

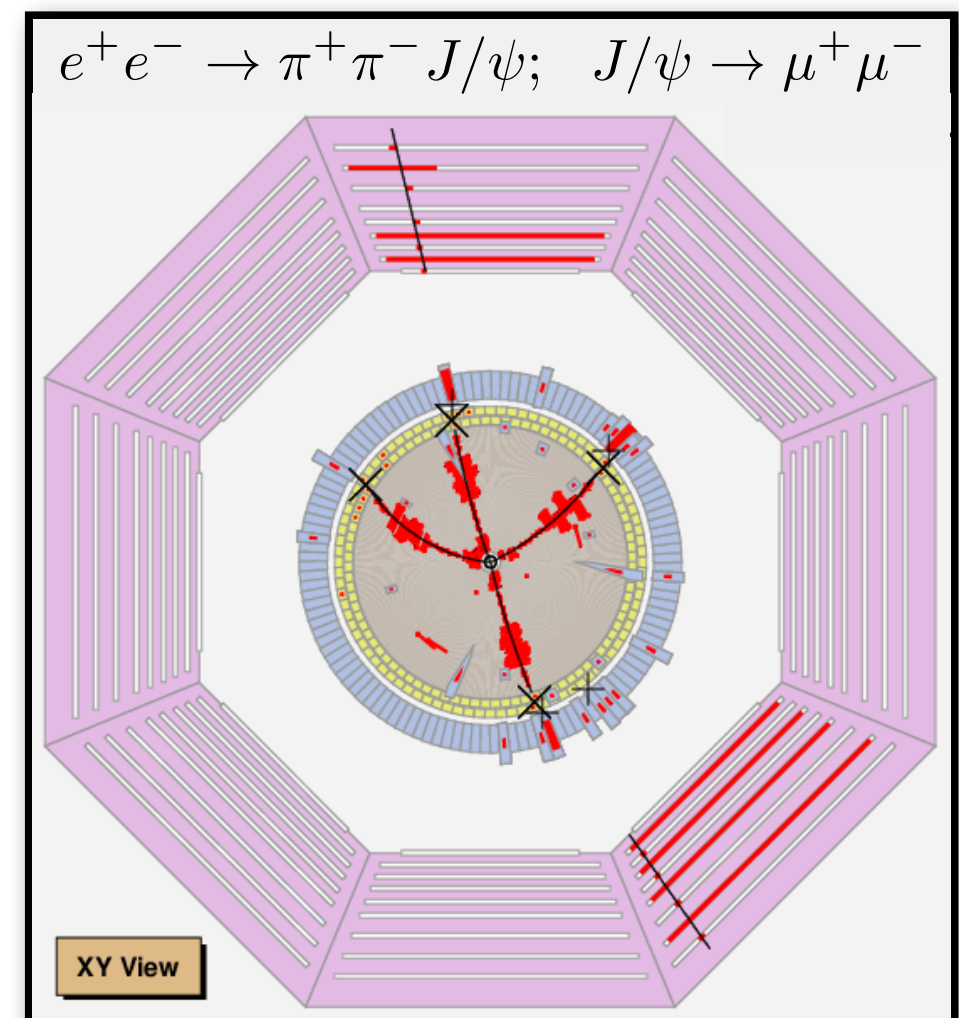
Hadron Spectroscopy at the BESIII Experiment

Ryan Mitchell (Indiana University)
Snowmass Cincinnati Meeting, May 17, 2022

BEPCII: Beijing Electron Positron Collider
symmetric e^+e^- collisions at E_{CM} between 2.0 and 5.0 GeV



BESIII: Beijing Spectrometer
a versatile detector covering 93% of 4π



running since 2009 at the Institute of High Energy Physics in Beijing, China

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel analyses</i>	no plans (analyze current data)
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow pp\pi$ $\psi(2S) \rightarrow pp\eta$ $\psi(2S) \rightarrow \Lambda\Sigma\pi$	2.7 billion $\psi(2S)$ decays	<i>further explorations in J/ψ, $\psi(2S)$, and other charmonium decays</i>	
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c\bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>		<i>rare and precision transitions; properties of ψ_2; search for η_{c2}...</i>	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi\pi J/\psi$ $ee \rightarrow \pi\pi\psi(2S)$ $ee \rightarrow D^*D^*$	> 20 fb ⁻¹ of data at E _{cm} above 4 GeV	<i>more data; coupled-channel analyses of e^+e^- cross sections</i>	BEPCCII-U UPGRADE: (1) 3× luminosity for E _{cm} above 4 GeV (2) maximum energy increase from 5 to 5.6 GeV ⇒ much larger data sets above 4 GeV (plans are being made); and expanded energy reach into new territory
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$		<i>new Z_c and Z_{cs} decays; E_{cm} dependence; coupled-channels...</i>	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi\chi_{c1}$ $X(3872) \rightarrow DD^*$		<i>increased precision and searches for new $X(3872)$ decay modes</i>	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb ⁻¹ above $\Lambda_c\Lambda_c$ threshold	<i>access to more D and D_s excited states</i>	
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	

Hadron Spectroscopy at the BESIII Experiment

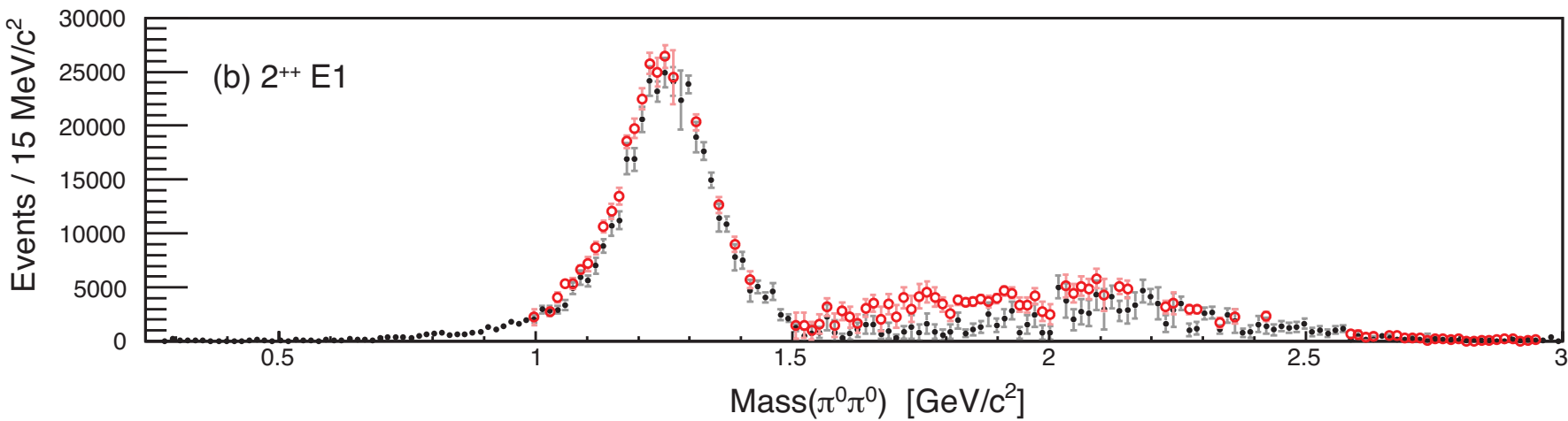
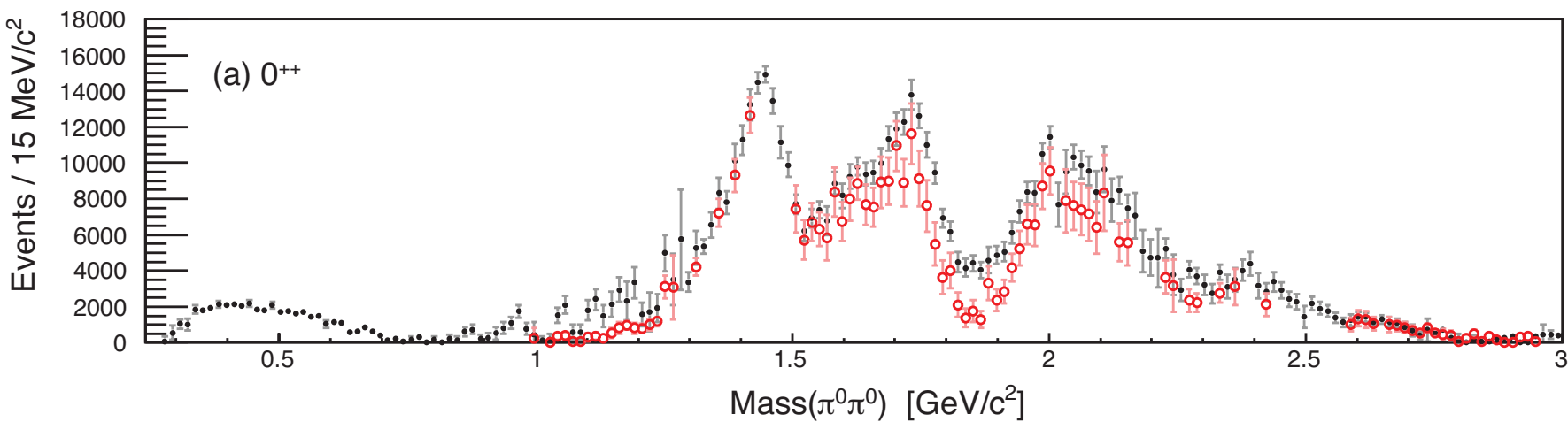
TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	10 billion J/ψ decays	glueballs, hybrids, coupled-channel	
CHARMED BARYON SPECTROSCOPY	$ee \rightarrow D_s D^{(*)} K$	2.7 billion J/ψ decays		
CHARMED BARYON SPECTROSCOPY	decays of the Λ_c	3 fb ⁻¹ at threshold	(and excitations), and possibly the P_c	reach into new territory

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel analyses</i>	no plans (current data)
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p \bar{p} \pi$	2.7 billion $\psi(2S)$ decays	<i>further explorations</i>	
CHARMONIUM SPECTROSCOPY				
“Y” MESON SPECTROSCOPY				UPGRADE:
“Z” MESON SPECTROSCOPY				luminosity above 4 GeV
“X” MESON SPECTROSCOPY				max energy base from 5.6 GeV
CHARMED MESON SPECTROSCOPY				larger data above 4 GeV (being made);
CHARMED BARYON SPECTROSCOPY				extended energy into new territory

$J/\psi \rightarrow \gamma \pi^0 \pi^0$ (1.3B J/ψ)

PRD92, 052003 (2015)



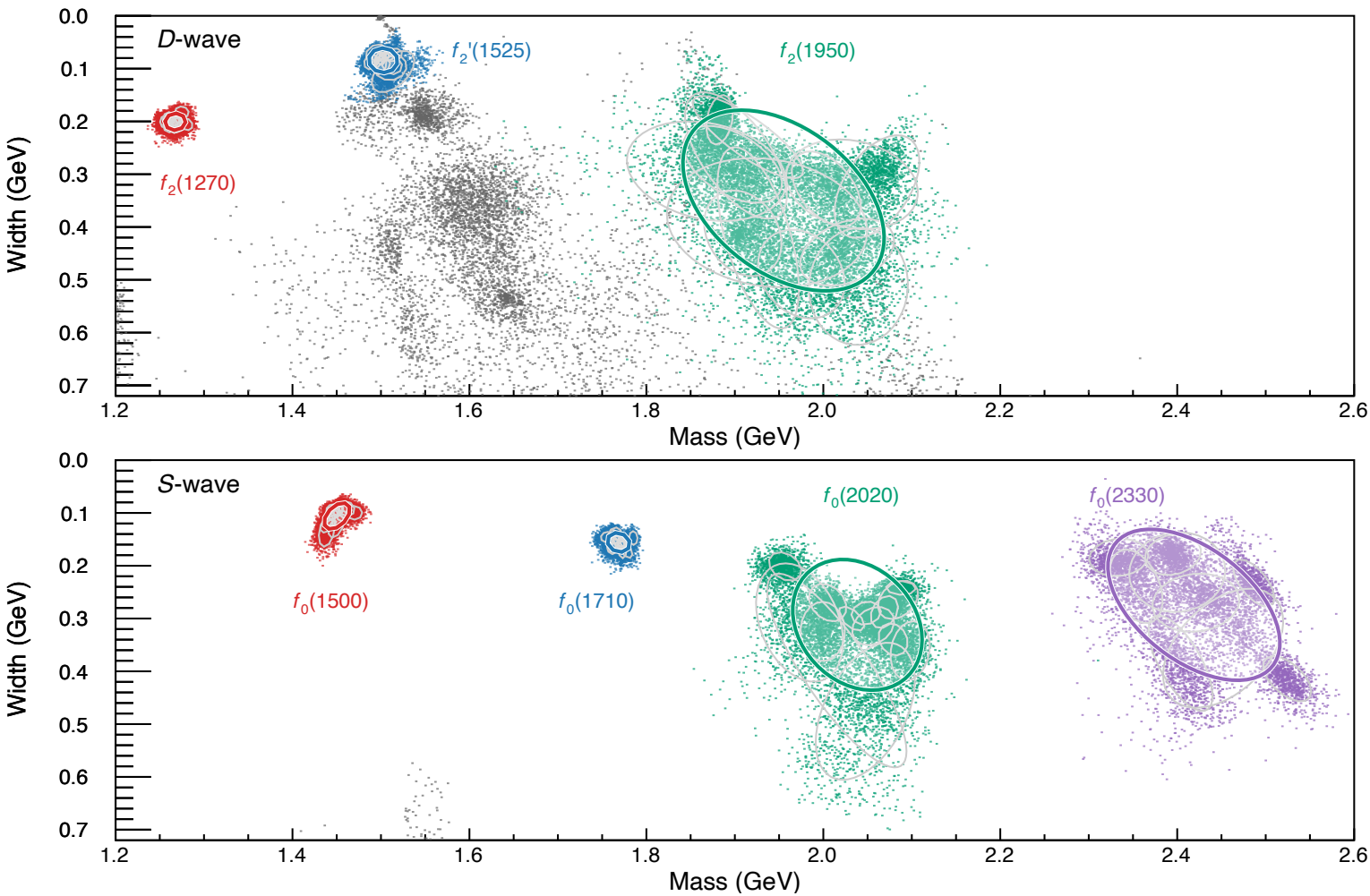
⇒ Radiative J/ψ decays are a key component in glueball searches.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$	10 billion J/ψ decays	glueballs, hybrids, coupled-channel analyses	
LIGHT BARYON SPECTROSCOPY				no plans (re-use current data)
CHARMONIUM SPECTROSCOPY				
“Y” MESON SPECTROSCOPY				BEU UPGRADE:
“Z” MESON SPECTROSCOPY				× luminosity above 4 GeV
“X” MESON SPECTROSCOPY				maximum energy increase from to 5.6 GeV
CHARMED MESON SPECTROSCOPY				much larger data above 4 GeV (are being made);
CHARMED BARYON SPECTROSCOPY				expanded energy into new territory

JPAC, Coupled-channel Analysis of $J/\psi \rightarrow \gamma\pi\pi$ and γKK

EPJC82, 80 (2022)



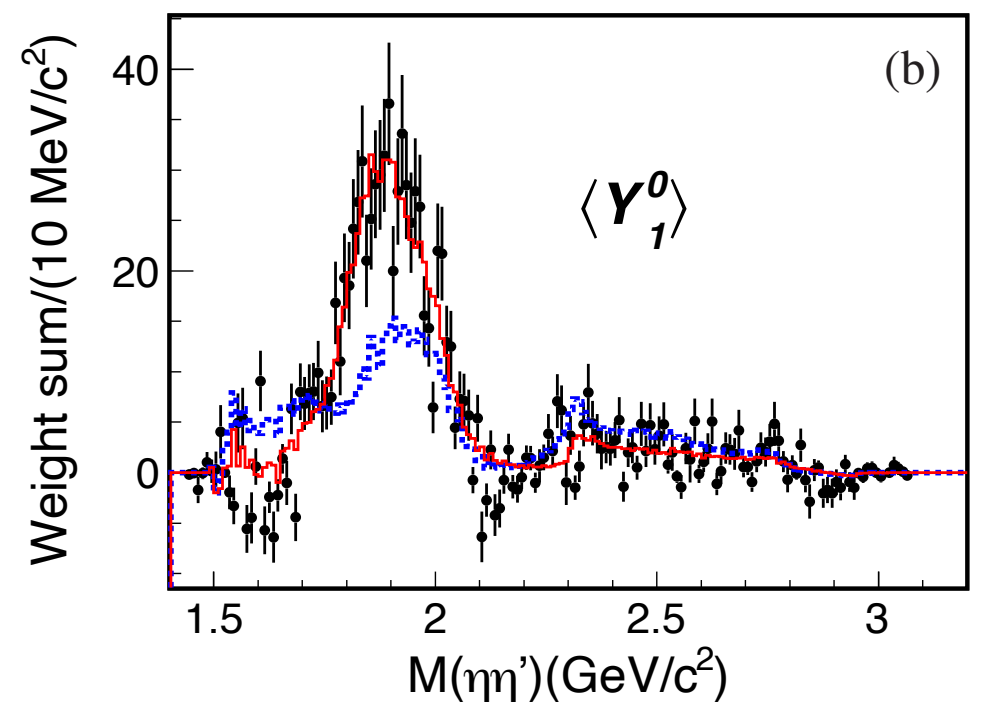
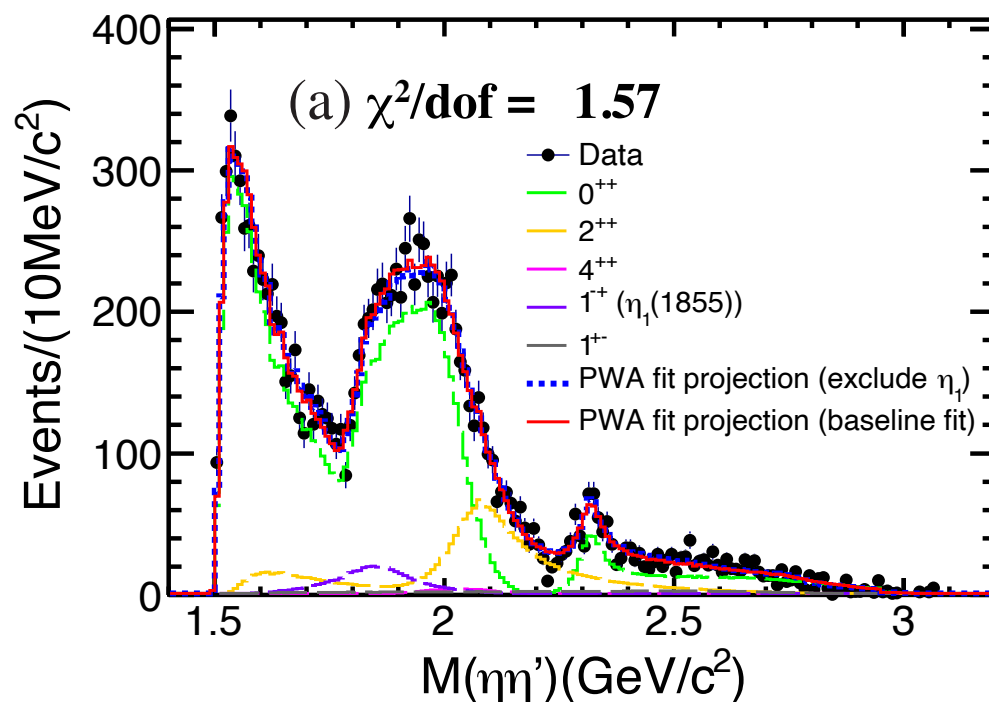
⇒ Multiple channels must be analyzed simultaneously to probe coupled-channel effects.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$	10 billion J/ψ decays	glueballs, hybrids, coupled-channel analyses	
LIGHT BARYON SPECTROSCOPY			further explorations	
CHARMONIUM SPECTROSCOPY				
“Y” MESON SPECTROSCOPY				
“Z” MESON SPECTROSCOPY				
“X” MESON SPECTROSCOPY				
CHARMED MESON SPECTROSCOPY				
CHARMED BARYON SPECTROSCOPY				

Discovery of the $\eta_1(1855)$ in $J/\psi \rightarrow \gamma\eta\eta'$ (10B J/ψ)

arXiv: 2202.00621



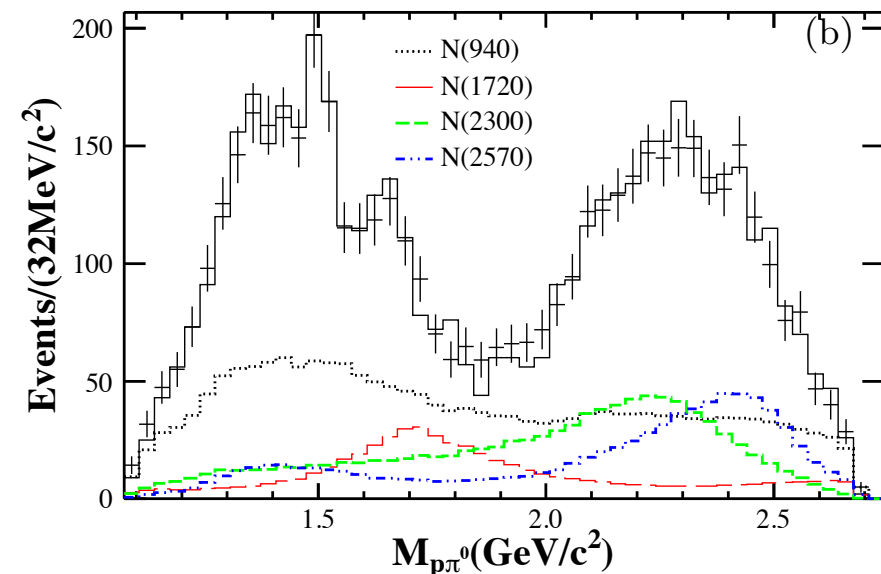
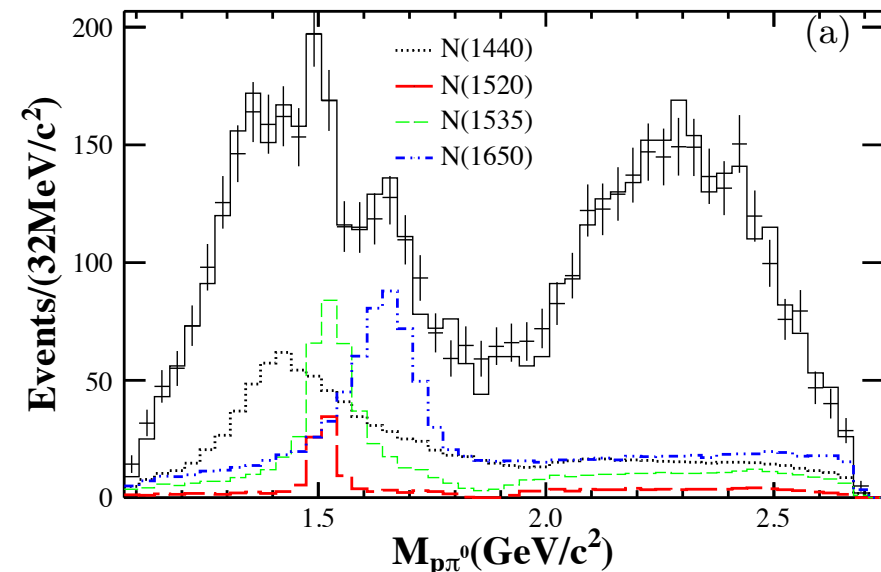
\Rightarrow Hybrid mesons (or at least exotic J^{PC} mesons) are also produced in J/ψ radiative decays.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	10 J/ψ
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p \bar{p} \pi$ $\psi(2S) \rightarrow p \bar{p} \eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$	2. ψ(2S)
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c \bar{c}$ $\psi(2S) \rightarrow \pi h_c$ decays of η_c & h_c	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$	
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$	> 20 at E _{cm}
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{c1}$ $X(3872) \rightarrow DD^*$	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb ⁻¹ th
CHARMED BARYON SPECTROSCOPY	decays of the Λ_c	

$$\psi(2S) \rightarrow p \bar{p} \pi^0 \quad (106M \psi(2S))$$

PRL110, 022001 (2013)



⇒ Baryon spectroscopy can be advanced using $\psi(2S)$ and other charmonium decays.

Hadron Spectroscopy at the BESIII Experiment

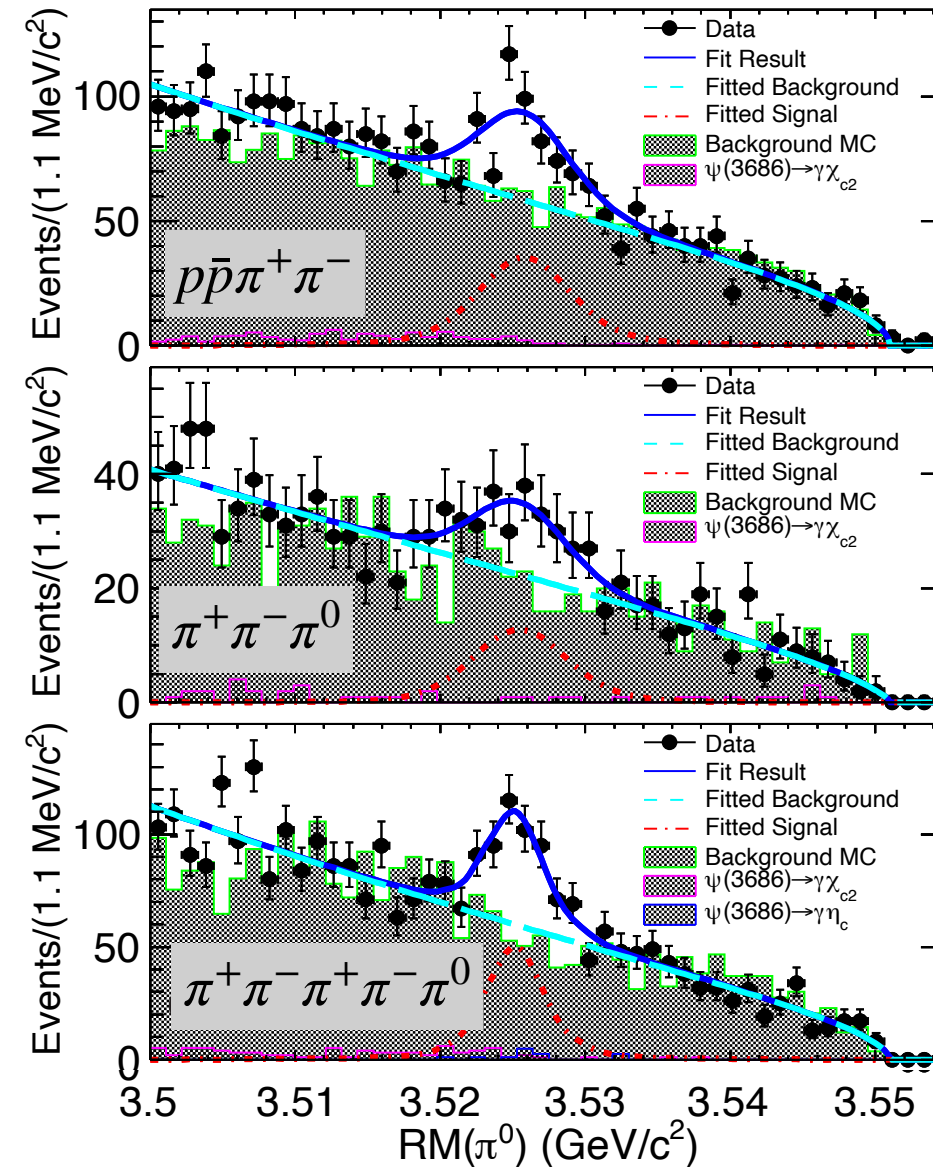
TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \pi \eta$	10 billion	<i>glueballs, hybrids,</i>	
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow \gamma p \bar{p}$ $\psi(2S) \rightarrow \gamma n \bar{n}$ $\psi(2S) \rightarrow \gamma \Lambda \bar{\Lambda}$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma \psi(1S)$ $\psi(2S) \rightarrow \gamma \psi(2S)$ <i>decays</i>	<div> <p>$\psi(2S) \rightarrow \gamma + \text{hadrons (106M } \psi(2S))$</p> <p>PRD96, 032002 (2017)</p> <p>\Rightarrow The $\psi(2S)$ data provides access to other charmonium states and provides opportunities for precision measurements.</p> </div>		
“Y” MESON SPECTROSCOPY	$ee \rightarrow \gamma \psi(2S)$ $ee \rightarrow \gamma \psi(2S)$ $ee \rightarrow \gamma \psi(2S)$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \gamma \psi(2S)$ $Z_c(4020) \rightarrow \gamma \psi(2S)$ $Z_{cs}(3985) \rightarrow \gamma \psi(2S)$			
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \gamma \psi(2S)$ $X(3872) \rightarrow \gamma \psi(2S)$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^* (2517)$ $ee \rightarrow D_s D(^*) K$	$> 5 \times 10^4$ above $\Lambda_c \Lambda_c$ threshold	<i>access to more D and D_s excited states</i>	<i>larger data sets above 4 GeV (plans are being made);</i>
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	<i>and expanded energy reach into new territory</i>

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p\bar{p}\pi$ $\psi(2S) \rightarrow p\bar{p}\eta$ $\psi(2S) \rightarrow \Lambda\Sigma\pi$
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c\bar{c}b\bar{a}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi\pi J/\psi$ $ee \rightarrow \pi\pi\psi(2S)$ $ee \rightarrow D^*D^*$
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (P) <i>etc.</i> $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D$
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi\chi_{c1}$ $X(3872) \rightarrow DD^*$
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>

$\psi(2S) \rightarrow \pi^0 h_c$ with h_c to hadrons (448M $\psi(2S)$)

PRD99, 072008 (2019)



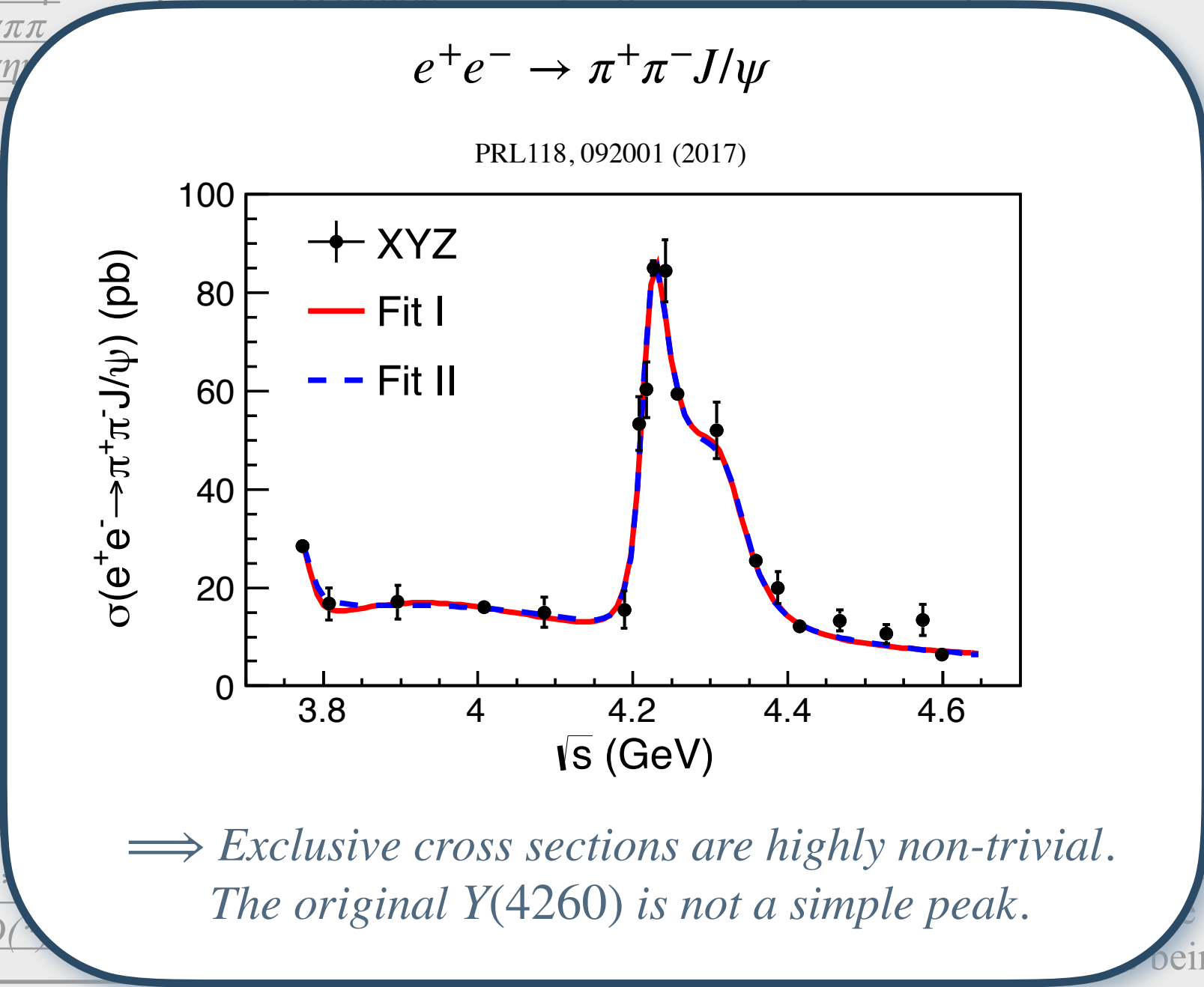
\Rightarrow Traditionally difficult states, like the $h_c(1P)$, can be studied in detail using both the $\psi(2S)$ data and higher-energy data.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel analyses</i>	no plans (analyze current data)
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow pp\pi$ $\psi(2S) \rightarrow pp\eta$ $\psi(2S) \rightarrow \Lambda\Sigma\pi$	2.7 billion $\psi(2S)$ decays	<i>further explorations in J/ψ, $\psi(2S)$, and other charmonium decays</i>	
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c\bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>		<i>rare and precision transitions; properties of ψ_2; search for η_{c2}...</i>	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi\pi J/\psi$ $ee \rightarrow \pi\pi\psi(2S)$ $ee \rightarrow D^*D^*$	> 20 fb ⁻¹ of data at E_{cm} above 4 GeV	<i>more data; coupled-channel analyses of e^+e^- cross sections</i>	BEPCCII-U UPGRADE: (1) 3× luminosity for E_{cm} above 4 GeV (2) maximum energy increase from 5 to 5.6 GeV ⇒ much larger data sets above 4 GeV (plans are being made); and expanded energy reach into new territory
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$		<i>new Z_c and Z_{cs} decays; E_{cm} dependence; coupled-channels...</i>	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi\chi_{c1}$ $X(3872) \rightarrow DD^*$		<i>increased precision and searches for new $X(3872)$ decay modes</i>	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb ⁻¹ above $\Lambda_c\Lambda_c$ threshold	<i>access to more D and D_s excited states</i>	
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	

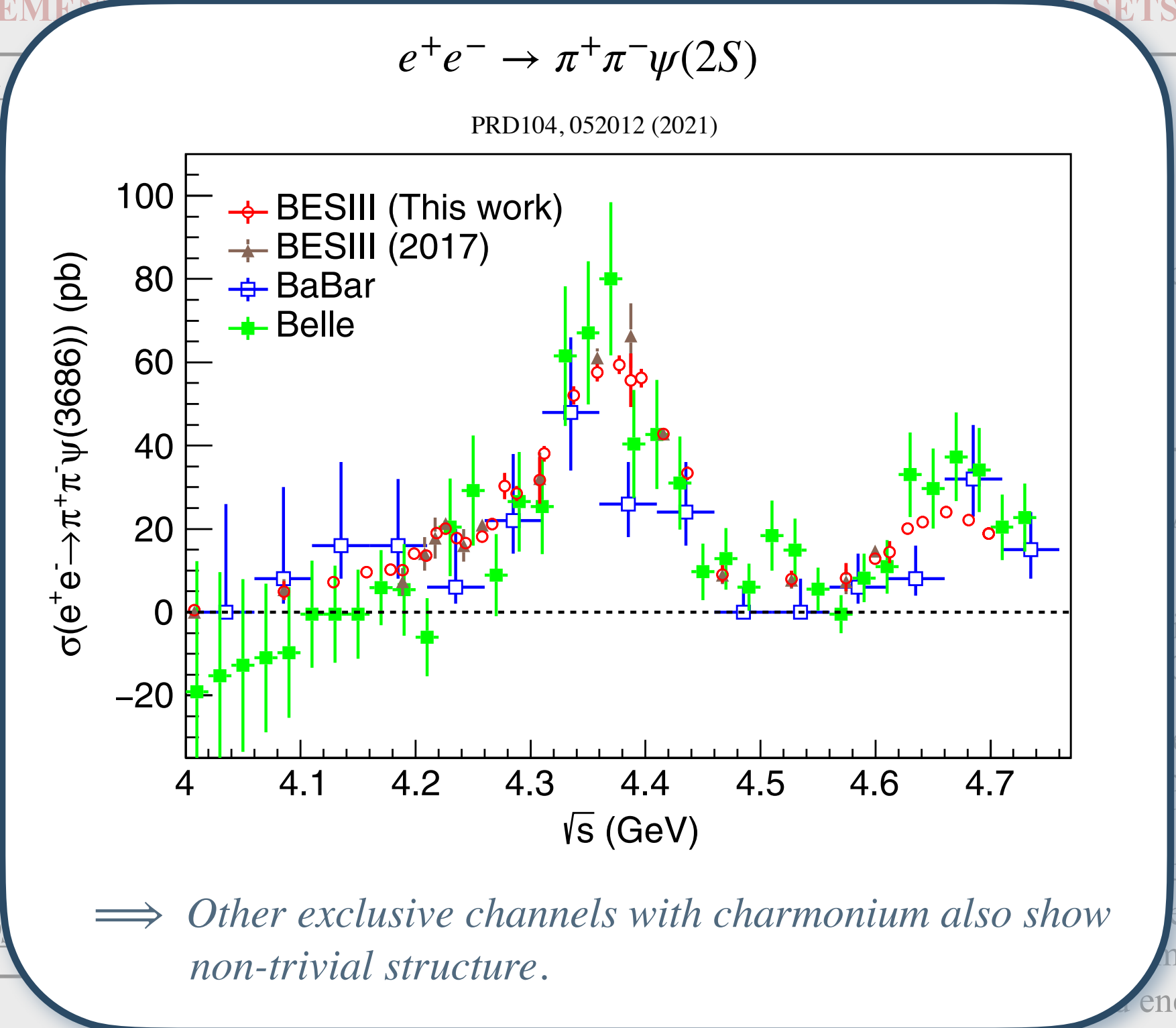
Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta$	10 billion	glueballs, hybrids,	
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow$ $\psi(2S) \rightarrow$ $\psi(2S) \rightarrow$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma$ $\psi(2S) \rightarrow$ decays of η			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi$ $ee \rightarrow \pi \pi \psi$ $ee \rightarrow D^*$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi$ $Z_c(4020) \rightarrow$ $Z_{cs}(3985) \rightarrow$			
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3$ $X(3872) \rightarrow$ $X(3872) \rightarrow$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow Ds^* Ds^*$ $ee \rightarrow Ds D^*$			
CHARMED BARYON SPECTROSCOPY	decays of the Λ_c		access to the Σ_c , Ξ_c , Ω_c (and excitations), and possibly the P_c	and expanded energy reach into new territory

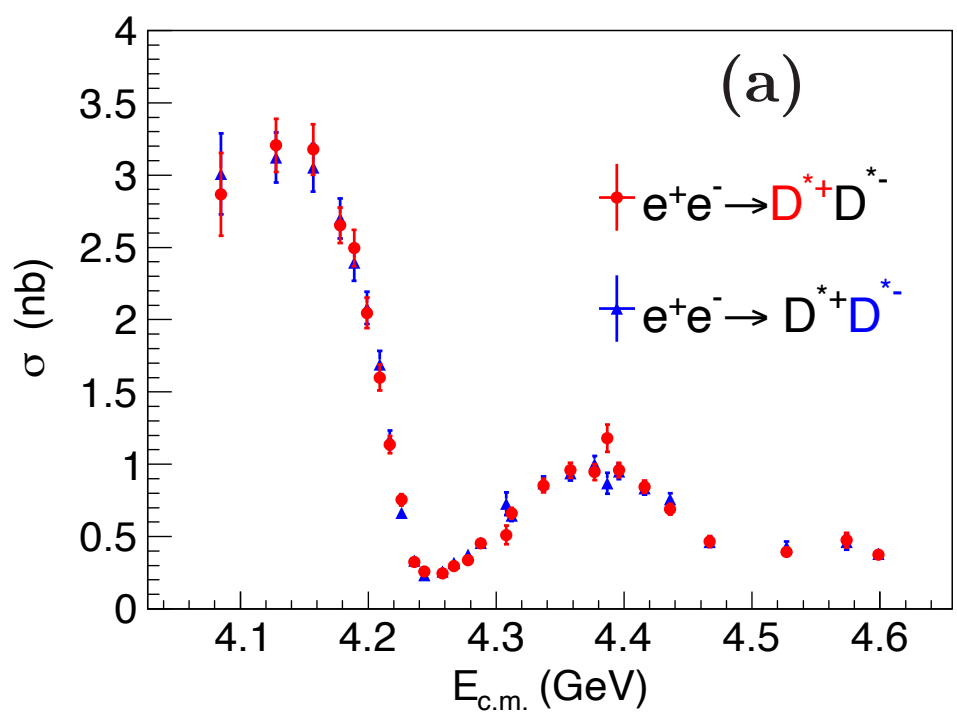
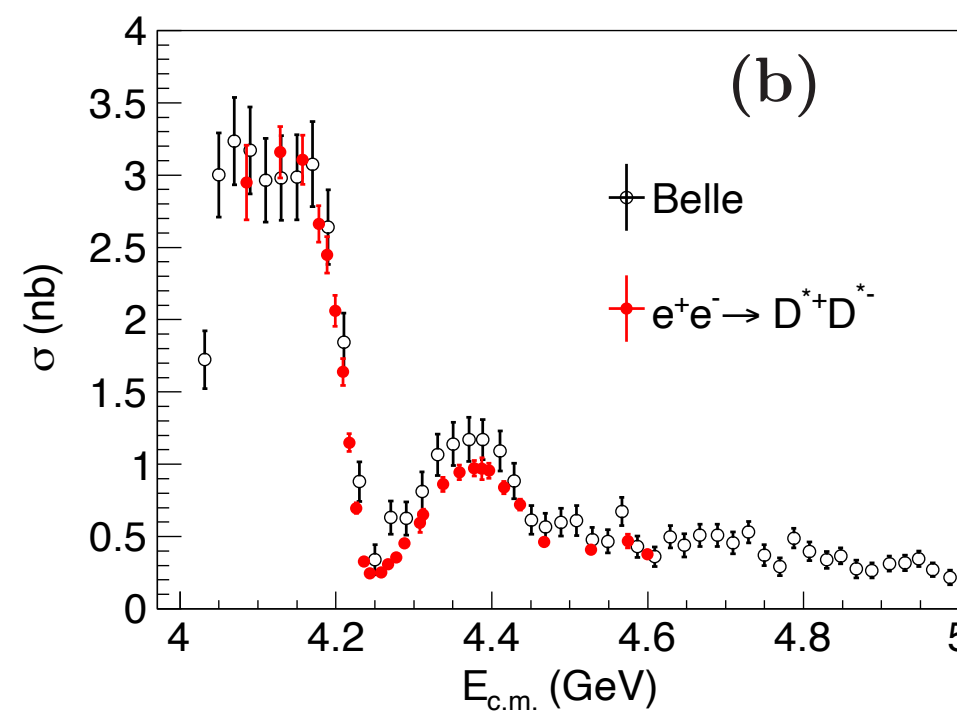


Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT	PROSPECTS	FUTURE
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \pi^+\pi^-$ $J/\psi \rightarrow \rho^+\rho^-$ $J/\psi \rightarrow \omega\pi^0$			
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p\bar{p}$ $\psi(2S) \rightarrow n\bar{n}$ $\psi(2S) \rightarrow \Lambda\bar{\Lambda}$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \pi^+\pi^-\psi(3686)$ $\psi(2S) \rightarrow \pi^+\pi^-\psi(3686)$ $\psi(2S) \rightarrow \pi^+\pi^-\psi(3686)$			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi^+\pi^-\psi(3686)$ $ee \rightarrow \pi^+\pi^-\psi(3686)$ $ee \rightarrow \pi^+\pi^-\psi(3686)$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi^+\pi^-\psi(3686)$ $Z_c(4020) \rightarrow \pi^+\pi^-\psi(3686)$ $Z_{cs}(3985) \rightarrow \pi^+\pi^-\psi(3686)$			
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma Z_c$ $X(3872) \rightarrow \pi^+\pi^-\psi(3686)$ $X(3872) \rightarrow \pi^+\pi^-\psi(3686)$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^*\pi$ $ee \rightarrow D_s^*\pi$ $ee \rightarrow D_s^*\pi$			
CHARMED BARYON SPECTROSCOPY	$\Lambda_c \rightarrow \pi^+\pi^-\psi(3686)$ $\Lambda_c \rightarrow \pi^+\pi^-\psi(3686)$ $\Lambda_c \rightarrow \pi^+\pi^-\psi(3686)$			



Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \pi \eta$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel</i>	
LIGHT BARYON SPECTROSCOPY				
CHARMONIUM SPECTROSCOPY				
“Y” MESON SPECTROSCOPY	<div>$e^+e^- \rightarrow D^{*+}D^{*-}$<p>arXiv:2112.06477</p><div><div><p>(a)</p></div><div><p>(b)</p></div></div></div>			
“Z” MESON SPECTROSCOPY				
“X” MESON SPECTROSCOPY				
CHARMED MESON SPECTROSCOPY				
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Z_c, Ξ_c, Σ_c^* (and excitations), and possibly the P_c</i>	<i>and expanded energy reach into new territory</i>

⇒ *The open-charm channels are larger and play a crucial role in the global picture of vector charmonium.*

Hadron Spectroscopy at the BESIII Experiment

TOPIC

LIGHT MESON
SPECTROSCOPY

LIGHT BARYON
SPECTROSCOPY

CHARMONIUM
SPECTROSCOPY

“Y” MESON
SPECTROSCOPY

“Z” MESON
SPECTROSCOPY

“X” MESON
SPECTROSCOPY

CHARMED MESON
SPECTROSCOPY

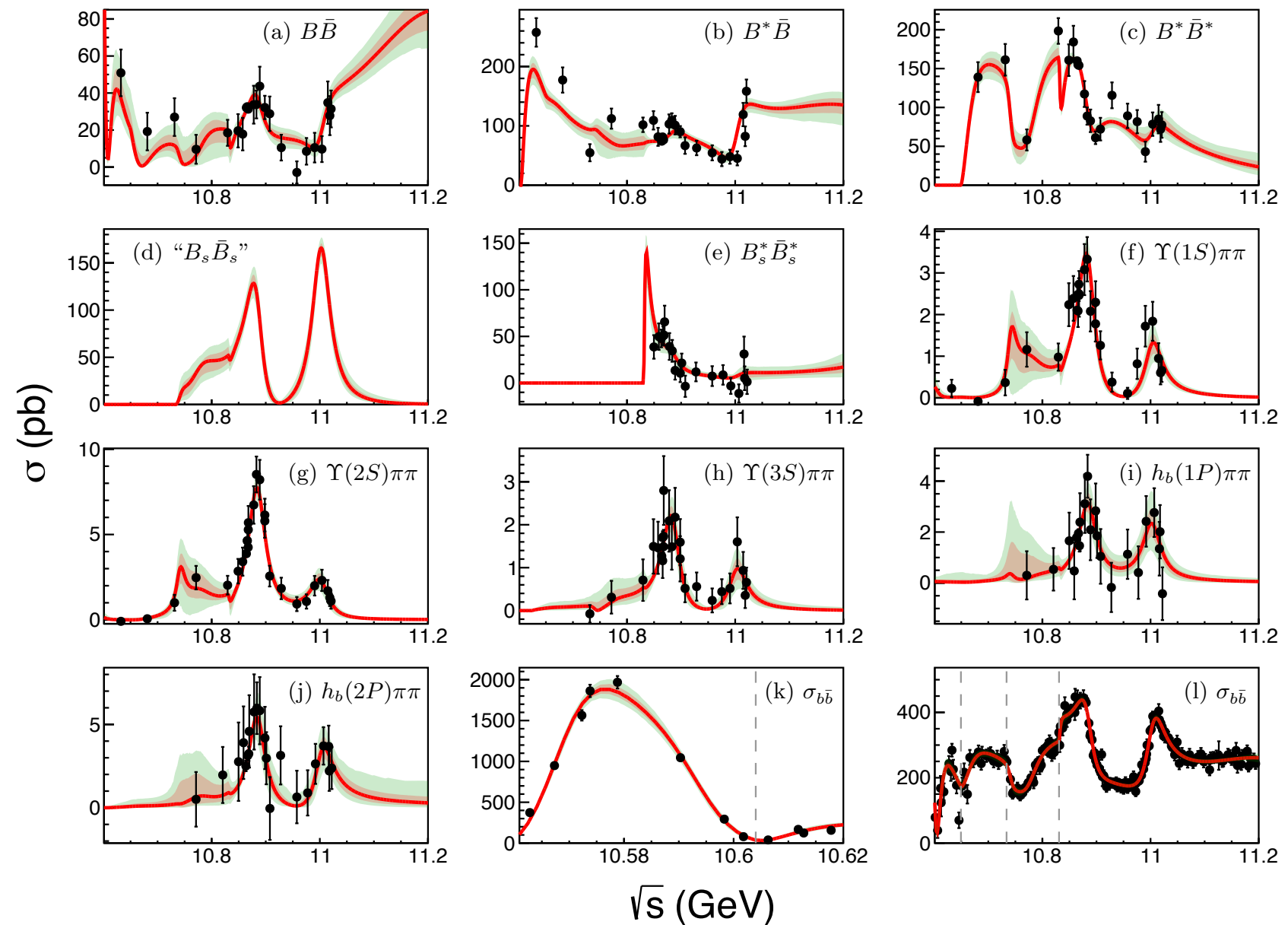
CHARMED BARYON
SPECTROSCOPY

EX
ACT

K-matrix Analysis of e^+e^- Annihilation in the Bottomonium Region

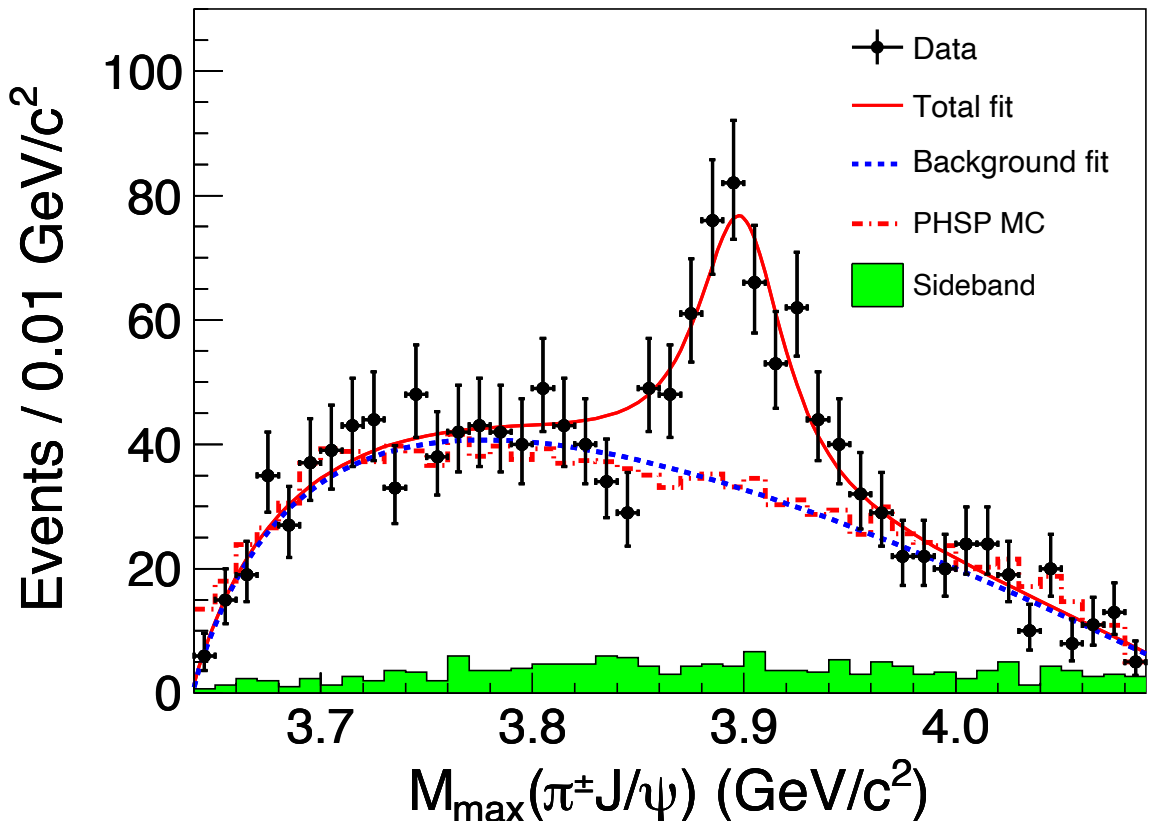
N. Hüsken,^{1,2} R.E. Mitchell,¹ and E.S. Swanson³

arXiv:2204.11915



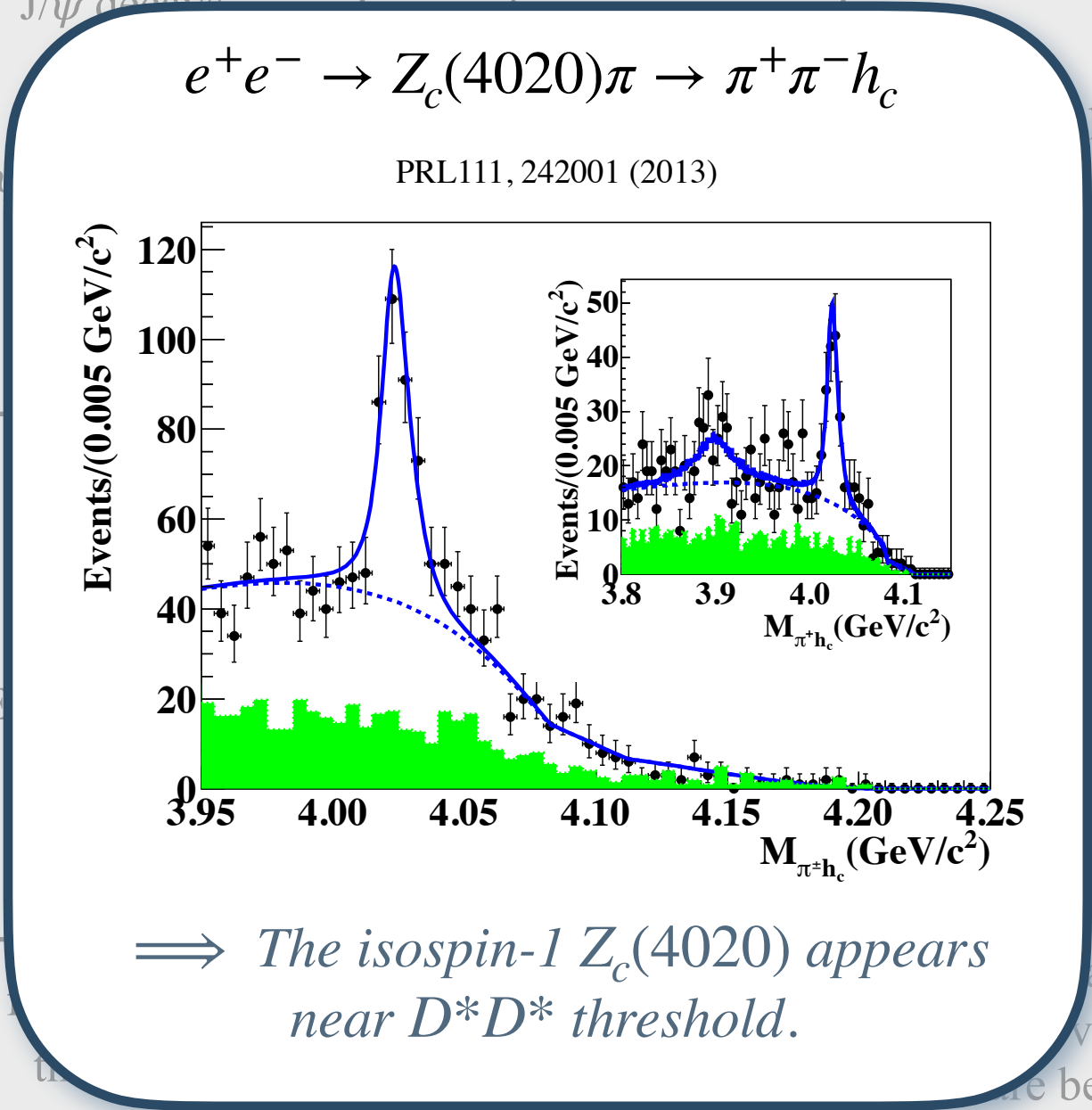
⇒ The infrastructure required to analyze many-channel systems is being developed.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$			
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p p \pi$ $\psi(2S) \rightarrow p p \eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c \bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$	> 3 fb at E _{cm} = 3.6-4.2 GeV	<div>$e^+e^- \rightarrow Z_c(3900)\pi \rightarrow \pi^+\pi^-J/\psi$<p>PRL110, 252001 (2013)</p></div> <p>⇒ <i>The isospin-1 $Z_c(3900)$ appears near DD^* threshold.</i></p>	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{c1}$ $X(3872) \rightarrow DD^*$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb threshold	D_s excited states	sets above 4 GeV (plans are being made);
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		access to the Σ_c , Ξ_c , Ω_c (and excitations), and possibly the P_c	and expanded energy reach into new territory

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel</i>	
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p p \pi$ $\psi(2S) \rightarrow p p \eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c \bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$			
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{c1}$ $X(3872) \rightarrow DD^*$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$			
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	<i>and expanded energy reach into new territory</i>



Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p p \pi$ $\psi(2S) \rightarrow p p \eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$	ψ
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c \bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$	
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$	> 2 at E_{cm}
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{c1}$ $X(3872) \rightarrow DD^*$	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D^*(*) K$	> 3 f
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>	

$e^+e^- \rightarrow K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

PRL126, 102001 (2021)

Events/(5.0 MeV/c²)

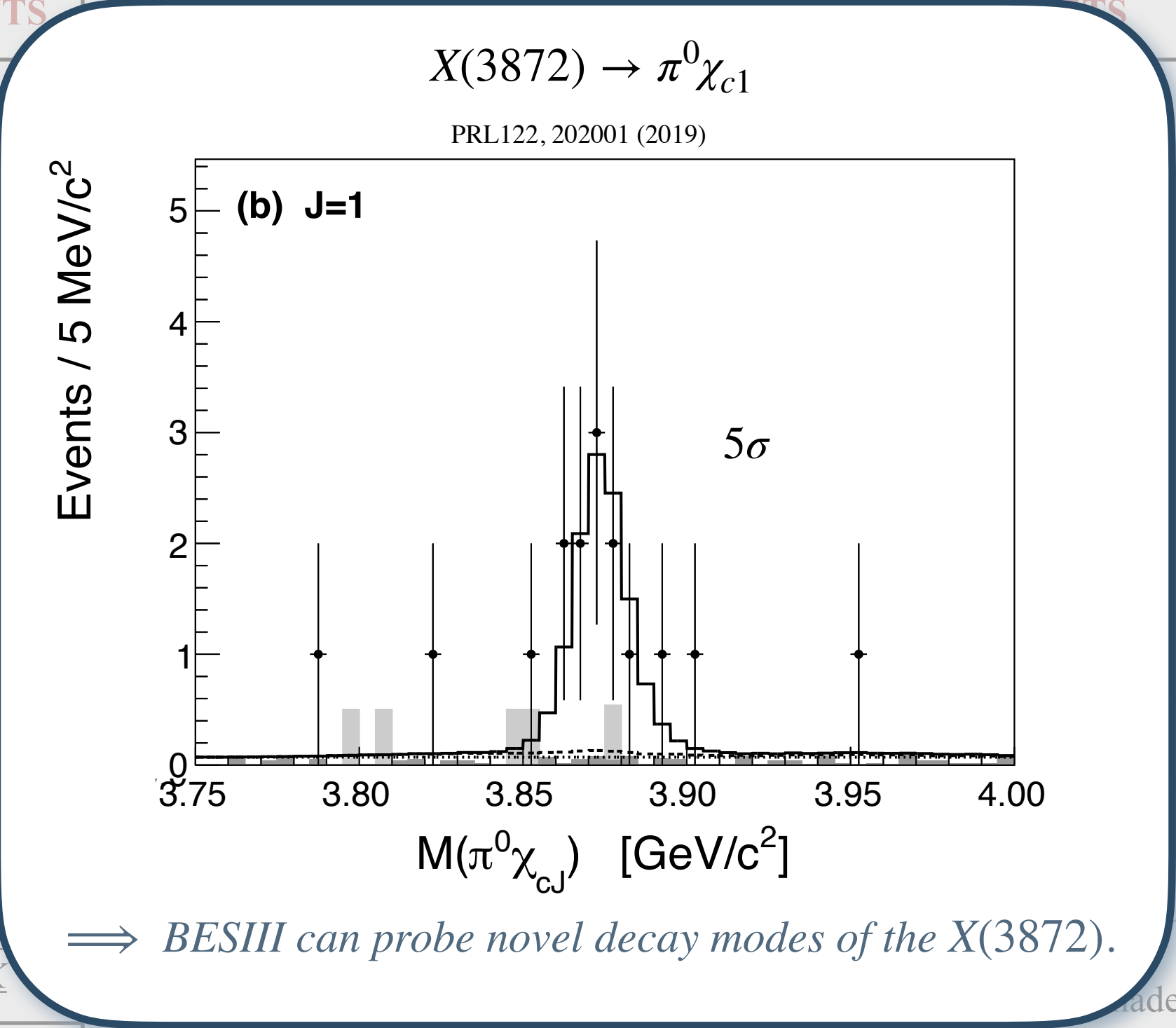
RM(K⁺) (GeV/c²)

Legend:
—+— Data
— Total fit
- - - $Z_{cs}(3985)^-$
... $\bar{D}^*(2600)^0 D^{*0}$
- - - non-Res.
/ / $D_s^{**} D_s^{(*)}$
■ comb. BKG

⇒ The isospin-1/2 $Z_{cs}(3985)$ appears near $D_s D^*$ threshold.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT	PROSPECTS	FUTURE
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$			
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p p \pi$ $\psi(2S) \rightarrow p p \eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$			
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c \bar{c}$ $\psi(2S) \rightarrow \pi h_c$ decays of η_c &			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$			
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D s$			
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{cJ}$ $X(3872) \rightarrow D \bar{D}$			
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D s^* D s^* (23)$ $ee \rightarrow D s D^* K$			
CHARMED BARYON SPECTROSCOPY	decays of the Λ_c		access to the Σ_c , Ξ_c , Ω_c (and excitations), and possibly the P_c	and expanded energy reach into new territory

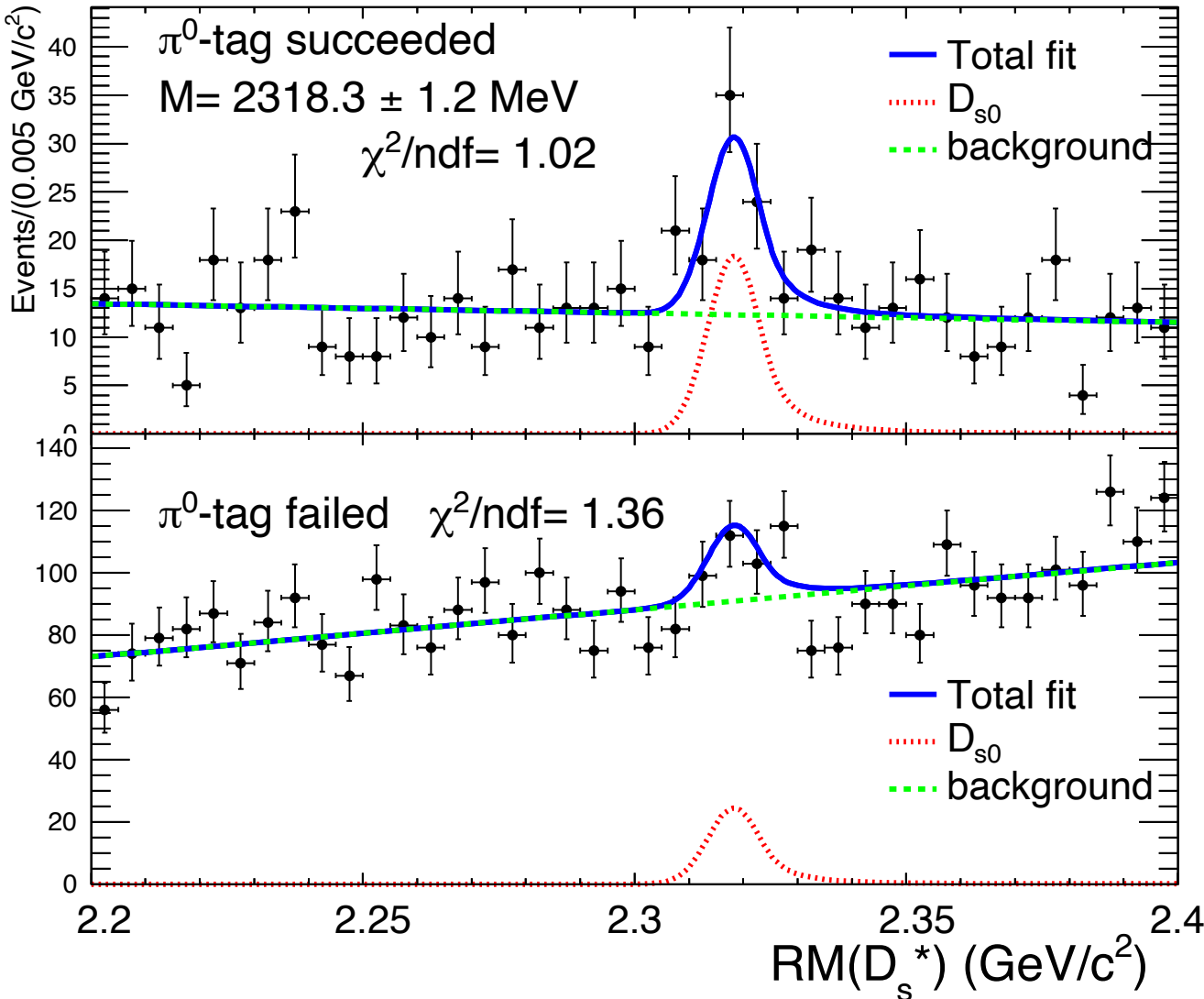


Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \eta \eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel analyses</i>	no plans (analyze current data)
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow pp\pi$ $\psi(2S) \rightarrow pp\eta$ $\psi(2S) \rightarrow \Lambda \Sigma \pi$	2.7 billion $\psi(2S)$ decays	<i>further explorations in J/ψ, $\psi(2S)$, and other charmonium decays</i>	
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c\bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>		<i>rare and precision transitions; properties of ψ_2; search for η_{c2}...</i>	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi \pi J/\psi$ $ee \rightarrow \pi \pi \psi(2S)$ $ee \rightarrow D^* D^*$	> 20 fb ⁻¹ of data at E _{cm} above 4 GeV	<i>more data; coupled-channel analyses of e^+e^- cross sections</i>	BEPCH-II UPGRADE: (1) 3× luminosity for E _{cm} above 4 GeV (2) maximum energy increase from 5 to 5.6 GeV ⇒ much larger data sets above 4 GeV (plans are being made); and expanded energy reach into new territory
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$		<i>new Z_c and Z_{cs} decays; E_{cm} dependence; coupled-channels...</i>	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi \chi_{c1}$ $X(3872) \rightarrow DD^*$		<i>increased precision and searches for new $X(3872)$ decay modes</i>	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb ⁻¹ above $\Lambda_c \Lambda_c$ threshold	<i>access to more D and D_s excited states</i>	
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \pi^0 \pi^0$ $J/\psi \rightarrow \pi^0 \pi^+ \pi^-$ $J/\psi \rightarrow \pi^+ \pi^- \pi^0$	$e^+e^- \rightarrow D_s^{*+}D_{s0}^{*-}(2317) + \text{c.c.}$ (500 pb ⁻¹ at 4.6 GeV) PRD97, 051103 (2018)		
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p \bar{p}$ $\psi(2S) \rightarrow n \bar{n}$ $\psi(2S) \rightarrow p \bar{p} \pi^0$			(data)
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \pi^0 \pi^0$ $\psi(2S) \rightarrow \pi^0 \pi^+ \pi^-$ $\psi(2S) \rightarrow \pi^+ \pi^- \pi^0$			
“Y” MESON SPECTROSCOPY	$ee \rightarrow \gamma \gamma$ $ee \rightarrow \pi^0 \pi^0$ $ee \rightarrow \pi^+ \pi^-$			GRADE:
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow p \bar{p} \pi^0$ $Z_c(4020) \rightarrow p \bar{p} \pi^0$ $Z_{cs}(3985) \rightarrow p \bar{p} \pi^0$			sity GeV
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma \gamma$ $X(3872) \rightarrow J/\psi \pi^0$ $X(3872) \rightarrow J/\psi \pi^+ \pi^-$			energy n /
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^{*+} D_s^{*-}$ $ee \rightarrow D_s^{*+} D_s^{*-} \pi^0$			data GeV (made); energy
CHARMED BARYON SPECTROSCOPY	decays of the		and possibly the P_c	into new territory



\Rightarrow Excited D_s states are produced with higher-energy e^+e^- collisions.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	RESULTS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi^+ \pi^-$ $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^0$ $J/\psi \rightarrow \gamma \eta$	
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow p \bar{p}$ $\psi(2S) \rightarrow p \bar{p} \pi^0$ $\psi(2S) \rightarrow \Lambda \bar{\Lambda}$	
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + \text{hadrons}$ $\psi(2S) \rightarrow \pi^+ \pi^- J/\psi$ decays of η_c	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi^+ \pi^- J/\psi$ $ee \rightarrow \pi^+ \pi^- \psi(2S)$ $ee \rightarrow D^{*+} D^-$	
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi^+ J/\psi$ $Z_c(4020) \rightarrow \pi^+ J/\psi$ $Z_{cs}(3985) \rightarrow \pi^+ J/\psi$	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi^+ \pi^- J/\psi$ $X(3872) \rightarrow \pi^+ \pi^- \psi(2S)$	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*$ $ee \rightarrow D_s D_s^*$	
CHARMED BARYON SPECTROSCOPY	decays of the Λ_c	

$e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^-$ (500 pb⁻¹ at 4.6 GeV)

PRL116, 052001 (2016)

\Rightarrow BESIII can study a wide variety of Λ_c decays.
With higher energies, more charmed baryons will be accessible.

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma\pi\pi\eta'$ $J/\psi \rightarrow \gamma\pi\pi$ $J/\psi \rightarrow \gamma\eta\eta'$	10 billion J/ψ decays	<i>glueballs, hybrids, coupled-channel analyses</i>	no plans (analyze current data)
LIGHT BARYON SPECTROSCOPY	$\psi(2S) \rightarrow pp\pi$ $\psi(2S) \rightarrow pp\eta$ $\psi(2S) \rightarrow \Lambda\Sigma\pi$	2.7 billion $\psi(2S)$ decays	<i>further explorations in J/ψ, $\psi(2S)$, and other charmonium decays</i>	
CHARMONIUM SPECTROSCOPY	$\psi(2S) \rightarrow \gamma + c\bar{c}$ $\psi(2S) \rightarrow \pi h_c$ <i>decays of η_c & h_c</i>		<i>rare and precision transitions; properties of ψ_2; search for η_{c2}...</i>	
“Y” MESON SPECTROSCOPY	$ee \rightarrow \pi\pi J/\psi$ $ee \rightarrow \pi\pi\psi(2S)$ $ee \rightarrow D^*D^*$	> 20 fb ⁻¹ of data at E_{cm} above 4 GeV	<i>more data; coupled-channel analyses of e^+e^- cross sections</i>	BEPCH-II UPGRADE: (1) 3× luminosity for E_{cm} above 4 GeV (2) maximum energy increase from 5 to 5.6 GeV ⇒ much larger data sets above 4 GeV (plans are being made); and expanded energy reach into new territory
“Z” MESON SPECTROSCOPY	$Z_c(3900) \rightarrow \pi J/\psi$ (PWA) $Z_c(4020) \rightarrow \pi h_c$ $Z_{cs}(3985) \rightarrow D_s D^*$		<i>new Z_c and Z_{cs} decays; E_{cm} dependence; coupled-channels...</i>	
“X” MESON SPECTROSCOPY	$ee \rightarrow \gamma X(3872)$ $X(3872) \rightarrow \pi\chi_{c1}$ $X(3872) \rightarrow DD^*$		<i>increased precision and searches for new $X(3872)$ decay modes</i>	
CHARMED MESON SPECTROSCOPY	$ee \rightarrow D_s^* D_s^*(2317)$ $ee \rightarrow D_s D(^*)K$	> 3 fb ⁻¹ above $\Lambda_c\Lambda_c$ threshold	<i>access to more D and D_s excited states</i>	
CHARMED BARYON SPECTROSCOPY	<i>decays of the Λ_c</i>		<i>access to the Σ_c, Ξ_c, Ω_c (and excitations), and possibly the P_c</i>	

Hadron Spectroscopy at the BESIII Experiment

TOPIC	EXAMPLE ACHIEVEMENTS	CURRENT DATA SETS	PROSPECTS	FUTURE DATA SETS
LIGHT MESON SPECTROSCOPY	$J/\psi \rightarrow \gamma \pi \pi \eta'$ $J/\psi \rightarrow \gamma \pi \pi$ $J/\psi \rightarrow \gamma \pi \pi \pi$	10 billion $\sqrt{s} = 1.045$	<i>glueballs, hybrids, coupled-channel</i>	no plans (analyze current data)
LIGHT BARYON SPECTROSCOPY	Λ_c			
CHARMONIUM SPECTROSCOPY	$\psi(3770)$ $\psi(4180)$ $\psi(4360)$ $\psi(4760)$ $\psi(5040)$ $\psi(5400)$ $\psi(5770)$ $\psi(6000)$ $\psi(7234)$ $\psi(7460)$ $\psi(7690)$ $\psi(8538)$ $\psi(8956)$ $\psi(9460)$ $\psi(9593)$ $\psi(9750)$ $\psi(9843)$ $\psi(10020)$ $\psi(10355)$ $\psi(10438)$ $\psi(10578)$ $\psi(10603)$ $\psi(10653)$ $\psi(10693)$ $\psi(10703)$ $\psi(10753)$ $\psi(10803)$ $\psi(10853)$ $\psi(10903)$ $\psi(10953)$ $\psi(11003)$ $\psi(11053)$ $\psi(11103)$ $\psi(11153)$ $\psi(11203)$ $\psi(11253)$ $\psi(11303)$ $\psi(11353)$ $\psi(11403)$ $\psi(11453)$ $\psi(11503)$ $\psi(11553)$ $\psi(11603)$ $\psi(11653)$ $\psi(11703)$ $\psi(11753)$ $\psi(11803)$ $\psi(11853)$ $\psi(11903)$ $\psi(11953)$ $\psi(12003)$ $\psi(12053)$ $\psi(12103)$ $\psi(12153)$ $\psi(12203)$ $\psi(12253)$ $\psi(12303)$ $\psi(12353)$ $\psi(12403)$ $\psi(12453)$ $\psi(12503)$ $\psi(12553)$ $\psi(12603)$ $\psi(12653)$ $\psi(12703)$ $\psi(12753)$ $\psi(12803)$ $\psi(12853)$ $\psi(12903)$ $\psi(12953)$ $\psi(13003)$ $\psi(13053)$ $\psi(13103)$ $\psi(13153)$ $\psi(13203)$ $\psi(13253)$ $\psi(13303)$ $\psi(13353)$ $\psi(13403)$ $\psi(13453)$ $\psi(13503)$ $\psi(13553)$ $\psi(13603)$ $\psi(13653)$ $\psi(13703)$ $\psi(13753)$ $\psi(13803)$ $\psi(13853)$ $\psi(13903)$ $\psi(13953)$ $\psi(14003)$ $\psi(14053)$ $\psi(14103)$ $\psi(14153)$ $\psi(14203)$ $\psi(14253)$ $\psi(14303)$ $\psi(14353)$ $\psi(14403)$ $\psi(14453)$ $\psi(14503)$ $\psi(14553)$ $\psi(14603)$ $\psi(14653)$ $\psi(14703)$ $\psi(14753)$ $\psi(14803)$ $\psi(14853)$ $\psi(14903)$ $\psi(14953)$ $\psi(15003)$ $\psi(15053)$ $\psi(15103)$ $\psi(15153)$ $\psi(15203)$ $\psi(15253)$ $\psi(15303)$ $\psi(15353)$ $\psi(15403)$ $\psi(15453)$ $\psi(15503)$ $\psi(15553)$ $\psi(15603)$ $\psi(15653)$ $\psi(15703)$ $\psi(15753)$ $\psi(15803)$ $\psi(15853)$ $\psi(15903)$ $\psi(15953)$ $\psi(16003)$ $\psi(16053)$ $\psi(16103)$ $\psi(16153)$ $\psi(16203)$ $\psi(16253)$ $\psi(16303)$ $\psi(16353)$ $\psi(16403)$ $\psi(16453)$ $\psi(16503)$ $\psi(16553)$ $\psi(16603)$ $\psi(16653)$ $\psi(16703)$ $\psi(16753)$ $\psi(16803)$ $\psi(16853)$ $\psi(16903)$ $\psi(16953)$ $\psi(17003)$ $\psi(17053)$ $\psi(17103)$ $\psi(17153)$ $\psi(17203)$ $\psi(17253)$ $\psi(17303)$ $\psi(17353)$ $\psi(17403)$ $\psi(17453)$ $\psi(17503)$ $\psi(17553)$ $\psi(17603)$ $\psi(17653)$ $\psi(17703)$ $\psi(17753)$ $\psi(17803)$ $\psi(17853)$ $\psi(17903)$ $\psi(17953)$ $\psi(18003)$ $\psi(18053)$ $\psi(18103)$ $\psi(18153)$ $\psi(18203)$ $\psi(18253)$ $\psi(18303)$ $\psi(18353)$ $\psi(18403)$ $\psi(18453)$ $\psi(18503)$ $\psi(18553)$ $\psi(18603)$ $\psi(18653)$ $\psi(18703)$ $\psi(18753)$ $\psi(18803)$ $\psi(18853)$ $\psi(18903)$ $\psi(18953)$ $\psi(19003)$ $\psi(19053)$ $\psi(19103)$ $\psi(19153)$ $\psi(19203)$ $\psi(19253)$ $\psi(19303)$ $\psi(19353)$ $\psi(19403)$ $\psi(19453)$ $\psi(19503)$ $\psi(19553)$ $\psi(19603)$ $\psi(19653)$ $\psi(19703)$ $\psi(19753)$ $\psi(19803)$ $\psi(19853)$ $\psi(19903)$ $\psi(19953)$ $\psi(20003)$ $\psi(20053)$ $\psi(20103)$ $\psi(20153)$ $\psi(20203)$ $\psi(20253)$ $\psi(20303)$ $\psi(20353)$ $\psi(20403)$ $\psi(20453)$ $\psi(20503)$ $\psi(20553)$ $\psi(20603)$ $\psi(20653)$ $\psi(20703)$ $\psi(20753)$ $\psi(20803)$ $\psi(20853)$ $\psi(20903)$ $\psi(20953)$ $\psi(21003)$ $\psi(21053)$ $\psi(21103)$ $\psi(21153)$ $\psi(21203)$ $\psi(21253)$ $\psi(21303)$ $\psi(21353)$ $\psi(21403)$ $\psi(21453)$ $\psi(21503)$ $\psi(21553)$ $\psi(21603)$ $\psi(21653)$ $\psi(21703)$ $\psi(21753)$ $\psi(21803)$ $\psi(21853)$ $\psi(21903)$ $\psi(21953)$ $\psi(22003)$ $\psi(22053)$ $\psi(22103)$ $\psi(22153)$ $\psi(22203)$ $\psi(22253)$ $\psi(22303)$ $\psi(22353)$ $\psi(22403)$ $\psi(22453)$ $\psi(22503)$ $\psi(22553)$ $\psi(22603)$ $\psi(22653)$ $\psi(22703)$ $\psi(22753)$ $\psi(22803)$ $\psi(22853)$ $\psi(22903)$ $\psi(22953)$ $\psi(23003)$ $\psi(23053)$ $\psi(23103)$ $\psi(23153)$ $\psi(23203)$ $\psi(23253)$ $\psi(23303)$ $\psi(23353)$ $\psi(23403)$ $\psi(23453)$ $\psi(23503)$ $\psi(23553)$ $\psi(23603)$ $\psi(23653)$ $\psi(23703)$ $\psi(23753)$ $\psi(23803)$ $\psi(23853)$ $\psi(23903)$ $\psi(23953)$ $\psi(24003)$ $\psi(24053)$ $\psi(24103)$ $\psi(24153)$ $\psi(24203)$ $\psi(24253)$ $\psi(24303)$ $\psi(24353)$ $\psi(24403)$ $\psi(24453)$ $\psi(24503)$ $\psi(24553)$ $\psi(24603)$ $\psi(24653)$ $\psi(24703)$ $\psi(24753)$ $\psi(24803)$ $\psi(24853)$ $\psi(24903)$ $\psi(24953)$ $\psi(25003)$ $\psi(25053)$ $\psi(25103)$ $\psi(25153)$ $\psi(25203)$ $\psi(25253)$ $\psi(25303)$ $\psi(25353)$ $\psi(25403)$ $\psi(25453)$ $\psi(25503)$ $\psi(25553)$ $\psi(25603)$ $\psi(25653)$ $\psi(25703)$ $\psi(25753)$ $\psi(25803)$ $\psi(25853)$ $\psi(25903)$ $\psi(25953)$ $\psi(26003)$ $\psi(26053)$ $\psi(26103)$ $\psi(26153)$ $\psi(26203)$ $\psi(26253)$ $\psi(26303)$ $\psi(26353)$ $\psi(26403)$ $\psi(26453)$ $\psi(26503)$ $\psi(26553)$ $\psi(26603)$ $\psi(26653)$ $\psi(26703)$ $\psi(26753)$ $\psi(26803)$ $\psi(26853)$ $\psi(26903)$ $\psi(26953)$ $\psi(27003)$ $\psi(27053)$ $\psi(27103)$ $\psi(27153)$ $\psi(27203)$ $\psi(27253)$ $\psi(27303)$ $\psi(27353)$ $\psi(27403)$ $\psi(27453)$ $\psi(27503)$ $\psi(27553)$ $\psi(27603)$ $\psi(27653)$ $\psi(27703)$ $\psi(27753)$ $\psi(27803)$ $\psi(27853)$ $\psi(27903)$ $\psi(27953)$ $\psi(28003)$ $\psi(28053)$ $\psi(28103)$ $\psi(28153)$ $\psi(28203)$ $\psi(28253)$ $\psi(28303)$ $\psi(28353)$ $\psi(28403)$ $\psi(28453)$ $\psi(28503)$ $\psi(28553)$ $\psi(28603)$ $\psi(28653)$ $\psi(28703)$ $\psi(28753)$ $\psi(28803)$ $\psi(28853)$ $\psi(28903)$ $\psi(28953)$ $\psi(29003)$ $\psi(29053)$ $\psi(29103)$ $\psi(29153)$ $\psi(29203)$ $\psi(29253)$ $\psi(29303)$ $\psi(29353)$ $\psi(29403)$ $\psi(29453)$ $\psi(29503)$ $\psi(29553)$ $\psi(29603)$ $\psi(29653)$ $\psi(29703)$ $\psi(29753)$ $\psi(29803)$ $\psi(29853)$ $\psi(29903)$ $\psi(29953)$ $\psi(30003)$ $\psi(30053)$ $\psi(30103)$ $\psi(30153)$ $\psi(30203)$ $\psi(30253)$ $\psi(30303)$ $\psi(30353)$ $\psi(30403)$ $\psi(30453)$ $\psi(30503)$ $\psi(30553)$ $\psi(30603)$ $\psi(30653)$ $\psi(30703)$ $\psi(30753)$ $\psi(30803)$ $\psi(30853)$ $\psi(30903)$ $\psi(30953)$ $\psi(31003)$ $\psi(31053)$ $\psi(31103)$ $\psi(31153)$ $\psi(31203)$ $\psi(31253)$ $\psi(31303)$ $\psi(31353)$ $\psi(31403)$ $\psi(31453)$ $\psi(31503)$ $\psi(31553)$ $\psi(31603)$ $\psi(31653)$ $\psi(31703)$ $\psi(31753)$ $\psi(31803)$ $\psi(31853)$ $\psi(31903)$ $\psi(31953)$ $\psi(32003)$ $\psi(32053)$ $\psi(32103)$ $\psi(32153)$ $\psi(32203)$ $\psi(32253)$ $\psi(32303)$ $\psi(32353)$ $\psi(32403)$ $\psi(32453)$ $\psi(32503)$ $\psi(32553)$ $\psi(32603)$ $\psi(32653)$ $\psi(32703)$ $\psi(32753)$ $\psi(32803)$ $\psi(32853)$ $\psi(32903)$ $\psi(32953)$ $\psi(33003)$ $\psi(33053)$ $\psi(33103)$ $\psi(33153)$ $\psi(33203)$ $\psi(33253)$ $\psi(33303)$ $\psi(33353)$ $\psi(33403)$ $\psi(33453)$ $\psi(33503)$ $\psi(33553)$ $\psi(33603)$ $\psi(33653)$ $\psi(33703)$ $\psi(33753)$ $\psi(33803)$ $\psi(33853)$ $\psi(33903)$ $\psi(33953)$ $\psi(34003)$ $\psi(34053)$ $\psi(34103)$ $\psi(34153)$ $\psi(34203)$ $\psi(34253)$ $\psi(34303)$ $\psi(34353)$ $\psi(34403)$ $\psi(34453)$ $\psi(34503)$ $\psi(34553)$ $\psi(34603)$ $\psi(34653)$ $\psi(34703)$ $\psi(34753)$ $\psi(34803)$ $\psi(34853)$ $\psi(34903)$ $\psi(34953)$ $\psi(35003)$ $\psi(35053)$ $\psi(35103)$ $\psi(35153)$ $\psi(35203)$ $\psi(35253)$ $\psi(35303)$ $\psi(35353)$ $\psi(35403)$ $\psi(35453)$ $\psi(35503)$ $\psi(35553)$ $\psi(35603)$ $\psi(35653)$ $\psi(35703)$ $\psi(35753)$ $\psi(35803)$ $\psi(35853)$ $\psi(35903)$ $\psi(35953)$ $\psi(36003)$ $\psi(36053)$ $\psi(36103)$ $\psi(36153)$ $\psi(36203)$ $\psi(36253)$ $\psi(36303)$ $\psi(36353)$ $\psi(36403)$ $\psi(36453)$ $\psi(36503)$ $\psi(36553)$ $\psi(36603)$ $\psi(36653)$ $\psi(36703)$ $\psi(36753)$ $\psi(36803)$ $\psi(36853)$ $\psi(36903)$ $\psi(36953)$ $\psi(37003)$ $\psi(37053)$ $\psi(37103)$ $\psi(37153)$ $\psi(37203)$ $\psi(37253)$ $\psi(37303)$ $\psi(37353)$ $\psi(37403)$ $\psi(37453)$ $\psi(37503)$ $\psi(37553)$ $\psi(37603)$ $\psi(37653)$ $\psi(37703)$ $\psi(37753)$ $\psi(37803)$ $\psi(37853)$ $\psi(37903)$ $\psi(37953)$ $\psi(38003)$ $\psi(38053)$ $\psi(38103)$ $\psi(38153)$ $\psi(38203)$ $\psi(38253)$ $\psi(38303)$ $\psi(38353)$ $\psi(38403)$ $\psi(38453)$ $\psi(38503)$ $\psi(38553)$ $\psi(38603)$ $\psi(38653)$ $\psi(38703)$ $\psi(38753)$ $\psi(38803)$ $\psi(38853)$ $\psi(38903)$ $\psi(38953)$ $\psi(39003)$ $\psi(39053)$ $\psi(39103)$ $\psi(39153)$ $\psi(39203)$ $\psi(39253)$ $\psi(39303)$ $\psi(39353)$ $\psi(39403)$ $\psi(39453)$ $\psi(39503)$ $\psi(39553)$ $\psi(39603)$ $\psi(39653)$ $\psi(39703)$ $\psi(39753)$ $\psi(39803)$ $\psi(39853)$ $\psi(39903)$ $\psi(39953)$ $\psi(40003)$ $\psi(40053)$ $\psi(40103)$ $\psi(40153)$ $\psi(40203)$ $\psi(40253)$ $\psi(40303)$ $\psi(40353)$ $\psi(40403)$ $\psi(40453)$ $\psi(40503)$ $\psi(40553)$ $\psi(40603)$ $\psi(40653)$ $\psi(40703)$ $\psi(40753)$ $\psi(40803)$ $\psi(40853)$ $\psi(40903)$ $\psi(40953)$ $\psi(41003)$ $\psi(41053)$ $\psi(41103)$ $\psi(41153)$ $\psi(41203)$ $\psi(41253)$ $\psi(41303)$ $\psi(41353)$ $\psi(41403)$ $\psi(41453)$ $\psi(41503)$ $\psi(41553)$ $\psi(41603)$ $\psi(41653)$ $\psi(41703)$ $\psi(41753)$ $\psi(41803)$ $\psi(41853)$ $\psi(41903)$ $\psi(41953)$ $\psi(42003)$ $\psi(42053)$ $\psi(42103)$ $\psi(42153)$ $\psi(42203)$ $\psi(42253)$ $\psi(42303)$ $\psi(42353)$ $\psi(42403)$ $\psi(42453)$ $\psi(42503)$ $\psi(42553)$ $\psi(42603)$ $\psi(42653)$ $\psi(42703)$ $\psi(42753)$ $\psi(42803)$ $\psi(42853)$ $\psi(42903)$ $\psi(42953)$ $\psi(43003)$ $\psi(43053)$ $\psi(43103)$ $\psi(43153)$ $\psi(43203)$ $\psi(43253)$ $\psi(43303)$ $\psi(43353)$ $\psi(43403)$ $\psi(43453)$ $\psi(43503)$ $\psi(43553)$ $\psi(43603)$ $\psi(43653)$ $\psi(43703)$ $\psi(43753)$ $\psi(43803)$ $\psi(43853)$ $\psi(43903)$ $\psi(43953)$ $\psi(44003)$ $\psi(44053)$ $\psi(44103)$ $\psi(44153)$ $\psi(44203)$ $\psi(44253)$ $\psi(44303)$ $\psi(44353)$ $\psi(44403)$ $\psi(44453)$ $\psi(44503)$ $\psi(44553)$ $\psi(44603)$ $\psi(44653)$ $\psi(44703)$ $\psi(44753)$ $\psi(44803)$ $\psi(44853)$ $\psi(44903)$ $\psi(44953)$ $\psi(45003)$ $\psi(45053)$ $\psi(45103)$ $\psi(45153)$ $\psi(45203)$ $\psi(45253)$ $\psi(45303)$ $\psi(45353)$ $\psi(45403)$ $\psi(45453)$ $\psi(45503)$ $\psi(45553)$ $\psi(45603)$ $\psi(45653)$ $\psi(45703)$ $\psi(45753)$ $\psi(45803)$ $\psi(45853)$ $\psi(45903)$ $\psi(45953)$ $\psi(46003)$ $\psi(46053)$ $\psi(46103)$ $\psi(46153)$ $\psi(46203)$ $\psi(46253)$ $\psi(46303)$ $\psi(46353)$ $\psi(46403)$ $\psi(46453)$ $\psi(46503)$ $\psi(46553)$ $\psi(46603)$ $\psi(46653)$ $\psi(46703)$ $\psi(46753)$ $\psi(46803)$ $\psi(46853)$ $\psi(46903)$ $\psi(46953)$ $\psi(47003)$ $\psi(47053)$ $\psi(47103)$ $\psi(47153)$ $\psi(47203)$ $\psi(47253)$ $\psi(47303)$ $\psi(47353)$ $\psi(47403)$ $\psi(47453)$ $\psi(47503)$ $\psi(47553)$ $\psi(47603)$ $\psi(47653)$ $\psi(47703)$ $\psi(47753)$ $\psi(47803)$ $\psi(47853)$ $\psi(47903)$ $\psi(47953)$ $\psi(48003)$ $\psi(48053)$ $\psi(48103)$ $\psi(48153)$ $\psi(48203)$ $\psi(48253)$ $\psi(48303)$ $\psi(48353)$ $\psi(48403)$ $\psi(48453)$ $\psi(48503)$ $\psi(48553)$ $\psi(48603)$ $\psi(48653)$ $\psi(48703)$ $\psi(48753)$ $\psi(48803)$ $\psi(48853)$ $\psi(48903)$ $\psi(48953)$ $\psi(49003)$ $\psi(49053)$ $\psi(49103)$ $\psi(49153)$ $\psi(49203)$ $\psi(49253)$ $\psi(49303)$ $\psi(49353)$ $\psi(49403)$ $\psi(49453)$ $\psi(49503)$ $\psi(49553)$ $\psi(49603)$ $\psi(49653)$ $\psi(49703)$ $\psi(49753)$ $\psi(49803)$ $\psi(49853)$ $\psi(49903)$ $\psi(49953)$ $\psi(50003)$ $\psi(50053)$ $\psi(50103)$ $\psi(50153)$ $\psi(50203)$ $\psi(50253)$ $\psi(50303)$ $\psi(50353)$ $\psi(50403)$ $\psi(50453)$ $\psi(50503)$ $\psi(50553)$ $\psi(50603)$ $\psi(50653)$ $\psi(50703)$ $\psi(50753)$ $\psi(50803)$ $\psi(50853)$ $\psi(50903)$ $\psi(50953)$ $\psi(51003)$ $\psi(51053)$ $\psi(51103)$ $\psi(51153)$ $\psi(51203)$ $\psi(51253)$ $\psi(51303)$ $\psi(51353)$ $\psi(51403)$ $\psi(51453)$ $\psi(51503)$ $\psi(51553)$ $\psi(51603)$ $\psi(51653)$ $\psi(51703)$ $\psi(51753)$ $\psi(51803)$ $\psi(51853)$ $\psi(51903)$ $\psi(51953)$ $\psi(52003)$ $\psi(52053)$ $\psi(52103)$ $\psi(52153)$ $\psi(52203)$ $\psi(52253)$ $\psi(52303)$ $\psi(52353)$ $\psi(52403)$ $\psi(52453)$ $\psi(52503)$ $\psi(52553)$ $\psi(52603)$ $\psi(52653)$ $\psi(52703)$ $\psi(52753)$ $\psi(52803)$ $\psi(52853)$ $\psi(52903)$			