

Recent Results in XYZ Physics at BESIII

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On behalf of **The BESIII Collaboration**

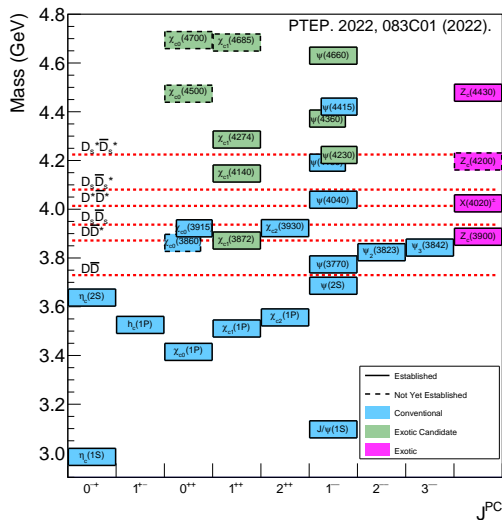
Lake Louise Winter Institute 2023

Outline

- Overview of charmonium spectrum
- BESIII and XYZ physics
- Recent results of note:
 - $e^+e^- \rightarrow \omega X(3872)$: A new production mechanism for $X(3872)$
 - $e^+e^- \rightarrow D^{*0}D^{*-}\pi^+$: Three peaks found in cross section
 - $e^+e^- \rightarrow K_S^0 D_S^+ D^{*-}, K_S^0 D_S^{*+} D^-$: A new isospin partner for $Z_{cs}(3985)^+$
- XYZ outlook at BESIII

The Charmonium System

List of Charmonium States



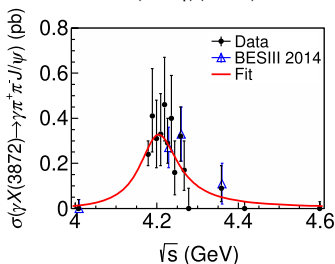
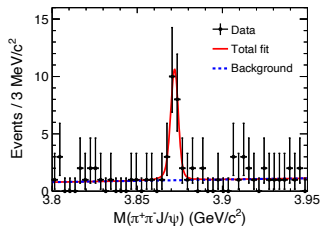
- Conventional charmonium ($c\bar{c}$) well-described by Cornell potential
- Some observed states have strange properties
- Others have properties totally incompatible with $c\bar{c}$ interpretation
- Some exotic candidates occur near open charm thresholds

The BESIII Experiment

arXiv:2204.08943

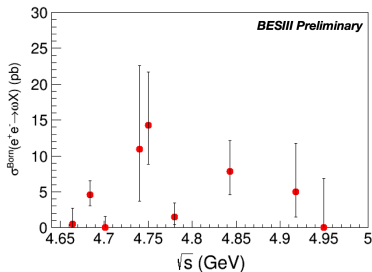
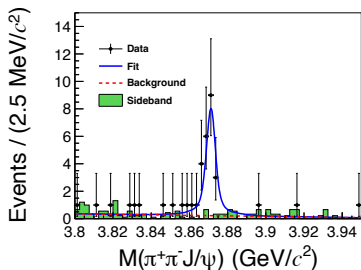
- BESIII runs at BEPCII accelerator in Beijing
- BEPCII is symmetric e^+e^- collider
- Data taken over wide range of energies include:
 - 10 billion J/ψ events for light hadron physics
 - 2.7 billion $\psi(2S)$ events for charmonium physics
 - 3 fb^{-1} of $\psi(3770)$ data for charm physics
- 23 fb^{-1} of targeted samples above 4 GeV for XYZ physics
 - Can produce the $Y(4230)$ directly
 - States produced nearly at rest with low backgrounds
 - Data at wide array of \sqrt{s} allows cross section measurement

X(3872) at BESIII

10.1103/PhysRevLett.112.092001
10.1103/PhysRevLett.122.232002

- X(3872) observed at BES in 2014 in $X(3872) \rightarrow \pi^+ \pi^- J/\psi$
- Production mechanism $e^+ e^- \rightarrow \gamma X(3872)$ greatest between 4.15 GeV and 4.30 GeV
- Very narrow for state at $D\bar{D}^*$ threshold
- Mass is too small to be pure charmonium
- Decays disproportionately to isospin-violating final states
- Molecular or mixed molecular-charmonium state expected

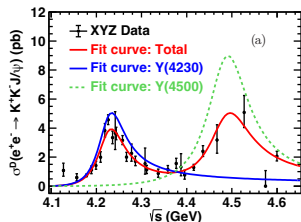
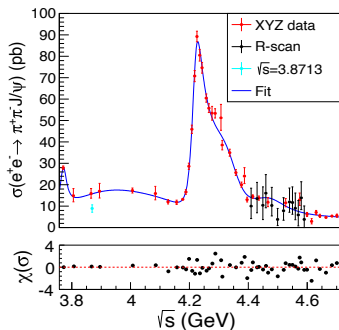
$$e^+e^- \rightarrow \omega X(3872)$$



- First observation of new production mechanism for $X(3872)$ at 7.5σ
- Collected using data with \sqrt{s} between 4.661 GeV and 4.951 GeV
- Cross section appears to peak around 4.75 GeV but further study required
- Suggests $X(3872)$ has some $\chi_{c1}(2P)$ component

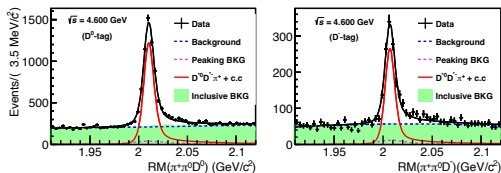
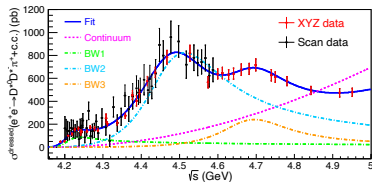
Y States at BESIII

10.1103/PhysRevD.106.072001
10.1088/1674-1137/ac945c



- $Y(4260)$ first discovered at BaBar
- Directly produced at BESIII, measured in $\pi^+\pi^- J/\psi$ mass
- No conventional charmonium expected in this region
- In 2017, structure resolved into $Y(4230)$ and a resonance at 4320 MeV
 - Is this the $Y(4360)$?
- In 2022, evidence for additional structure around 4.5 GeV found
- Also observed in $e^+e^- \rightarrow K^+K^- J/\psi$
 - May indicate strange-quark content
 - Related: $e^+e^- \rightarrow K_S^0 K_S^0 J/\psi$ (arXiv:2211.08561)

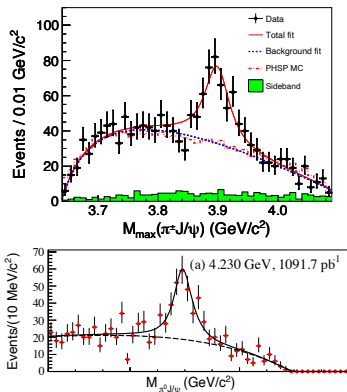
$$e^+e^- \rightarrow D^{*0}D^{*-}\pi^+$$

(a) D^* candidates

(b) Cross section

- Three charmonium-like structures found in open-charm final state
- Left and right structures consistent with $Y(4230)$, $Y(4660)$
 - Would disfavor hybrid interpretation of $Y(4230)$
 - First observation of $Y(4660)$ in open charm final states
- Center structure compatible with $Y(4500)$ — but not with possible hidden strange content

Z States at BESIII

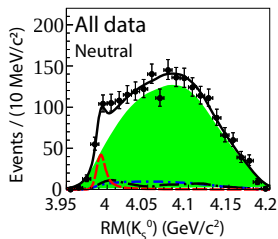
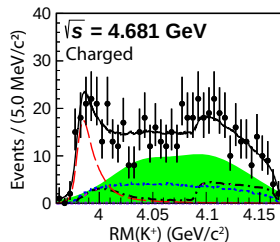
10.1103/PhysRevLett.110.252001
10.1103/PhysRevLett.115.112003

- $Z_c(3900)^\pm$ discovered in $\pi^\pm J/\psi$ mass in 2013 in process $e^+e^- \rightarrow \pi^+\pi^- J/\psi$ (top)
- Hidden charm, but also charged?
 - Clearly suggests minimal quark content $c\bar{c}q\bar{q}$ where q is u or d
- Neutral counterpart $Z_c(3900)^0$ observed in 2015 in process $e^+e^- \rightarrow \pi^0\pi^0 J/\psi$ (bottom)
- Similarly, isospin triplet $Z_c(4020)$ observed in $e^+e^- \rightarrow \pi\pi h_c$

$$e^+e^- \rightarrow K_S^0 D_s^+ D^{*-} \text{ and } e^+e^- \rightarrow K_S^0 D_s^{*+} D^-$$

arXiv:2204.13703

\blacktriangle Data \color{green} Comb. Bkg \color{red} $Z_{cs}(3985)$
 \color{black} Total PDF \color{blue} Non-resonant \color{black} $D_s^{**}D_s$



- Charged structure $Z_{CS}(3985)^+$ first observed in 10.1103/PhysRevLett.126.102001
- Evidence for neutral isospin partner $Z_{CS}(3985)^0$ found at 4.6σ
- Z_{CS} states predicted as $c\bar{c}s\bar{q}$

| | Mass (MeV/ c^2) | Width (MeV) |
|------------------|--------------------------------|------------------------------|
| $Z_{CS}(3985)^+$ | $3982.5^{+1.8}_{-2.6} \pm 2.1$ | $12.8^{+5.3}_{-4.4} \pm 3.0$ |
| $Z_{CS}(3985)^0$ | $3992.2 \pm 1.7 \pm 1.6$ | $7.7^{+4.1}_{-3.8} \pm 4.3$ |

Summary and Outlook

- Several significant contributions to XYZ physics
- New production of the $X(3872)$ observed
- Multiple Y -like structures found in open charm decays
- Isospin-triplet hidden charm-states with strangeness seen
- BESIII plans to operate for up to 10 more years
- Upgrades planned for 2024
 - Increase center of mass energy up to 5.6 GeV \rightarrow access new thresholds!
 - Increase luminosity by a factor of 3 \rightarrow better statistics!
- Many more analyses in the works