XYZ spectroscopy at BESIII

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(on the behalf of BESIII collaboration)

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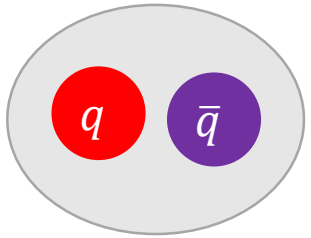
Outline

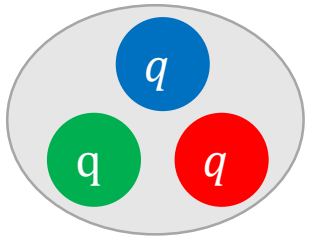
- **Introduction**
  - Hadrons and XYZ states
- **XYZ spectroscopy at BESIII**
  - BESIII data samples for XYZ study
  - The XYZ states
    - ✓ X(3872),X(3823)
    - ✓ Abundant structures above 4GeV
    - ✓ $Z_c(3900)/Z_c(3885)$, $Z_c(4020)/Z_c(4025)$
- **Summary**

Constitution of hadrons in QCD

- Quark Model

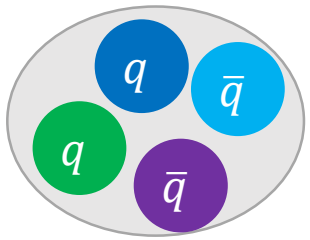


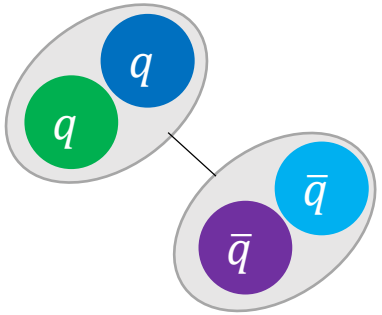
Mesons
Color-anticolor pairs

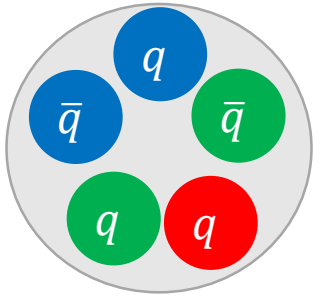


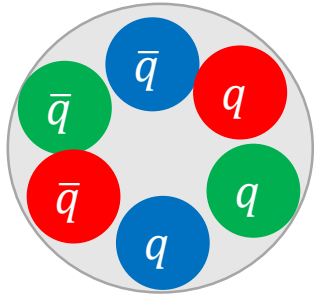
Baryons
Red-blue-green triplets

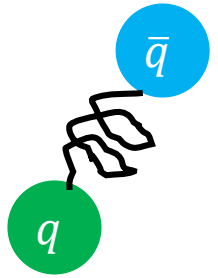
- Exotic states predicted by QCD











... ...

Tetraquark
Tightly bound
diquark&anti-diquark

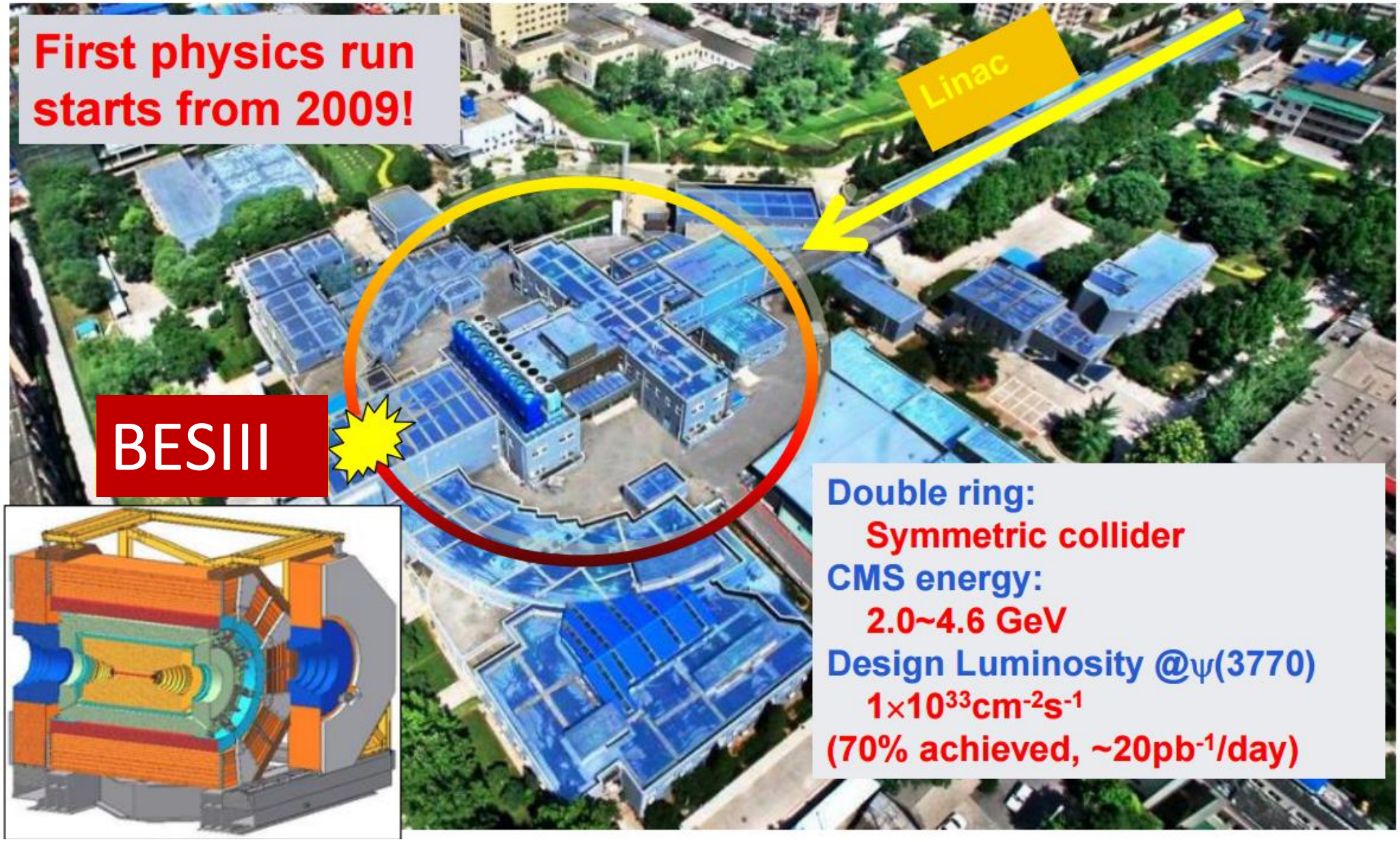
Molecule
Loosely bound
meson&anti-meson

Pentaquark
S=+1

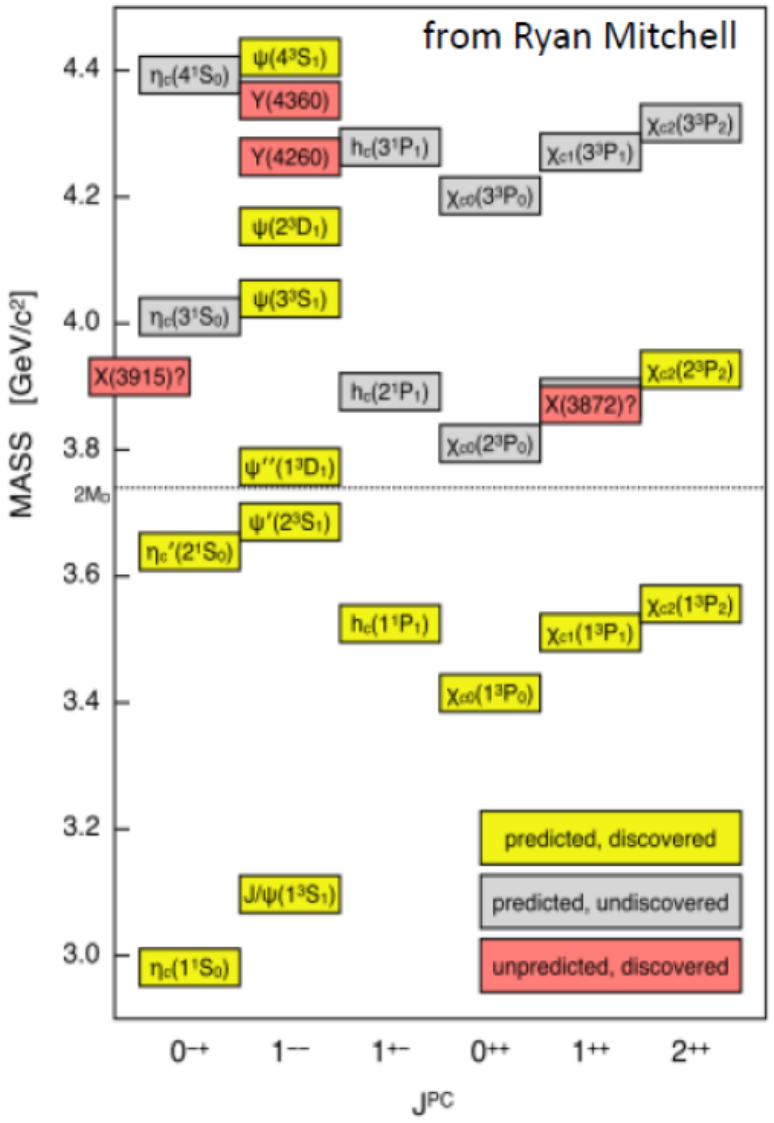
Six-quark state
Tightly bound
6 quarks

Hybrid
More than 2
quarks and gluon

BEPCII and BESIII



Charmonium Spectroscopy



- **Below open charm threshold**

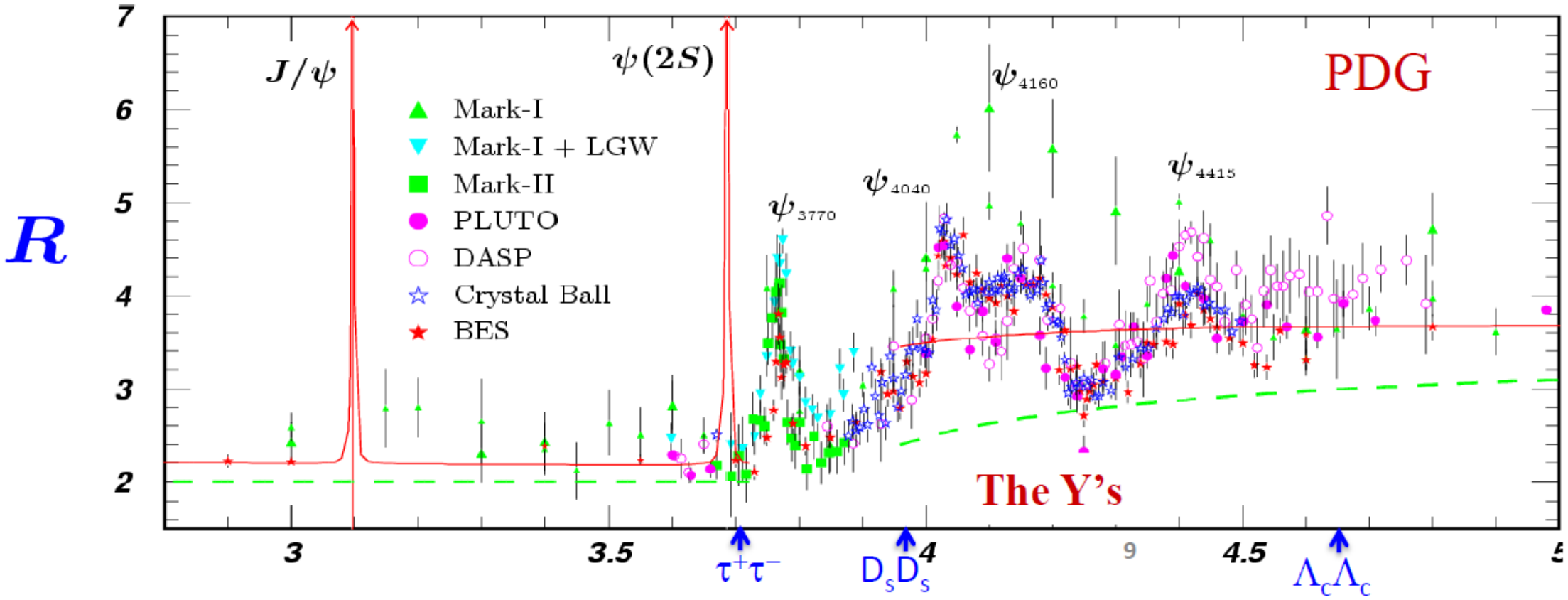
  Good agreement between discovery and theoretical prediction.

- **Above open charm threshold**

  Many expected states are not observed

  Many unexpected states are observed: XYZ states

Data samples for XYZ states at BESIII



- Luminosity~5 fb^{-1}
- Large data samples around Ψ(4040), Y(4260), Y(4360), Ψ(4415) and Y(4660)

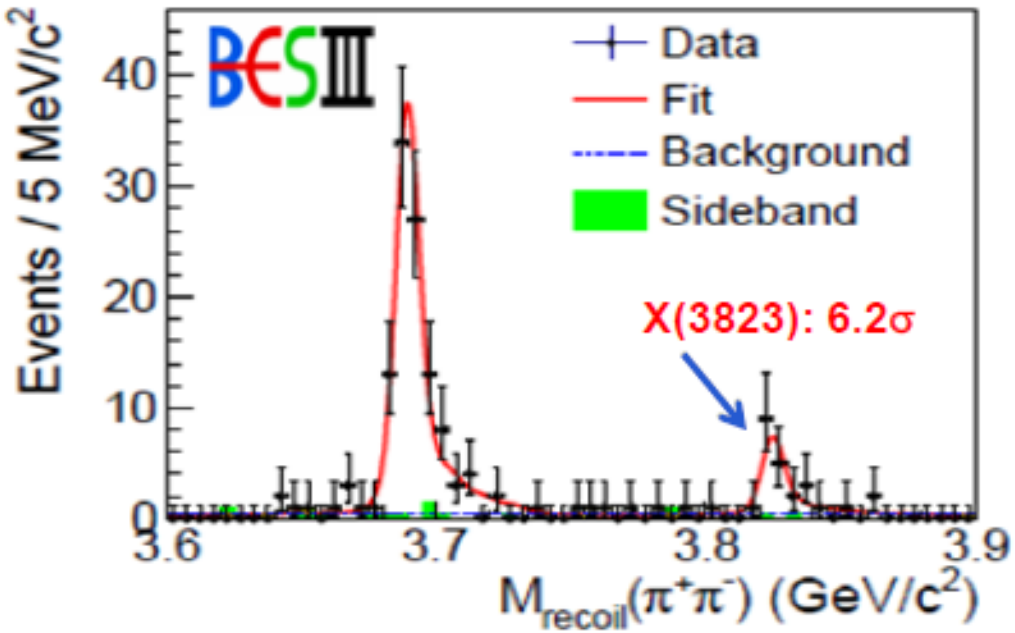
X(3823)/X(3872)

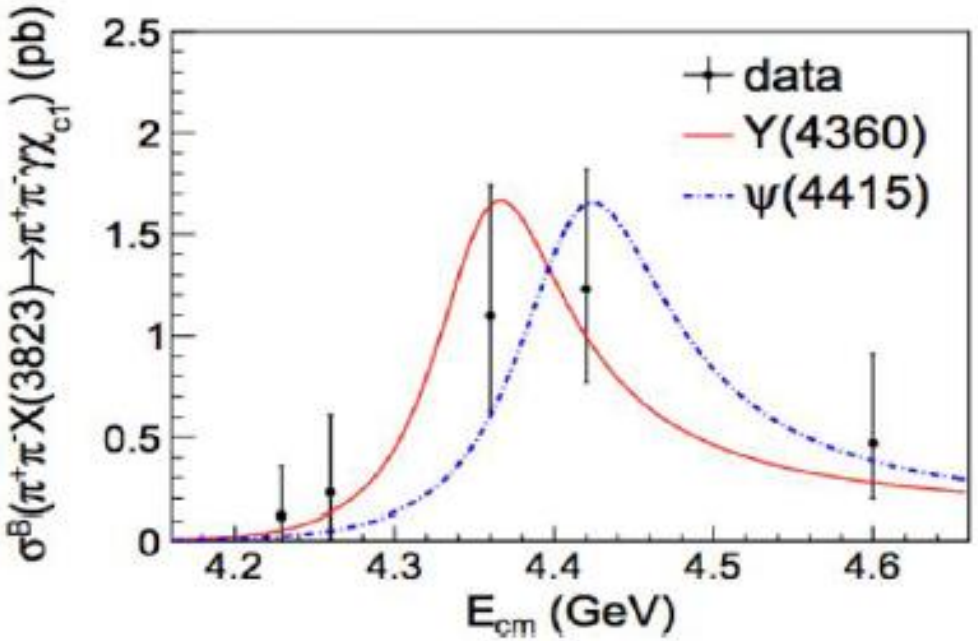
- X(3823) in $e^+e^-\to\pi^+\pi^-\gamma\chi_{c1}$ PRL 115,011803 (2015)

- X(3872) in $Y(4260)\to\gamma\pi^+\pi^- J/\Psi$ PRL 112,092001 (2014)

$e^+e^- \to \pi^+\pi^- X(3823) \to \pi^+\pi^- \gamma\chi_{c1}$

PRL 115,011803 (2015)

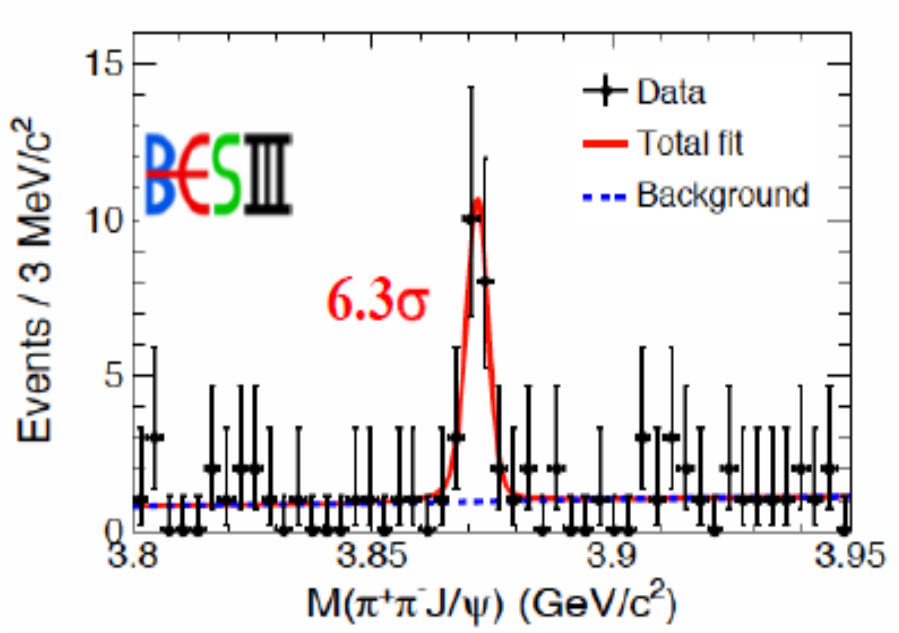


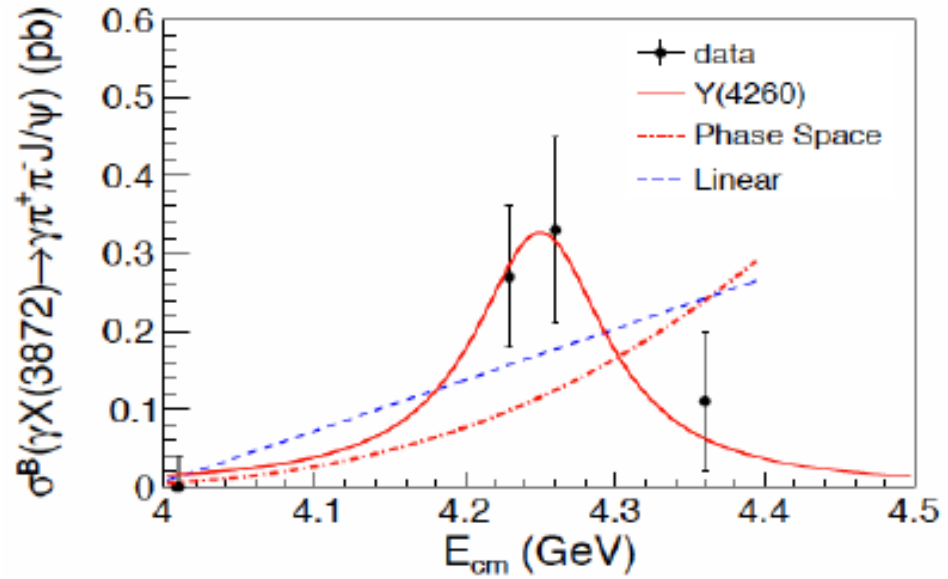


- Potential channel: $1^3D_2 \to \gamma\chi_{c1}, \gamma\chi_{c2}$ with large width.
- $M=3821.7\pm1.3\pm0.7$MeV, $\Gamma<16$MeV.
- Good candidate of $\Psi(1^3D_2)$.
- Both Y(4360) and Ψ(4415) line shape give reasonable description.

Y(4260)→γX(3872)→γ $\pi^+\pi^-$J/Ψ

PRL 112,092001 (2014)





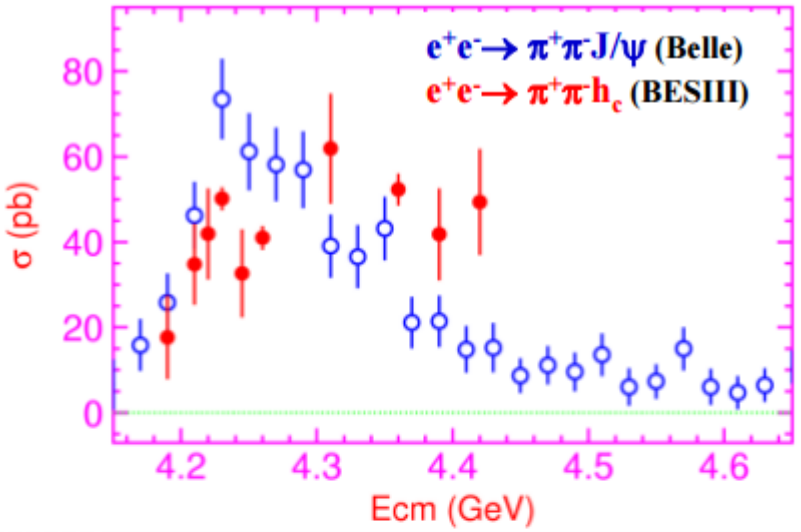
- M=3871.9±0.7±0.2MeV, Γ<2.4MeV.
- A new Y(4260) decay mode and new X(3872) production mode: Y(4260) → γX(3872)
- If we take B(X(3872) → $\pi^+\pi^-$ J/Ψ) ~ 5%, (>2.6% in PDG)

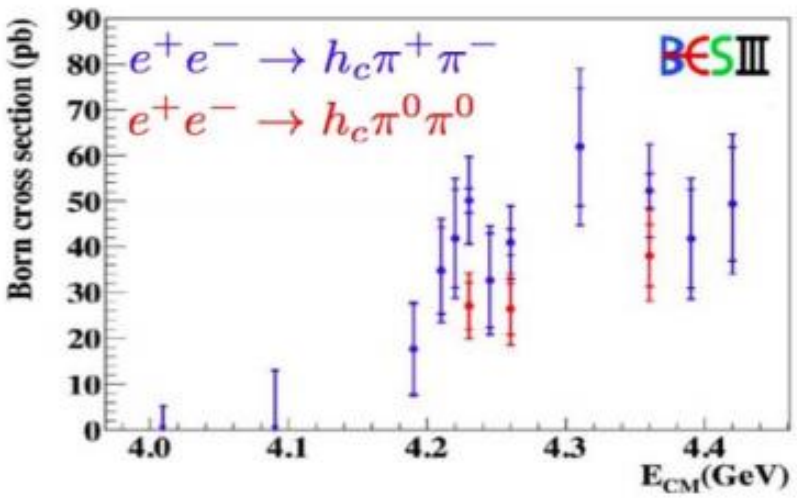
$\frac{\sigma(e^+e^-\to\gamma X(3872))}{\sigma(e^+e^-\to\pi^+\pi^- J/\Psi)}$ ~ 11.2% large transition ratio!

Abundant structures above 4GeV

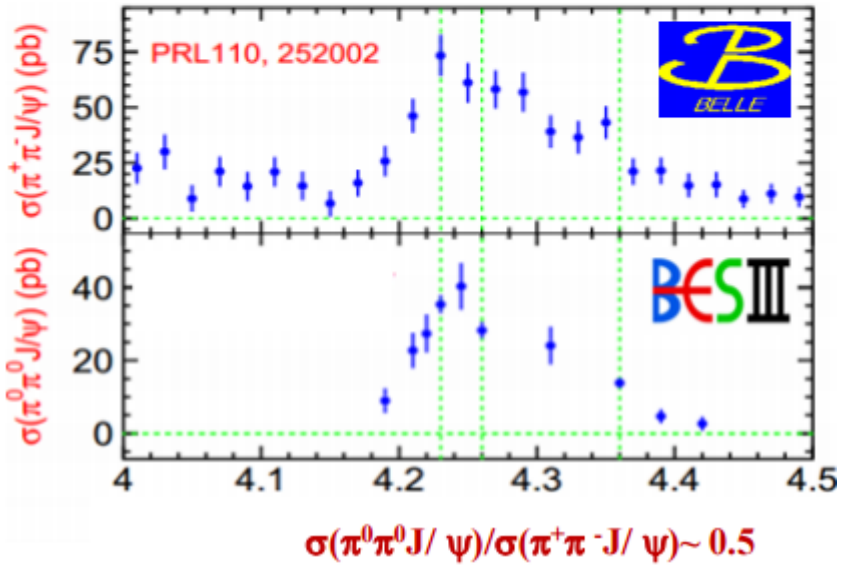
- Cross section of $e^+e^-\to\pi^+\pi^- J/\Psi(h_c)$ PRL 110, 252001(2013)
- Cross section of $e^+e^-\to\omega\chi_{c0}$ PRL 114, 092003(2015)
- Cross section of $e^+e^-\to\eta J/\Psi$ PRD 91,112005(2015)
- Cross section of $e^+e^-\to\eta' J/\Psi$ Preliminary

$e^+e^-\to\pi\pi J/\Psi$ and $e^+e^-\to\pi\pi h_c$





$\sigma(\pi^0\pi^0 h_c)/\sigma(\pi^+\pi^- h_c)=0.63\pm0.09$

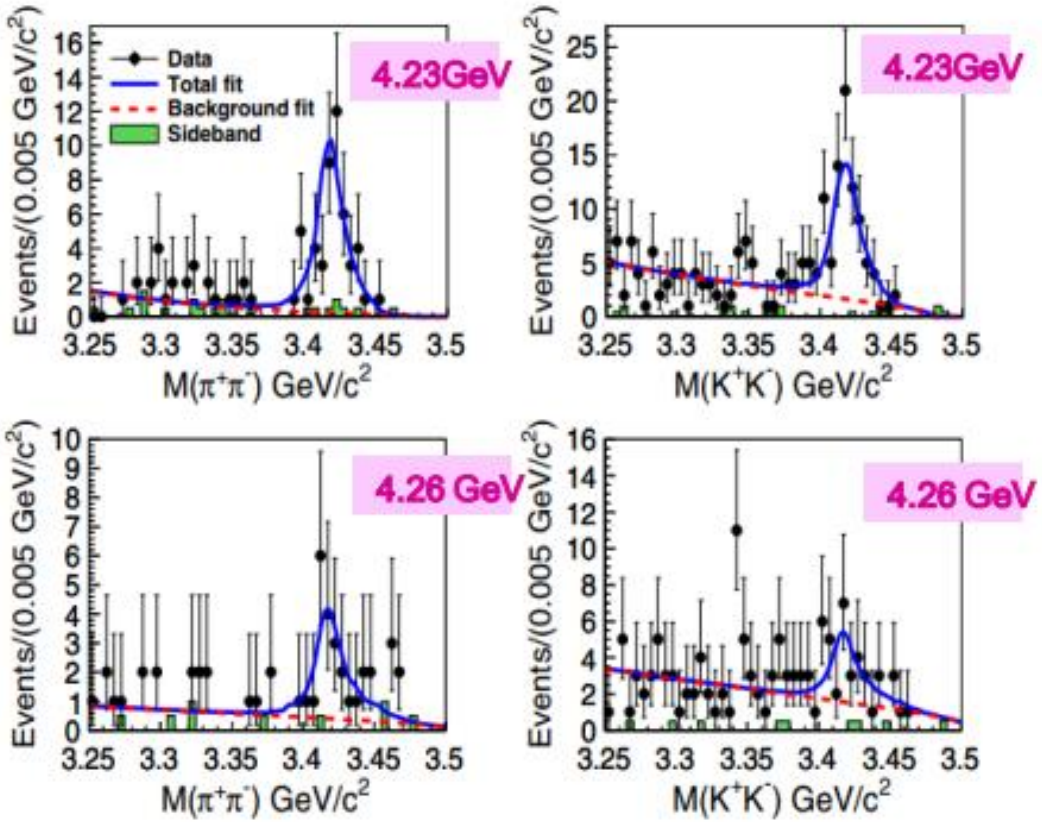


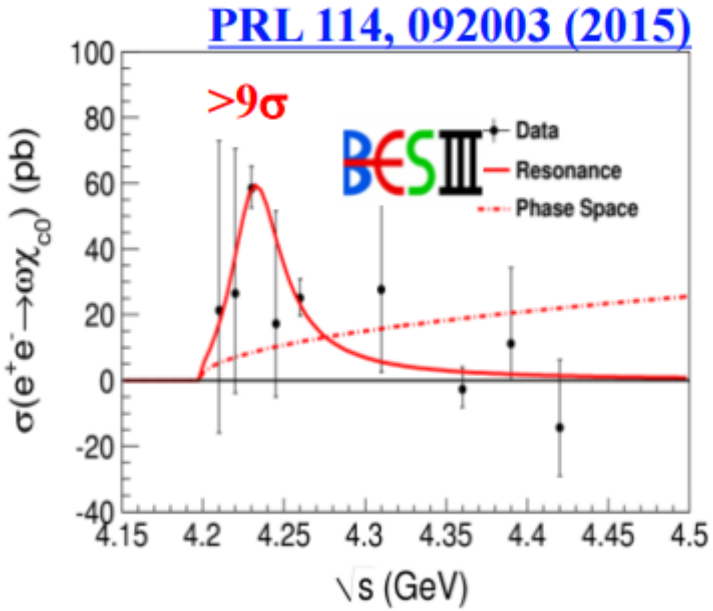
$\sigma(\pi^0\pi^0 J/\psi)/\sigma(\pi^+\pi^- J/\psi)\sim 0.5$

$\sigma(\pi^0\pi^0 J/\Psi)$ arXiv:1506.06018
$\sigma(\pi^+\pi^- h_c)$ PRL 111,242001 (2013)
$\sigma(\pi^0\pi^0 h_c)$ PRL 113,212002 (2014)

- $\sigma(\pi^+\pi^- h_c)\sim \sigma(\pi^+\pi^- J/\Psi)$ different line shape
- A possible structure near 4.23GeV for $\sigma(\pi^+\pi^- h_c)$
- No large iso-spin violation in $\sigma(\pi\pi h_c)$ and $\sigma(\pi\pi J/\Psi)$

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



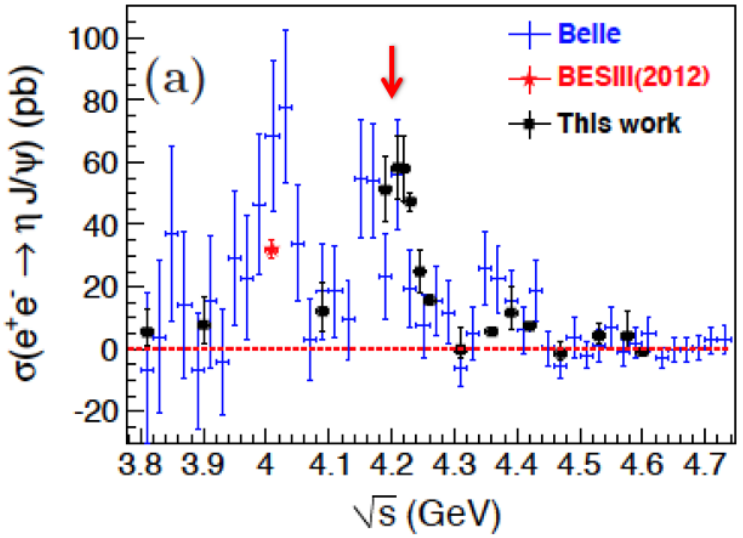


- A tetraquark? PRD 91,117501 (2015)
- Ψ(4S)? EPJC 74:3208 (2014)
- Threshold effect?
- .....

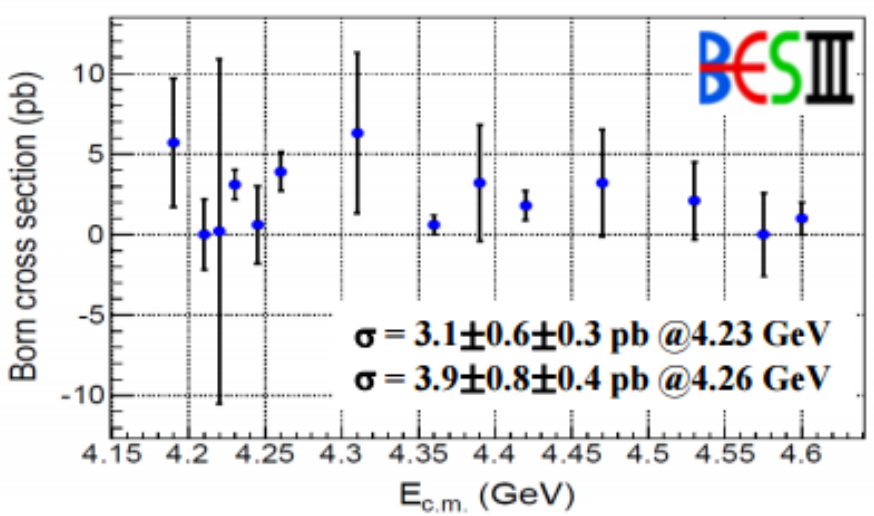
- Cross section peak near 4.23GeV
- Fit with BW
  Mass=4230±8±6MeV
  Width=39±12±2MeV

Observation of $e^+e^-\to\eta J/\Psi$ and $e^+e^-\to\eta' J/\Psi$

PRD 91,112005 (2015)



BESIII Preliminary



- Agree with previous results with improved precision
- Structure near 4.2GeV: Ψ (4160)->ηJ/Ψ

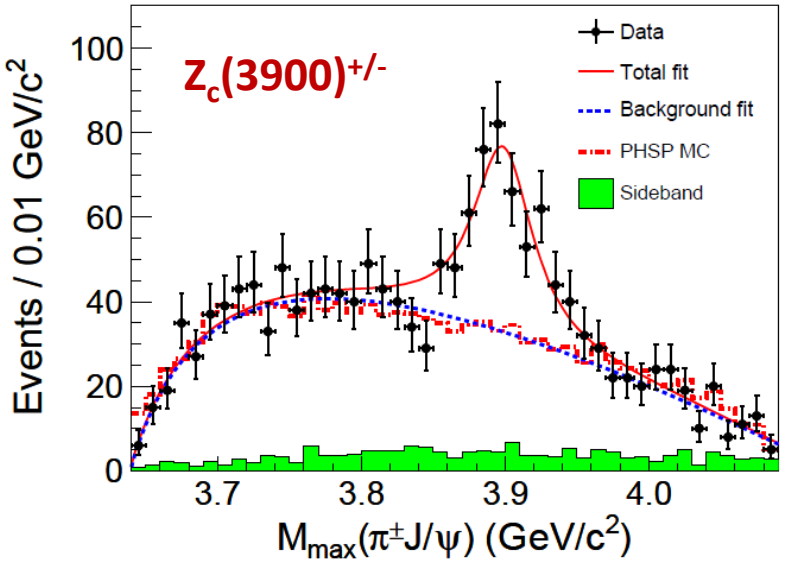
- First observation at 4.23GeV and 4.26GeV, couldn't tell the line-shape due to the statistics.
- $\sigma(\eta' J/\Psi)$ is much lower than $\sigma(\eta J/\Psi)$ which is in contradiction to the NRQCD calculation. PRD 89, 074006 (2014)

Z_c states at BESIII

- $Z_c(3900)^{\pm}$ in $e^+e^- \to \pi^+ \pi^- J/\Psi$ PRL 110,252001 (2013)
- $Z_c(3900)^0$ in $e^+e^- \to \pi^0 \pi^0 J/\Psi$ arXiv:1506.06018
- $Z_c(3885)^{\pm}$ in $e^+e^- \to \pi^+ (D\bar{D}^*)^-$ PRL 112, 022001 (2014)
- $Z_c(3885)^0$ in $e^+e^- \to \pi^0 (D\bar{D}^*)^0$ Preliminary
- $Z_c(4020)^{\pm}$ in $e^+e^- \to \pi^+ \pi^- h_c$ PRL 111.242001 (2013)
- $Z_c(4020)^0$ in $e^+e^- \to \pi^0 \pi^0 h_c$ PRL 113,212002 (2014)
- $Z_c(4025)^{\pm}$ in $e^+e^- \to \pi^+ (D^*\bar{D}^*)^-$ PRL 112,132001 (2013)
- $Z_c(4025)^0$ in $e^+e^- \to \pi^0 (D^*\bar{D}^*)^0$ arXiv:1507.02404

$e^+e^- \to \pi Z_c(3900) \to \pi\pi J/\Psi$

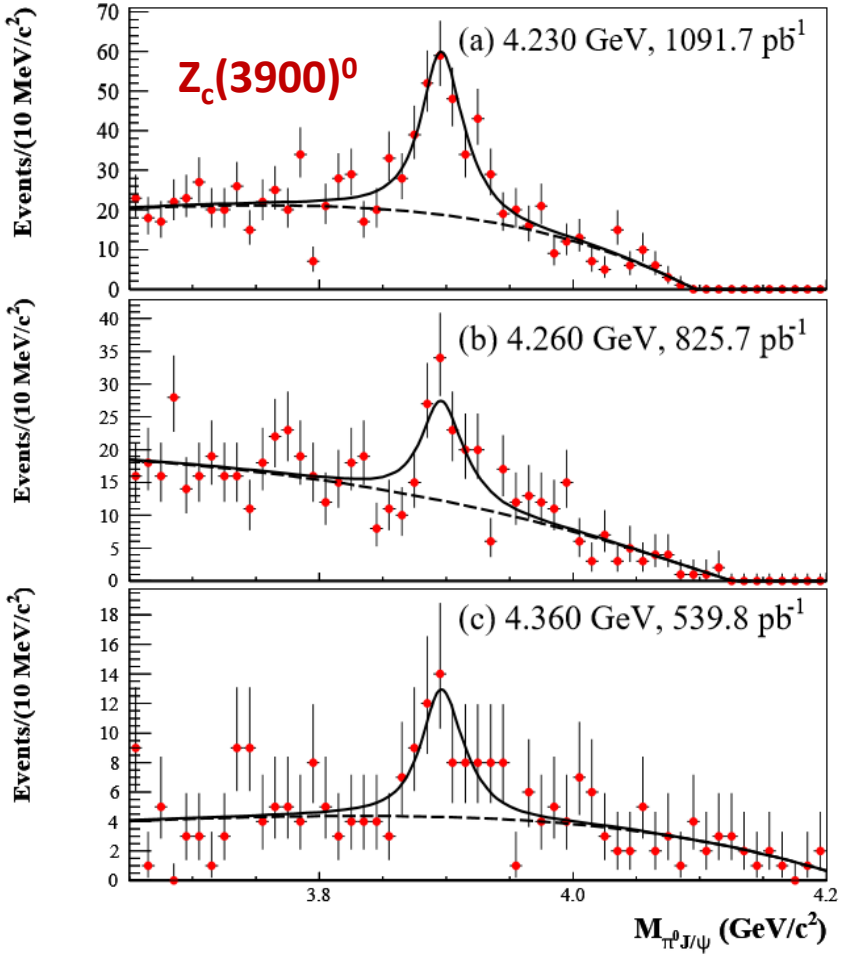
PRL 110,252001 (2013)



- $Z_c(3900)^{\pm}$, observed by BESIII, confirmed by Bell and CLEO-c data.
- $Z_c(3900)^0$, evidence with 3.7σ at CLEO-c, observed by BESIII.

$Z_c(3900)$	Mass(MeV)	Width(MeV)
$Z_c(3900)^{\pm}$	3899.0±3.6±4.9	46 ±10±20
$Z_c(3900)^0$	3894.8±2.3±2.7	29.6±8.2±8.2

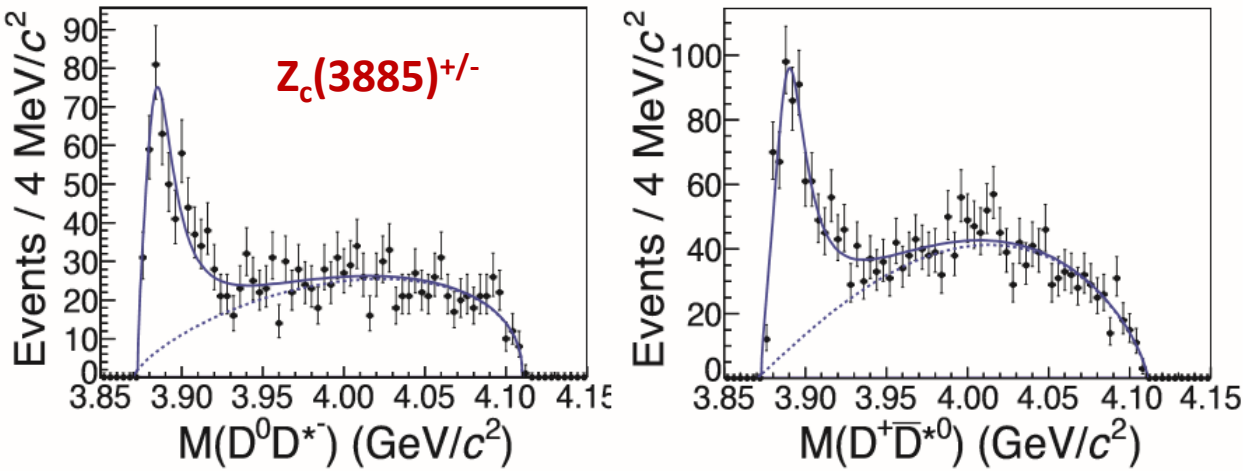
arXiv:1506.06018



Iso-spin triplet is established!

$e^+e^- \to \pi Z_c(3885) \to \pi (D\bar{D}^*)$

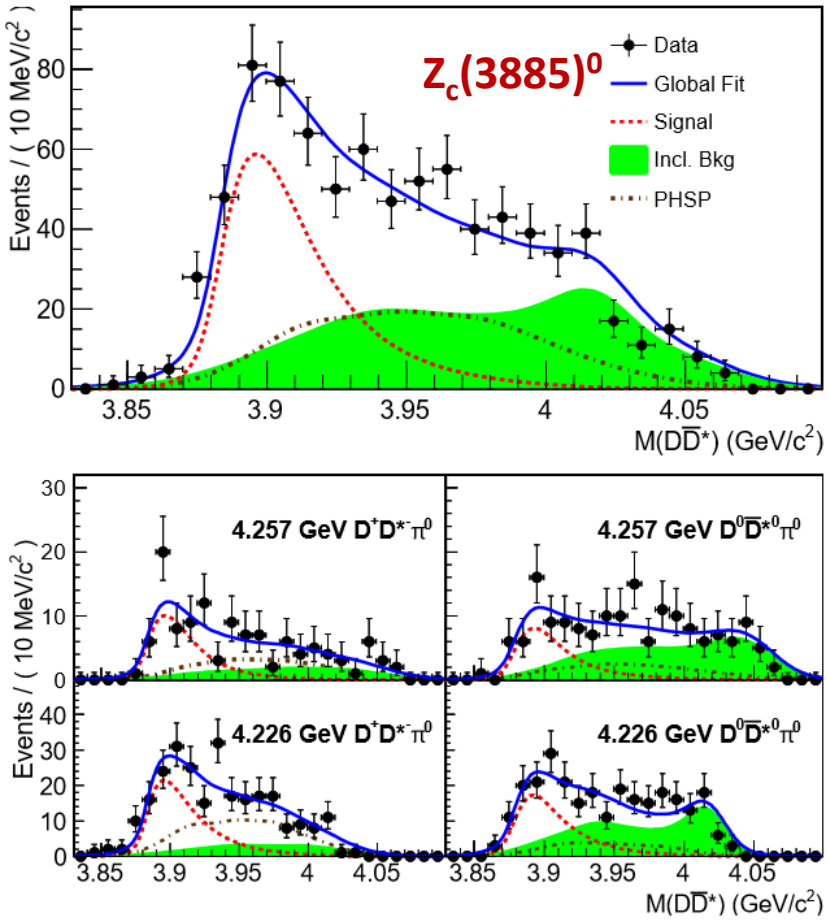
PRL 112.022001 (2014)



- $Z_c(3885)^{\pm}$, observed by BESIII.
- Have a mass and width close to $Z_c(3900)$.

$Z_c(3885)$	Mass(MeV)	Width(MeV)
$Z_c(3885)^{\pm}$	$3883.9 \pm 1.5 \pm 4.2$	$24.8 \pm 3.3 \pm 1.0$
$Z_c(3885)^0$	$3885.7\ ^{+4.3}_{-5.7} \pm 8.4$	$35\ ^{+11}_{-12} \pm 15$

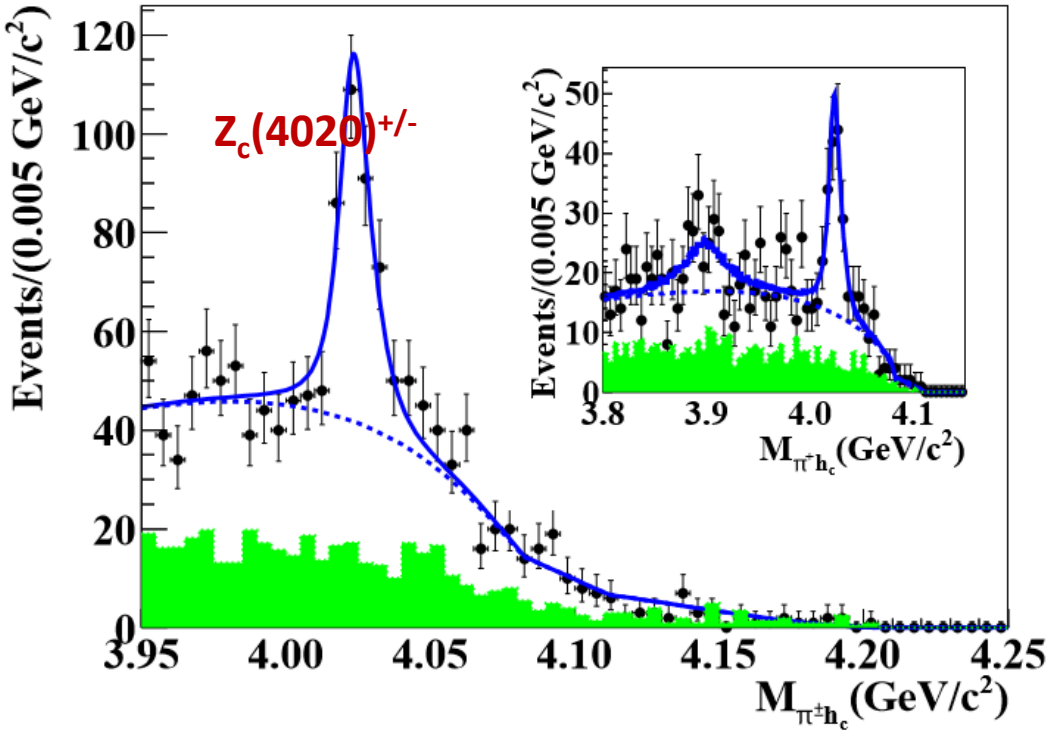
preliminary



Iso-spin triplet is established!

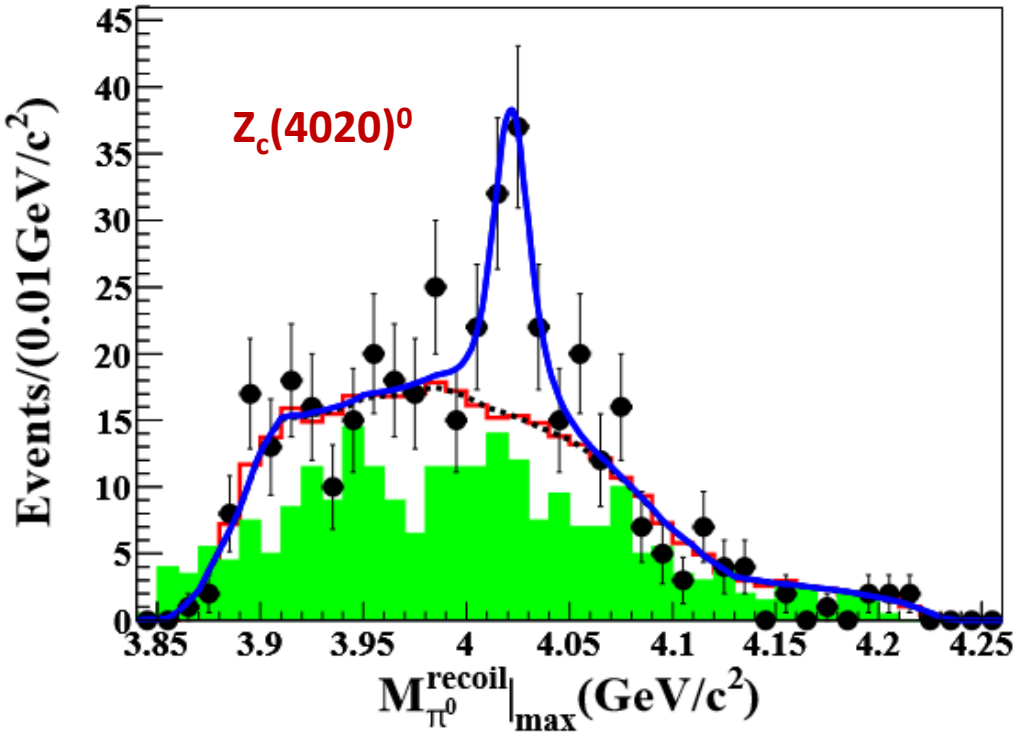
$e^+e^- \to \pi Z_c(4020) \to \pi\pi h_c$

PRL 111,242001 (2013)



$Z_c(4020)$	Mass(MeV)	Width(MeV)
$Z_c(4020)^{+/-}$	4022.9±0.8±2.7	7.9±2.7±2.6
$Z_c(4020)^0$	4023.8±2.2±3.8	Fixed(=7.9)

PRL 113,212002 (2014)

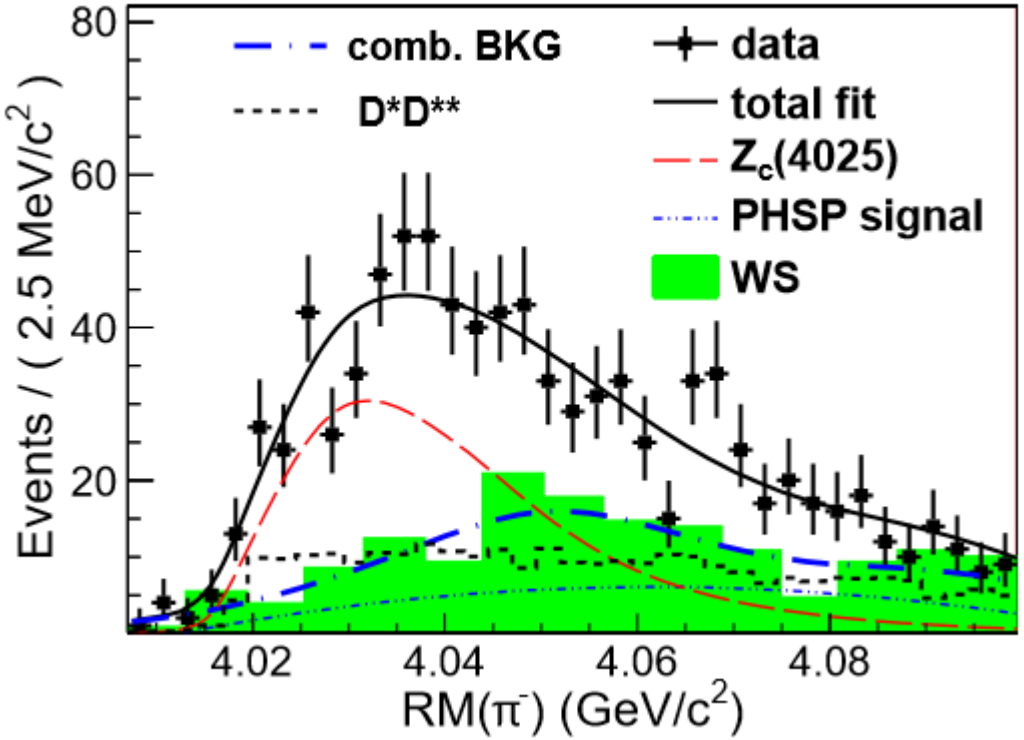


- $Z_c(4020)$, observed by BESIII.
- A hint for $Z_c(3900)^{\pm} \to \pi^{\pm} h_c$.
- $Z_c(4020)$, near the $D^*\bar{D}^*$ threshold.

Iso-spin triplet is established!

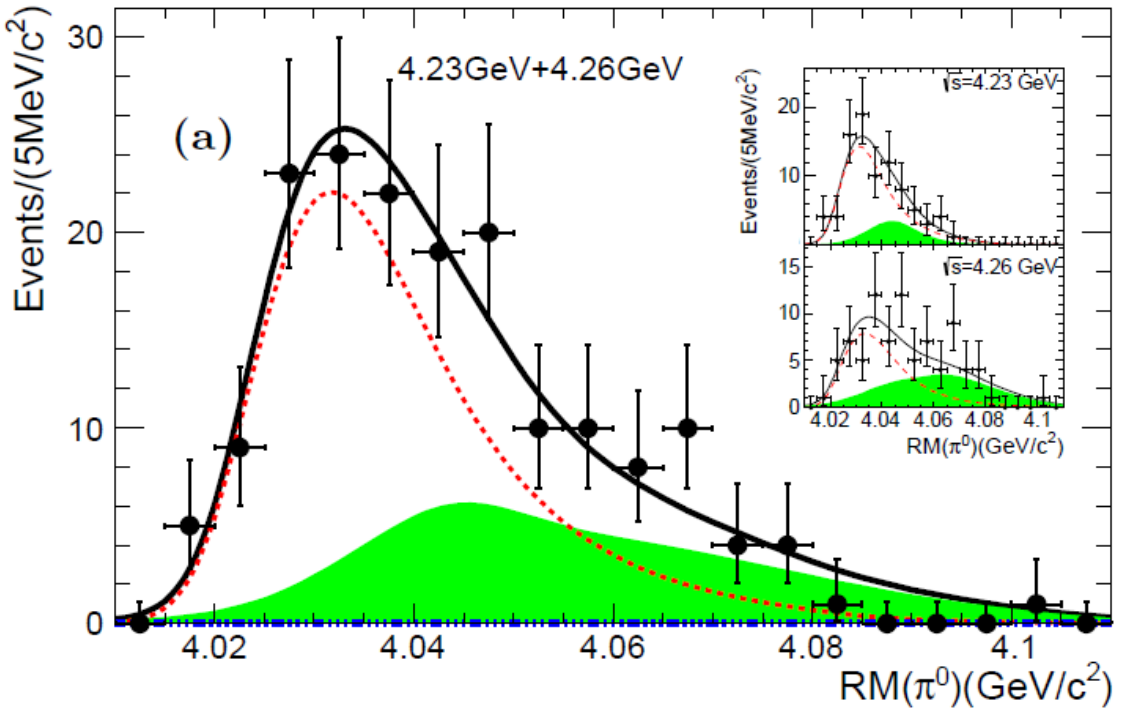
$e^+e^- \to \pi Z_c(4025) \to \pi (D^*\bar{D}^*)$

PRL 112,132001 (2013)



$Z_c(4025)$	Mass(MeV)	Width(MeV)
$Z_c(4025)^{\pm}$	$4026.3 \pm 2.6 \pm 3.7$	$24.8 \pm 5.6 \pm 7.7$
$Z_c(4025)^0$	$4025.5\ ^{+2.0}_{-4.7} \pm 3.1$	$23.0 \pm 6.0 \pm 1.0$

arXiv:1507.02404

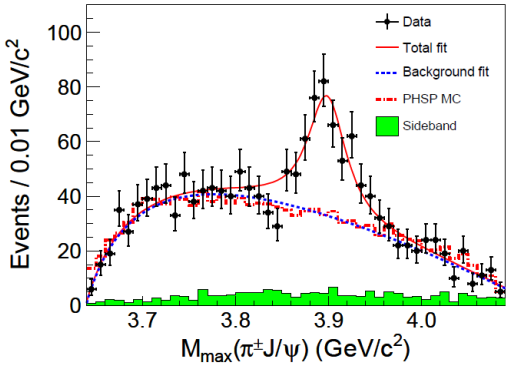


- $Z_c(4020)$, observed by BESIII.
- The $Z_c(4020)$ and $Z_c(4025)$ are consistent within 1.5σ.
- If they are the same state:

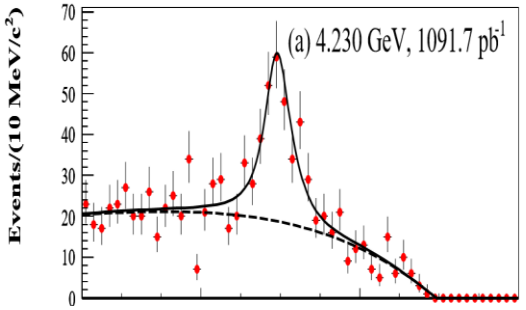
$$\frac{\Gamma(Z_c(4025) \to D^*\bar{D}^*)}{\Gamma(Z_c(4020) \to \pi h_c)} = 12 \pm 5$$

Iso-spin triplet is established!

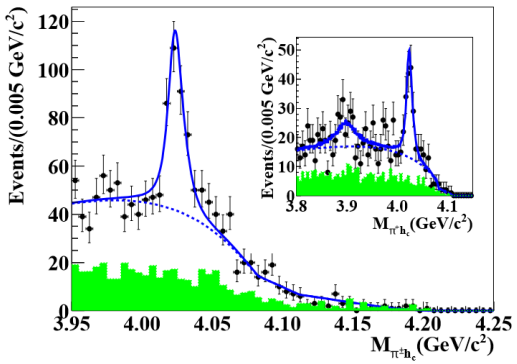
Summary of Z_c states at BESIII



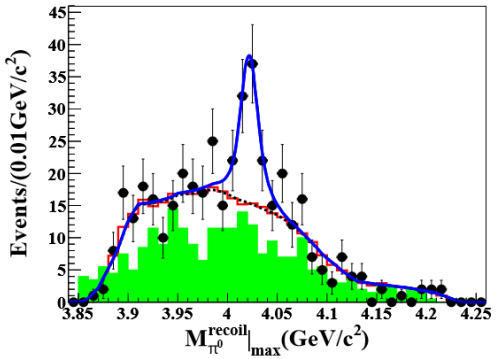
$e^+e^- \to \pi^+ \pi^- J/\psi$



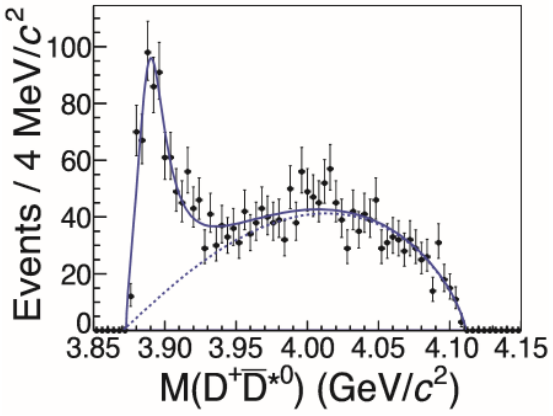
$e^+e^- \to \pi^0 \pi^0 J/\psi$



$e^+e^- \to \pi^+ \pi^- h_c$

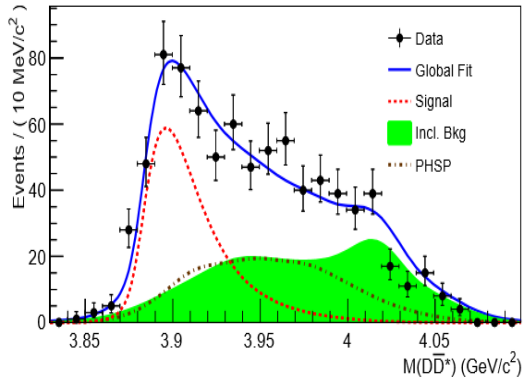


$e^+e^- \to \pi^0 \pi^0 h_c$



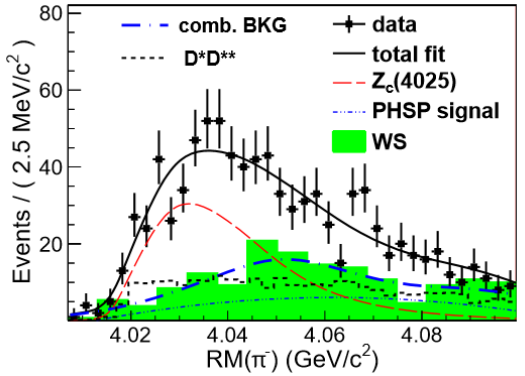
$e^+e^- \to \pi^+ (D\bar{D}^*)^-$

$Z_c(3900)^{\pm}$?



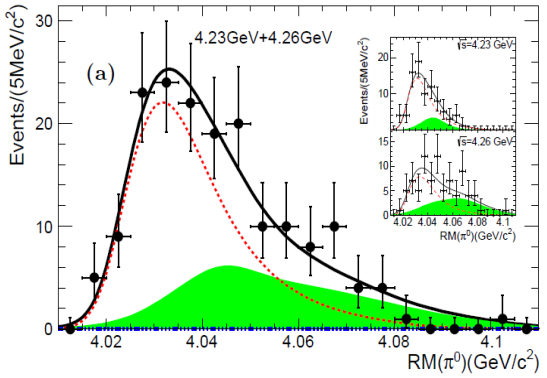
$e^+e^- \to \pi^0 (D\bar{D}^*)^0$

$Z_c(3900)^0$?



$e^+e^- \to \pi^+ (D\bar{D}^*)^-$

$Z_c(4020)^{\pm}$?

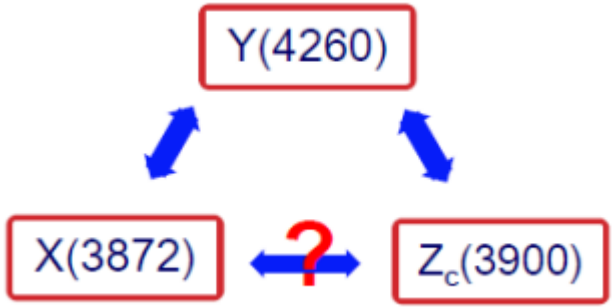


$e^+e^- \to \pi^0 (D\bar{D}^*)^0$

$Z_c(4020)^0$?

Summary

- Lots of progress in charmonium-like studies at BESIII recently.
- Observation of $e^+e^- \to \gamma X(3872)$ & $\pi^+\pi^- X(3823)$.
- Observation of Z_c states.
- Measurements of many hidden charm final states.
- X, Y, Z particles are correlated.
- BESIII will continue to study the XYZ states.



Thank you!