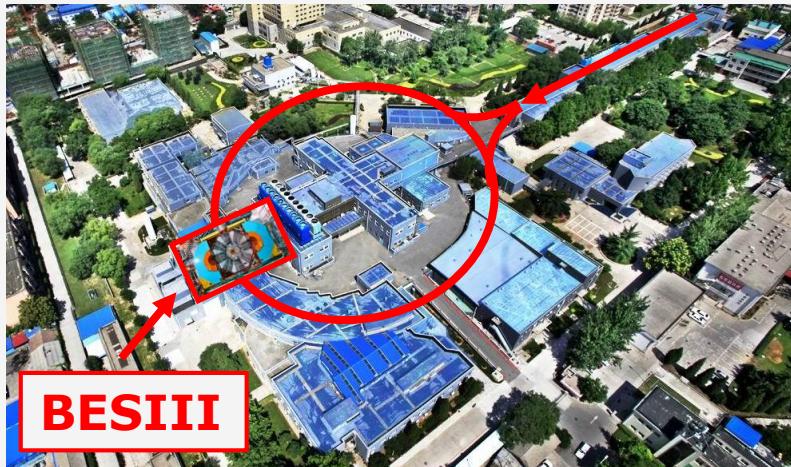


Recent results on XYZ states from the BESIII experiment

Nils Hüsken
Westfälische Wilhelms-Universität Münster, Germany
on behalf of the BESIII Collaboration

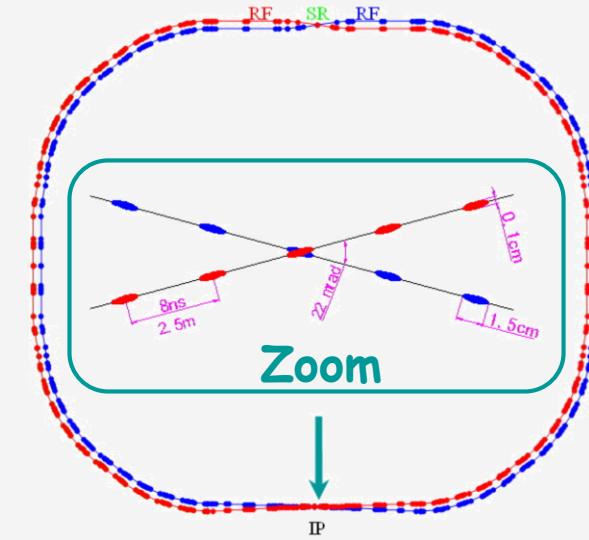


The BESIII Experiment

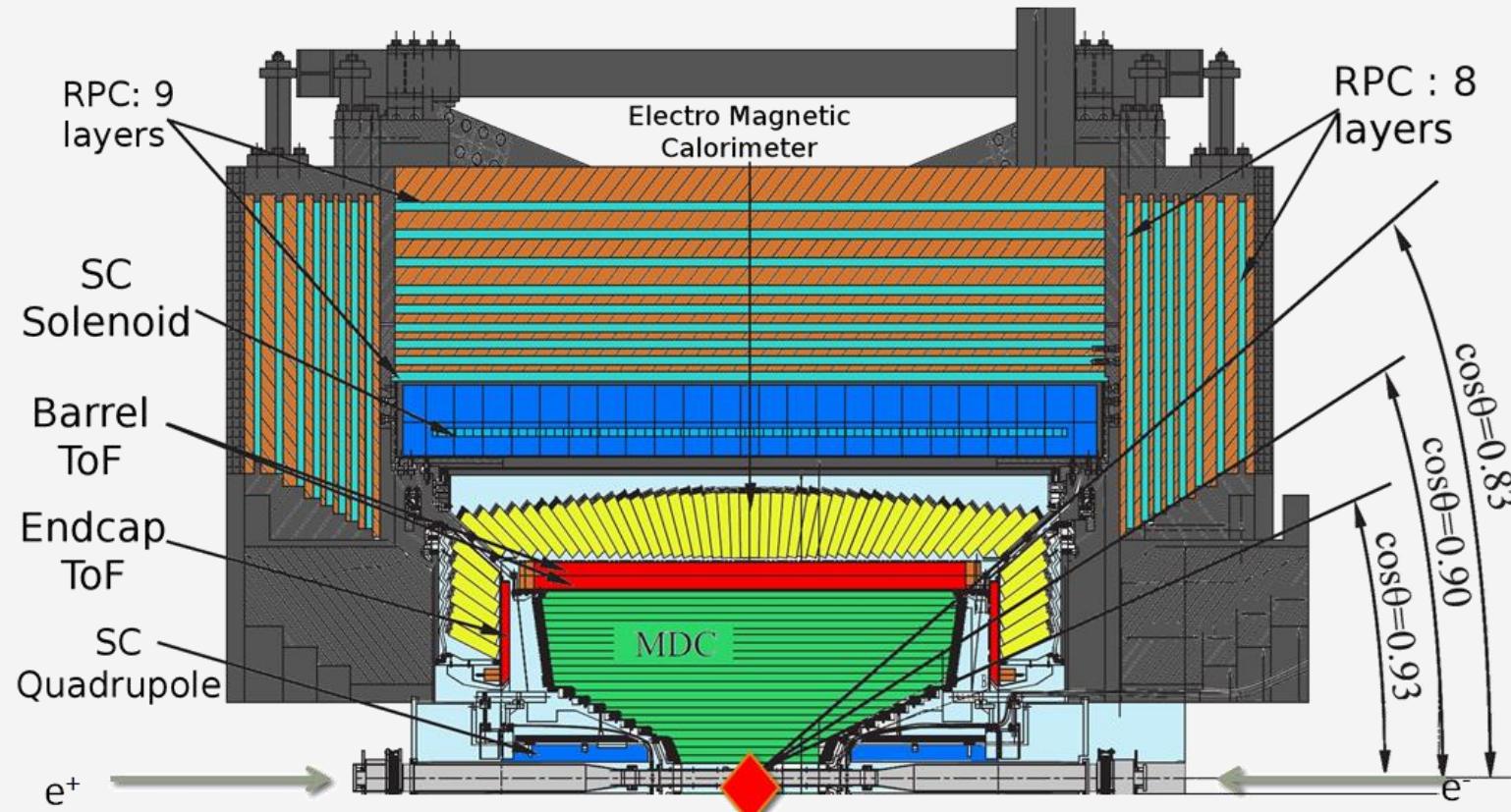


- BEijing Spectrometer (BESIII) at the Beijing Electron Positron Collider (BEPCII)
- located at the Institute for High Energy Physics (IHEP), Beijing, China
- symmetric, double-ring e^+e^- collider in the τ – charm region

- peak luminosity: $\approx 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ at $\sqrt{s} = 3.770 \text{ GeV}$
- energy range: $2 \text{ GeV} \leq \sqrt{s} \leq 4.6 \text{ GeV}$
- crossing angle of 11 mrad

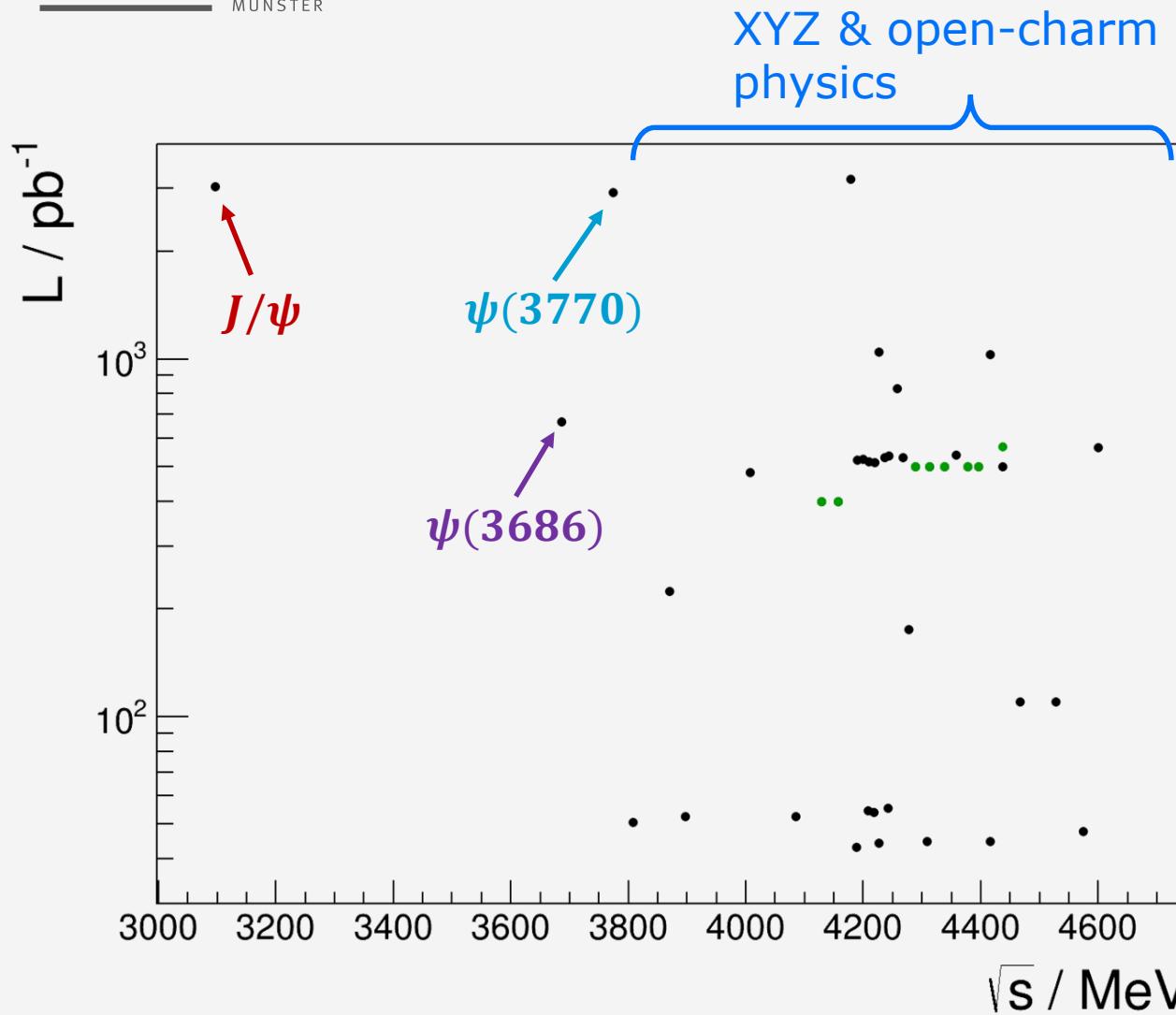


The BESIII Experiment



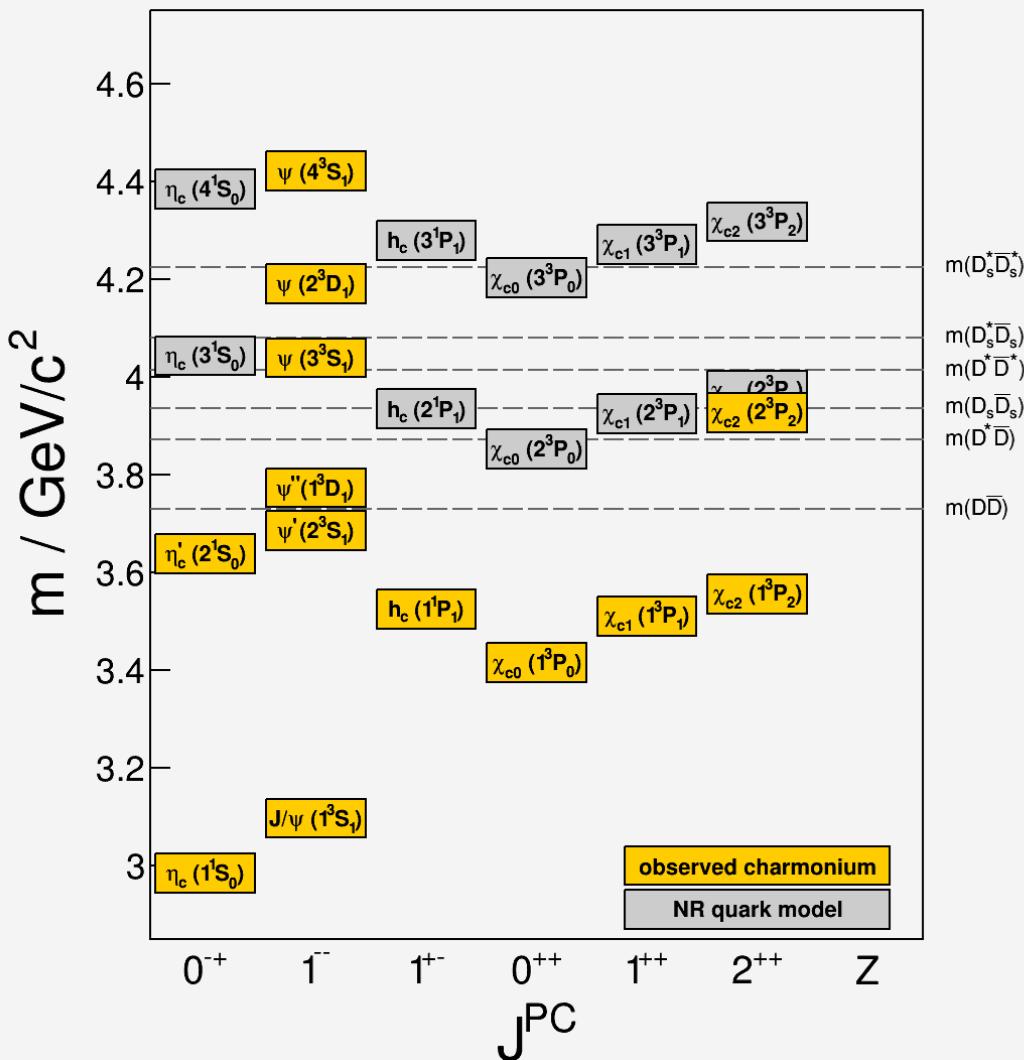
- **MDC:** Drift chamber in 1.0 T magnetic field
- **TOF:** Plastic scintillator based time-of-flight system
- **EMC:** Electromagnetic calorimeter
- **RPC:** resistive plate chambers for muon identification

The BESIII Experiment



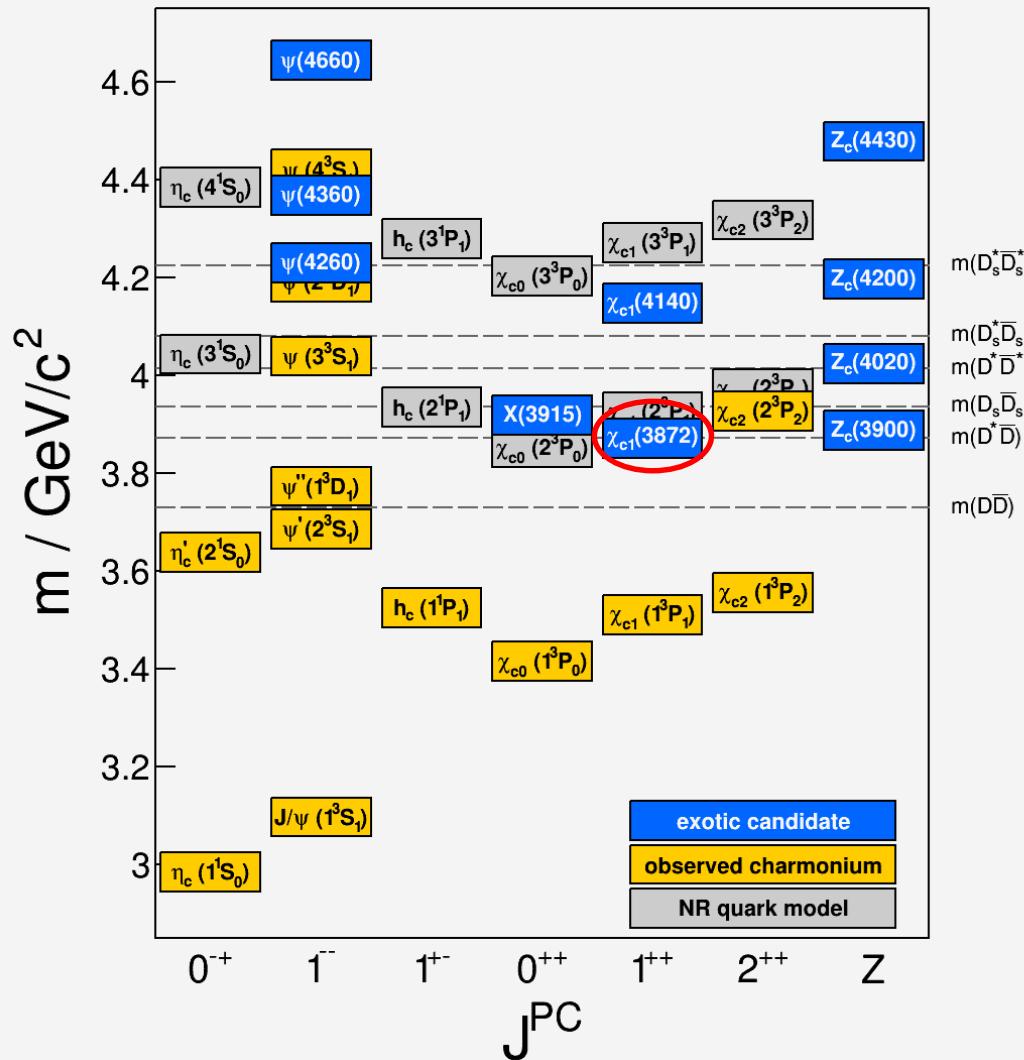
- in recent years, BESIII accumulated roughly 16 fb^{-1} of e^+e^- collision data above $\sqrt{s} = 3.8 \text{ GeV}$
- these can be used to study open-charm & XYZ meson production & decays
- new data at 8 additional energies taken throughout 2019 will allow to improve lineshape analysis of vector-exotics

Beyond conventional charmonium

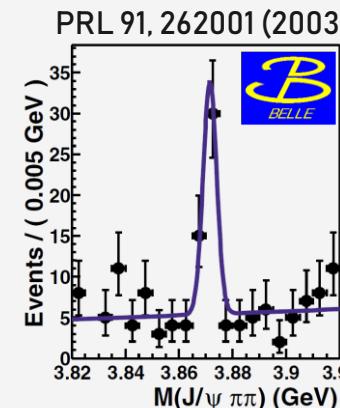


- Until 2003, charmonium was thought to be well understood...

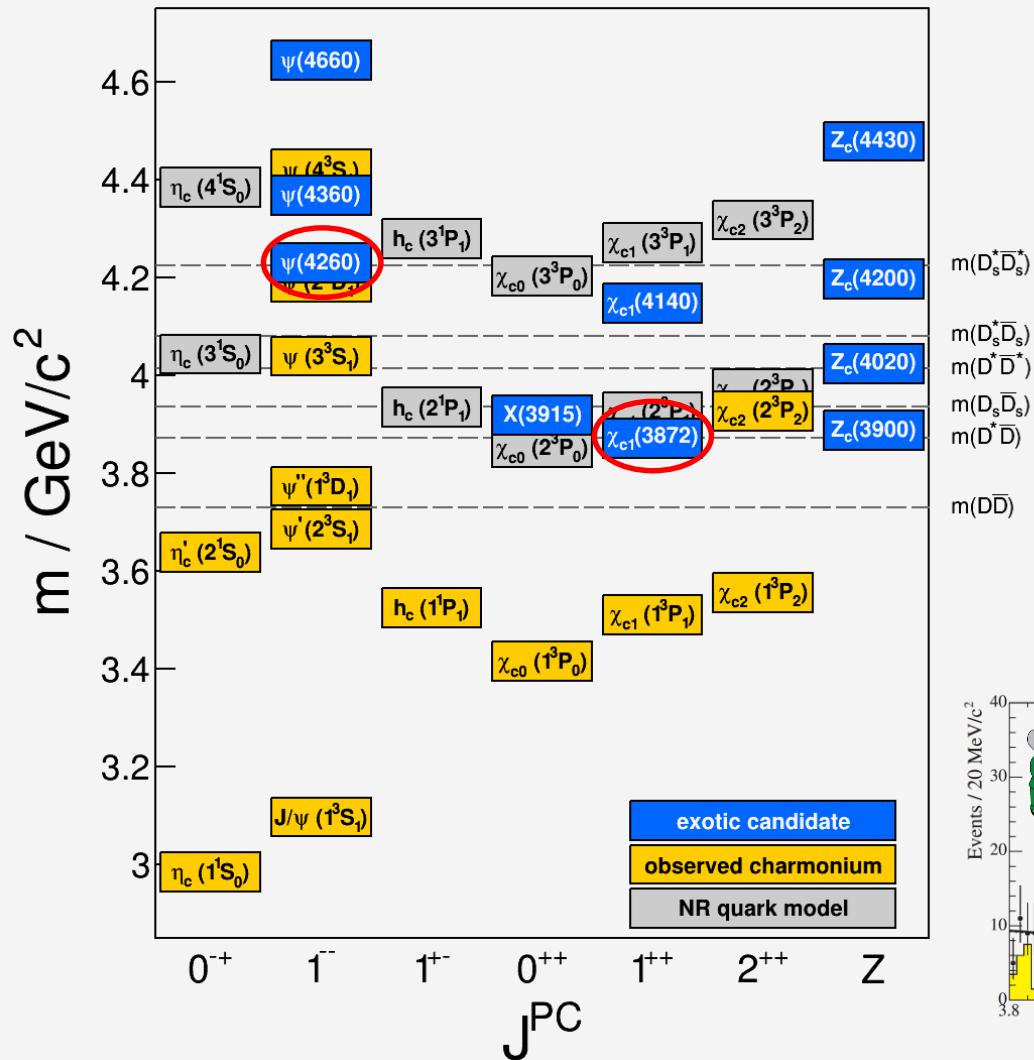
Beyond conventional charmonium



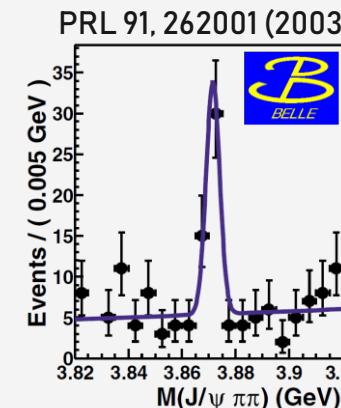
- Until 2003, charmonium was thought to be well understood...
- 2003: discovery of the $X(3872)$ by Belle
- recent years: multiple new states discovered in various experiments



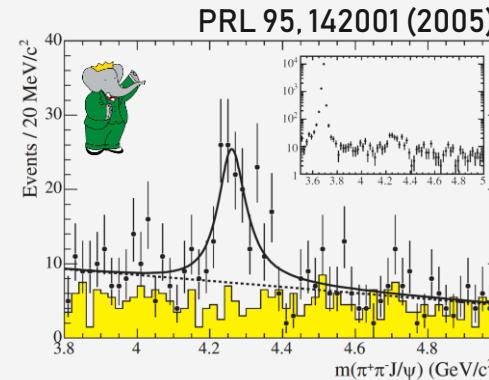
Beyond conventional charmonium



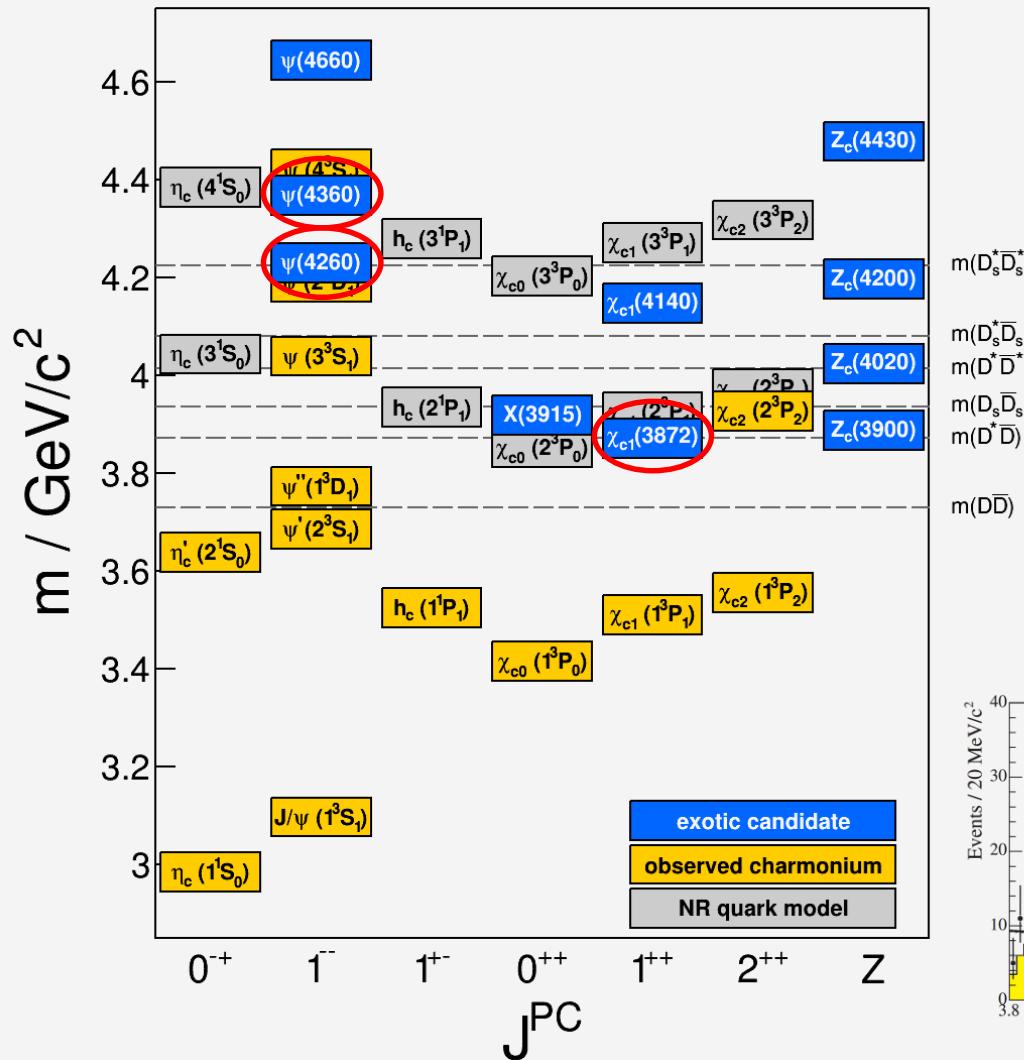
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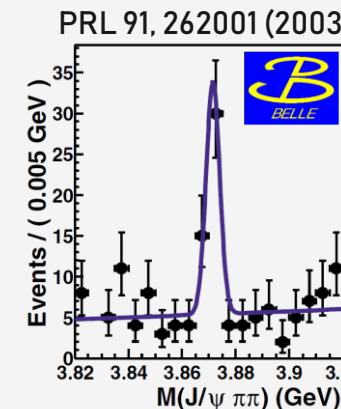
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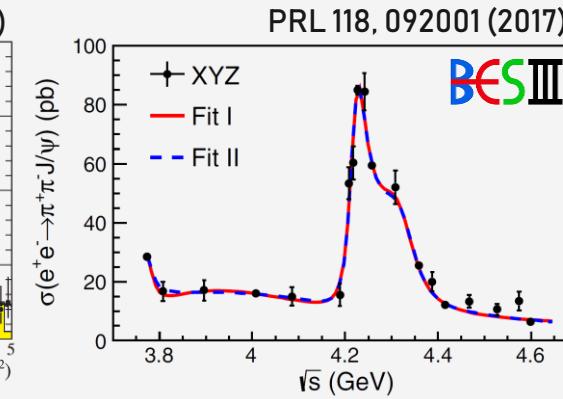
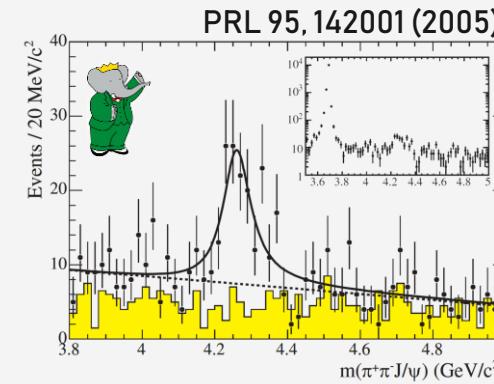
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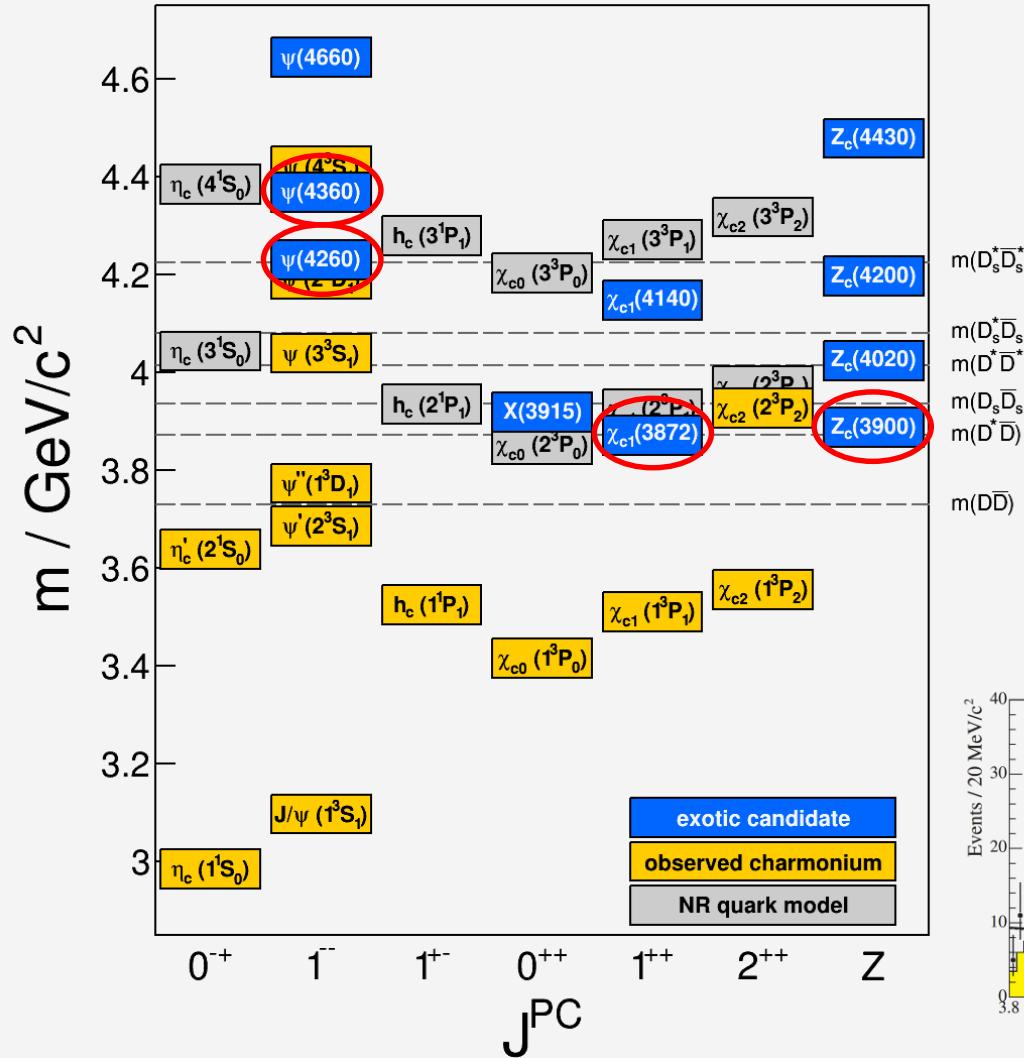
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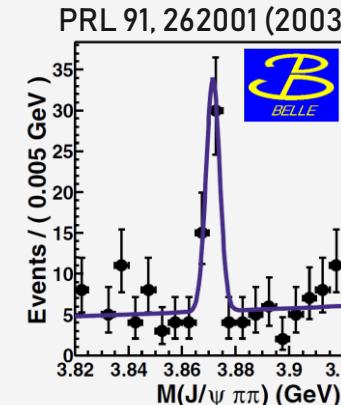
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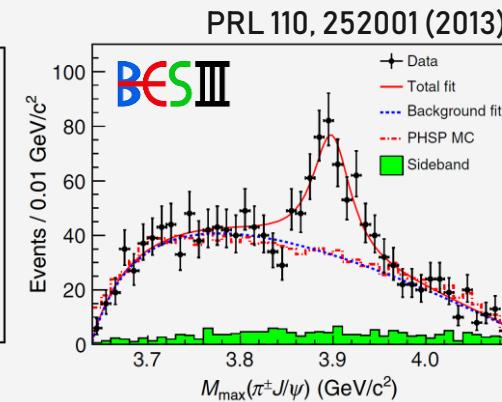
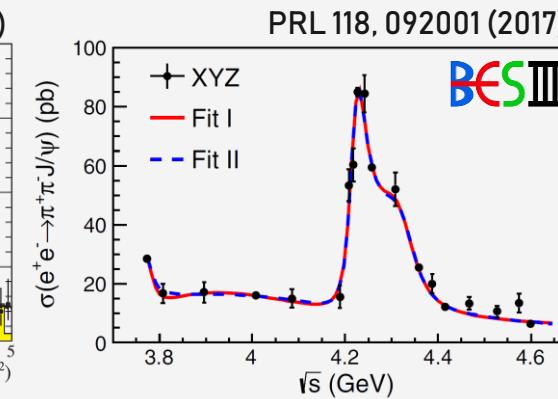
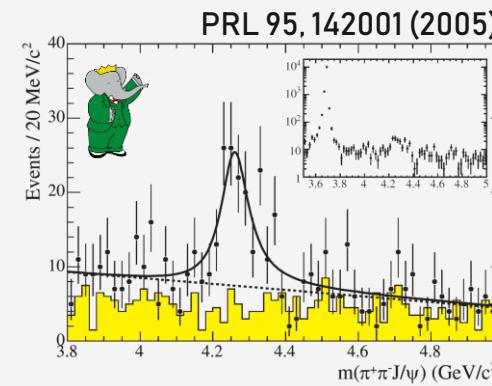
Beyond conventional charmonium



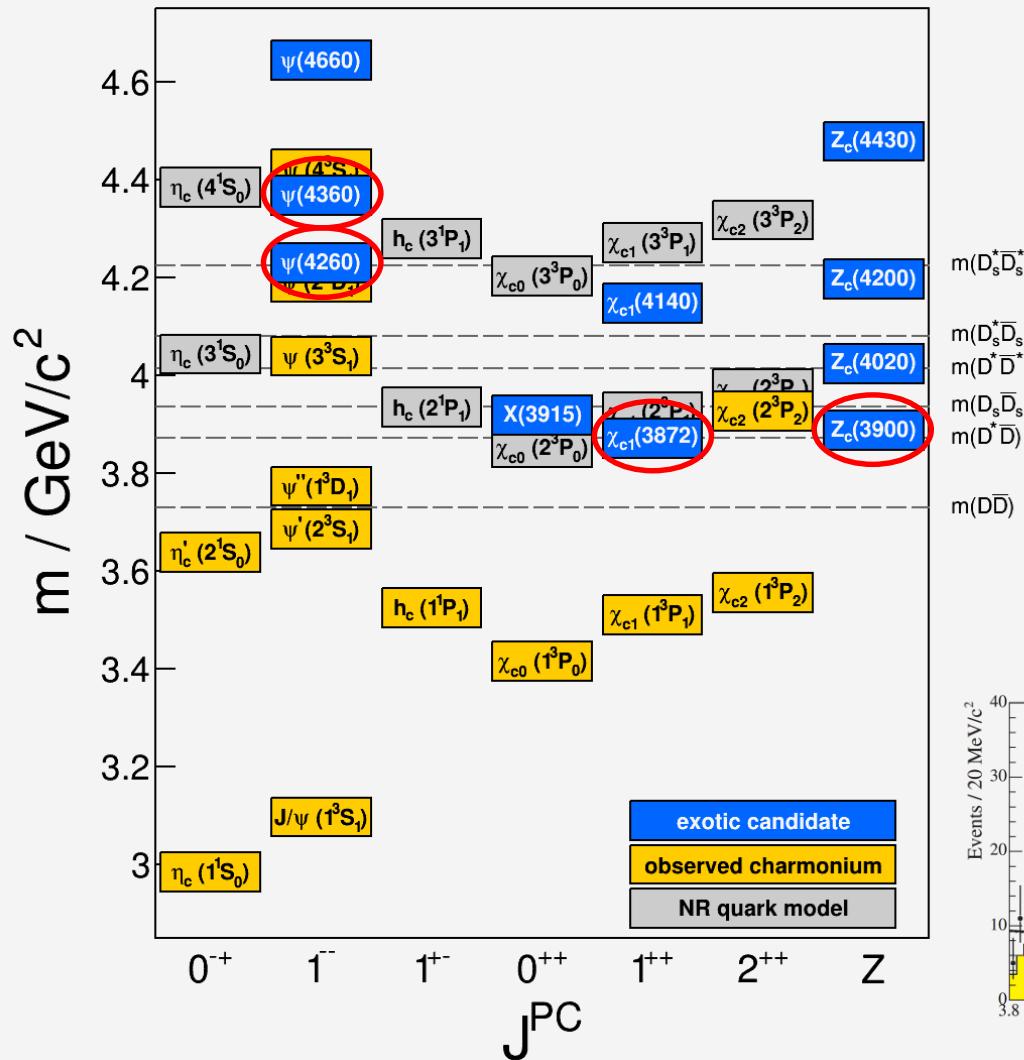
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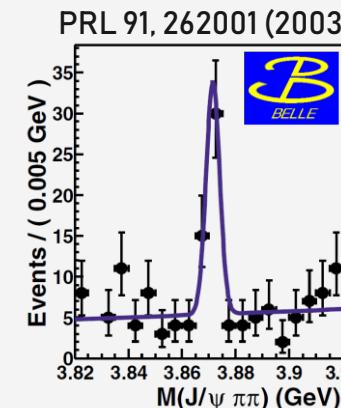
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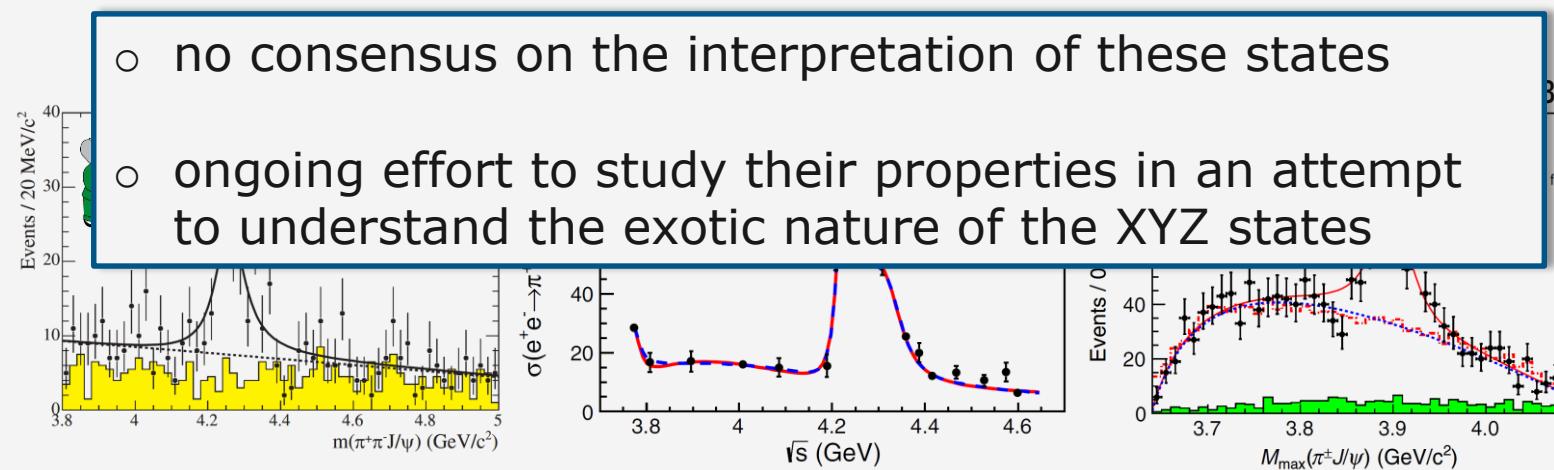
Beyond conventional charmonium



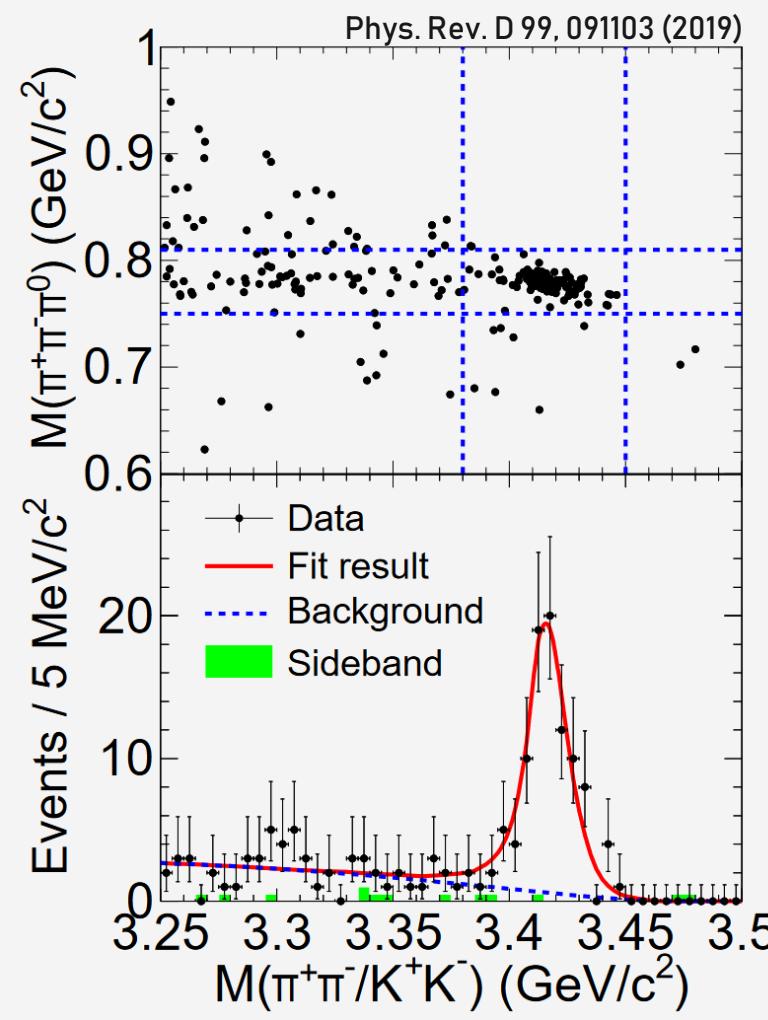
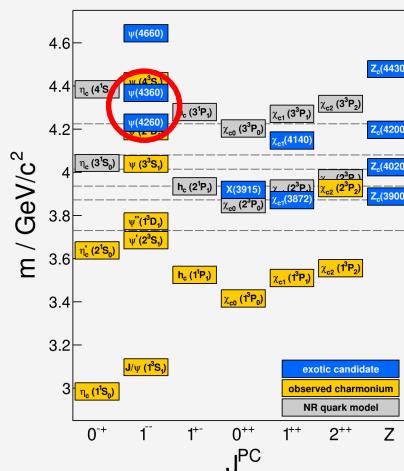
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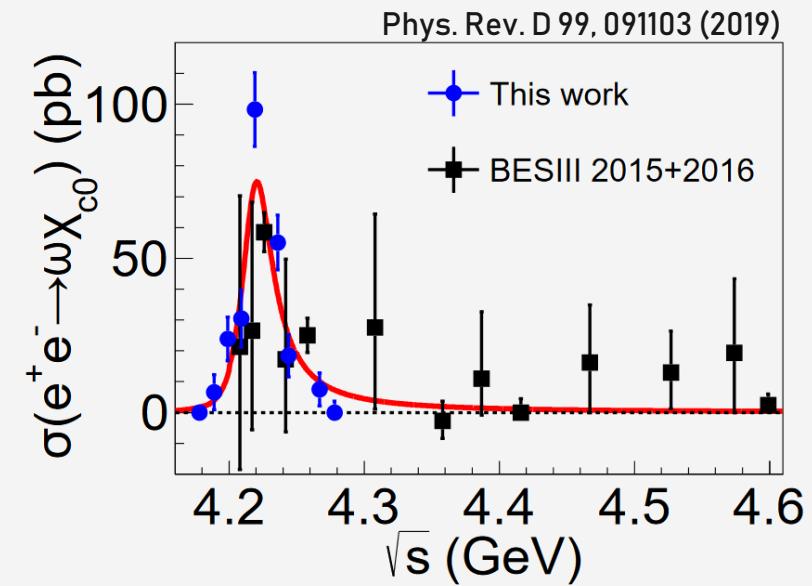
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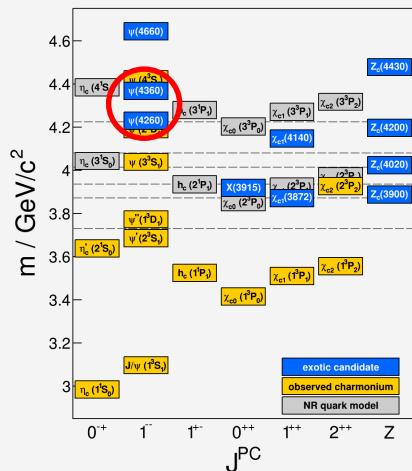
Recent results: $Y(4260)$



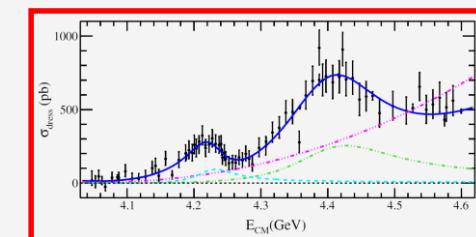
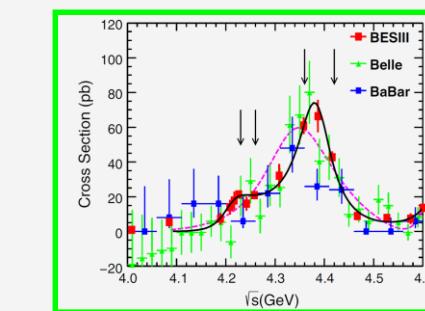
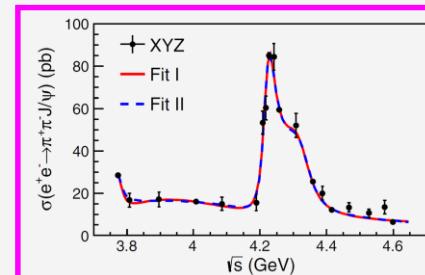
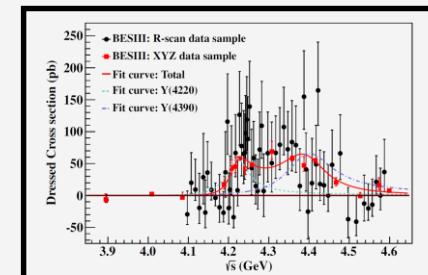
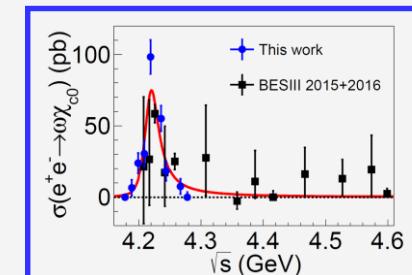
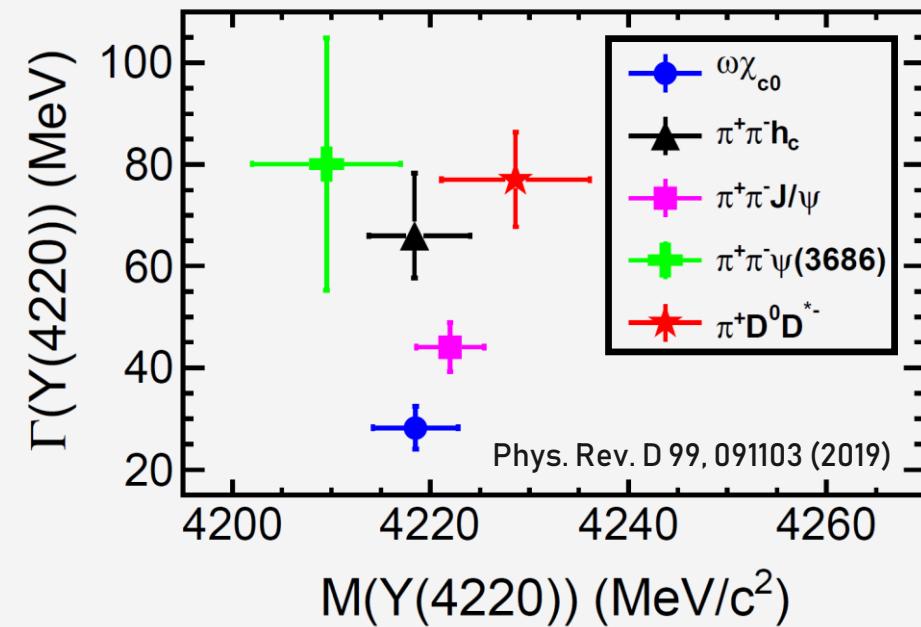
- new study of $e^+e^- \rightarrow \omega\chi_{c0}$ at $4.18 \text{ GeV} \leq \sqrt{s} \leq 4.28 \text{ GeV}$
- reconstructing $\omega \rightarrow \pi^+\pi^-\pi^0$ and $\chi_{c0} \rightarrow \pi^+\pi^-/\text{K}^+\text{K}^-$
- observation of a resonance with $m = 4218.5 \pm 1.6 \pm 4.0 \text{ MeV}/c^2$, $\Gamma = 28.2 \pm 3.9 \pm 1.6 \text{ MeV}$
- confirmation of an earlier measurement



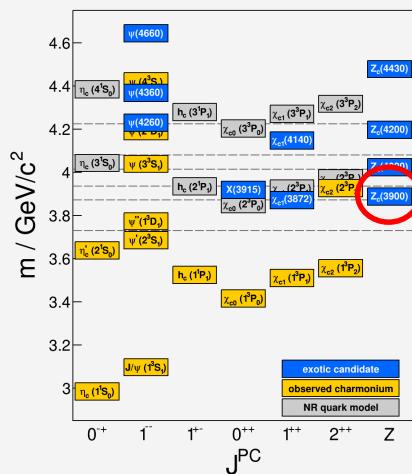
Recent results: $Y(4260)$



- similar resonances seen in $\omega\chi_{c0}$, $\pi^+\pi^-h_c$, $\pi^+\pi^-J/\psi$, $\pi^+\pi^-\psi(2S)$ and $\pi^+D^0D^{*-}$
- all agree on a lower mass value
 $Y(4260) \rightarrow Y(4220)$
- inconsistencies regarding the width,
 might be caused by Breit-Wigner parameterization

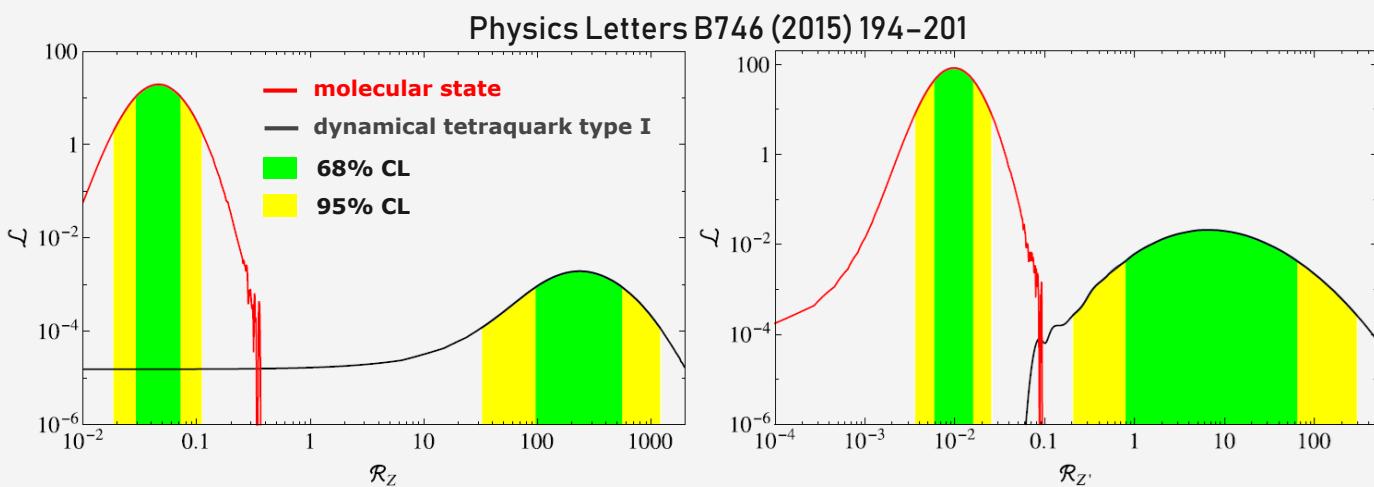


Recent results: $Z_c(3900)$

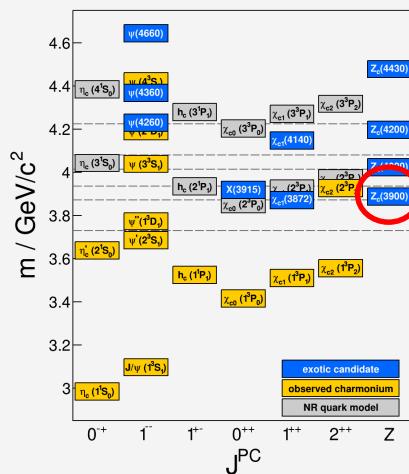


$$R_{Z^{(\prime)}} = \frac{Br(Z_c^{(\prime)} \rightarrow \rho \eta_c)}{Br(Z_c^{(\prime)} \rightarrow \pi J/\psi (h_c))}$$

to discriminate between
molecular & tetraquark
assignments



Recent results: $Z_c(3900)$

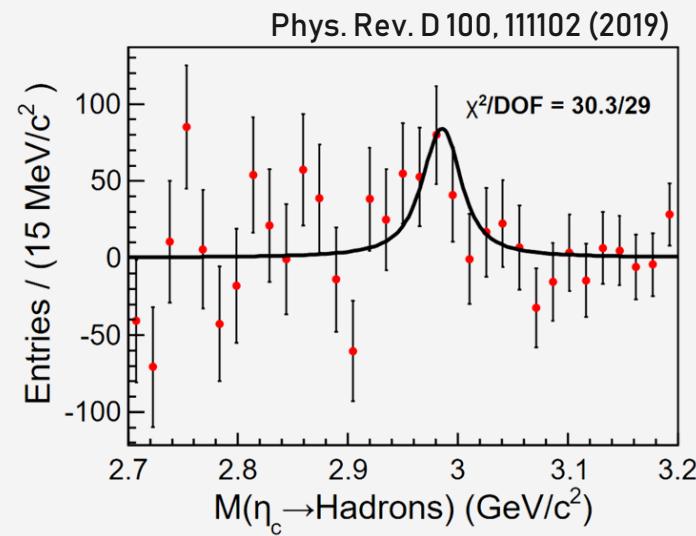
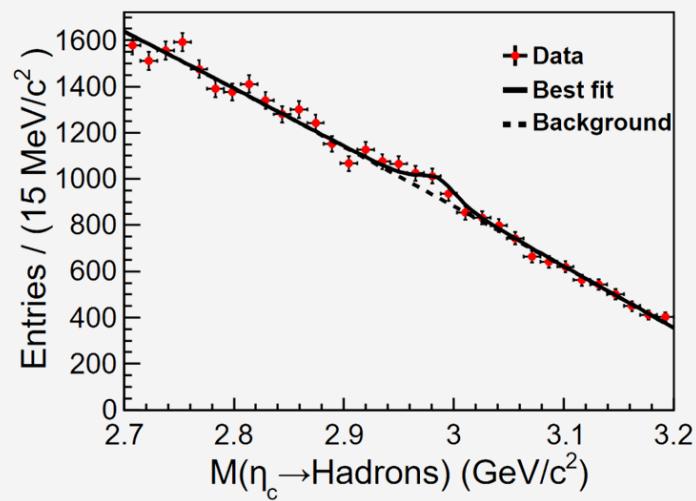
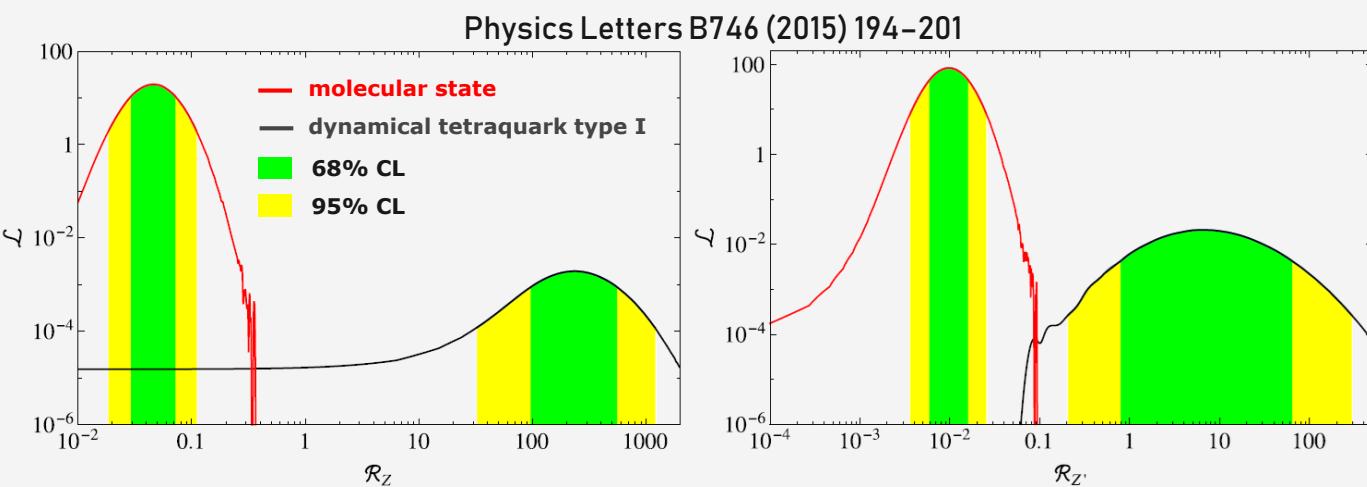


prediction:

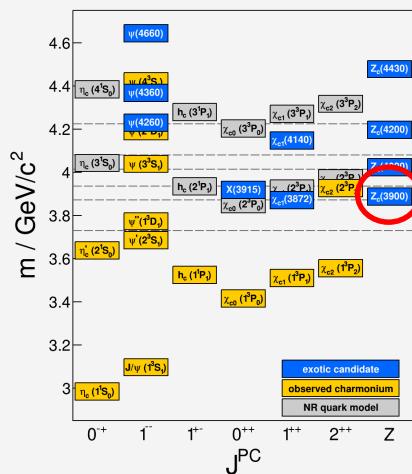
$$R_{Z^{(\prime)}} = \frac{\text{Br}(Z_c^{(\prime)} \rightarrow \rho \eta_c)}{\text{Br}(Z_c^{(\prime)} \rightarrow \pi J/\psi (h_c))}$$

to discriminate between
molecular & tetraquark
assignments

- process $e^+e^- \rightarrow \eta_c \rho^\pm \pi^\mp$ studied at five energies between $4.23 \text{ GeV} \leq \sqrt{s} \leq 4.60 \text{ GeV}$
- η_c reconstructed in 9 decay modes
- signal of $e^+e^- \rightarrow \eta_c \pi^+\pi^-\pi^0$ observed with a significance of 4.2σ



Recent results: $Z_c(3900)$

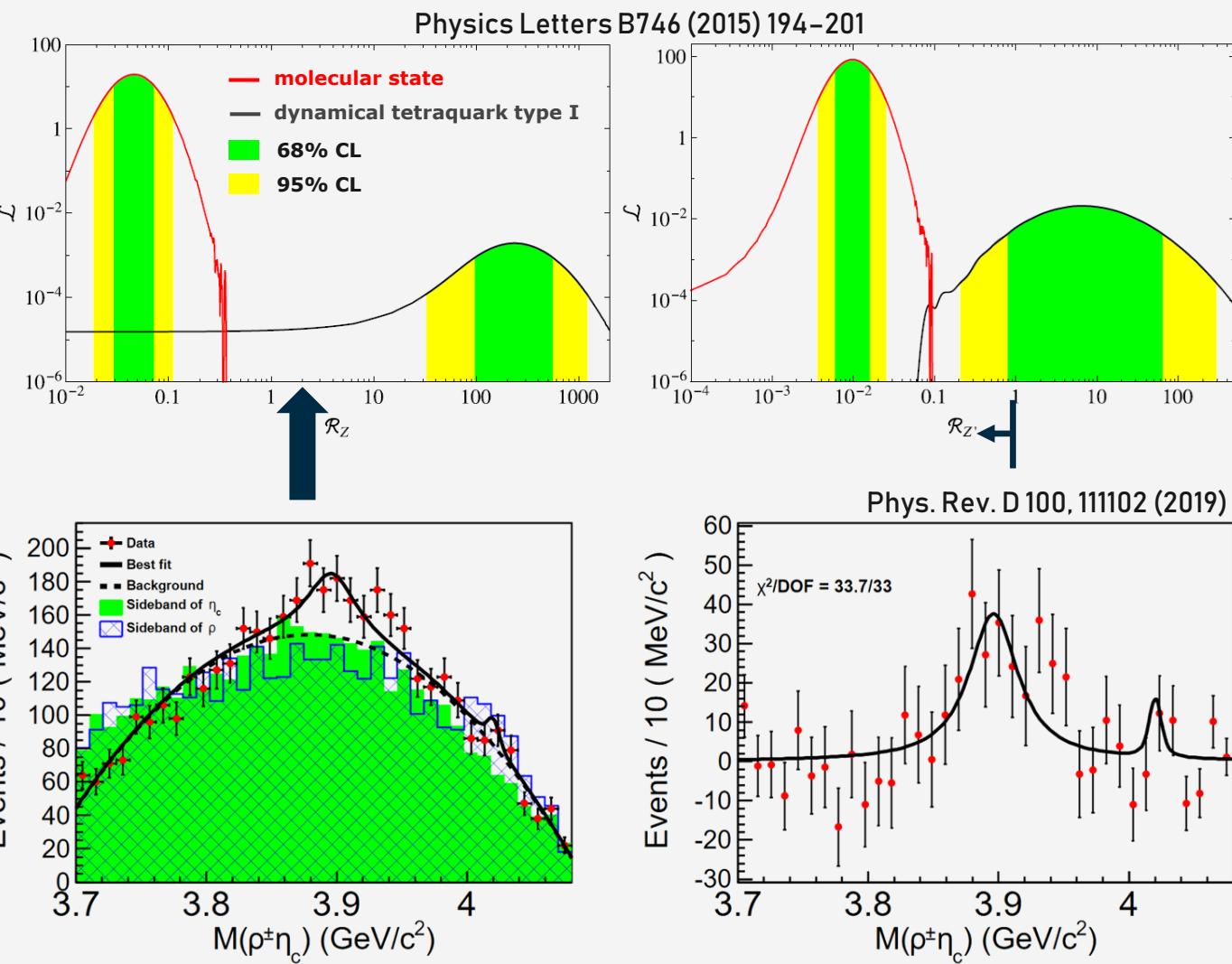


prediction:

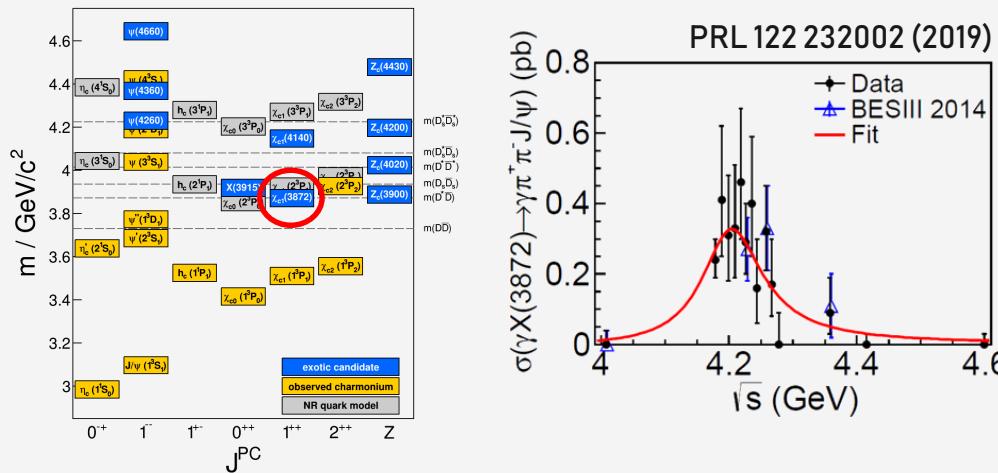
$$R_{Z^{(\prime)}} = \frac{Br(Z_c^{(\prime)} \rightarrow \rho \eta_c)}{Br(Z_c^{(\prime)} \rightarrow \pi J/\psi (h_c))}$$

to discriminate between
molecular & tetraquark
assignments

- strong evidence (4.3σ) for $Z_c(3900) \rightarrow \rho \eta_c$ at $\sqrt{s} = 4.23$ GeV
- no signal observed for $Z_c'(4020) \rightarrow \rho \eta_c$
- ratio $R_Z = 2.2 \pm 0.9$ and $R_{Z'} < 0.9$

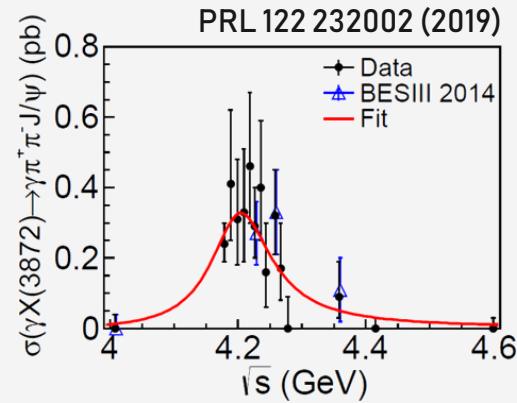
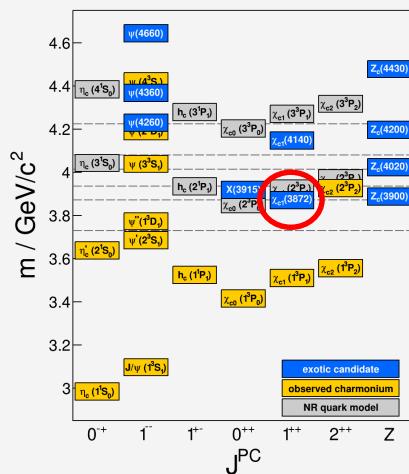


Recent results: $X(3872)$



- BESIII: $X(3872)$ production in $e^+e^- \rightarrow \gamma X(3872)$
- allows to look for decay modes other than $X(3872) \rightarrow \pi^+\pi^-J/\psi$

Recent results: $X(3872)$

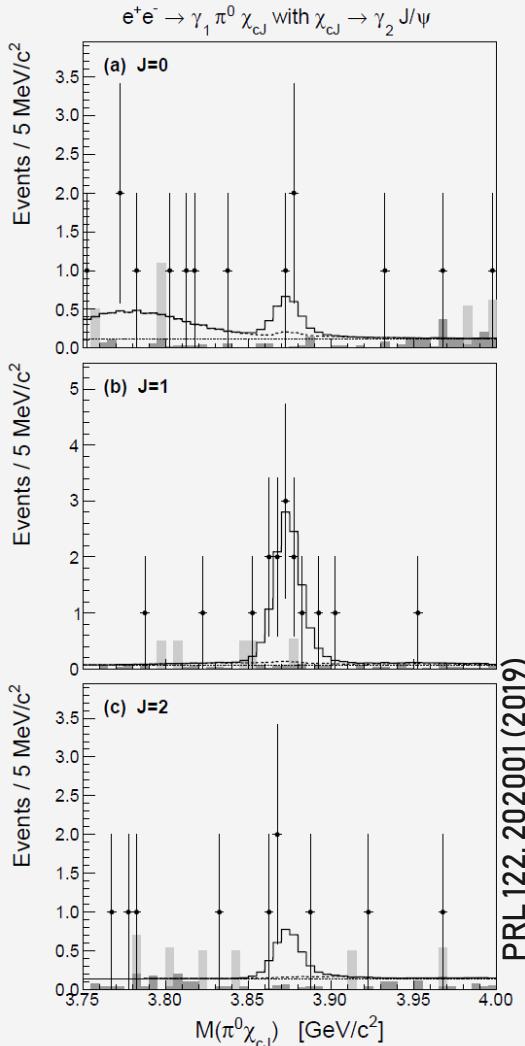


- observation of $X(3872) \rightarrow \pi^0 \chi_{c1}$ with 5.2σ , no signal for $\chi_{c0,2}$

$$R_J = \frac{Br(X(3872) \rightarrow \pi^0 \chi_{cJ})}{Br(X(3872) \rightarrow \pi^+ \pi^- J/\psi)} \quad \text{with} \quad R_0 < 19 \quad (90\% \text{ CL})$$

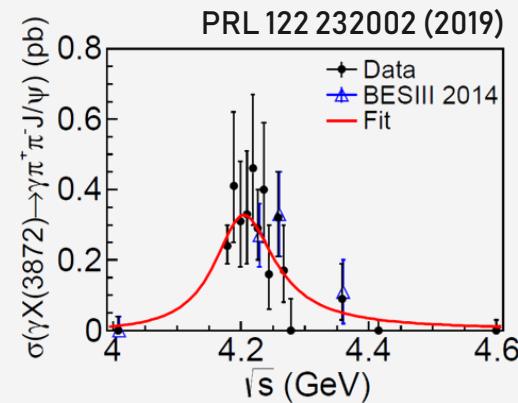
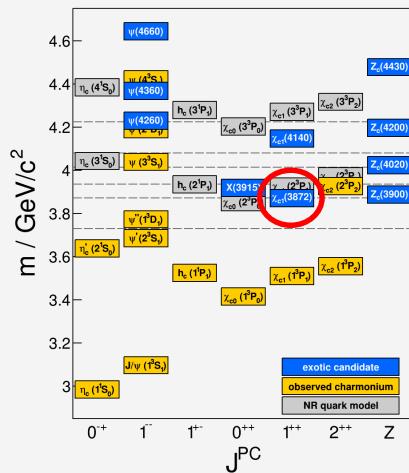
$$R_1 = 0.88^{+0.33}_{-0.27} \pm 0.10$$

$$R_2 < 1.1 \quad (90\% \text{ CL})$$

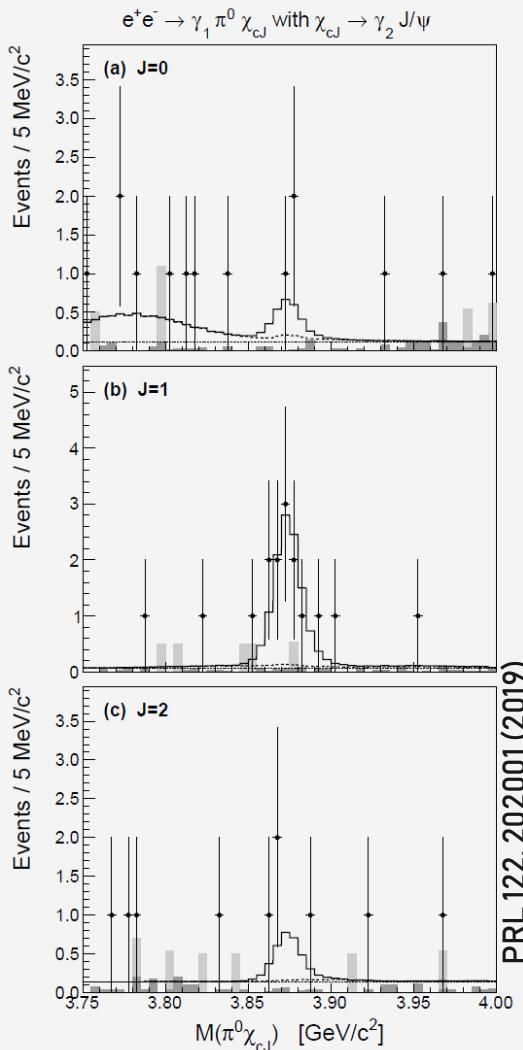


PRL 122, 202001 (2019)

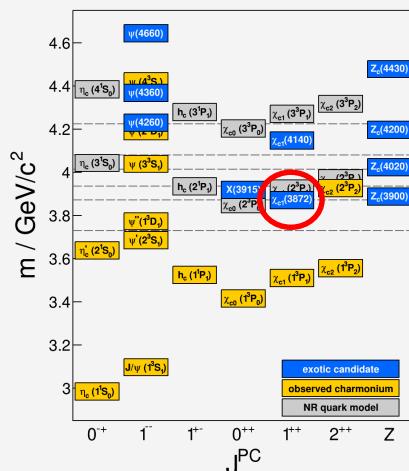
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- allows to look for decay modes other than $X(3872) \rightarrow \pi^+\pi^-J/\psi$
- observation of $X(3872) \rightarrow \pi^0\chi_{c1}$ with 5.2σ , no signal for $\chi_{c0,2}$
- $R_J = \frac{Br(X(3872) \rightarrow \pi^0\chi_{cJ})}{Br(X(3872) \rightarrow \pi^+\pi^-J/\psi)}$ with $R_0 < 19$ (90% CL)
 $R_1 = 0.88^{+0.33}_{-0.27} \pm 0.10$
 $R_2 < 1.1$ (90% CL)
- PRD 77, 014013 (2008): $\Gamma(X(3872) \rightarrow \pi^0\chi_{c1}) \sim 0.06 \text{ keV}$ in case of a conventional $c\bar{c}$
- combining $3.2\% < Br(X(3872) \rightarrow \pi^+\pi^-J/\psi) < 6.4\%$ with $R_1 = 0.88$ would imply $c\bar{c}$ -state with $\Gamma_{\text{tot}}(X(3872)) \sim 1.0 - 2.0 \text{ keV} \rightarrow$ strongly disfavors $c\bar{c}$ interpretation



Recent results: $X(3872)$



BESIII:
 $R_{\gamma\psi} < 0.59$ (90% CL)

- multiple other decay modes were studied: $X(3872) \rightarrow D^{*0}\bar{D}^0$, $\gamma J/\psi$, $\gamma\psi(2S)$, γD^+D^-
- $R_{\gamma\psi} = \frac{Br(X(3872) \rightarrow \gamma\psi(2S)}{Br(X(3872) \rightarrow \gamma J/\psi)}$ might discriminate a $D^{*0}\bar{D}^0$ molecule ($R_{\gamma\psi} \approx 3 \times 10^{-3}$) from a charmonium state ($R_{\gamma\psi} \approx 1.2 - 15$)
- LHCb: $R_{\gamma\psi} = 2.46 \pm 0.64 \pm 0.29$, BaBar: $R_{\gamma\psi} = 3.4 \pm 1.4$, however Belle: $R_{\gamma\psi} < 2.1$ (90% CL)

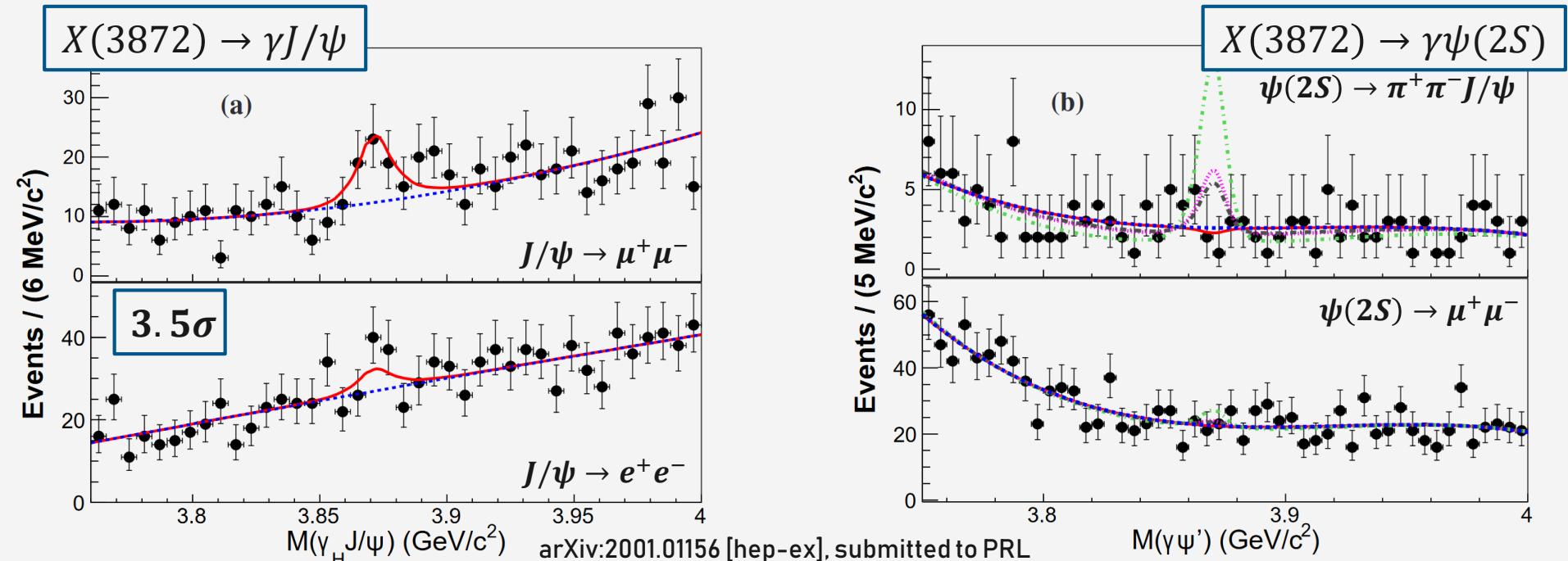
PLB598, 197 (2004)
Phys. Rep. 429, 243 (2006)
PRD90, 054010 (2014)

PRD72, 054026 (2005) Nucl. Phys. A714, 183 (2003)
PRD69, 054008 (2004) PRD85, 114002 (2012)
PRD79, 094004 (2009) PRD83, 094009 (2011) PLB697, 3 (2011)

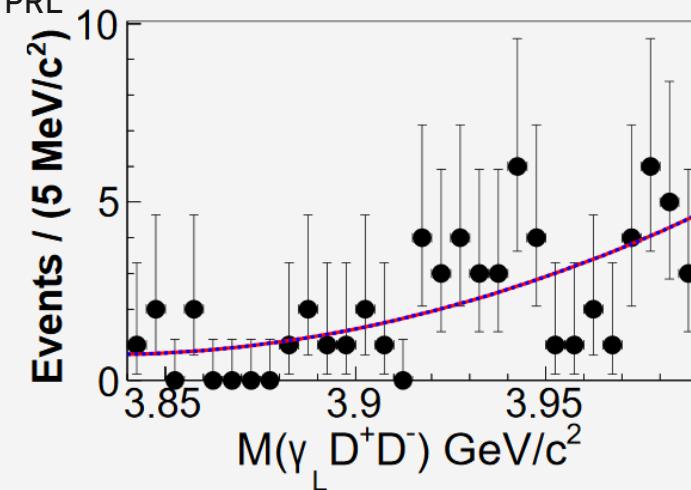
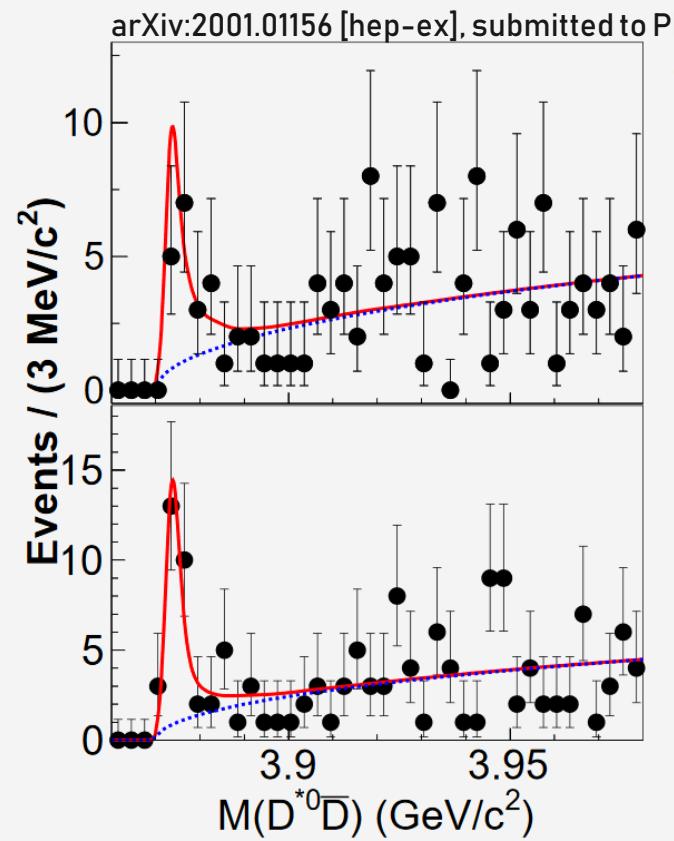
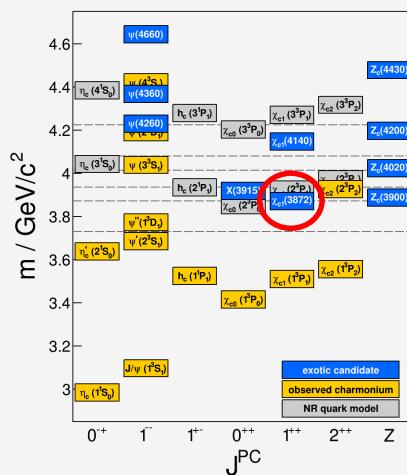
Nucl. Phys. B886, 665 (2014)

PRL 102, 132001 (2009)

PRL 107, 091803 (2011)

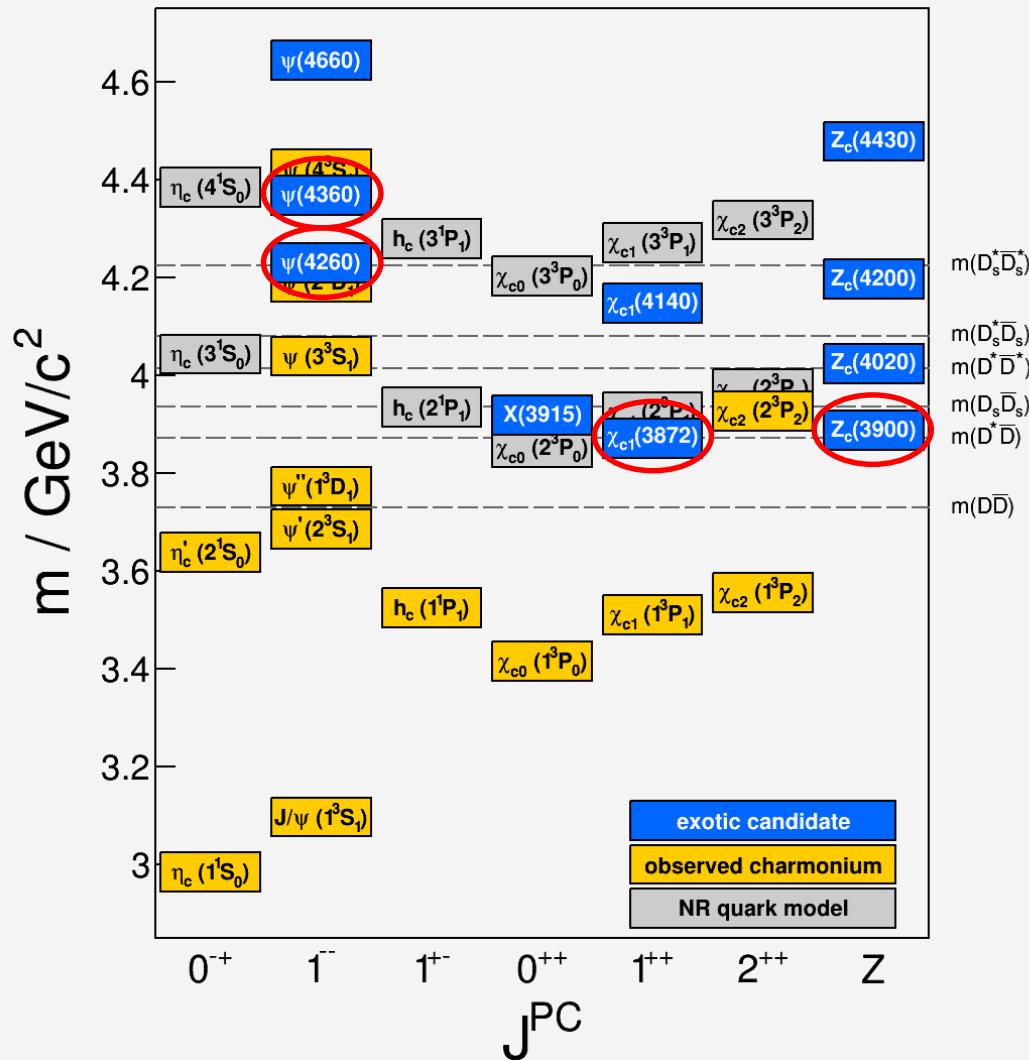


Recent results: $X(3872)$



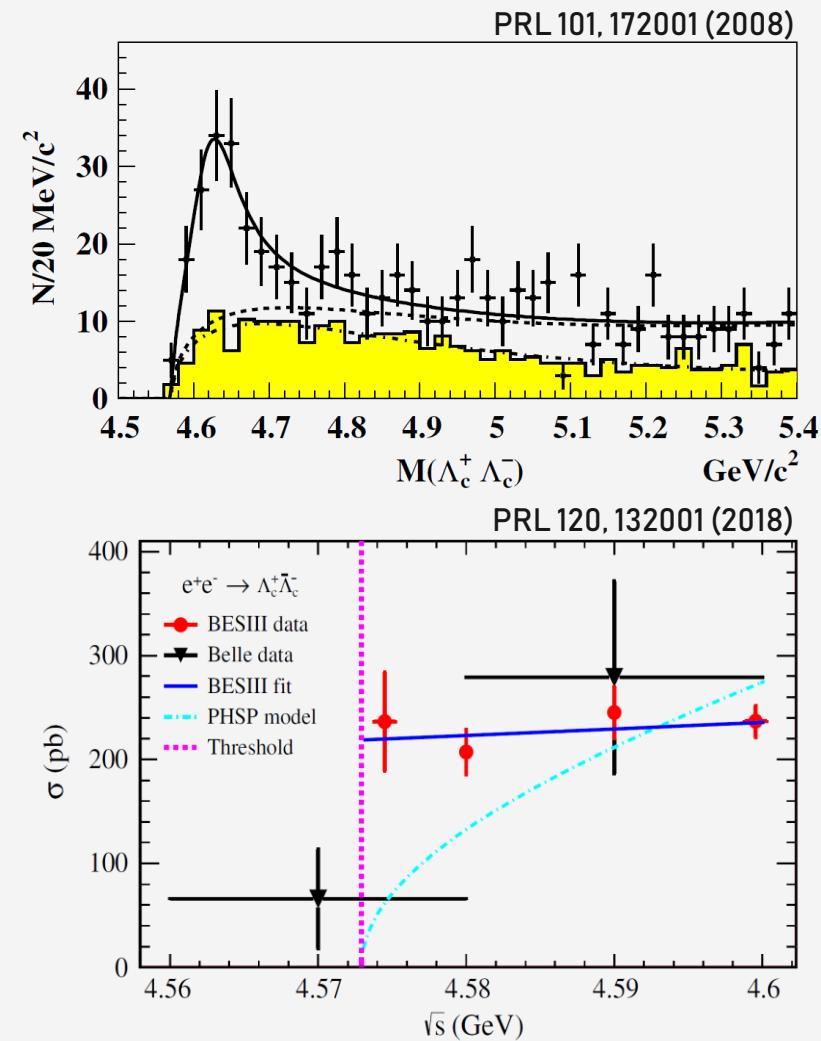
- clear signal found for $X(3872) \rightarrow D^{*0}\bar{D}^0$ in both $D^{*0} \rightarrow \gamma D^0$ and $D^{*0} \rightarrow \pi^0 D^0$ decay modes
- no signal for $X(3872) \rightarrow \gamma D^+ D^-$

mode	$\gamma J/\psi$	$\gamma\psi'$	$\gamma D^0\bar{D}^0$	$\pi^0 D^0\bar{D}^0$	$D^{*0}\bar{D}^0 + c.c.$	$\gamma D^+ D^-$	$\omega J/\psi$	$\pi^0\chi_{c1}$
ratio	0.79 ± 0.28	-0.03 ± 0.22	0.54 ± 0.48	-0.13 ± 0.47	11.77 ± 3.09	$0.00^{+0.48}_{-0.00}$	$1.6^{+0.4}_{-0.3} \pm 0.2$	$0.88^{+0.33}_{-0.27} \pm 0.10$
UL	-	< 0.42	< 1.58	< 1.16	-	< 0.99	-	-

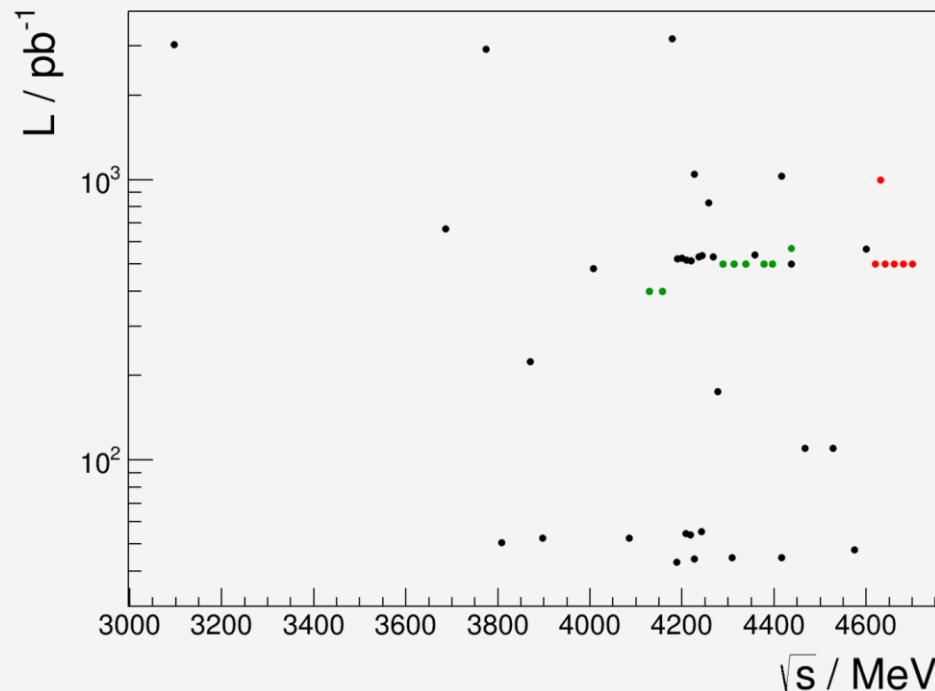


- to fully understand the XYZ states, studying their properties is highly important
 - BESIII is uniquely suited to perform such studies, working directly in the energy region of interest
 - strong signal of $Y(4220) \rightarrow \omega\chi_{c0}$
 - first evidence for the decay $Z_c(3900)^{\pm} \rightarrow \eta_c\rho^{\pm}$
 - first observation of $X(3872) \rightarrow \pi^0\chi_{c1}$
 - evidence for $X(3872) \rightarrow \gamma J/\psi$, but not $\gamma\psi(2S)$

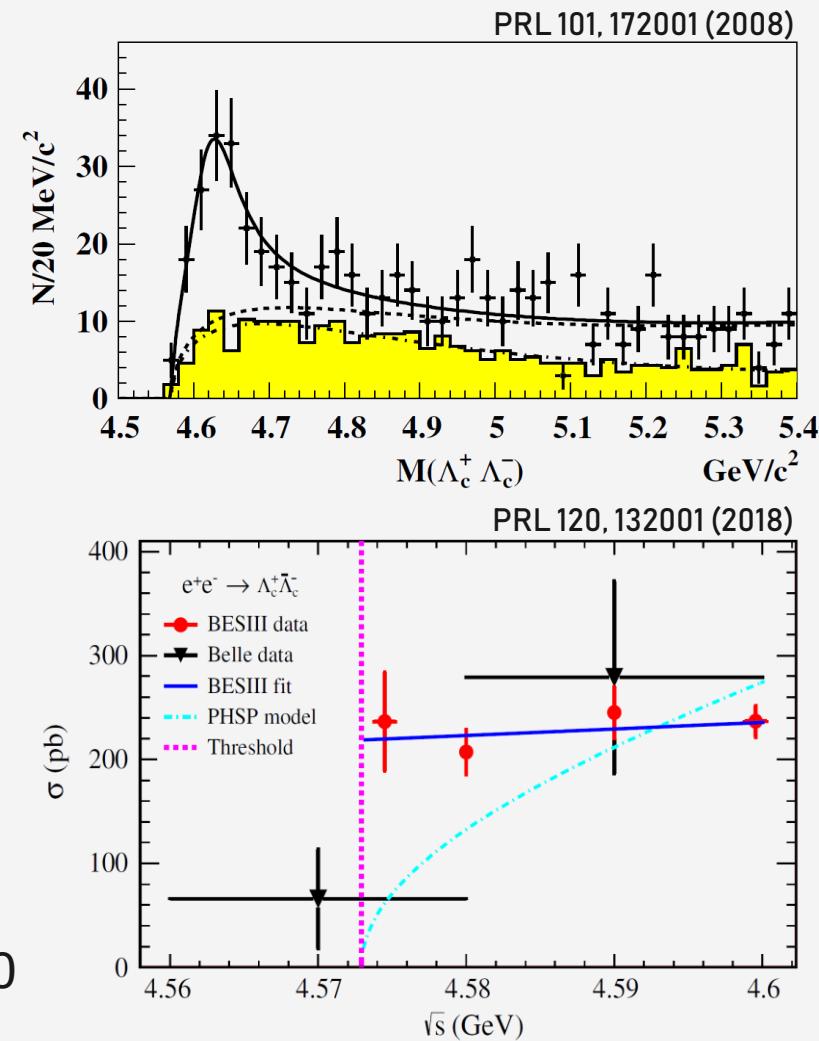
- $Y(4660)$ observed by Belle & BaBar in $Y(4660) \rightarrow \pi\pi\psi(2S)$, $\Lambda_c\bar{\Lambda}_c$
- BESIII measurement of $e^+e^- \rightarrow \Lambda_c\bar{\Lambda}_c$ indicates different trend



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- BESIII measurement of $e^+e^- \rightarrow \Lambda_c\bar{\Lambda}_c$ indicates different trend



- energy upgrade to $\sqrt{s} \leq 4.7$ GeV allows study of this region in 2020



Thank you for your attention!

