BESIII上粲偶素与类粲偶素研究

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第一届基础物理研讨会暨基础物理平台年会

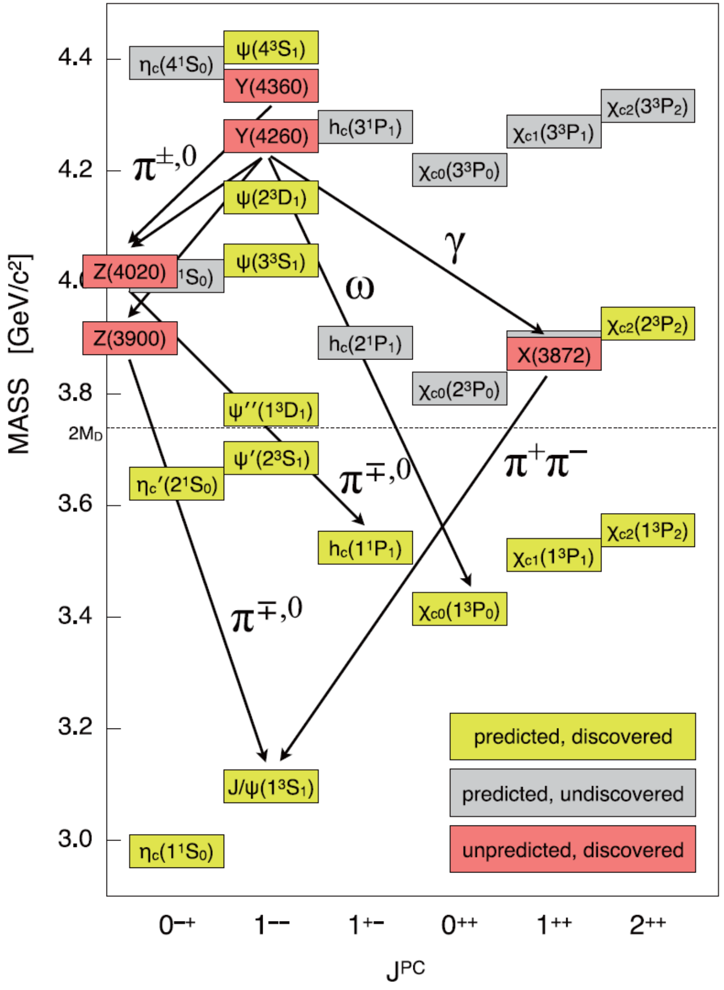
2024年11月1日-2日，郑州，河南省科学院

Outline

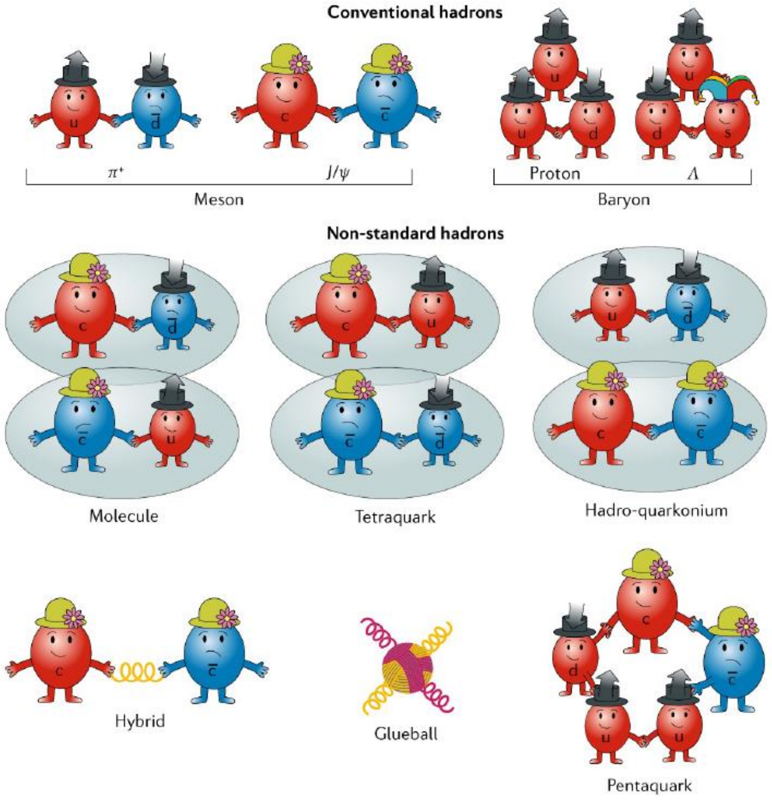
- Introduction
- Recent progresses about charmonium(-like) studies
- Summary

Studies of charmonium(-like) states

charmonia: $c\bar{c}$



Exotic states with hidden charm



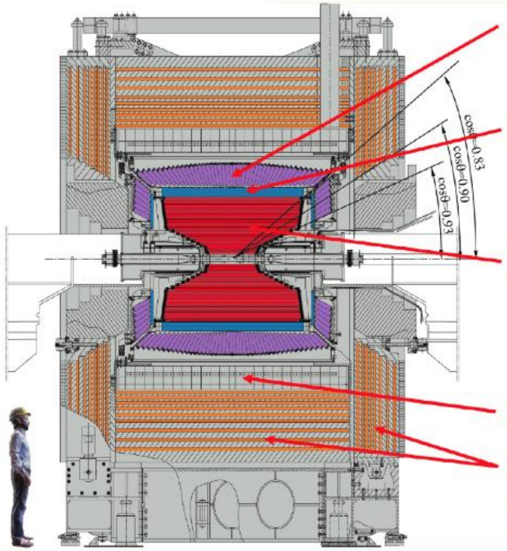
CZY & S. L. Olsen, *Nature Reviews Physics* **1**, 480 (2019)

Primarily studies the properties of charmonium(-like) states, including but are not limited to

- Searching for new states
- Determining the internal structure
- Measuring masses and widths
- Measuring transitions and decays
- Searching for new decay channels

Better understanding strong interaction

BESIII at BEPCII



EMC: CsI crystals
$\Delta E/E$ = 2.5% @ 1 GeV - Barrel
$\Delta E/E$ = 5.0% @ 1 GeV - Endcaps

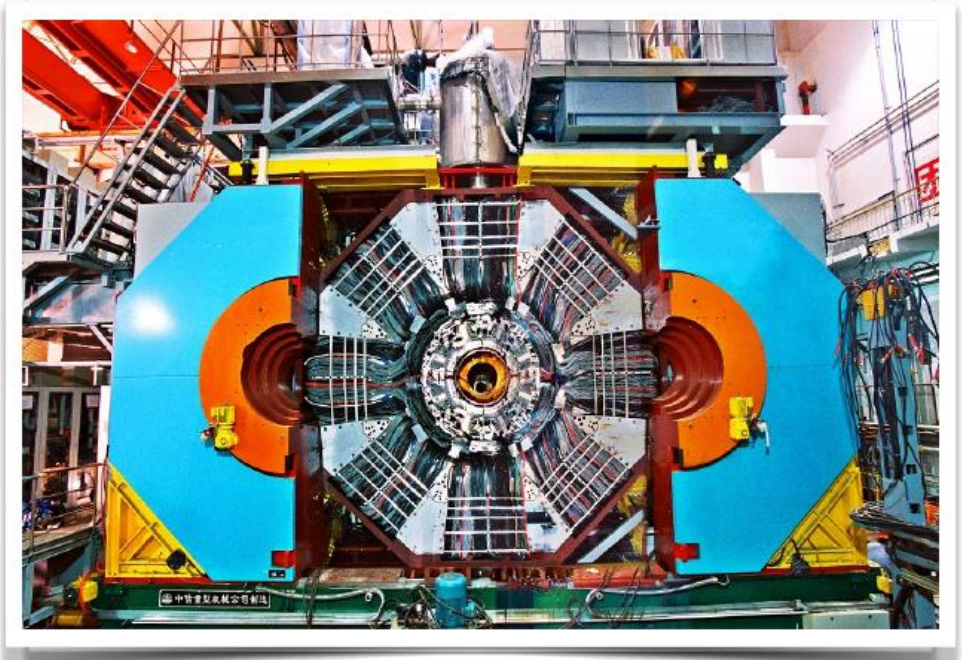
TOF:
σ_T = 80 ps Barrel
σ_T = 110 (60) ps Endcap

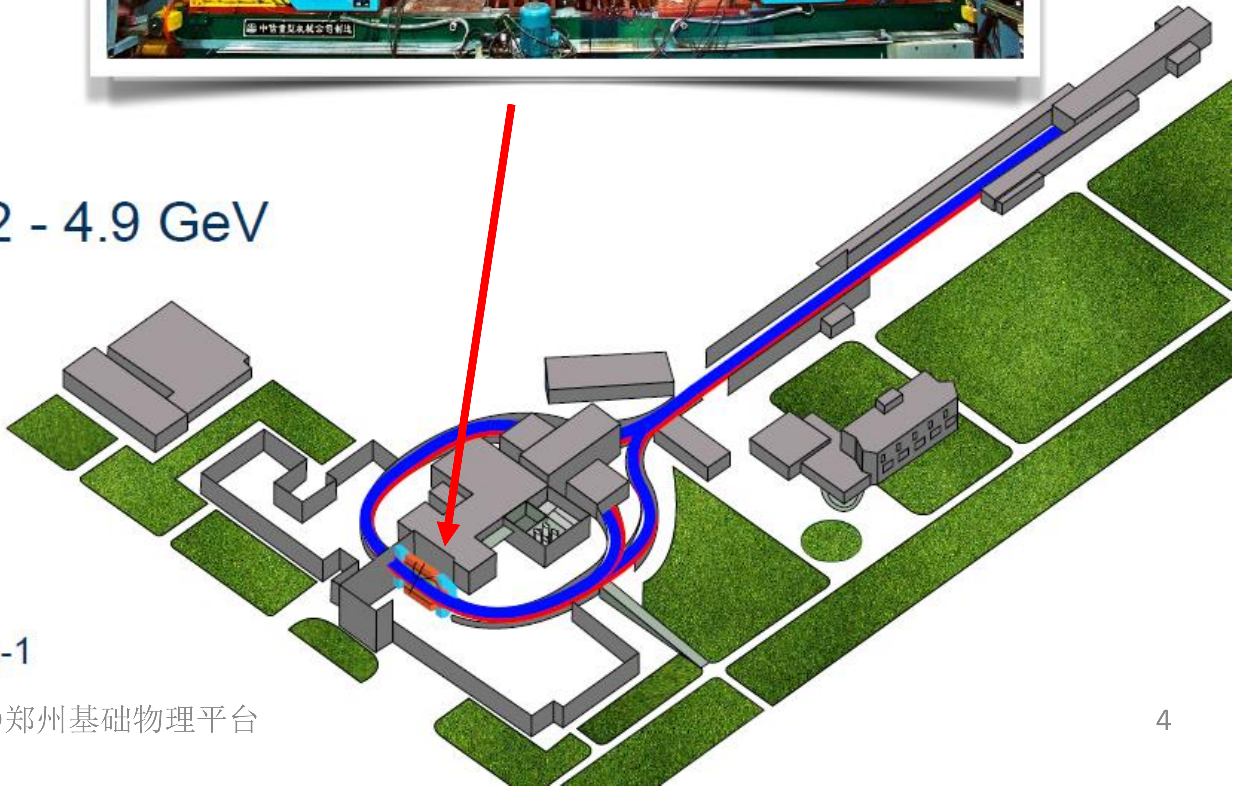
MDC: small cell & He gas
σ_{xy} = 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Magnet: 1T Super conducting

Muon ID: 9 layer RPC

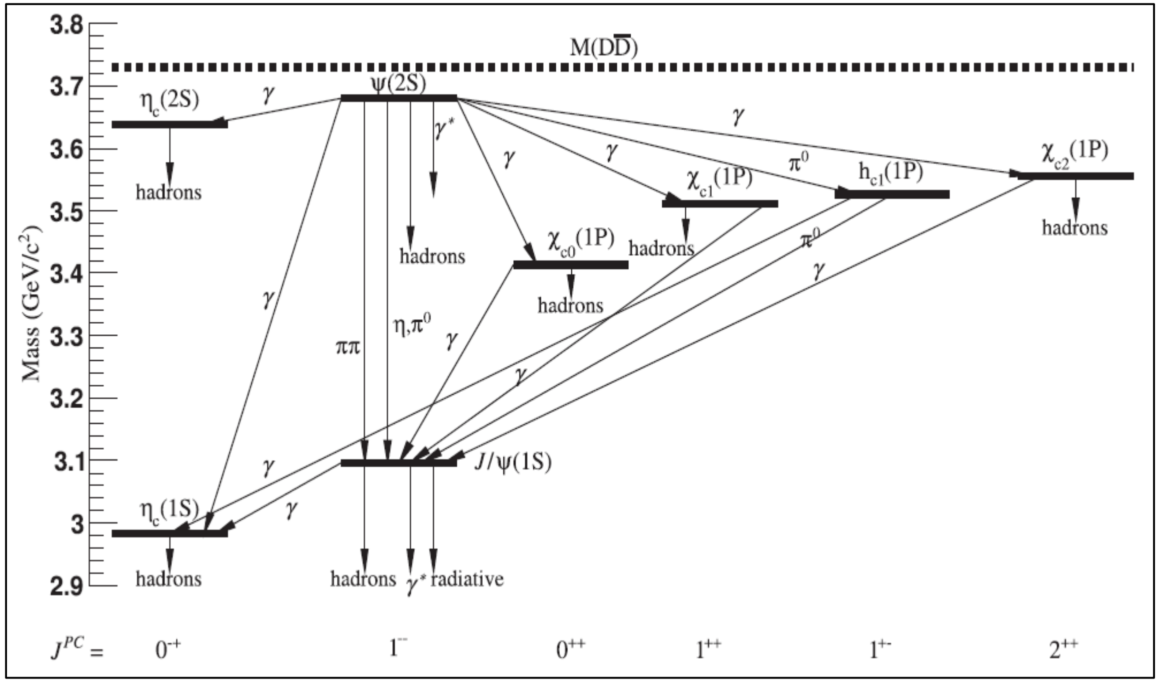
Trigger: Tracks & Showers



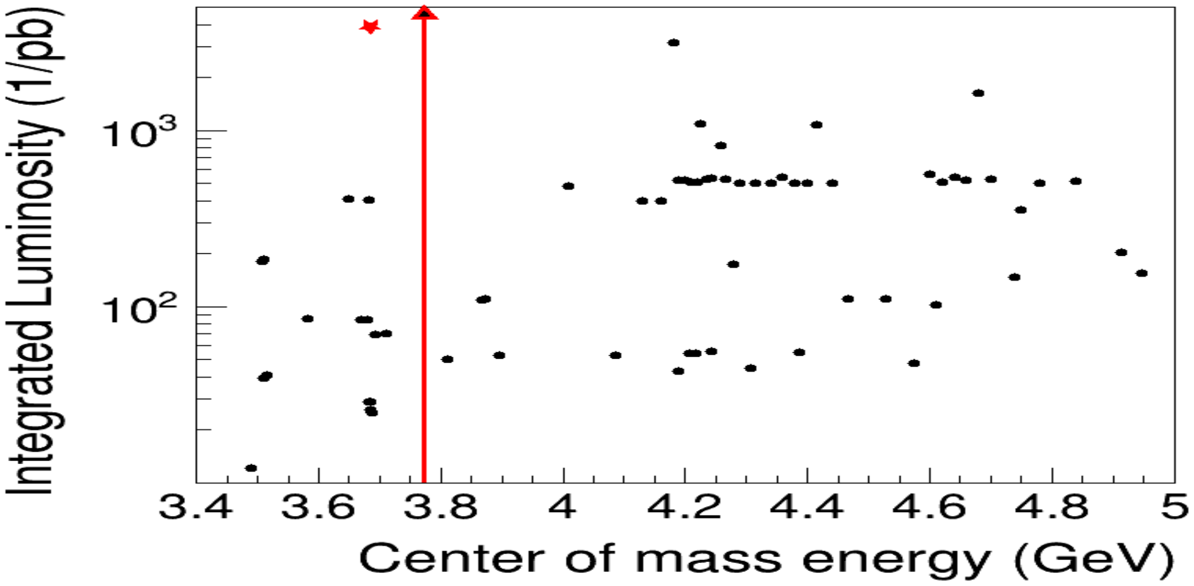


- Center of mass energy range: $\sqrt{s}$ = 2 - 4.9 GeV
- Single beam current: 0.91 A
- Crossing angle: 11 mrad
- Design luminosity: $1 \cdot 10^{33}$ cm^{-2} s^{-1}
- Achieved luminosity: $1.01 \cdot 10^{33}$ cm^{-2} s^{-1}

How to study charmonium(-like) sates at BESIII



- Below charm threshold
  - 2.7B $\psi(2S)$ sample
  - Transitions from $\psi(2S)$

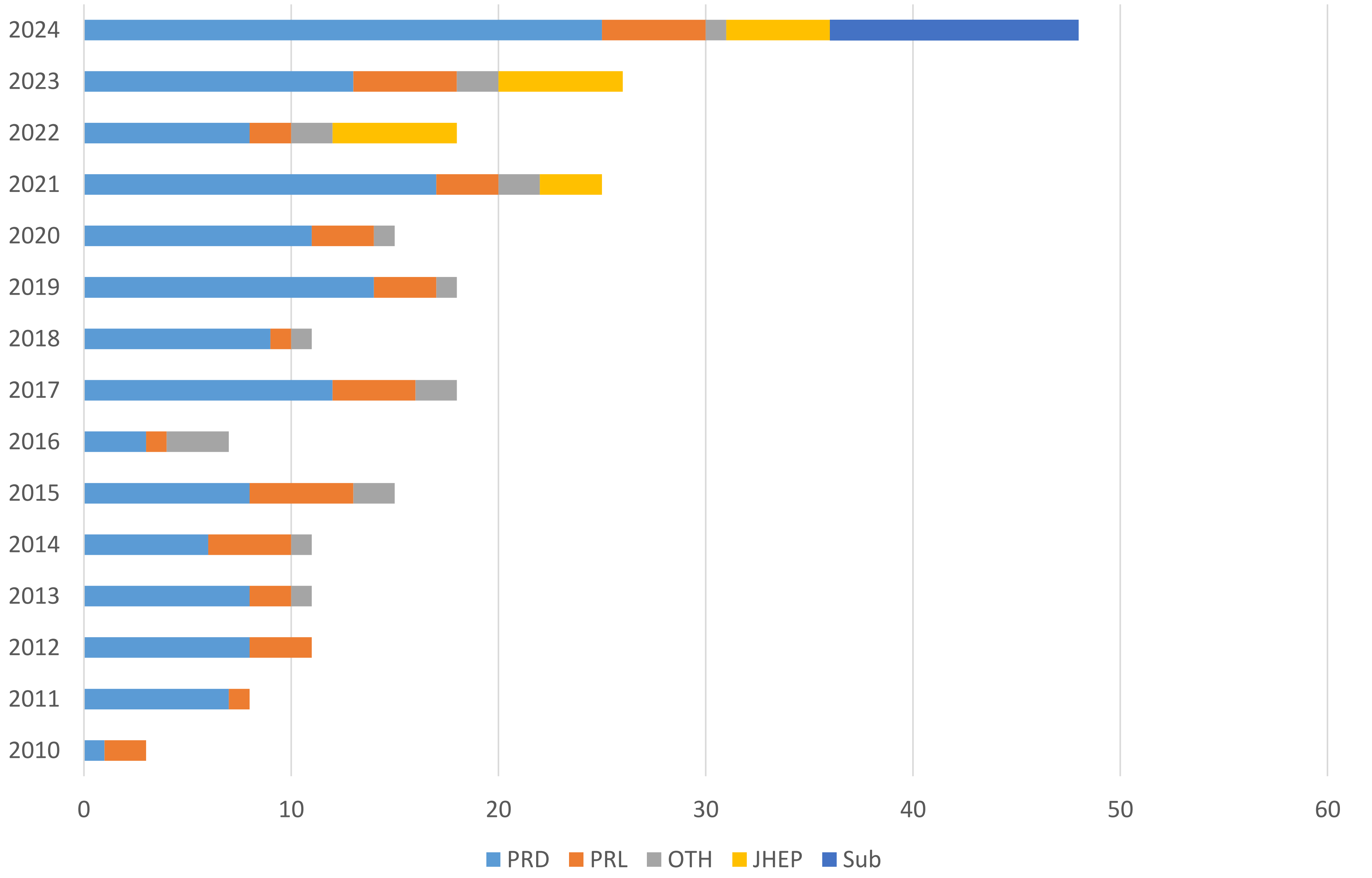


- Above charm threshold
  - 20 fb^{-1} collision data @ 3.773 GeV
  - 22 fb^{-1} scan data above 4 GeV
  - Line shapes of cross -sections for Y, whose (radiative & hadronic) transitions for X and Z

Recent progresses

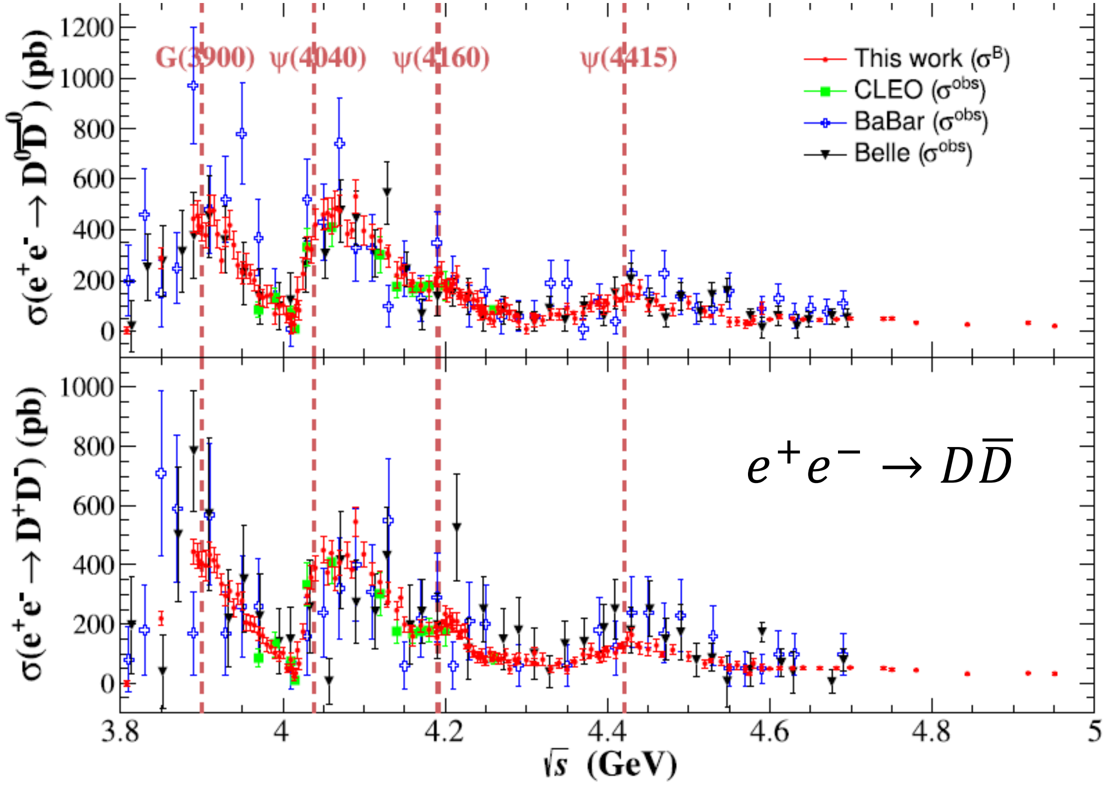
- Precise cross-sections of $e^+e^- \to open\ charm$
- Cross-sections of $e^+e^- \to hidden\ charm$ （张杰磊，吴连近）
- Cross-sections of $e^+e^- \to light\ hadrons\ (bayon\ involved\ or\ not)$
- Coupled channel analysis and partial wave analysis
- $\eta_c/\eta_c(2S)$ decays and new 12% rules （姬清平）
- $\chi_{cJ}, h_c, \psi(2S)$ decays, $non-D\bar{D}$ decays of $\psi(3773)$, relative phase angle of strong/EM amplitudes of ψ decays （姬清平，宋娇娇）

BESIII 粲偶素组历年发表物理文章



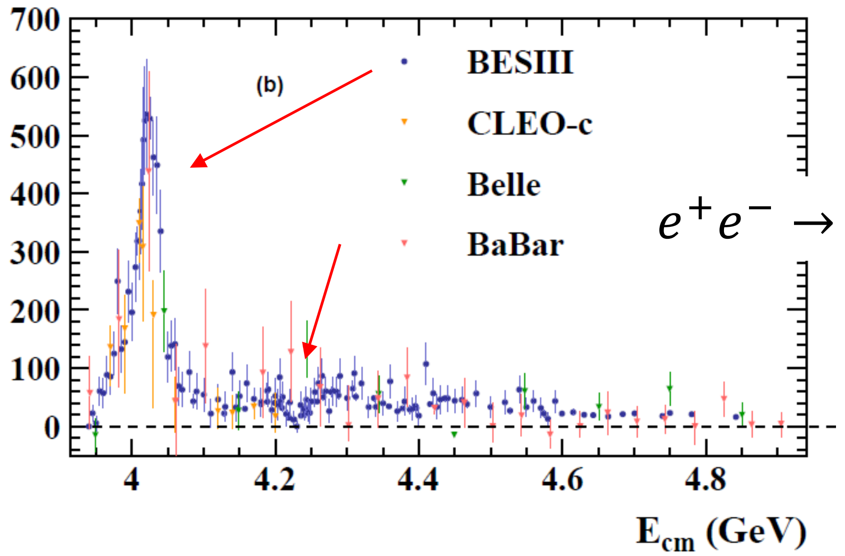
Precise cross sections of $e^+e^- \to open\ charm$

BESIII [Phys. Rev. Lett. 133, 081901 (2024)](#)



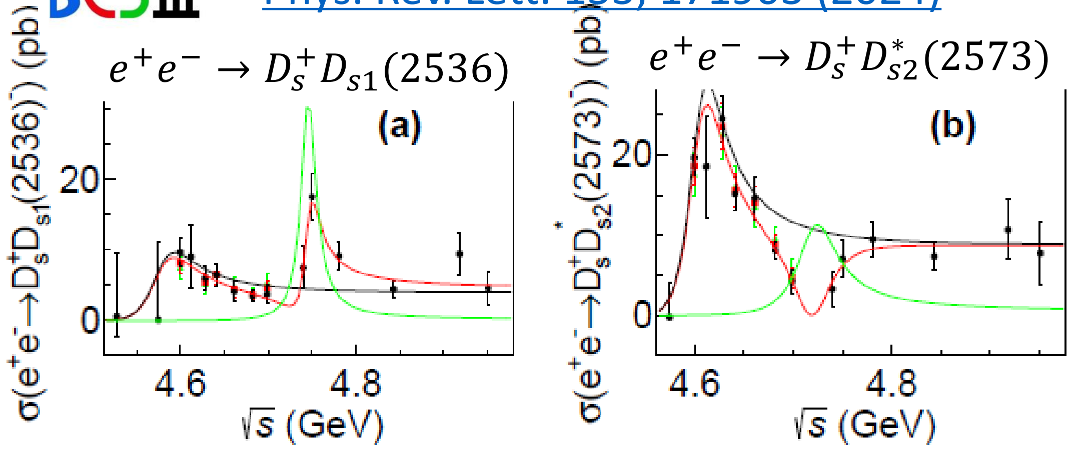
$e^+e^- \to D\bar{D}$

BESIII [arXiv:2403.14998](#), submitted to [PRL](#)



$e^+e^- \to D_s^+ D_s^-$

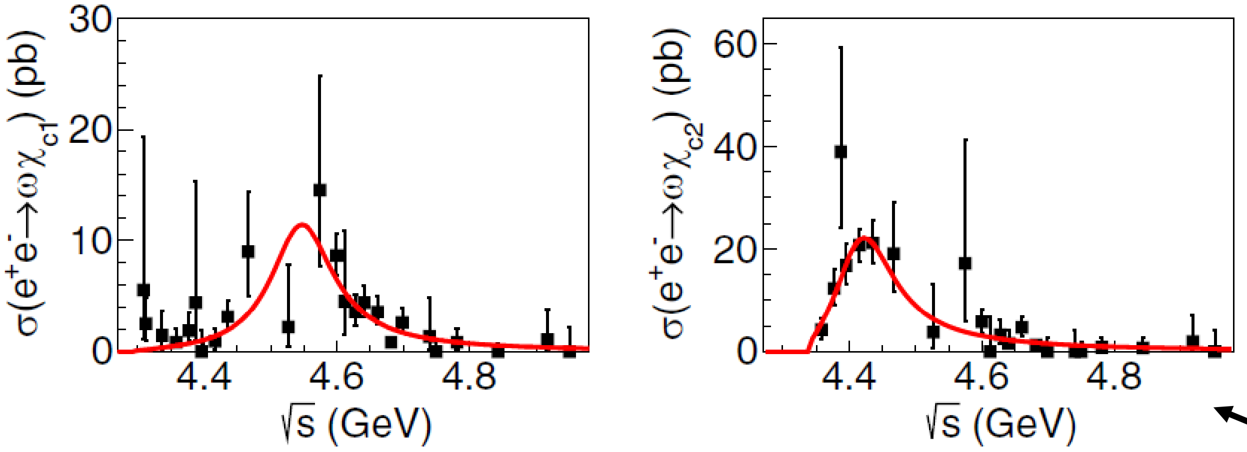
BESIII [Phys. Rev. Lett. 133, 171903 (2024)](#)



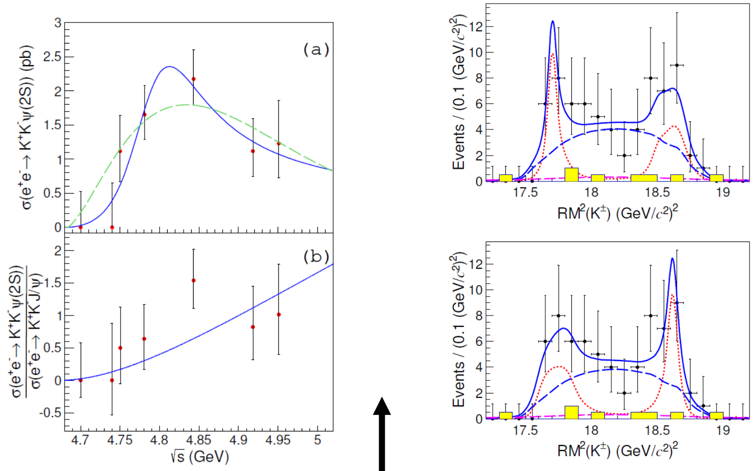
structures, structures, structures

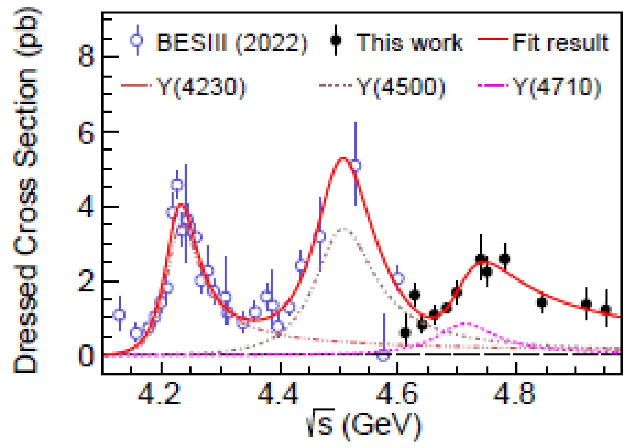
Cross sections of $e^+e^- \to$ ***hidden charm***

BESIII Phys. Rev. Lett. 132, 161901 (2024)

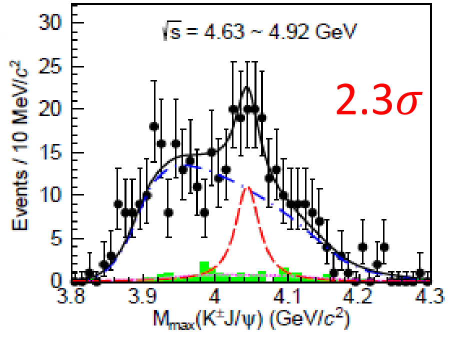


BESIII arXiv:2407.20009, submitted to PRL





BESIII



PRL 131, 211902 (2023) 21

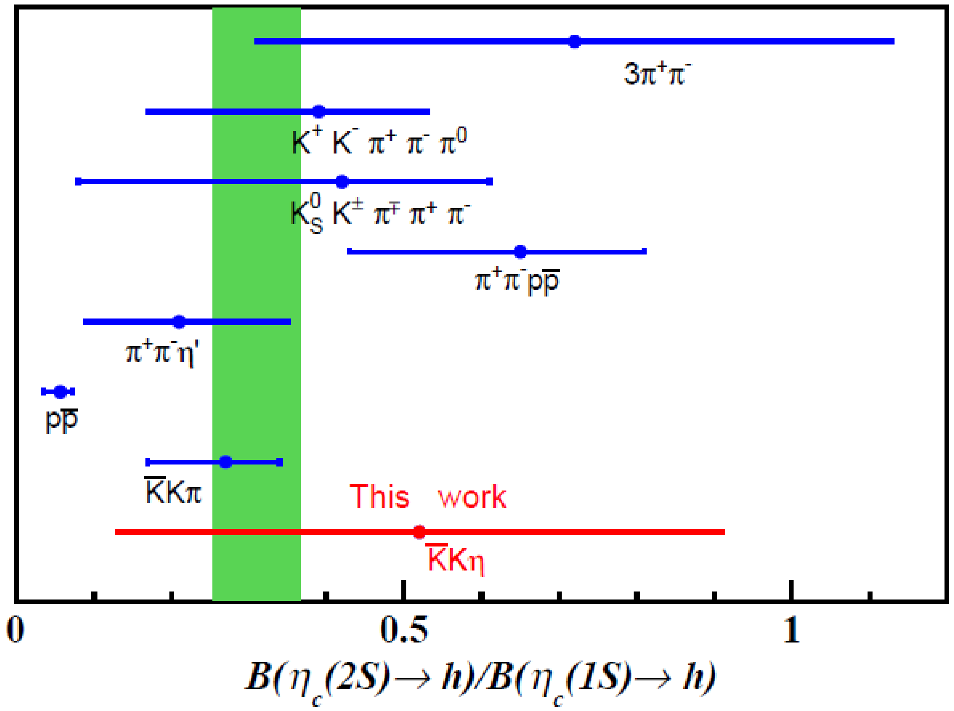
- $e^+e^- \to K^+K^-\psi(2S)$
- $e^+e^- \to \omega\chi_{c1/2}$
- $e^+e^- \to K^+K^-J/\psi$
- $e^+e^- \to K^+K^-\eta_c$
- $e^+e^- \to K^+K^-\chi_{c0}$ (arXiv)
- $e^+e^- \to K\bar{K}h_c$
- $e^+e^- \to K^+K^-\psi(3770)$ (PRD)
- $e^+e^- \to K^+K^-X(3872)$ (PRD)

$\eta_c(1S/2S)$ decays, extend 12% rule of $\psi(1S/2S)$

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

[2] $\frac{Br(\eta_c(2S)\to h)}{Br(\eta_c(1S)\to h)} \approx 1$ If there is a glueball component mixed in η_c (1S) and $\eta_c(2S)$, the value will less than 1

BESIII arXiv:2408.02940, accepted by PRD



•[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)

Submitted or published in 2024:

$\eta_c(2S) \to p\bar{p}, \omega\omega, \omega\phi, K^+K^-\eta, K^+K^-\eta', 2(\pi^+\pi^-)\eta \ (including\ \eta_c(1S)), 2(\pi^+\pi^-), K\bar{K}\pi$

Ways to beyond the limited statistics (analysis）

- Partial reconstruction and more decay channels

$e^+e^- \to \phi\chi_{c0}/\eta_{c2}(1D)$

χ_{c0} Decay	Full			Miss $K^\pm$			Miss $\pi^\pm$			Miss π^0		
	$K^\pm$	$\pi^\pm$	π^0	$K^\pm$	$\pi^\pm$	π^0	$K^\pm$	$\pi^\pm$	π^0	$K^\pm$	$\pi^\pm$	π^0
$\pi^+\pi^-$	2	2	0	1	2	0	2	1	0	-	-	-
$\pi^+\pi^-\pi^0\pi^0$	2	2	2	1	2	2	2	1	2	2	2	1
$K^+K^-\pi^+\pi^-$	4	2	0	3	2	0	4	1	0	-	-	-
$2(\pi^+\pi^-)$	2	4	0	1	4	0	2	3	0	-	-	-
$3(\pi^+\pi^-)$	2	6	0	1	6	0	2	5	0	-	-	-

Various reconstructions in $e^+e^- \to K^+K^-\psi(2S)$

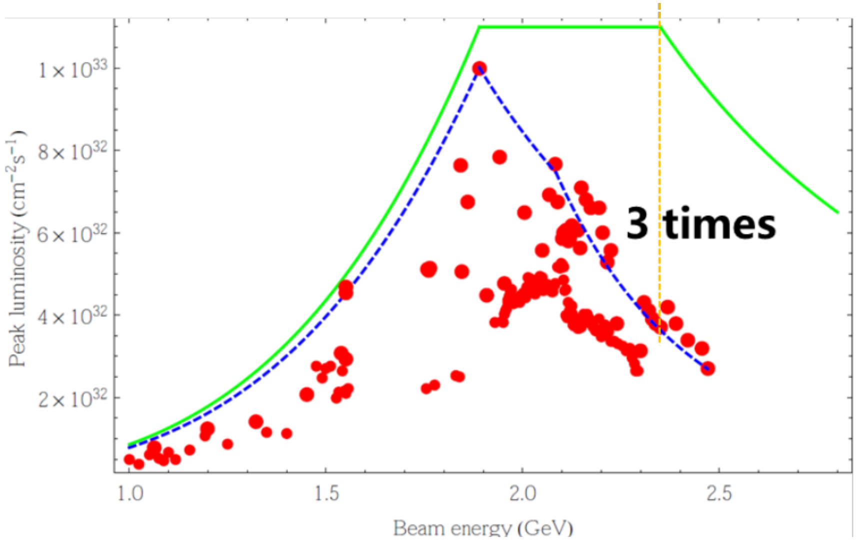
- Approach (i): tag K^+， K^-， and J/ψ from $\psi(2S) \to X\, J/\psi$
- Approach (ii): tag K^+or K^-， and $\psi(2S)$ with $\pi^+\pi^- J/\psi$, 1C
- Approach (iii): tag K^+， K^-， and $\psi(2S)$ with l^+l^-
- Approach (iv): tag K^+or K^-， and $\psi(2S)$ with l^+l^-, 1C

- (deep) machine learning and AI assistant?

Ways to beyond the limited statistics (data)

BEPCII will upgrade in both Lum. and Max. E

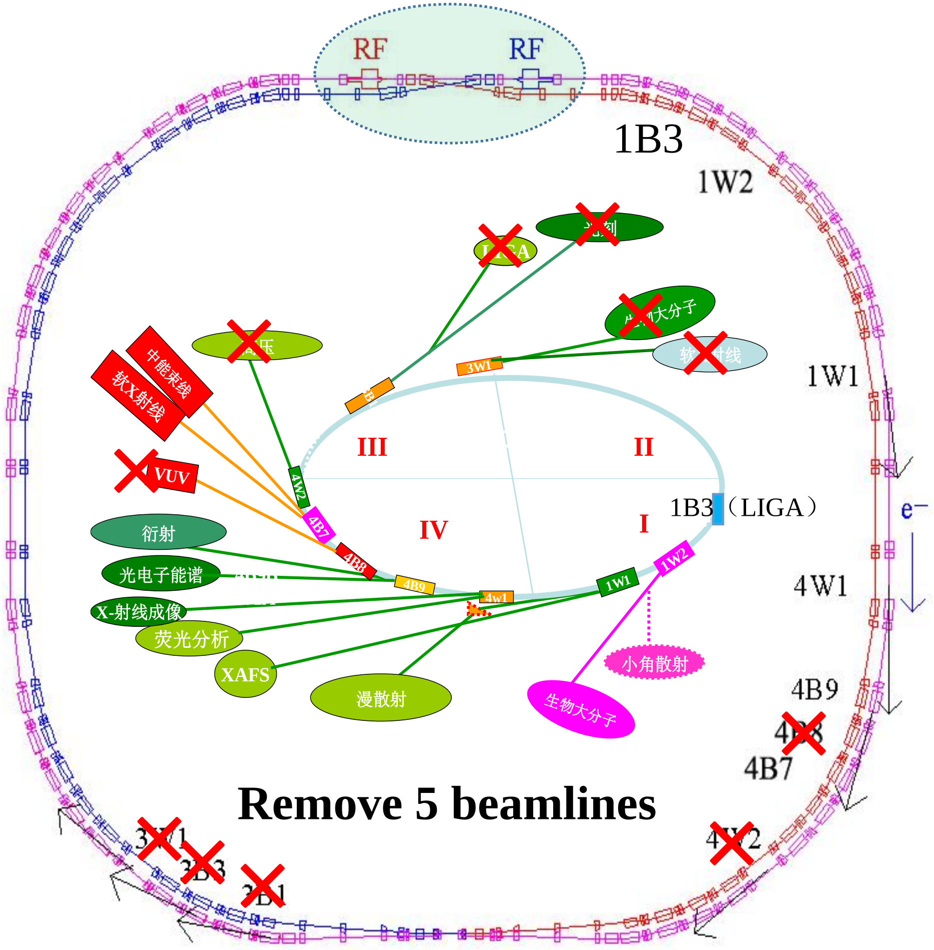
- Luminosity is increased by a factor 3 @ 2.35 GeV
- Maximun beam energy is increased up to 2.8 GeV



Accelerator physics

Key Technologies: Double beam power & Optics upgrade & Higher gradient of magnets

	BEPCII @ 2.35GeV	BEPCII-U @ 2.35GeV	BEPCII-U @ 2.8GeV
L $[10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	**3.5**	**11**	**3.7**
β_y^* [cm]	**1.5**	**1.35**	**3.0**
Beam current [mA]	400	900	450
SR Power [kW]	**110**	**250**	**250**
$\xi_{y,\mathrm{lum}}$	0.029	0.033	0.043
Emittance [nmrad]	**147**	**152**	**200**
Couping [%]	**0.53**	**0.35**	**0.5**
Bucket Height	0.0069	0.011	0.009
$\sigma_{z,0}$ [cm]	1.54	1.07	1.4
σ_z [cm]	**1.69**	**1.22**	**1.6**
RF Voltage [MV]	**1.6**	**3.3**	**3.3**



No dedicated SR operation, only parasitic SR experiments, 10 months/year BESIII time.

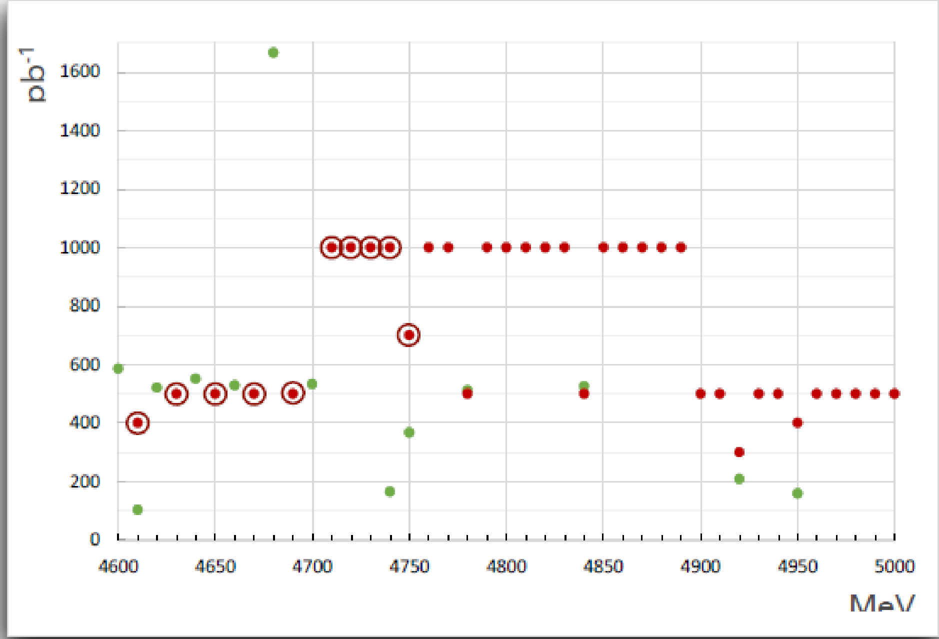
BEPCII Operation plan

- Sep. 2021 – Jun. 2024 Data taking at ψ (3770) for 20fb^{-1}
- Jul. 2024 – Dec. 2024 Summer shutdown for upgrade
- Jan. 2025 – Jul. 2025 Data taking at beam energy 1.843GeV ψ (3686)
- Aug. 2025 – Sep. 2025 2nd SC magnet hor. test & the 4th RF cavity installation
- Oct. 2025 – Jul. 2026 Data taking around beam energy 2.35GeV (project test)
- Aug. 2026 – Sep. 2026 2 SC magnets installation & LINAC final upgrade
- Oct. 2026 – Sep. 2028 Data taking within beam energy 2.1-2.5GeV
- Sep. 2028 – Jul. 2030 Data taking within beam energy 2.5-2.8GeV

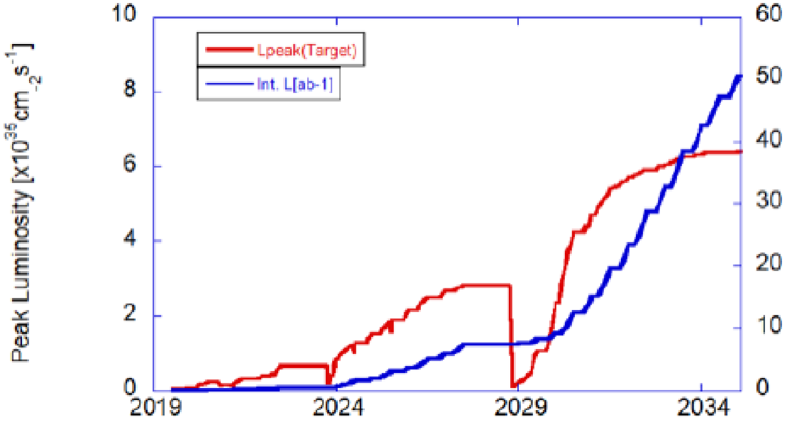
A short term plan for next two years

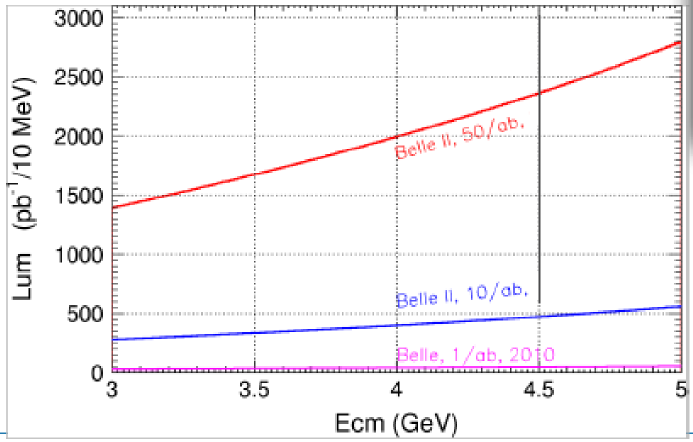
- A Short term plan for 2025-2026: [9/fb + 18/fb]
  - 4.61 - 4.75 GeV, 10 points, 7.1/fb in total [114 days] $\Rightarrow Y(4710)$, $Y \to Z_{cs}$

    $Z_{cs}^{(\prime)}$ in both open charm and hiddern charm processes
    - PlanB：4.61 - 4.71 GeV first, 3.4/fb in total [55 days]
  - 4.4-4.6 GeV, add 7 points, 20 MeV step, 3.5/fb [56 days] $\Rightarrow Y(4500)$
  - data samples around 4.7 GeV for Zcs, 2-3 points, 2-3/fb each, exact enery to be determined from the scan result [96-144 days]
  - 4.76 - 5.0 GeV, 25 points, 18.2/fb in total [319 days]



- Compitition from Belle II





Yuping @ BESIII 2024 summer Col. meeting

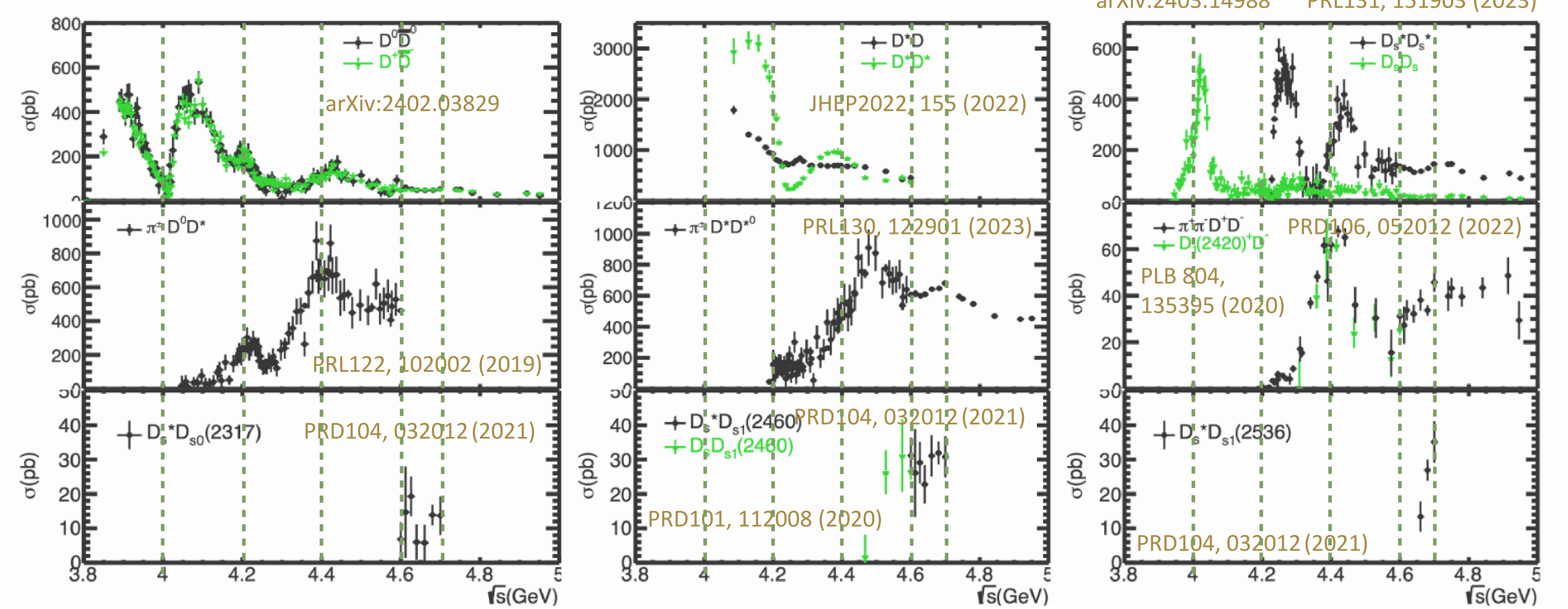
近未（~3年）

- 在正负电子对撞机II升级之后，获取超过30亿的 ψ(2S) 事例，以及在大于 4.4 GeV的能区获取约 30 /fb 的扫描数据
- 开展粲阈以下粲偶素衰变的精确测量，特别是 η_c 与 $\eta_c(2S)$ 衰变到相同末态的系列测量，检验“新12% 规则”；以及考虑到共振态与连续过程的干涉效应之后更新一批 ψ(3686) 的衰变分支比，并抽取强相互作用振幅与电磁相互作用振幅之间的相角
- 寻找及测量更多 ψ(3770) 的非$D\bar{D}$衰变模式，特别是精确测量含粲偶素末态的电磁与强跃迁过程，为进一步理解 ψ(3773) 的性质提供有效信息
- 通过研究4.4 至4.6 GeV 正负电子湮灭到特定遍举道过程的截面线型，寻找新的、尚未发现的矢量（类）粲偶素，确认或者否认 Y(4500) 的存在
- 利用在4.6 至 4.7 GeV能量点扫描数据，研究矢量（类）粲偶素跃迁到 Z_{cs} （及其激发态）过程或者跃迁到C宇称为正的 X 粒子过程，寻找类似于 X(3872)、Y(4230)、$Z_c(3900)$ 这三个粒子之间的跃迁关系，寻找 Y(4660) 粒子新的衰变过程，特别是含奇异粒子的隐粲过程，为确定 Y(4660) 的粒子本性提供更多实验输入
- 利用 4.7 GeV 附近的更大样本寻找 Z_{cs} 新的衰变模式，特别是它的隐粲过程衰变模式，以其进一步理解它的产生与衰变的动力学机制
- 利用新获取的质心能量从 4.7 到 5.0 GeV 的数据，研究在此能区是否有新的尚未发现的矢量共振态。
- **其他**

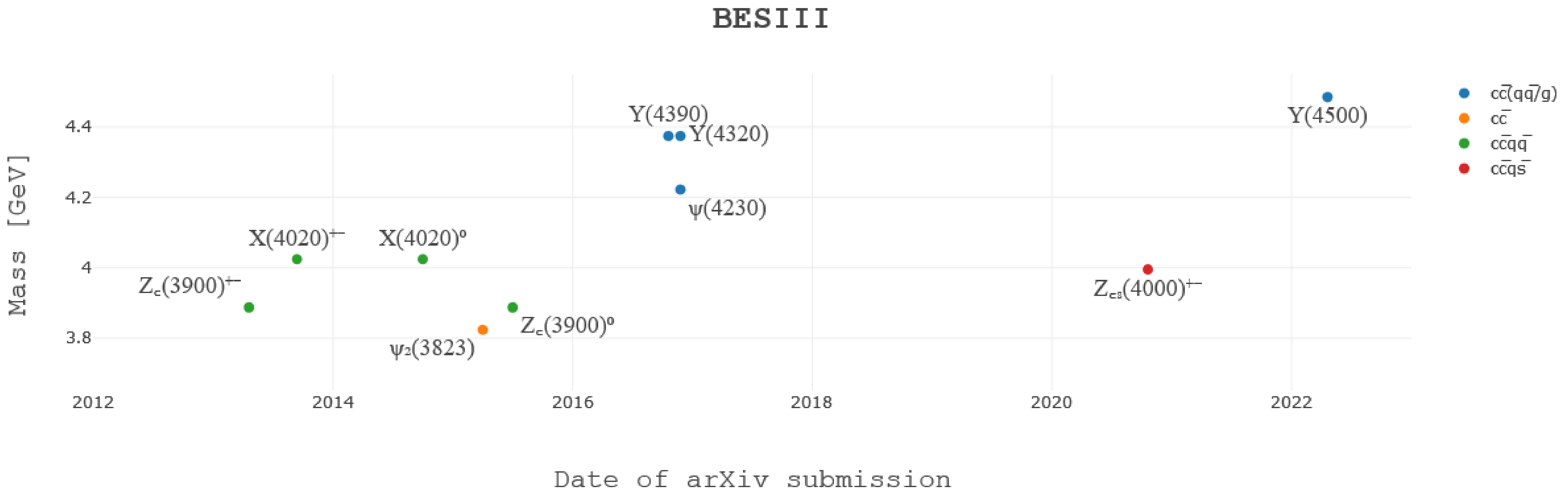
Thanks for your attention!

backup

粲介子对末态截面


arXiv:2403.14988
PRL131, 151903 (2023)
arXiv:2402.03829
JHEP2022, 155 (2022)
PRL130, 122901 (2023)
PRD106, 052012 (2022)
PLB 804,
135395 (2020)
PRL122, 102002 (2019)
PRD104, 032012 (2021)
PRD104, 032012 (2021)
PRD101, 112008 (2020)
PRD104, 032012 (2021)
σ(pb)
√s(GeV)

Previous discovered



From QWG ExoticHub

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

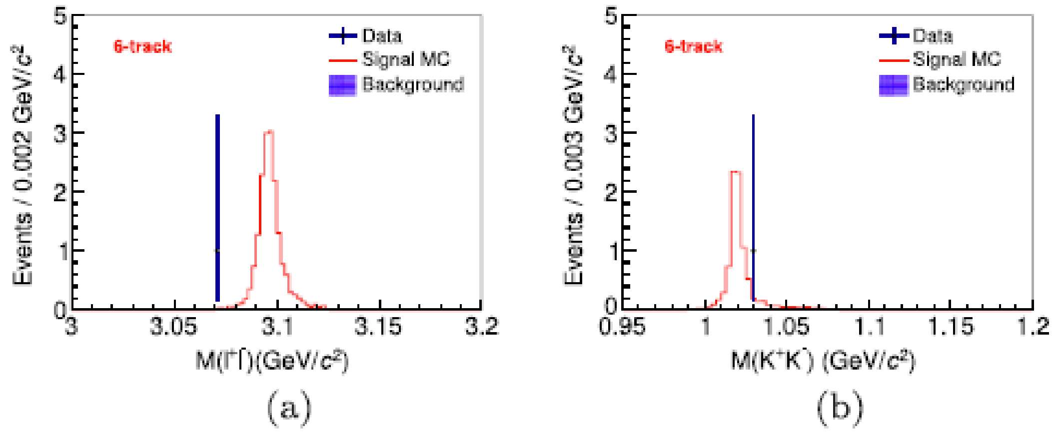
  ✓ $e^+e^- \to Y \to \gamma X(3872)$ [PRL 112, 092001 (2014)]

  ✓ $e^+e^- \to Y \to \omega X(3872)$ [PRL 130, 151904 (2023)]

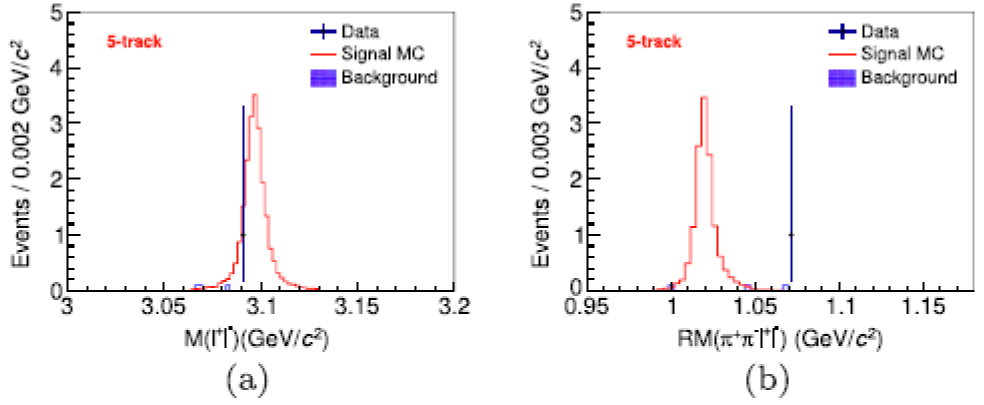
  ? $e^+e^- \to Y \to \phi X(3872)$

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



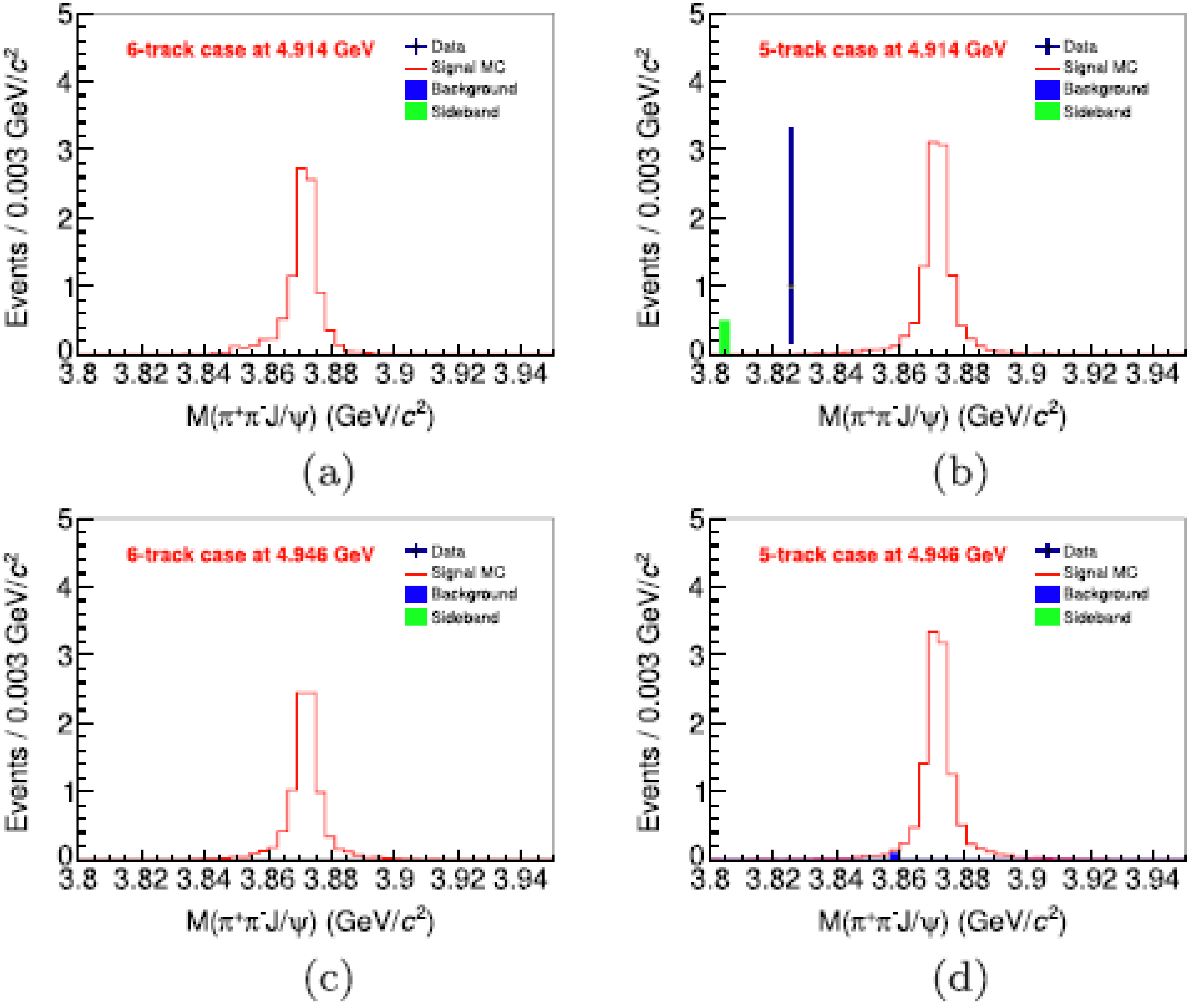
6-track



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)

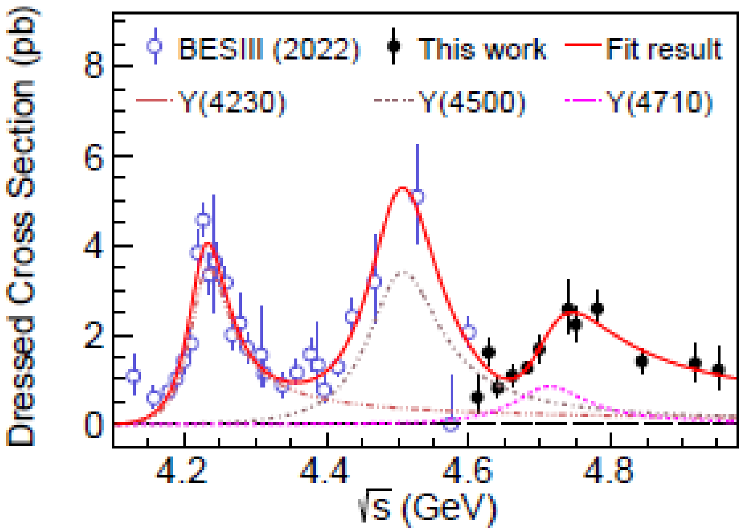
BESIII

$\sqrt{s}$	$\mathcal{L}_{\rm int}$	$N_{\rm obs}$	$N_{\rm sdb}$	$N^{\rm up}_{\rm signal}$	$(1+\delta)$	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



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

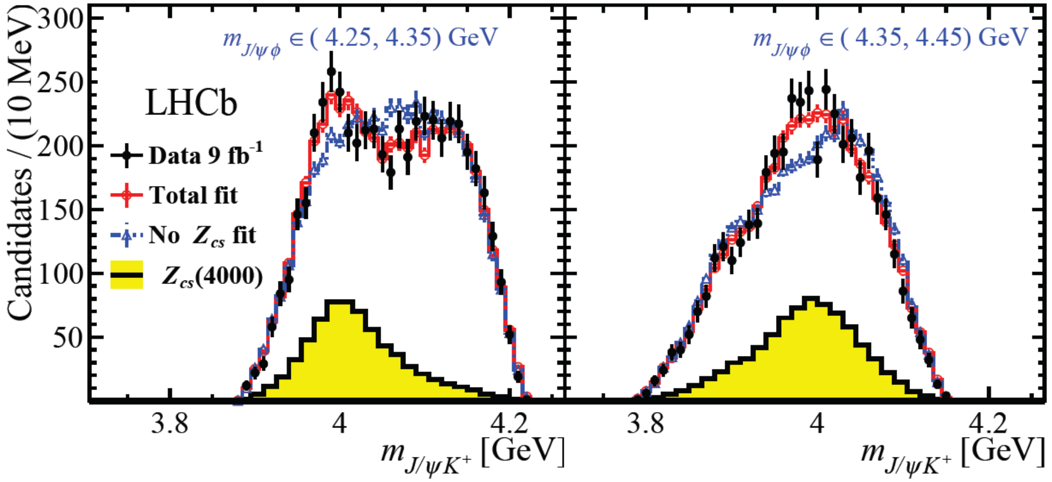
CPC 46, 111002 (2022)

PRL 131, 211902 (2023)

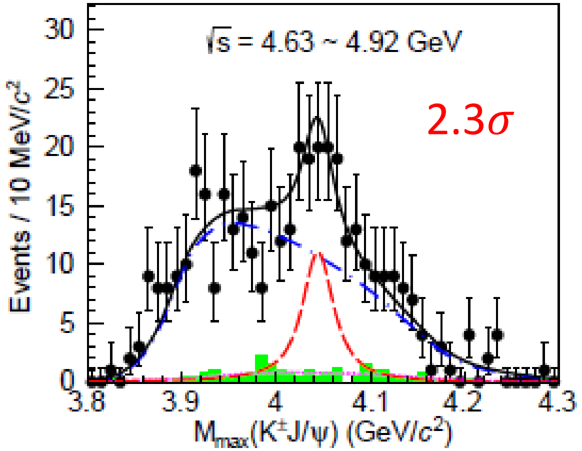
Extension from J/ψ to $\psi(2S)$?

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)

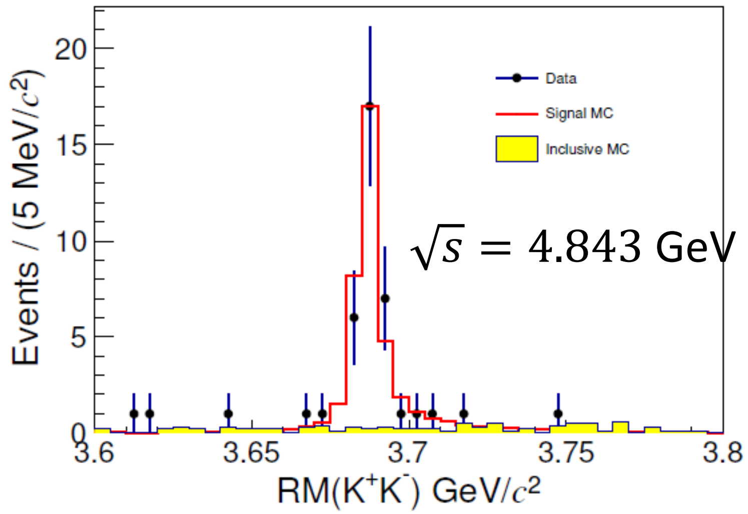


PRL 131, 211902 (2023) 21

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

Analysis strategy

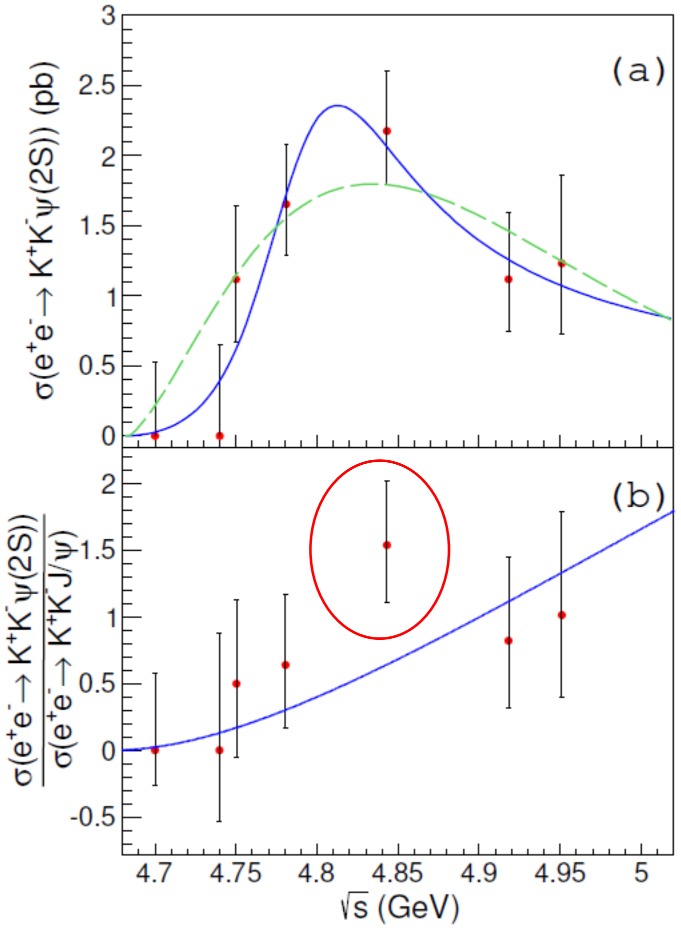
- Data sets: $\sqrt{s} = 4.699 \ - 4.951$ GeV, 2.5 fb^{-1}
- Various reconstructions in $e^+e^- \to K^+K^-\psi(2S)$
  - Approach (i): tag K^+, K^-, and J/ψ from $\psi(2S) \to X\ J/\psi$
  - Approach (ii): tag K^+or K^-, and $\psi(2S)$ with $\pi^+\pi^-J/\psi$, 1C
  - Approach (iii): tag K^+, K^-, and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

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

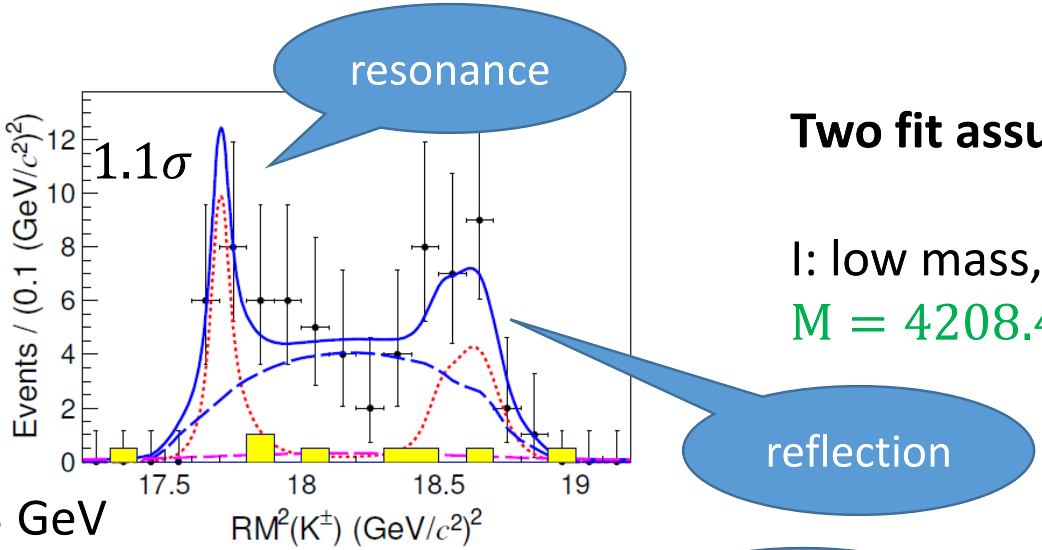
(b) Solid line represents PHSP, 2σ deviation at 4.845 GeV

Indicate distinct production mechanism

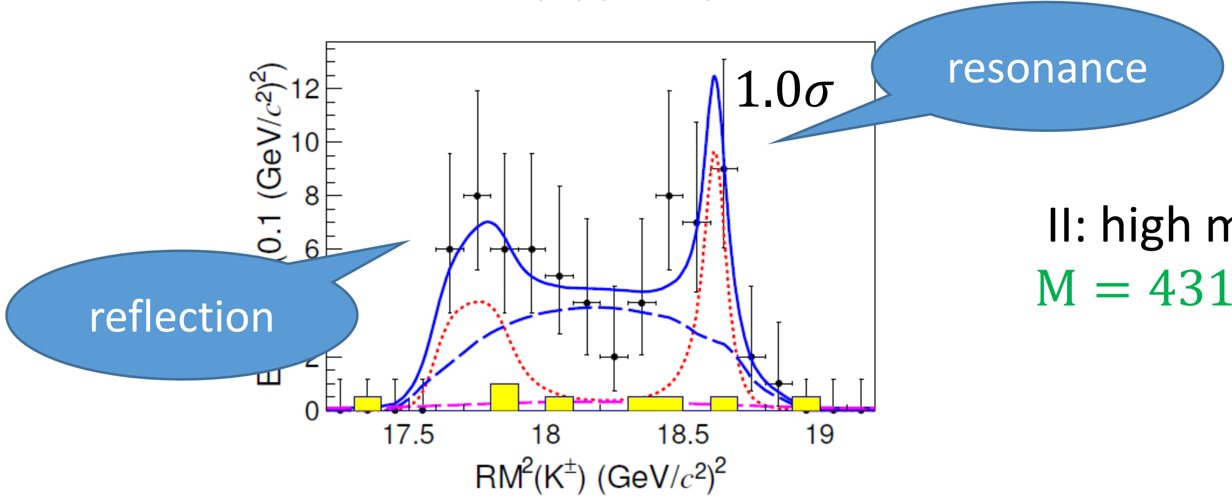
arXiv:2407.20009, submitted to Phys. Rev. Lett.

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

BESIII



$\sqrt{s} = 4.843$ GeV



Two fit assumptions (interference is ignored)

I: low mass, high reflection

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

II: high mass, low reflection => 4.315 GeV

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

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

Search for $e^+e^- \to \phi\chi_{c0}$

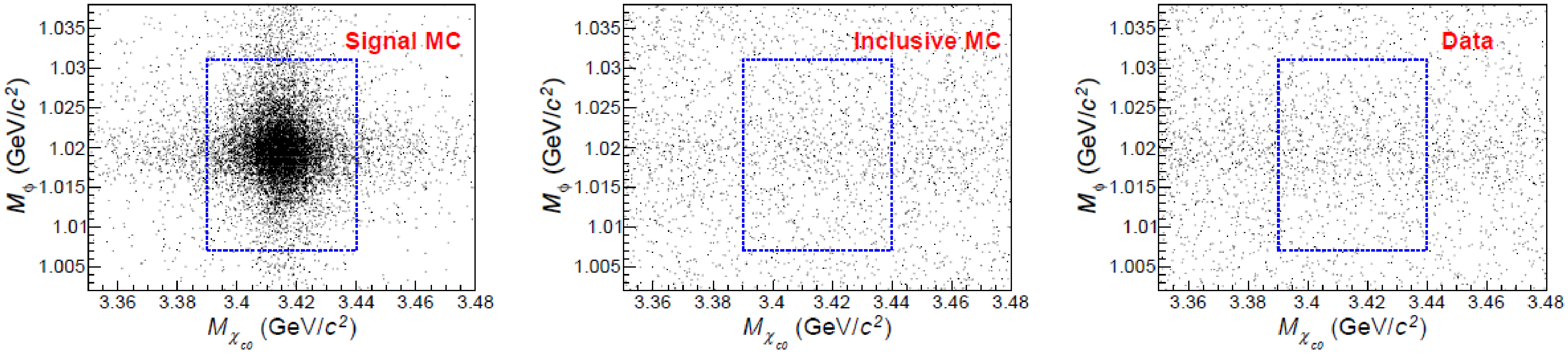
- Y(4660): heaviest vector charmonium-like state that has been well-established experimentally
  - Belle and BaBar: $\pi^+\pi^-\psi(3686)$ (discover), $D_s^+D_{s1}^-(2536)$, $\Lambda_c^+\Lambda_c^-$
  - Theories: tetra-quark ($[cs][\bar{c}\bar{s}]$ or $[cq][\bar{c}\bar{q}]$), charmonium, molecules ($f_0(980)\psi(2S)$, $\Lambda_c\bar{\Lambda}_c$, $D\bar{D}$, light hadron-charmonium pair), hybrid ($c\bar{c}g$)
  - BESIII: $\pi^+\pi^-\psi(3686)$, $\pi^+\pi^-\psi_2(3823)$, $\phi\chi_{c1/2}$, $K_S^0K_S^0J/\psi$, $D^{*0}D^{*-}\pi^+$, $\Lambda_c^+\Lambda_c^-$
- Evidence of $e^+e^- \to Y(4660) \to \phi\chi_{c2}$ would indicate strange quark component in the Y (4660)
  - Replace χ_{c2} with χ_{c0}
  - Previous $e^+e^- \to \phi\chi_{c0}$ at BESIII: upper limit at 4.6 GeV only one energy point

Phys. Rev.D 97, 032008 (2018).

Analysis strategy

- Data sets: $\sqrt{s} = 4.4 \ - 4.95$ GeV, 6.7 fb^{-1}
- Five χ_{c0} decay channels (with $\phi \to K^+K^-$) and various reconstruction methods
  - 4C or 1C kinematic fit, optimized χ^2 cuts, varied signal regions

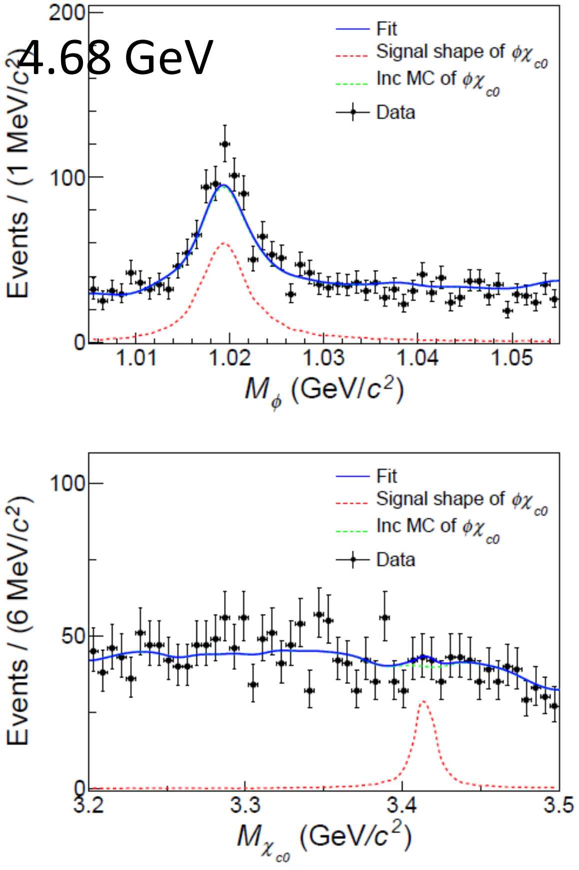
χ_{c0} Decay	Full $K^\pm\pi^\pm\pi^0$	Miss $K^\pm$ $K^\pm\pi^\pm\pi^0$	Miss $\pi^\pm$ $K^\pm\pi^\pm\pi^0$	Miss π^0 $K^\pm\pi^\pm\pi^0$
$\pi^+\pi^-$	2 2 0	1 2 0	2 1 0	- - -
$\pi^+\pi^-\pi^0\pi^0$	2 2 2	1 2 2	2 1 2	2 2 1
$K^+K^-\pi^+\pi^-$	4 2 0	3 2 0	4 1 0	- - -
$2(\pi^+\pi^-)$	2 4 0	1 4 0	2 3 0	- - -
$3(\pi^+\pi^-)$	2 6 0	1 6 0	2 5 0	- - -



Summed all energy and decay channels

Cross sections

$$\sigma^B(\sqrt{s}) = \frac{N_{\rm sig}}{\mathcal{L}_{\rm int}\sum \varepsilon^i \mathcal{B}^i_{\chi_{c0}}\,\mathcal{B}_\phi\,(1+\delta)_{\rm ISR}\,\frac{1}{|1-\Pi|^2}}$$

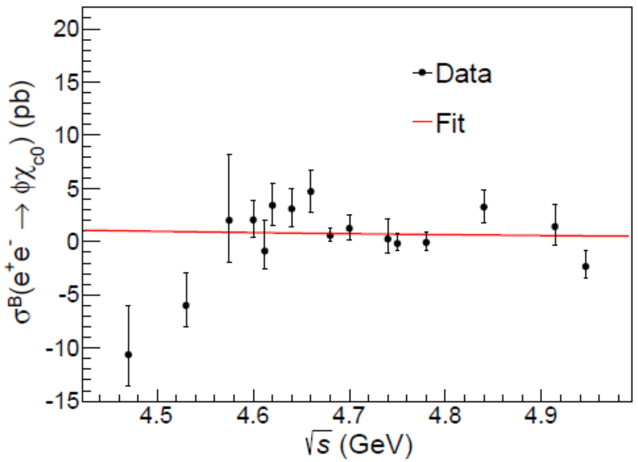


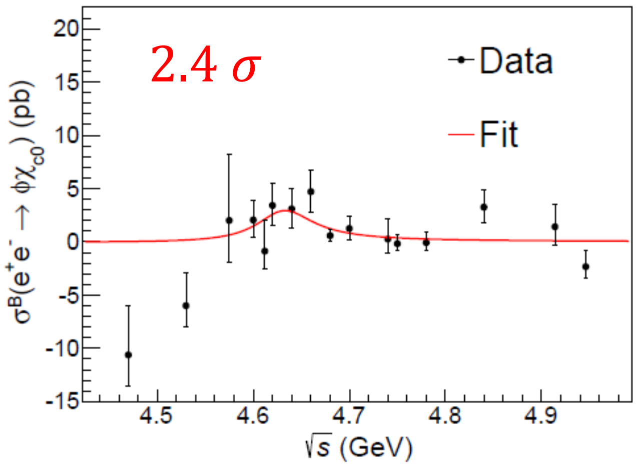
Two dimensional fit

$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}$ (pb^{-1})	$\bar{\varepsilon}$ (%)	$N_{\rm sig}$	$N^{\rm up}_{\rm sig}$	$N^{\rm up}_{\rm F}$	$(1+\delta)_{\rm ISR}$	$\frac{1}{\lvert 1-\Pi\rvert^2}$	σ^B (pb)	$\sigma^{\rm UL}$ (pb)
4.470	111.1	10.4	$-5.0^{+1.6}_{-0.8}$	4.1	6.2	0.822	1.055	$-10.6^{+3.4}_{-1.7}\pm 1.3$	13.2
4.530	112.1	16.5	$-4.8^{+2.1}_{-1.2}$	4.8	6.2	0.874	1.054	$-6.0^{+2.6}_{-1.5}\pm 0.6$	7.7
4.575	48.9	21.1	$0.8^{+2.4}_{-1.5}$	6.4	8.1	0.779	1.055	$2.0^{+6.0}_{-3.8}\pm 0.2$	20.3
4.600	586.9	22.5	$10.4^{+8.5}_{-7.4}$	23.8	26.2	0.775	1.055	$2.0^{+1.7}_{-1.5}\pm 0.2$	5.2
4.612	103.8	22.8	$-0.8^{+2.6}_{-1.5}$	6.2	7.1	0.777	1.055	$-0.9^{+2.9}_{-1.6}\pm 0.1$	7.8
4.620	521.5	23.3	$16.4^{+8.4}_{-7.4}$	29.4	32.1	0.797	1.055	$3.4^{+1.7}_{-1.5}\pm 0.3$	6.7
4.640	552.4	24.4	$17.3^{+9.3}_{-8.2}$	31.4	34.0	0.838	1.055	$3.1^{+1.7}_{-1.5}\pm 0.3$	6.1
4.660	529.6	26.1	$26.6^{+9.5}_{-8.6}$	40.9	40.9	0.825	1.054	$4.7^{+1.7}_{-1.5}\pm 0.4$	7.2
4.680	1669.3	26.0	$11.7^{+12.8}_{-11.6}$	31.5	40.2	0.936	1.054	$0.6^{+0.6}_{-0.6}\pm 0.1$	2.0
4.700	536.5	26.9	$8.9^{+8.0}_{-6.9}$	21.7	26.5	0.995	1.055	$1.2^{+1.1}_{-1.0}\pm 0.1$	3.7
4.740	164.3	27.8	$0.6^{+4.3}_{-3.0}$	9.6	10.4	1.031	1.055	$0.3^{+1.8}_{-1.3}\pm 0.0$	4.5
4.750	367.2	28.3	$-0.9^{+4.7}_{-3.4}$	9.6	13.4	1.016	1.055	$-0.2^{+0.9}_{-0.6}\pm 0.0$	2.6
4.780	512.8	29.7	$-0.5^{+6.6}_{-5.3}$	12.8	15.1	0.897	1.055	$-0.1^{+1.0}_{-0.8}\pm 0.0$	2.2
4.840	527.3	30.2	$22.0^{+9.1}_{-8.0}$	35.8	38.2	0.855	1.056	$3.3^{+1.3}_{-1.2}\pm 0.3$	5.7
4.914	208.1	31.7	$3.8^{+5.5}_{-4.5}$	13.6	20.3	0.819	1.056	$1.4^{+2.1}_{-1.7}\pm 0.1$	7.6
4.946	160.3	31.6	$-4.8^{+2.8}_{-1.8}$	5.6	7.0	0.818	1.056	$-2.3^{+1.4}_{-0.9}\pm 0.2$	3.4

arXiv:2410.12620

Search for $Y(4660) \to \phi\chi_{c0}$





Parameters	Continuum	BW
$\Gamma_{e^+e^-}\mathcal{B}_{\phi\chi_{c0}}$ (eV)	-	0.29 ± 0.08
M(MeV)	4630 (fixed)	4630 (fixed)
Γ_{tot} (MeV)	-	72 (fixed)
f	0.3 ± 0.1	-
n	6 ± 15	-
χ^2/ndf	29.2/14	22.2/15

- The product of $\Gamma_{ee}^{Y(4660)} B(Y(4660) \to \phi\chi_{c0}$ is determined to be 0.29 ± 0.08 eV
- upper limit @ 90% C.L.: 0.40 eV

arXiv:2410.12620