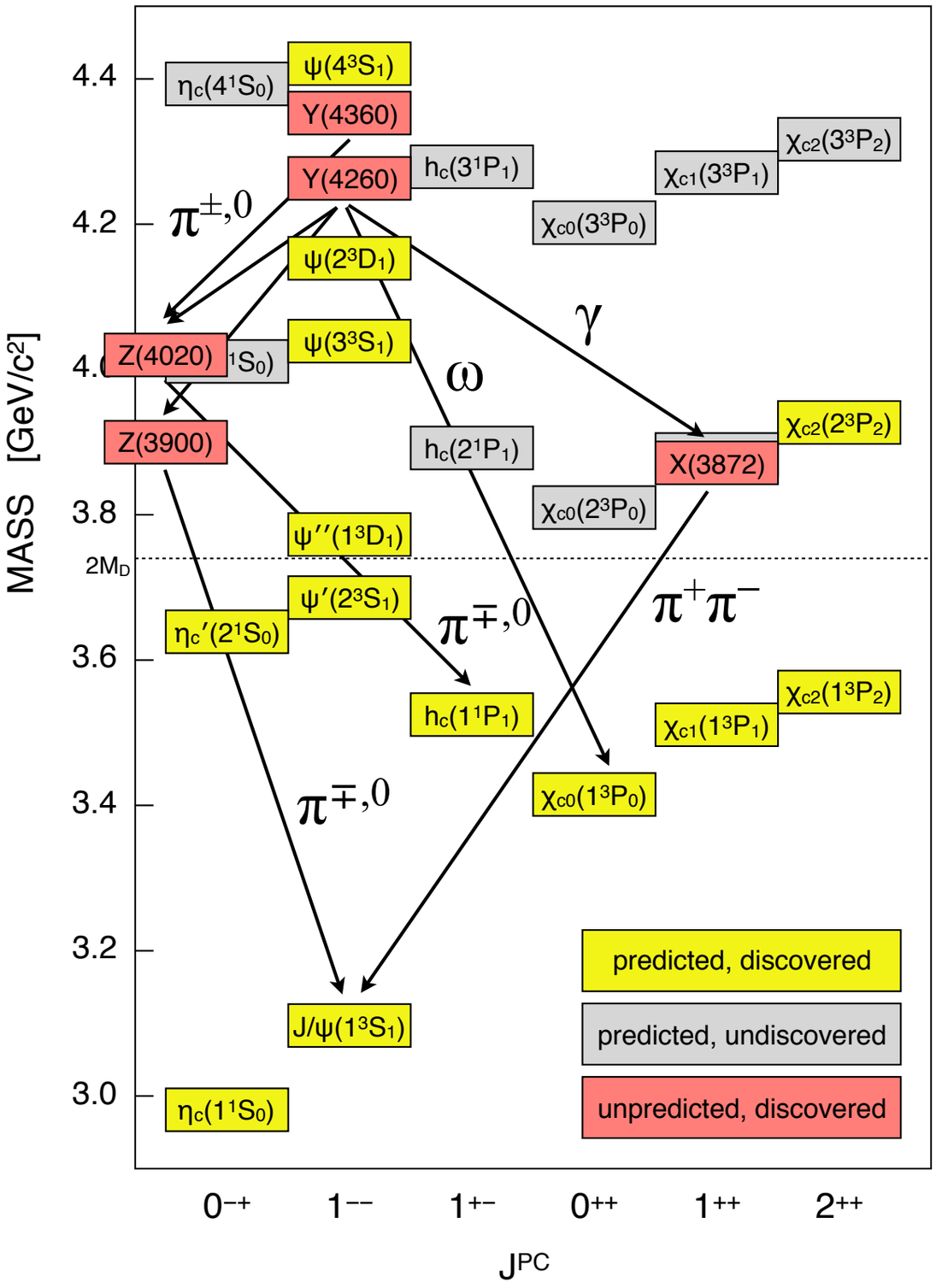
Charmonium Proposal for a High-Statistics Scan from 4.3 to 4.4 GeV

Ryan Mitchell
for the Charmonium Group

BESIII Collaboration Meeting
March 15, 2017

Overview of XYZ Physics at BESIII



Goal:

Investigate the "XYZ" states that do not fit into the conventional quark model of charmonium.

Data Sets:

2011: 482 pb^{-1} at **4.01 GeV**
2013: 1092 pb^{-1} at **4.23 GeV**
826 pb^{-1} at **4.26 GeV**
540 pb^{-1} at **4.36 GeV**
~50 pb^{-1} at **3.81, 3.90, 4.09, 4.19, 4.21, 4.22, 4.245, 4.31, 4.39, 4.42 GeV**
2014: 1029 pb^{-1} at **4.42 GeV**
110 pb^{-1} at **4.47 GeV**
110 pb^{-1} at **4.53 GeV**
48 pb^{-1} at **4.575 GeV**
567 pb^{-1} at **4.6 GeV**
2017(?): 10 × 500 pb^{-1} between **4.19** and **4.30 GeV**

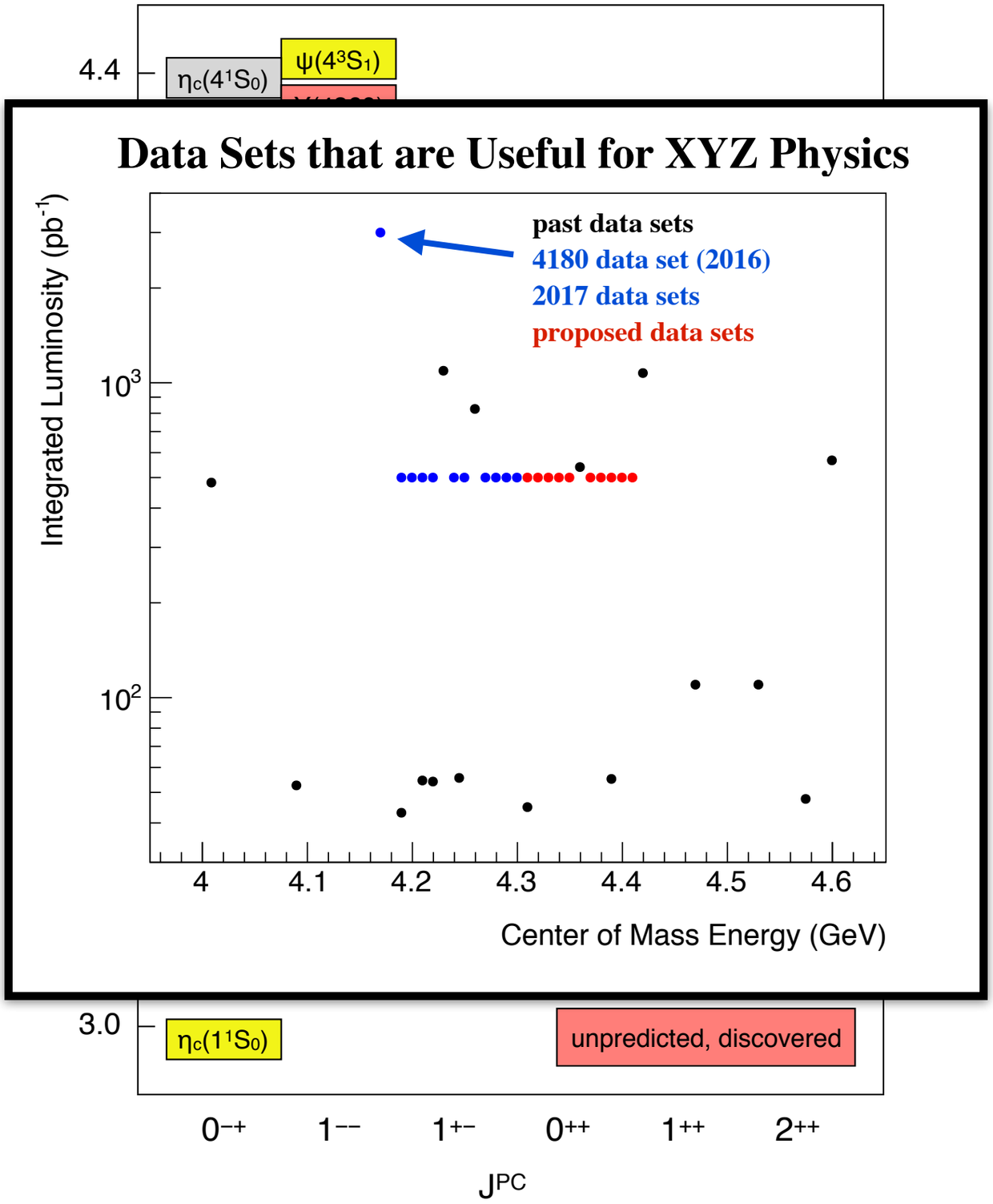
This Proposal:

10 × 500 pb^{-1} between **4.31** and **4.41 GeV**

A Few Physics Highlights:

discovery of $e^+e^- \to \gamma X(3872)$
discovery of complicated **Y**-like structure
discovery of the $Z_c(3900)$ and $Z_c(4020)$

Overview of XYZ Physics at BESIII



Goal:

Investigate the "XYZ" states that do not fit into the conventional quark model of charmonium.

Data Sets:

2011: 482 pb^{-1} at **4.01 GeV**
2013: 1092 pb^{-1} at **4.23 GeV**
826 pb^{-1} at **4.26 GeV**
540 pb^{-1} at **4.36 GeV**
~50 pb^{-1} at **3.81, 3.90, 4.09, 4.19, 4.21, 4.22, 4.245, 4.31, 4.39, 4.42 GeV**
2014: 1029 pb^{-1} at **4.42 GeV**
110 pb^{-1} at **4.47 GeV**
110 pb^{-1} at **4.53 GeV**
48 pb^{-1} at **4.575 GeV**
567 pb^{-1} at **4.6 GeV**
2017(?): 10 × 500 pb^{-1} between **4.19** and **4.30 GeV**

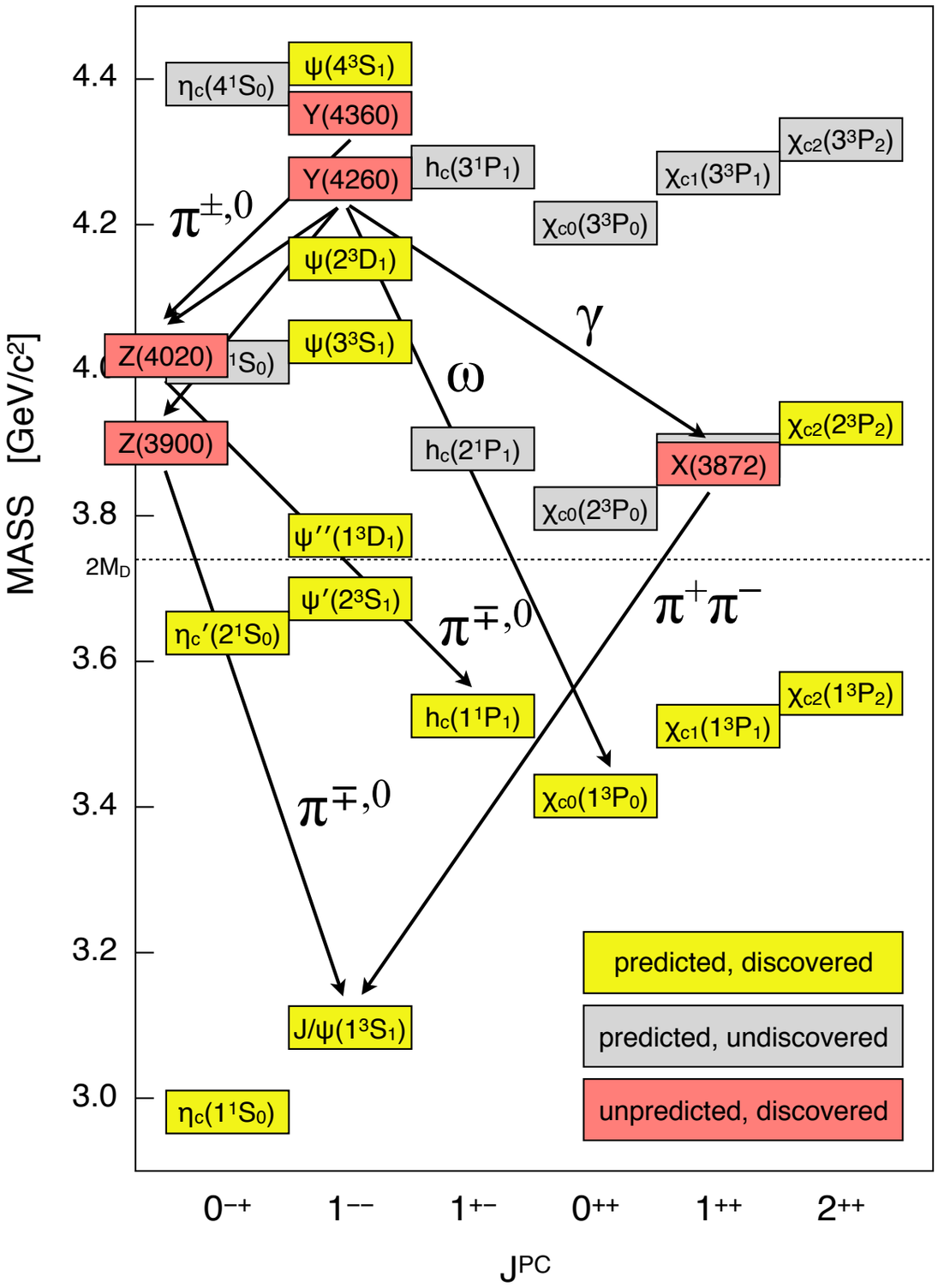
This Proposal:

10 × 500 pb^{-1} between **4.31** and **4.41 GeV**

A Few Physics Highlights:

discovery of $e^+e^- \to \gamma X(3872)$
discovery of complicated **Y**-like structure
discovery of the $Z_c(3900)$ and $Z_c(4020)$

Overview of XYZ Physics at BESIII



Goal:

Investigate the "XYZ" states that do not fit into the conventional quark model of charmonium.

Data Sets:

2011: 482 pb^{-1} at **4.01 GeV**

2013: 1092 pb^{-1} at **4.23 GeV**
826 pb^{-1} at **4.26 GeV**
540 pb^{-1} at **4.36 GeV**
~50 pb^{-1} at **3.81, 3.90, 4.09, 4.19, 4.21, 4.22, 4.245, 4.31, 4.39, 4.42 GeV**

2014: 1029 pb^{-1} at **4.42 GeV**
110 pb^{-1} at **4.47 GeV**
110 pb^{-1} at **4.53 GeV**
48 pb^{-1} at **4.575 GeV**
567 pb^{-1} at **4.6 GeV**

2017(?): 10 × 500 pb^{-1} between **4.19** and **4.30 GeV**

This Proposal:

10 × 500 pb^{-1} between **4.31** and **4.41 GeV**

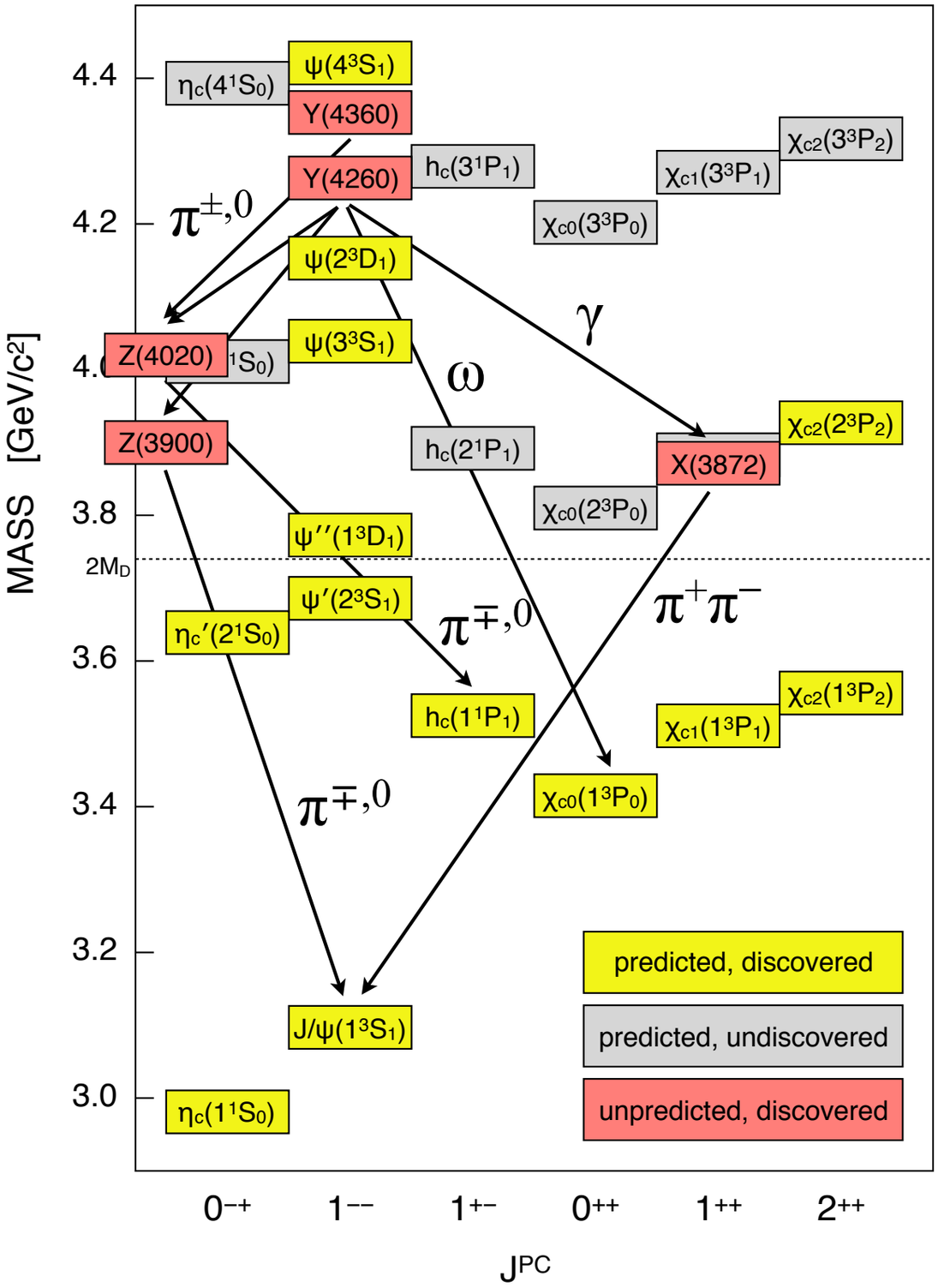
A Few Physics Highlights:

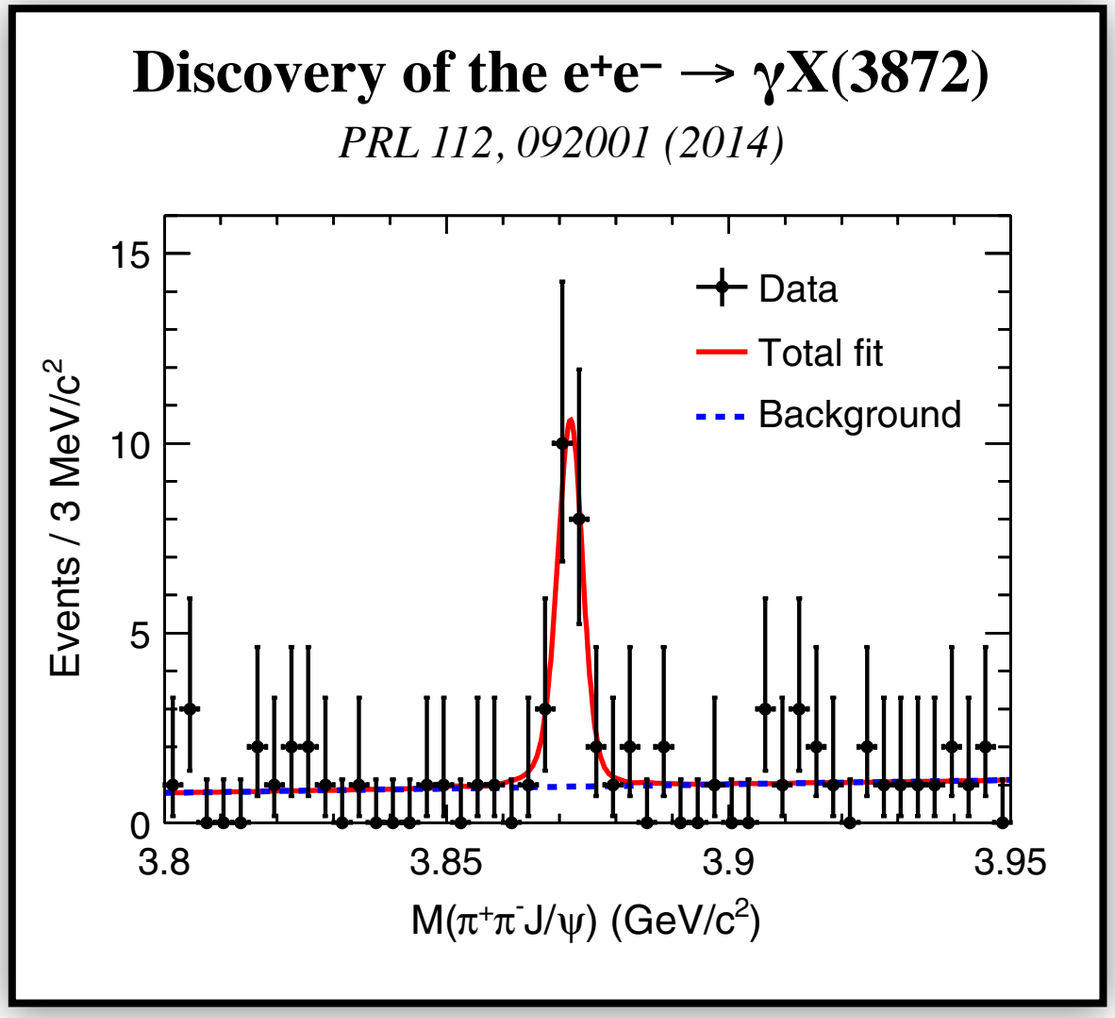
discovery of $e^+e^- \to \gamma X(3872)$

discovery of complicated **Y**-like structure

discovery of the $Z_c(3900)$ and $Z_c(4020)$

Overview of XYZ Physics at BESIII





This Proposal:

$10 \times 500\ \text{pb}^{-1}$ between **4.31** and **4.41 GeV**

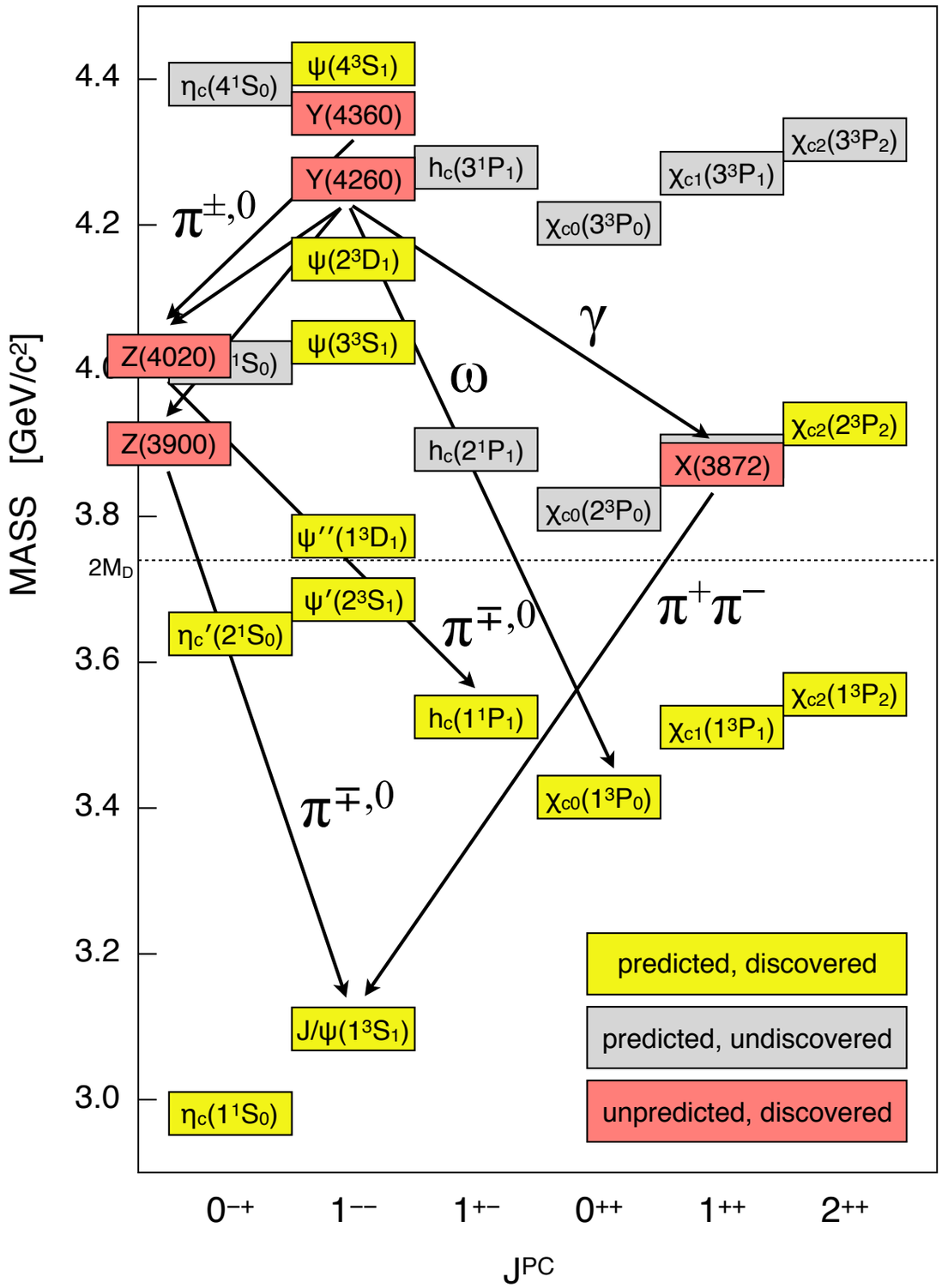
A Few Physics Highlights:

discovery of $e^+e^- \to \gamma X(3872)$

discovery of complicated **Y**-like structure

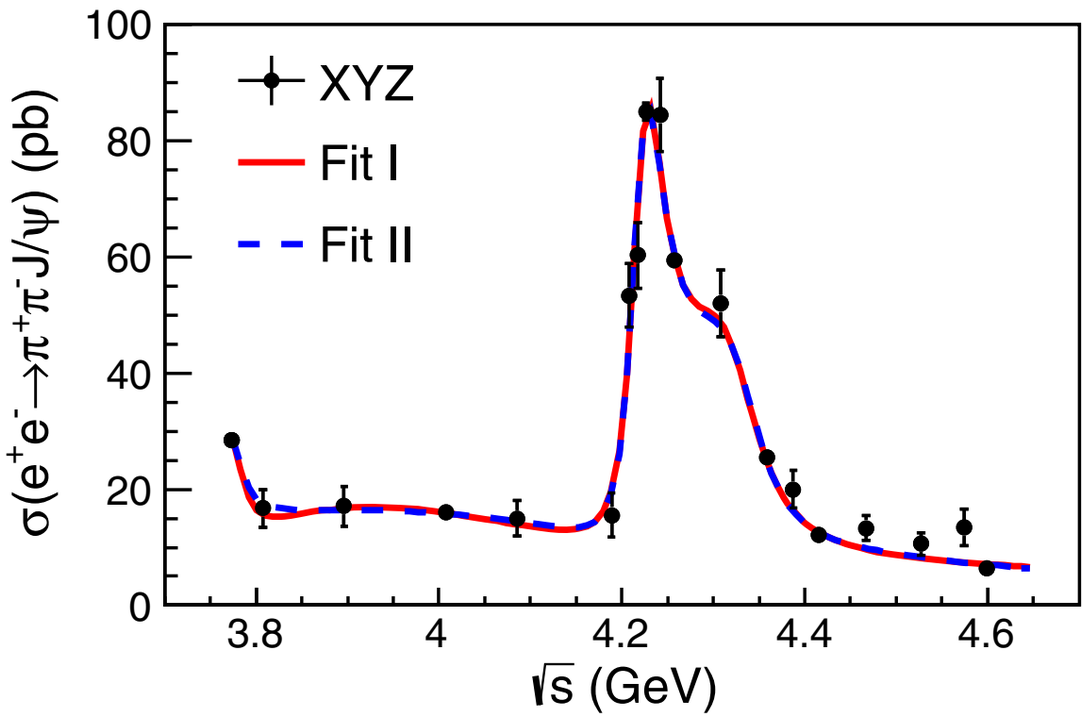
discovery of the $\mathbf{Z_c(3900)}$ and $\mathbf{Z_c(4020)}$

Overview of XYZ Physics at BESIII



Discovery of complex structure in $\pi^+\pi^- J/\psi$

PRL 118, 092001 (2017)



narrow peak at 4220; wide peak at 4320 MeV

This Proposal:

10×500 pb^{-1} between **4.31** and **4.41 GeV**

A Few Physics Highlights:

discovery of $e^+e^- \to \gamma$**X(3872)**

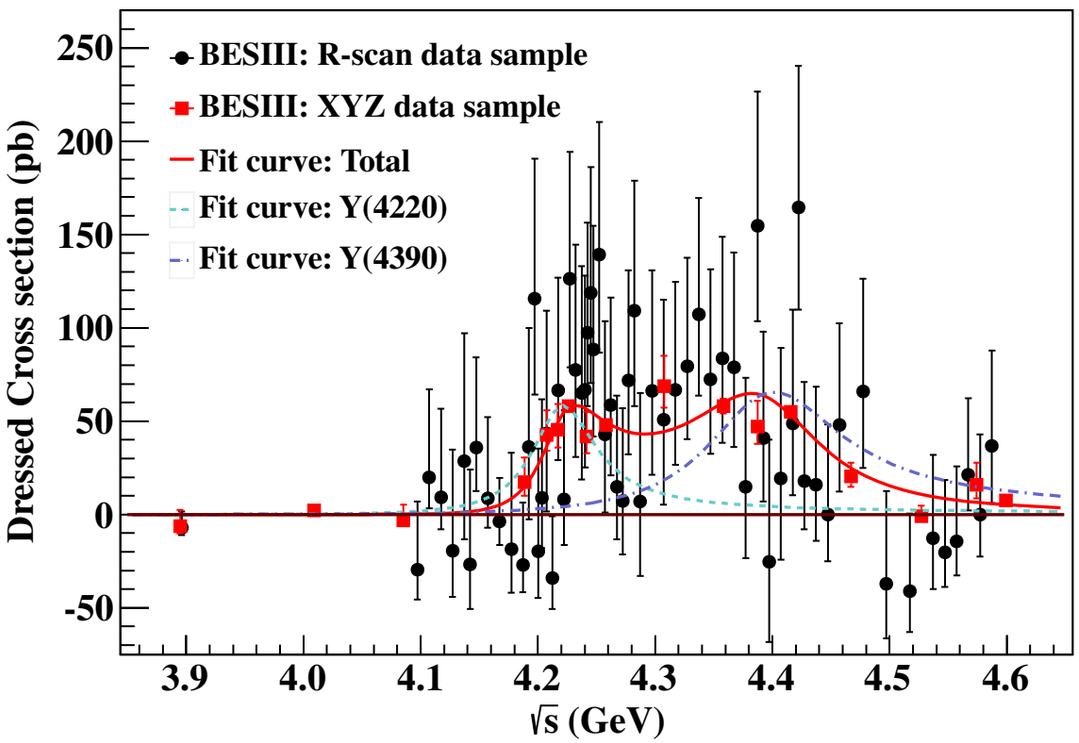
discovery of complicated **Y**-like structure

discovery of the $\mathbf{Z_c(3900)}$ and $\mathbf{Z_c(4020)}$

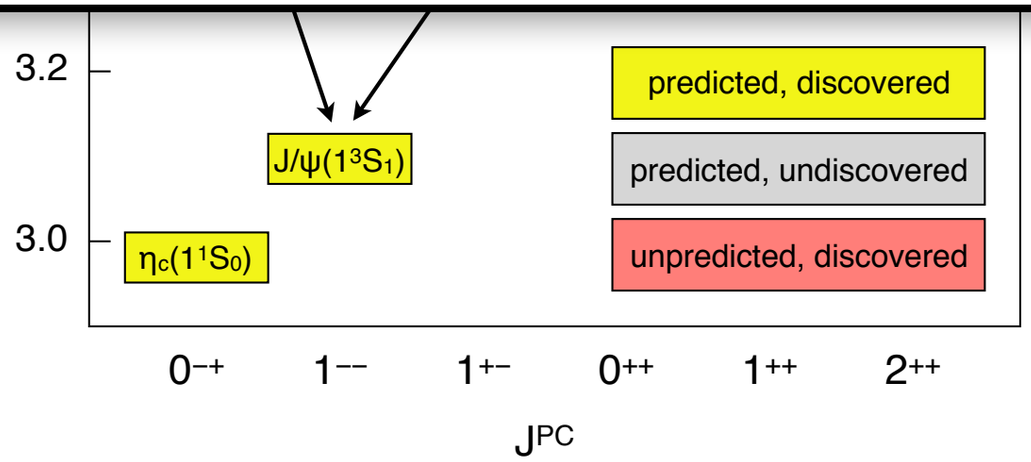
Overview of XYZ Physics at BESIII

Discovery of complex structure in $\pi^+\pi^- h_c$

PRL 118, 092002 (2017)

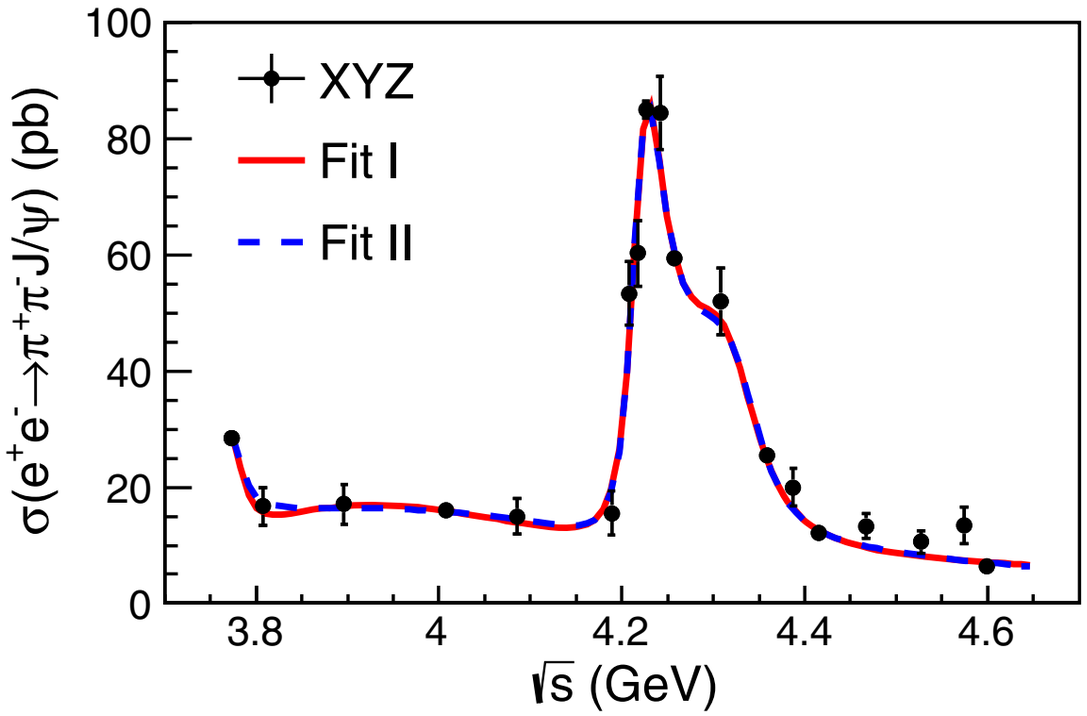


narrow peak at 4220; wide peak at 4390 MeV



Discovery of complex structure in $\pi^+\pi^- J/\psi$

PRL 118, 092001 (2017)



narrow peak at 4220; wide peak at 4320 MeV

This Proposal:

$10 \times 500\ \text{pb}^{-1}$ between **4.31** and **4.41 GeV**

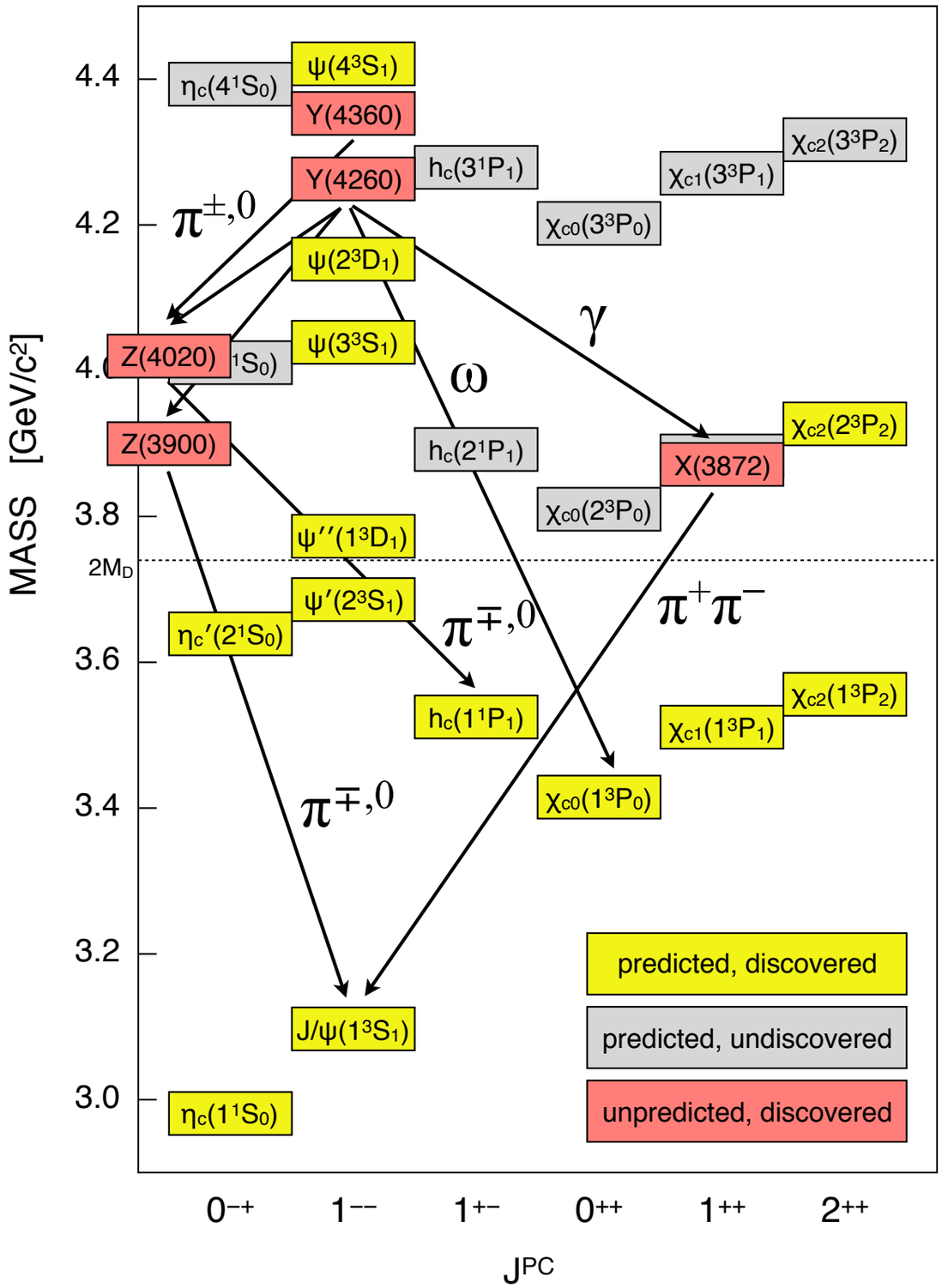
A Few Physics Highlights:

discovery of $e^+e^- \to \gamma X(3872)$

discovery of complicated **Y**-like structure

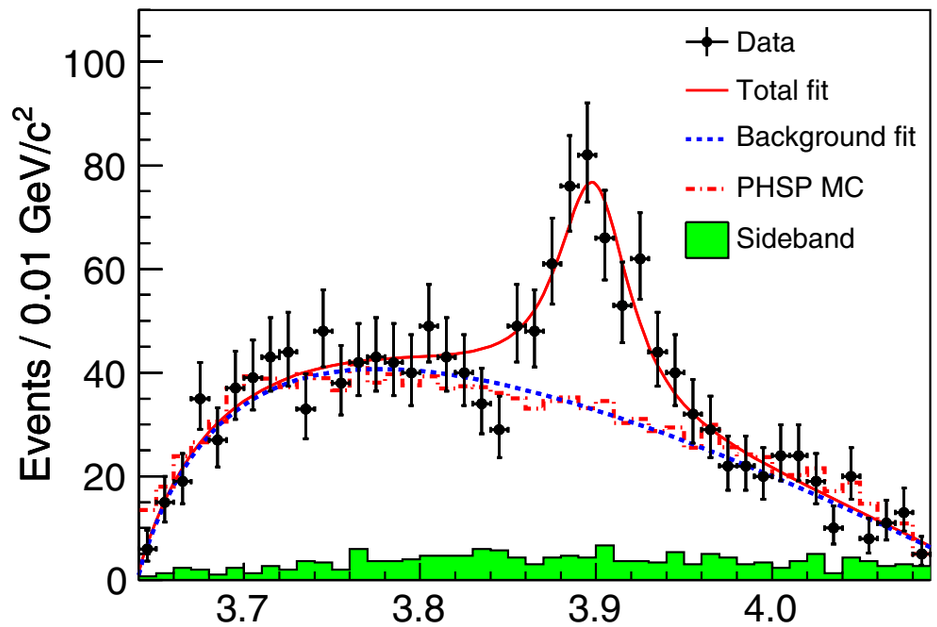
discovery of the $Z_c(3900)$ and $Z_c(4020)$

Overview of XYZ Physics at BESIII



Discovery of the $Z_c(3900)$ in $\pi^+\pi^- J/\psi$

PRL 110, 252001 (2013)



*(**461** citations as of 3/12/17)*

This Proposal:

$10 \times 500\ \text{pb}^{-1}$ between **4.31** and **4.41 GeV**

A Few Physics Highlights:

discovery of $e^+e^- \to \gamma$**X(3872)**

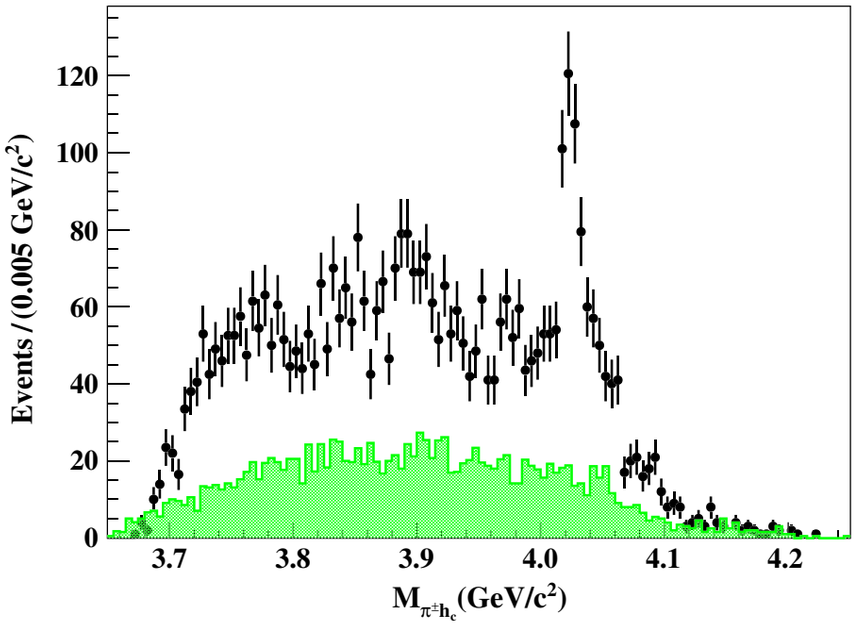
discovery of complicated **Y**-like structure

discovery of the **$Z_c(3900)$** and **$Z_c(4020)$**

Overview of XYZ Physics at BESIII

Discovery of the $Z_c(4020)$ in $\pi^+\pi^- h_c$

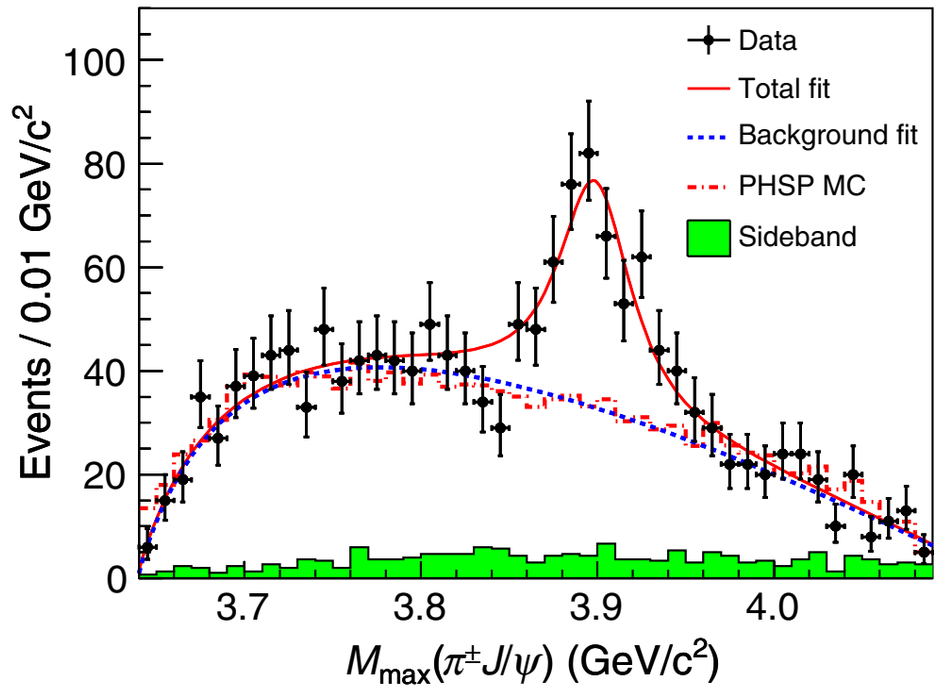
PRL 111, 242001 (2013)



*(**220** citations as of 3/12/17)*

Discovery of the $Z_c(3900)$ in $\pi^+\pi^- J/\psi$

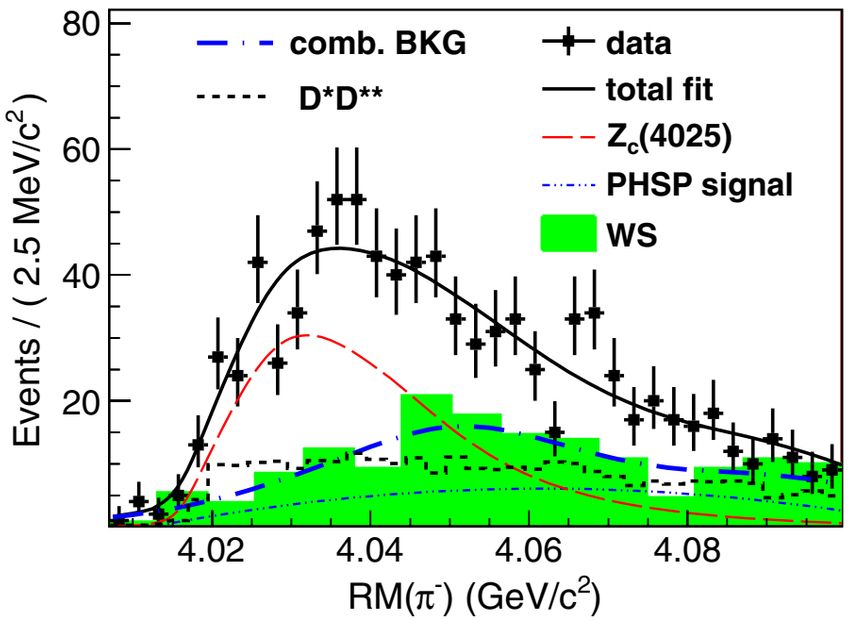
PRL 110, 252001 (2013)



*(**461** citations as of 3/12/17)*

Discovery of the $Z_c(4020)$ in $\pi^\pm(D^*D^*)^\mp$

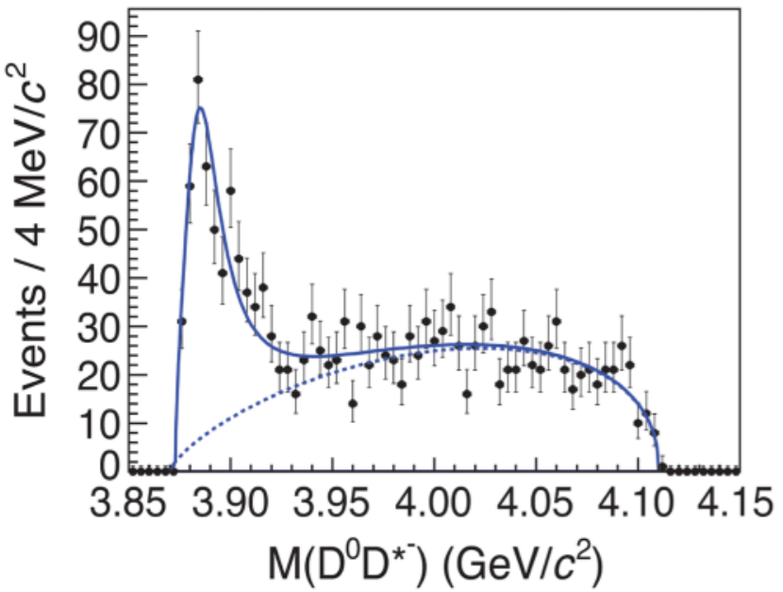
PRL 112, 132001 (2014)



*(**208** citations as of 3/12/17)*

Discovery of the $Z_c(3900)$ in $\pi^\pm(D^*D)^\mp$

PRL 112, 022001 (2014)

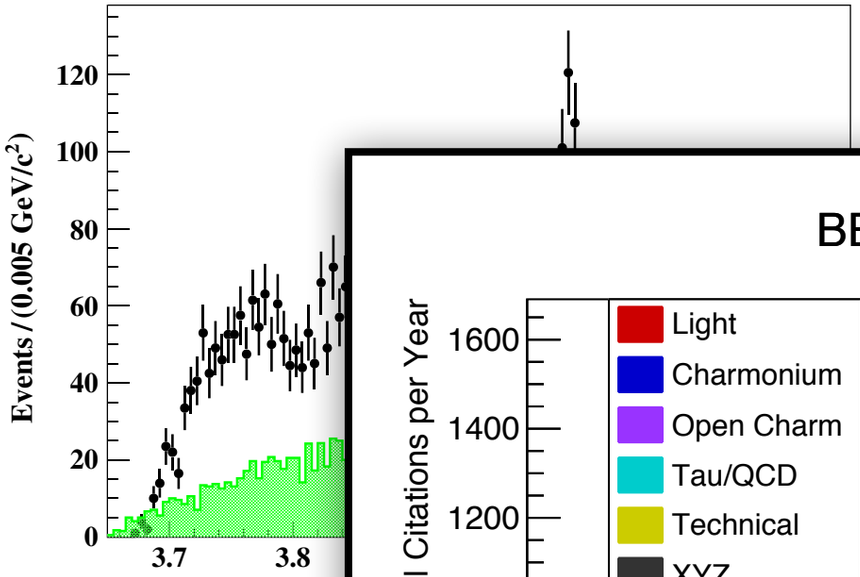


*(**174** citations as of 3/12/17)*

Overview of XYZ Physics at BESIII

Discovery of the $Z_c(4020)$ in $\pi^+\pi^- h_c$

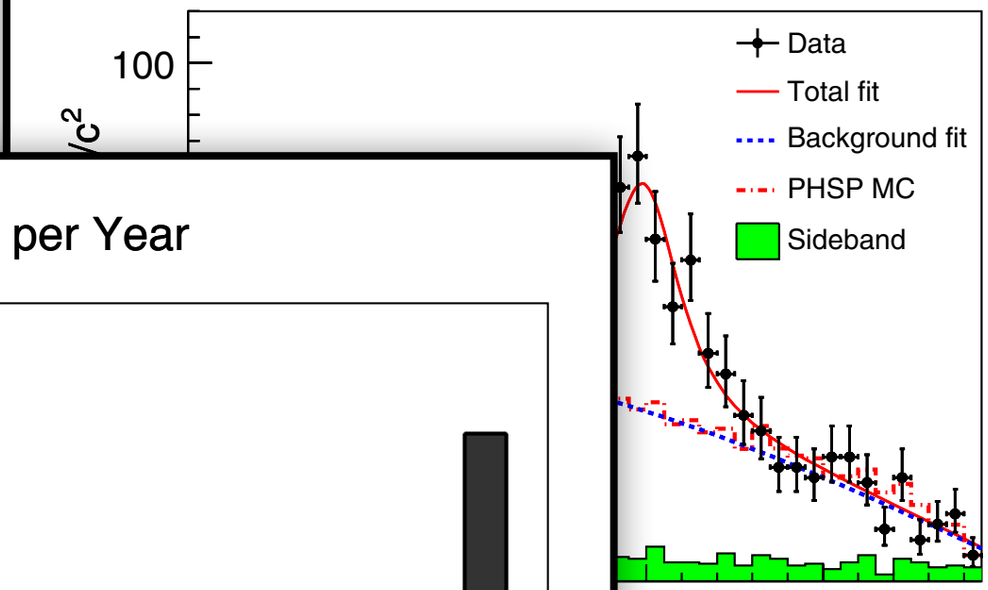
PRL 111, 242001 (2013)



*(**220** citations as of 3/12/17)*

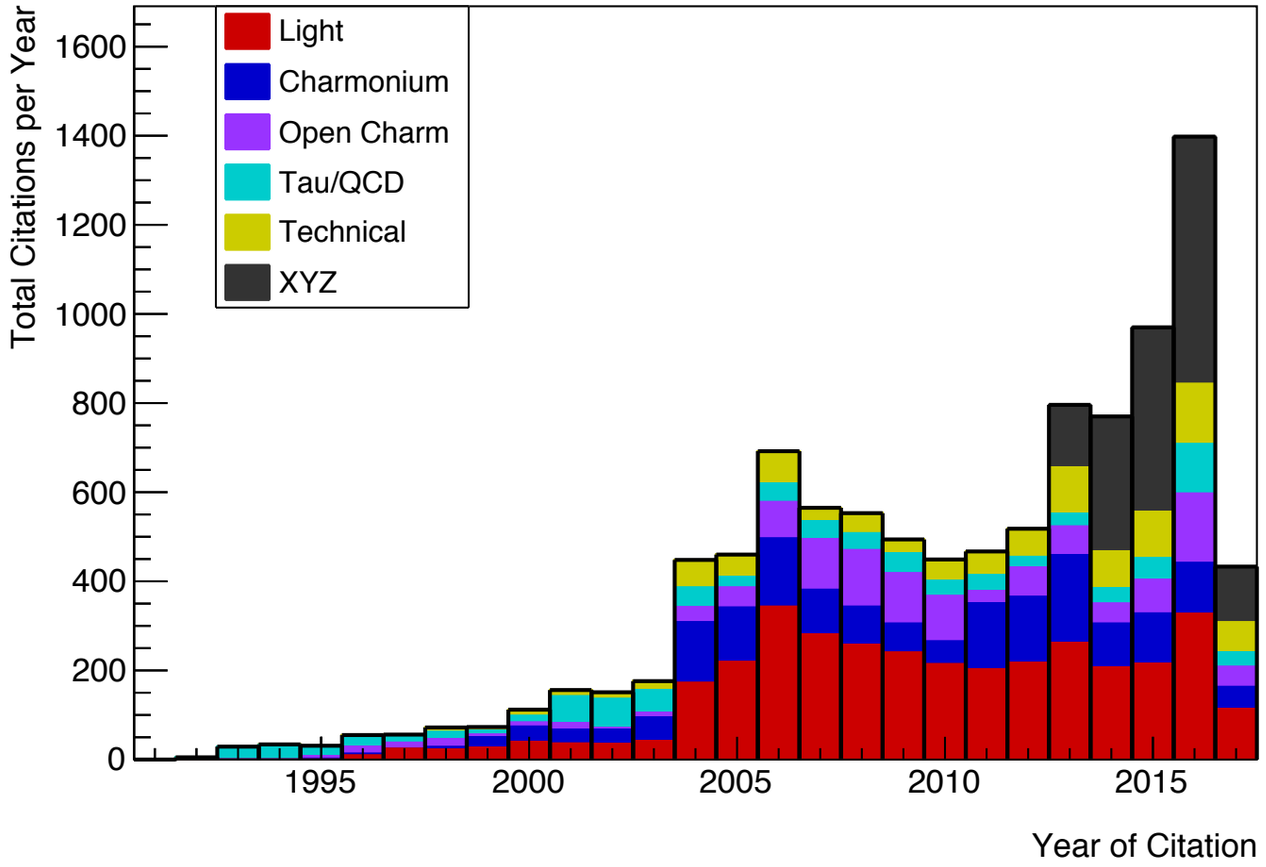
Discovery of the $Z_c(3900)$ in $\pi^+\pi^- J/\psi$

PRL 110, 252001 (2013)



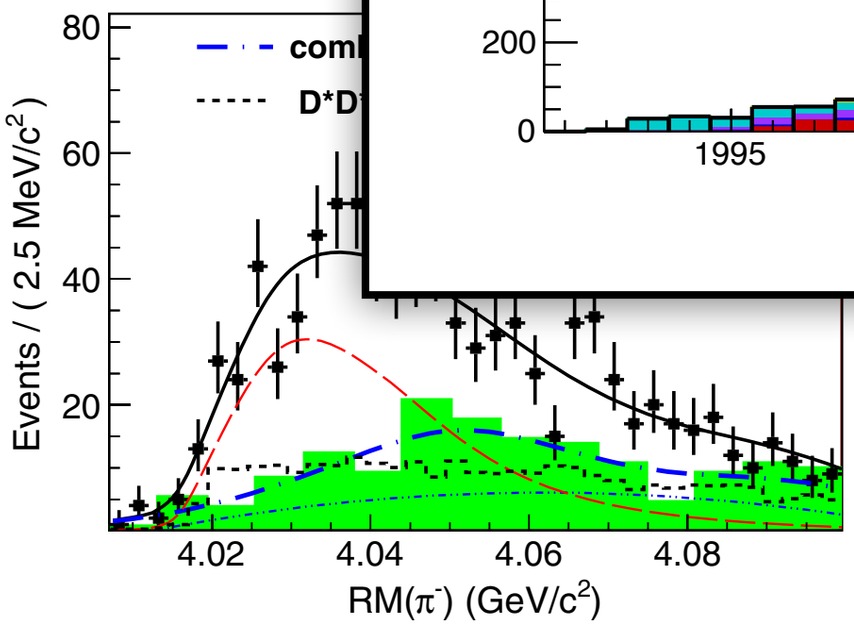
of 3/12/17)

BES Citations per Year



Discovery of the

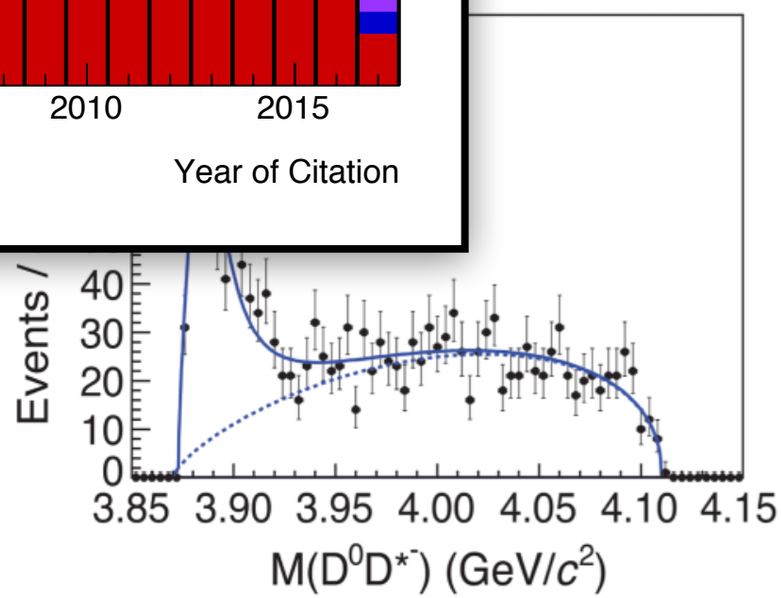
PRL 1



*(**208** citations as of 3/12/17)*

(3900) in $\pi^{\pm}(D^*D)^{\mp}$

1 (2014)



*(**174** citations as of 3/12/17)*

The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

— Open charm cross sections are even more intriguing.

$\Rightarrow$ A fine high-statistics energy scan is needed for a more systematic approach.

2. The Z Problem:

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$, but at 4.42 GeV the Dalitz plots are generally more complex.

— $\pi\pi J/\psi$ shows a strange diagonal structure in the Dalitz plot *(progress has been made!)*.

— $\pi\pi\psi(2S)$ shows a structure at 4040 (but we can't easily fit it)???

$\Rightarrow$ Amplitude analyses at multiple energies would probe threshold behaviors.

Next Proposal:

Building on the ongoing 2017 scan, continue to scan from 4.31 to 4.41 GeV.

2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

— Open charm cross sections are even more intriguing.

⇒ A fine high-statistics energy scan is needed for a more systematic approach.

2. The Z

At 4.2

but at

— 3

— 3

⇒ Am

made!).

behaviors.

Next Pr

Build

2017:

NEX

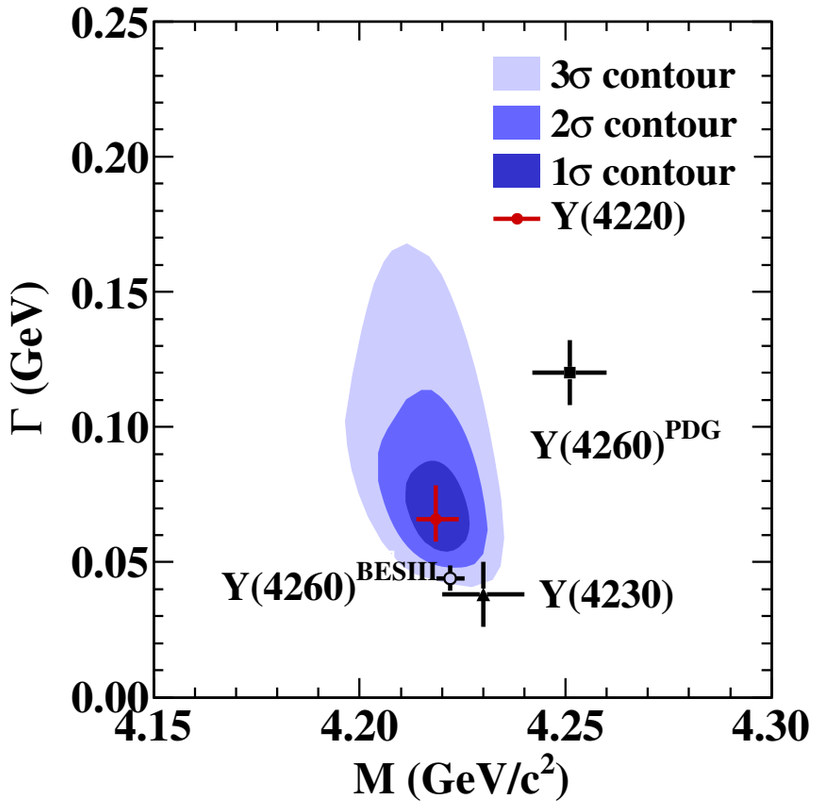
(go

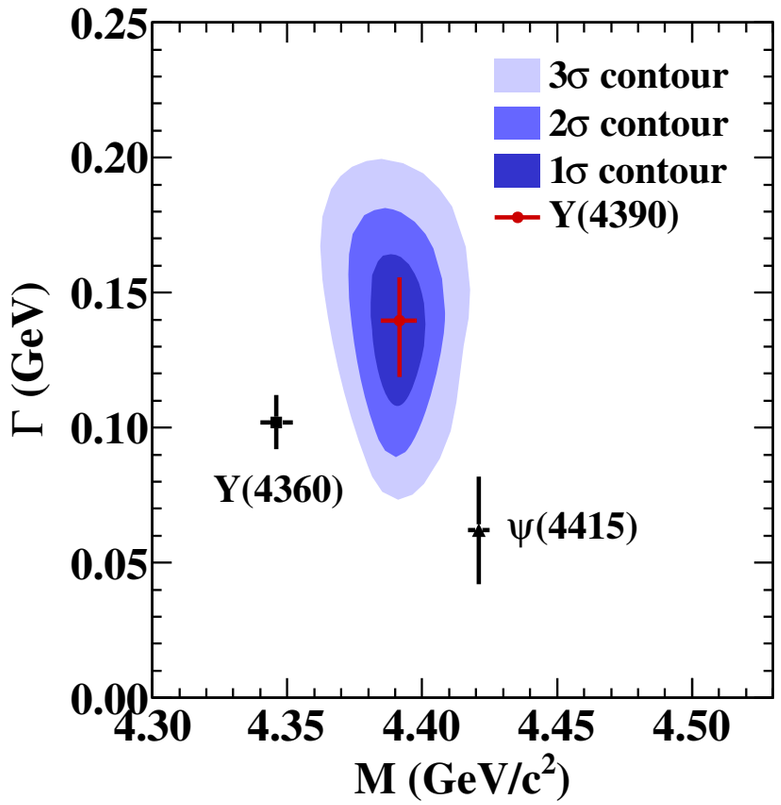
eV

GeV

Structures in $\pi^+\pi^- h_c$ compared to others

PRL 118, 092002 (2017)





The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

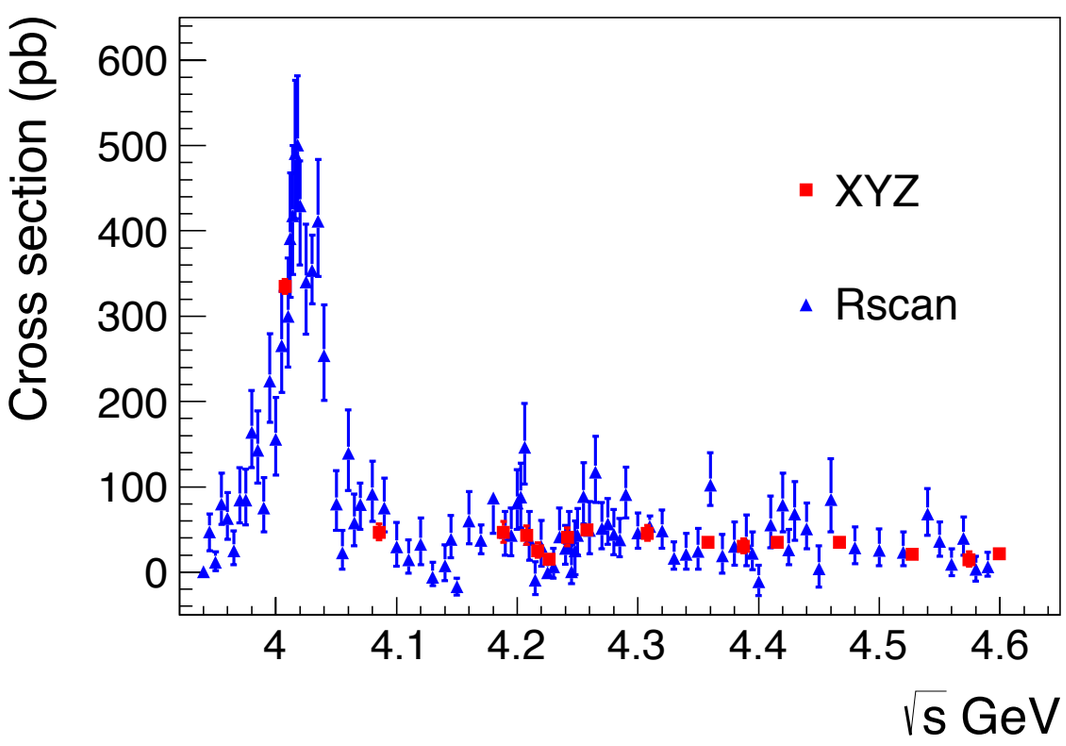
— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

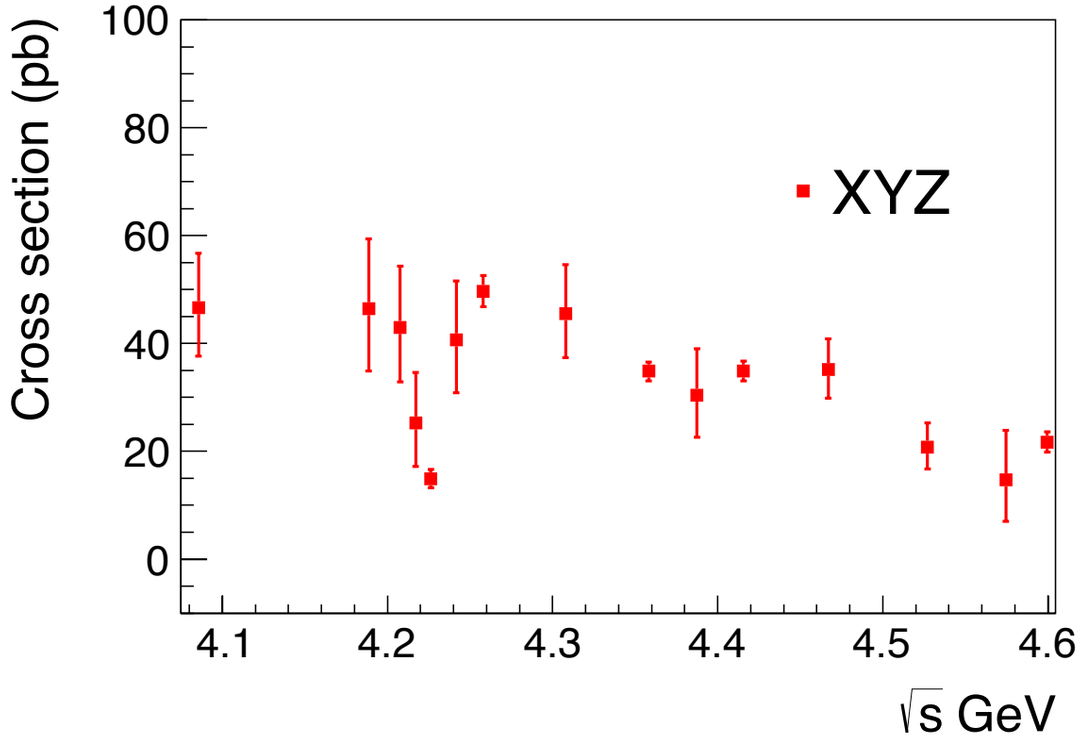
— Open charm cross sections are even more intriguing.

⇒ A fine high-statistics energy scan is needed for a more systematic approach.

$e^+e^- \to D_s^+D_s^-$ Cross Sections

Still In Progress (from LI Ke)





The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

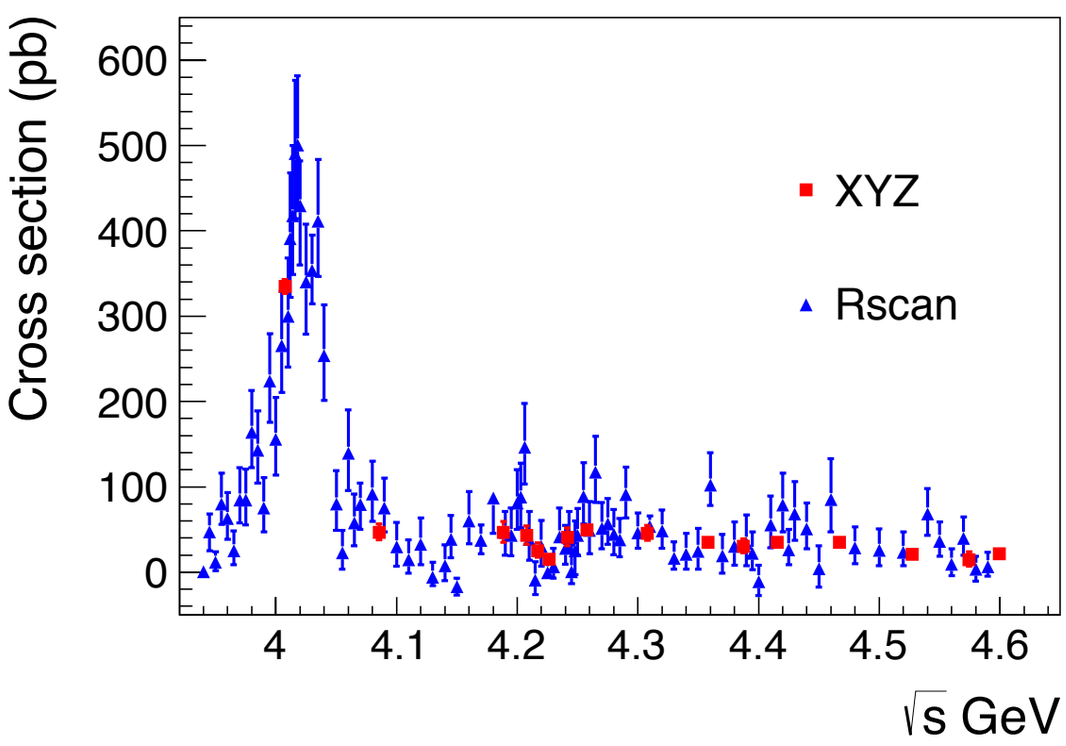
— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

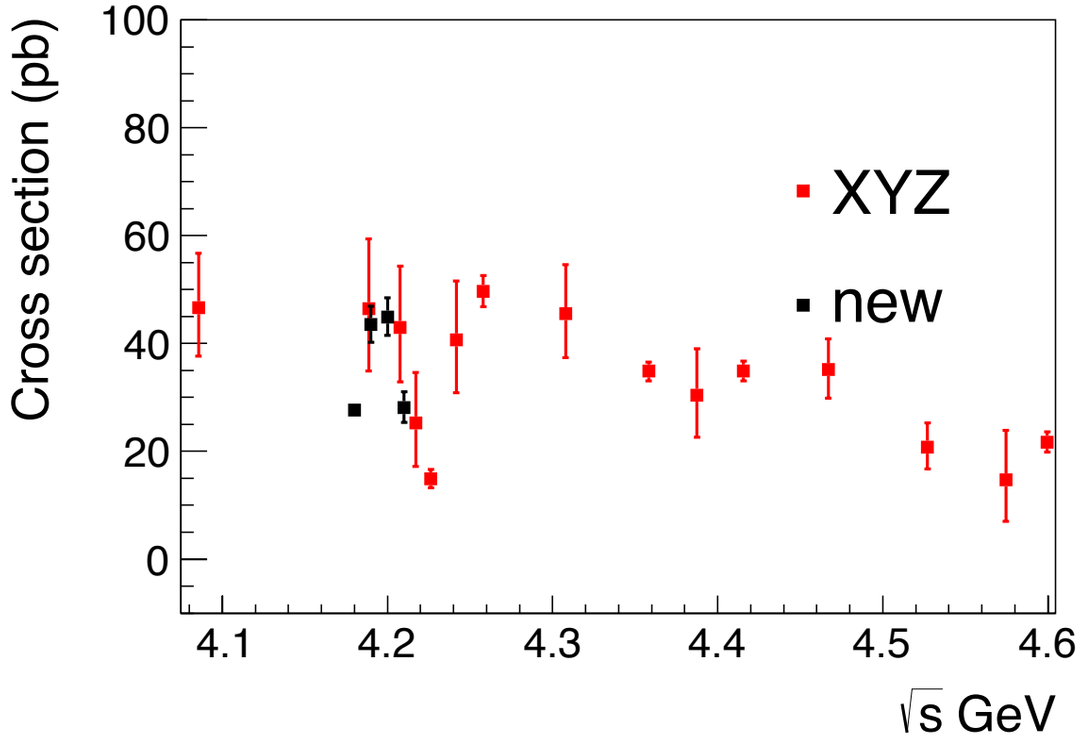
— Open charm cross sections are even more intriguing.

⇒ A fine high-statistics energy scan is needed for a more systematic approach.

$e^+e^- \to D_s^+D_s^-$ Cross Sections

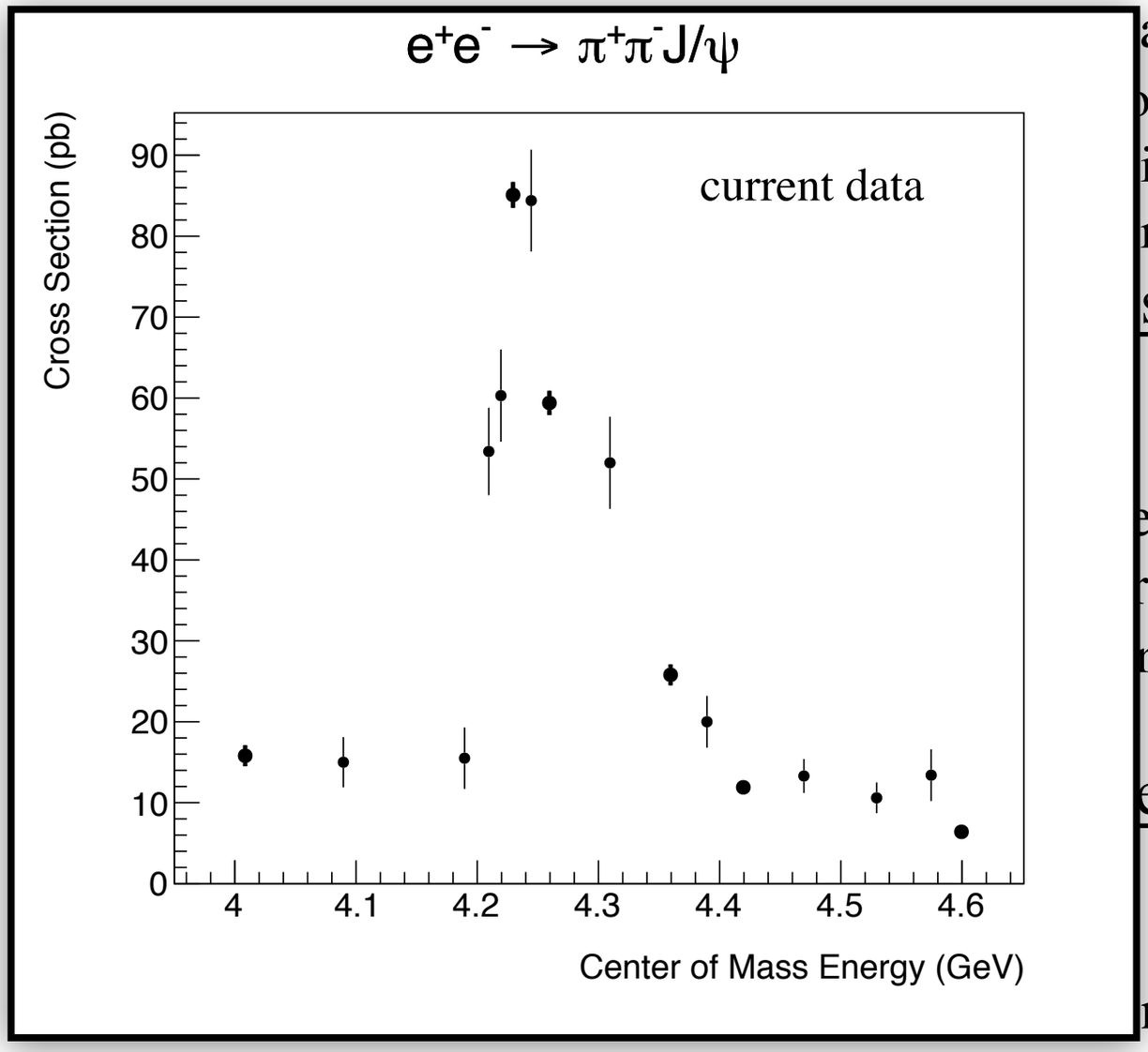
Still In Progress (from LI Ke)





The "Y Problem" and the "Z Problem"

1. The Y Problem:



ave become increasingly complex.

ooks like a simple peak.

istent with $\pi\pi J/\psi$.

re intriguing.

s needed for a more systematic approach.

e for the $Z_c(3900)$ and the $Z_c(4020)$,

rally more complex.

re in the Dalitz plot *(progress has been made!)*.

we can't easily fit it)???

ergies would probe threshold behaviors.

nue to scan from 4.31 to 4.41 GeV.

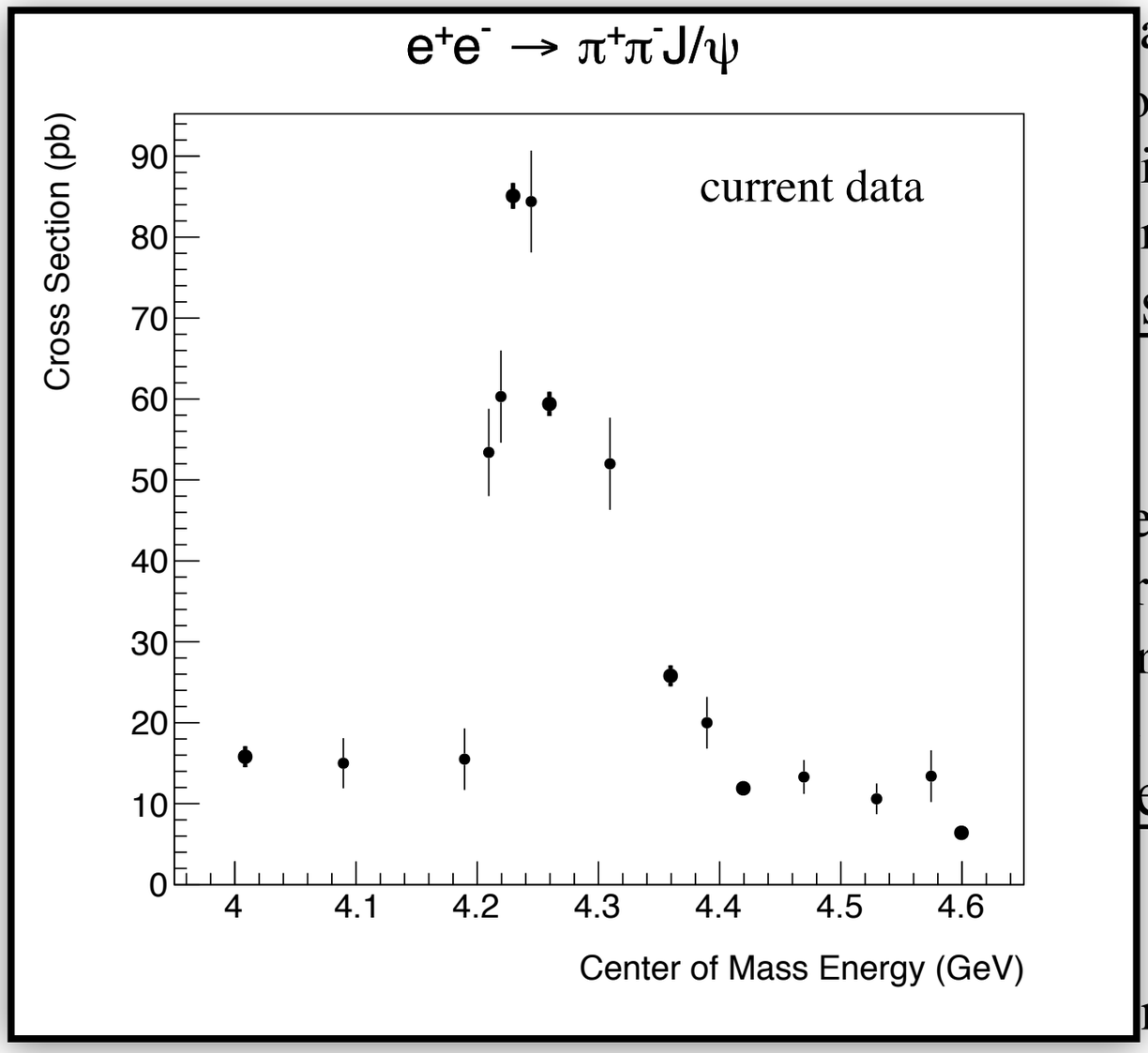
2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

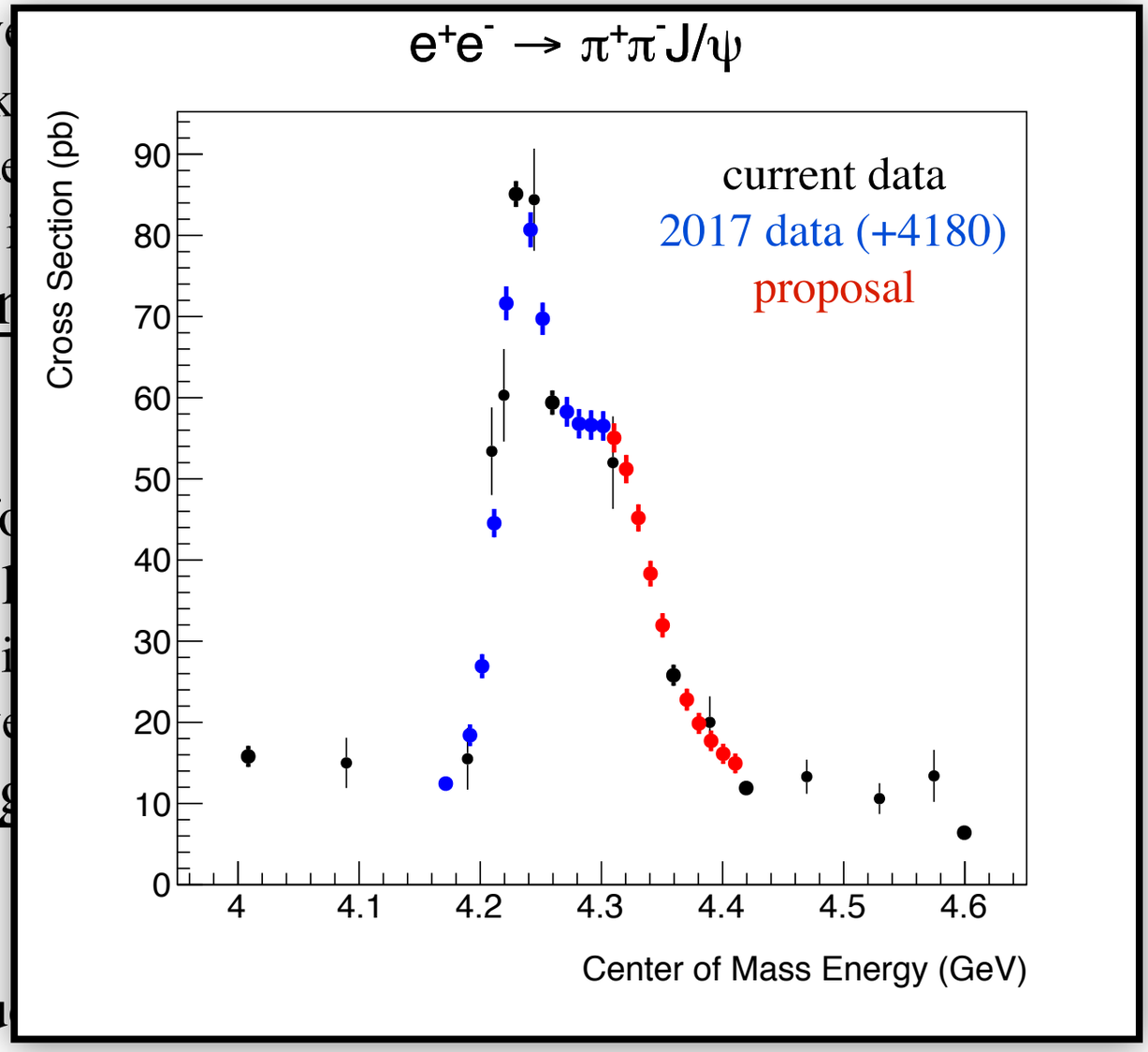
NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The “Y Problem” and the “Z Problem”

1. The Y Problem:





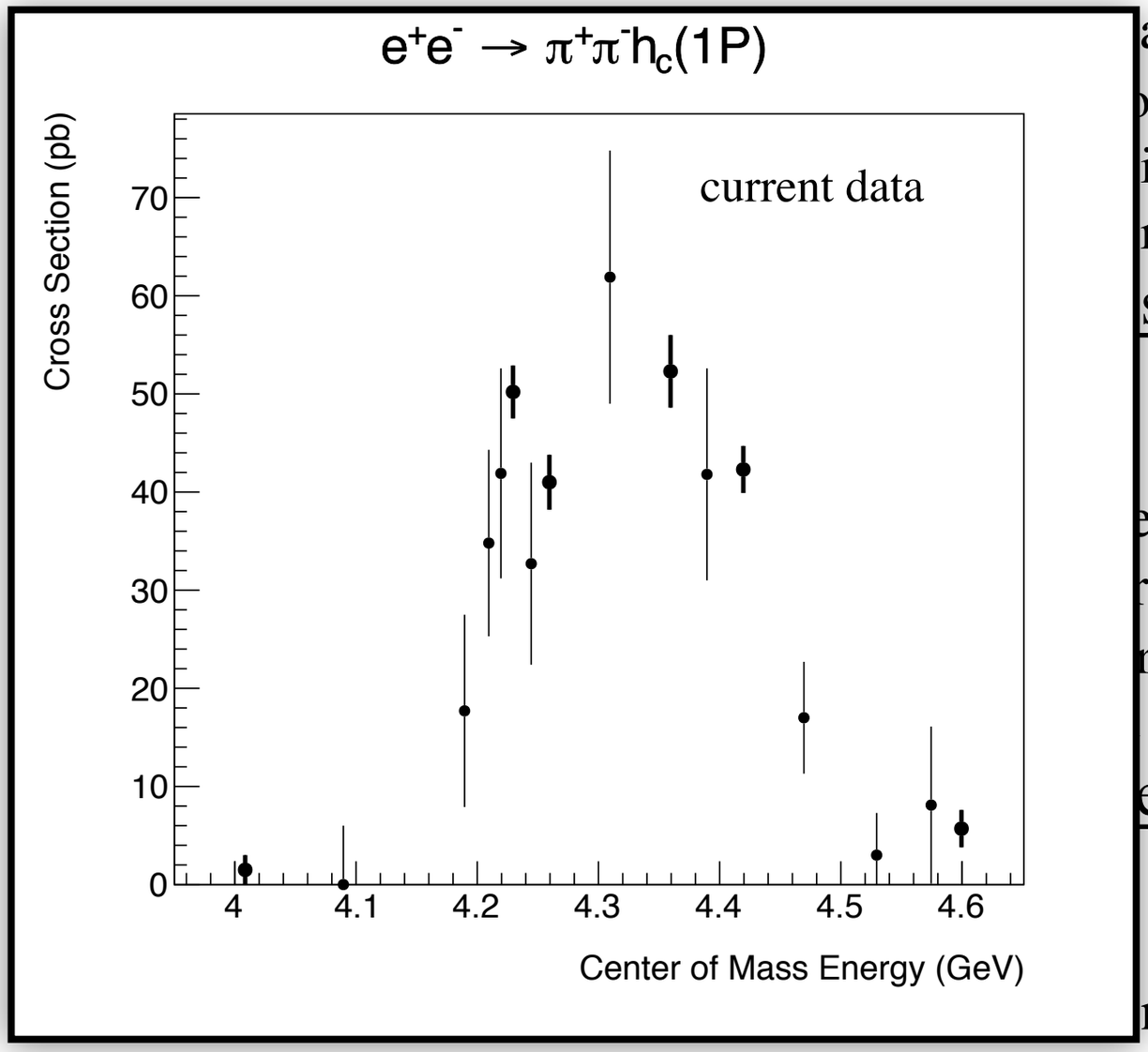
2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"

1. The Y Problem:



ave become increasingly complex.

ooks like a simple peak.

istent with $\pi\pi J/\psi$.

re intriguing.

s needed for a more systematic approach.

e for the $Z_c(3900)$ and the $Z_c(4020)$,

rally more complex.

re in the Dalitz plot *(progress has been made!)*.

we can't easily fit it)???

ergies would probe threshold behaviors.

nue to scan from 4.31 to 4.41 GeV.

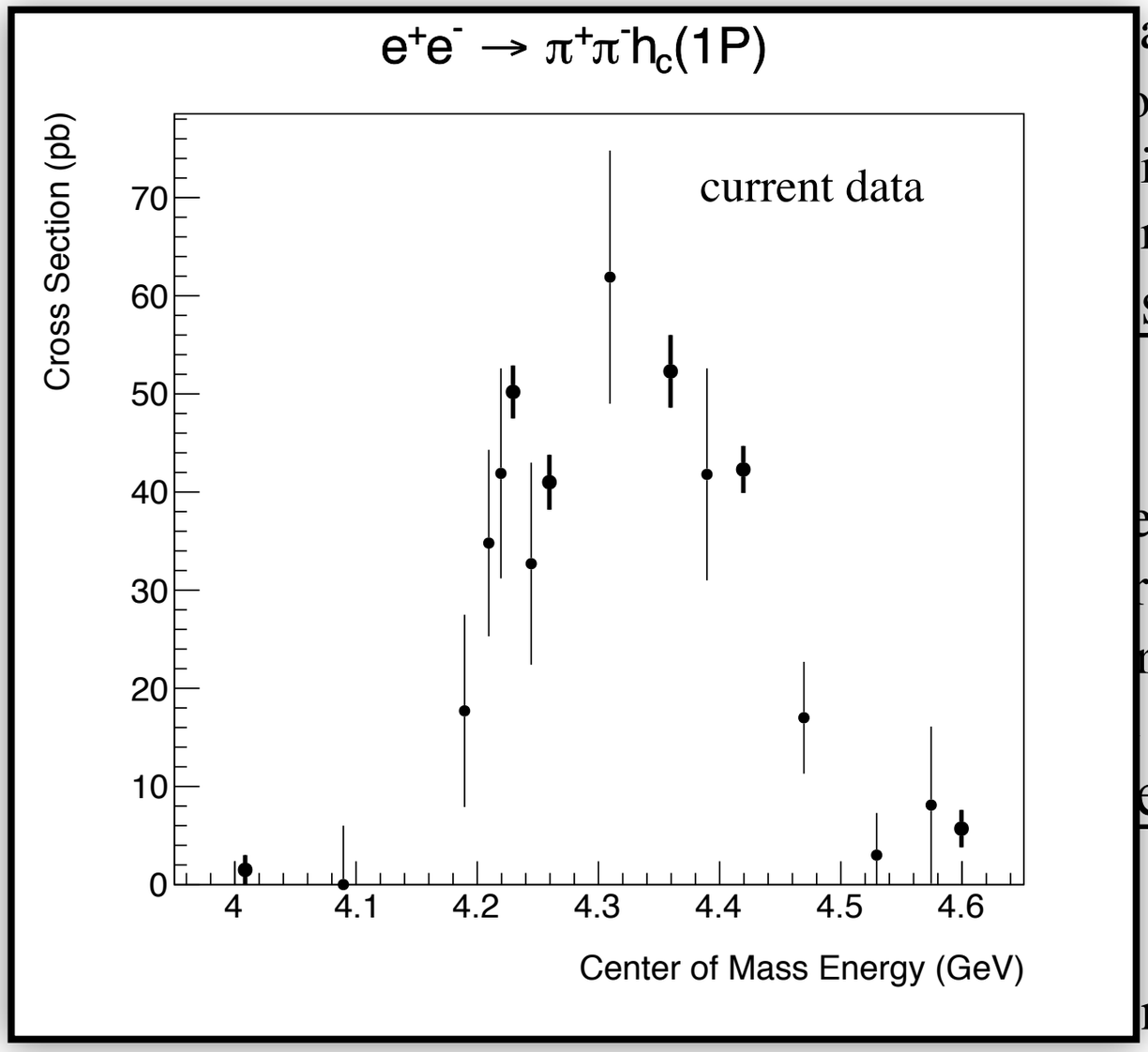
2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

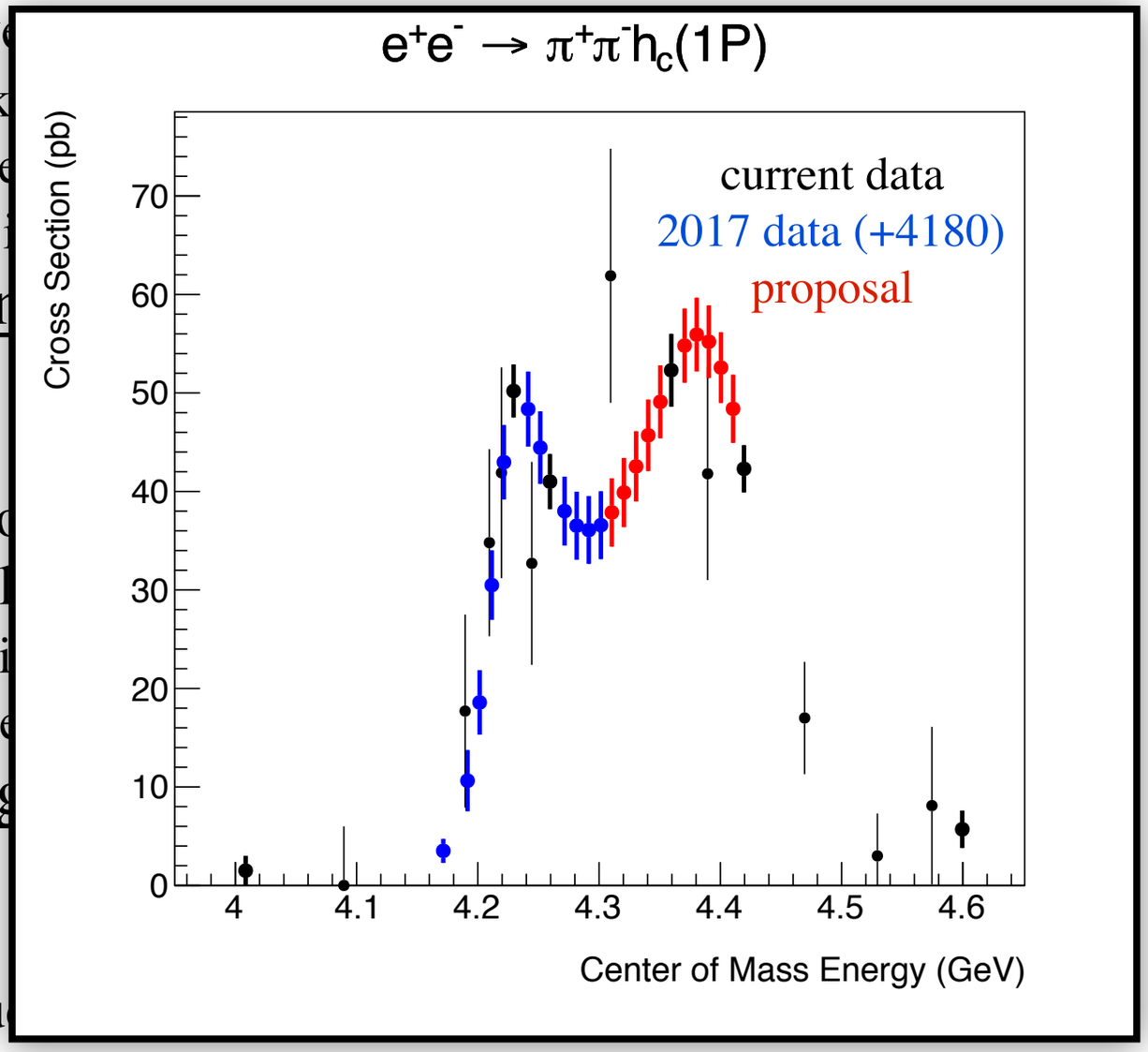
NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The “Y Problem” and the “Z Problem”

1. The Y Problem:





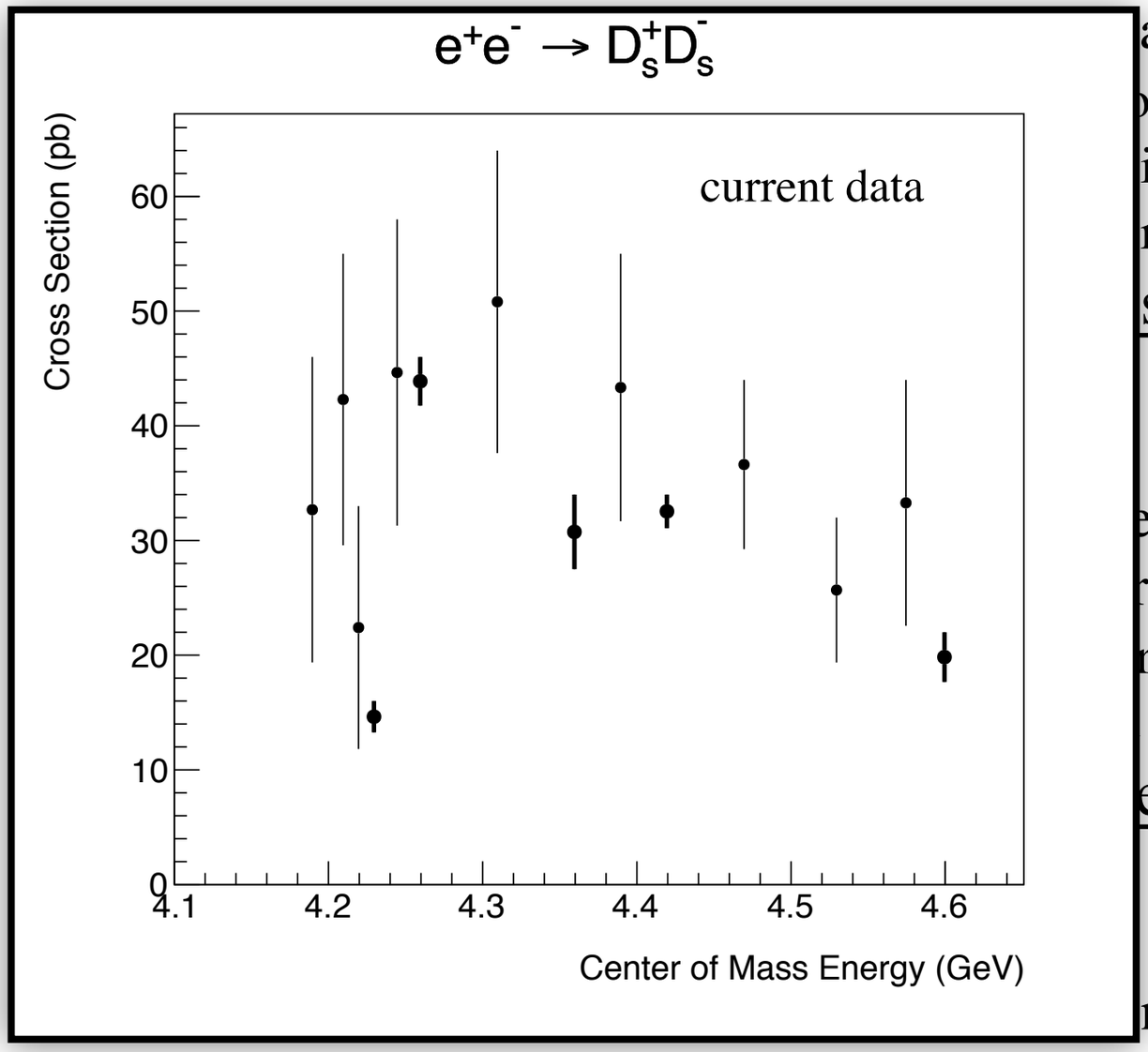
2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"

1. The Y Problem:



ave become increasingly complex.
ooks like a simple peak.
istent with $\pi\pi J/\psi$.
re intriguing.
s needed for a more systematic approach.

e for the $Z_c(3900)$ and the $Z_c(4020)$,
rally more complex.
re in the Dalitz plot *(progress has been made!)*.
we can't easily fit it)???
ergies would probe threshold behaviors.

nue to scan from 4.31 to 4.41 GeV.

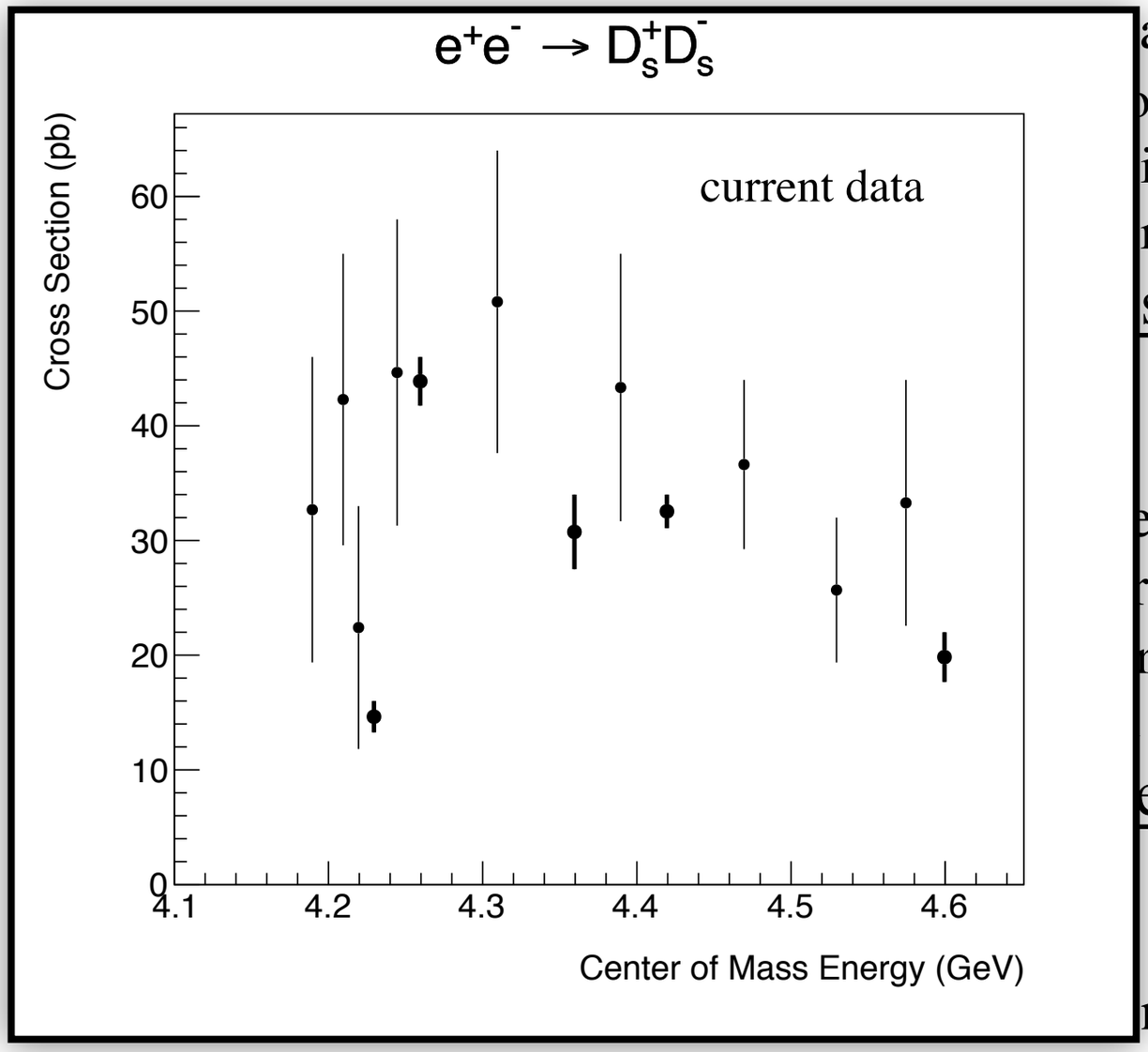
2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

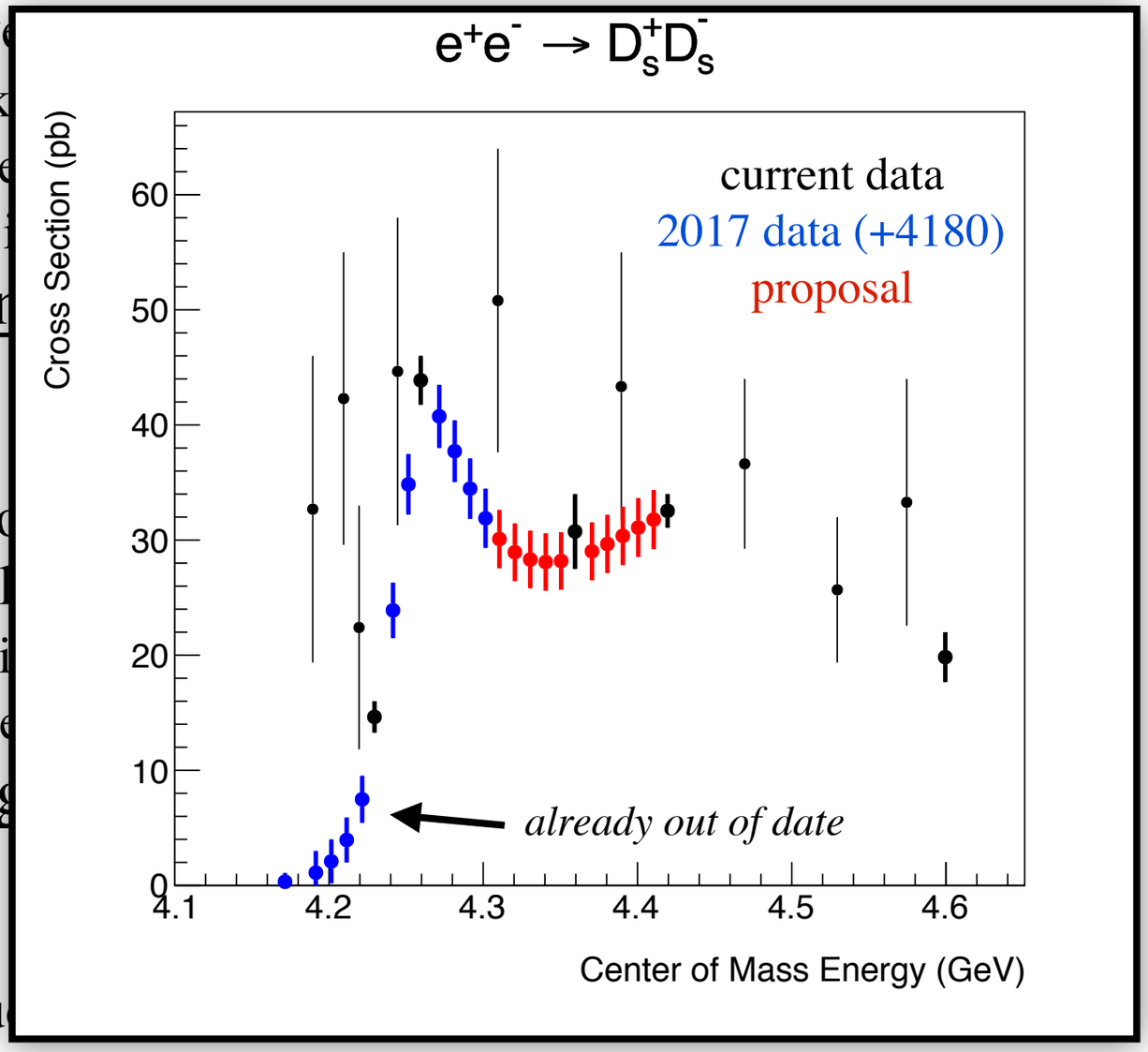
NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The “Y Problem” and the “Z Problem”

1. The Y Problem:





2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a fun

— Even the Y(4260) in ππ

— The $\pi\pi h_c$ cross section i

— Open charm cross secti

⇒ A fine high-statistics e

2. The Z Problem:

At 4.23 and 4.26 GeV, we

but at 4.42 GeV the Dalitz

— $\pi\pi J/\psi$ shows a strange

— $\pi\pi\psi(2S)$ shows a struct

⇒ Amplitude analyses at

Next Proposal:

Building on the ongoing 2(

2017: 500pb^{-1} at 4.19, 4.2

NEXT: 500pb^{-1} at 4.31,

(going to 4.41 GeV connec

Other e^+e^- Cross Sections *(selection)*

* all open charm cross sections:
  — investigate coupled channels.
* $\omega\chi_{c1}$ and $\omega\chi_{c2}$:
  — enhancements at threshold like $\omega\chi_{c0}$?
* $\gamma\eta_c$ and $\gamma\chi_{c0}$:
  — consistent with lattice QCD hybrid calculations?
* $\pi^+\pi^- h_c(2P)$:
  — discover the $h_c(2P)$?
* $\pi^+\pi^-\psi(2S)$:
  — will the Y(4360) also turn out to be more complicated?
* $\eta J/\psi$, $\eta' J/\psi$, XJ/ψ…:
  — other surprises?
* $X\eta_c$:
  — can we access η_c channels?
* + many more…

The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

— Open charm cross sections are even more intriguing.

$\Rightarrow$ A fine high-statistics energy scan is needed for a more systematic approach.

2. The Z Problem:

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$, but at 4.42 GeV the Dalitz plots are generally more complex.

— $\pi\pi J/\psi$ shows a strange diagonal structure in the Dalitz plot *(progress has been made!)*.

— $\pi\pi\psi(2S)$ shows a structure at 4040 (but we can't easily fit it)???

$\Rightarrow$ Amplitude analyses at multiple energies would probe threshold behaviors.

Next Proposal:

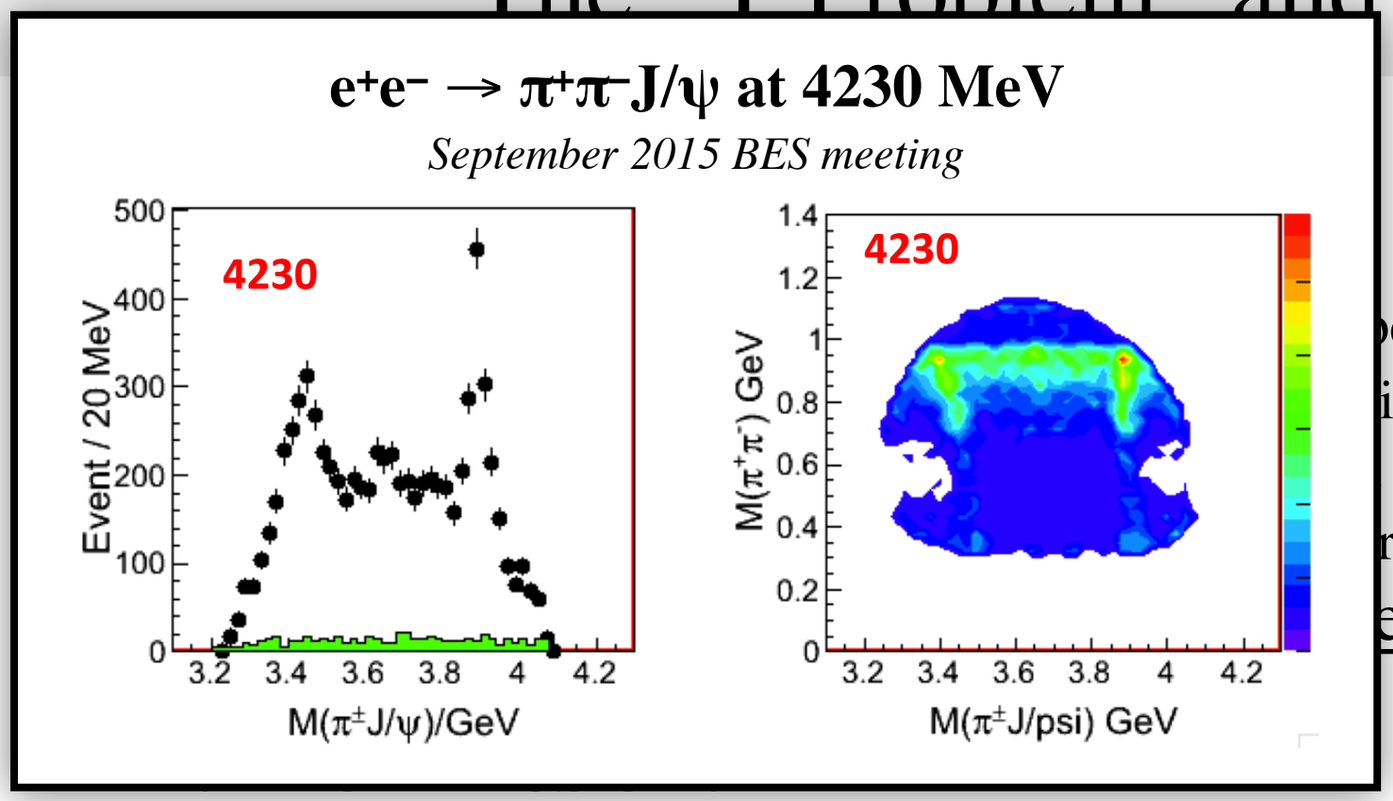
Building on the ongoing 2017 scan, continue to scan from 4.31 to 4.41 GeV.

2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"



become increasingly complex.

like a simple peak.

with ππJ/ψ.

riguing.

eded for a more systematic approach.

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$, but at 4.42 GeV the Dalitz plots are generally more complex.

— ππJ/ψ shows a strange diagonal structure in the Dalitz plot *(progress has been made!)*.

— ππψ(2S) shows a structure at 4040 (but we can't easily fit it)???

⇒ Amplitude analyses at multiple energies would probe threshold behaviors.

Next Proposal:

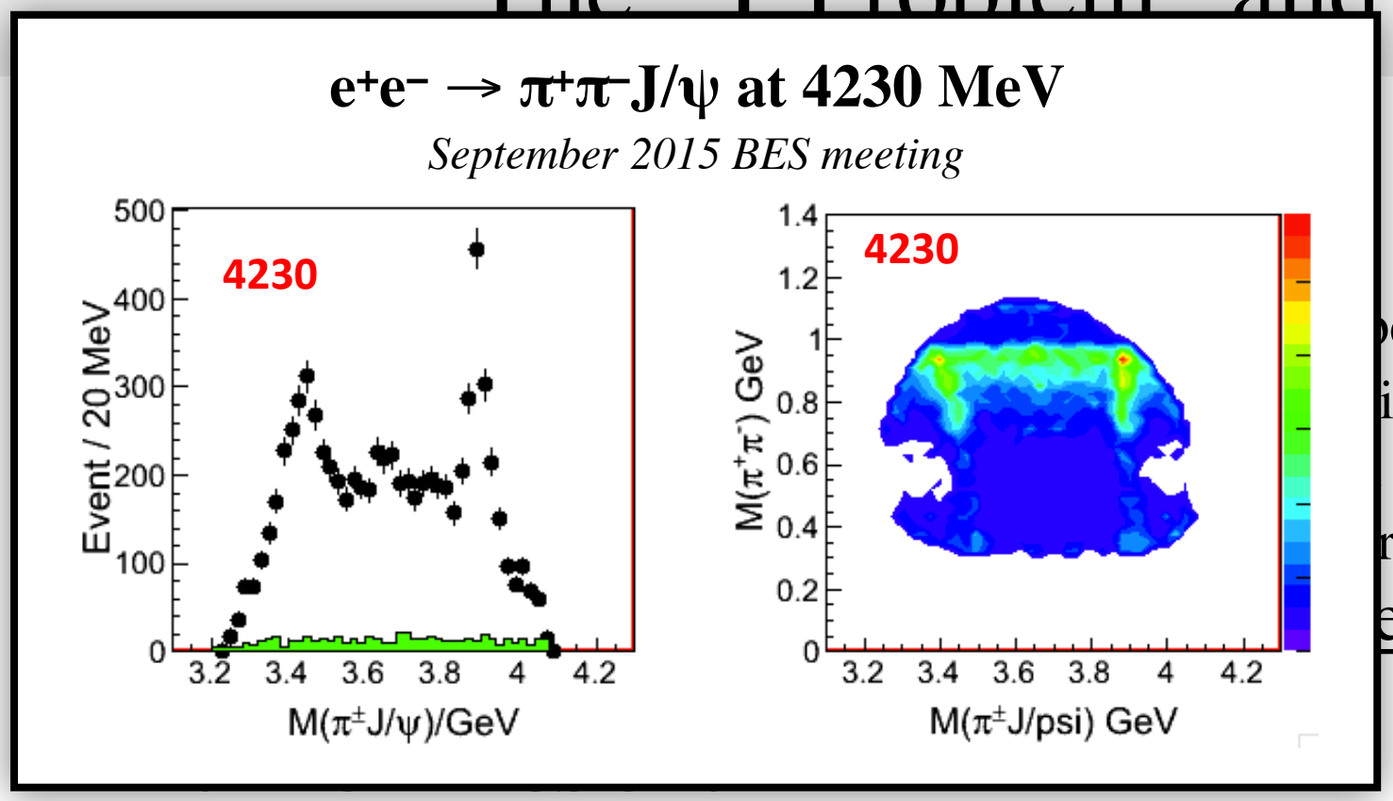
Building on the ongoing 2017 scan, continue to scan from 4.31 to 4.41 GeV.

2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

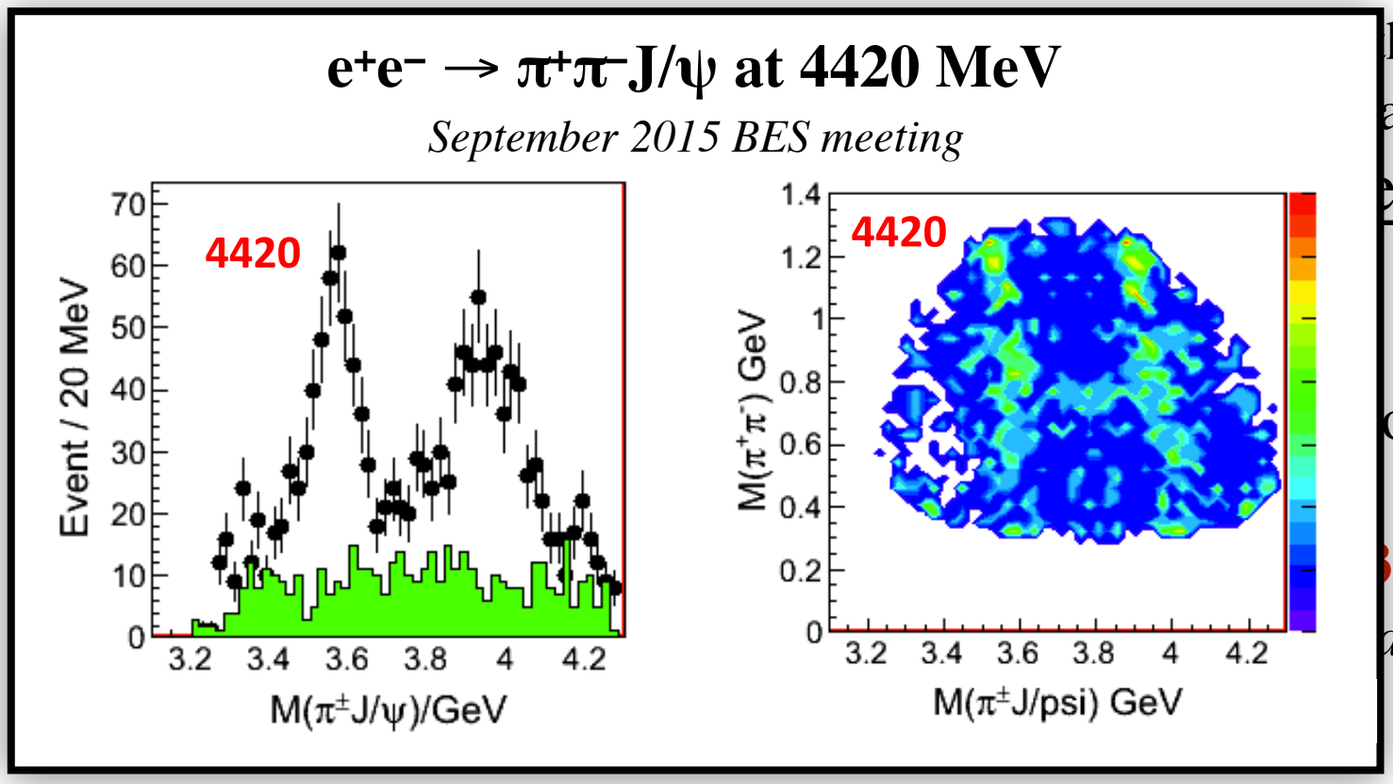
(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

The "Y Problem" and the "Z Problem"



become increasingly complex.
like a simple peak.
with ππJ/ψ.
riguing.
eded for a more systematic approach.

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$,
but at 4.42 GeV the Dalitz plots are generally more complex.



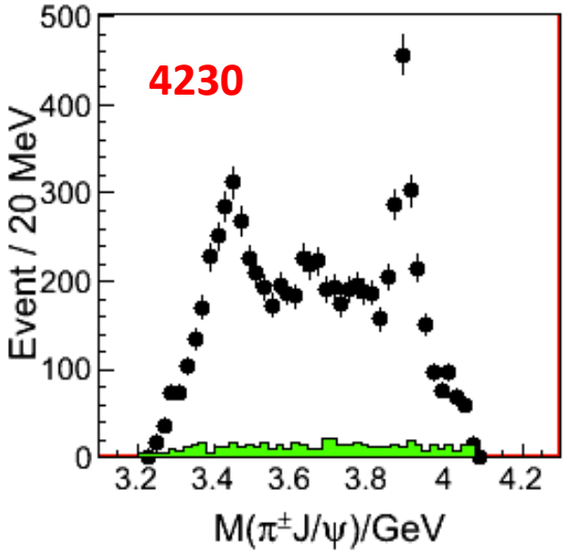
he Dalitz plot *(progress has been made!)*.
an't easily fit it)???
es would probe threshold behaviors.

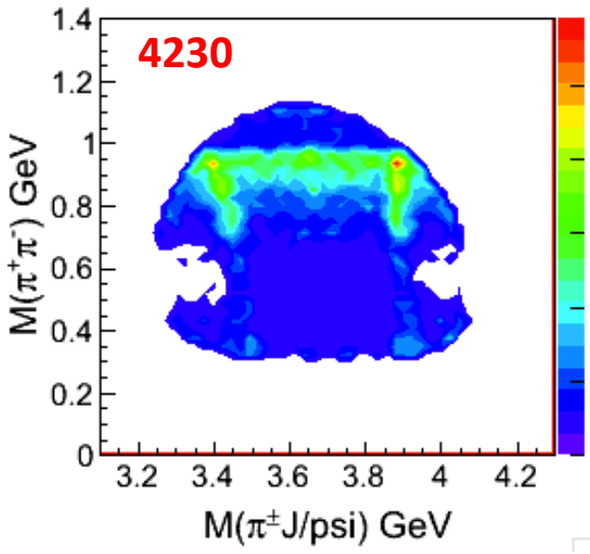
o scan from 4.31 to 4.41 GeV.
4.25, 4.27, 4.28, 4.29, 4.30 GeV
5, 4.37, 4.38, 4.39, 4.40, 4.41 GeV
a set at 4.42 GeV)

The "Y Problem" and th

$e^+e^- \to \pi^+\pi^- J/\psi$ at 4230 MeV

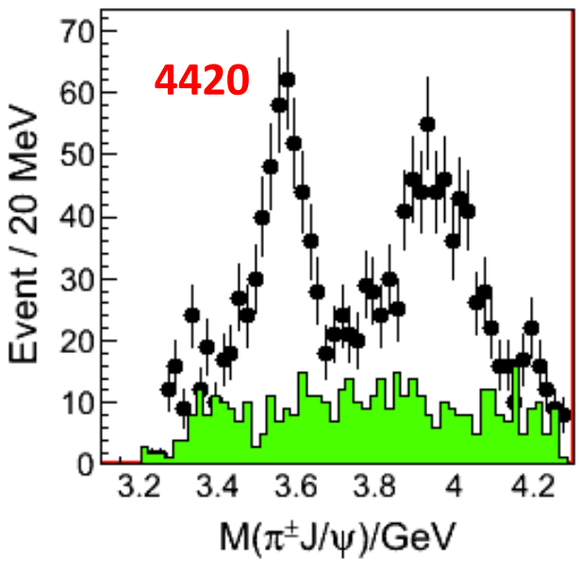
September 2015 BES meeting

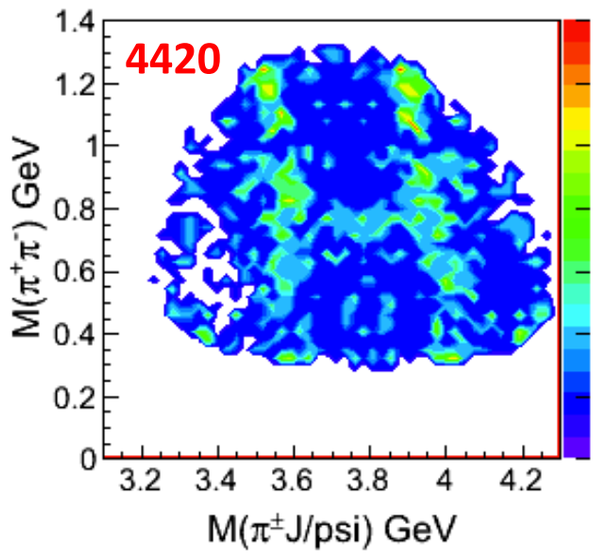




$e^+e^- \to \pi^+\pi^- J/\psi$ at 4420 MeV

September 2015 BES meeting

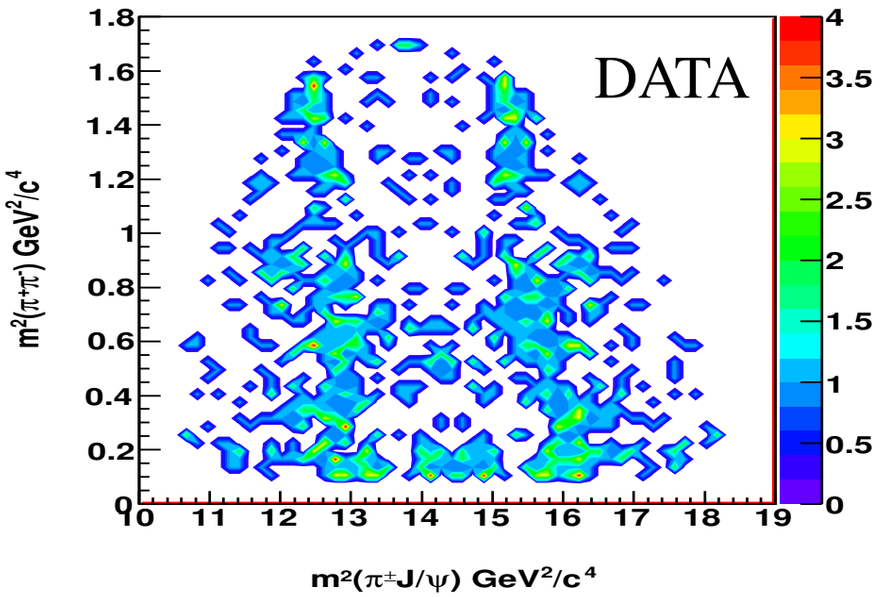




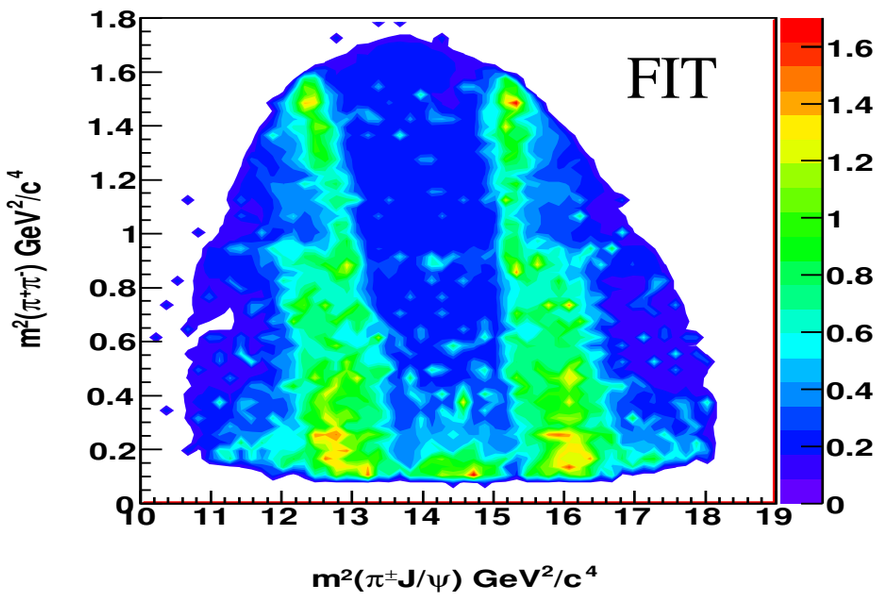
At 4.23 and 4.26 GeV, we found evidence for the Z
but at 4.42 GeV the Dalitz plots are generally mor

$e^+e^- \to \pi^+\pi^- J/\psi$ at 4420 MeV

In Progress (from SUN Zhentian)



(tighter cuts than before)



Successful fit with $Z_c(3900)$ and a wider $Z_c(40xx)$!

The "Y Problem" and the "Z Problem"

1. The Y Pro

e^+e^- cross s

— Even t

— The ππ

— Open c

⇒ A fine hi

x.

tic approach.

2. The Z Pro

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$,

but at 4.42 GeV the Dalitz plots are generally more complex.

— ππJ/ψ

— ππψ(2

⇒ Amplitu

en made!).

l behaviors.

Next Proposa

Building on

2017: 500

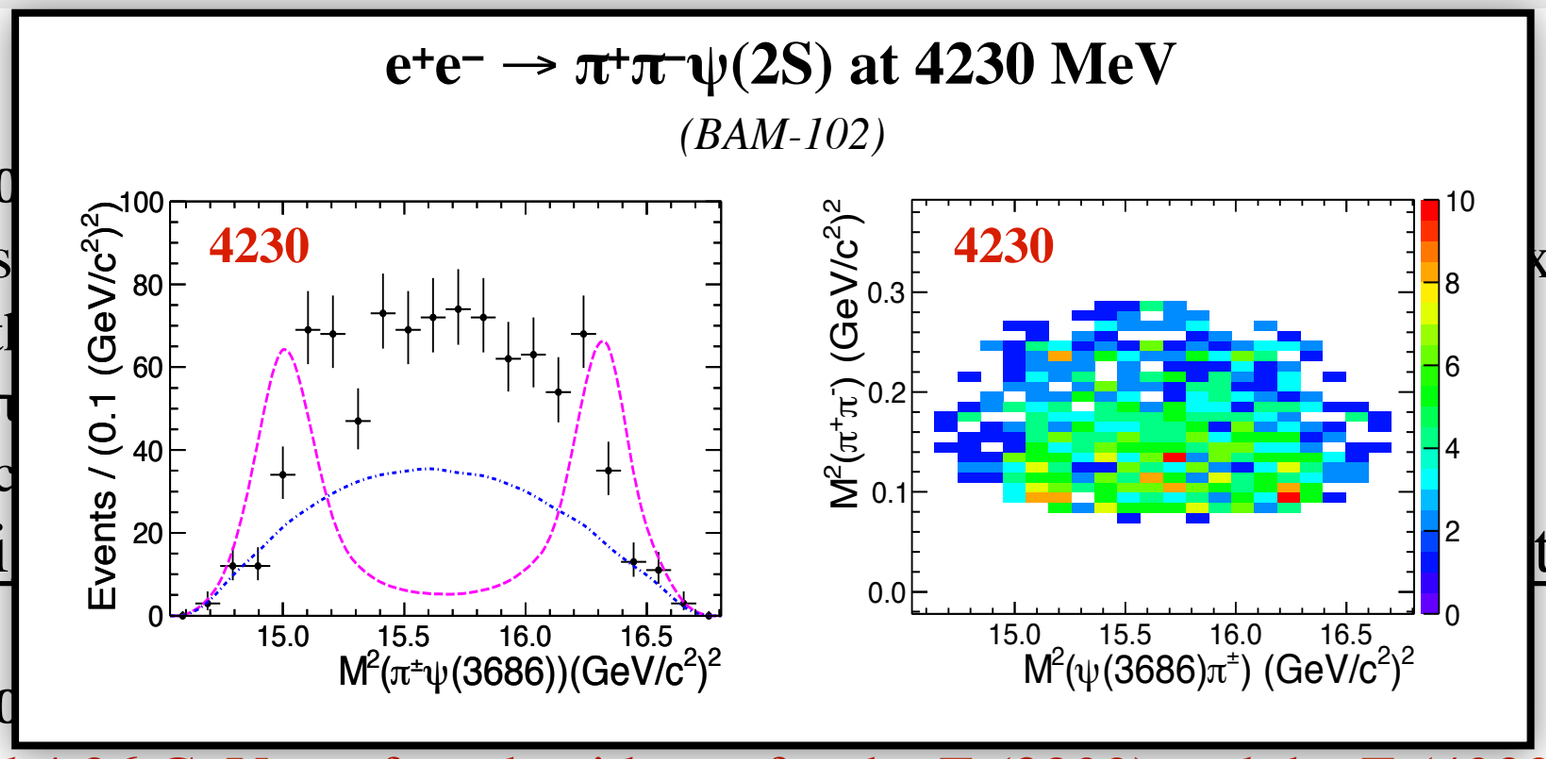
NEXT: 50

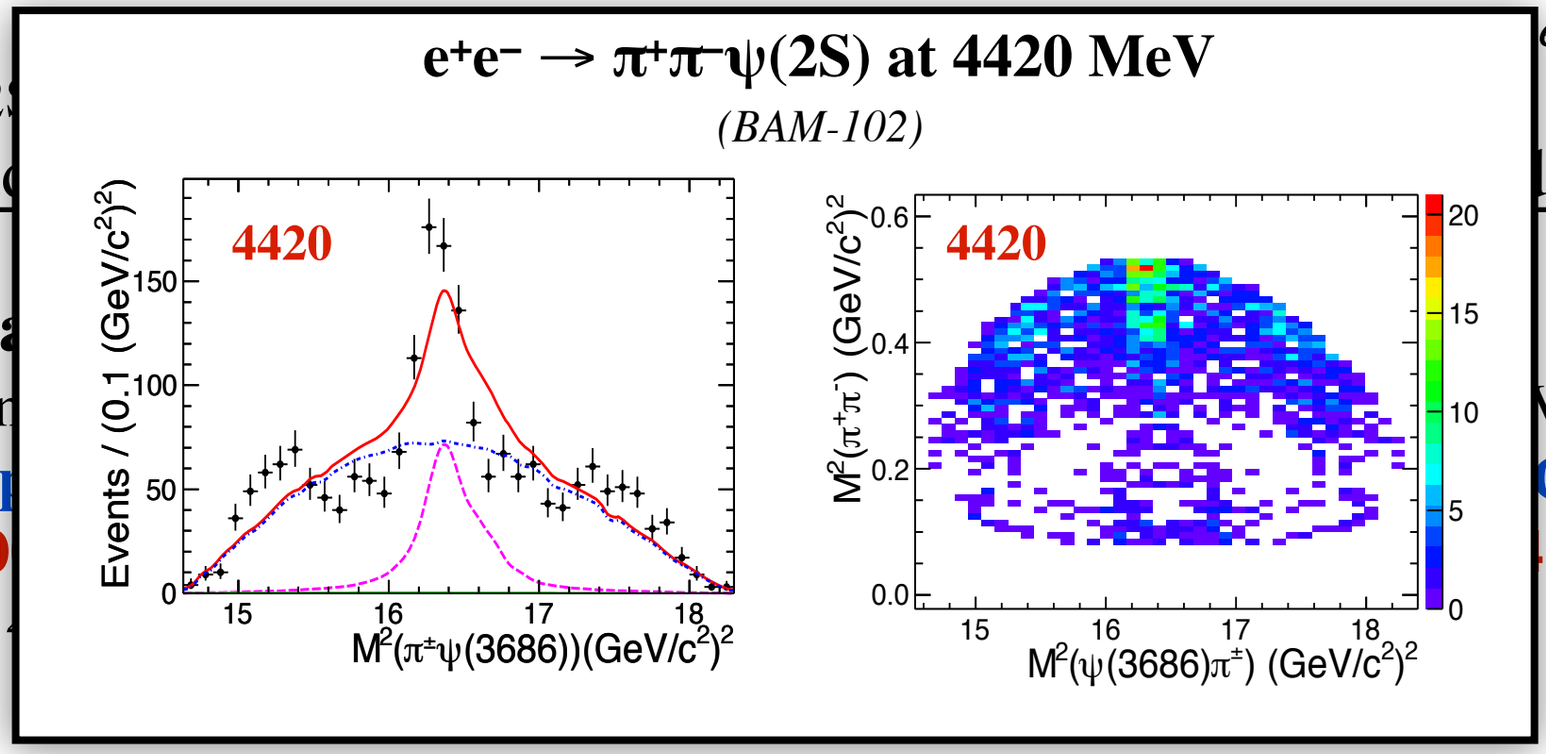
(going to

V.

GeV

.1 GeV





The "Y Problem" and the "Z Problem"

1. The Y Problem:

e^+e^- cross sections as a function of E_{CM} have become increasingly complex.

— Even the Y(4260) in $\pi\pi J/\psi$ no longer looks like a simple peak.

— The $\pi\pi h_c$ cross section is clearly inconsistent with $\pi\pi J/\psi$.

— Open charm cross sections are even more intriguing.

$\Rightarrow$ A fine high-statistics energy scan is needed for a more systematic approach.

2. The Z Problem:

At 4.23 and 4.26 GeV, we found evidence for the $Z_c(3900)$ and the $Z_c(4020)$, but at 4.42 GeV the Dalitz plots are generally more complex.

— $\pi\pi J/\psi$ shows a strange diagonal structure in the Dalitz plot *(progress has been made!)*.

— $\pi\pi\psi(2S)$ shows a structure at 4040 (but we can't easily fit it)???

$\Rightarrow$ Amplitude analyses at multiple energies would probe threshold behaviors.

Next Proposal:

Building on the ongoing 2017 scan, continue to scan from 4.31 to 4.41 GeV.

2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV

NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV

(going to 4.41 GeV connects us to our large data set at 4.42 GeV)

Summary

- The BESIII XYZ program has been very successful.
- But there are problems remaining:
    - The “Y problem” requires a *systematic* study of e^+e^- cross sections as a function of E_{CM}.
    - The “Z problem” requires amplitude analyses for *multiple* E_{CM} and *multiple* channels *(preferably simultaneous analyses)*.
- We propose to scan from 4.31 to 4.41 in 10 MeV steps, building on 2017’s scan from 4.19 to 4.30:

2017: 500pb^{-1} at 4.19, 4.20, 4.21, 4.22, 4.24, 4.25, 4.27, 4.28, 4.29, 4.30 GeV
NEXT: 500pb^{-1} at 4.31, 4.32, 4.33, 4.34, 4.35, 4.37, 4.38, 4.39, 4.40, 4.41 GeV