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Recent results on XYZ states from the BESIII experiment

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on behalf of the BESIII Collaboration

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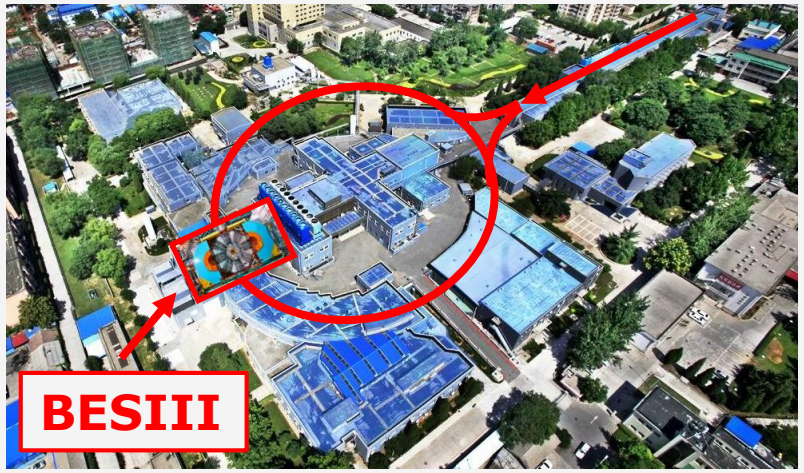
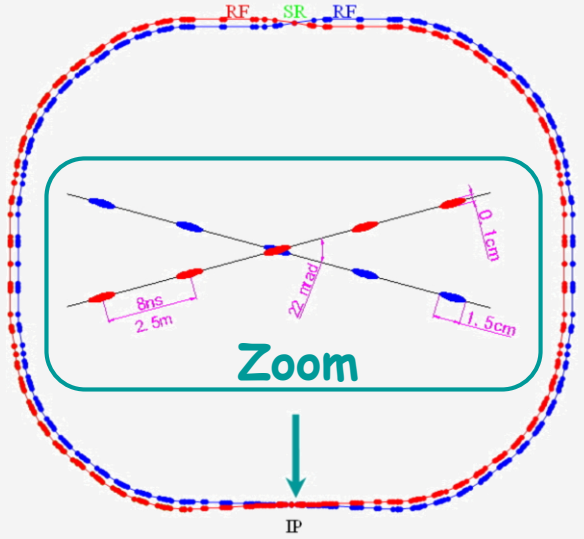
BESIII Beijing Spectrometer(BESIII) Experiment

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



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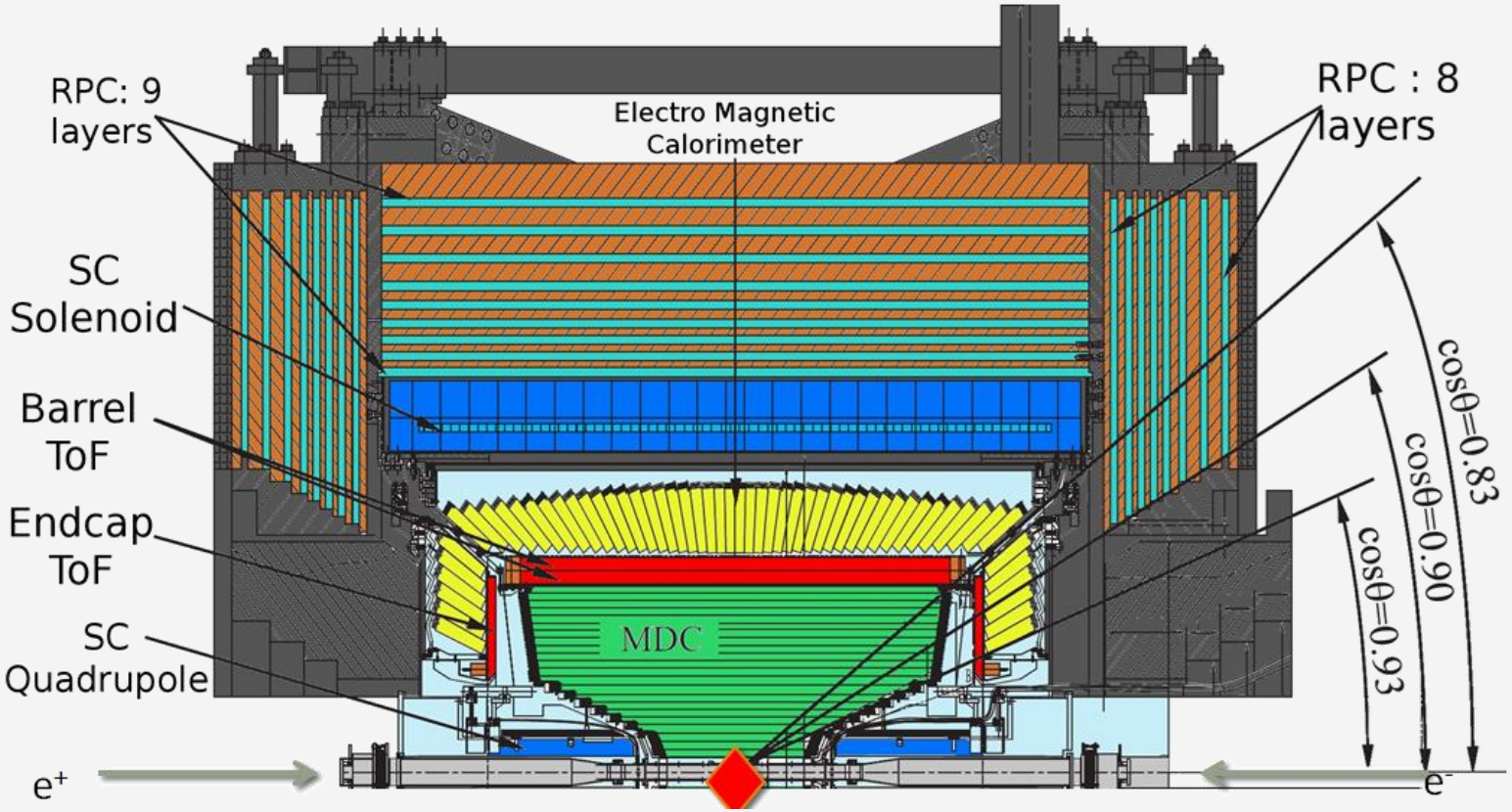

- **MDC:** Drift chamber in 1.0 T magnetic field
- **TOF:** Plastic scintillator based time-of-flight system
- **EMC:** Electromagnetic calorimeter
- **RPC:** resistive plate chambers for muon identification

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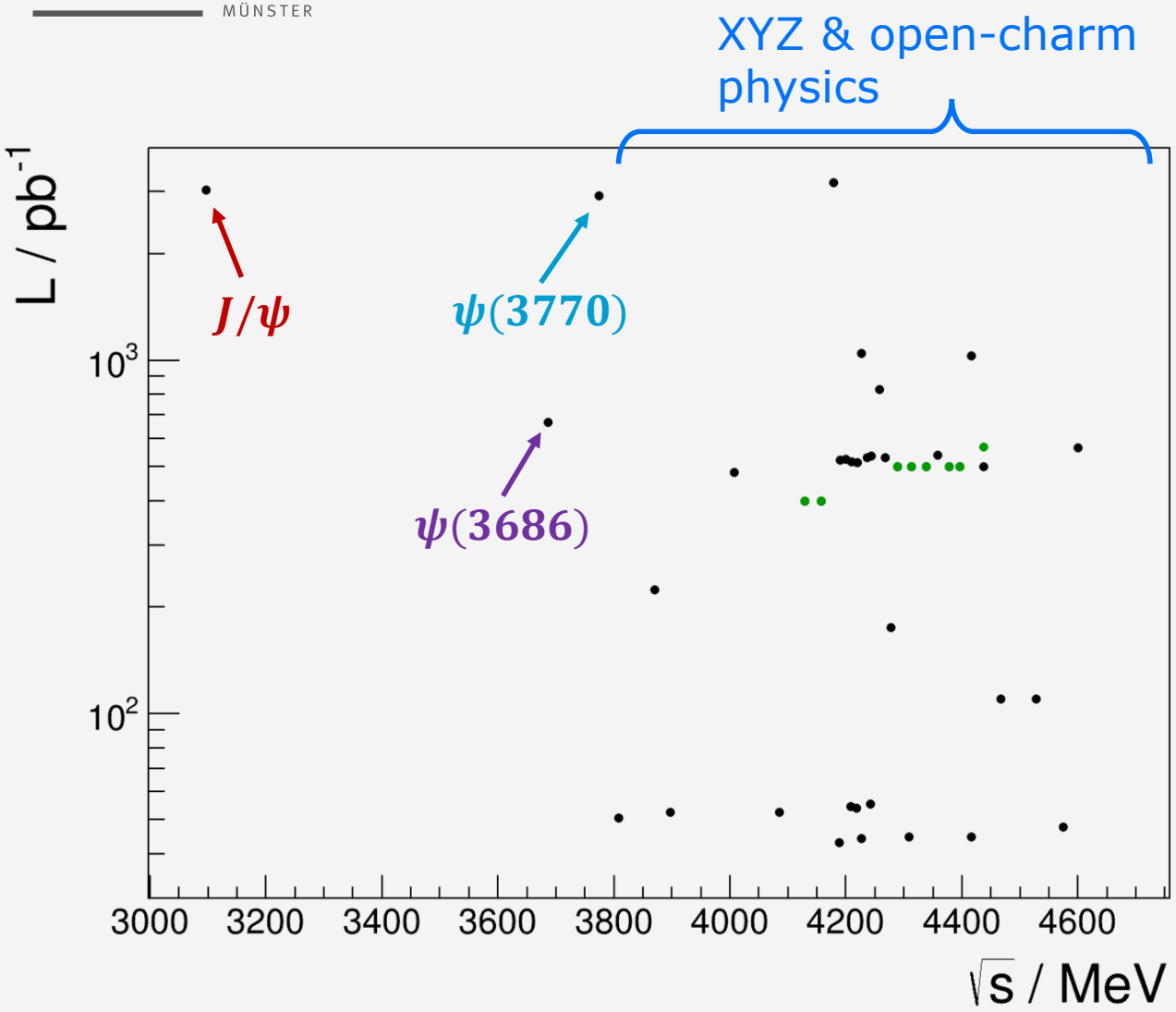
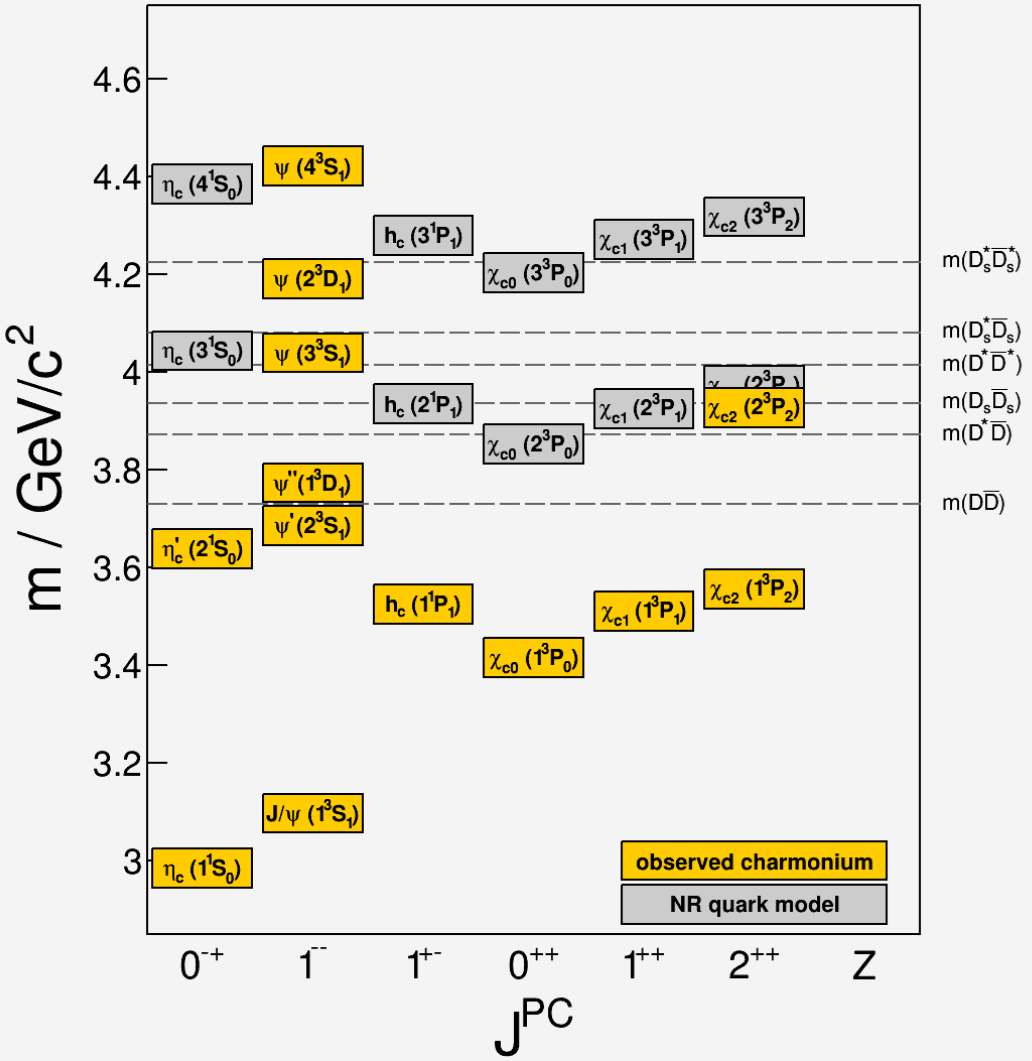


- in recent years, BESIII accumulated roughly $16\,\mathrm{fb}^{-1}$ of e^+e^- collision data above $\sqrt{s} = 3.8\,\mathrm{GeV}$
- these can be used to study open-charm & XYZ meson production & decays
- new data at 8 additional energies taken throughout 2019 will allow to improve lineshape analysis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

Beyond conventional charmonium



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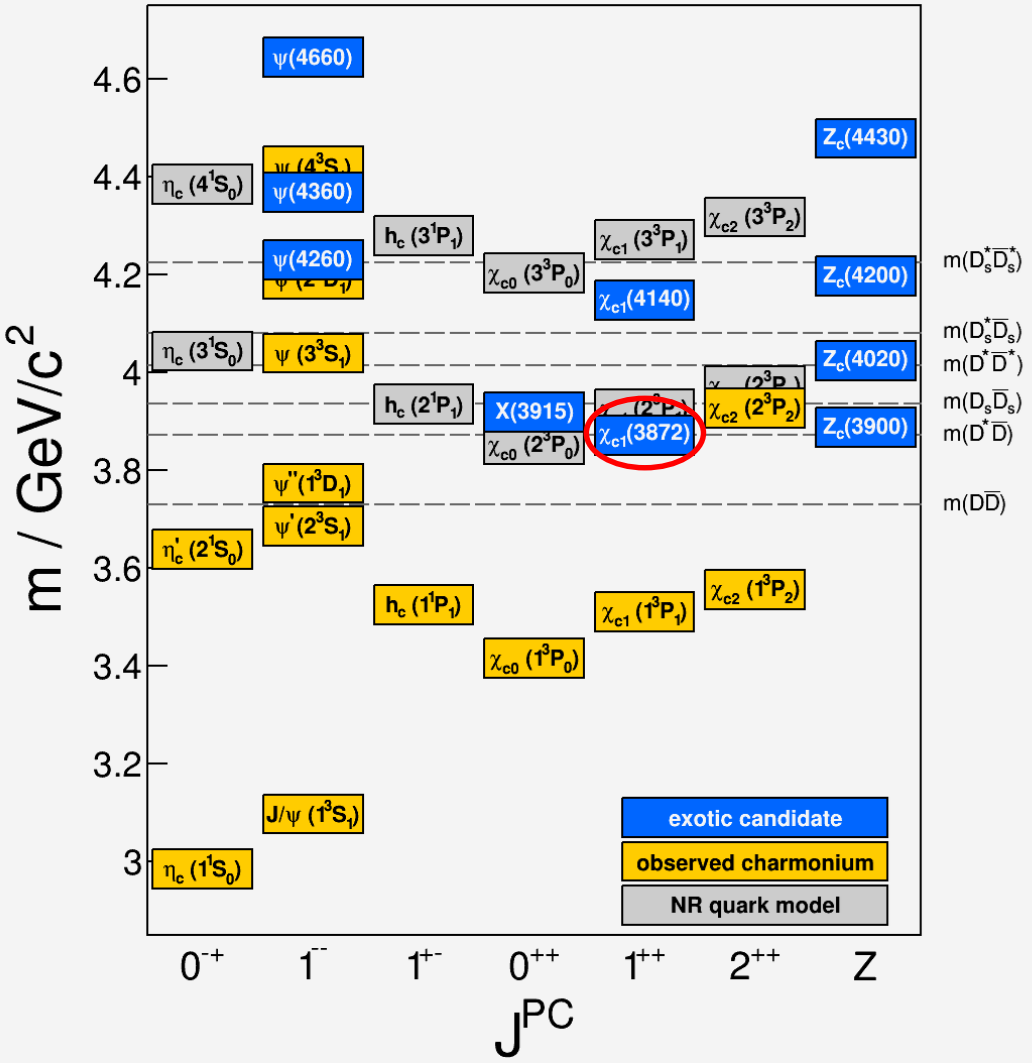

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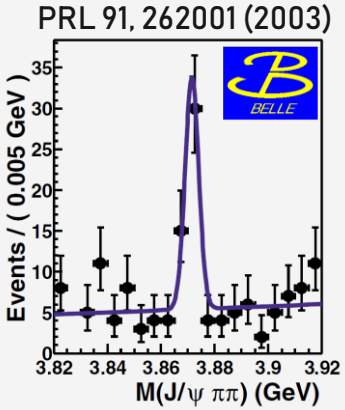

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- recent years: multiple new states discovered in various experiments

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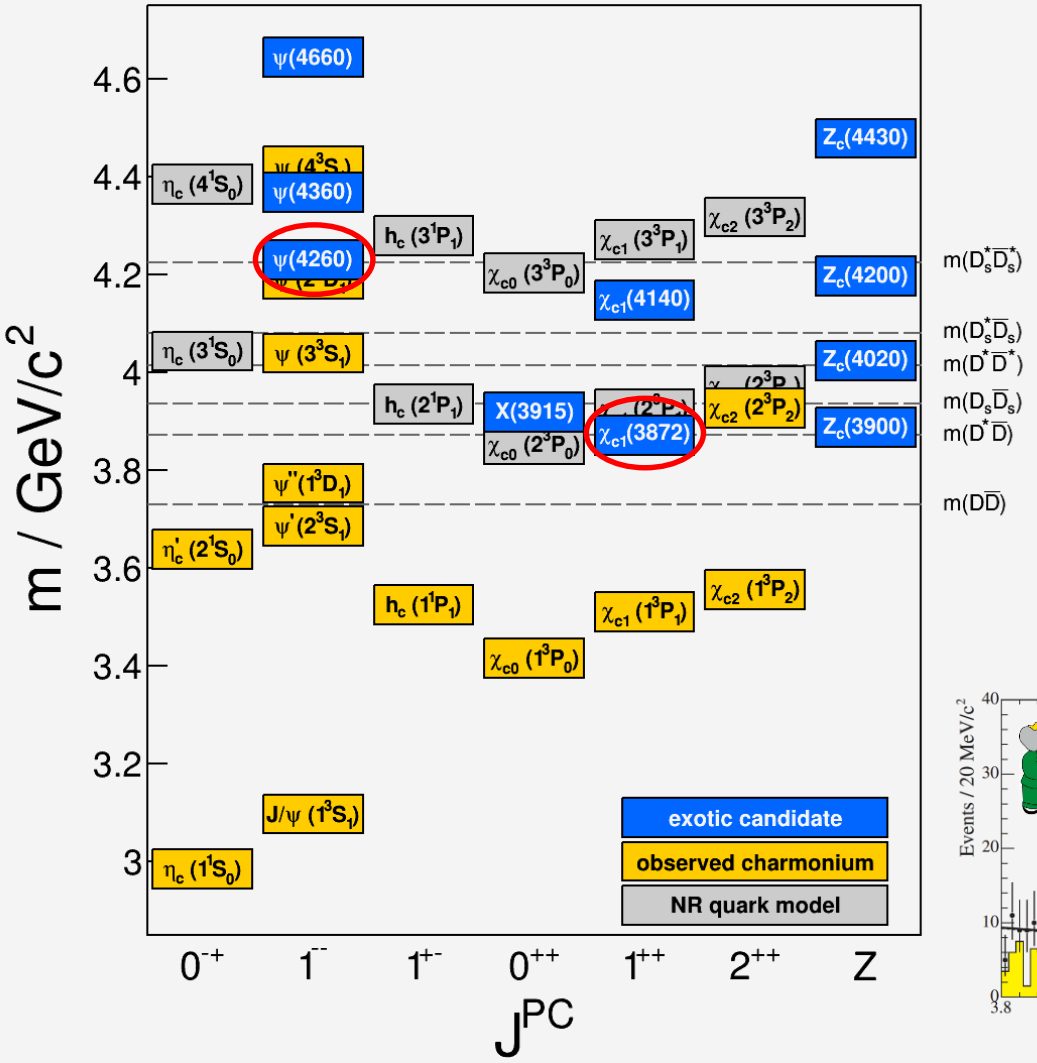

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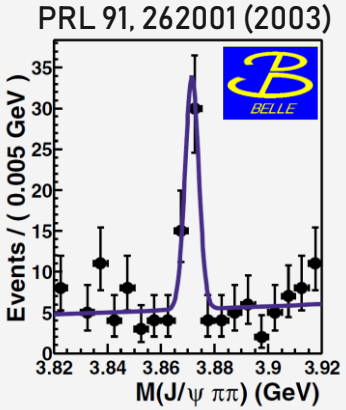

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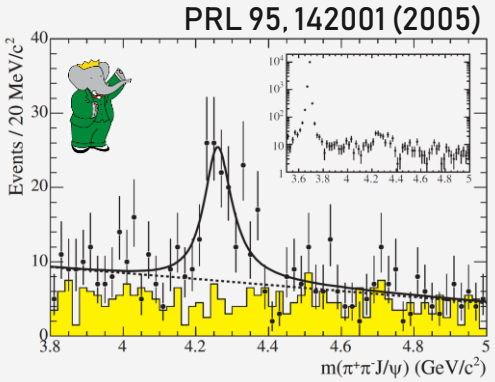

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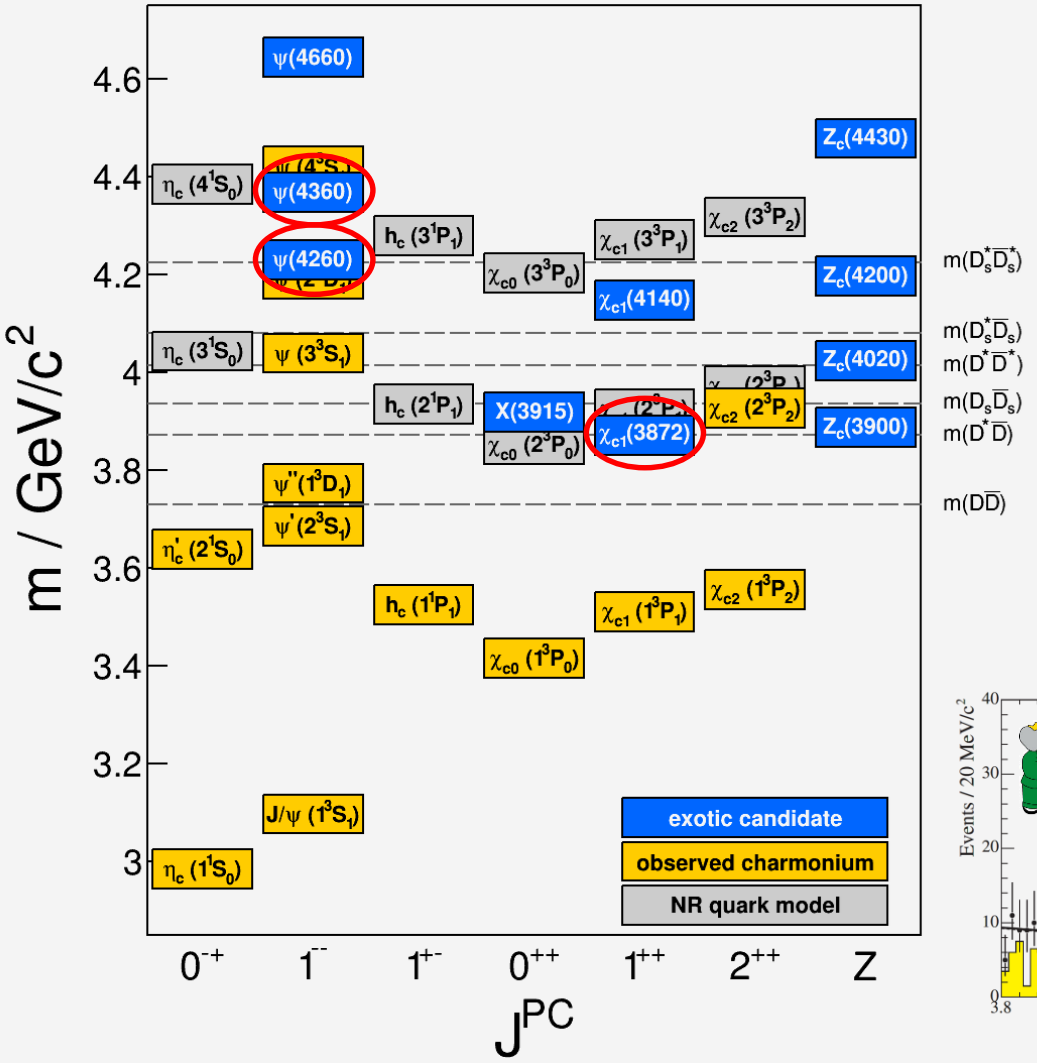

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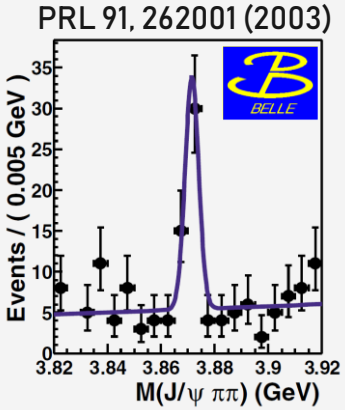

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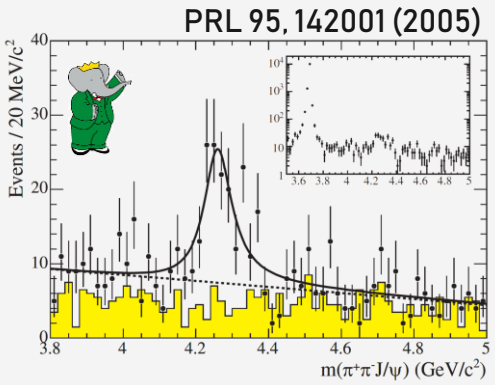

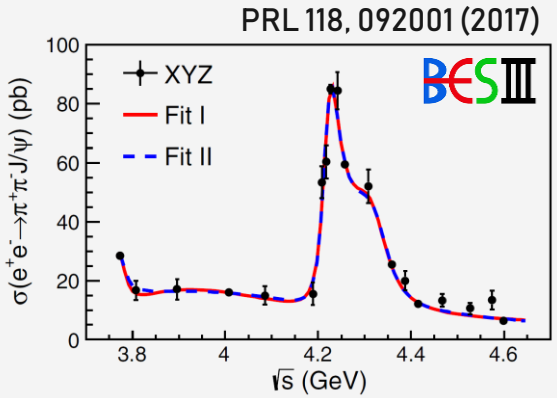

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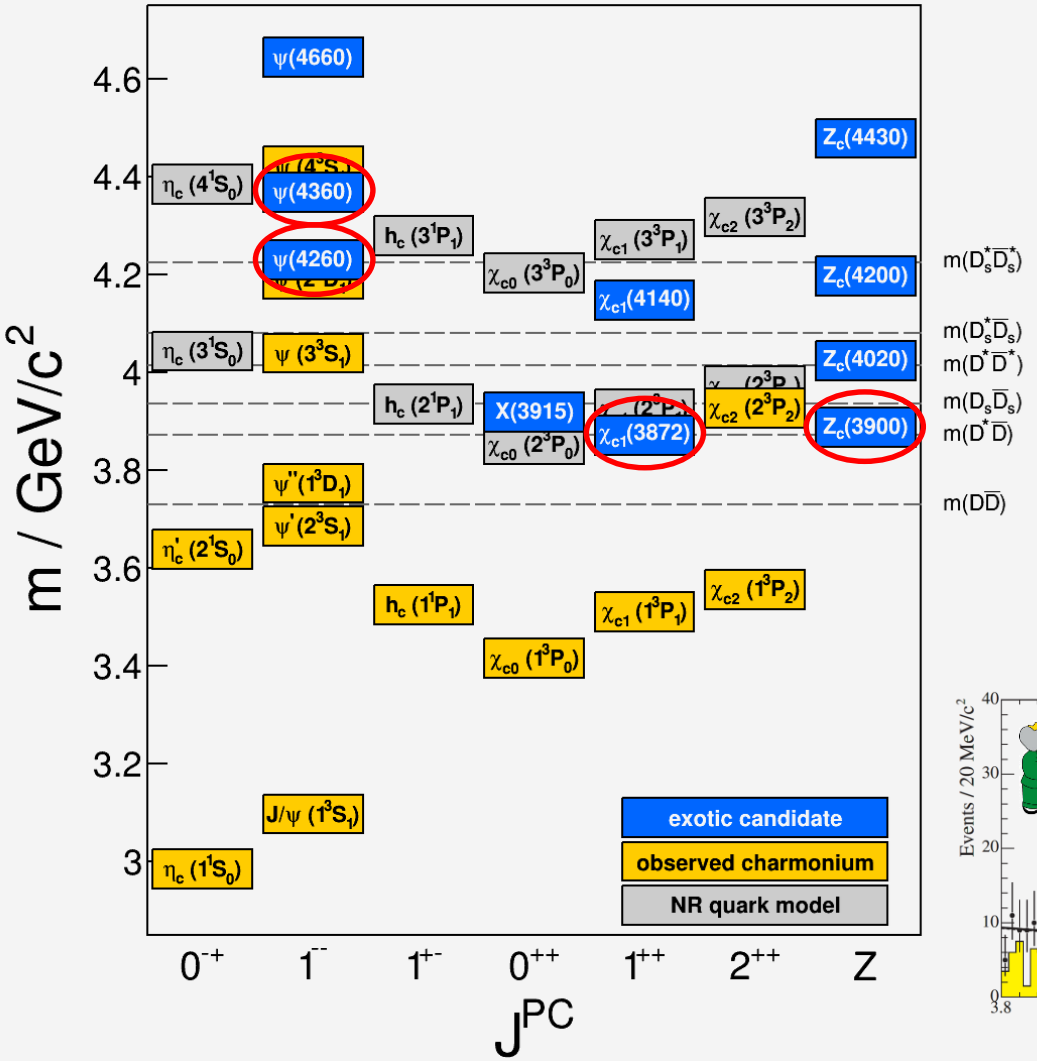

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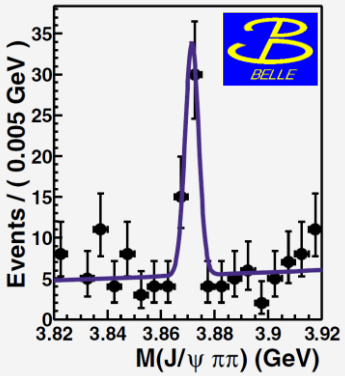
PRL 91, 262001 (2003)



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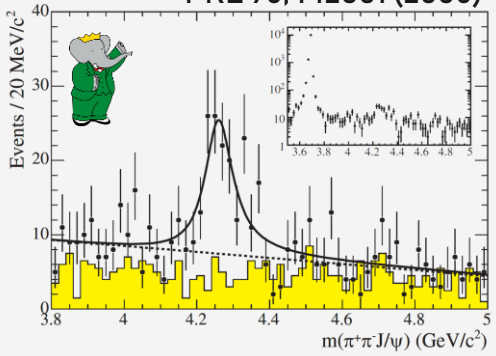
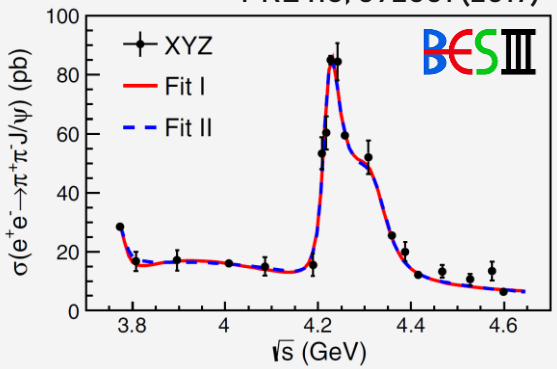
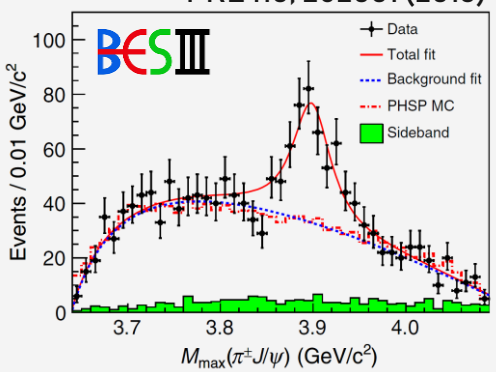
PRL 95, 142001 (2005)



PRL 118, 092001 (2017)



PRL 110, 252001 (2013)



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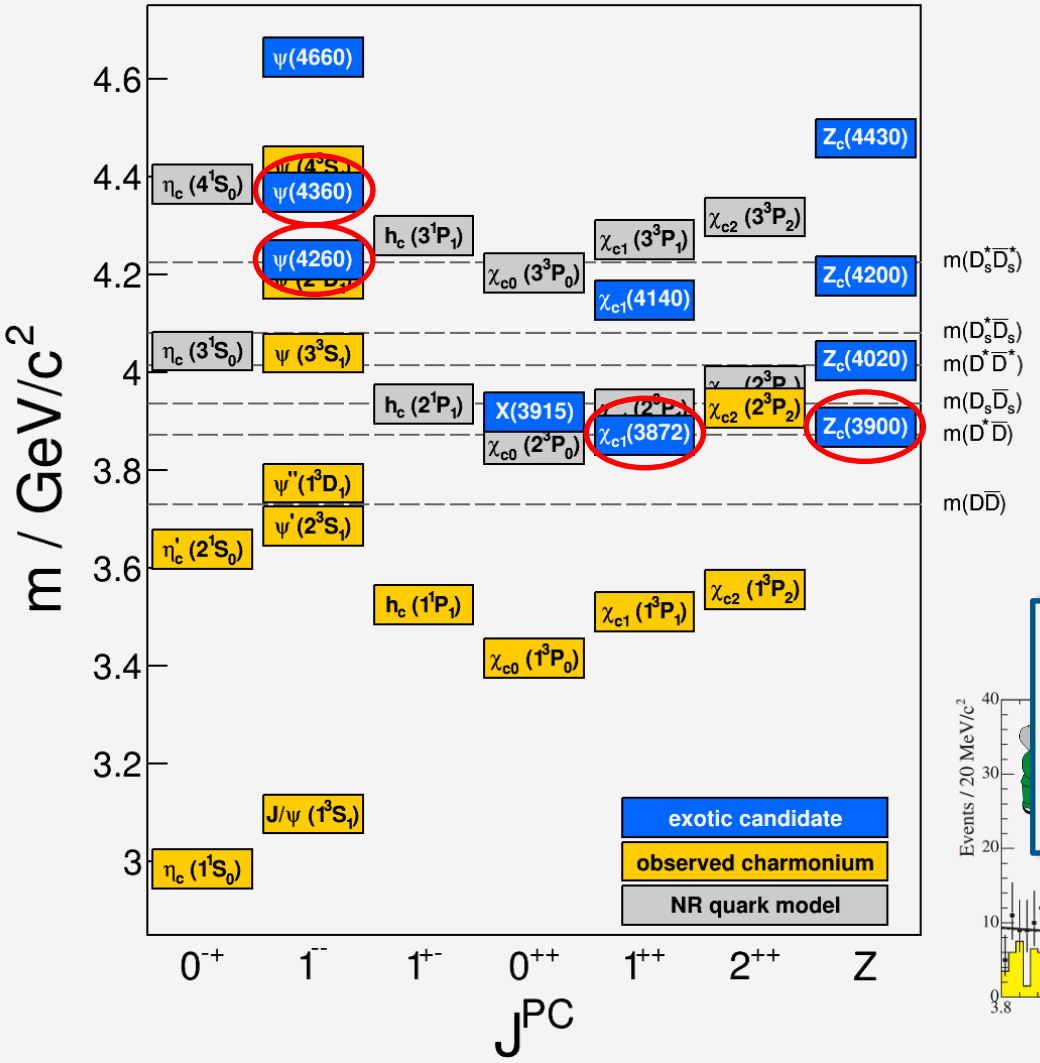

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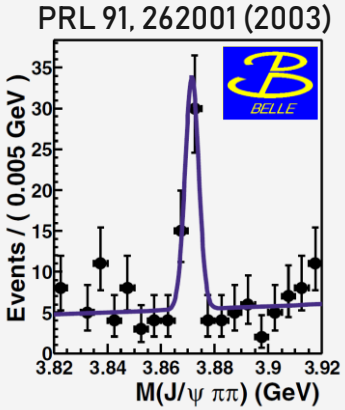

- 2003: discovery of the $X(3872)$ by Belle
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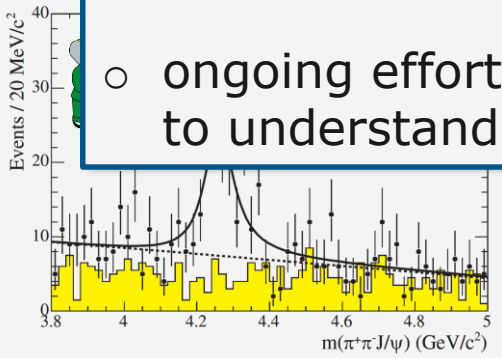
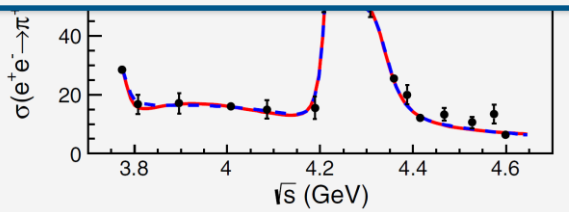
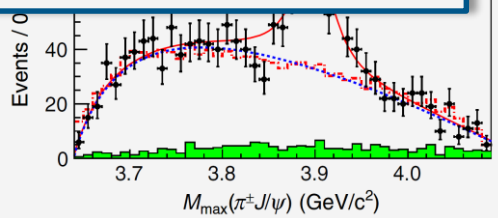
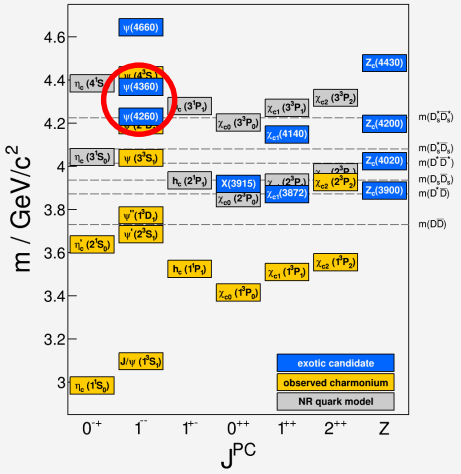
- no consensus on the interpretation of these states
- ongoing effort to study their properties in an attempt to understand the exotic nature of the XYZ states

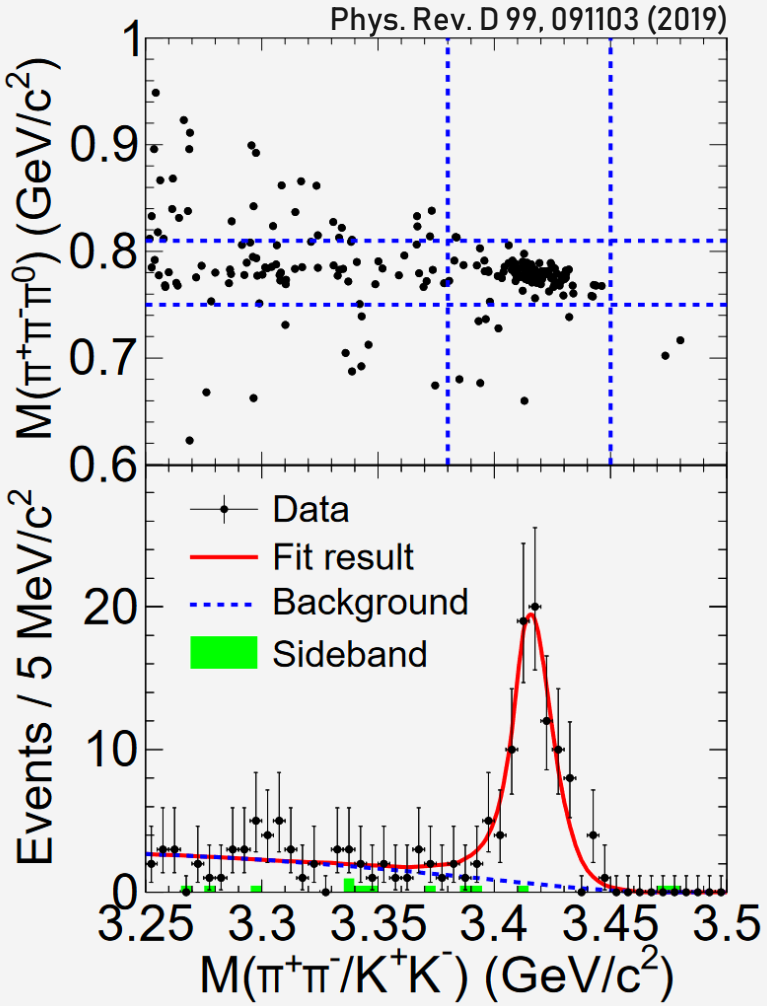




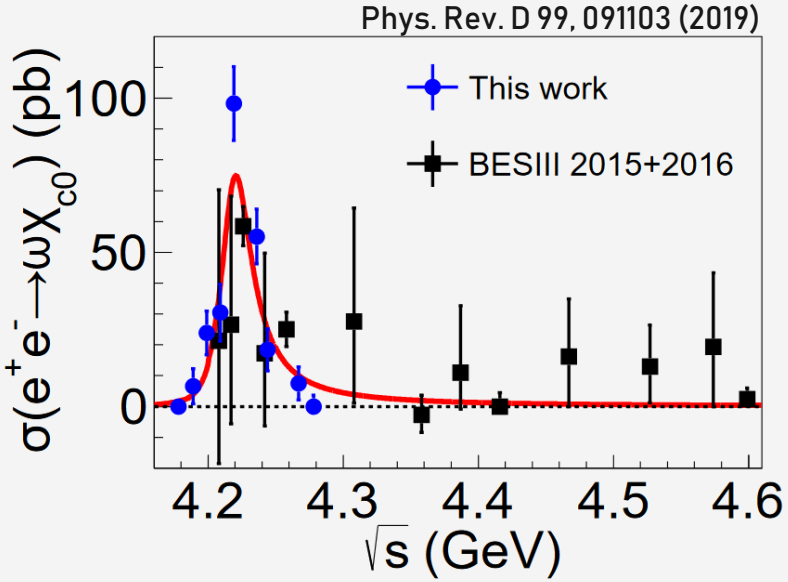


Recent results: $Y(4260)$





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



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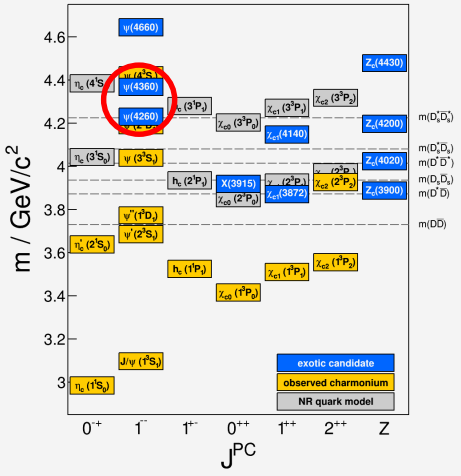
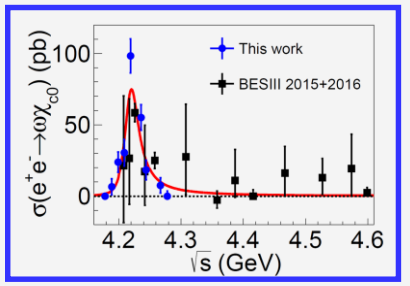
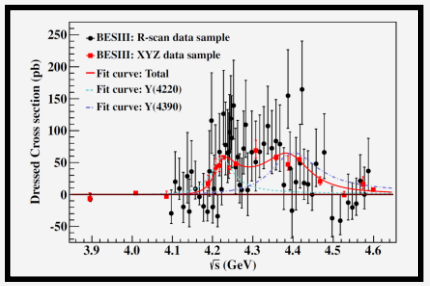
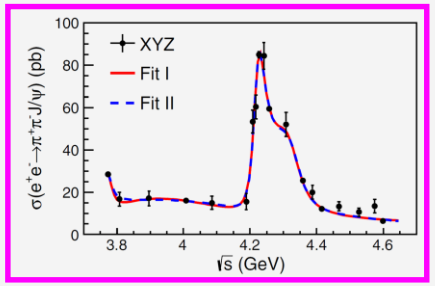
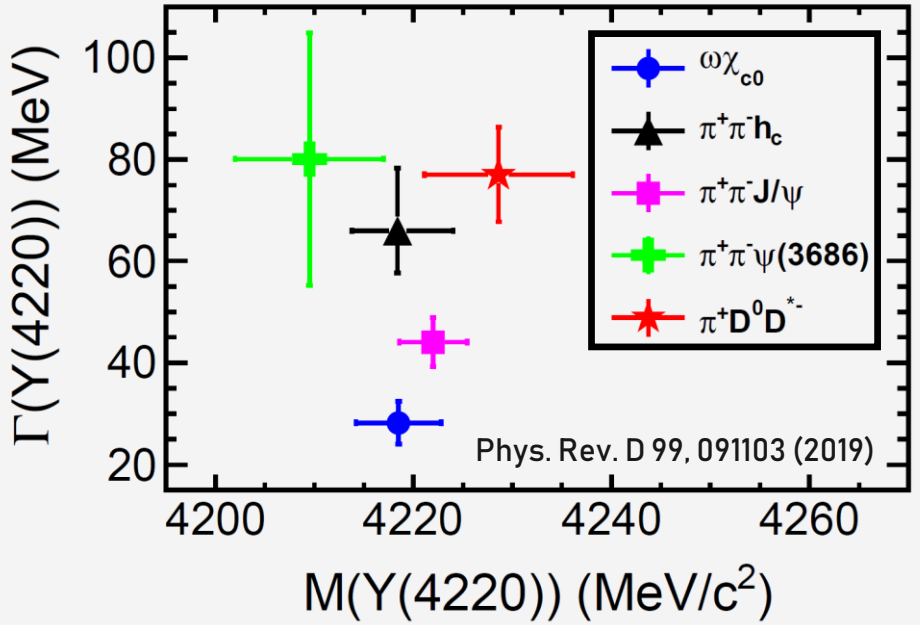


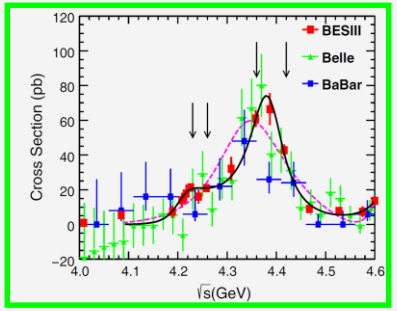
- similar resonances seen in $\omega\chi_{c0}$, $\pi^+\pi^- h_c$, $\pi^+\pi^- J/\psi$, $\pi^+\pi^-\psi(2S)$ and $\pi^+ D^0 D^{*-}$
- all agree on a lower mass value $Y(4260) \rightarrow Y(4220)$
- inconsistencies regarding the width, might be caused by Breit-Wigner parameterization

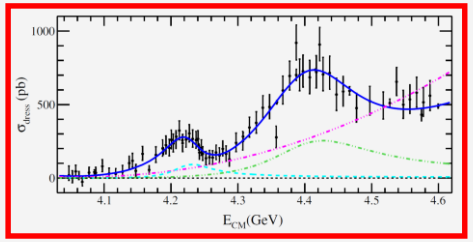




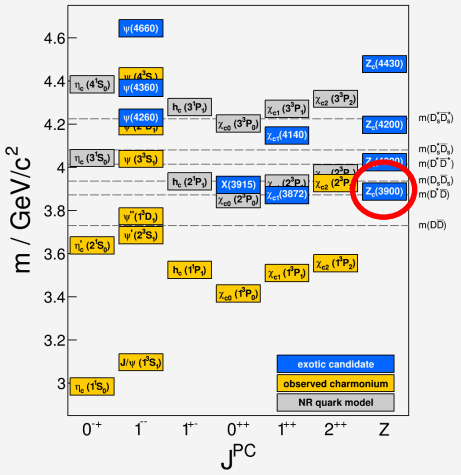








Recent results: $Z_c(3900)$

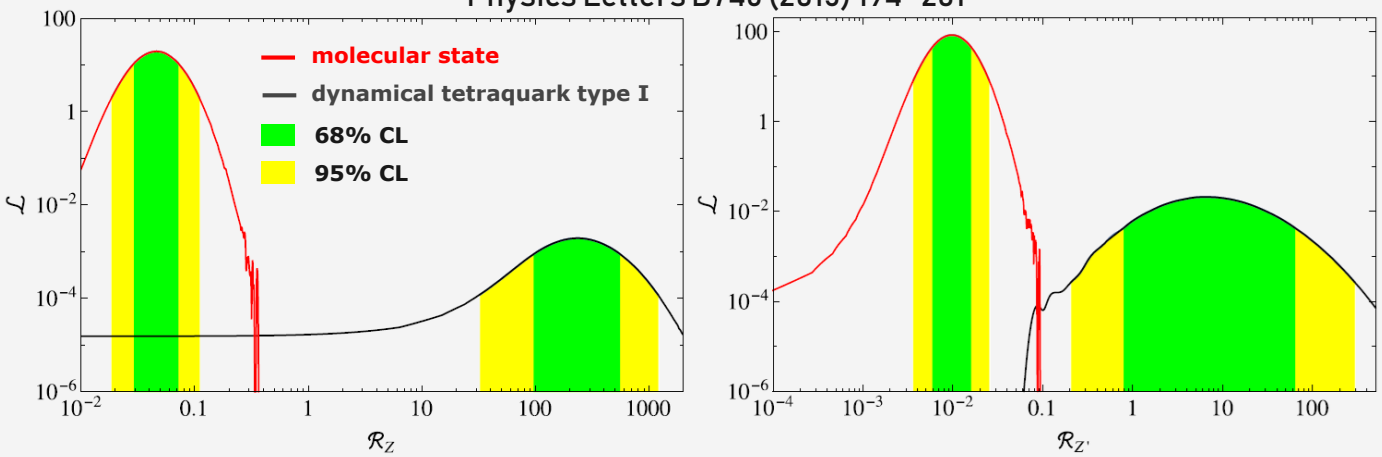


prediction:

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

to discriminate between molecular & tetraquark assignments

Physics Letters B746 (2015) 194–201



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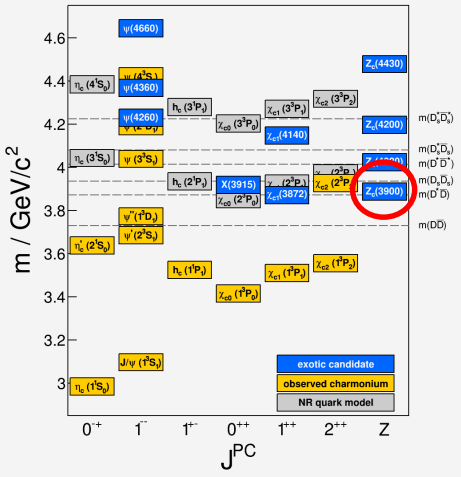

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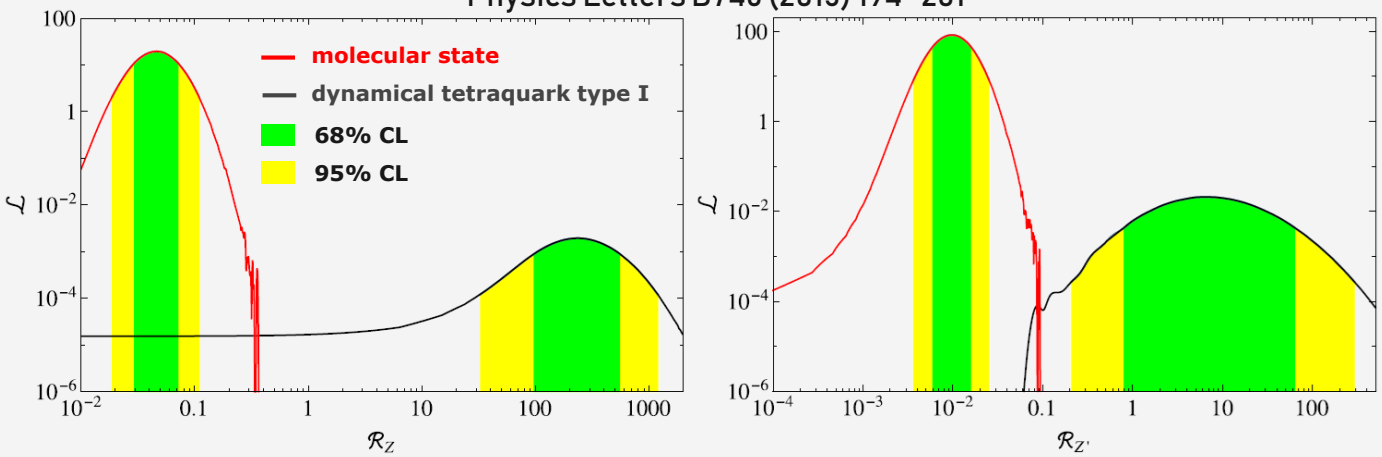
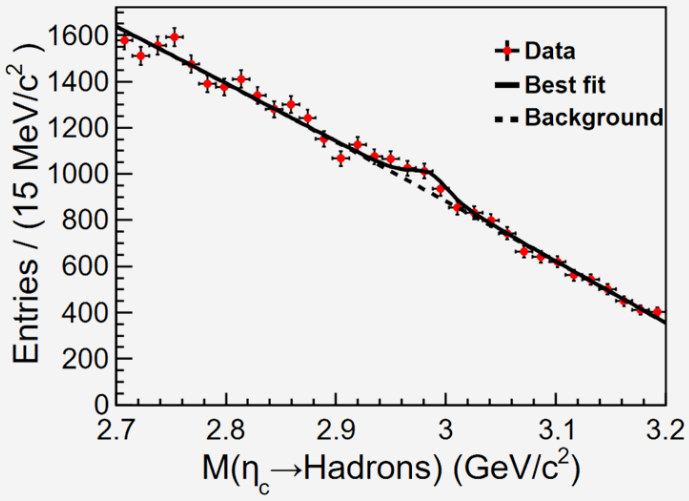
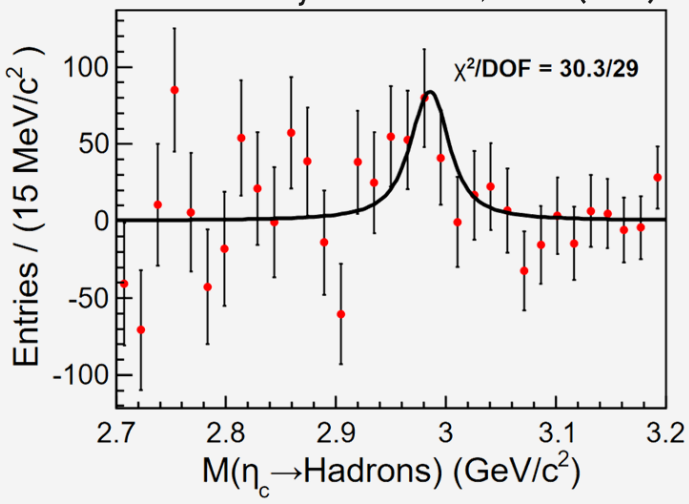


- process $e^+e^- \to \eta_c\rho^\pm\pi^\mp$ studied at five energies between $4.23\ \text{GeV} \leq \sqrt{s} \leq 4.60\ \text{GeV}$
- η_c reconstructed in 9 decay modes
- signal of $e^+e^- \to \eta_c\pi^+\pi^-\pi^0$ observed with a significance of 4.2σ

Phys. Rev. D 100, 111102 (2019)





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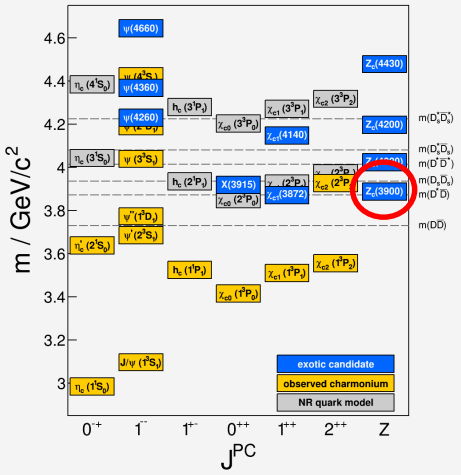

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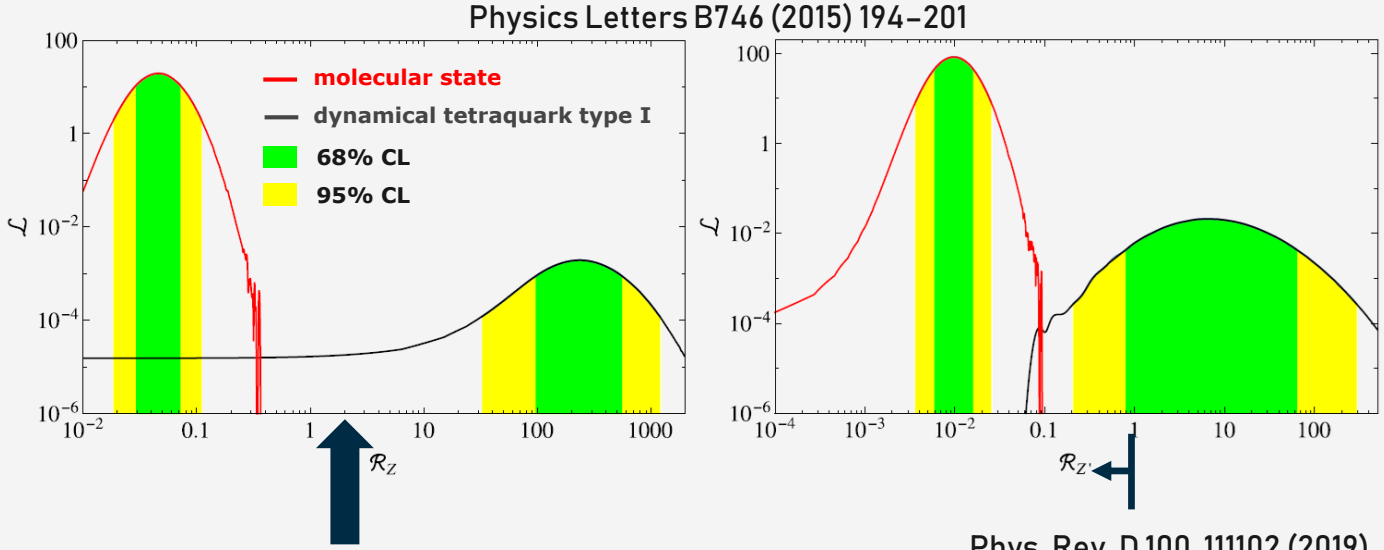
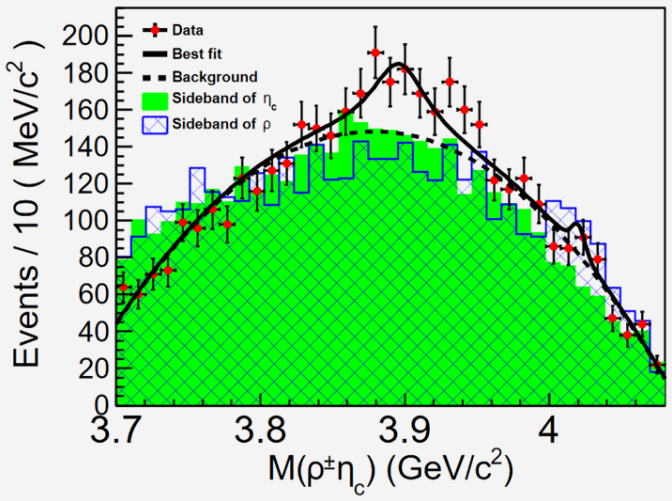
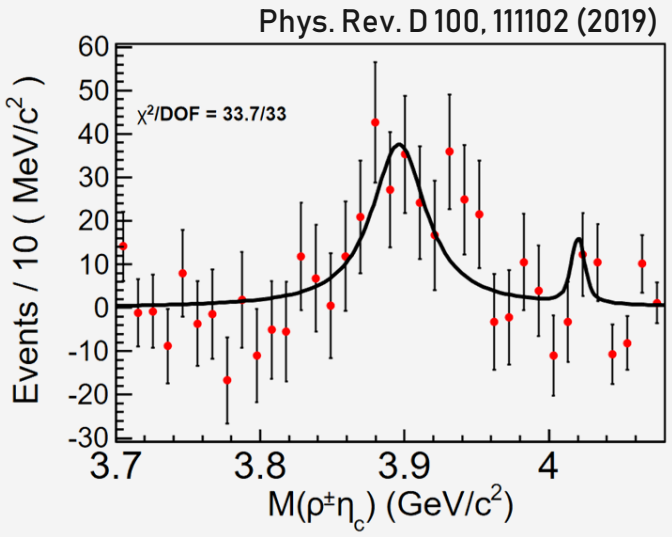


- strong evidence $(4.3\,\sigma)$ for $Z_c(3900) \to \rho\eta_c$ at $\sqrt{s} = 4.23$ GeV
- no signal observed for $Z_c'(4020) \to \rho\eta_c$
- ratio $R_Z = 2.2 \pm 0.9$ and $R_{Z'} < 0.9$





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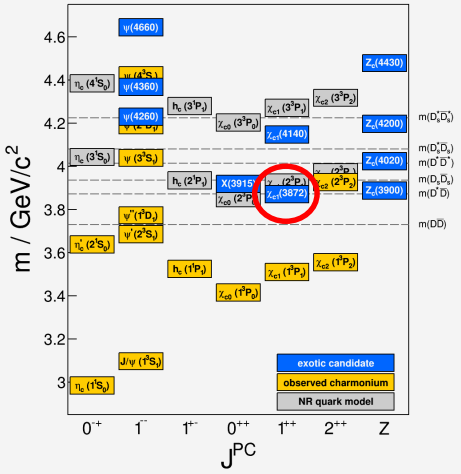

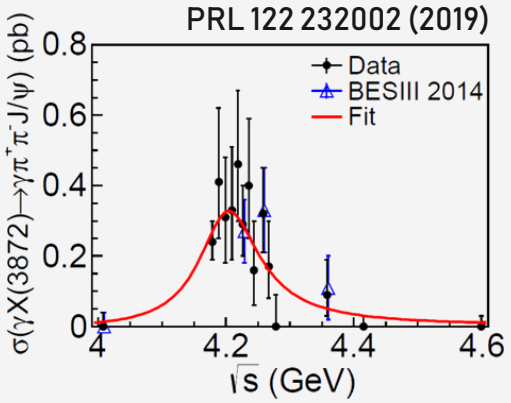

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- allows to look for decay modes other than $X(3872) \to \pi^+\pi^- J/\psi$

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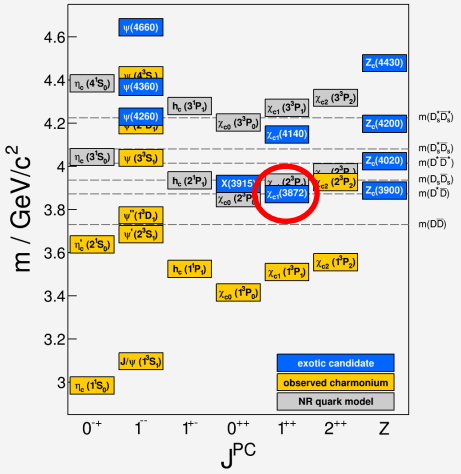

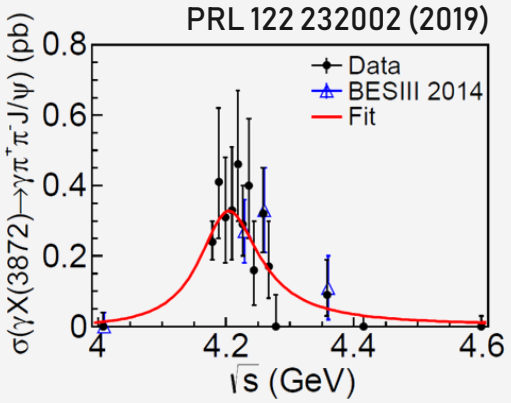

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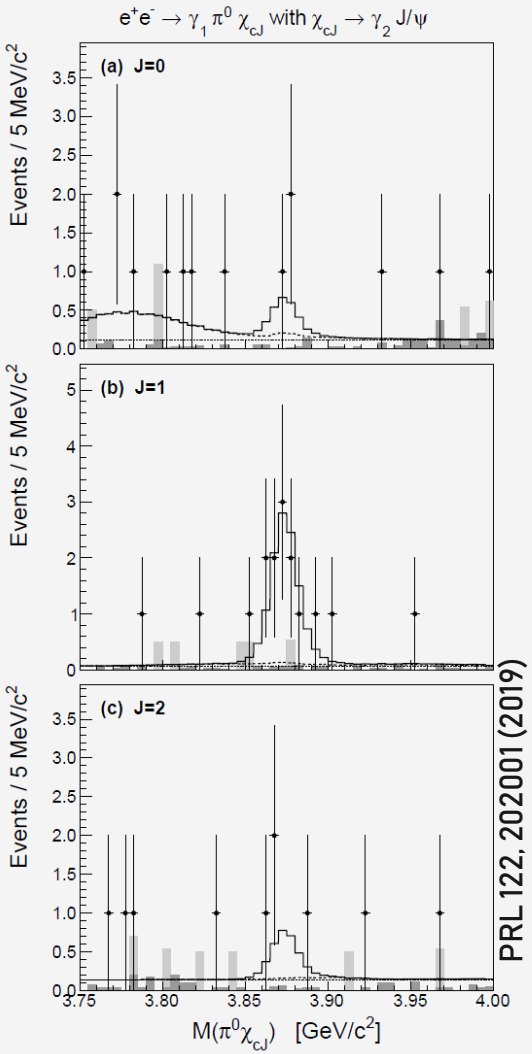
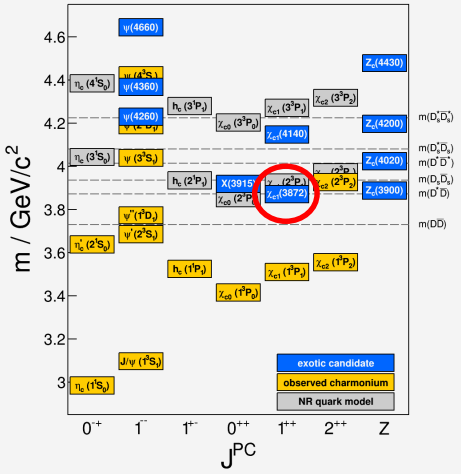
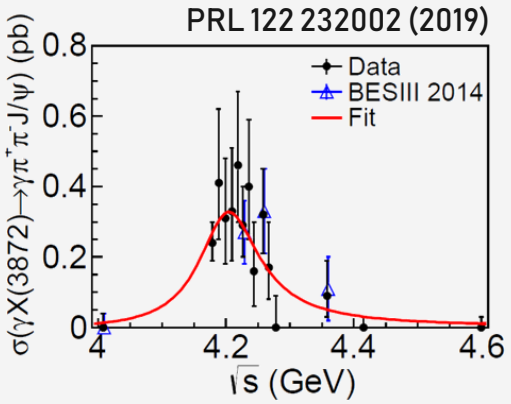


- observation of $X(3872) \to \pi^0 \chi_{c1}$ with $5.2\,\sigma$, no signal for $\chi_{c0,2}$
- $R_J = \dfrac{Br(X(3872) \to \pi^0 \chi_{cJ})}{Br(X(3872) \to \pi^+\pi^- J/\psi)}$ with

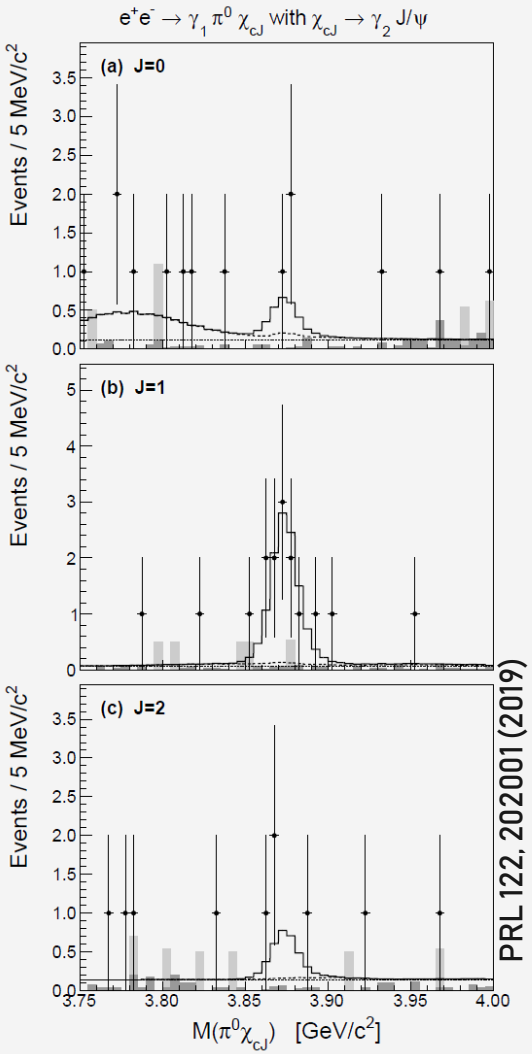
$$R_0 < 19 \quad (90\%\ \mathrm{CL})$$
$$R_1 = 0.88^{+0.33}_{-0.27} \pm 0.10$$
$$R_2 < 1.1 \quad (90\%\ \mathrm{CL})$$

Recent results: $X(3872)$



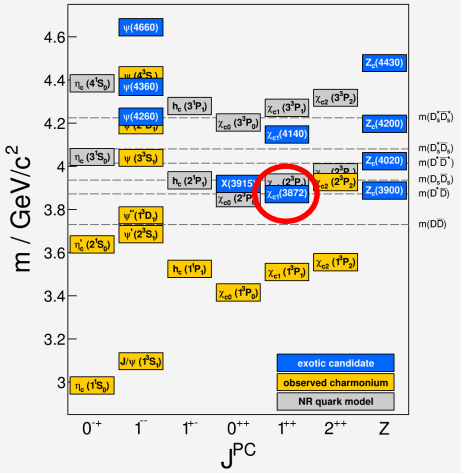


- BESIII: $X(3872)$ production in $e^+e^- \to \gamma X(3872)$
- allows to look for decay modes other than $X(3872) \to \pi^+\pi^- J/\psi$



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

Recent results: $X(3872)$



- multiple other decay modes were studied: $X(3872) \to D^{*0}\bar{D}^0$, $\gamma J/\psi$, $\gamma\psi(2S)$, γD^+D^-
- $R_{\gamma\psi} = \frac{Br(X(3872)\to\gamma\psi(2S))}{Br(X3872)\to\gamma J/\psi)}$ might discriminate a $D^{*0}\bar{D}^0$ molecule ($R_{\gamma\psi} \approx 3\times10^{-3}$) from a charmonium state ($R_{\gamma\psi} \approx 1.2 - 15$)

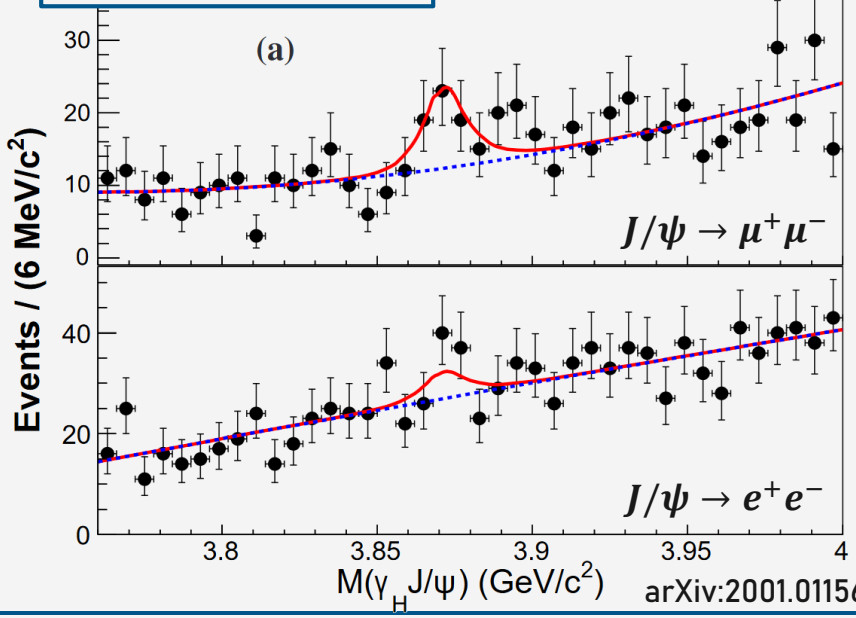
PLB598, 197 (2004)
Phys. Rep.429, 243 (2006)
PRD90, 054010(2014)
PRD72, 054026 (2005) Nucl. Phys. A714, 183 (2003)
PRD69, 054008 (2004) PRD85, 114002 (2012)
PRD79, 094004 (2009) PRD83, 094009 (2011) PLB697, 3 (2011)

- LHCb: $R_{\gamma\psi} = 2.46 \pm 0.64 \pm 0.29$, BaBar: $R_{\gamma\psi} = 3.4 \pm 1.4$, however Belle: $R_{\gamma\psi} < 2.1\ (90\%\ CL)$

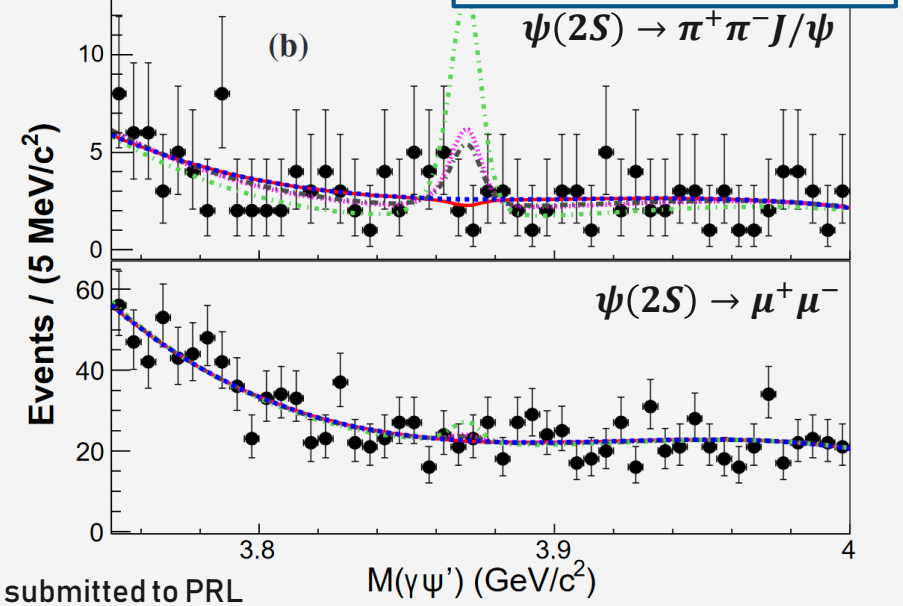
Nucl. Phys. B886, 665(2014) PRL 102,132001 (2009) PRL 107,091803 (2011)

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

$X(3872) \to \gamma J/\psi$

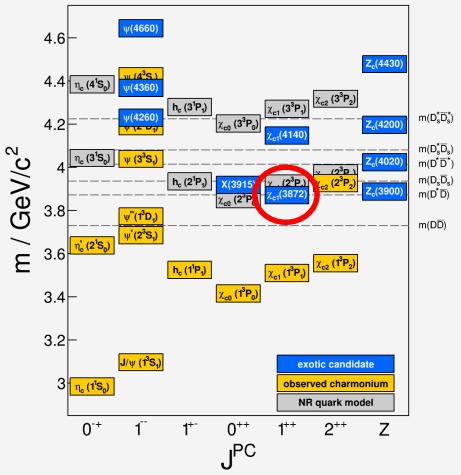


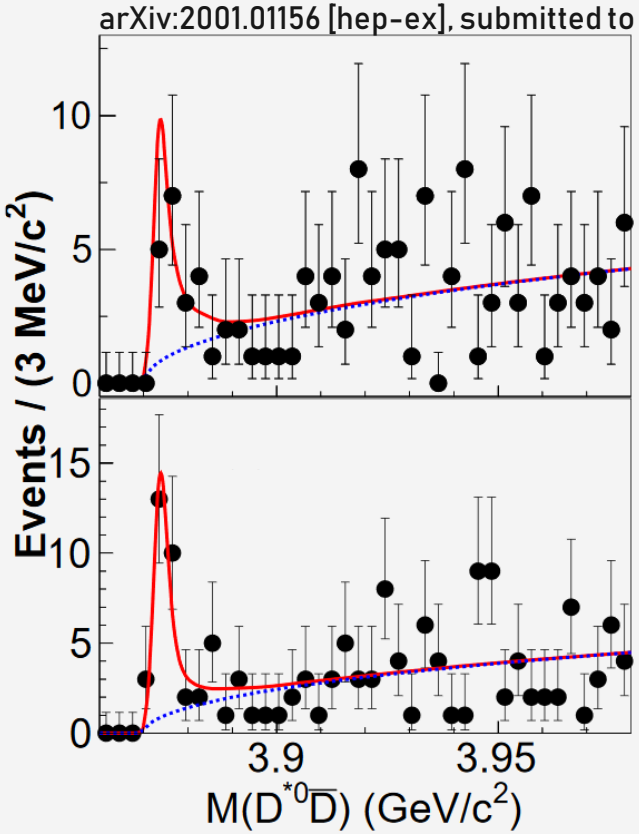
$X(3872) \to \gamma\psi(2S)$

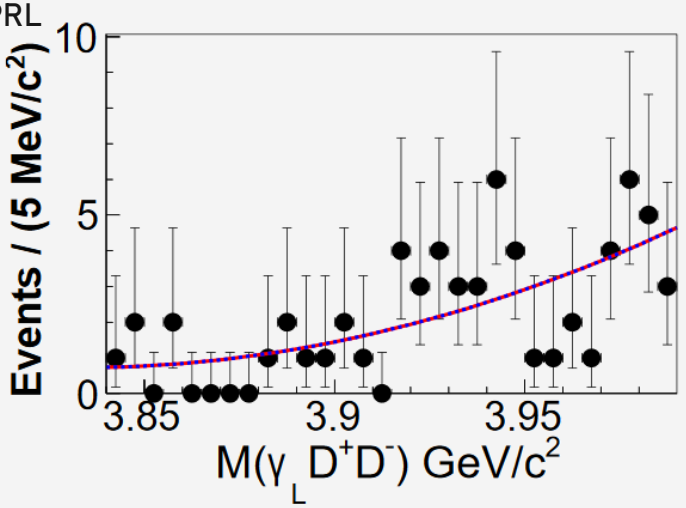


arXiv:2001.01156 [hep-ex], submitted to PRL

Recent results: $X(3872)$



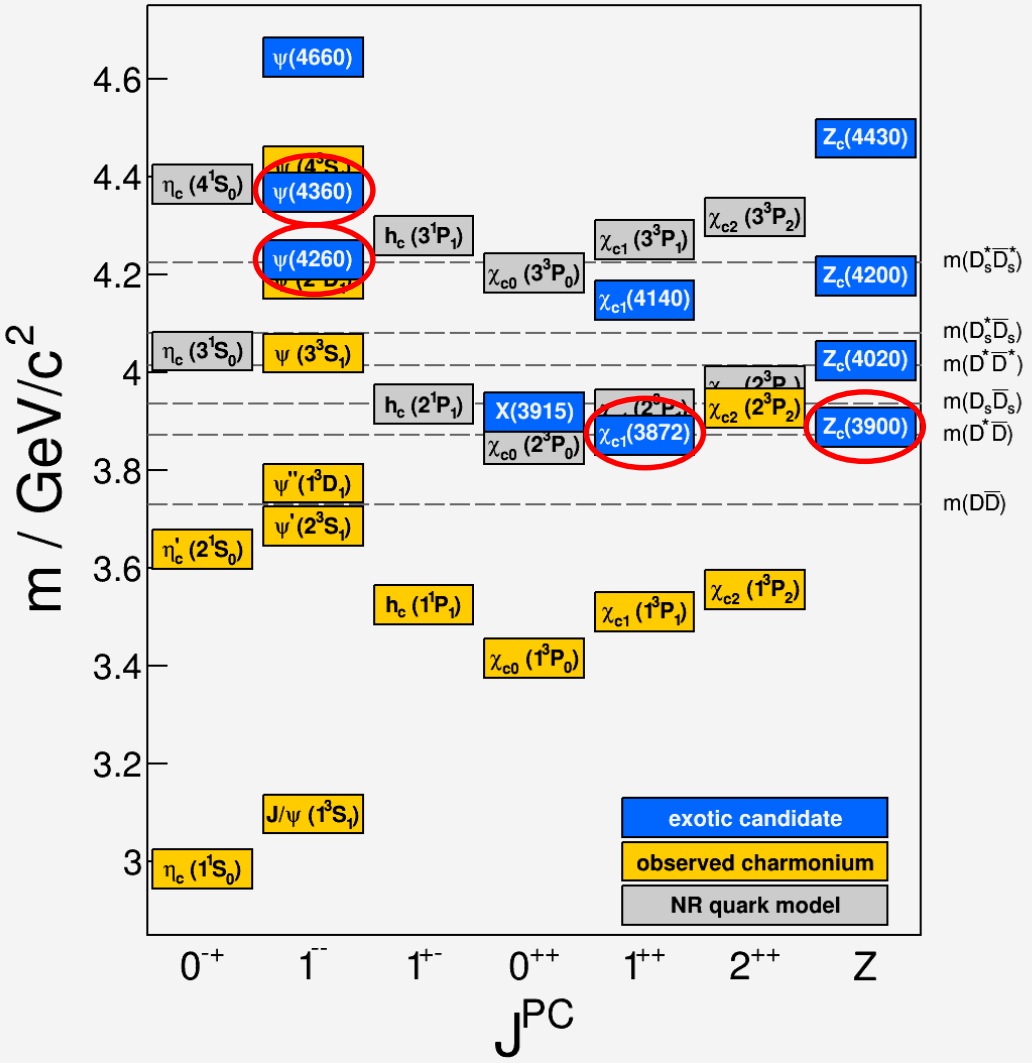




- clear signal found for $X(3872) \to D^{*0}\bar{D}^0$ in both $D^{*0} \to \gamma D^0$ and $D^{*0} \to \pi^0 D^0$ decay modes
- no signal for $X(3872) \to \gamma D^+ D^-$

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	-	-

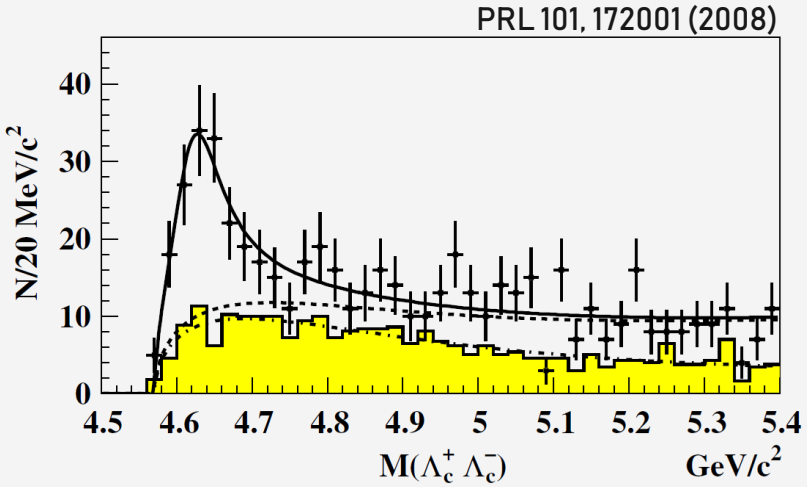
Summary

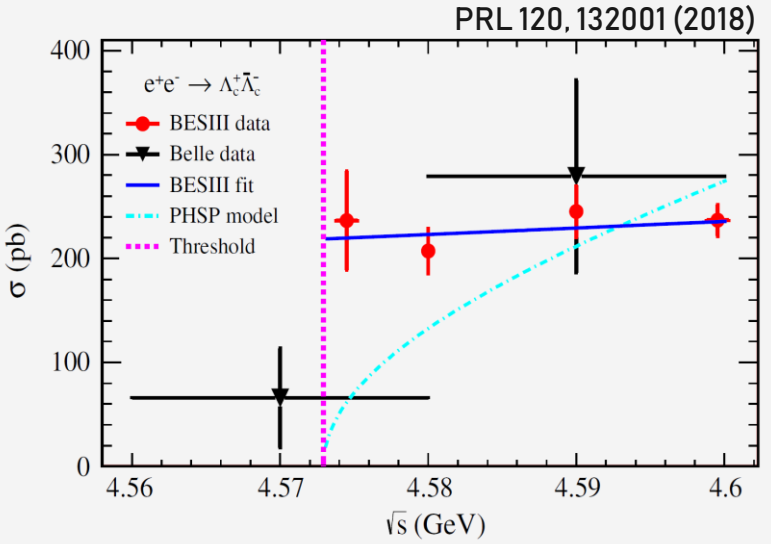


- to fully understand the XYZ states, studying their properties is highly important
- BESIII is uniquely suited to perform such studies, working directly in the energy region of interest
- strong signal of $Y(4220) \to \omega\chi_{c0}$
- first evidence for the decay $Z_c(3900)^{\pm} \to \eta_c\rho^{\pm}$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

Outlook

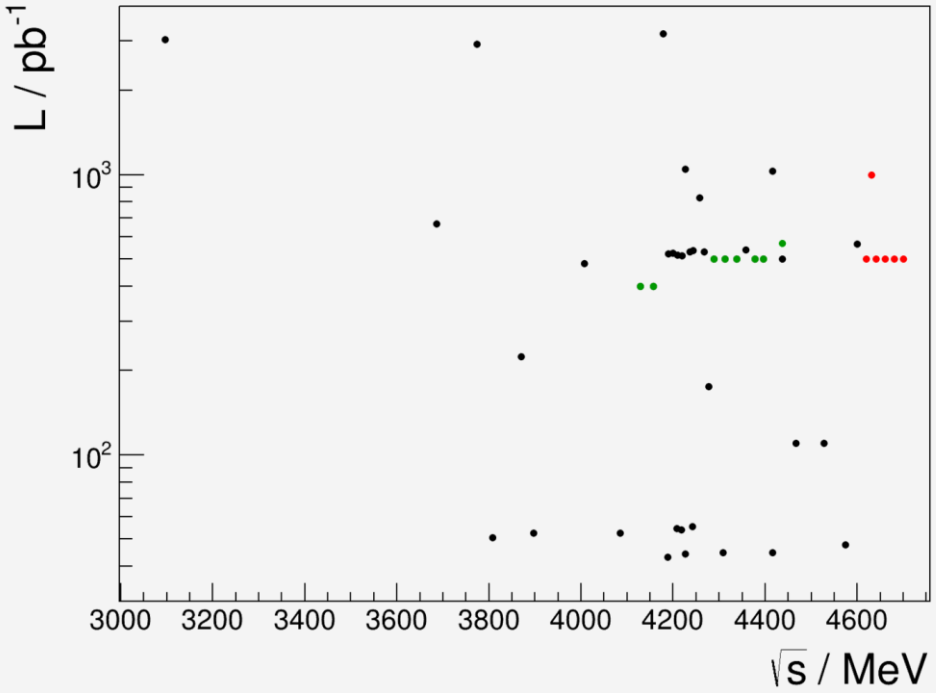
- $Y(4660)$ observed by Belle & BaBar in $Y(4660) \to \pi\pi\psi(2S)$, $\Lambda_c\overline{\Lambda}_c$
- BESIII measurement of $e^+e^- \to \Lambda_c\overline{\Lambda}_c$ indicates different trend

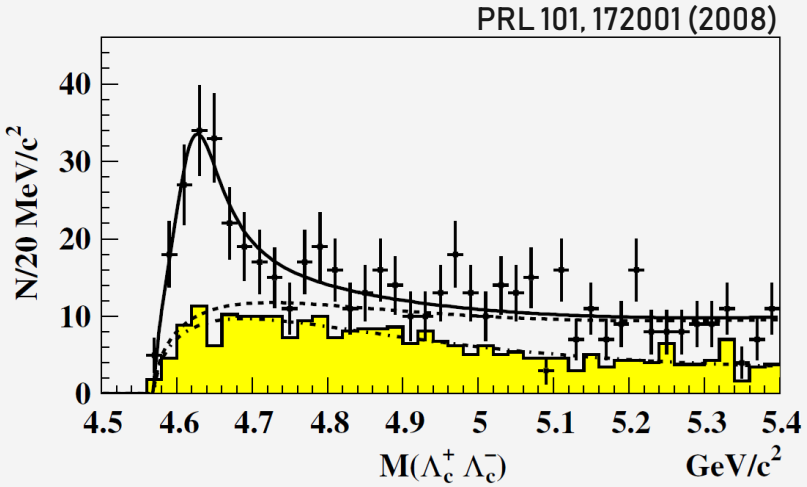


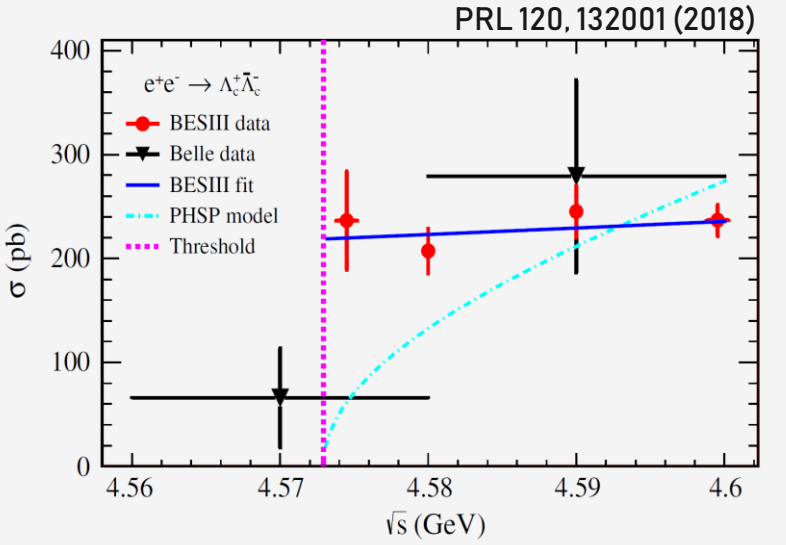


Outlook

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







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

Thank you for your attention!