Recent charmonium-like results at BESIII

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第二十一届全国重味物理和CP破坏研讨会

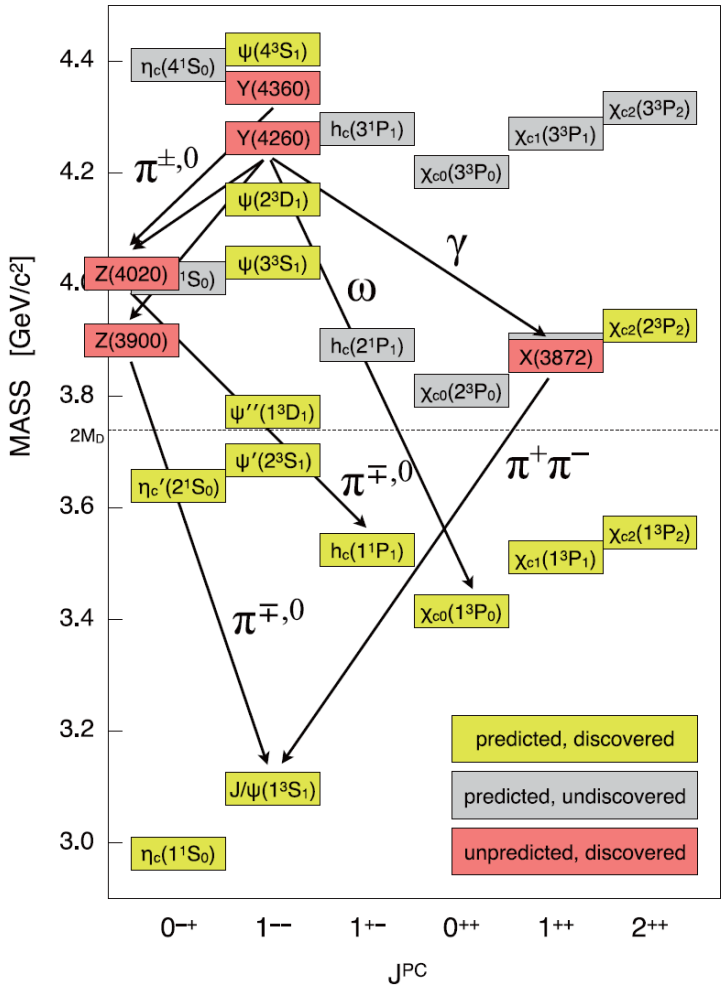
湖南 衡阳 25/10-29/10/2024

Outline

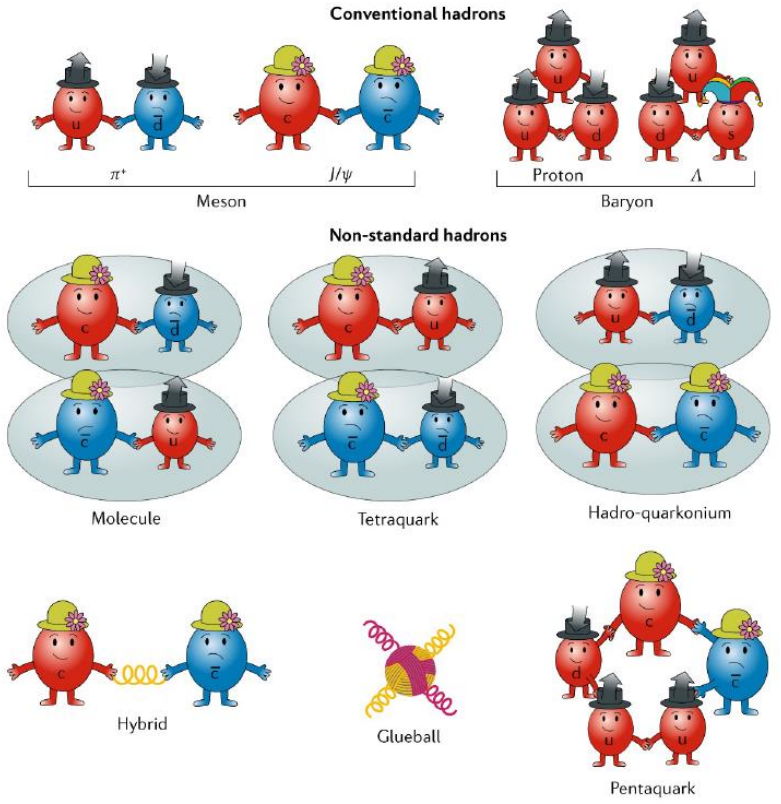
- Introduction
- ~~Three~~ Two recent charmonium-like (XYZ) results at BESIII
  - ✓ $e^+e^- \to \phi X(3872)$ with $\phi \to K^+K^-$
  - ✓ $e^+e^- \to K^+K^-\psi(2S)$
  - ✓ ~~$e^+e^- \to \phi\chi_{c0}/\phi\eta_{c2}(1D)$ with $\phi \to K^+K^-$~~
- Outlook

What are charmonium-like (XYZ) states

charmonia: $c\bar{c}$



Exotic states with hidden charm



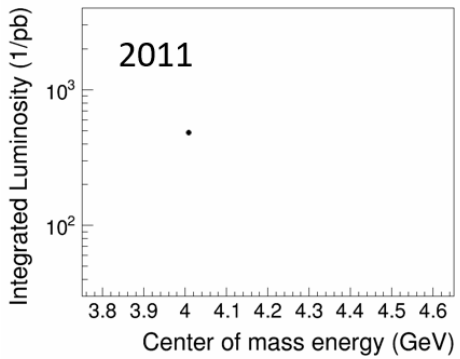
CZY & S. L. Olsen, *Nature Reviews Physics* **1**, 480 (2019)

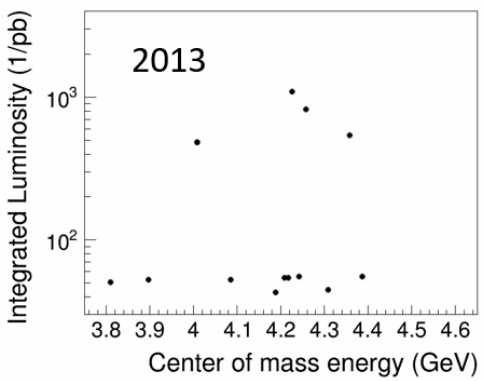
Y: vector states

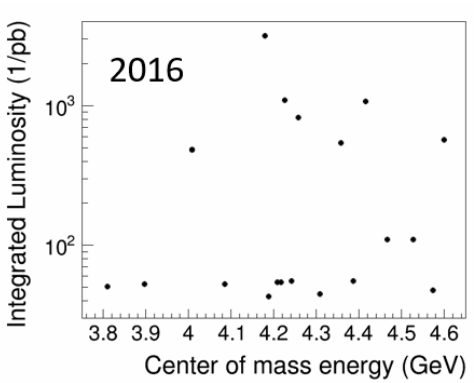
Z: $isospin \neq 0$

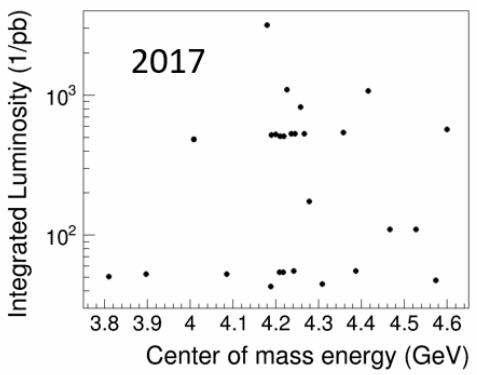
X: remained

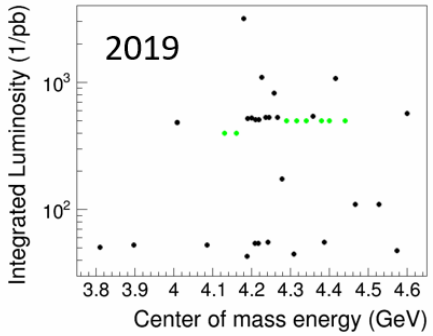
How to study charmonium-like states at BESIII

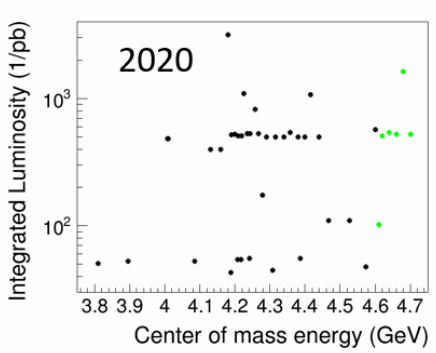


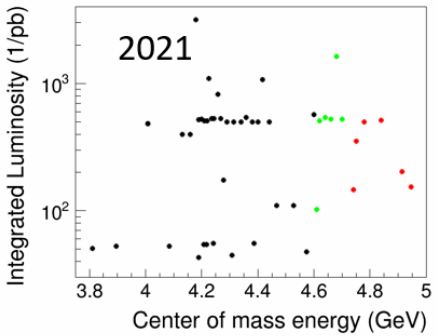


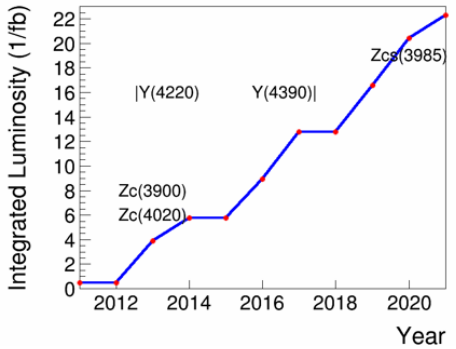










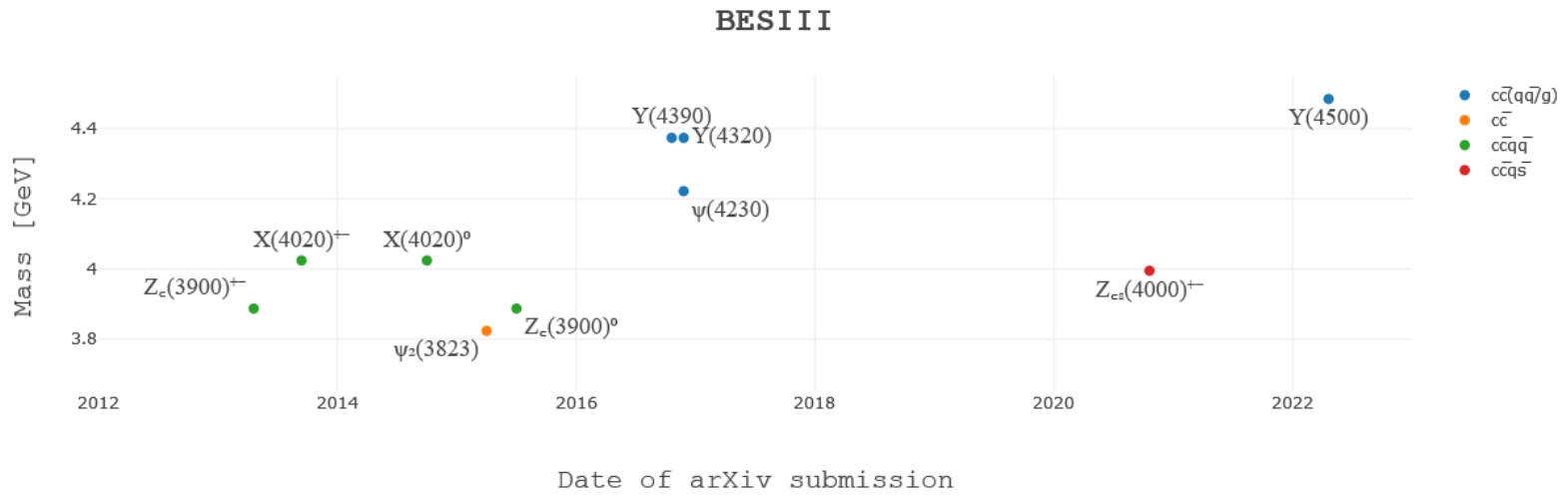


Data samples accumulated at BESIII among the years

$22 fb^{-1}$ above 4 GeV

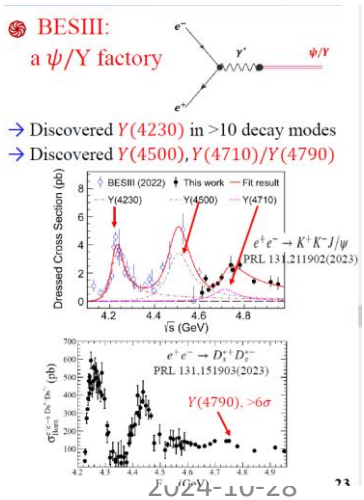
Line shapes of cross-sections for Y, whose (radiative & hadronic) transitions for X and Z

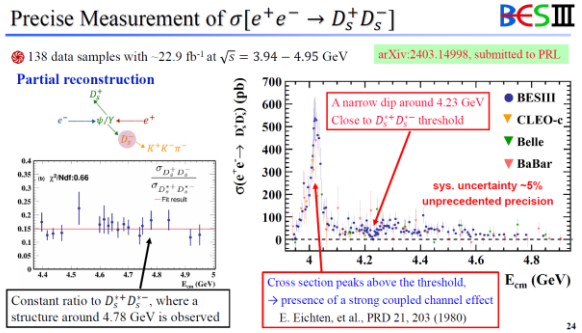
Previous discovered

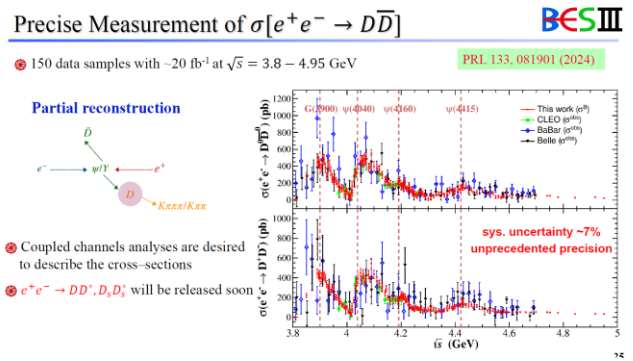


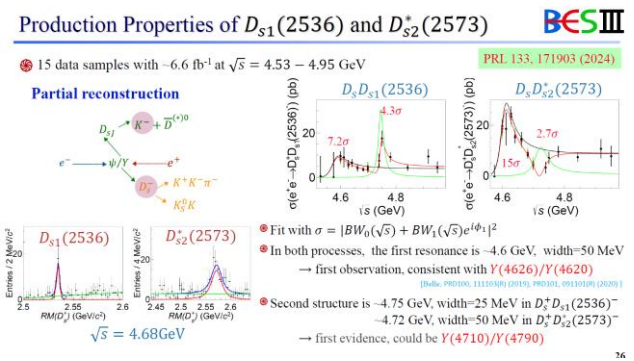
From QWG ExoticHub

From L. Y. Dong's talk @ this workshop









Two recent results

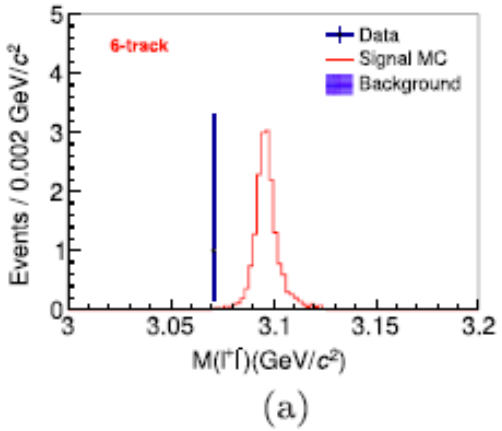
- $e^+e^- \to \phi X(3872)$ with $\phi \to K^+K^-$
- $e^+e^- \to K^+K^-\psi(2S)$

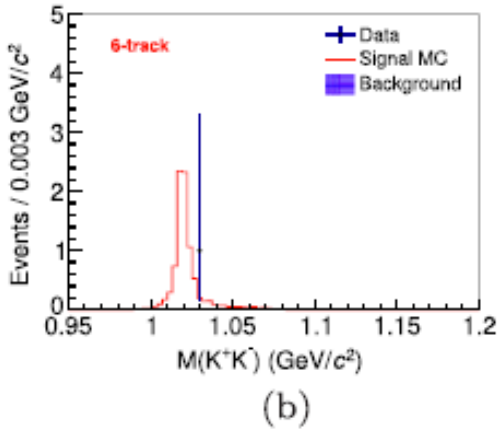
Search for new production mode of X(3872)

- X(3872): $J^{PC} = 1^{++}$, very narrow, mass quite near to DD^*threshold
- Known X production modes
  - B decays
  - Double $c\bar{c}$ productions
  - $\gamma\gamma$ collisions
  - Charmonium/Bottomonium(-like) decays
  - Prompt processes in pp collisions
- At BESIII
  - ✓$e^+e^- \to Y \to \gamma X(3872)$ [PRL 112, 092001 (2014)]
  - ✓$e^+e^- \to Y \to \omega X(3872)$ [PRL 130, 151904 (2023)]
  - **?** $e^+e^- \to Y \to \phi X(3872)$

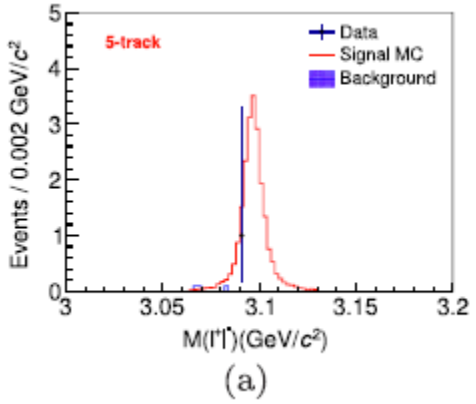
Analysis method

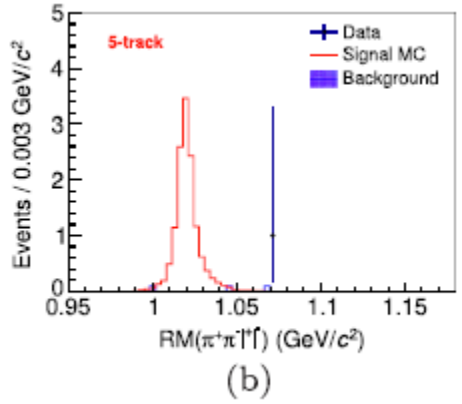
- 368.5 pb^{-1} e^+e^- colliding data at $\sqrt{s} = 4.914$ and 4.946 GeV
- $\phi \to K^+K^-, X(3872) \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^- \; or \; \mu^+\mu^-$
  - 6-track: 4C fit, ϕ and J/ψ mass windows of signal and sidebands
  - 5-track: missing one K, 1C fit, mass windows, and MUC for μ PID





6-track

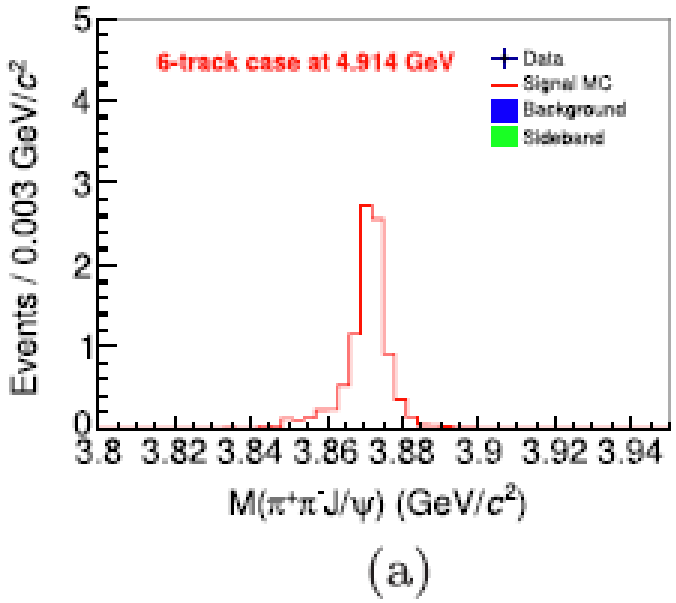


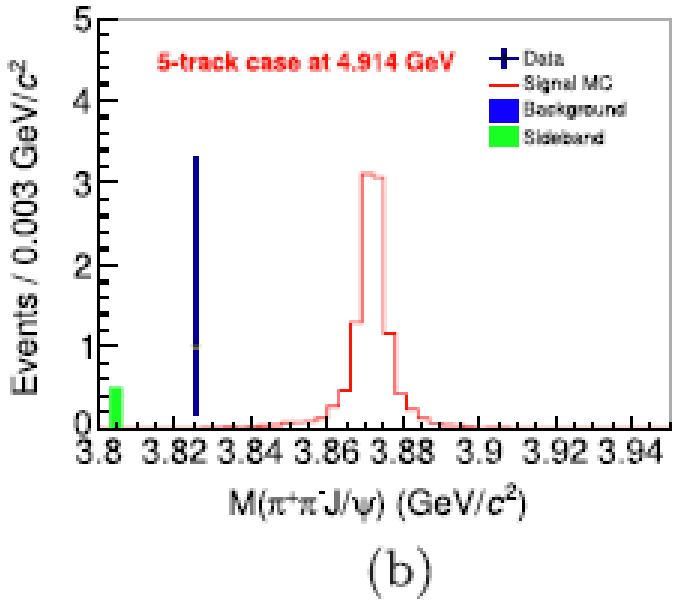


5-track

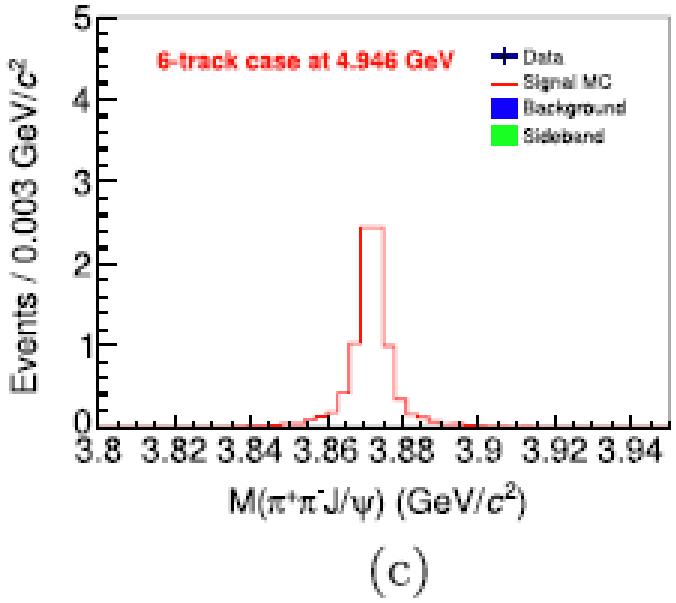
Results

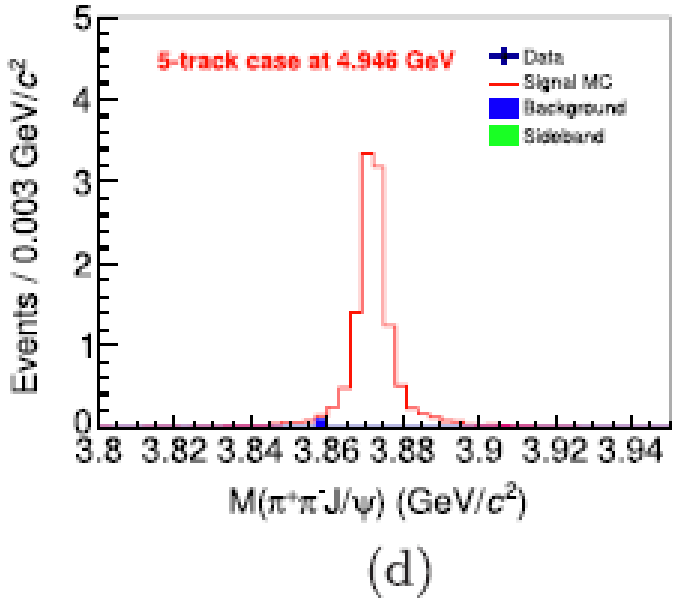
Almost no signal





6-track





5-track

Upper limits of the cross sections

$$\sigma(e^+e^- \to \phi\chi_{c1}(3872)) \cdot \mathcal{B}[\chi_{c1}(3872) \to \pi^+\pi^- J/\psi] = \frac{N_{\rm sig}}{\mathcal{L}_{\rm int}(1+\delta)\frac{1}{|1-\Pi|^2}\epsilon\mathcal{B}_{\rm sub}},$$

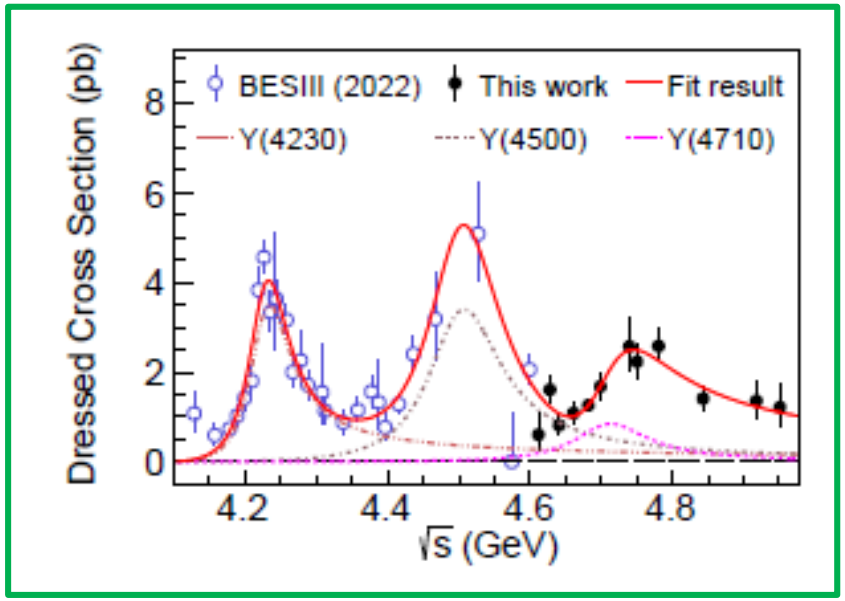
Phys. Rev. D 110, L031103 (2024)

$\sqrt{s}$	$\mathcal{L}_{\rm int}$	$N_{\rm obs}$	$N_{\rm sdb}$	$N^{\rm up}_{\rm signal}$	$(1+\delta)$	ϵ^5	ϵ^6	$\sigma^{\rm up}_B$	
4.914	208.11	0	1	1.70	0.690	19.7	2.8	0.85	pb
4.946	160.37	0	0	2.00	0.755	20.8	7.0	0.96	pb

$\sigma_{\phi\chi_{c1}(3872)}/\sigma_{\phi\chi_{c1}} < 9$ same order to $\sigma_{\omega\chi_{c1}(3872)}/\sigma_{\omega\chi_{c1}} \sim 5$

Search for $e^+e^- \to K^+K^-\psi(2S)$

- Y interest
  - $J^{PC} = 1^{--}$
  - Overpopulates the prediction of potential models
  - Not in the R-value structures, and *favor* hidden-charm final state
  - When strange-quark is involved



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

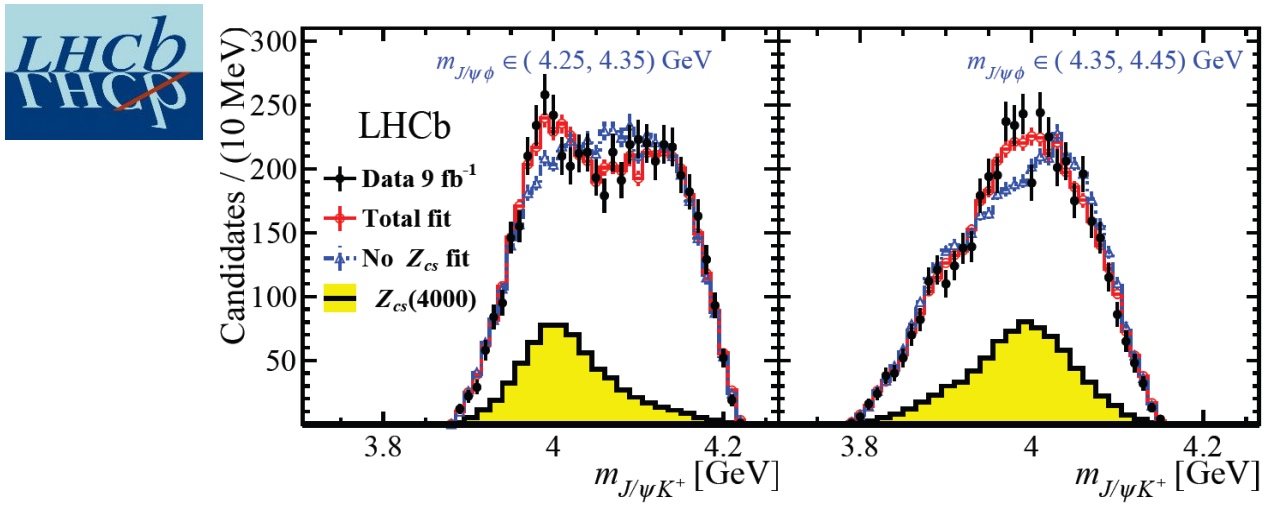
CPC 46, 111002 (2022)

PRL 131, 211902 (2023)

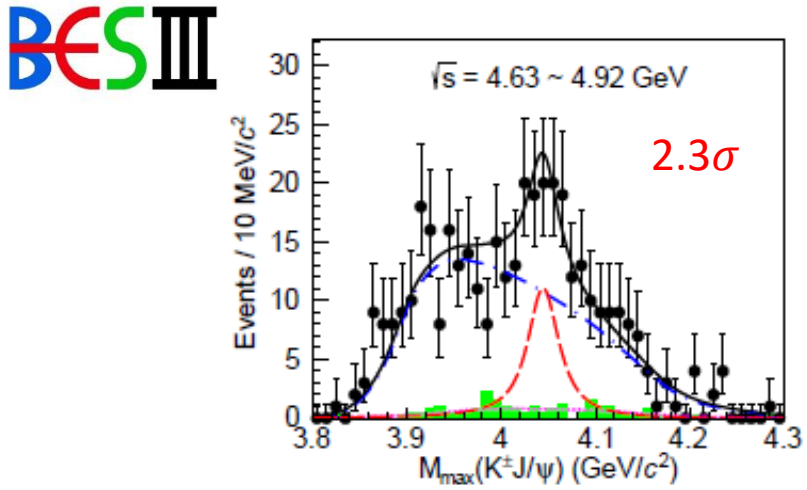
Extension from J/ψ to $\psi(2S)$?

Search for $e^+e^- \to K^+K^-\psi(2S)$ [cont']

- Z interest
  - Non-zero iso-spin, good tetra-quark candidate
  - From Z_c $(\pi J/\psi)$ to Z_{cs} (KJ/ψ)



PRL 127, 082001 (2021)

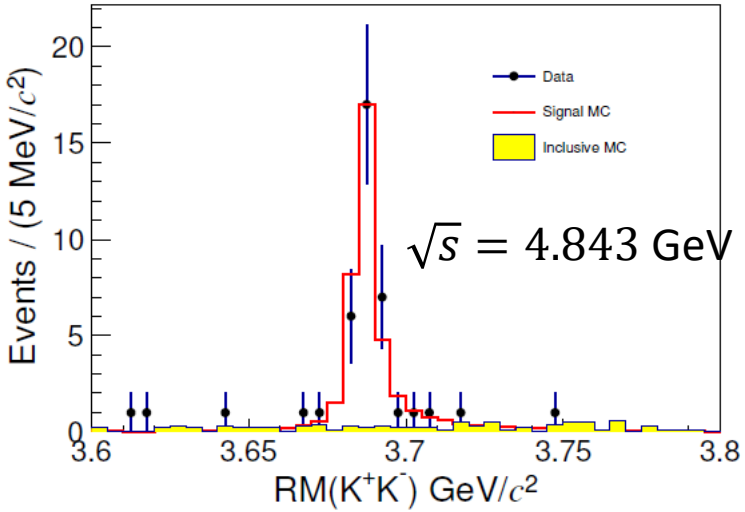


PRL 131, 211902 (2023) 21

Again, extension from J/ψ to $\psi(2S)$?

Analysis strategy

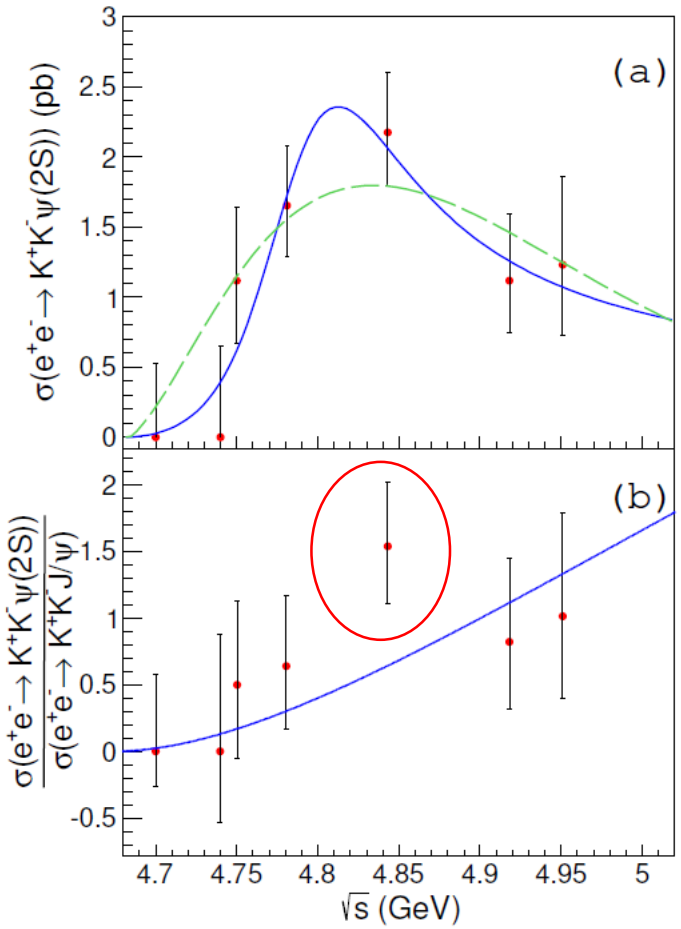
- Data sets: $\sqrt{s} = 4.699 - 4.951$ GeV, 2.5 fb^{-1}
- Various reconstructions
  - Approach (i): tag K^+, K^-, and J/ψ from $\psi(2S) \to X\, J/\psi$
  - Approach (ii): tag K^+or K^-, and $\psi(2S)$ with $\pi^+\pi^- J/\psi$, 1C
  - Approach (iii): tag K^+, K^-, and $\psi(2S)$ with l^+l^-
  - Approach (iv): tag K^+or K^-, and $\psi(2S)$ with l^+l^-, 1C



No peaking background from inclusive MC

Cross sections

$$\sigma^{\mathrm{B}} = \frac{N_{\mathrm{s}}}{\mathcal{L}_{\mathrm{int}}\epsilon_r(1+\delta)\frac{1}{|1-\Pi|^2}};$$



(a) Both BW and Expo functions can fit the data well

$M = 4787.7 \pm 17.7$ MeV, $\Gamma = 110.3 \pm 33.9$ MeV

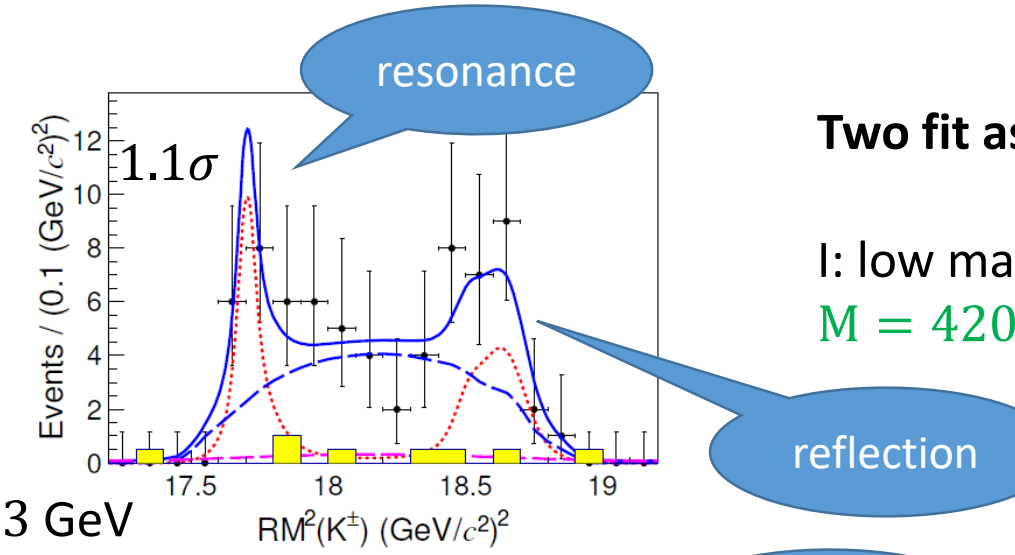
$\Gamma^{ee}B\left(Y \to K^+K^-\psi(2S)\right) = 0.13 \pm 0.02$ eV

(b) Solid line represents PHSP, 2σ deviation at 4.845 GeV

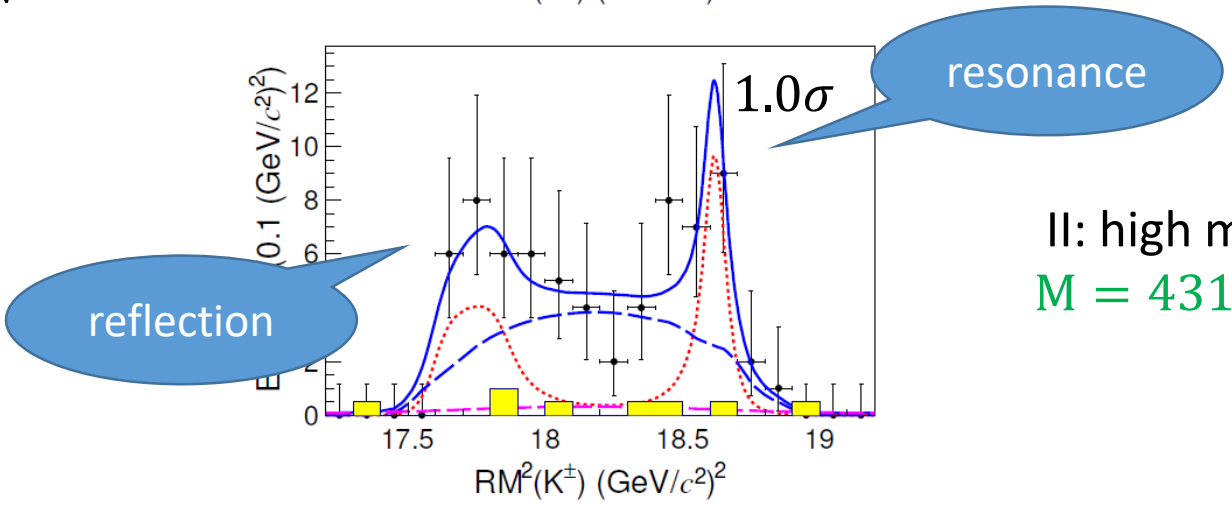
Indicate distinct production mechanism

arXiv:2407.20009, submitted to Phys. Rev. Lett.

Search for $Z_{cs} \to K^{\pm}\psi(2S)$



$\sqrt{s} = 4.843$ GeV



Two fit assumptions (interference is ignored)

I: low mass, high reflection

$M = 4208.4 \pm 3.1$ MeV, $\Gamma = 6.1 \pm 5.7$ MeV

II: high mass, low reflection => 4.315 GeV

$M = 4316.0 \pm 2.7$ MeV, $\Gamma = 9.0 \pm 8.6$ MeV

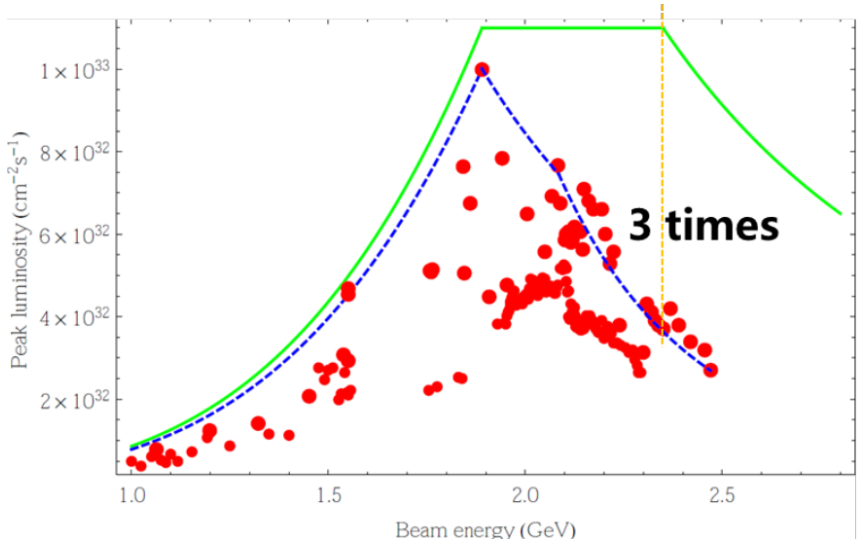
arXiv:2407.20009, submitted to Phys. Rev. Lett.

Summary and outlook

- Charmonium-like physics is still an active topic at BESIII
- Ways to beyond the limited statistics (analysis vs. data)

BEPCII will upgrade in both Lum. and Max. E

- Luminosity is increased by a factor 3 @ 2.35 GeV
- Maximun beam energy is increased up to 2.8 GeV



More data, more exciting results!

Thanks for your attention!