Charmonium-like states at BESIII

Will Imoehl
Indiana University
on behalf of the BESIII collaboration

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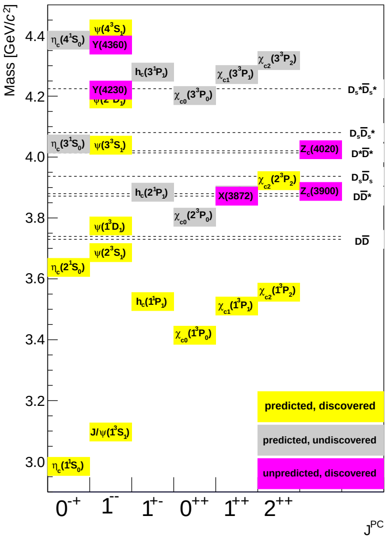
Outline

- Intro to the XYZ states
- Intro to the BESIII experiment
- Highlights of past XYZ results
- Recent searches for $X(3872)$ decay modes
- Recent searches for Y decay modes
- The $Z_{cs}(3985)$

Intro to the Charmonium Spectrum and the XYZ States

Phys. Rev. D 72, 054026 (2005)

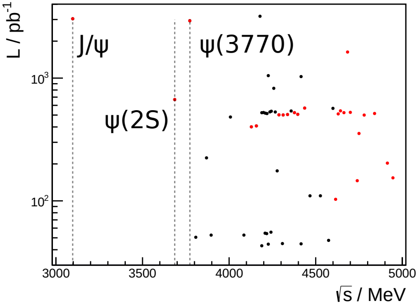


- Bound state of $c\bar{c}$
- Modelled by Cornell potential
- States below $D\bar{D}$ all discovered
- Many states above $D\bar{D}$ missing
- Several unexpected states above $D\bar{D}$
- $\chi_{c1}(3872)$ (a.k.a. $X(3872)$) has $J^{PC} = 1^{++}$
- More ψ states than expected (a.k.a. Y states)
- Z_c states are isovectors, clearly exotic nature

XYZ states appear near open charm thresholds

$Y(4230)$ decays to $X(3872)$ and Z_c's - implies similar nature

Intro to the BESIII Experiment

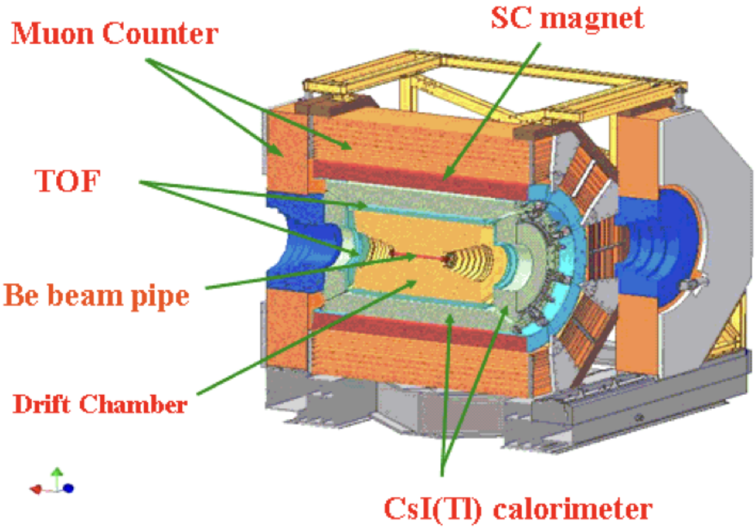


- Symmetric e^+e^- collisions with $2 < E_{\rm cm} < 5$ GeV
- 10 billion J/ψ (light hadron)
- 2.7 billion $\psi(2S)$ (charmonium)
- 3 fb^{-1} at $\psi(3770)$ (charm)
- 23 fb^{-1} at $E_{\rm cm} > 4$ GeV for XYZ physics

Excellent environment for XYZ physics

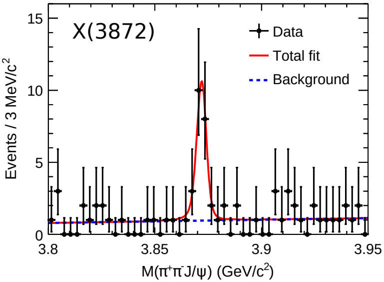
- $Y(4230)$ can be directly produced via e^+e^- annihilation
- Perform energy scans and measure cross sections
- Resonance parameters determined by fits to cross sections
- States are produced nearly at rest
- Low backgrounds
- Can reconstruct complicated decay modes of XYZ states

The BESIII Detector

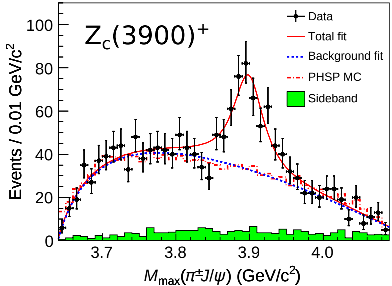


Highlights of Past Results at BESIII

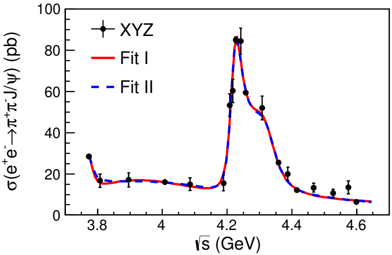
Phys. Rev. Lett. 112, 092001 (2014)



Phys. Rev. Lett. 110, 252001 (2013)



Phys. Rev. Lett. 118, 092001 (2017)



Top left: first observation of $e^+e^- \to \gamma X(3872)$

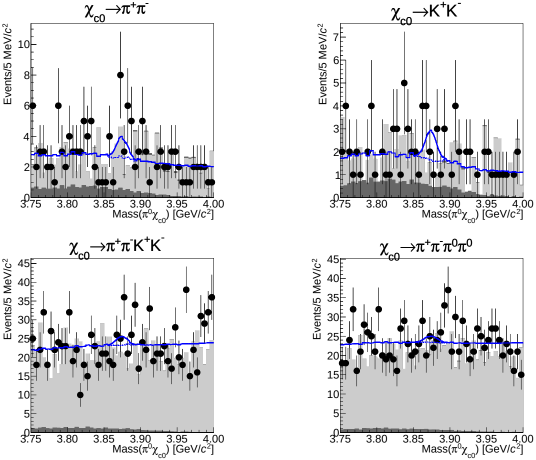
Bottom left: first observation of $Z_c(3900)^+$

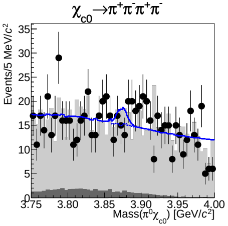
Top right: $Y(4260)$ resolved into $Y(4230)$ and $Y(4360)$

Search for New $X(3872)$ Decays

Search for $X(3872) \to \pi^0 \chi_{c0}$

10.1103/PhysRevD.105.072009





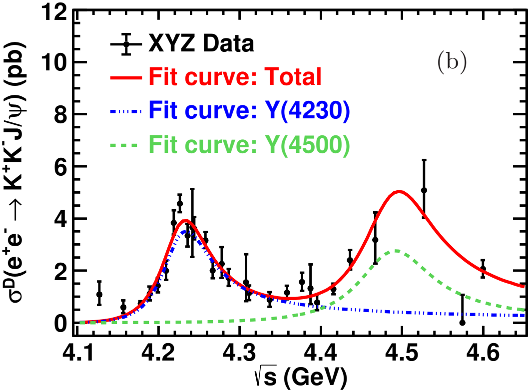
Upper limits also set for $X(3872) \to \pi\pi\chi_{c0}$

	Theoretical		Measured
	Four Quark	$c\bar{c}$	90% C.L. UL
$\frac{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^0\chi_{c1})}$	≈ 3	0	< 4.5

Search for New Y Decays

$Y(4230)$ in $e^+e^- \to K^+K^-J/\psi$ arXiv:2204.07800

Motivation: probe strange quark content of $Y(4230)$ and search for predicted state near 4.5 GeV

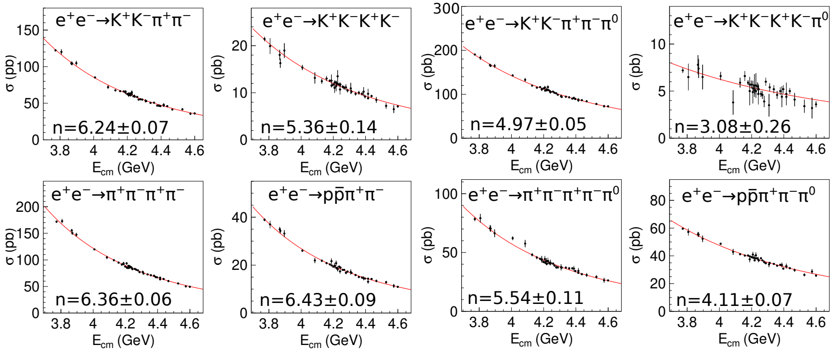


- First observation of $Y(4230) \to K^+K^-J/\psi$
- Cross section clearly rises after $Y(4230)$, more statistics needed to figure out what is happening near 4.5 GeV

Light Hadron Decays

10.1103/PhysRevD.104.112009

Motivation: no light hadron decays for charmonium(-like) states have been observed above 4 GeV

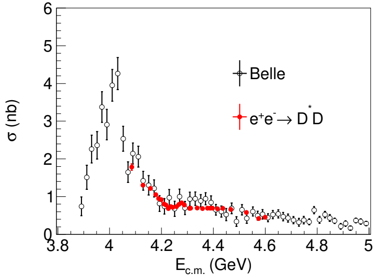


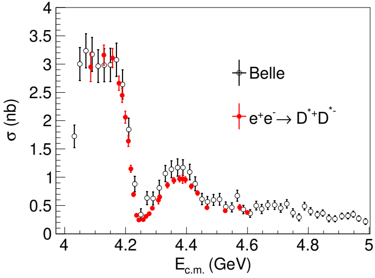
- Precise light hadron cross section measurements
- Fit with $\frac{1}{\sqrt{E_{\mathrm{cm}}}^{n}}$
- No observed charmonium resonances
- No evidence for $Y(4230)$ for any final state

Measurement of $\sigma(e^+e^- \to D^{*+}D^{(*)-})$

arXiv:2112.06477

Motivation: Open charm cross section measurements essential to fully understand XYZ states (input to coupled channel analyses)





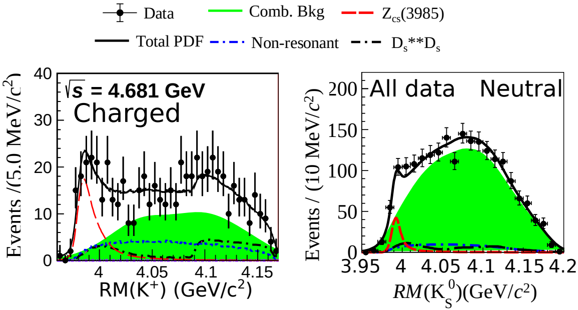
Cross section for $e^+e^- \to D^*D$ (left) and $e^+e^- \to D^*D^*$ (right)
Improved precision will help coupled channel analysis

Search for New Z States

The $Z_{cs}(3985)$

Phys.Rev.Lett.126.102001 and arXiv:2204.13703

Found at $D_s D^*$ and $D_s^* D$ thresholds in $e^+e^- \to K(D_s D^* + D_s^* D)$



- Strange partner of Z_c
- 5.3σ observation of charged state (minimally $c\bar{c}s\bar{u}$)
- 4.6σ evidence for neutral state (minimally $c\bar{c}s\bar{d}$)

State	Mass (MeV/c^2)	Width (MeV)	Significance
$Z_{cs}(3985)^+$	$3985.2^{+2.1}_{-2.0} \pm 1.7$	$13.8^{+8.1}_{-5.2} \pm 4.9$	5.3σ
$Z_{cs}(3985)^0$	$3992.2 \pm 1.7 \pm 1.6$	$7.7^{+4.1}_{-3.8} \pm 4.3$	4.6σ

Summary and Outlook

- BESIII is very active in XYZ studies
- Searches for $X(3872)$ and $Y(4230)$ decays
- More precise open charm cross sections
- Observe $Z_{cs}(3985)^-$, evidence for $Z_{cs}(3985)^0$
- Accelerator upgrade planned for 2024
  - Luminosity increase up to factor of 3 depending on energy
  - Energies up to 5.6 GeV
- More analyses are on the way

Thanks for your attention!