XYZ states at BESIII

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Charm 2020, May 31 – June 4, 2021

Outline

- Recent results about X(3872) (produced by $e^+e^- \to \gamma X$)
- Recent results about Y states (produced by $e^+e^- \to Y$)
- (Recents results about Z will be mentioned on Friday by Ziyi)
- Summary

Upgraded Beijing Electron Positron Collider (BEPCII)

Beam energy:
1-2.5 GeV

Design luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

Bunch length:1.5 cm

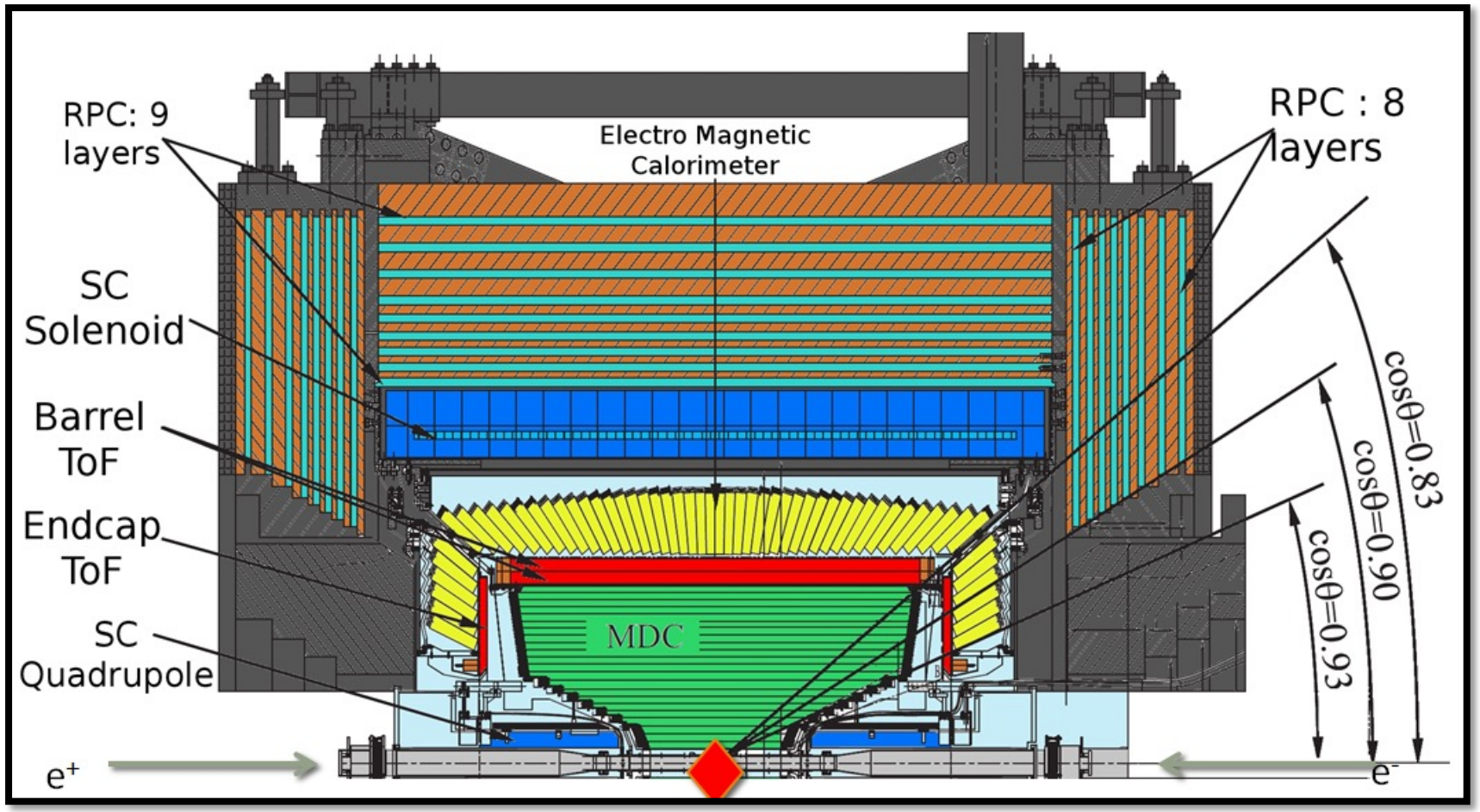
Total current: 0.91 A

Linac: ~200 m

Circular:~240 m

Double rings with tiny crossing angle

BESIII detector



>500 Members from 72 institutions in 15 countries!

Charged-particle momentum resolution@1GeV: 0.5%

Photon energy resolution@1 GeV: 2.5% (5%) for barrel (endcap); position resolution 6mm

dE/dx resolution: 6% for electrons from Bhabha process

Time resolution of TOF: 68 ps (60 ps) for barrel (endcap)

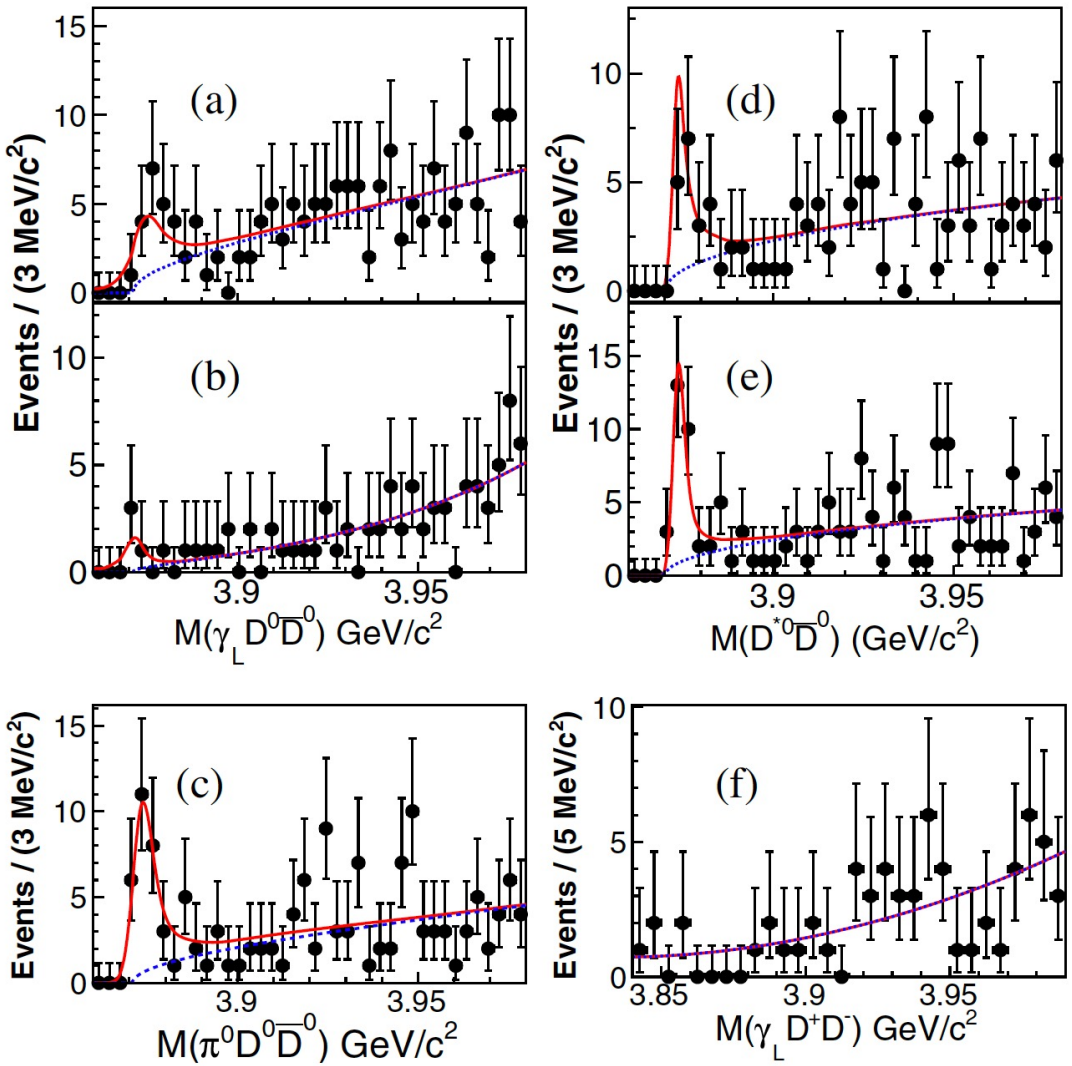
SC magnetic: 1 T

Trigger and DAQ: 4 kHz, with event size 12 Kbytes

PRL 124, 242001 (2020)

9 fb^{-1} at 4.178-4.278 GeV

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



(a)-(b): γD^0 in/below the D^{*0} region

(c): $\pi^0 D^0$ in the D^{*0} region

(d)-(e): $D^{*0} \to \gamma D^0$ or $\pi^0 D^0$

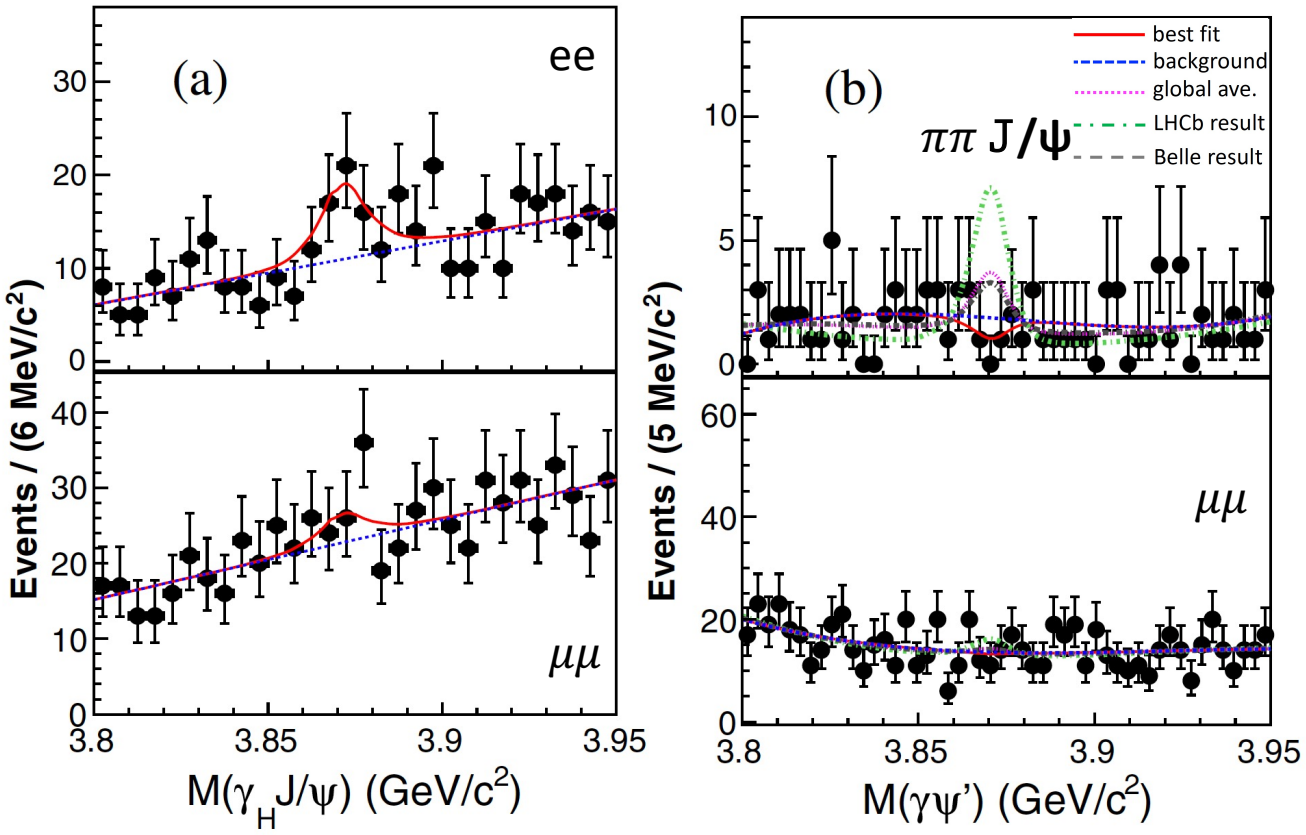
(f): charged D meson mode

- **X(3872)->$\overline{D^0}D^{*0}$** is dominant!
- No obvious X(3872) for non-D^{*0} decay!

PRL 124, 242001 (2020)

9 fb^{-1} at 4.178-4.278 GeV

X(3872)->γ J/ψ, γ ψ(2S)



- 3.5σ evidence for X(3872)→γJ/ψ
- No signal for the X(3872)→γψ(2S) decay at BESIII
- In tension with the LHCb measurement (C.L. < 0.0048)

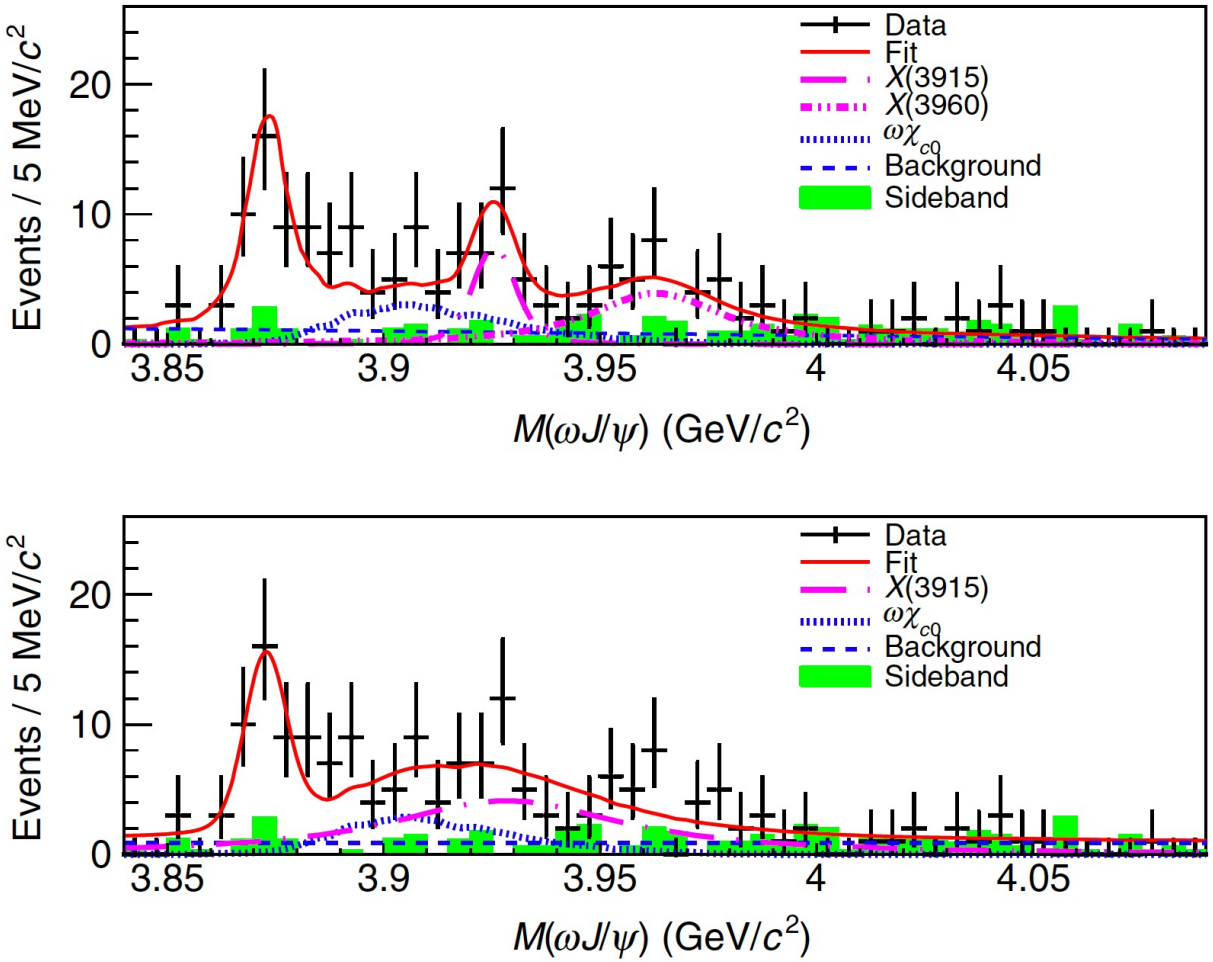
	Molecule?	Tetraquark?
$\frac{B[X(3872)\to\gamma\psi(2S)]}{B[X(3872)\to\gamma J/\psi]}$	< 0.59 (BESIII) @ 90% C.L. < 2.1 (Belle) @ 90% C.L.	= 3.4±1.4 (BaBar) = 2.46±0.64±0.29 (LHCb)

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

PRL 122, 232002 (2019)

11.6 fb^{-1} at 4.008-4.600 GeV

Observation of X(3872)->ω J/ψ



Two fit scenarios: 2 BWs(in the brackets) or 3 BWs

Signal for **X(3872)->ω J/ψ > 5 σ**

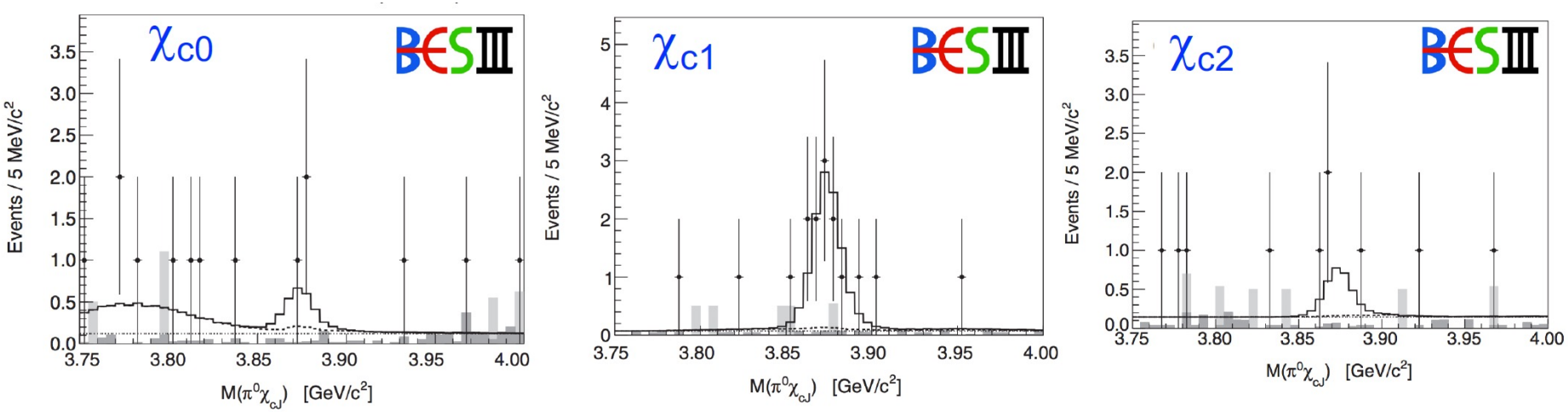
	Mass	Width
$X(3872)$	$3873.3 \pm 1.1 (3872.8 \pm 1.2)$	$1.2 (1.2)$
$X(3915)$	3926.4 ± 2.2 (3932.6 ± 8.7)	3.8 ± 7.5 (59.7 ± 15.5)
$X(3960)$	3963.7 ± 5.5	33.3 ± 34.2

$$R = \frac{X(3872) \to \omega J/\psi}{X(3872) \to \pi^+\pi^- J/\psi} = 1.6^{+0.4}_{-0.3} \pm 0.2$$

PRL 122, 22001 (2019)

9 fb^{-1} at 4.15-4.30 GeV

X(3872)->$\pi^0 \chi_{c1}$



- 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 $\chi_{c1}(2P)$

$B[X(3872)\to \pi^0\chi_{c0}]/B[X(3872)\to \rho J/\psi] < 19$ @ 90% C.L.

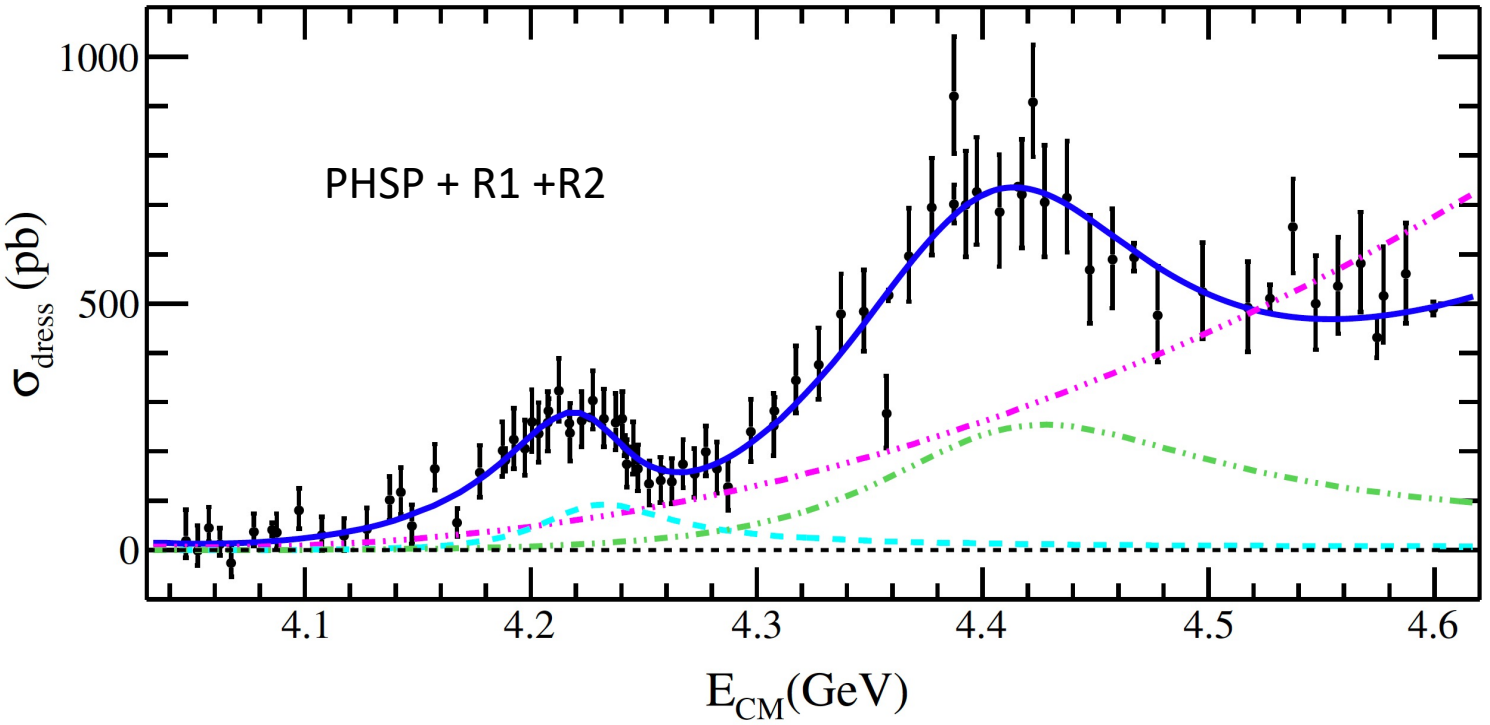
$B[X(3872)\to \pi^0\chi_{c1}]/B[X(3872)\to \rho J/\psi] = 0.88^{+0.33}_{-0.27} \pm 0.10$

$B[X(3872)\to \pi^0\chi_{c2}]/B[X(3872)\to \rho J/\psi] < 1.1$ @ 90% C.L.

PRL 122, 102002 (2019)

4.050-4.600 GeV

$e^+e^- \to \pi^+ D^0 D^{*-}$



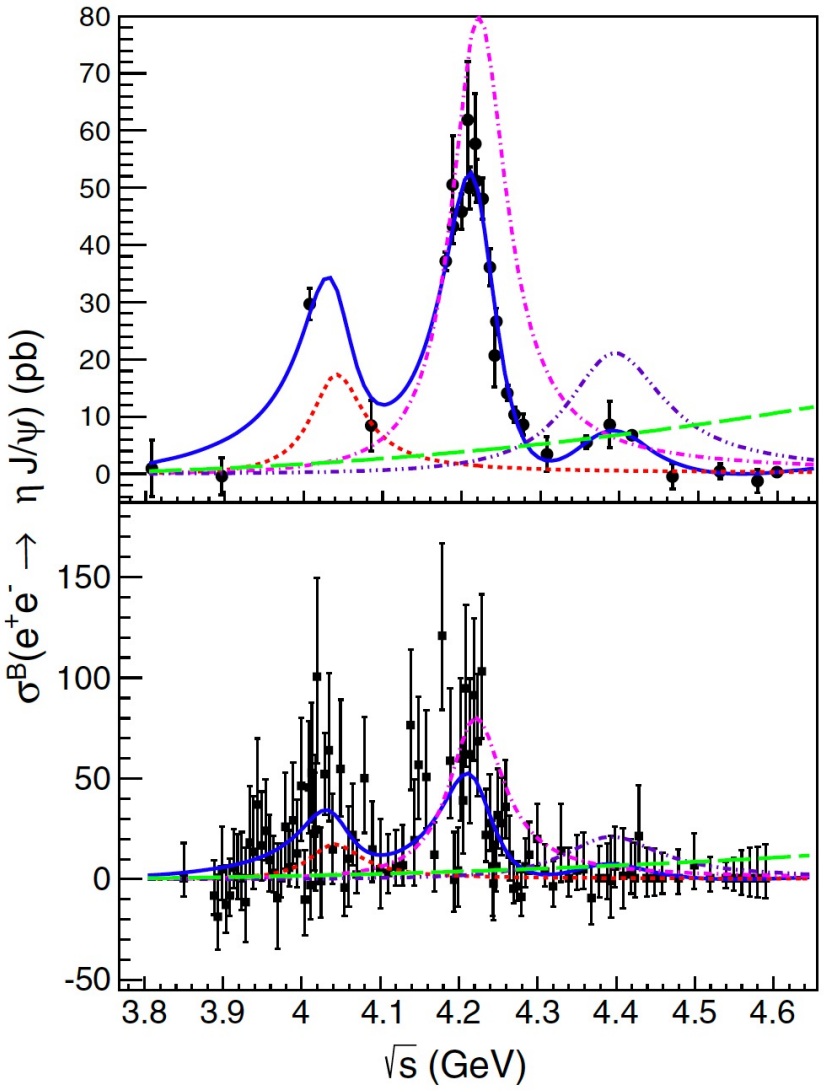
First observation of the open charm decay of Y(4220)!

The peak around 4.4 GeV needs futher study!

More open charm channles are under analysis in this energy region!

PRD 102, 031101(R) (2020)

13.1 fb^{-1} at 3.810-4.600 GeV

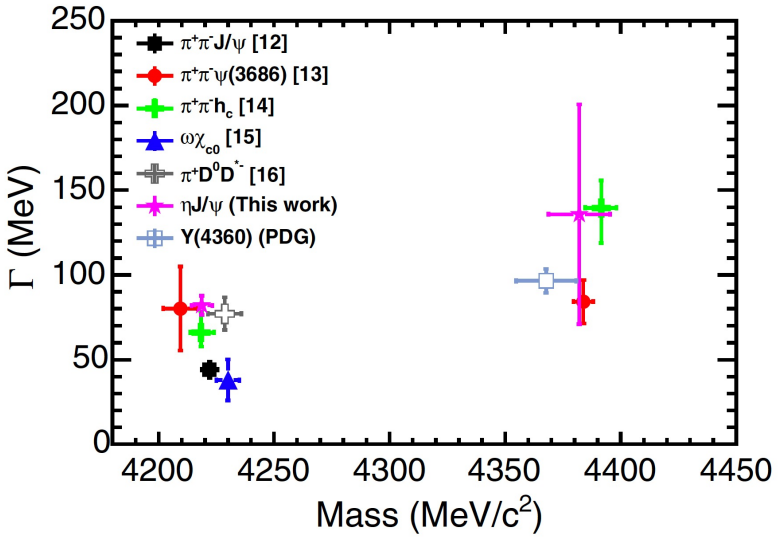


$e^+e^- \to \eta J/\psi$

The cross section is at same order as $e^+e^- \to \pi\pi J/\psi$!

3 structures are observed:

Ψ(4040)+Y(4220)+Y(4390)?

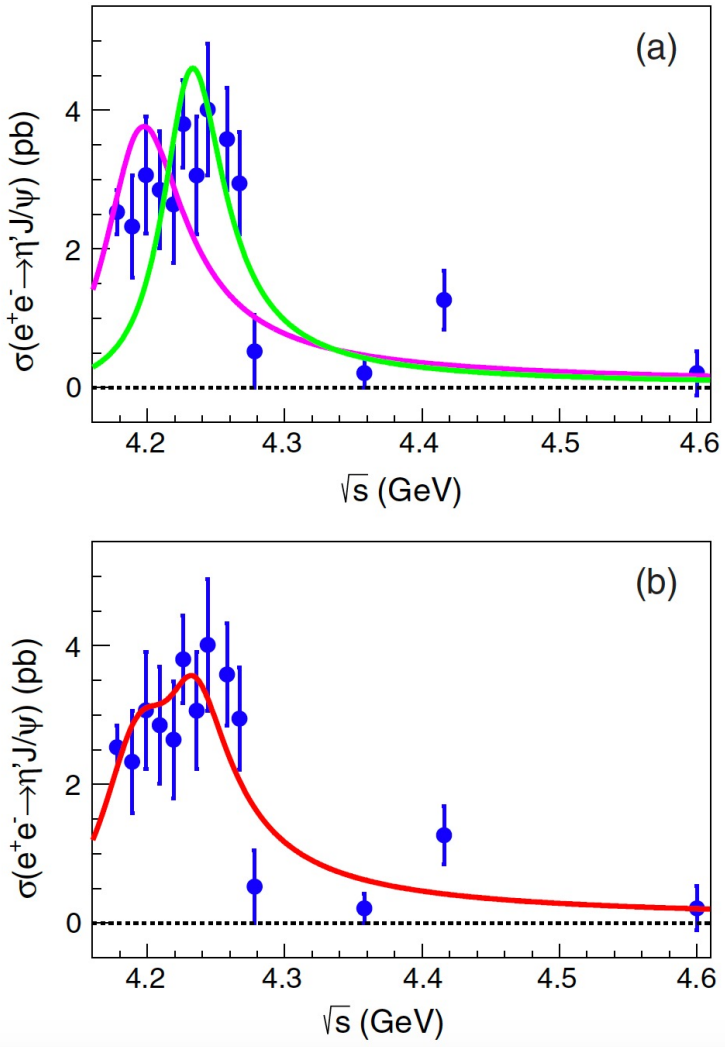


Parameters	Solution 1	Solution 2	Solution 3
M_1(MeV/c^2)		4039(fixed)	
Γ_1(MeV)		80(fixed)	
$\Gamma_1^{e^+e^-}\mathcal{B}r_1$ (eV)	1.5 ± 0.3	1.4 ± 0.3	7.0 ± 0.6
ϕ_1 (rad)	3.3 ± 0.3	3.1 ± 0.3	4.5 ± 0.2
M_2(MeV/c^2)		4218.6 ± 3.8	
Γ_2(MeV)		82.0 ± 5.7	
$\Gamma_2^{e^+e^-}\mathcal{B}r_2$ (eV)	8.0 ± 1.7	4.8 ± 1.0	7.0 ± 1.5
ϕ_2 (rad)	4.2 ± 0.4	3.6 ± 0.3	2.9 ± 0.3
M_3(MeV/c^2)		4382.0 ± 13.3	
Γ_3(MeV)		135.8 ± 60.8	
$\Gamma_3^{e^+e^-}\mathcal{B}r_3$ (eV)	3.4 ± 2.2	1.5 ± 1.0	1.7 ± 1.1
ϕ_3 (rad)	2.8 ± 0.4	3.3 ± 0.4	3.0 ± 0.4

PRD 101, 012008 (2020)

11 fb^{-1} at 4.178-4.600 GeV

$e^+e^- \to \eta' J/\psi$



Enhancement around 4.2 GeV is clear!

It could not be described by single ψ(4160) or Y(4260) well!

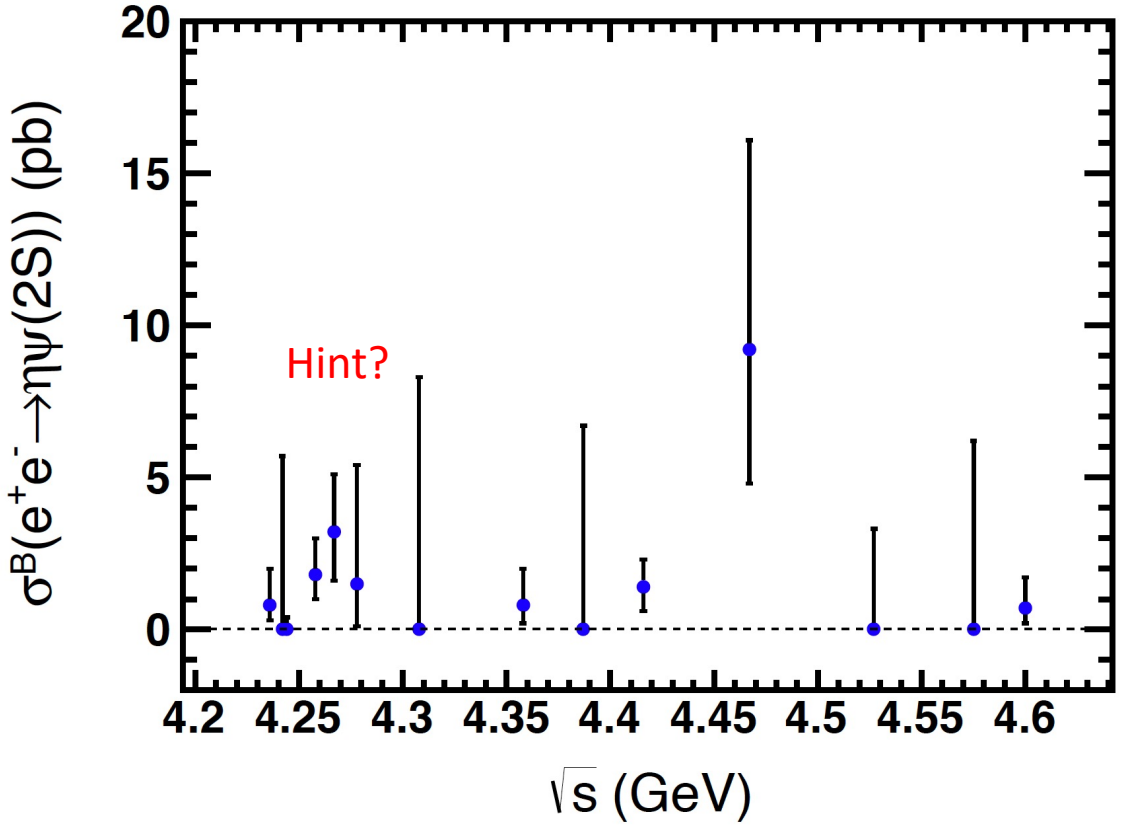
A conerant sum of the two offers better description!

More data will tell us more!

arXiv: 2103.01480, submited to JHEP

5.25 fb^{-1} at 4.236-4.600 GeV

$e^+e^- \to \eta\ \psi(2S)$



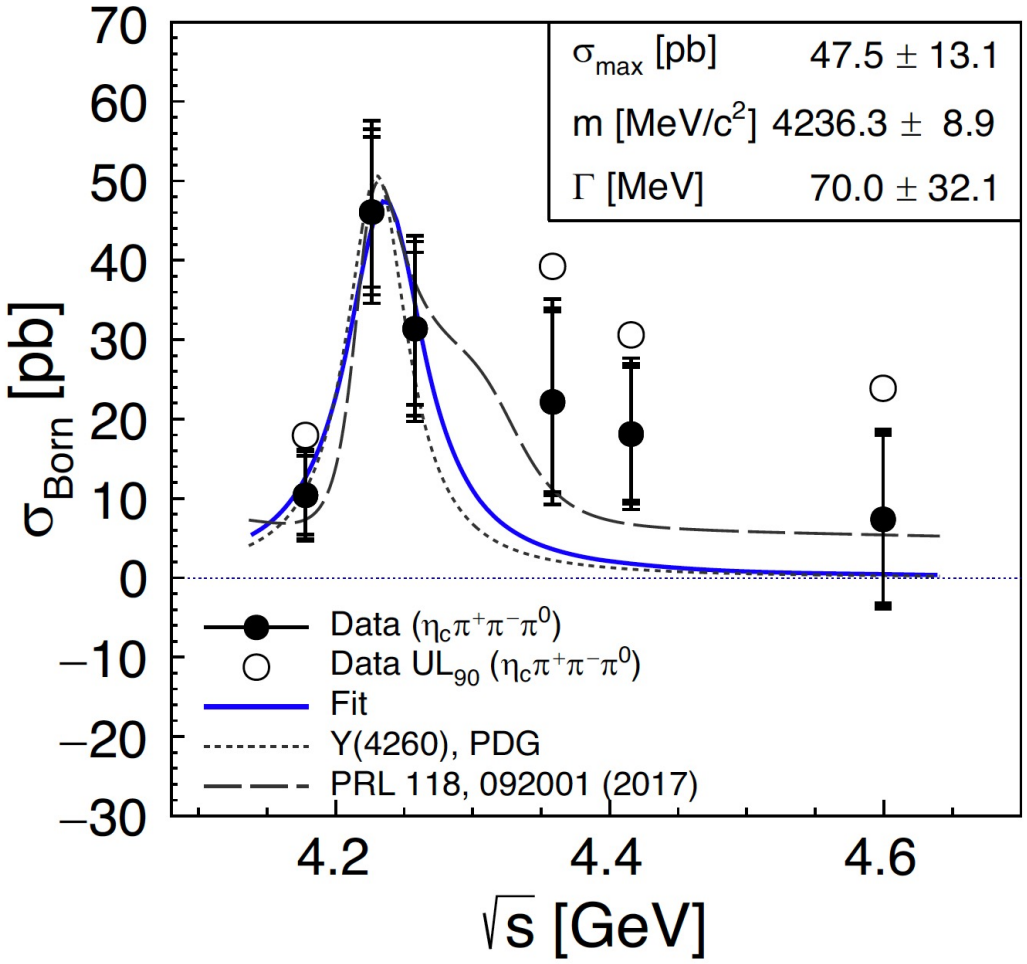
First observation of this production process!

Due to low statatistics, it is hard to get the information about Y state from this cross section lineshape!

PRD 103, 032006 (2021)

7.3 fb^{-1} at 4.178-4.600 GeV

$e^+e^- \to \eta_c 3\pi$



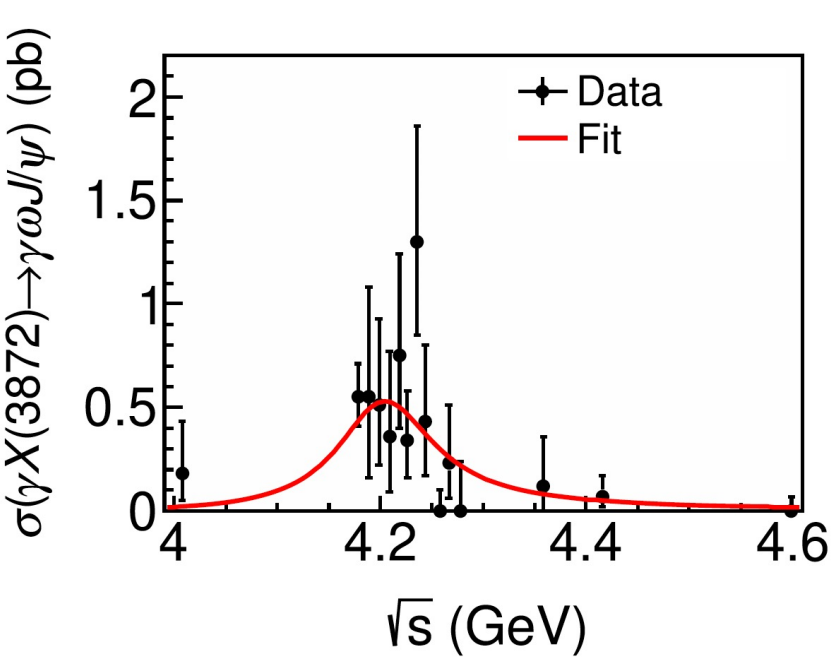
First observation of this production process!

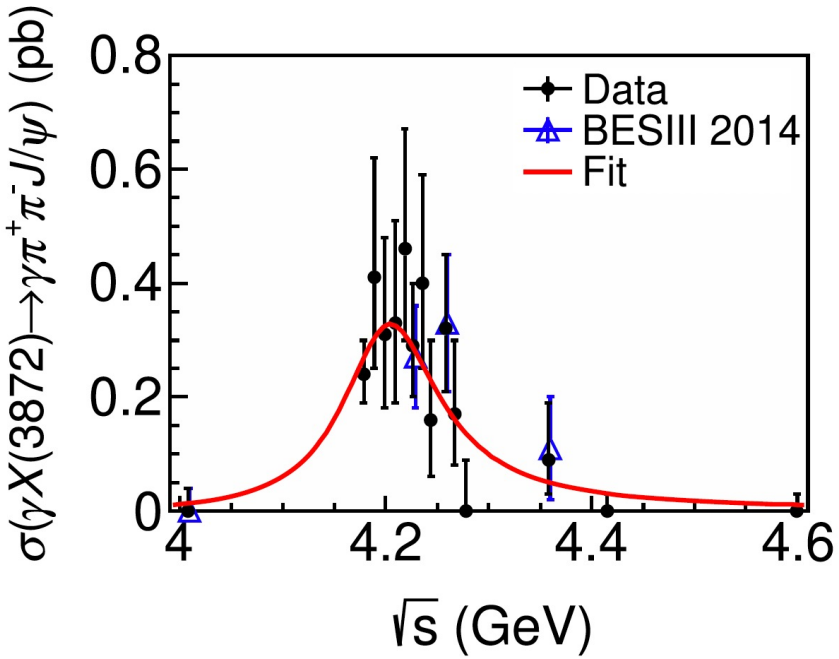
The cross section line shape is consistent with Y(4260)!

PRL 122, 232002 (2019)

11.6 fb^{-1} at 4.008-4.600 GeV

e^+e^- -> γ X(3872)





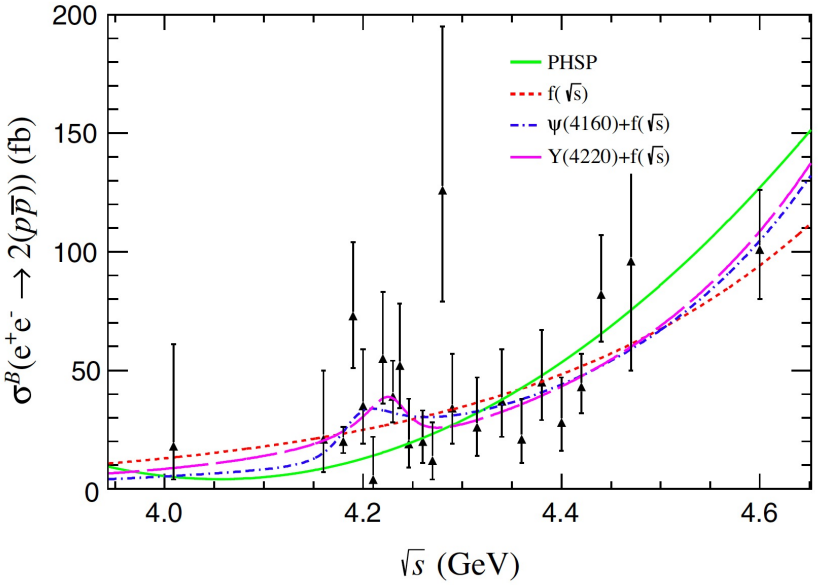
Simultaneous fit: M = $4200.6^{+7.9}_{-133.3} \pm 3.3$ MeV; $\Gamma = 115^{+38}_{-26} \pm 12$ MeV

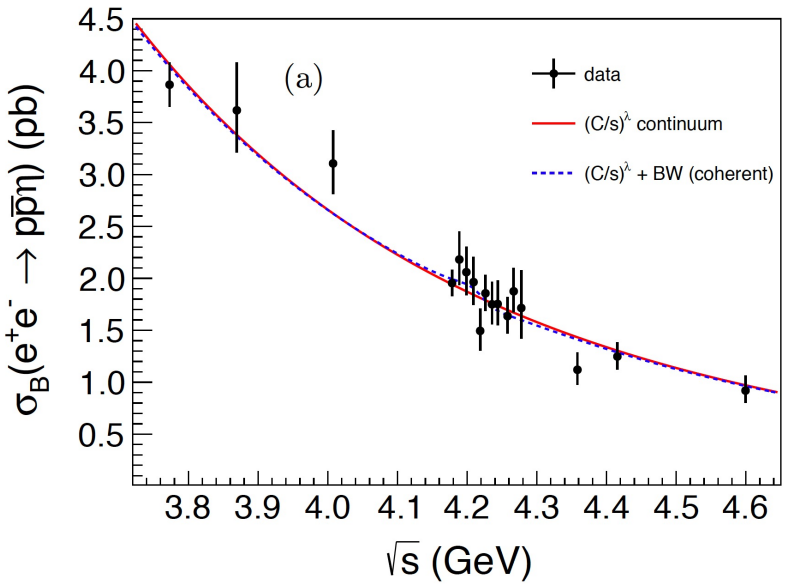
Agree with ψ(4160), and Y(4220) also.

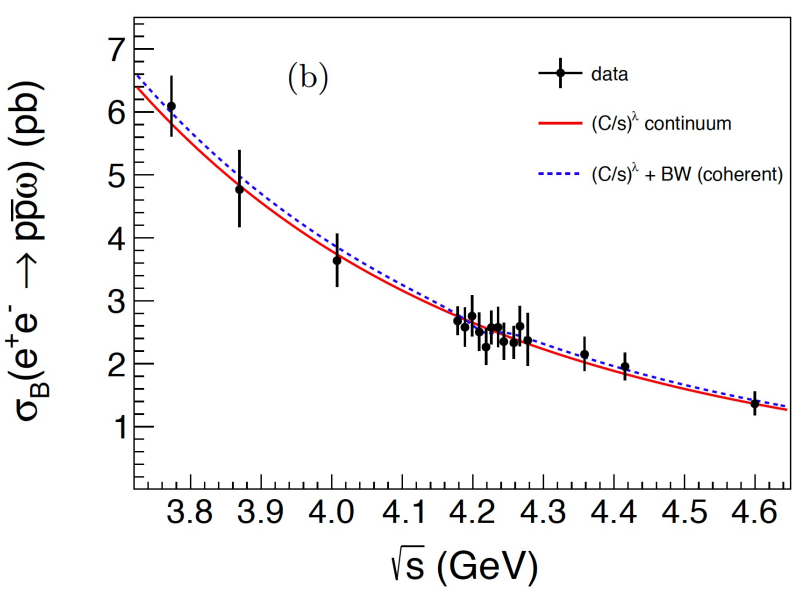
e^+e^- -> light hadrons

PRD 103, 052003 (2021)

arXiv: 2102.04268







No significant Y state is observed!

Summary

- As a charm factory, BESIII provides a lot of information about XYZ particles!
- There are still lots of open questions!
- BESIII will run an other 10 years!

Thanks very much for your attention!

BACK UP!

Still a rich program ahead

arXiv:1912.05983

Table 7.1: List of data samples collected by BESIII/BEPCII up to 2019, and the proposed samples for the remainder of the physics program. The most right column shows the number of required data taking days in current (T_C) or upgraded (T_U) machine. The machine upgrades include top-up implementation and beam current increase.

Energy	Physics motivations	Current data	Expected final data	T_C / T_U
1.8 - 2.0 GeV	R values Nucleon cross-sections	N/A	0.1 fb^{-1} (fine scan)	60/50 days
2.0 - 3.1 GeV	R values Cross-sections	Fine scan (20 energy points)	Complete scan (additional points)	250/180 days
J/ψ peak	Light hadron & Glueball J/ψ decays	3.2 fb^{-1} (10 billion)	3.2 fb^{-1} (10 billion)	N/A
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.67 fb^{-1} (0.45 billion)	4.5 fb^{-1} (3.0 billion)	150/90 days
$\psi(3770)$ peak	$D^0/D^{\pm}$ decays	2.9 fb^{-1}	20.0 fb^{-1}	610/360 days
3.8 - 4.6 GeV	R values XYZ/Open charm	Fine scan (105 energy points)	No requirement	N/A
4.180 GeV	D_s decay XYZ/Open charm	3.2 fb^{-1}	6 fb^{-1}	140/50 days
4.0 - 4.6 GeV	XYZ/Open charm Higher charmonia cross-sections	16.0 fb^{-1} at different $\sqrt{s}$	30 fb^{-1} at different $\sqrt{s}$	770/310 days
4.6 - 4.9 GeV	Charmed baryon/XYZ cross-sections	0.56 fb^{-1} at 4.6 GeV	15 fb^{-1} at different $\sqrt{s}$	1490/600 days
4.74 GeV	$\Sigma_c^+\bar{\Lambda}_c^-$ cross-section	N/A	1.0 fb^{-1}	100/40 days
4.91 GeV	$\Sigma_c\bar{\Sigma}_c$ cross-section	N/A	1.0 fb^{-1}	120/50 days
4.95 GeV	Ξ_c decays	N/A	1.0 fb^{-1}	130/50 days