Recent XYZ and Charmonium results at BESIII

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Outline

- Three recent results
  1. Evidence of $\eta_c(2S) \to \pi^+\pi^-\eta$
  2. Search for Y states via $e^+e^- \to \phi\eta'$
  3. Observation of Y(4500) in $e^+e^- \to K^+K^-J/\psi$
- Summary

Evidence of $\eta_c(2S) \to \pi^+\pi^-\eta$

arXiv:2211.11935

Motivation

- Similar to the "12%" rule in J/ψ and $\psi(2S)$ decays

[1] $$\frac{Br(\eta_c(2S)\to h)}{Br(\eta_c(1S)\to h)} \approx \frac{Br(\psi(2S)\to h)}{Br(J/\psi\to h)} = 0.128 \quad (M_{\psi_{(2S)}} - M_{J/\psi} \approx M_{\eta_c(2S)} - M_{\eta_c(1S)})$$

[2] $$\frac{Br(\eta_c(2S)\to h)}{Br(\eta_c(1S)\to h)} \approx 1$$

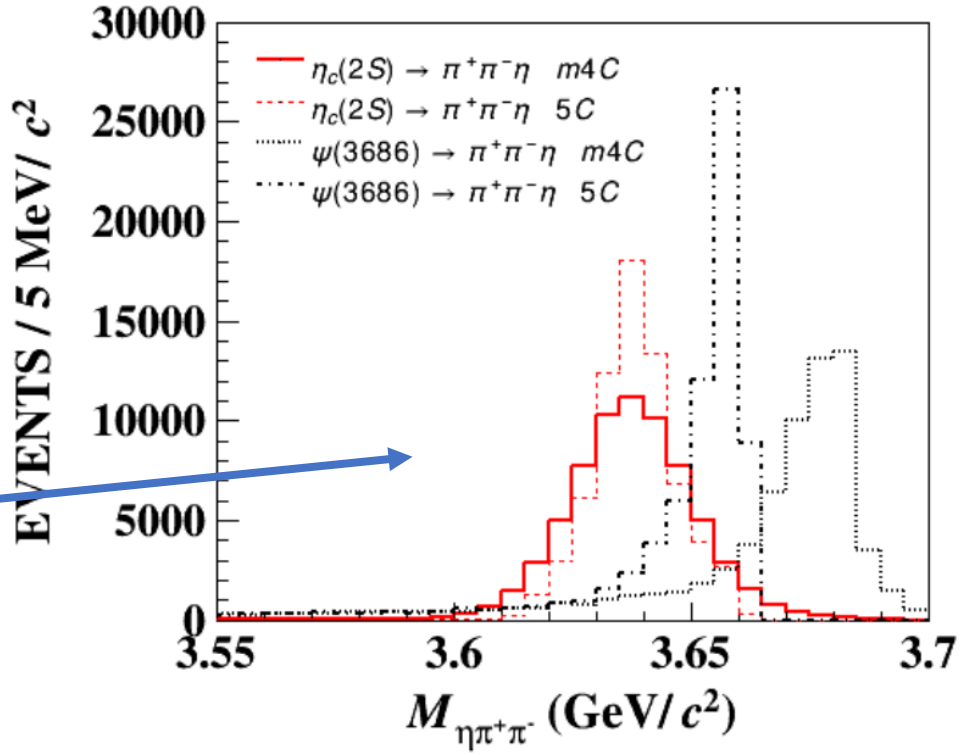
If there is a glueball component mixed in $\eta_c\ (1S)$ and $\eta_c(2S)$, the value will less than 1

- Our knowledge of $\eta_c(2S)$ decays is very limited
  - In PDG, only 4 with uncertainty > 50%, summed < 5%

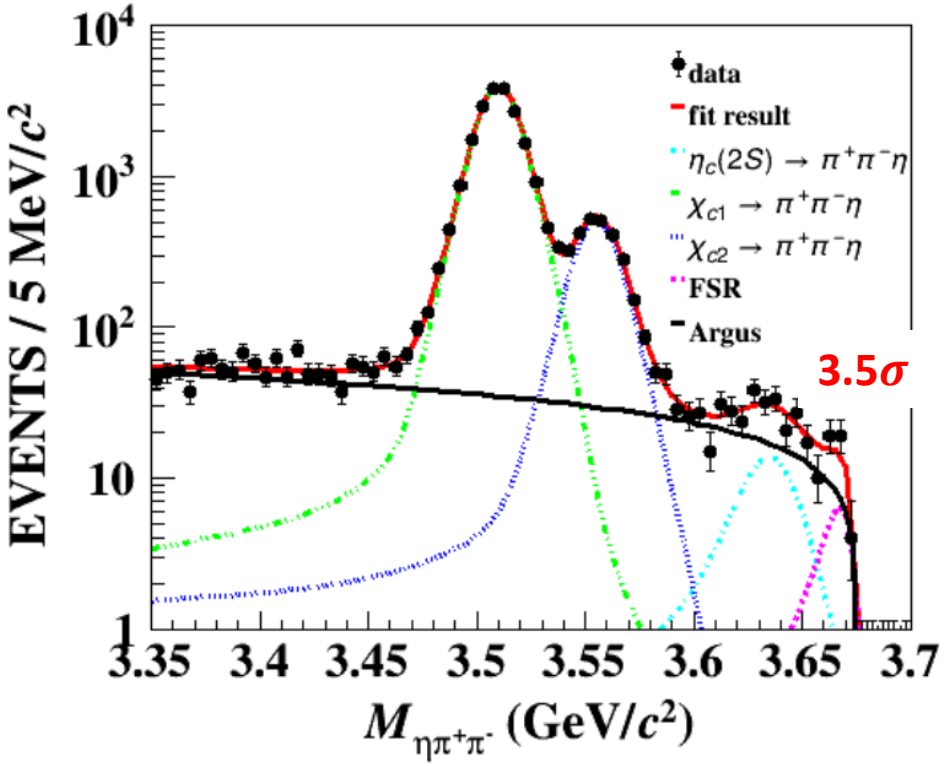
•[1] Anselmino, M. and Genovese, M. and Predazzi, E.，Phys. Rev. D 44，1597—1598(1991)
•[2] K. T. Chao, Y. F. Gu and S. F. Tuan, Commun. Theor. Phys. 25, 471-478 (1996)

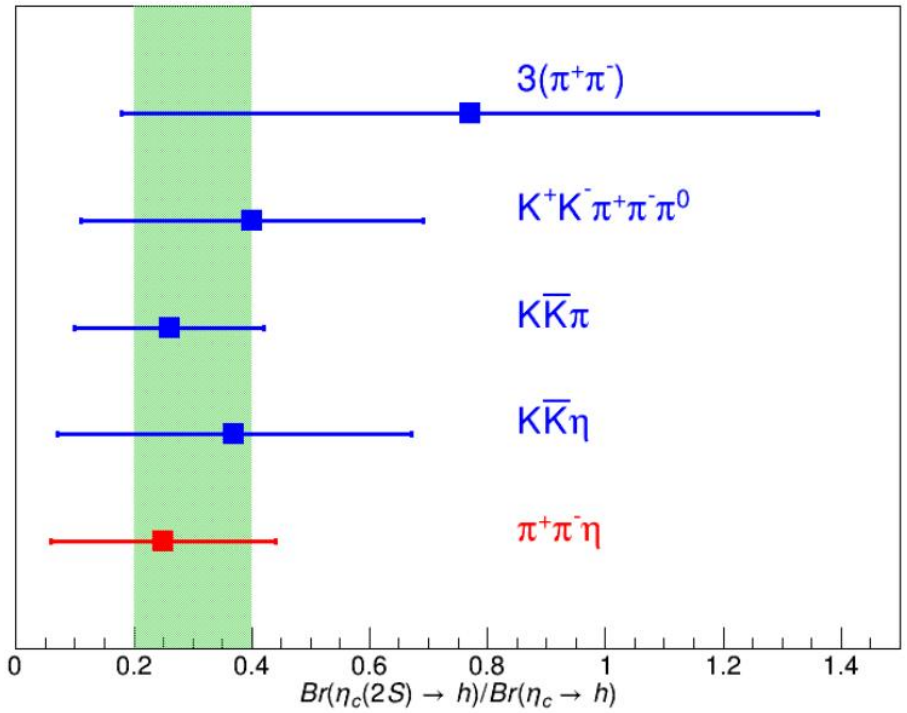
Data sample and analysis

- 448 million $\psi(2S)$ data
- Full reconstruction
  - $\psi(2S) \to \gamma\eta_c(2S) \to \gamma\pi^+\pi^-\eta \to 3\gamma\pi^+\pi^-$
- Specific kinematic constraint to reduce background



Results





$$Br(\eta_c(2S) \to \pi^+\pi^-\eta) = (42.4 \pm 11.6 \pm 3.8 \pm 30.3) \times 10^{-4}$$

$\psi(2S)$ data samples at BESIII

- After 2022
  - 2.7B at $\psi(2S)$ peak
  - 400/pb at 3.65 GeV and 400/pb at 3.682 GeV for continuum background and possible interference
- More precision measurement and more sensitive search

Table 3.1: Some tentative measurements and correspondingly required statistic of $\psi(3686)$ sample to achieve the desired precision.

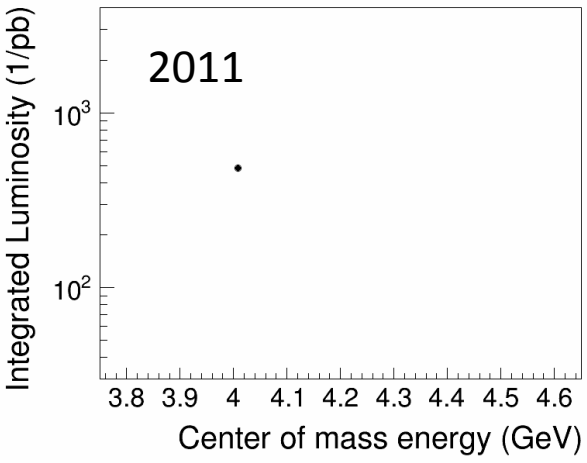
Measurement	Expected precision	Needed $\psi(3686)$ sample in 10^9
$h_c \to hadrons$	Observation of 5×10^{-4}	2
$\eta_c(2S) \to X$	Observation of 1×10^{-6}	5
$\chi_{c1} \to \pi^+\pi^-\eta_c$	Evidence	> 1
$h_c \to \pi^+\pi^- J/\psi$	Evidence	> 2
$\chi_{cJ} \to \gamma V$	Observation of 1×10^{-6}	1
$h_c \to p\bar{p}$	Evidence	> 2

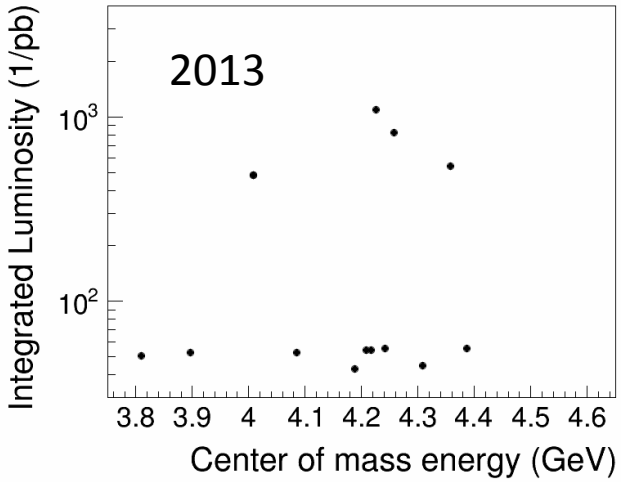
BESIII white paper
CPC Vol. 44, No. 4 (2020)

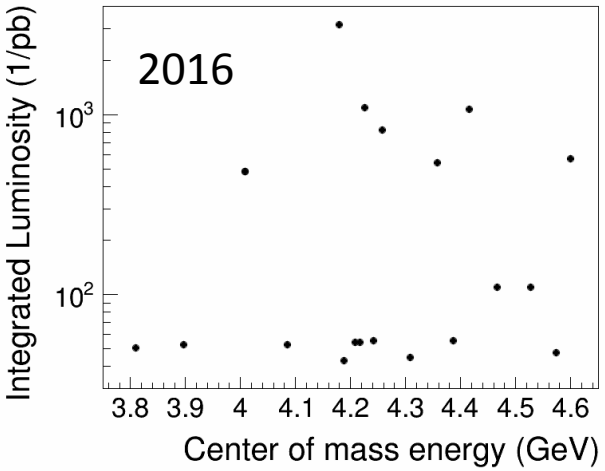
Search for Y states via $e^+e^- \to \phi\eta'$

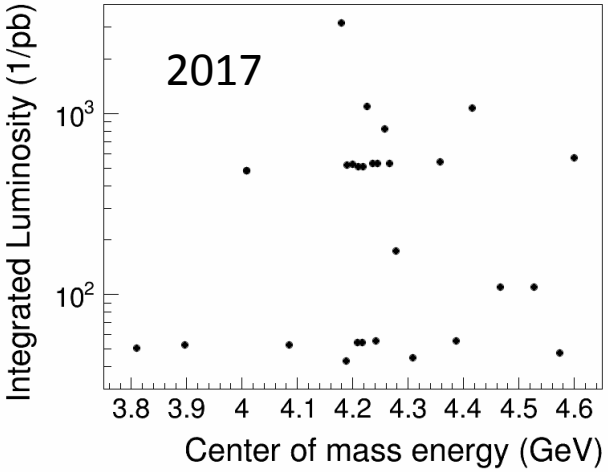
arXiv:2210.06988

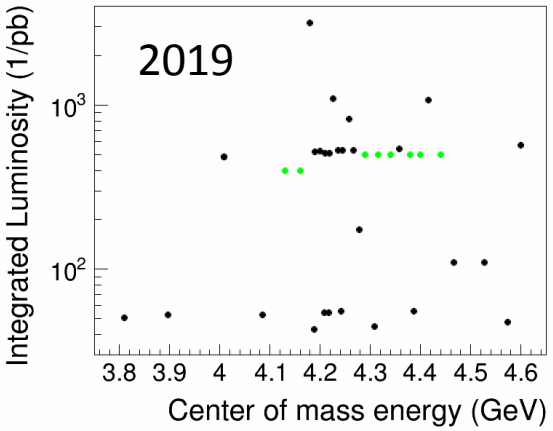
Data samples indicated for XYZ states at BESIII

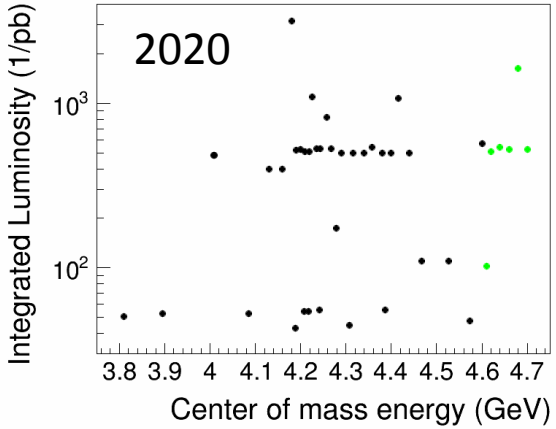


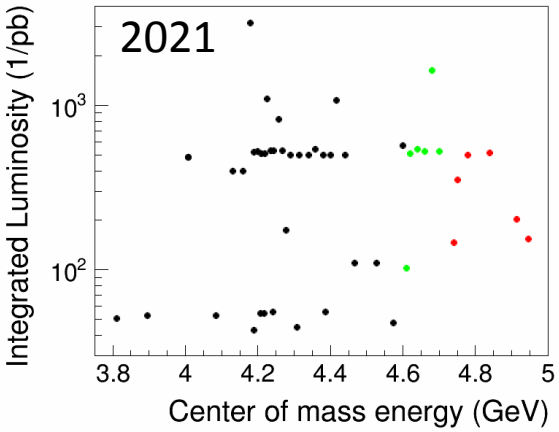


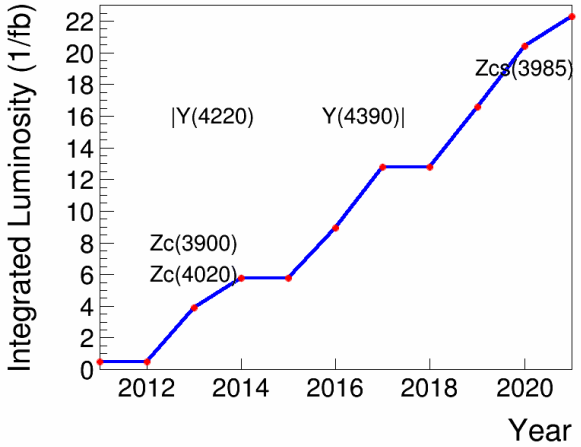




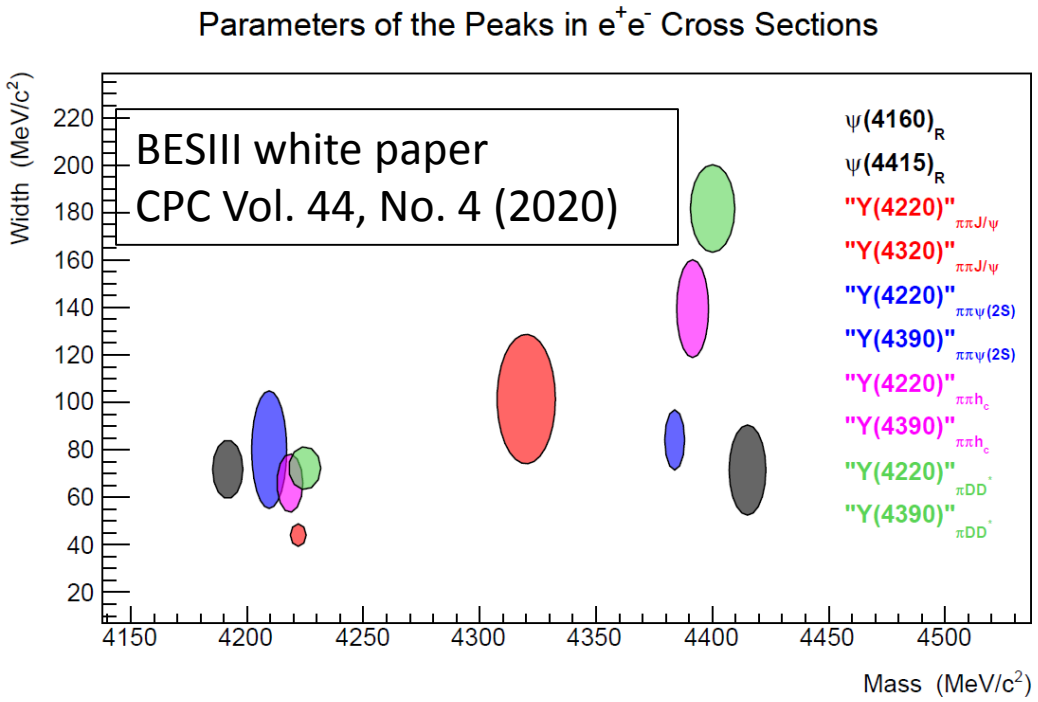


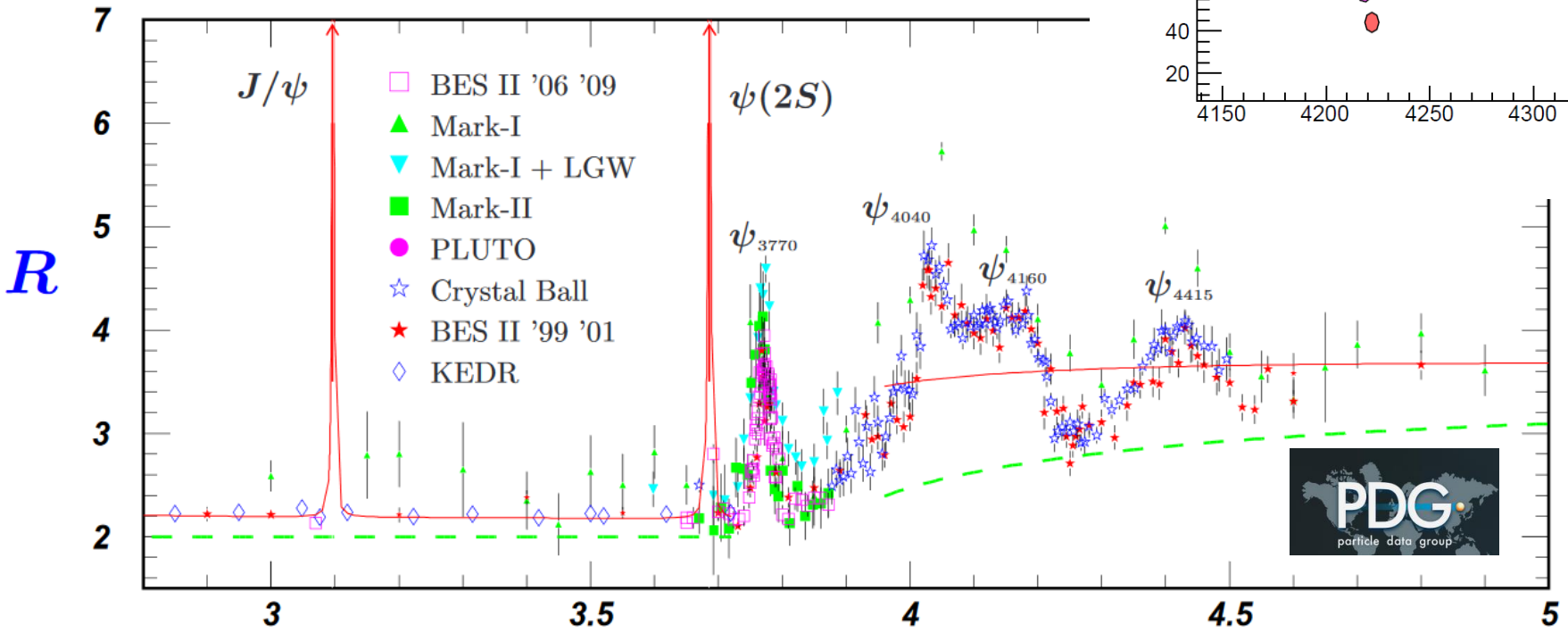






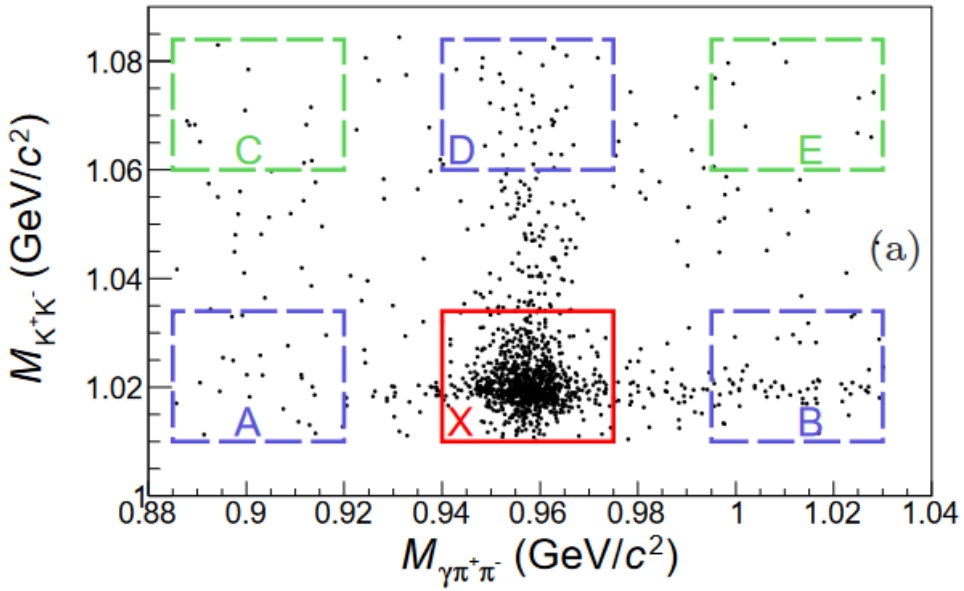
R-values and Y states



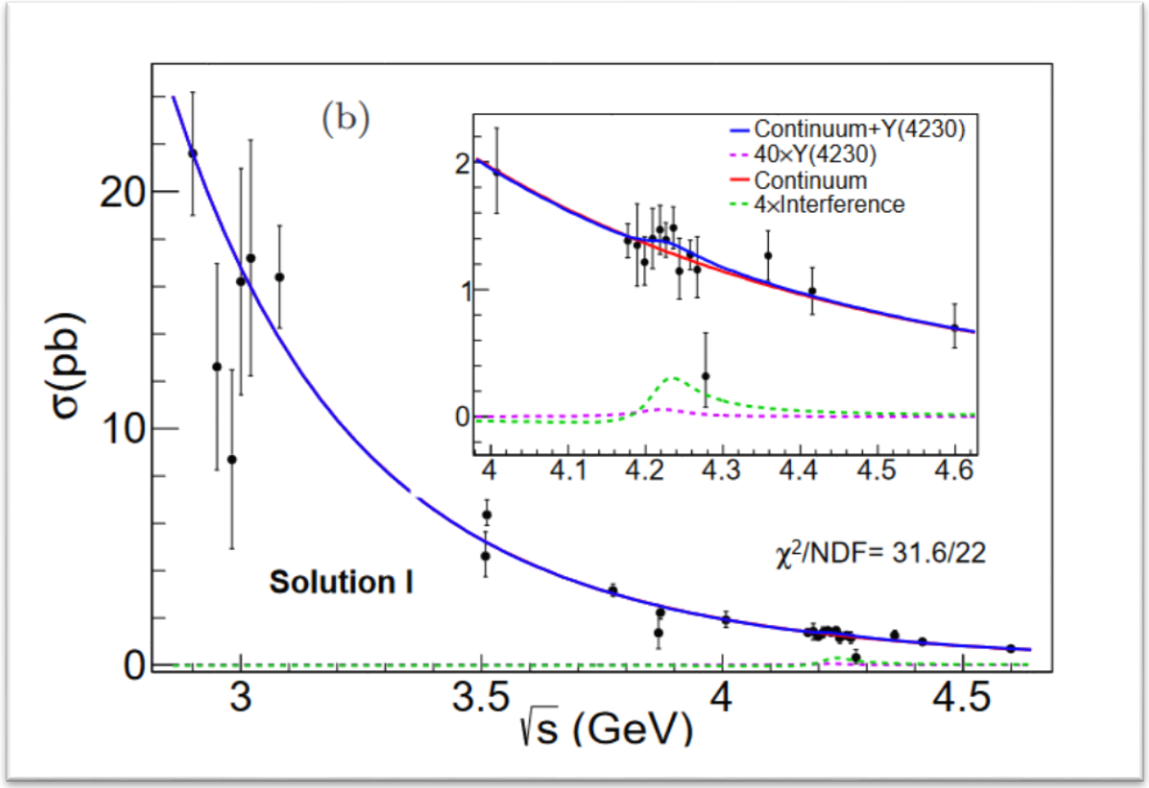


Cross sections measurement of $e^+e^- \to \phi\eta'$

- 3.508-4.600 GeV, 15.1/fb
- $\phi \to K^+K^-,\ \eta' \to \gamma\pi^+\pi^- / \eta\pi^+\pi^-$



2D sideband method



	$Y(4230)$ (Best Fit)		$Y(4230)$ (Upper Limit)	
	Solution I	Solution II	Solution I	Solution II
$\Gamma_{ee}\mathcal{B}_{\phi\eta'}$ (eV)	$(1.3 \pm 2.9) \times 10^{-4}$	0.48 ± 0.03	9.8×10^{-4}	0.50
ϕ (rad)	0.88 ± 1.06	-1.59 ± 0.02	-	-

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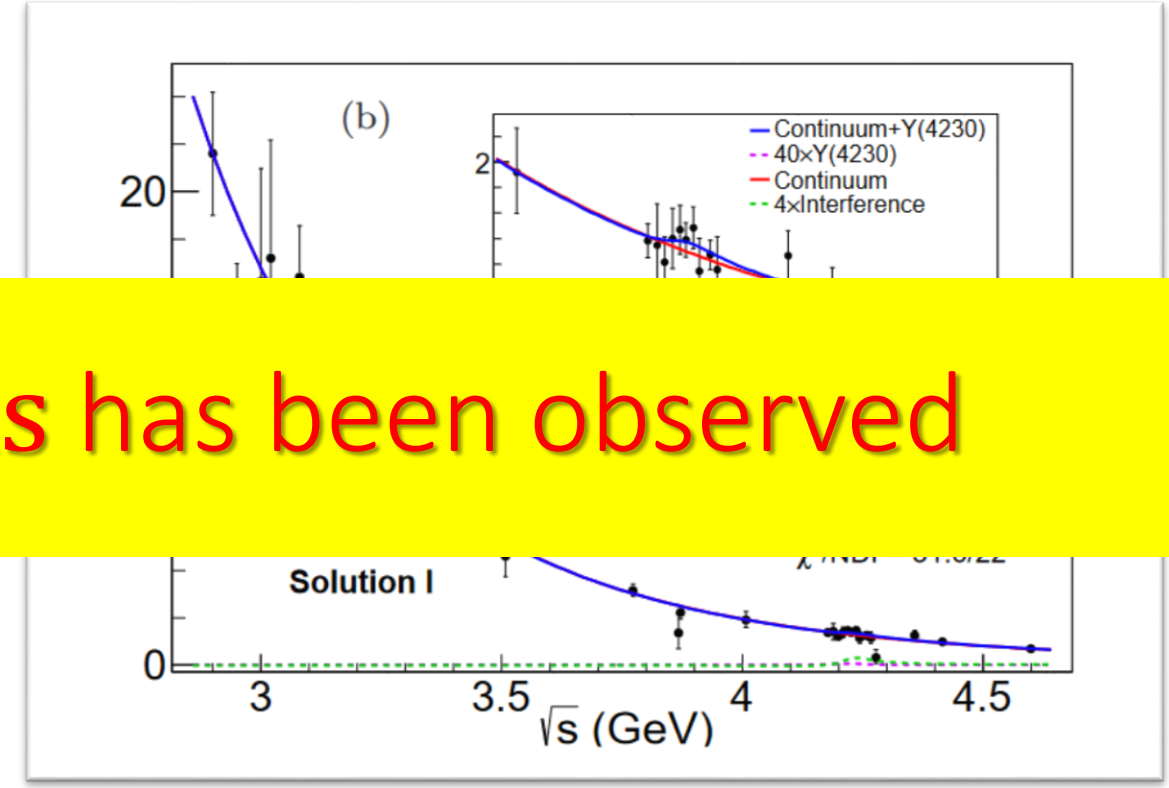
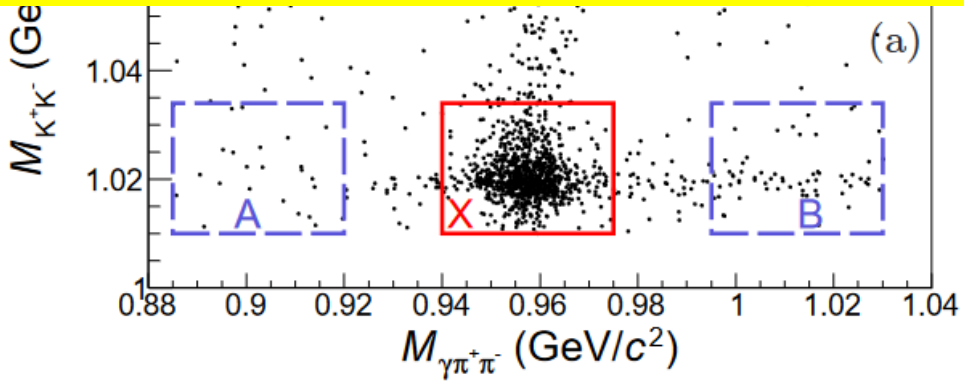


No Y → light hadrons has been observed



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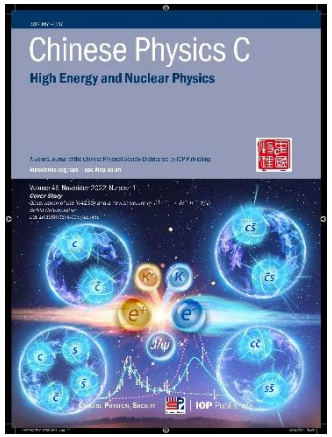
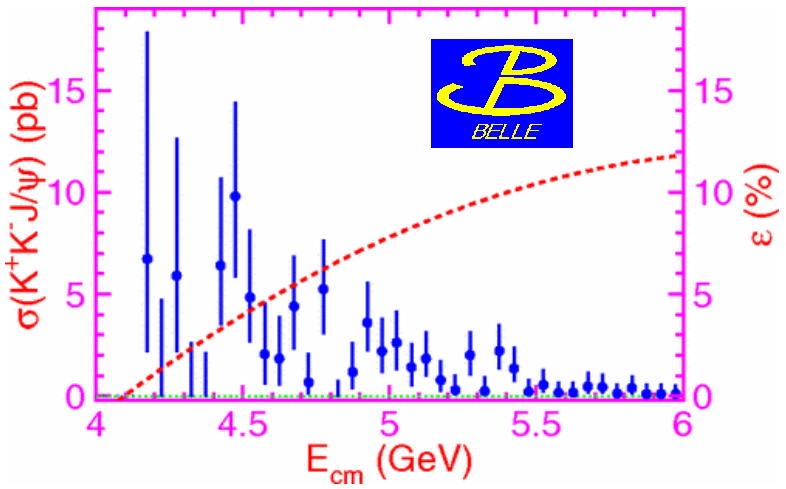
Observation of Y(4500) in $e^+e^- \to K^+K^-J/\psi$

CPC 46, 111002 (2022)

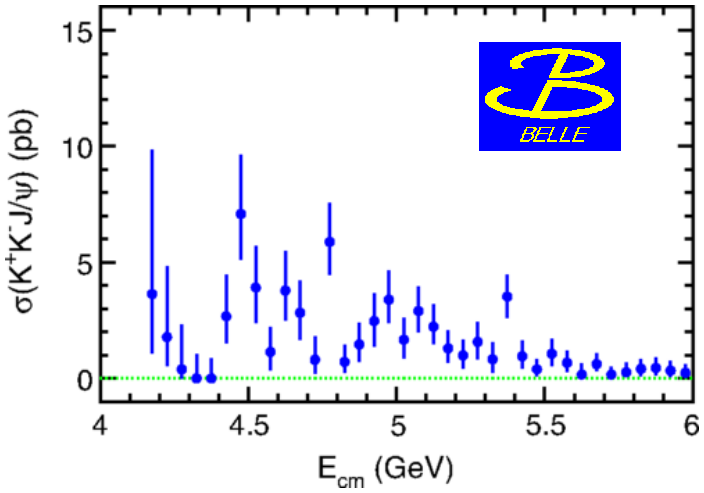


Previous studies

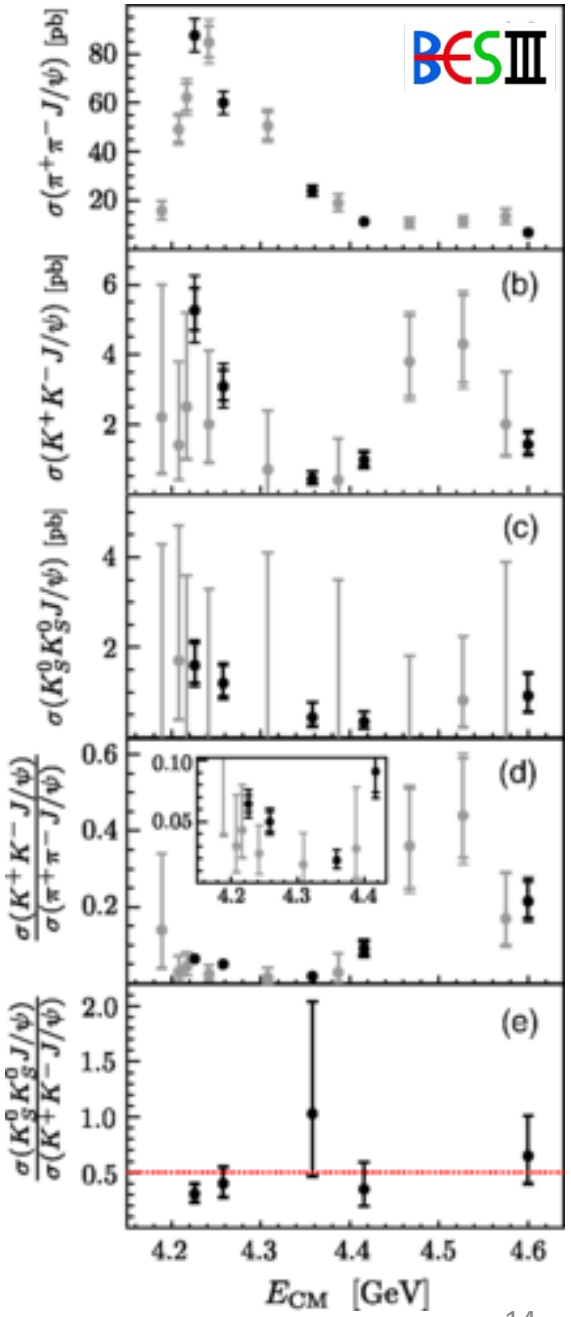
M. Ablikim *et al.* (BESIII Collaboration)
Phys. Rev. D 97, 071101(R) (2018)



C. Z. Yuan *et al.* (Belle Collaboration)
Phys. Rev. D 77, 011105(R) (2008)

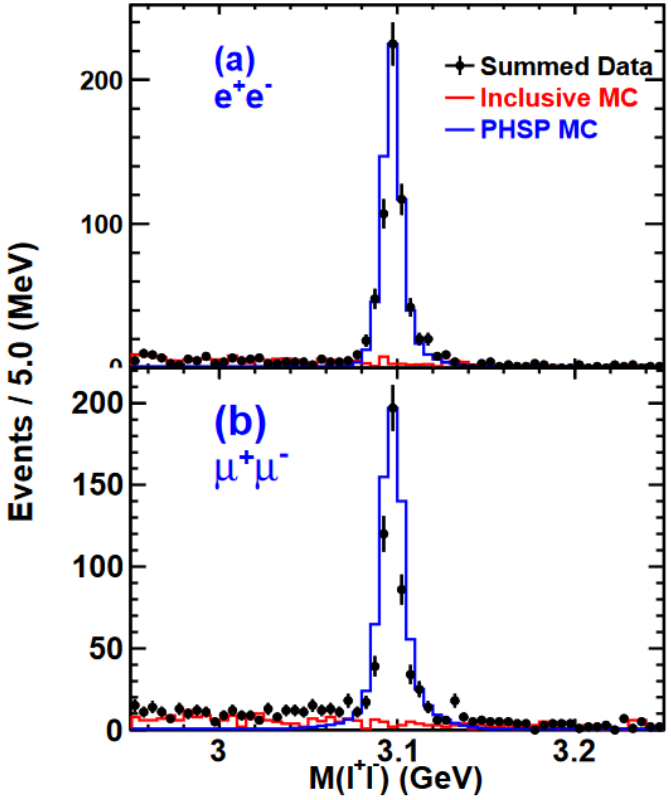


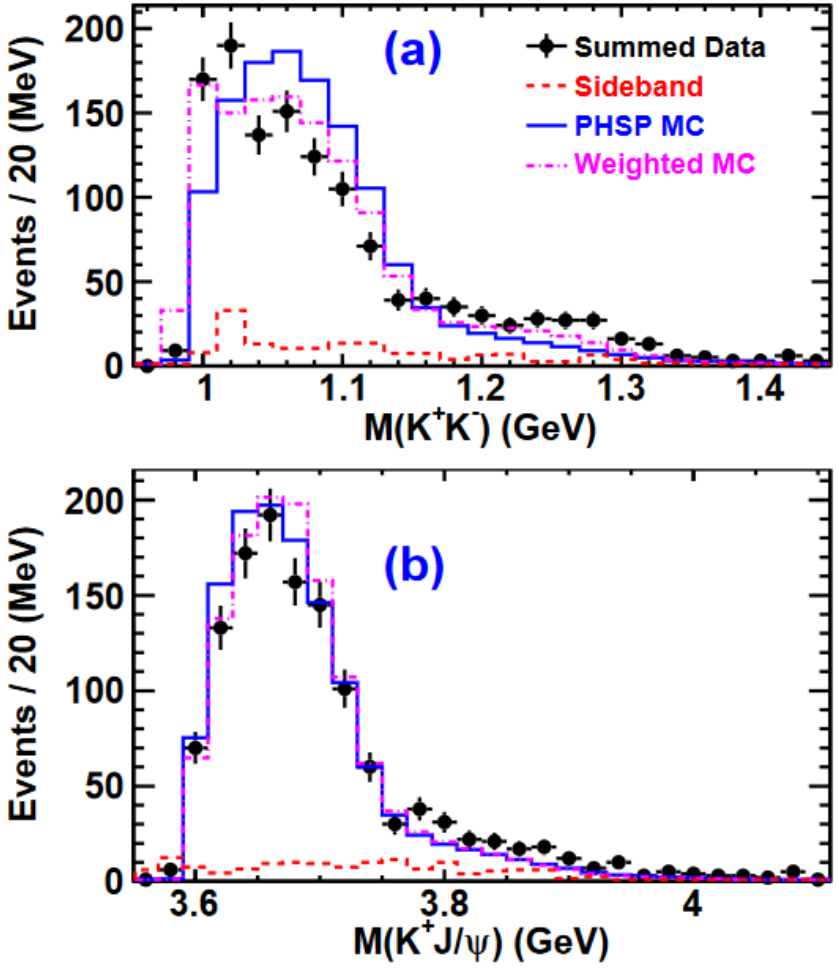
C. P. Shen *et al.* (Belle Collaboration)
Phys. Rev. D 89, 072015 (2014)



Cross sections of $e^+e^- \to K^+K^-J/\psi$

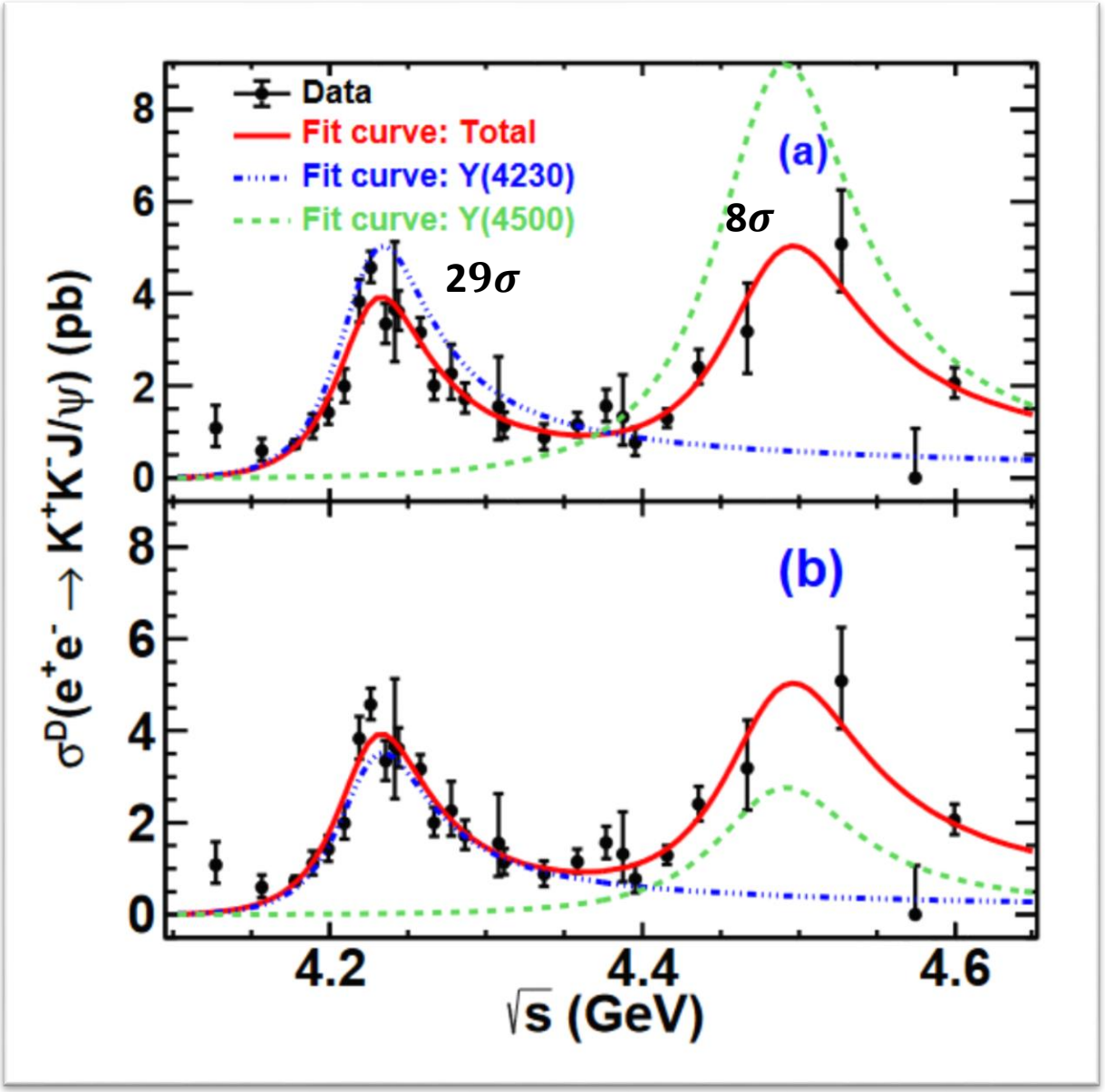
- 4.127-4.600 GeV, 15.6/fb
- Partial reconstruction with missing one kaon





- Complex and energy-dependent structures in $M(K^+K^-)$ $f_0(980) or\ f_2(1270)$?
- No obvious structure in $M(K\ J/\psi)$

Sum of weighted efficiencies of various components



	Parameters	Solution I	Solution II
$Y(4230)$	M(MeV)	$4225.3 \pm 2.3 \pm 21.5$	
	Γ_{tot}(MeV)	$72.9 \pm 6.1 \pm 30.8$	
	$\Gamma_{ee}\mathcal{B}$(eV)	$0.42 \pm 0.04 \pm 0.15$	$0.29 \pm 0.02 \pm 0.10$
$Y(4500)$	M(MeV)	$4484.7 \pm 13.3 \pm 24.1$	
	Γ_{tot}(MeV)	$111.1 \pm 30.1 \pm 15.2$	
	$\Gamma_{ee}\mathcal{B}$(eV)	$1.35 \pm 0.14 \pm 0.07$	$0.41 \pm 0.08 \pm 0.13$
Phase angle	φ(rad)	$1.72 \pm 0.09 \pm 0.52$	$5.49 \pm 0.35 \pm 0.58$

- **Helpful for understanding internal structure and decay mechanism of Y(4230)**
- **(4500) is the first candidate of vector charmonium-like state with substantial strange quark component**

Summary

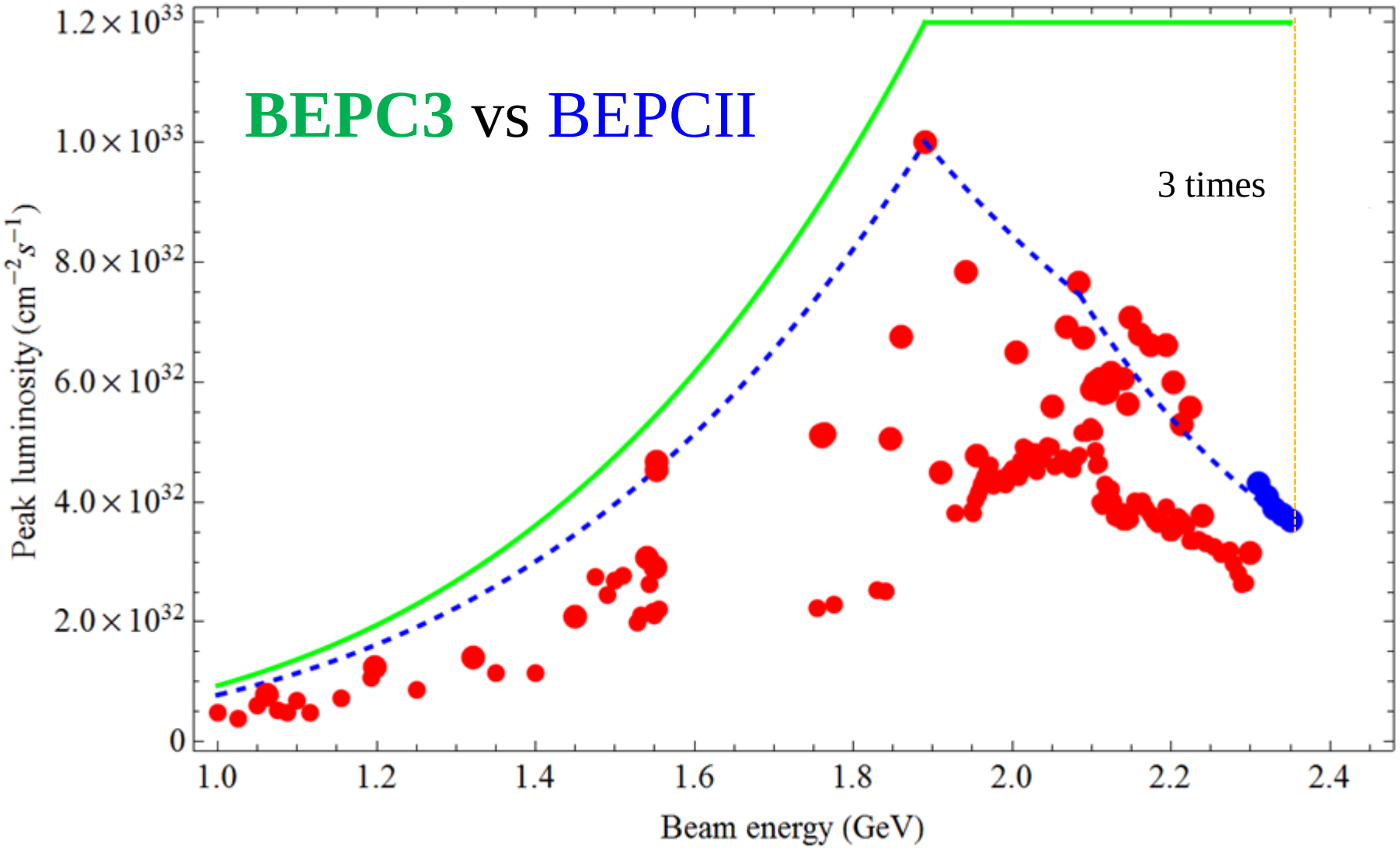
- Three recent results are presented to illustrate XYZ and charmonium studies at BESIII
- A very active field at BESIII: search for new exotic states, search for new decay modes, measure resonance parameters, measure branching fractions, etc.
- More exciting results are on the way.

Non-perturbative
Strong interaction

Thanks for your attention!

backup

Luminosity Performance Gain at Different Energy



- 2024-Mar, shutdown for hardware modification
- 2024-Sep , restart
- 2025-Dec, project acceptance