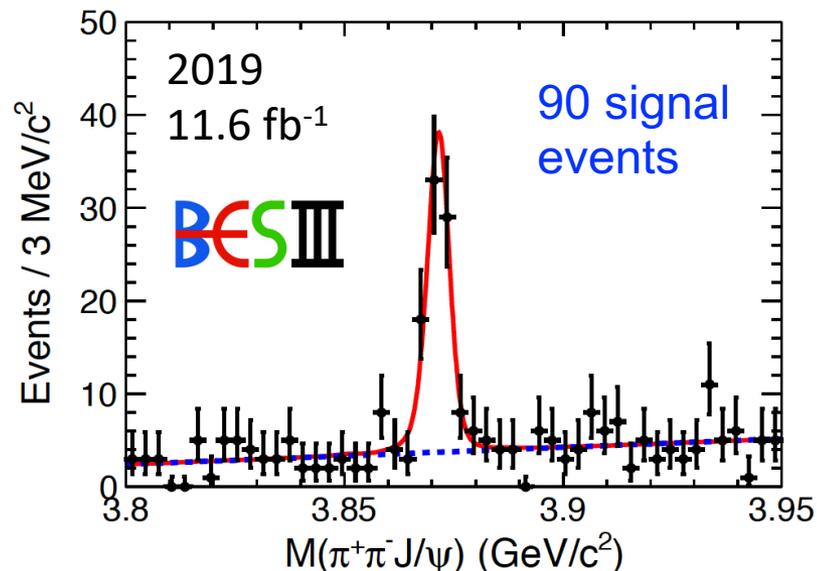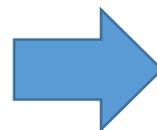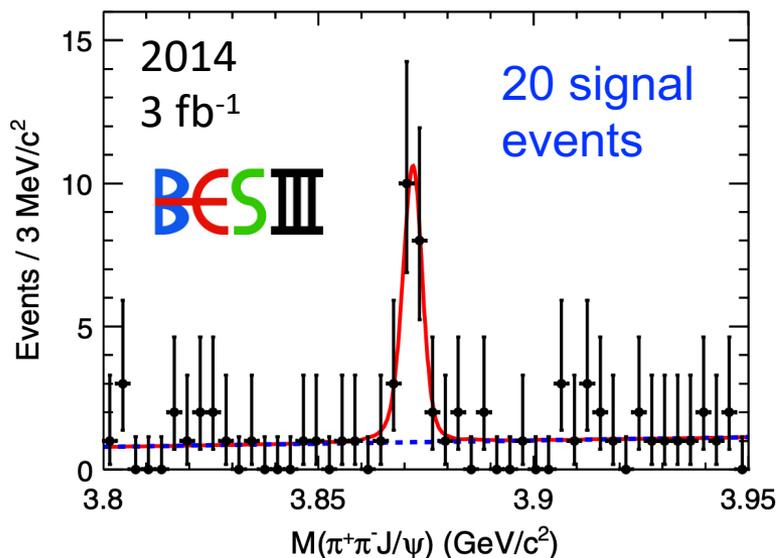
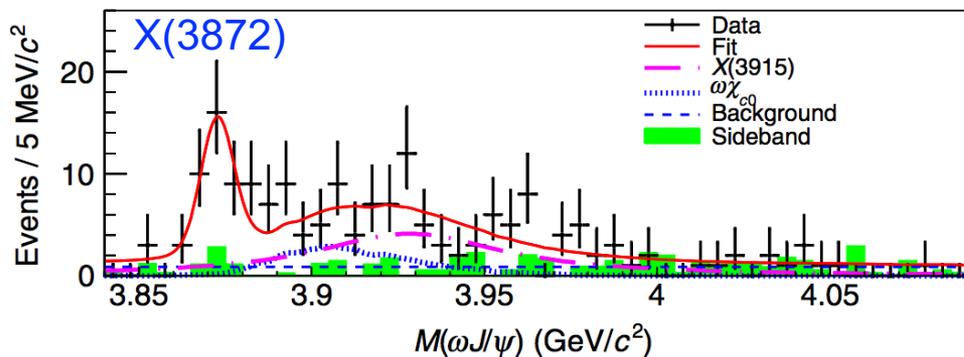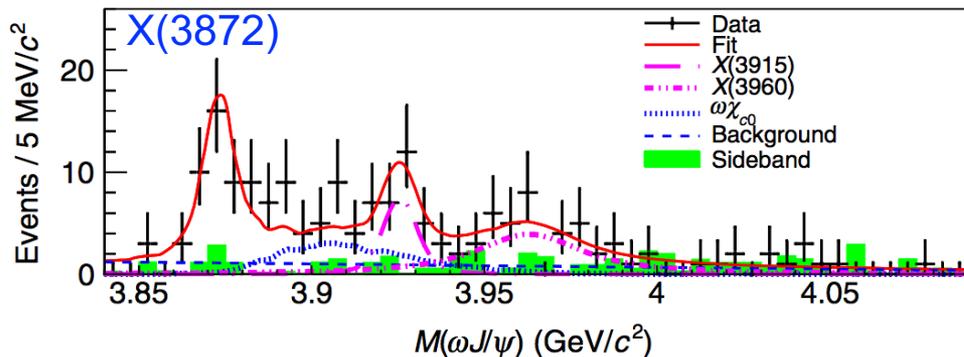- ➤ X(3872)→π⁺π⁻J/ψ is still the golden channel (productive & clean);
  (20 signal events in 2014 → ~90 signal evens in 2019)

- ➤ ISR ψ(2S) events as reference, remaining background π⁺π⁻π⁺π⁻ etc.

- ➤ Radiative photon angular distribution is on progress…

X(3872)$\rightarrow\omega J/\psi$

BES III PRL 122, 232002 (2019)

> $e^+e^-\rightarrow\gamma X(3872)\rightarrow\gamma\omega J/\psi$ at BESIII

> Observed X(3872)$\rightarrow\omega J/\psi$ signal with >5σ significance (first time)

$$Br[X\rightarrow\omega J/\psi]/Br[X\rightarrow\rho J/\psi]=1.6^{+0.4}_{-0.3}\pm 0.2$$

$$R_{X(3872)}=\left|\frac{A(\rho J/\psi)}{A(\omega J/\psi)}\right|\sim 0.2-0.3$$

$$R_{\psi(2S)}=\frac{g_{\pi^0 J/\psi}}{g_{\eta J/\psi}}\approx 0.03$$

PRD 85, 011501(R) (2012)

> Big iso-spin violation effect (x10 amplitude)

> X(3872) is very exotic !

$X(3872) \to \overline{D^0} D^{*0}$

$D^{*0} \to \gamma D^0$

$D^{*0} \to \pi^0 D^0$

20 signal events

(d)

25 signal events

(e)

(b)

(f)

$M(\gamma_L D^0 \overline{D}^0)$ GeV/c^2

$M(D^{*0} \overline{D}^0)$ (GeV/c^2)

$M(\gamma_L D^+ D^-)$ GeV/c^2
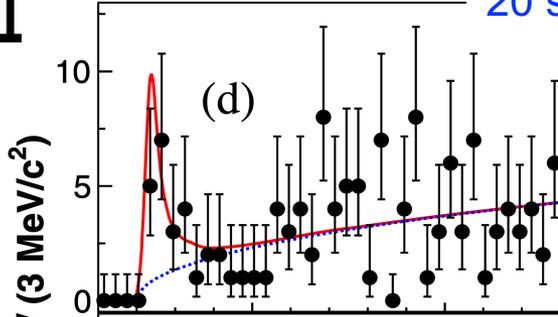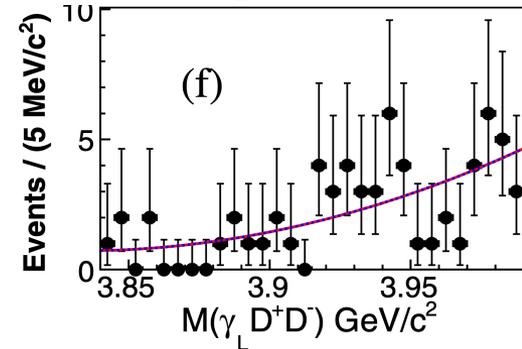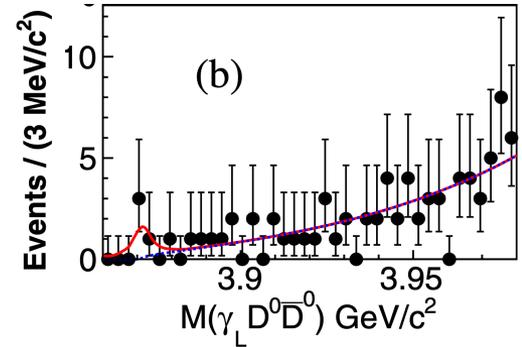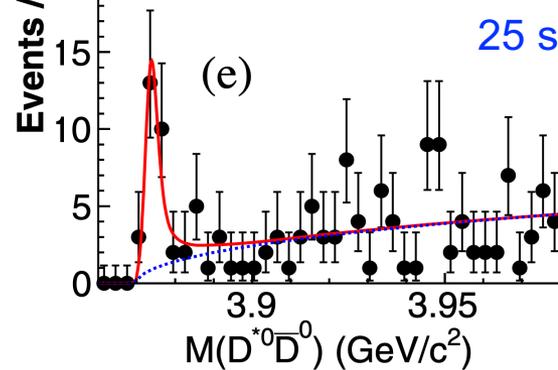
$X(3872) \to \overline{D^0} D^{*0}$ is dominant

- ➤ BESIII observed the decay $X(3872) \to \overline{D^0} D^{*0}$ with >7.4σ significance.

- ➤ No obvious signal observed from $\gamma D^+ D^- / \gamma D^0 D^0$

X(3872)$\rightarrow\gamma$J/ψ & $\gamma\psi$(2S)

Legend:
- best fit
- background
- global ave.
- LHCb result
- Belle result

PRL 124, 242001 (2020)
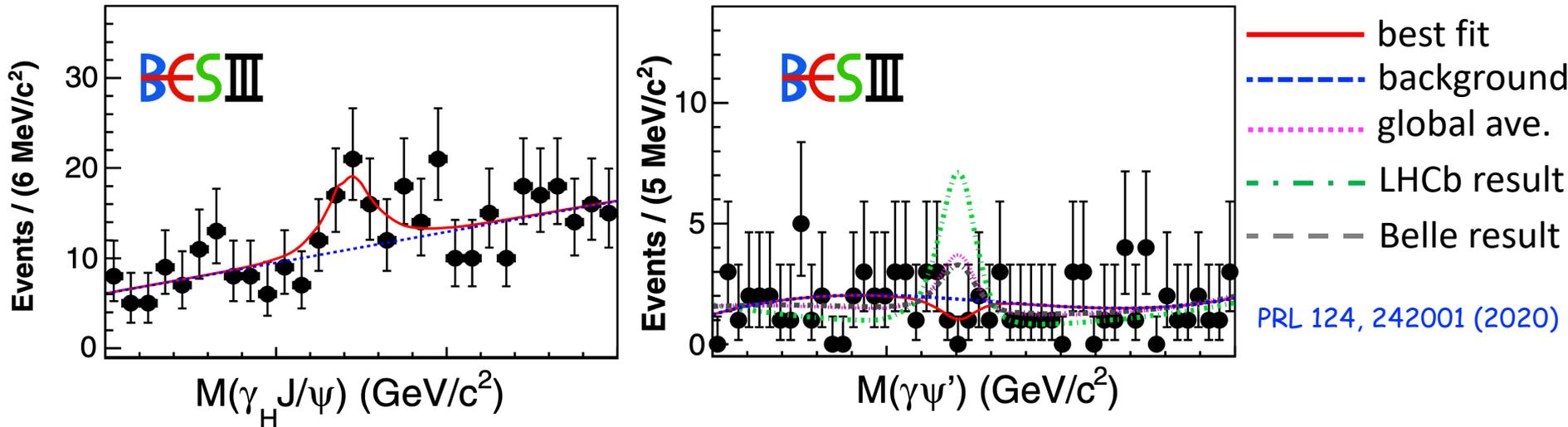
- ➤ 3.5σ evidence for X(3872)$\rightarrow\gamma$J/ψ
- ➤ No signal for the X(3872)$\rightarrow\gamma\psi$(2S) decay at BESIII
- ➤ In tension with the LHCb measurement (C.L. < 0.0048)

Molecule? Tetraquark?

PRL 107, 091803 (Belle)
PRL 102, 132001 (BaBar)
NPB 886(665) (LHCb)

$$\frac{B[X(3872)\rightarrow\gamma\psi(2S)]}{B[X(3872)\rightarrow\gamma J/\psi]}$$

< 0.59	(BESIII) @ 90% C.L.	= 3.4 ± 1.4 (BaBar)
< 2.1	(Belle) @ 90% C.L.	= 2.46 ± 0.64 ± 0.29 (LHCb)

New decay modes of X(3872)→$\pi^0\chi_{c1}$

PRL 122, 202001 (2019)
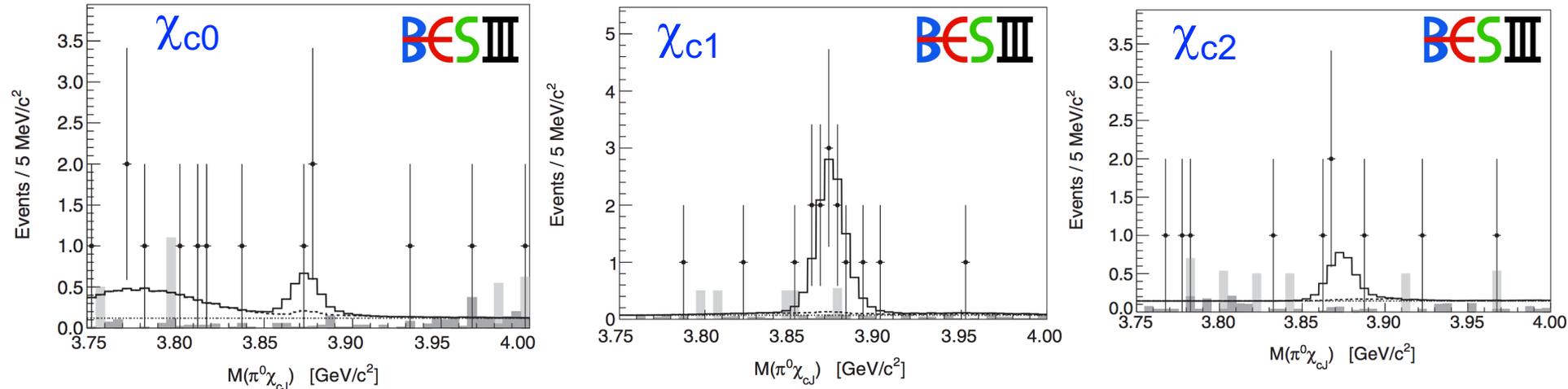
- Search for new decay modes, very clean environment
- Observed the X(3872)→$\pi^0\chi_{c1}$ decay for the first time with >5σ significance
- Iso-spin violation, comparable decay rate with $\rho^0 J/\psi$ → disfavor $\chi_{c1}(2P)$

$B[X(3872)\rightarrow \pi^0\chi_{c0}]/B[X(3872)\rightarrow\rho J/\psi]$ < 19 @ 90% C.L.
$B[X(3872)\rightarrow \pi^0\chi_{c1}]/B[X(3872)\rightarrow\rho J/\psi]=0.88^{+0.33}_{-0.27}\pm0.10$
$B[X(3872)\rightarrow \pi^0\chi_{c2}]/B[X(3872)\rightarrow\rho J/\psi]$ < 1.1 @ 90% C.L.

Branching ratios of X(3872) decay

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

Decay mode	Branching fraction
$X(3872) \to \pi^+ \pi^- J/\psi$	$(4.1^{+1.9}_{-1.1})\%$
$X(3872) \to D^{*0} \bar{D}^0 + c.c.$	$(52.4^{+25.3}_{-14.3})\%$
$X(3872) \to \gamma J/\psi$	$(1.1^{+0.6}_{-0.3})\%$
$X(3872) \to \gamma \psi(3686)$	$(2.4^{+1.3}_{-0.8})\%$
$X(3872) \to \pi^0 \chi_{c1}$	$(3.6^{+2.2}_{-1.6})\%$
$X(3872) \to \omega J/\psi$	$(4.4^{+2.3}_{-1.3})\%$
$B^+ \to X(3872) K^+$	$(1.9 \pm 0.6) \times 10^{-4}$
$B^0 \to X(3872) K^0$	$(1.1^{+0.5}_{-0.4}) \times 10^{-4}$
$X(3872) \to$ unknown	$(31.9^{+18.1}_{-31.5})\%$

Phys. Rev. Lett. 124, 242001 (2020)

BES III

➢ Using $\pi^+\pi^-$J/ψ as the normalization channel

➢ The relative Brs of X(3872)

Li & Yuan, PRD 100, 094003 (2019)

➢ An simple average using world data

Braaten, arXiv:1908.02807

➢ Dynamics/production maybe needed…

➢ Over 30% unknown?

Summary

- BESIII is also a good player for the study X(3872)

- Production mechanics is unique, i.e. via radiative transitions from Y(4260) (~7 pb cross section)

- In future, take more data and fully cover the cross section line shape

- Clean environment allow to search new X(3872) decay channels ($\pi^0\chi_{c1}$), measure Brs ($\omega J/\psi$, $\overline{D^0}D^{*0}$, $\gamma\psi'$) etc.

More news will come from BESIII !

Backup

Data sets at BESIII
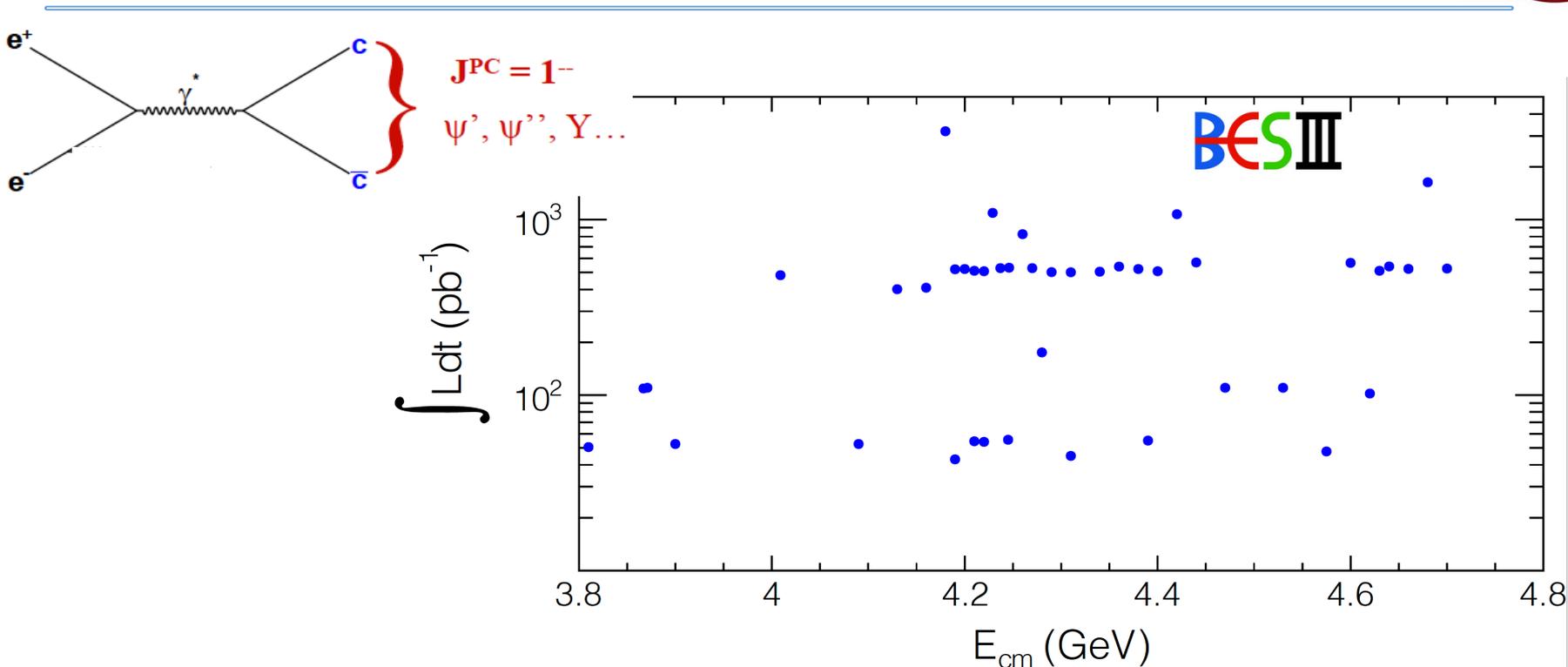
- ➢ A scan experiment for vector charmonium-(like) states

- ➢ Over 20 fb^{-1} data between 3.8 – 4.7 GeV during last 7 years

- ➢ Scan step 500 pb^{-1}/10 MeV; will continue...

BESIII experiment

A 4π detector