Radiative Transitions in e+e- Collisions above 4 GeV

Bin Zhong
Nanjing Normal University
(For the BESIII Collaboration)

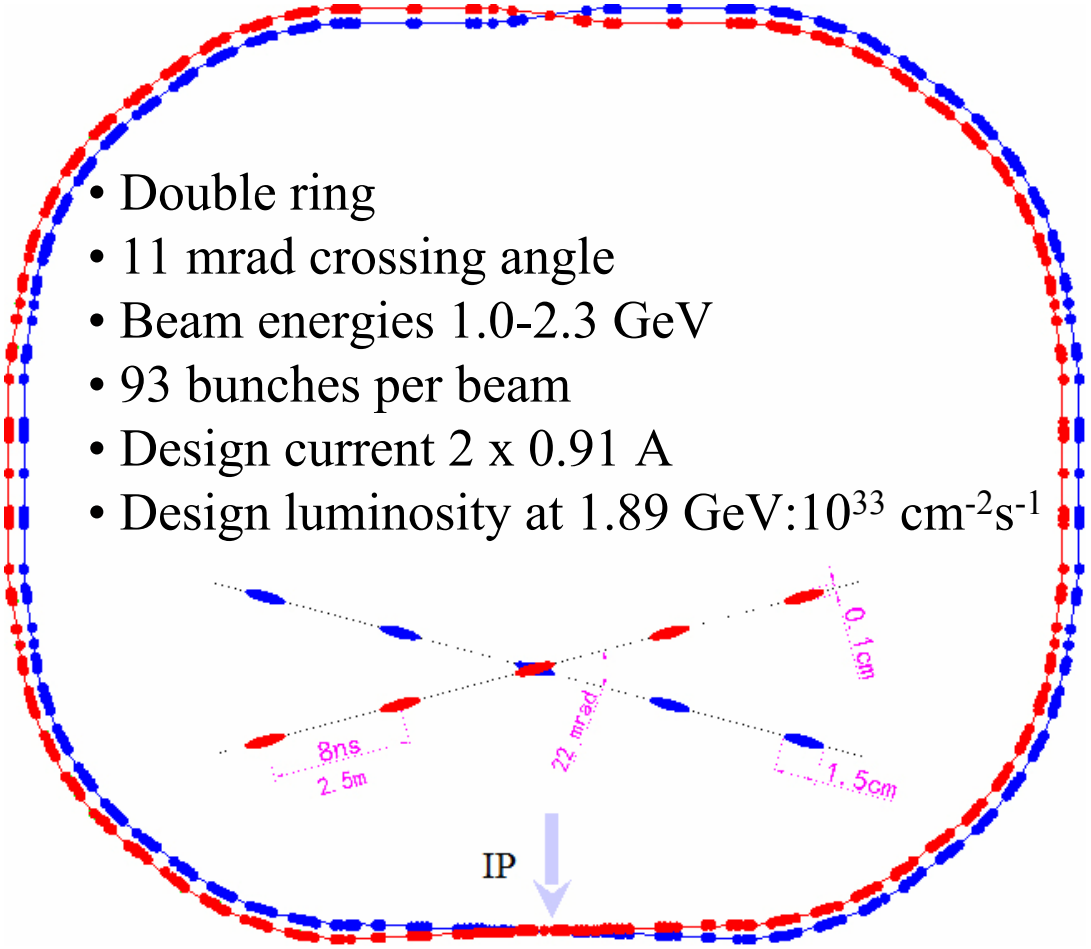
QWG 2016
6th June . -10th June., 2016, PNNL, USA

Outline

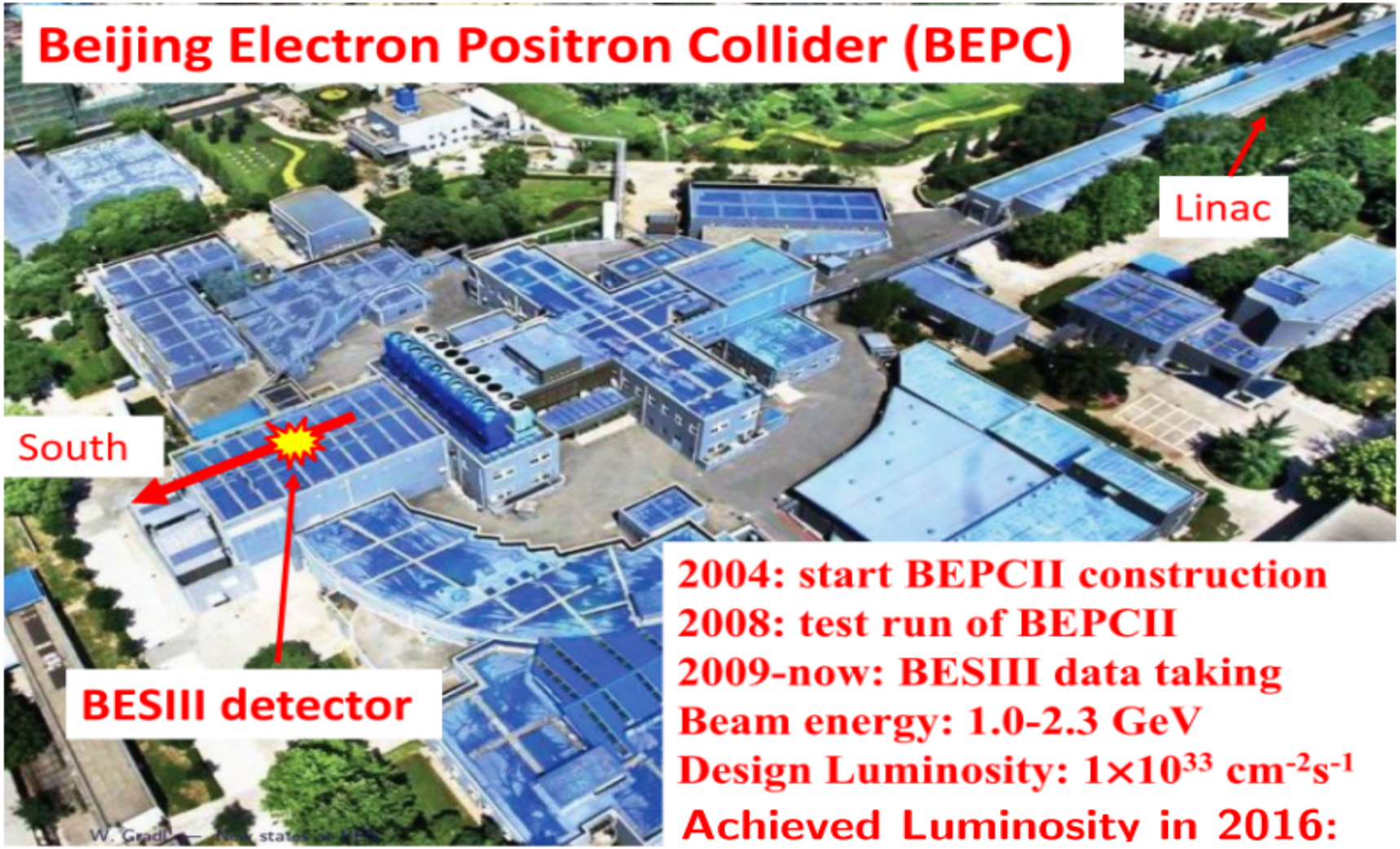
- BEPCII and BESIII
- Observation of X(3872)
- Search for Y(4140) via $e^+e^- \to \gamma\phi J/\psi$
- $e^+e^- \to \gamma\chi_{cJ}$

  $\chi_{cJ} \to \gamma J/\psi \to \gamma\mu^+\mu^-$
- Summary

The Beijing Electron-Positron Collider II



BEPC II achievements

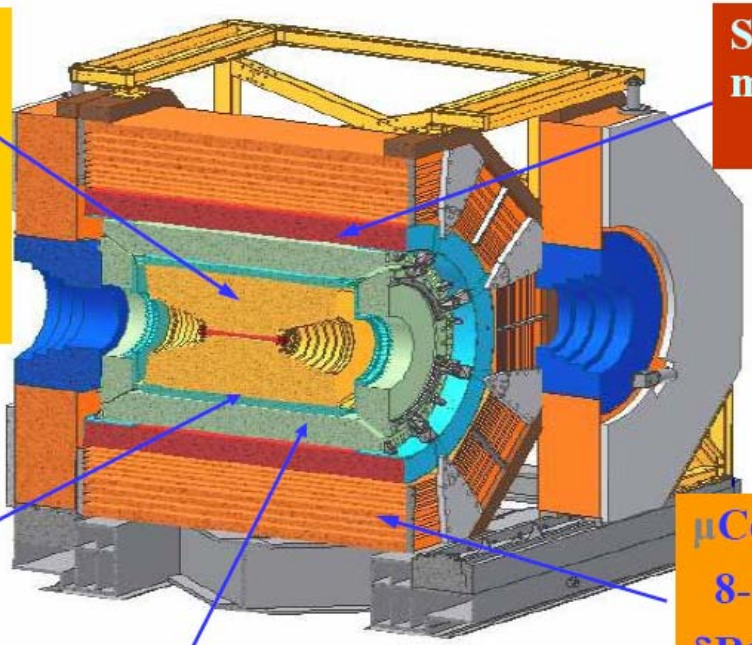


2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BESIII data taking
Beam energy: 1.0-2.3 GeV
Design Luminosity: 1×10^{33} $cm^{-2}s^{-1}$
Achieved Luminosity in 2016:

$L_{peak}=1\times10^{33}cm^{-2}s^{-1}$

2016-06

The Beijing Spectrometer III



Main Drift Chamber
(MDC)
$\sigma(p_T)/p_T$=0.32%⊕0.37%
(1 GeV)
$\sigma_{dE/dx}$ = 5.3%

Super-conducting magnet
1.0 tesla

Time Of Flight
(TOF)
σ_T = 80ps Barrel
100ps endcap

μCounter
8- 9 layers
δRΦ=1.4 cm~1.7 cm

EMC: $\Delta E/\sqrt{E}$ = 2.5 % @ 1 GeV
$\sigma_{z,\phi}$ = 0.6 cm /$\sqrt{E}$

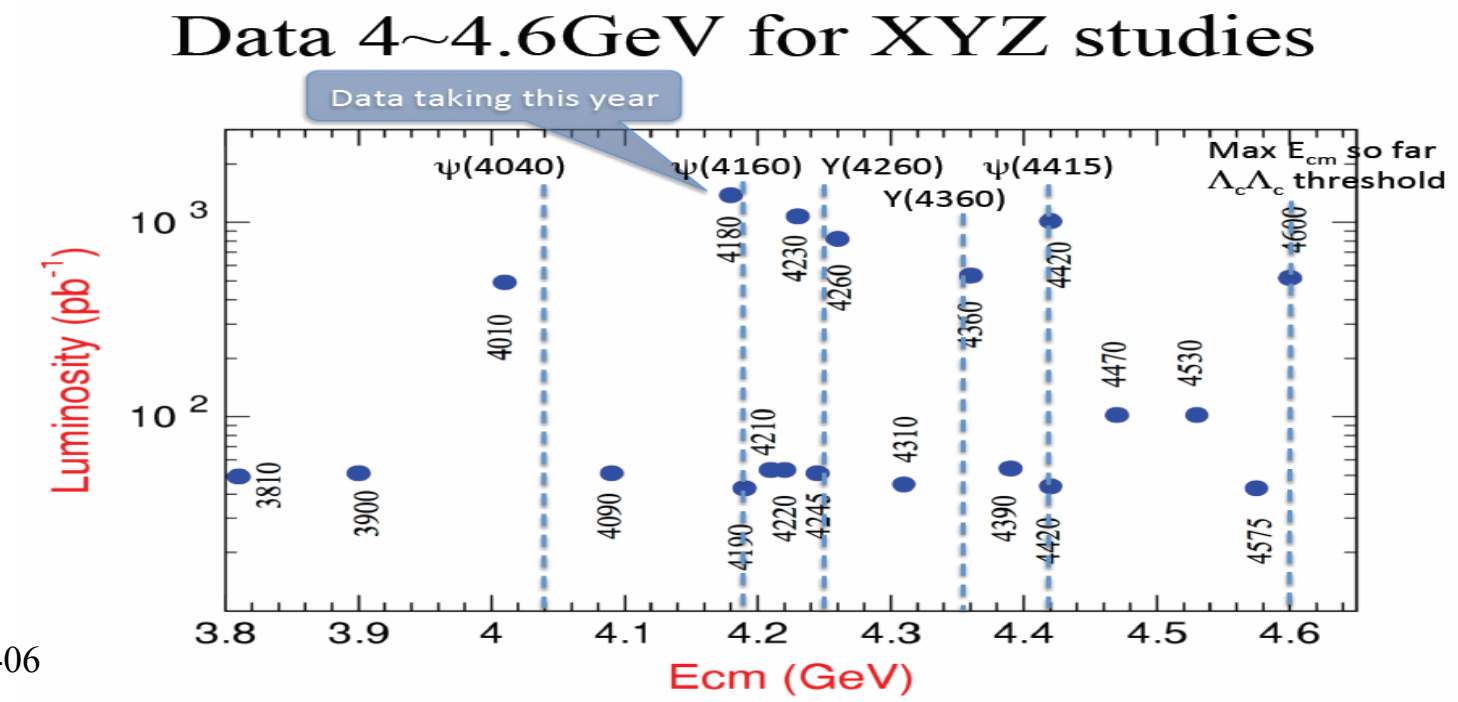
BESIII data samples

World's largest samples of direct e^+e^- collisions in the tau-charm region

1.3B J/ψ + 0.6B ψ(2S) + 2.9/fb ψ(3770)

XYZ physics: 3.8 - 4.6 GeV

Other scan and continuum data below the J/ψ



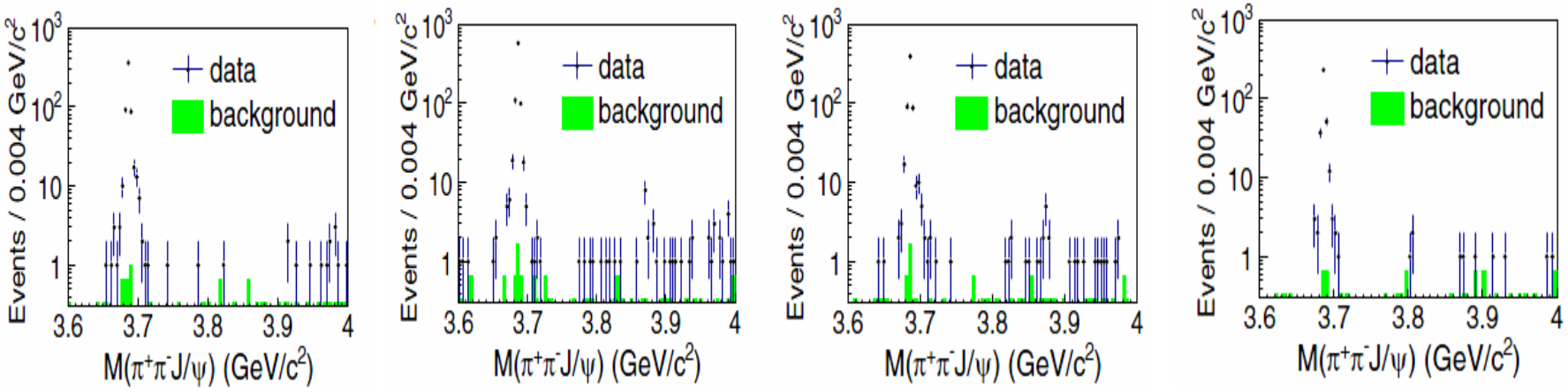
Observation of X(3872)(1)

PRL 112, 092001 (2014)

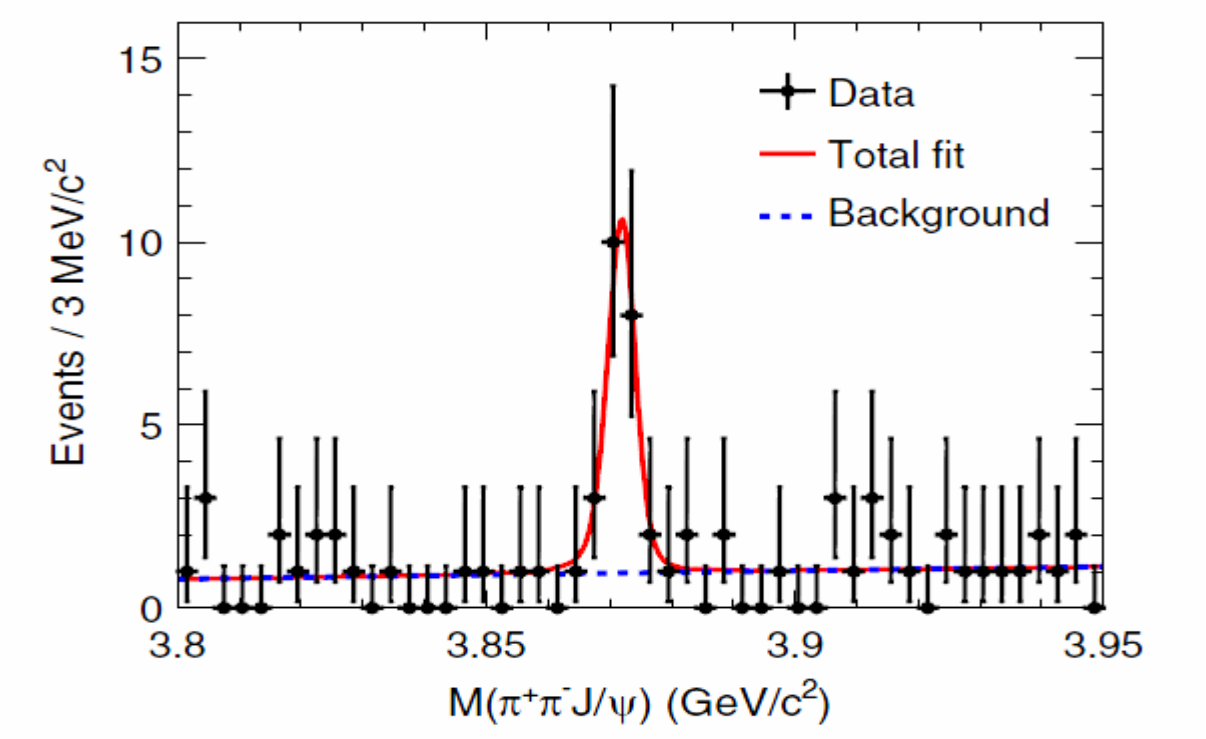
X(3872) was discovered by Belle in 2003.

LHCb has determined its $J^{PC} = 1^{++}$

$e^+e^- \to \gamma X(3872) at \sqrt{s} = 4.009, 4.230, 4.260, 4.360$ GeV

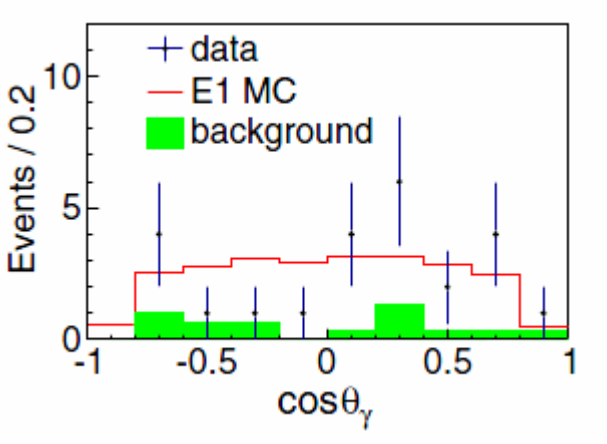


Observation of X(3872) (2)

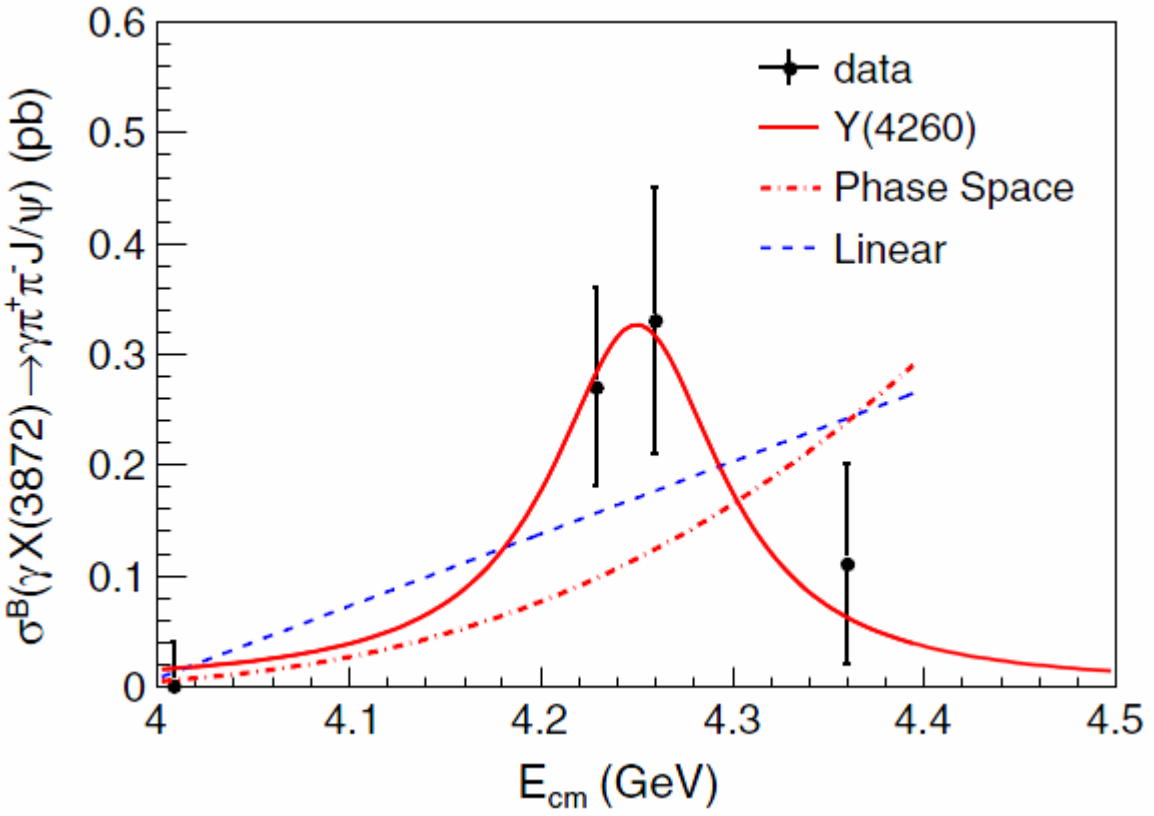


$\sqrt{s}$ (GeV)	$N^{\rm obs}$	$N^{\rm up}$	ε (%)	$1+\delta$	$\sigma^B \cdot \mathcal{B}$ (pb)	$\sigma^{\rm up} \cdot \mathcal{B}$ (pb)
4.009	0.0 ± 0.5	< 1.4	28.7	0.861	$0.00 \pm 0.04 \pm 0.01$	< 0.11
4.229	9.6 ± 3.1	$\cdots$	34.4	0.799	$0.27 \pm 0.09 \pm 0.02$	$\cdots$
4.260	8.7 ± 3.0	$\cdots$	33.1	0.814	$0.33 \pm 0.12 \pm 0.02$	$\cdots$
4.360	1.7 ± 1.4	< 5.1	23.2	1.023	$0.11 \pm 0.09 \pm 0.01$	< 0.36

Observation of X(3872)(3)



A pure E1 transition between Y(4260) and X(3872)



The production of X(3872) favors Y(4260)

Search for Y(4140) via $e^+e^- \rightarrow \gamma\phi J/\psi$ (1)

PRD 91, 032002 (2015)

- CDF first reported evidence for Y(4140) in M($\phi J/\psi$) from $B^+ \rightarrow \phi J/\psi K^+$; the subsequent analysis claim a statistical significance of more than 5σ.

- LHCb and D0 confirmed Y (4140)

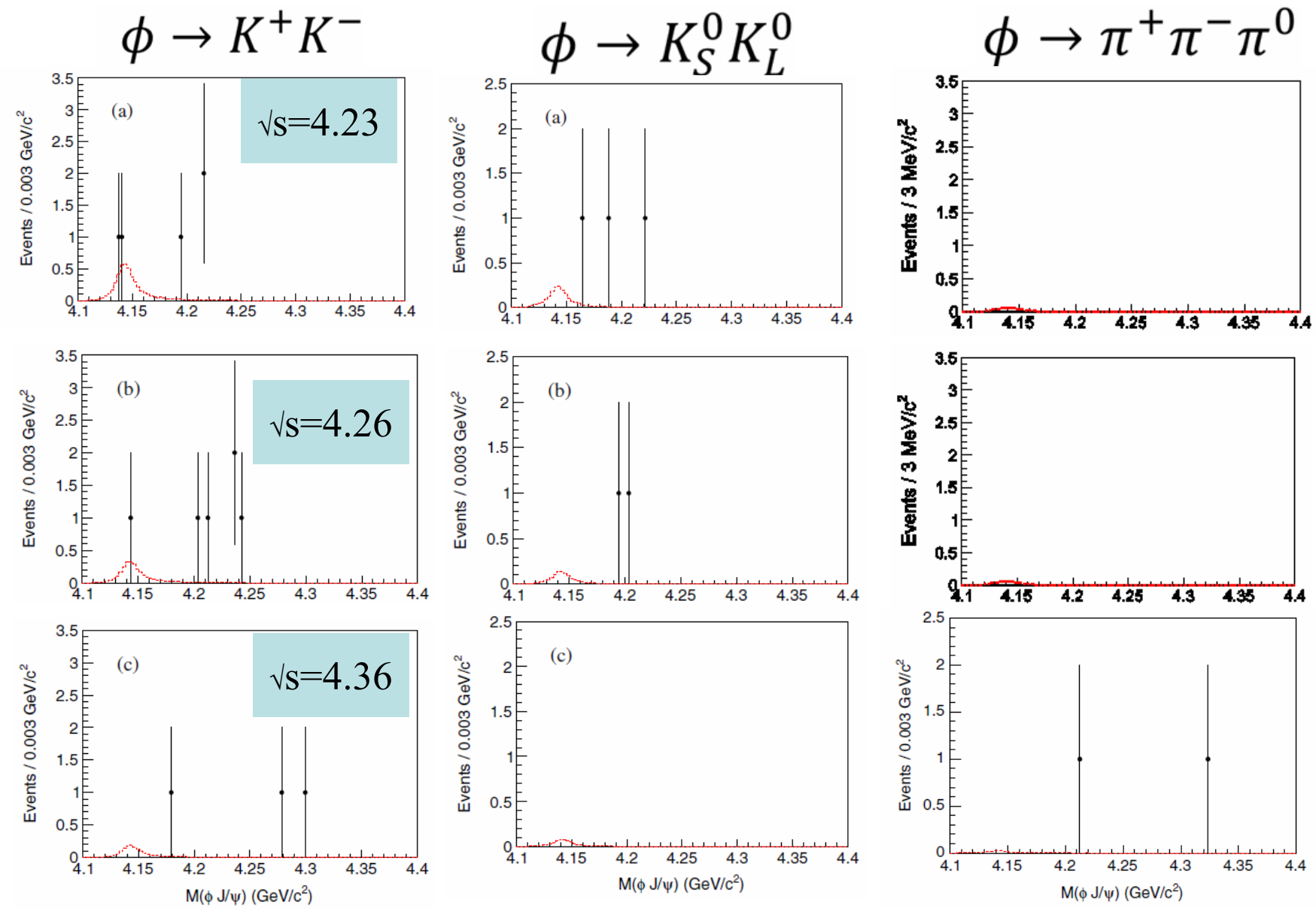
Three decay modes to reconstructed ϕ:

- $\phi \rightarrow K^+K^-$
- $\phi \rightarrow K^0_S K^0_L, K^0_S \rightarrow \pi^+\pi^-$
- $\phi \rightarrow \pi^+\pi^-\pi^0$

Two decay modes to reconstructed J/ψ:

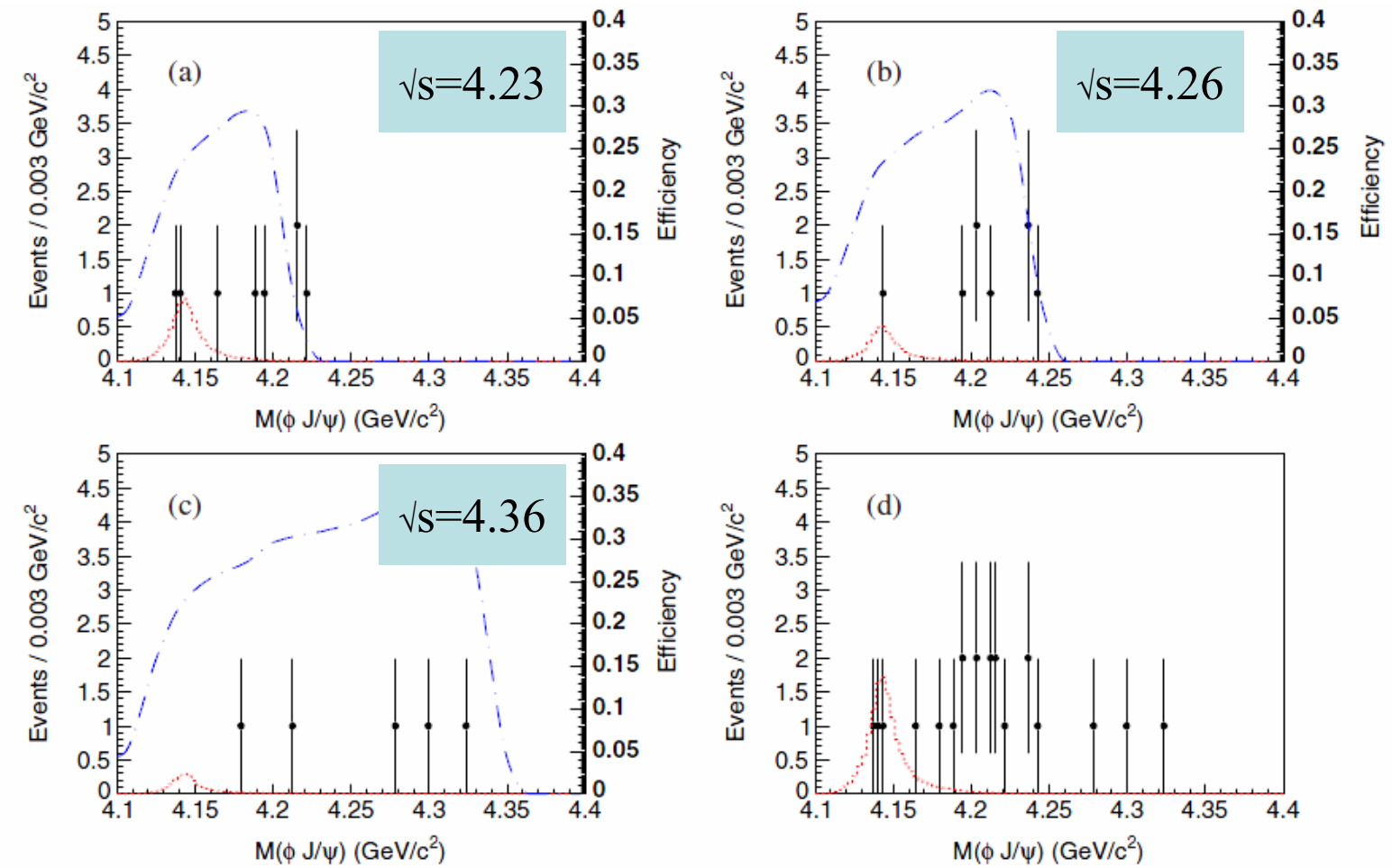
- $J/\psi \rightarrow e^+e^-$
- $J/\psi \rightarrow \mu^+\mu^-$

Search for Y(4140) via $e^+e^- \to \gamma\phi J/\psi$ (2)



Search for Y(4140) via $e^+e^- \to \gamma\phi J/\psi$ (3)

Combine 6 modes (3 ϕ modes $\otimes$ 2 J/ψ modes)



Red dashed histogram: MC signal scaled to the measured upper limit
The blue dashed-dot line shows the efficiency distribution

Search for Y(4140) via $e^+e^- \to \gamma\phi J/\psi$ (4)

No significant Y(4140) signal found @ BESIII

Set upper limit at the 90% CL. for

$$\sigma^B \times \mathcal{B} = \sigma^B(e^+e^- \to \gamma Y(4140)) \times \mathcal{B}(Y(4140) \to \phi J/\psi)$$

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

Compared with the X(3872) product ion

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

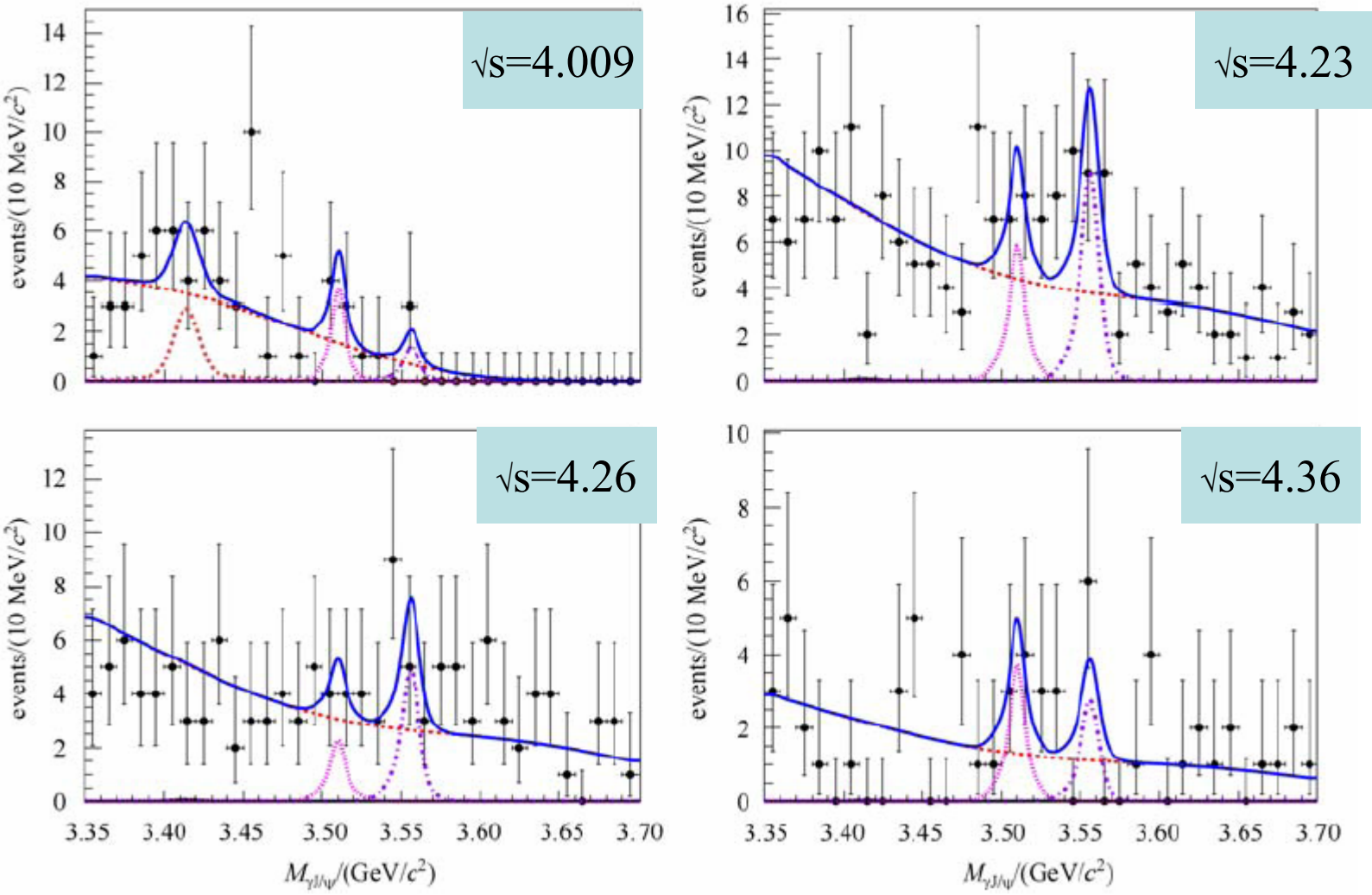
Take $\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi) = 5\%$. arXiv: 0910.3138

And $\mathcal{B}(Y(4140) \to \phi J/\psi) = 30\%$, molecular calculation, PRD 80, 05401

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

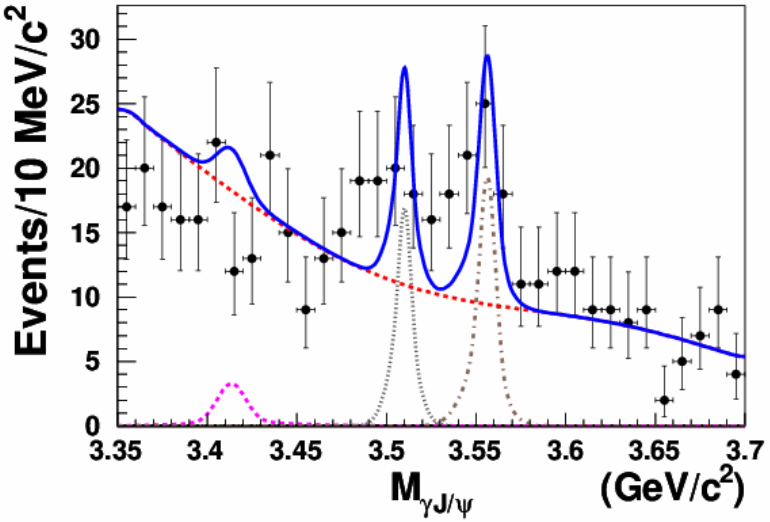
Evidence for $e^+e^- \to \gamma\chi_{cJ}$ above 4GeV (1)

CPC 39, 041001 (2015)



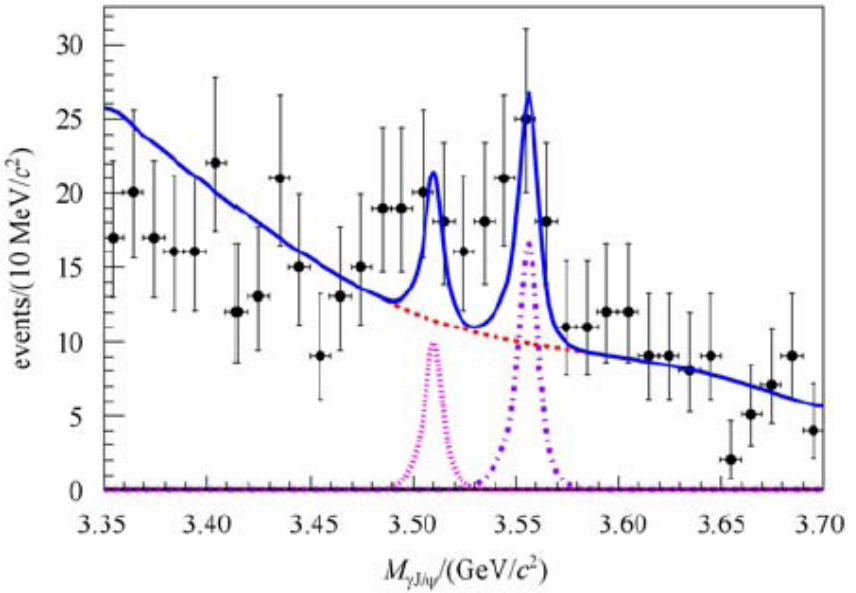
Evidence for $e^+e^- \to \gamma\chi_{cJ}$ above 4GeV (2)

Fit to M(γJ/ψ) for *summing the events in the 4 CME points*



the statistical significance is **1.2 σ, 3.0 σ, 3.4 σ**

Fit the distributions for all CME data sets *assuming that the signals are from decays of the Y(4260)*



the statistical significance is **0, 2.4 σ, 4.0 σ**.

Evidence for $e^+e^- \to \gamma\chi_{cJ}$ above 4GeV (3)

Born cross sections of $e^+e^- \to \gamma\chi_{cJ}$ at different CME

$\sqrt{s}$/GeV		N^{obs}	significance (σ)	N^{UP}	ϵ (%)	$1+\delta^r$	$1+\delta^v$	σ^{UP}/pb	σ^B/pb
4.009	χ_{c0}	7.0±6.6	1.6	18	36.4±0.2	0.738	1.04	179	65.0±61.3±4.2
	χ_{c1}	4.4±2.6	2.2	9	23.4±0.1			5.3	2.4±1.4±0.2
	χ_{c2}	1.8±1.7	1.5	6	8.7±0.1			18	4.7±4.4±0.6
4.230	χ_{c0}	0.2±2.3	0.0	7	37.2±0.2	0.840	1.06	26	0.7±8.0±0.1
	χ_{c1}	6.7±4.3	1.9	14	44.4±0.2			1.7	0.7±0.5±0.1
	χ_{c2}	13.3±5.2	2.9	22	42.0±0.2			5.0	2.7±1.1±0.3
4.260	χ_{c0}	0.1±1.9	0.0	5	36.7±0.2	0.842	1.06	25	0.5±8.8±0.1
	χ_{c1}	3.0±3.0	1.1	7	42.7±0.2			1.1	0.4±0.4±0.1
	χ_{c2}	7.5±3.9	2.3	14	41.7±0.2			4.2	2.0±1.1±0.2
4.360	χ_{c0}	0.1±0.7	0.0	3	32.4±0.2	0.943	1.05	23	0.7±5.0±0.1
	χ_{c1}	5.2±4.9	2.4	10	31.7±0.2			2.9	1.4±1.3±0.1
	χ_{c2}	4.4±4.5	2.0	9	30.3±0.2			5.0	2.3±2.3±0.2

Summary

- With the large data samples above 4GeV and good performance of BEPCII and BESIII, three results about radiative transitions came out:

  Observation of X(3872)

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

  $e^+e^- \to \gamma\chi_{cJ}$

- More exciting results will come from BESIII.

Thank you !