XYZ particles at BESIII

Cai Hao

hcai@whu.edu.cn

Wuhan University (WHU)

(On behalf of the BESIII collaboration)

31st Rencontres de Blois

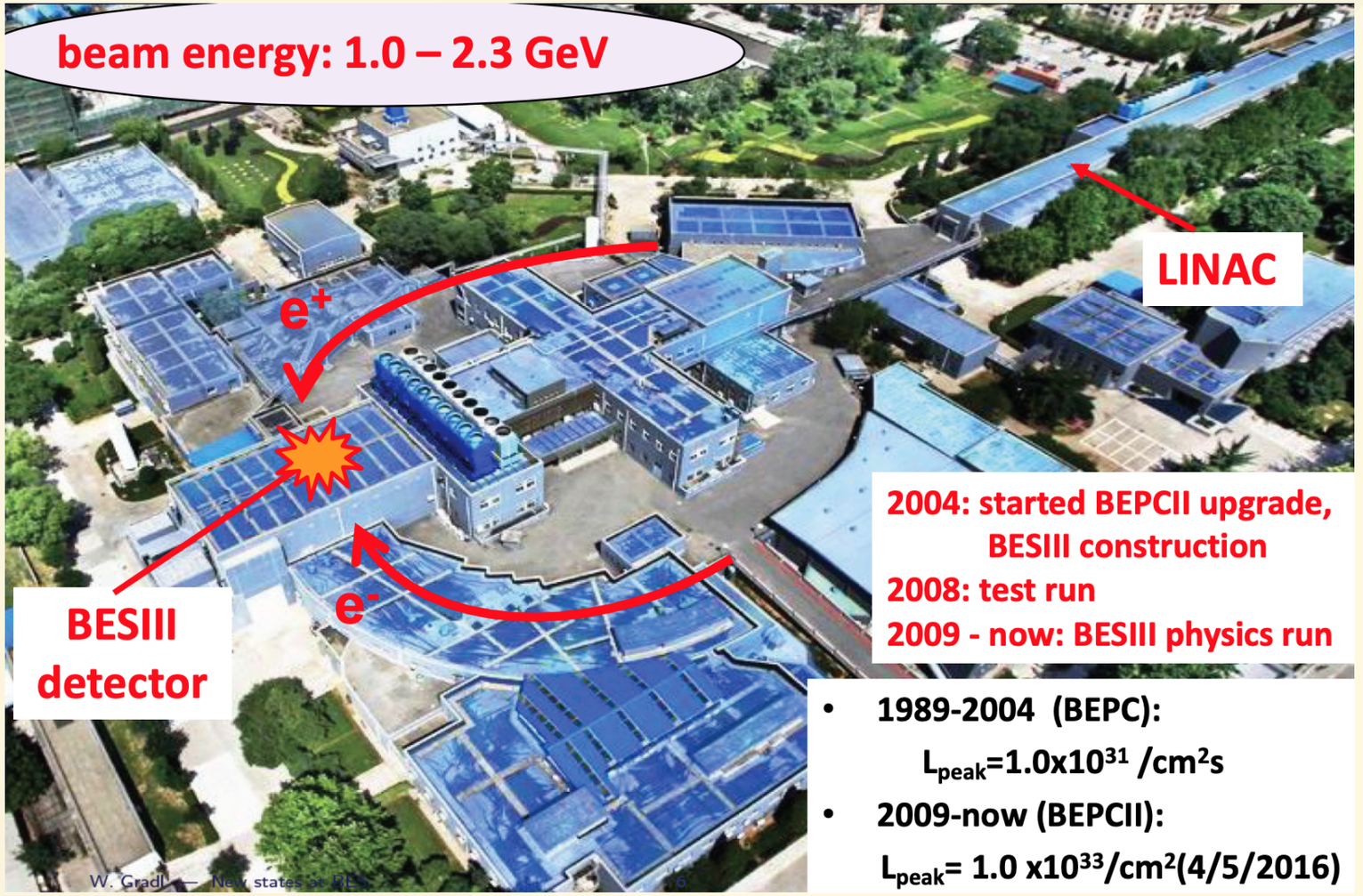
Outline

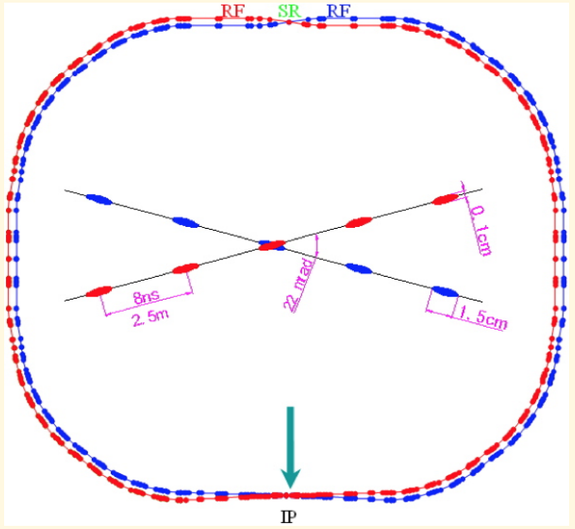
- Introduction
- The X states
- The Y states
- The Z states
- Summary

Mesons with complete $I^G J^{PC}$ assignment	
PDG Name	Former Common Name(s)
$\psi_2(3823)^1$	$X(3823)$
$\chi_{c1}(3872)$	$X(3872)$
$Z_c(3900)$	$Z_c(3900)$
$\chi_{c2}(3930)^2$	$\chi_{c2}(2P)$, $Z(3930)$
$\chi_{c1}(4140)$	$Y(4140)$
$Z_c(4200)$	$Z_c(4200)$
$\psi(4230)$	$Y(4230)$
$R_{c0}(4240)$	$Z_c(4240)$
$\psi(4260)$	$Y(4260)$
$\chi_{c1}(4274)$	$Y(4274)$
$\psi(4360)$	$Y(4360)$
$Z_c(4430)$	$Z_c(4430)$
$\chi_{c0}(4500)$	$X(4500)$
$\psi(4660)$	$X(4630)$, $Y(4660)$
$\chi_{c0}(4700)$	$X(4700)$
$Z_b(10610)$	$Z_b(10610)$
$Z_b(10650)$	$Z_b^{(\prime)}(10650)$

Mesons with incomplete $I^G J^{PC}$ assignment.	
PDG Name	Former Common Name(s)
$X(3915)^3$	$\chi_{c0}(3915)$, $X(3915)$, $Y(3940)$
$X(3940)$	$X(3940)$
$X(4020)$	$Z_c^{(\prime)}(4020)$
$X(4050)^{\pm}$	$Z_1(4050)$
$X(4055)^{\pm}$	$Z_c(4055)$
$X(4160)$	$X(4160)$
$X(4250)^{\pm}$	$Z_2(4250)$
$X(4350)$	$X(4350)$

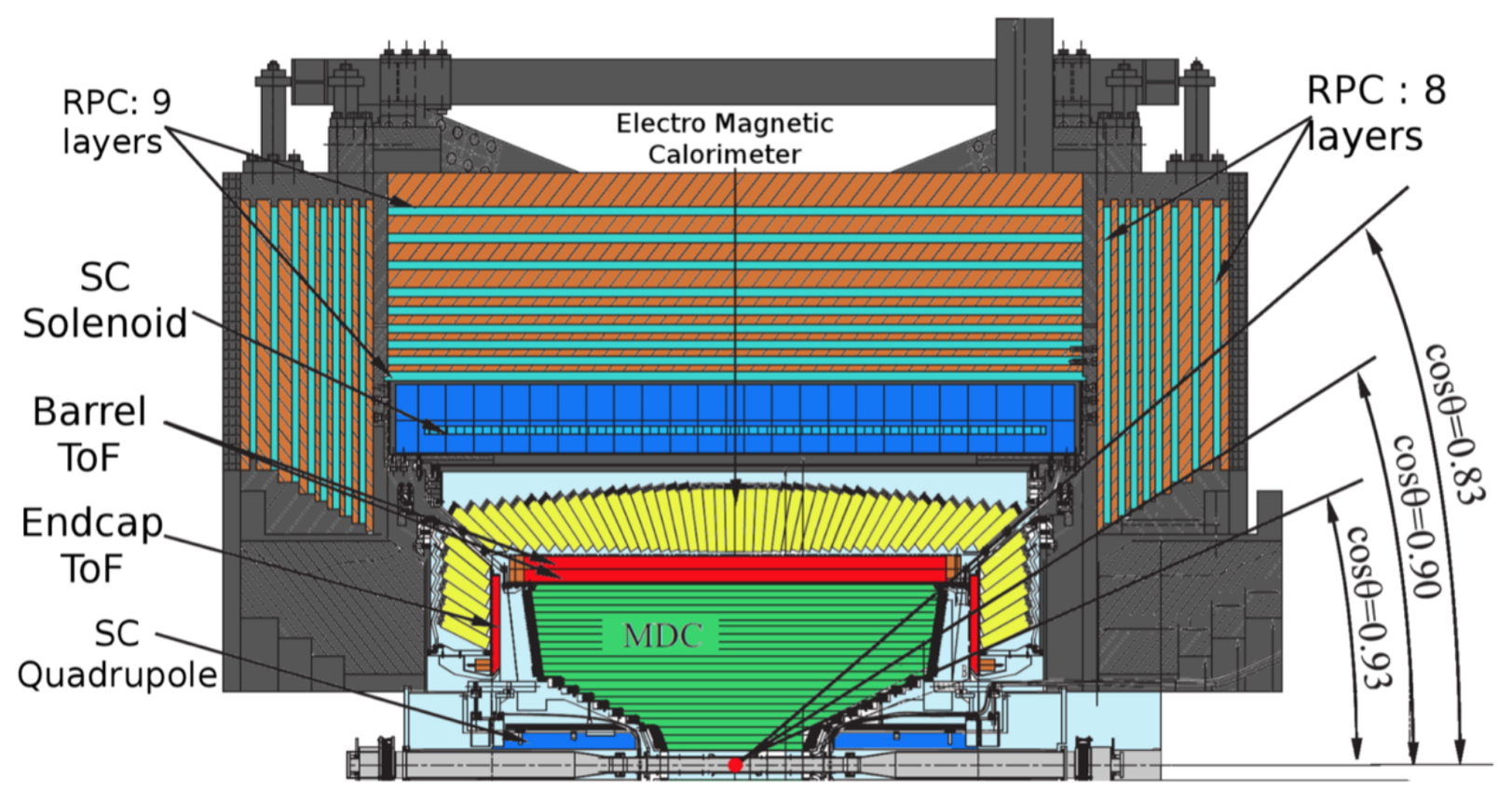
Beijing Electron Positron Collider (BEPC)





- Energy spread: 5.16×10^{-4}
- No. of bunches: 93
- Bunch length: 1.5cm
- Totoal current: 0.91A
- SR mode: 025A@2.5GeV
- Crossing angle: 11mrad

Beijing Spectrometers III (BESIII)

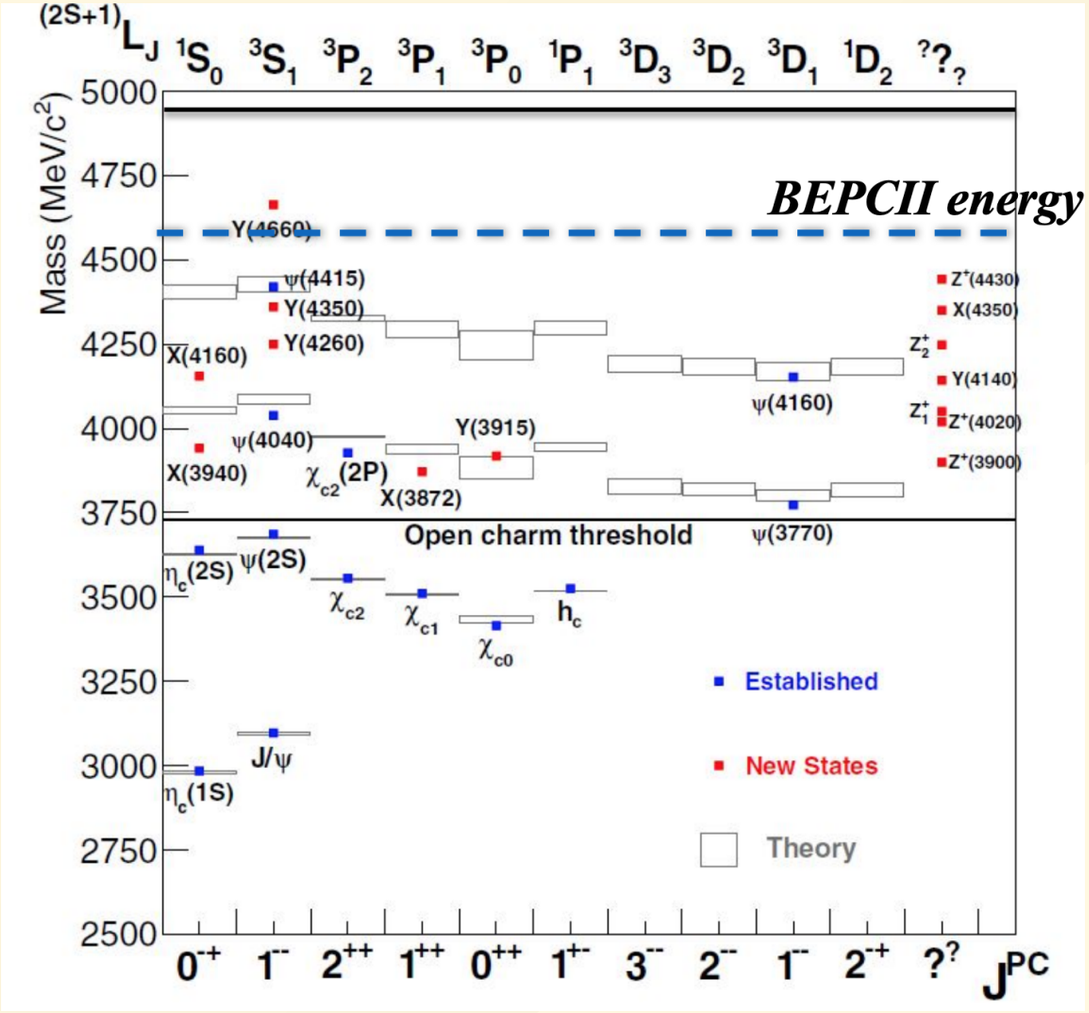


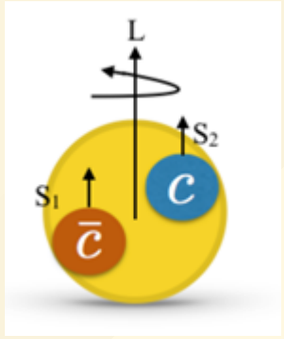
BESIII Collaboration

- 14 countries
- 67 institutes
- ~500 members

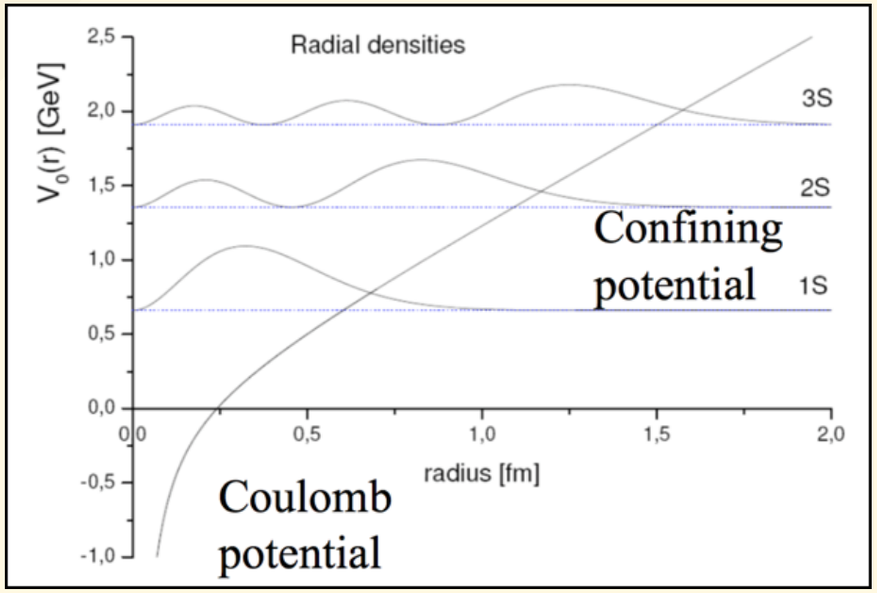
- Main Drift Chamber(MDC)
  - $\sigma(p)/p = 0.5\%$
  - $\sigma_{\mathrm{dE/dX}} = 5.0\%$
- Time-of-flight(TOF)
  - $\sigma(p)/p = 0.5\%$
  - $\sigma_{\mathrm{dE/dX}} = 5.0\%$
- Electro Magnetic Calorimeter(EMC)
  - $\sigma(E)/E = 2.5\%$
  - $\sigma_{z,\phi} = 0.5 \sim 0.7\mathrm{cm}$
- RPC MUON Detector
  - $\sigma(xy) < 2\mathrm{cm}$

Charmonium Spectrum

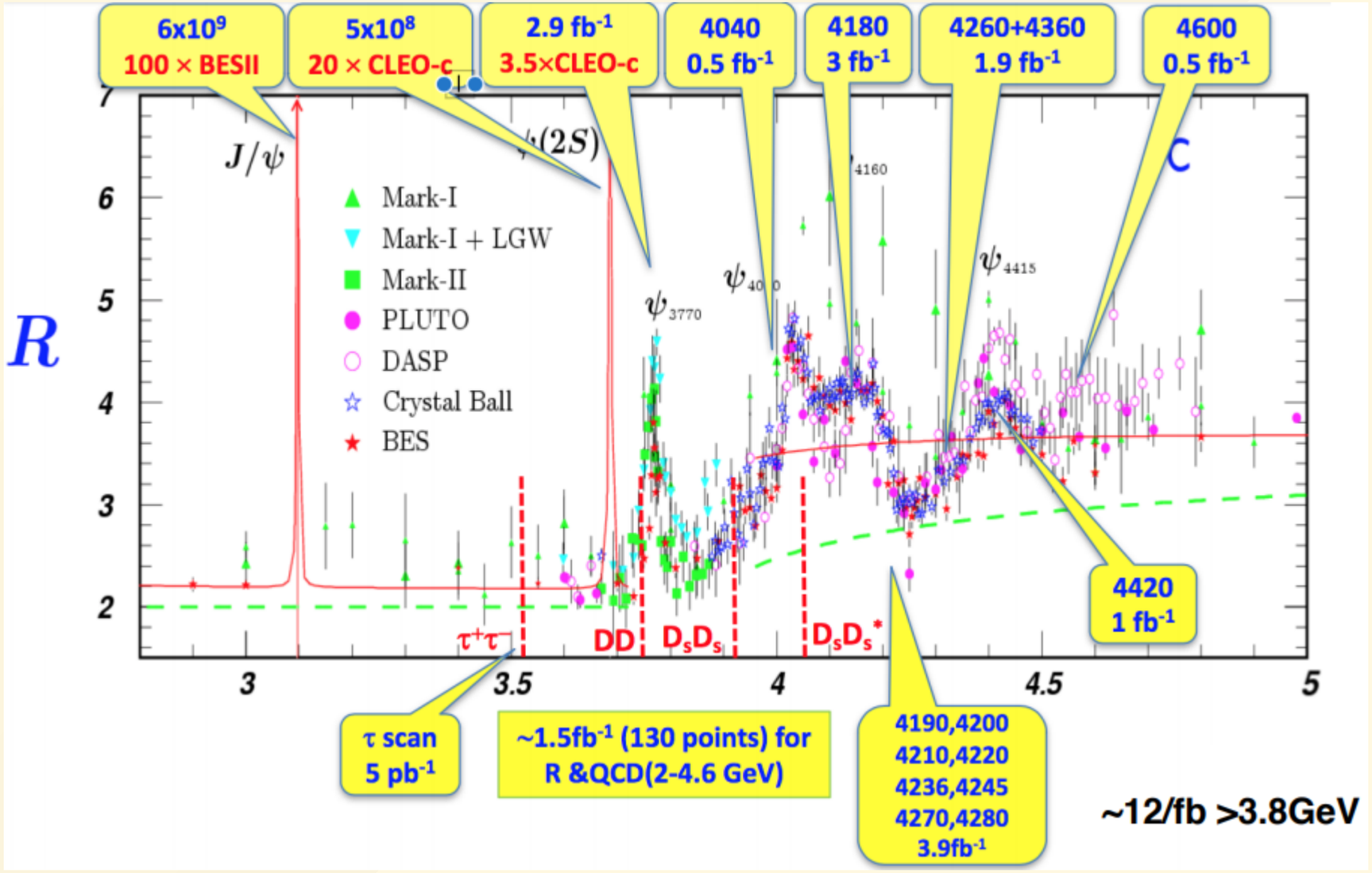




Overpopulated observed new charmonium-like states, i.e. "XYZ".



Data samples at BESIII

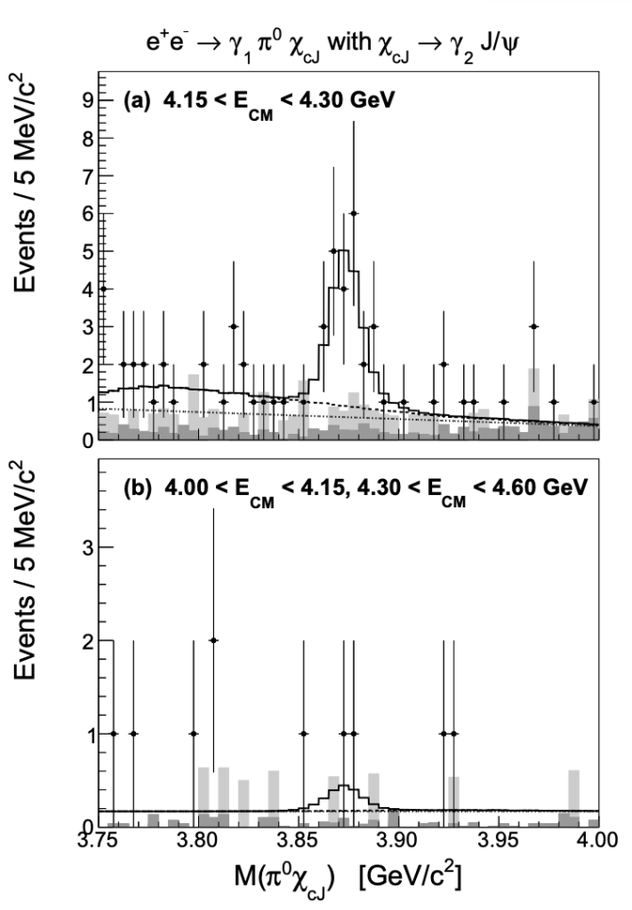


The X states

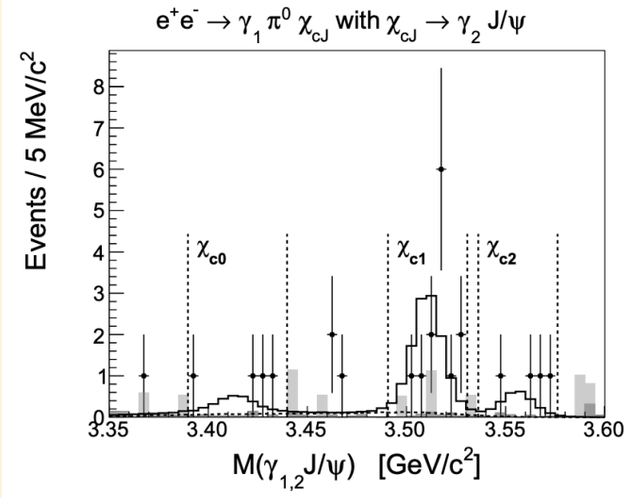
X states

- charmonium-like states with $J^{PC} \neq 1^{--}$;
- Observed in B decays, proton-proton, and proton-antiproton collisions before.

Observation of $X(3872) \to \pi^0 \chi_{c1}(1P)$



BESIII:arXiv:1901.03992



BESIII:arXiv:1901.03992

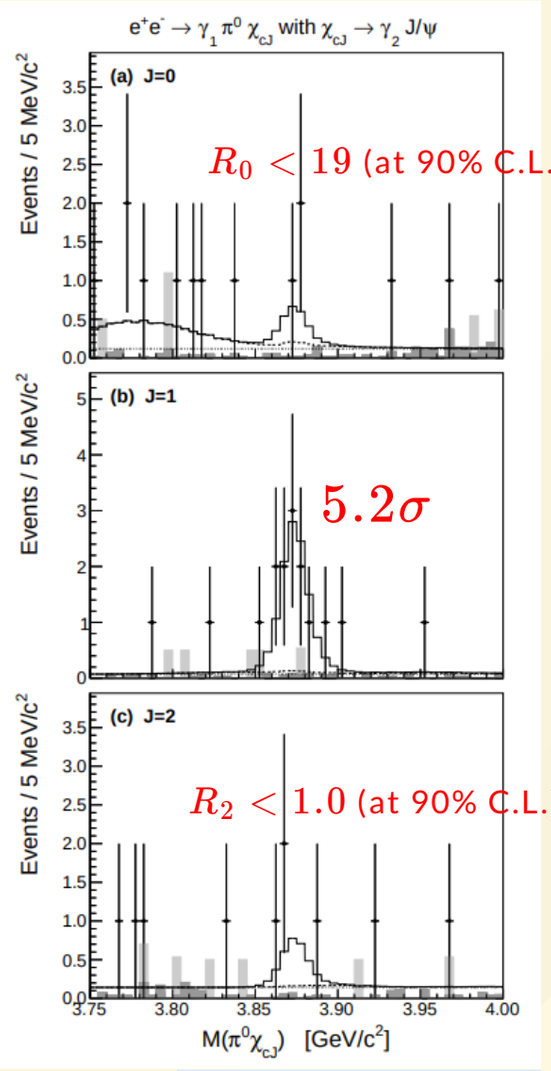
- Data sets used:

  $9.0\mathrm{fb}^{-1}$ for $4.15 < E_{cm} < 4.30\mathrm{GeV}$
  $0.7\mathrm{fb}^{-1}$ for $4.00 < E_{cm} < 4.15\mathrm{GeV}$
  $2.8\mathrm{fb}^{-1}$ for $4.30 < E_{cm} < 4.60\mathrm{GeV}$

- In range of $4.15 < E_{cm} < 4.30\mathrm{GeV}$,for the sum of events in all the three χ_{cJ} range, a clear $X(3872)$ signal is seen with $N = 16.9^{+5.2}_{-4.5}$, and 4.8σ significance.

- No evidence of $X(3872)$ in other E_{cm} ranges.

Observation of $X(3872) \to \pi^0\chi_{c1}(1P)$



BESIII:arXiv:1901.03992

- The first observation of a new decay mode $X(3872) \to \pi^0\chi_{c1}$ with a statistical significane of more than 5σ.

$$R_1 = \frac{\mathcal{B}(X(3872) \to \pi^0\chi_{c1})}{\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)} = 0.88^{+0.33}_{-0.27} \pm 0.10$$

- No signal for $\pi^0\chi_{c0}$ and $\pi^0\chi_{c2}$
- Pionic transition has been proposed to distinguish if $X(3872)$ is a conventional $c\bar{c}$ states in PRD 77, 014013 (2008), which predicts

$$\Gamma(X(3872) \to \pi^0\chi_{c1}) \sim 0.06\text{keV}$$

From PDG and PRD 77, 111101(2008), PRD 97,012005 (2018), there are

$$3.2\% < \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi) < 6.4\%$$

$$\Gamma_{TOT}(X(3872) \to \pi^0\chi_{c1}) \sim 0.5 - 1\text{keV}$$

which is orders of magnitude smaller than all other observed charmonium stats, and disfavors $c\bar{c}$ interpretation $\chi_{c1}(2P)$.

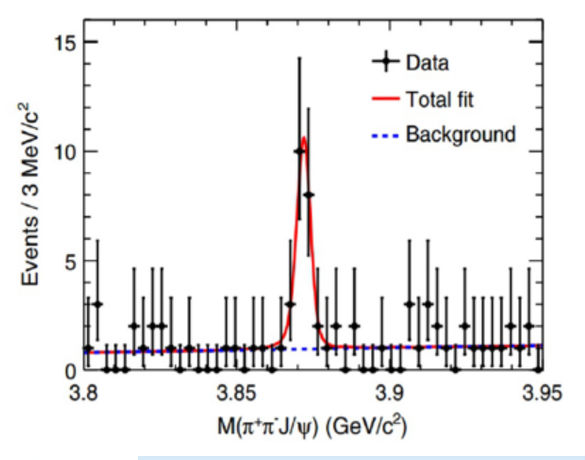
- In tetraquark/molecular state hypothesis, the decay width could be sizeable shown in PRD 77, 014013(2008) and PRD 92, 034019(2015).

Observation of $X(3872) \to \omega J/\psi$

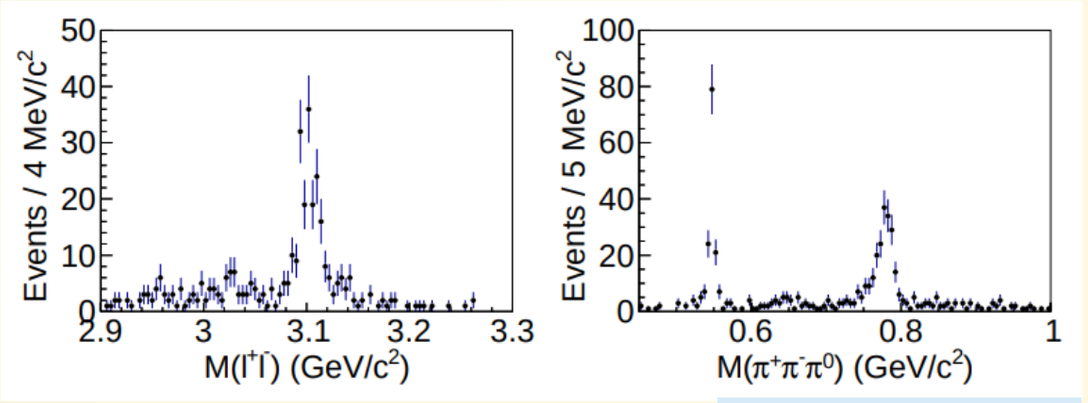
- **Belle** and **BABAR** report evidence for this decay, and give

$$\frac{\mathcal{B}(X(3872) \to \pi^+\pi^-\pi^0 J/\psi)}{\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)} = 1.0 \pm 0.4 \pm 0.3$$

- **BESIII** has also given the measurement of $X(3872) \to \pi\pi J/\psi$ in PRL 112, 092001(2014).



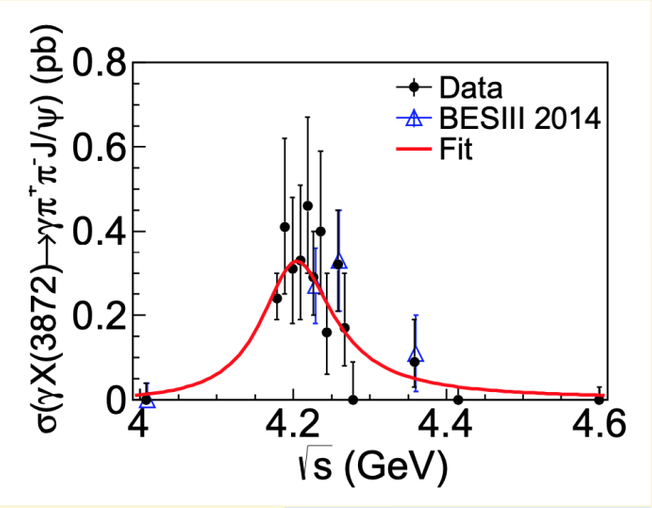
BESIII:PRL 112, 092001(2014)



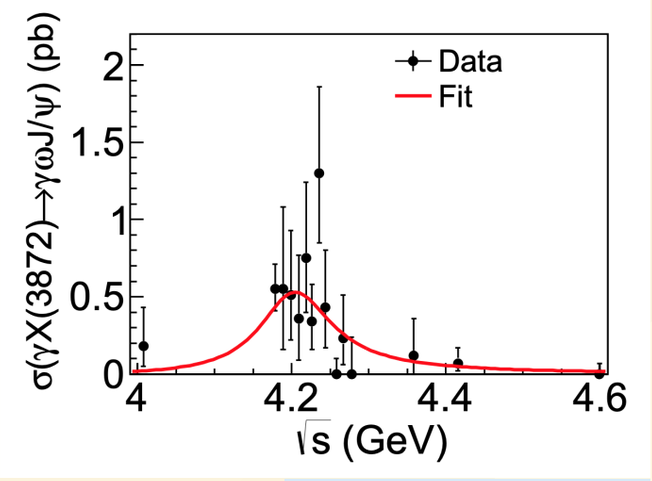
BESIII:arXiv:1903.04695

- **BESIII** is also expected to study $X(3872) \to \omega J/\psi$ with 11.6fb^{-1} data accumulated from 4.008 to 4.600 GeV.
- J/ψ is fully reconstructed with $e^+e^-/\mu^+\mu^-$.
- There are significant $e^+e^- \to \gamma\omega J/\psi$ signals, compared with $e^+e^- \to \gamma_{ISR}\psi(2S)$, $\psi(2S) \to \eta J/\psi$

Observation of $X(3872) \to \omega J/\psi$



BESIII:arXiv:1903.04695



BESIII:arXiv:1903.04695

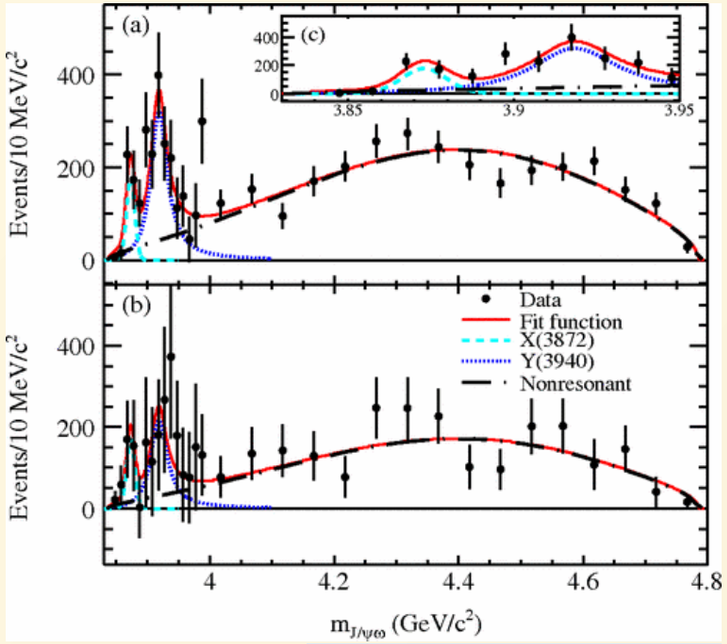
- Cross section measurement of $X(3872) \to \gamma(\pi\pi J/\psi)$ suggests a connection between $X(3872)$ and $Y(4260)$.
- New analysis confirms the connection through $X(3872) \to \gamma\omega J/\psi$

$$\mathrm{M}[Y(4200)] = 4200.6^{+7.9}_{-13.3} \pm 3.0\mathrm{MeV}/c^2$$

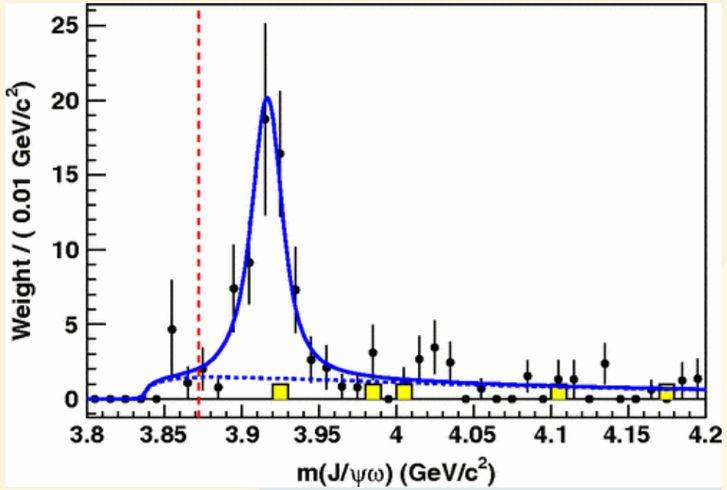
$$\mathrm{W}[Y(4200)] = 115^{+38}_{-26} \pm 12\mathrm{MeV}$$

- Simultaneous ($\omega J/\psi$ and $\pi\pi J/\psi$) fit to the cross section with a single Breit-Wigner resonance. The relative decay ratio is:

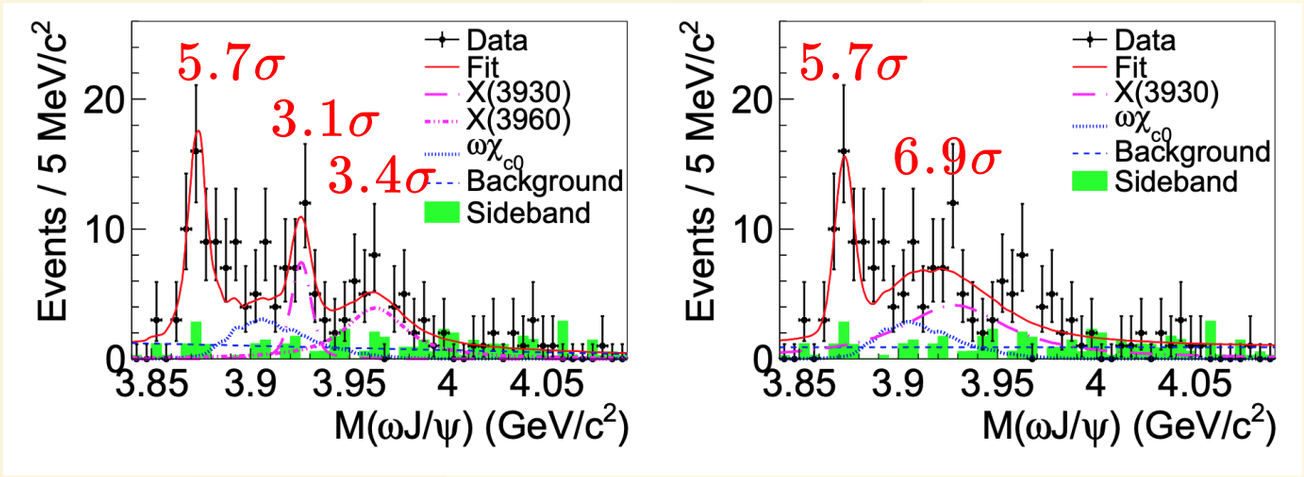
$$\mathcal{R} = \frac{\mathcal{B}[X(3872) \to \omega J/\psi]}{\mathcal{B}[X(3872) \to \pi\pi J/\psi]} = 1.6^{+0.4}_{-0.3} \pm 0.2$$



Belle: PRL 94,182002(2005)



BABAR: PRD 86, 072002(2012)



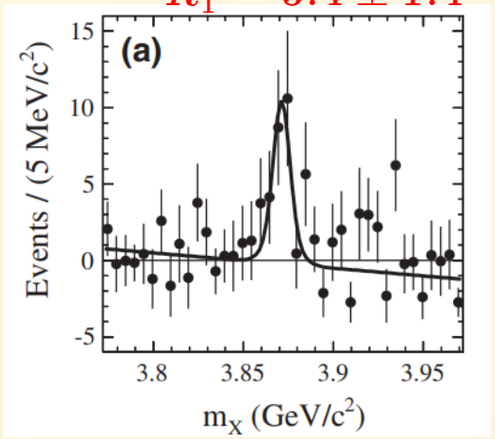
BESIII: arXiv:1903.04695v1

	$X(3872)$	$X(3915)$	$X(3960)$	$X(3915)$
Mass (in MeV/c^2)	$3873.3 \pm 1.1 \pm 1.0$	$3926.4 \pm 2.2 \pm 1.2$	$3963.7 \pm 5.5 \pm 1.3$	$3932.6 \pm 8.7 \pm 4.7$
Width (in MeV)	1.2	$3.8 \pm 7.5 \pm 2.6$	$33.3 \pm 34.2 \pm 8.3$	$59.7 \pm 15.5 \pm 3.7$

- At least one additional Breit-Wigner resonace is needed to describe the $\omega J/\psi$ mass distribution
- The resonance parameters of the $X(3915)$ agree with those of the $Y(3940)$ in $B \to K\omega J/\psi$ and of the $X(3915)$ in $\gamma\gamma \to \omega J/\psi$ by the Belle and BABAR experiments within erros.

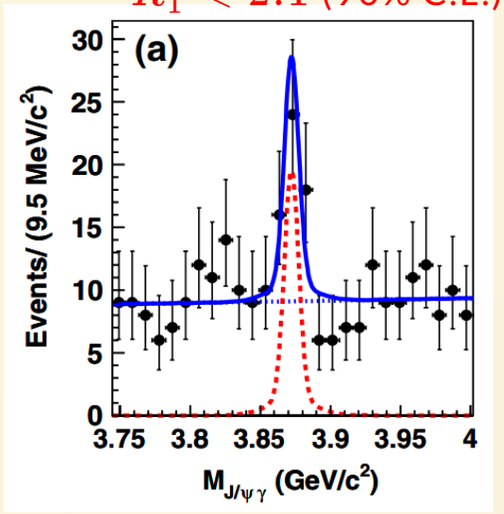
Open charm decay and radiative transitions of the X(3872)

$R_1 = 3.4 \pm 1.4$

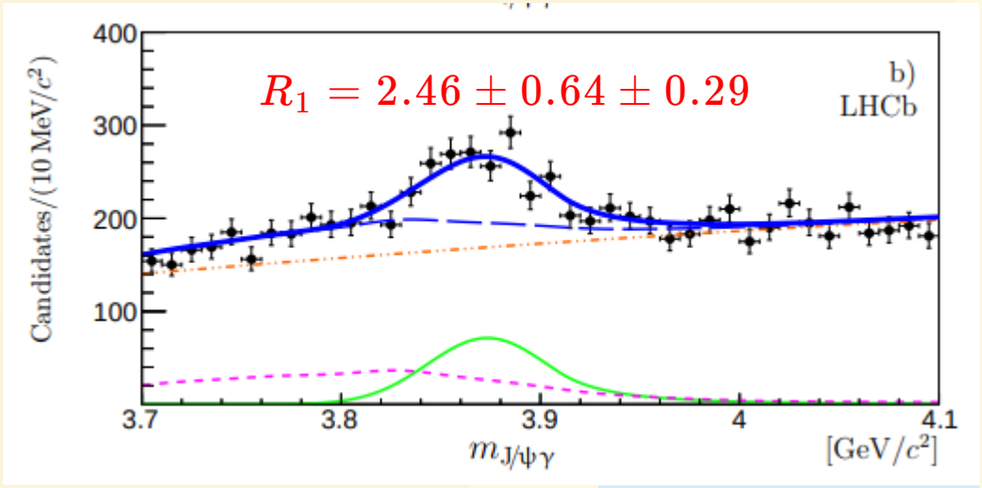


BABAR:PRL 102,132001(2009)

$R_1 < 2.1$ (90% C.L.)



Belle:PRL 107,091803(2011)



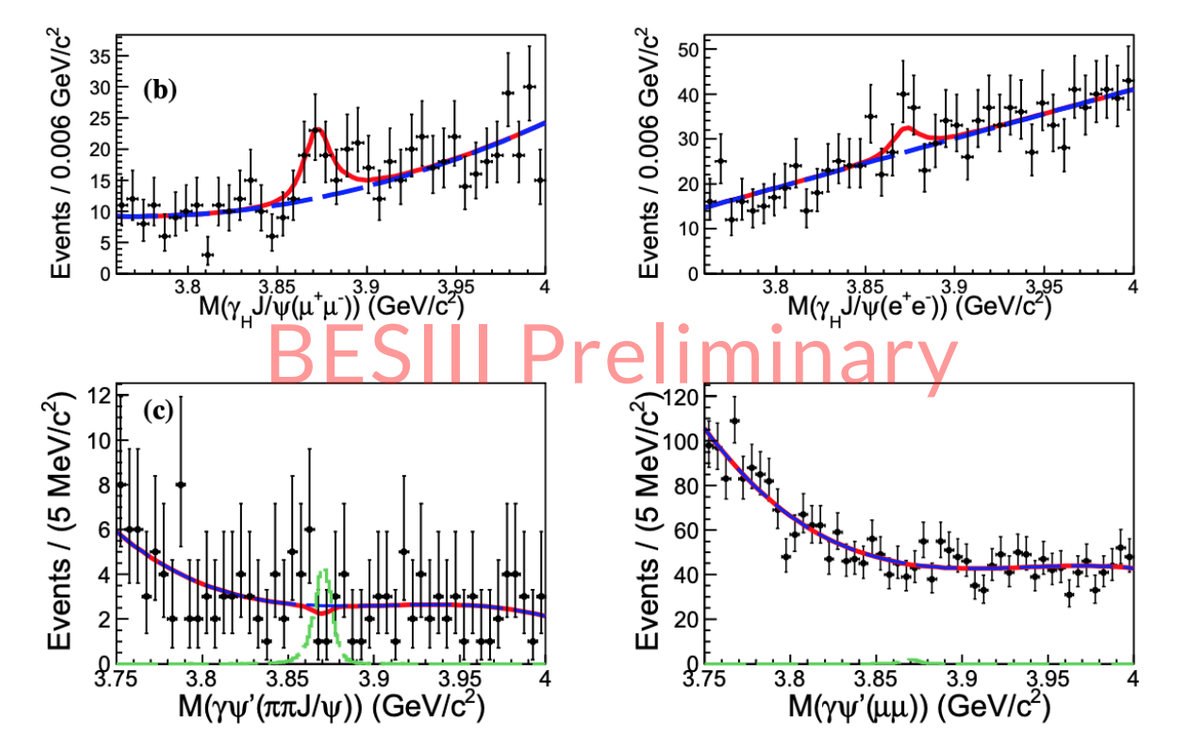
LHCb:NPB 886,665(2014)

- **BESIII** can investigate more modes
  - $X(3872) \to \gamma J/\psi, J/\psi \to \mu\mu/ee$
  - $X(3872) \to \gamma\psi(3686), \psi(3686) \to \pi^+\pi^- J/\psi, \psi(3686) \to \mu\mu$
  - $X(3872) \to D^0\bar{D}^{*0} + c.c., D^{*0} \to \gamma D^0, \pi^0 D^0, D^0 \to K\pi, K\pi\pi, K\pi\pi\pi$
  - $X(3872) \to \gamma D^+ D^-, D^\pm \to K\pi\pi, K\pi\pi\pi$
- World average:

$$R_1 = \frac{\mathcal{B}[X(3872) \to \gamma\psi(3686)]}{\mathcal{B}[X(3872) \to \gamma J/\psi]} = 2.6 \pm 0.6$$

$$R_2 = \frac{\mathcal{B}[X(3872) \to \gamma J/\psi]}{\mathcal{B}[X(3872) \to \pi^+\pi^- J/\psi]} = 0.24 \pm 0.05$$

Open charm decay and radiative transitions of the X(3872)



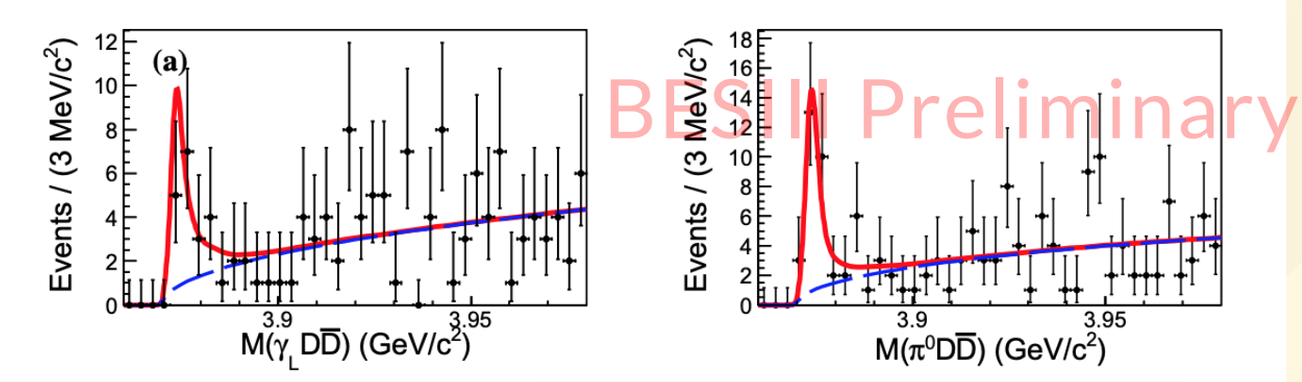
- Simultaneous fit
- $X(3872) \to \gamma J/\psi$ is seen (3.5σ)
- No signal of $X(3872) \to \gamma\psi(3686)$

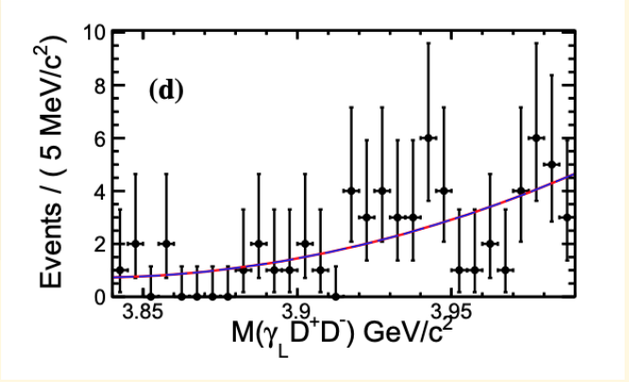
$$\frac{B[X(3872) \to \gamma\psi(3686)]}{B[X(3872) \to \gamma J/\psi]} < 0.59$$

at 90% C.L.

- Consistent with **Belle**'s result, and not with those of **BABAR** and **LHCb**.

Open charm decay and radiative transitions of the X(3872)





- Simultaneous fit to $D^0 D^{*0}$, significance $\sim 7.4\sigma$
- No evident signal for $\gamma D^+ D^-$

TABLE II. Relative branching ratio compared with $X(3872) \to \pi^+\pi^- J/\psi$.

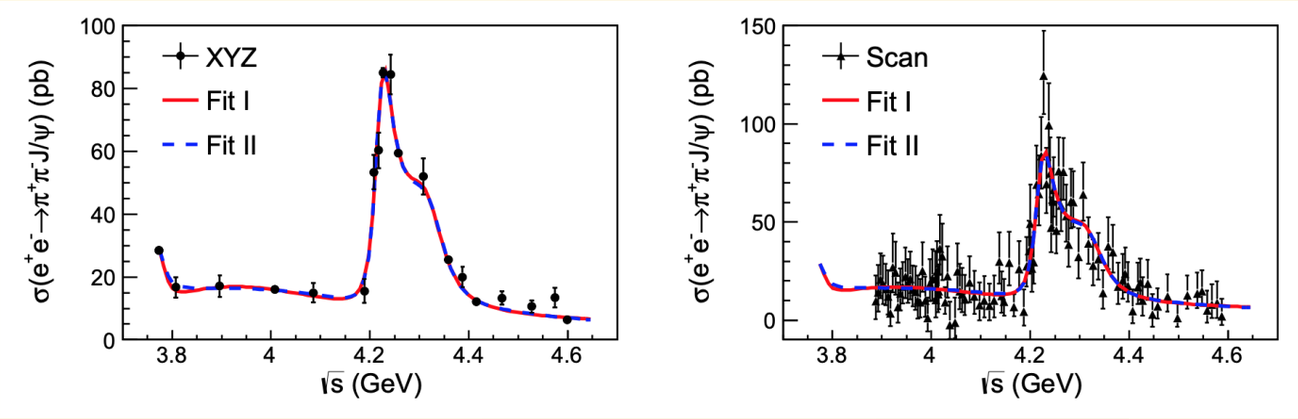
mode	$D^{*0}\bar{D}^0 + c.c.$	$\gamma J/\psi$	$\gamma\psi'$	$\gamma D^+ D^-$	$\omega J/\psi$	$\pi^0\chi_{c1}$
ratio	14.81 ± 3.80	0.79 ± 0.28	< 0.42	< 0.99	$1.7^{+0.4}_{-0.3} \pm 0.2$ [27]	$0.88^{+0.33}_{-0.27} \pm 0.10$ [37]

The Y states

Y states:

- charmonium-like states with $J^{PC} = 1^{--}$;
- Observed in direct e^+e^- annihilation or initial state radiation (ISR).

Cross section of $e^+e^- \to \pi^+\pi^- J/\psi$



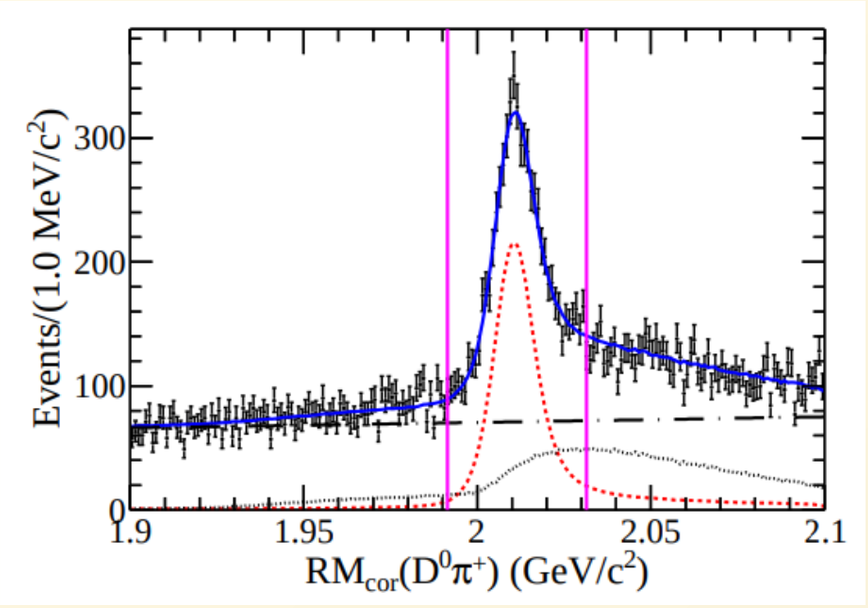
BESIII:PRL118, 092001(2017)

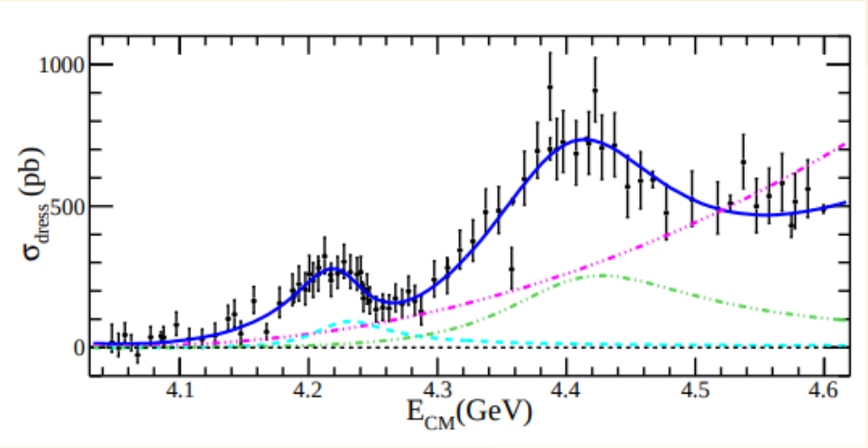
Parameters	Fit result
$M(R_1)$	$3812.6^{+61.9}_{-96.6}\ (\cdots)$
$\Gamma_{\rm tot}(R_1)$	$476.9^{+78.4}_{-64.8}\ (\cdots)$
$M(R_2)$	$4222.0 \pm 3.1\ (4220.9 \pm 2.9)$
$\Gamma_{\rm tot}(R_2)$	$44.1 \pm 4.3\ (44.1 \pm 3.8)$
$M(R_3)$	$4320.0 \pm 10.4\ (4326.8 \pm 10.0)$
$\Gamma_{\rm tot}(R_3)$	$101.4^{+25.3}_{-19.7}\ (98.2^{+25.4}_{-19.6})$

BESIII:PRL118, 092001(2017)

- Simultaneous fit to the "XYZ data" and "Scan data"
- Structure at 4.260GeV is not a simple BW, but rather two:
  - R2: consistent with the Y(4260), however narrower
  - R3: comparable to the Y(4360)
    - Significance > 7.6σ
  - Y(4008) is not confirmed
- Y(4220) and Y(4320) could be more precise description of these two states.

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





BESIII:PRL 122,102002(2019)

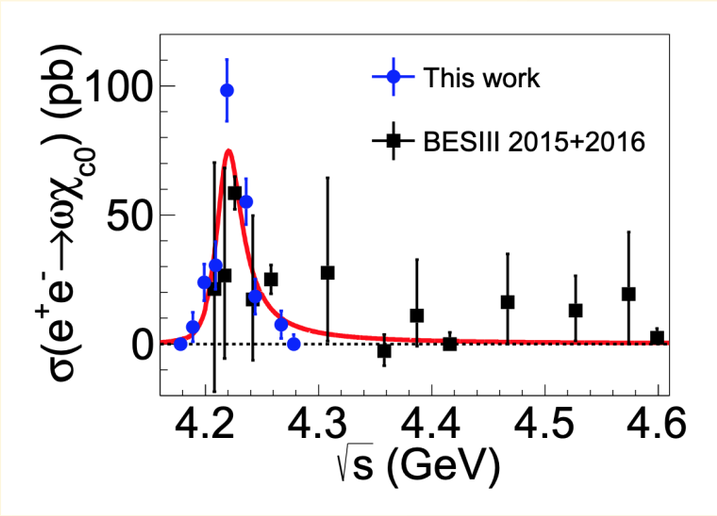
- Detect $D^0 \to K^-\pi^+$ and bachelor π^+, and reconstruct D^{*-} in the missing mass specturm.
- Two enhancements are clearly visible.
- A stable resonant structure is consistent with previous observations of Y(4220) state and the theoretical prediction of a $D\overline{D}_1(2420)$ molecule in PRD 90, 074039 (2014).

$$\mathrm{M}(R_1) = 4228.6 \pm 4.1 \pm 6.3\mathrm{MeV}/c^2$$

$$\Gamma(R_1) = 77.0 \pm 6.8 \pm 6.3\mathrm{MeV}$$

- The higher bump around 4.4GeV cannot be described by either single resonance of the Y(4260), Y(4320), Y(4360), $\psi(4415)$. Further more data set and a detailed amplitude analysis are needed.

Update measurement of $e^+e^- \to \omega\chi_{c0}$

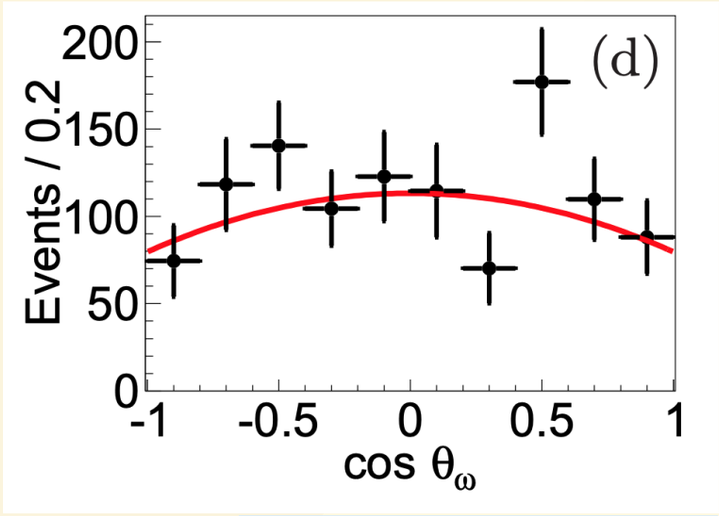


BESIII:PRD 99, 091103(R)(2019)

- The cross section of $e^+e^- \to \omega\chi_{c0}$ is measured, and an enhancement was found in the cross section around 4.22GeV.

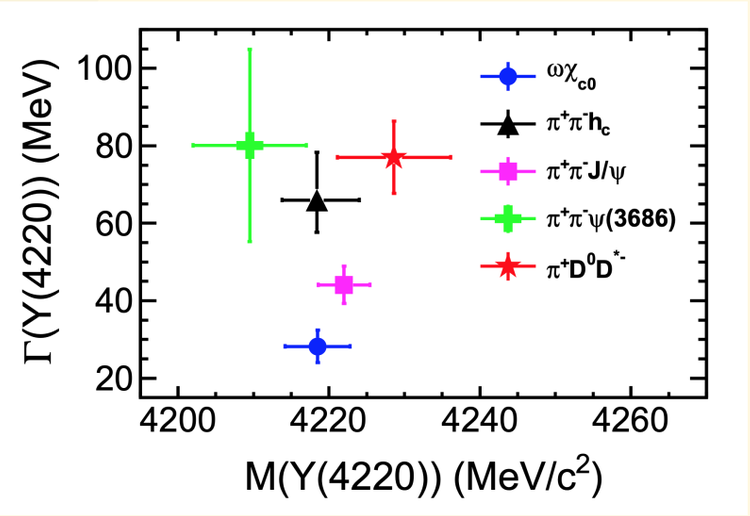
$$\mathrm{M} = (4218.5 \pm 1.6 \pm 4.0)\ \mathrm{MeV}\ /c^2$$

$$W = (28.2 \pm 3.9 \pm 1.6)\ \mathrm{MeV}$$



BESIII:PRD 99, 091103(R)(2019)

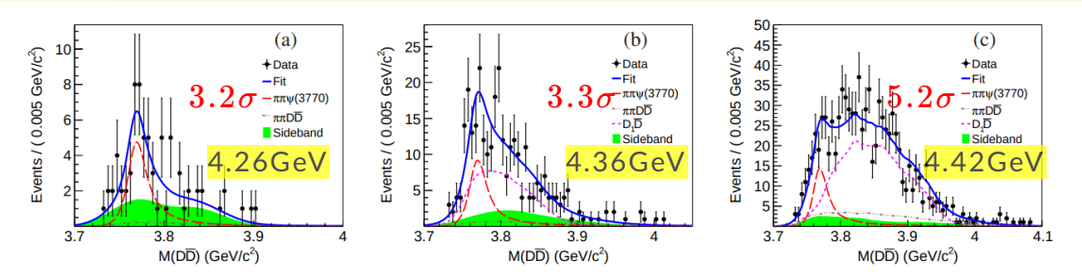
- The angular distribution of the $e^+e^- \to \omega\chi_{c0}$ process is extracted for the first time, which indicates evidence for a combination of S and D-wave contributions in the $Y(4220) \to \omega\chi_{c0}$ process



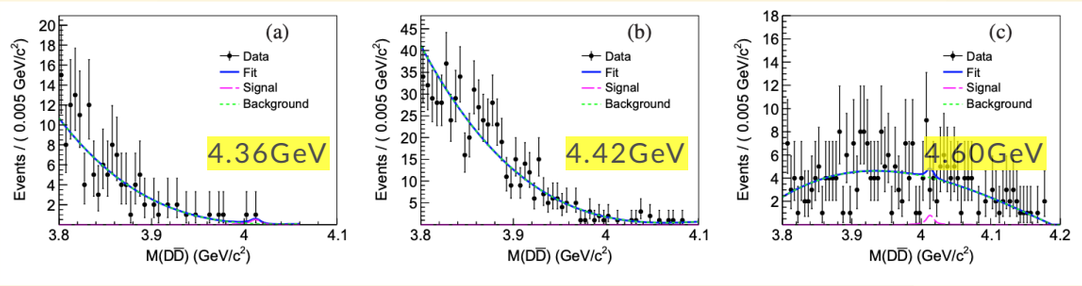
BESIII:PRD 99, 091103(R)(2019)

- This fig shows the measured mass and width of the Y(4220) from the different processes. The masses are consistent with each other, while the widths are not.

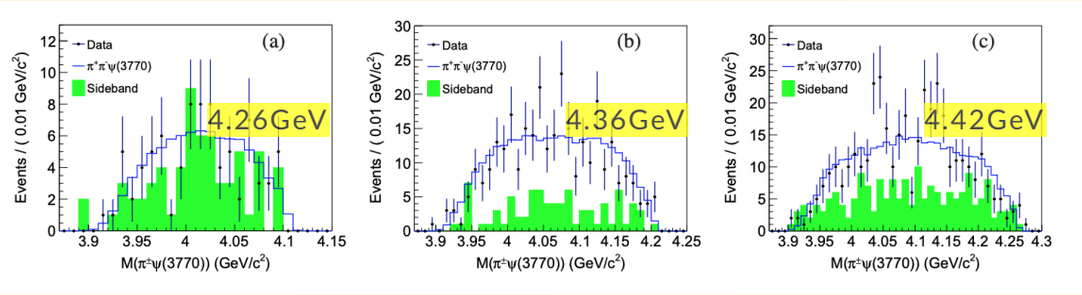
Observation of $e^+e^- \to \pi^+\pi^-\psi(3770)$



BESIII:arXiv:1903.08126



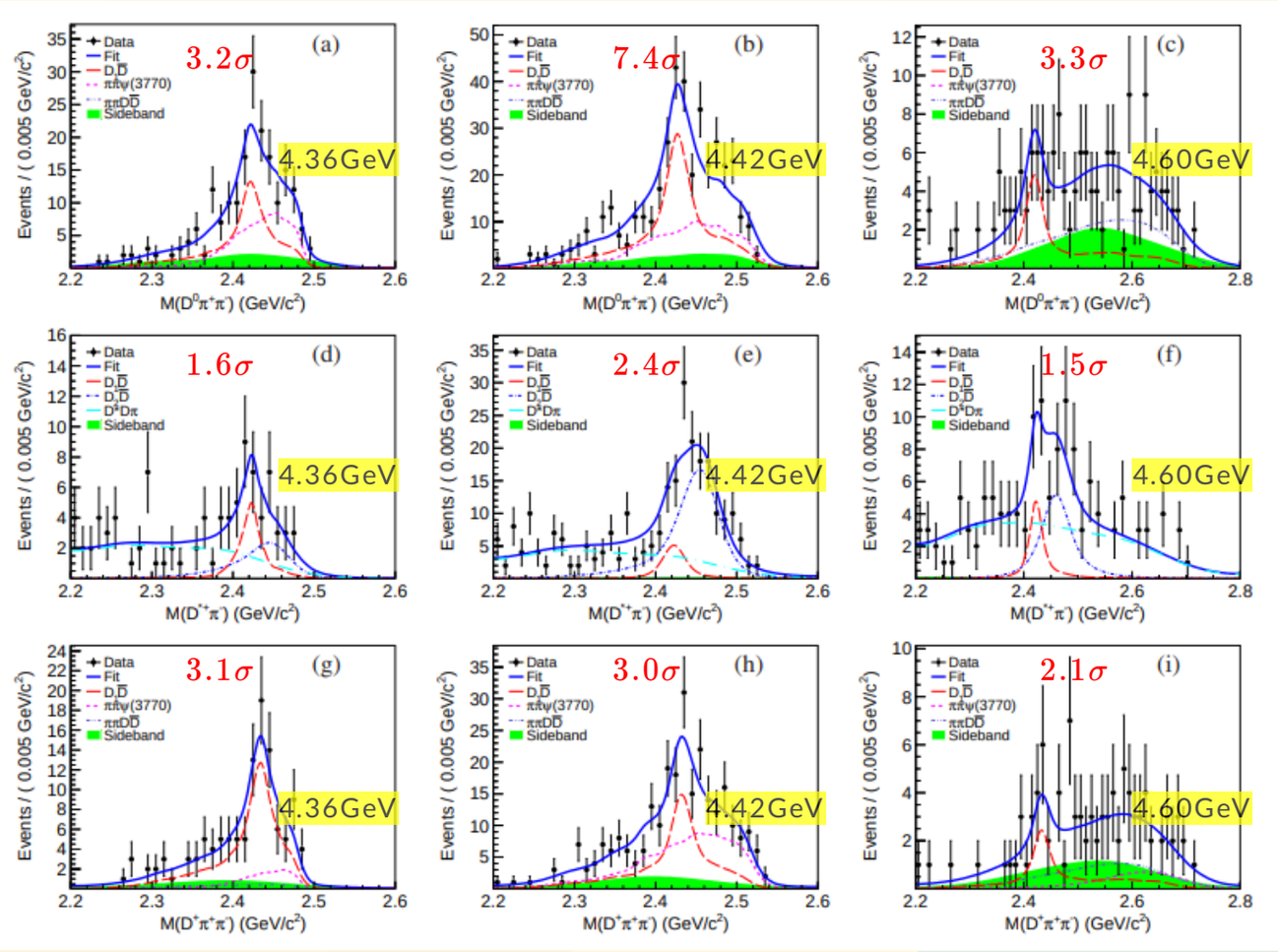
BESIIIarXiv:1903.08126



BESIIIarXiv:1903.08126

- $\psi(3770)$ is found in the $D\bar{D}$ invariant mass spectrum with a statistical significance of 5.2σ at $\sqrt{s} = 4.42\text{GeV}$.
- No signal for the proposed heavy-quark-spin-symmetry partner of $X(3872)$, the state $X_2(4013)$, is found in the $D\bar{D}$ invariant mass spectra.
- The upper limit of the Born cross section of the process $e^+e^- \to \rho^0 X_2(4013)$ combined with the branching fraction is measured.
- Distribution of the $M(\pi\psi(3770))$ hints for peaks at 4.04 and 4.13 GeV in $\sqrt{s} = 4.42\text{GeV}$ data.

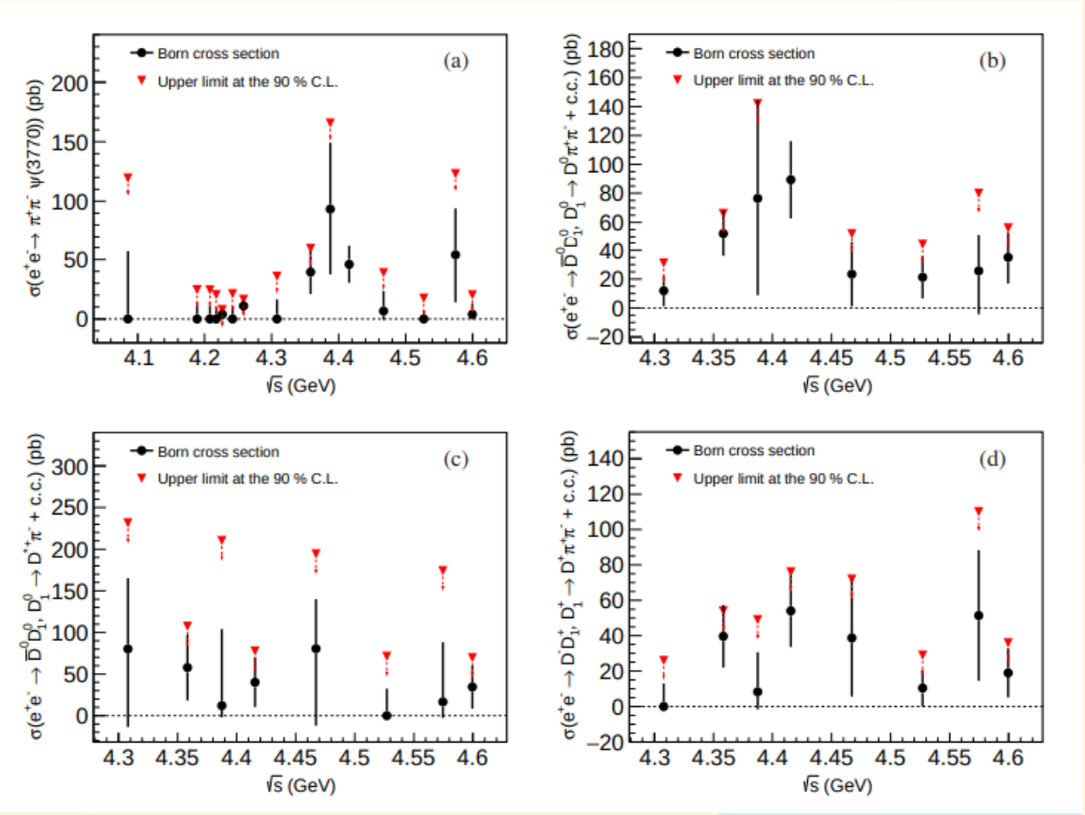
Observation $e^+e^- \to D_1(2420)\bar{D}$



BESIII:arXiv:1903.08126

- $D^0\pi^+\pi^-, D^{*+}\pi^-, D^+\pi^+\pi^-$ invariant mass distribution @4.36GeV, 4.42GeV and 4.60GeV
- $D_1(2420)^0 \to D^0\pi^+\pi^-$ is observed with statistical significance of 7.4σ @4.42GeV

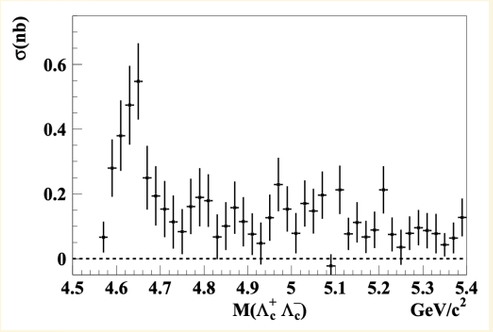
Cross section measurement for $e^+e^- \to \pi^+\pi^-\psi(3770)$ etc.



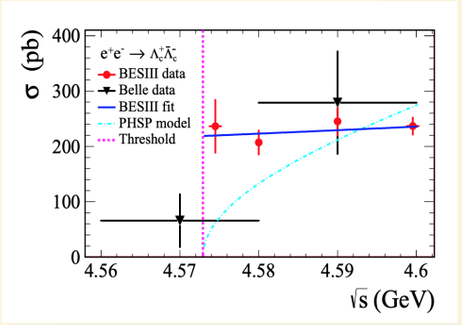
BESIII:arXiv:1903.08126

- Born cross section measurements:
  - (a) $e^+e^- \to \pi^+\pi^-\psi(3770)$
  - (b) $e^+e^- \to D_1(2420)^0\bar{D}^0 \to \pi^+\pi^- D^0\bar{D}^0$
  - (c) $e^+e^- \to D_1(2420)^0\bar{D}^0$
    $\to D^{*+}\bar{D}^0\pi^- \to \pi^+\pi^- D^0\bar{D}^0$
  - (d) $e^+e^- \to D_1(2420)^+D^- \to \pi^+\pi^- D^+D^-$
- We observe $e^+e^- \to \pi^+\pi^-\psi(3770)$ for the first time @4.42GeV
- No fast rise of the cross section above the $D_1(2420)\bar{D}$ threshold.

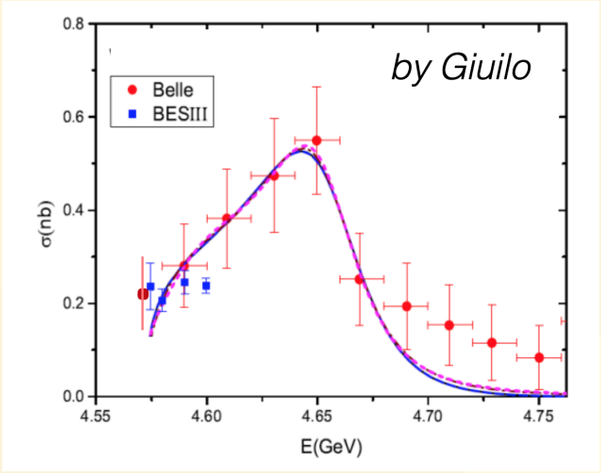
Lineshape of $e^+e^- \to \Lambda_c^+ \bar{\Lambda}_c^-$



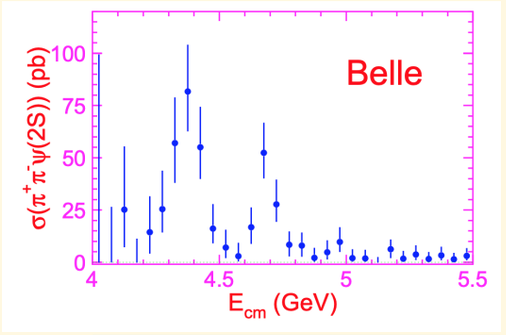
Belle:PRL 101, 172001(2008)



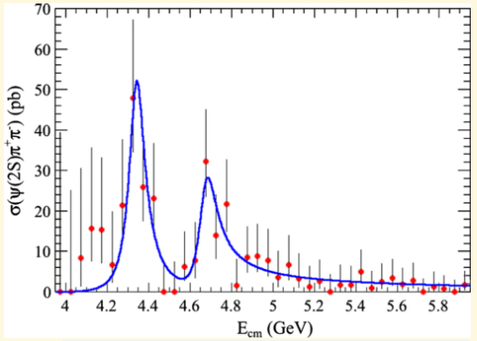
BESIII:PRL 120, 132001(2018)



- **Belle** data show a wide resonance, consistent with the Y(4660), seen by **BABAR** and **Belle** in $e^+e^- \to \pi^+\pi^-\psi(3686)$, hardly compatible with **BESIII** flat behaviour up to 4.6GeV.
- BESIII future data above 4.6GeV will follow a sharp rise of the Y(4660) or a flat cross section near threshold?



Belle:PRL99, 142002(2007)



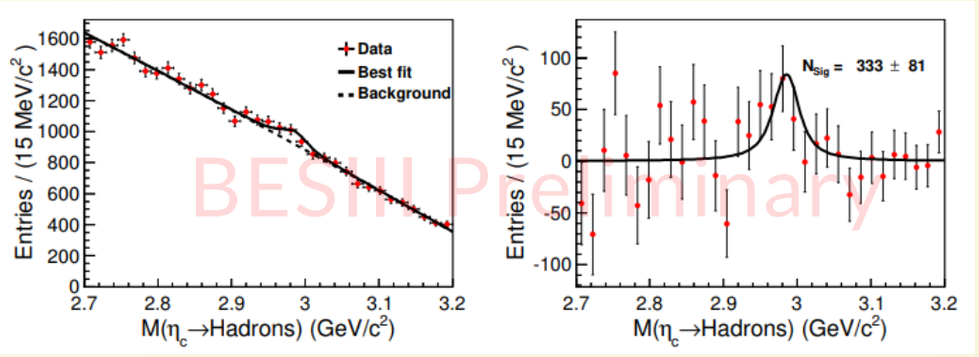
Belle:PRL99, 142002(2007)

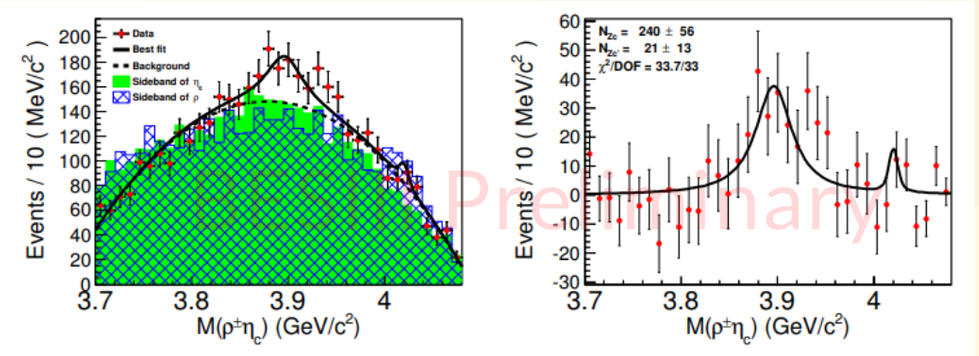
The Z states

Z states:

- The iso-triplet charmonium-like states;
- **BESIII** has an interesting Zc family.
  - $Z_c^{\pm}(3900)$: $e^+e^- \to \pi^+\pi^- J/\psi$ **BESIII**:PRL 110, 252001(2013)
  - $Z_c^{0}(3900)$: $e^+e^- \to \pi^0\pi^0 J/\psi$ **BESIII**:PRL 115, 112003(2015)
  - $Z_c^{\pm}(4020)$: $e^+e^- \to \pi^+\pi^- h_c$ **BESIII**:PRL 111, 242001(2013)
  - $Z_c^{0}(4020)$: $e^+e^- \to \pi^0\pi^0 h_c$ **BESIII**:PRL 113, 212002(2014)
  - $Z_c^{\pm}(3885)$: $e^+e^- \to \pi^{\pm}(D\bar{D}^*)^{\mp}$ **BESIII**:PRL 112, 022001(2014), **BESIII**:PRD 92, 092006(2015)
  - $Z_c^{0}(3885)$: $e^+e^- \to \pi^0(D^*\bar{D})^0$ **BESIII**:PRL 115, 222002(2015)
  - $Z_c^{\pm}(4025)$: $e^+e^- \to \pi^{\pm}(D^*\bar{D}^*)^{\mp}$ **BESIII**:PRL 112, 132001(2014)
  - $Z_c^{0}(4025)$: $e^+e^- \to \pi^0(D^*\bar{D}^*)^0$ **BESIII**:PRL115, 182002(2015)

Search for $Z_c(3900)/Z_c(4020) \to \rho\eta_c$



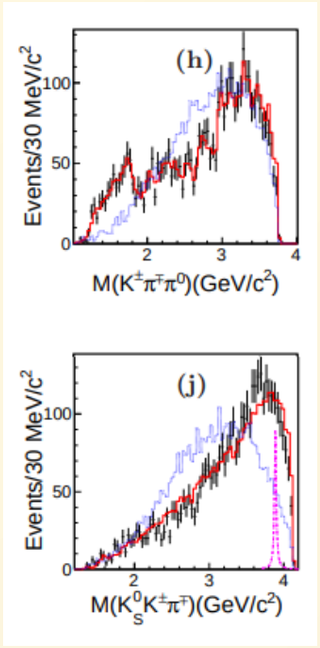


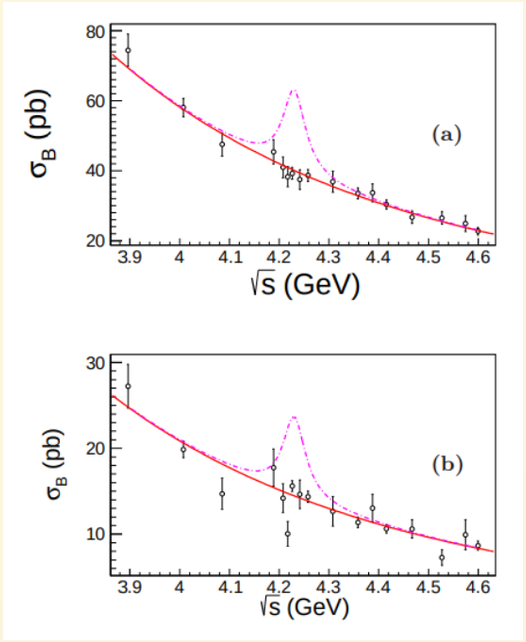
	$\sqrt{s} = 4.226$ GeV	$\sqrt{s} = 4.258$ GeV	$\sqrt{s} = 4.358$ GeV	Type-I	Type-II	Molecule
$R_{Z_c(3900)}$	2.2 ± 0.9	< 5.6	...	230^{+330}_{-140}	$0.27^{+0.40}_{-0.17}$	$0.046^{+0.025}_{-0.017}$
$R_{Z_c(4020)}$	< 1.6	< 0.9	< 1.4	$6.6^{+56.8}_{-5.8}$		$0.010^{+0.006}_{-0.004}$

BESIII Preliminary

- Search for new decay mode of $Z_c(3900)$ and $Z_c(4020)$
- Start with looking for $e^+e^- \to \pi^+\pi^-\pi^0\eta_c$, η_c decays to 9 hardronic decays.
- Strong evidence of $e^+e^- \to \pi Z_c(3900)$, $Z_c(3900) \to \rho\eta_c$ is observed at $\sqrt{s} = 4.23\text{GeV}$, statistical significance is 4.3σ. (3.9σ including systematics)
- $e^+e^- \to \pi Z_c(4020)$, $Z_c(4020) \to \rho\eta_c$ is not seen in all data sets.
- Measure Born cross section @4.226GeV:
  - $\sigma^B(e^+e^- \to \pi^+\pi^-\pi^0\eta_c) = (46 \pm 12 \pm 10)\text{pb}$
  - $\sigma^B(e^+e^- \to \pi Z_c) \times \mathcal{B}(Z_c \to \rho\eta_c) = (47 \pm 11 \pm 11)\text{pb}$
- Ratios $R_Z = \frac{\mathcal{B}(Z_c \to \rho\eta_c)}{\mathcal{B}(Z_c \to \pi J/\psi)}$ and $R_{Z'} = \frac{\mathcal{B}(Z_c' \to \rho\eta_c)}{\mathcal{B}(Z_c' \to \pi h_c)}$ are helpful to discriminate the tetra-quark and molecule models shown in PLB 746, 194(2015)
  - R_Z: not consistent with any of the model calculations
  - $R_{Z'}$: smaller than the calculations based on tetra-quarks model, while not in contradiction with the molecule model calculation

Measurments of $e^+e^- \to K^0_S K^\pm \pi^\mp \pi^0$ and $K^0_S K^\pm \pi^\mp \eta$





	$\sqrt{s}$ (GeV)	σ_B (pb)	R
$e^+e^- \to \pi^0 Z_c(3900)^0$, $Z_c(3900)^0 \to K^0_S K^\pm \pi^\mp$	4.226	< 0.24	$< 2.5 \times 10^{-2}$
	4.258	< 0.38	$< 1.2 \times 10^{-1}$
	4.358	< 0.51	$< 2.6 \times 10^{-1}$
	4.416	< 0.27	-
	4.600	< 0.33	-
$e^+e^- \to \pi^\pm Z_c(3900)^\mp$, $Z_c(3900)^\mp \to K^0_S K^\mp \pi^0$	4.226	< 0.17	$< 9.1 \times 10^{-3}$
	4.258	< 0.28	$< 5.6 \times 10^{-2}$
	4.358	< 0.57	-
	4.416	< 0.34	-
	4.600	< 0.45	-
$e^+e^- \to \pi^\pm Z_c(3900)^\mp$, $Z_c(3900)^\mp \to K^0_S K^\mp \eta$	4.226	< 0.18	$< 1.0 \times 10^{-2}$
	4.258	< 0.56	$< 1.4 \times 10^{-1}$
	4.358	< 0.53	-
	4.416	< 0.76	-
	4.600	< 0.58	-

BESIII:PRD 99,012003(2019)

- Search light hadron decay modes of $Y(4260)$ and $Z_c(3900)$
- The mixing MC sample including intermediate resonances is used to estimate the detection efficiency.
- The upper limits of the $Y(4260)$ products are given.
  - $\Gamma_{e^+e^-}\mathcal{B}(Y(4260) \to K^0_S K^\pm \pi^\mp \pi^0) < 0.05\text{eV}$ at 90% C.L.
  - $\Gamma_{e^+e^-}\mathcal{B}(Y(4260) \to K^0_S K^\pm \pi^\mp \eta) < 0.19\text{eV}$ at 90% C.L.
- The 90% C.L. upper limits on the cross sections of $Z_c(3900)$ are given @4.226, 4.258, 2.358, 4.416 and 4.600GeV.

Summary

- BESIII is now producing many new results on the Charmonium-like states, and continues to deepen understanding of those processes involving the XYZ states.
- More results are being obtained for X(3872), such as the study of its radiactive decay mode.
- New Y states have been observed in several decays with some puzzling behavior. There is a hint of a strong connection between X,Y states and radiative decays.
- The BEPCII energy upgrade enables BESIII to study the Y(4360)/Y(4660) states.
- A large number of Z states has been discovered in charmonium and open-charm decays. The search for Z_c's new decay mode always attracts people's attention.

Thanks!