



university of  
groningen

kvi - center for advanced  
radiation technology

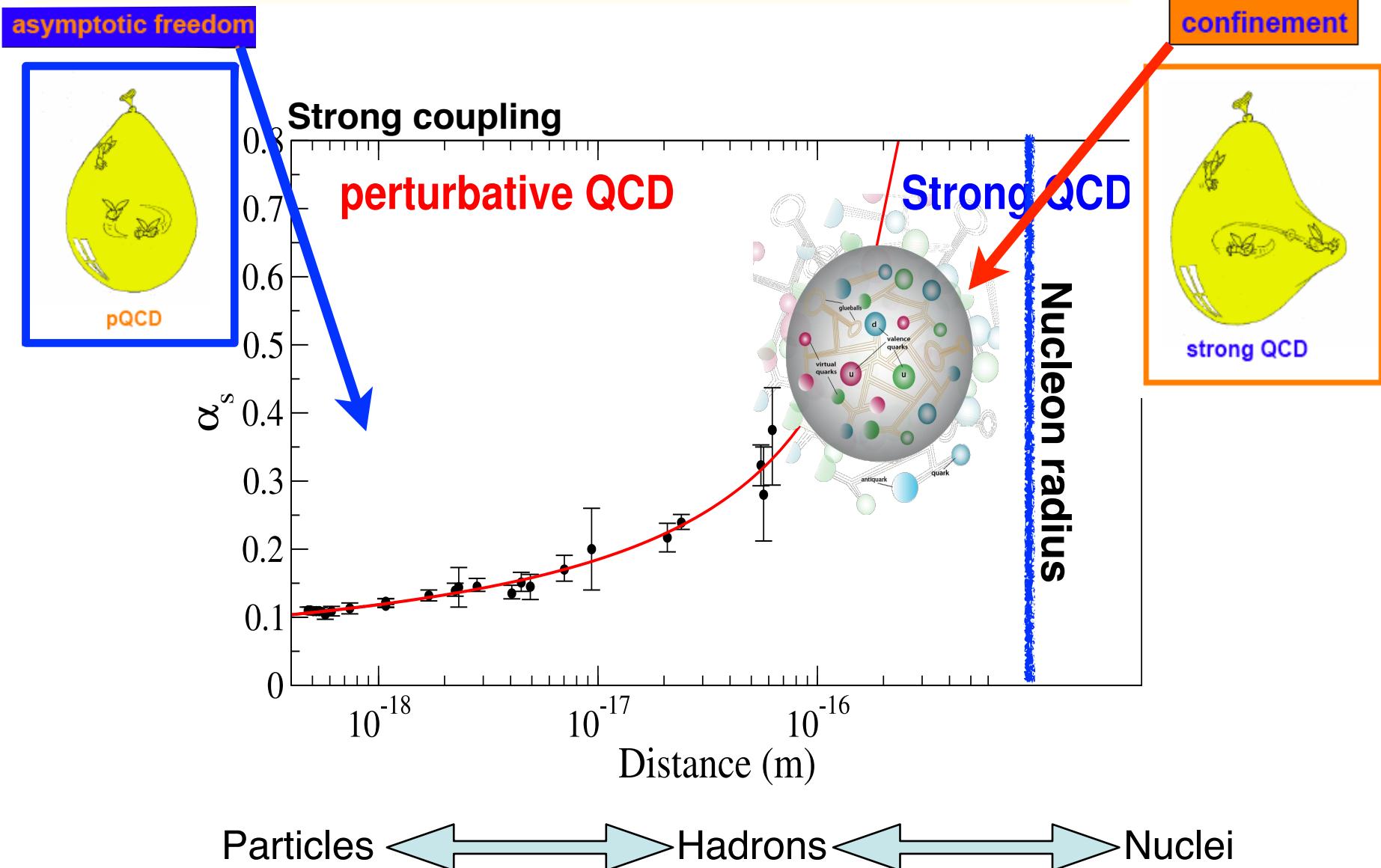
BES III

Eu N  
P C

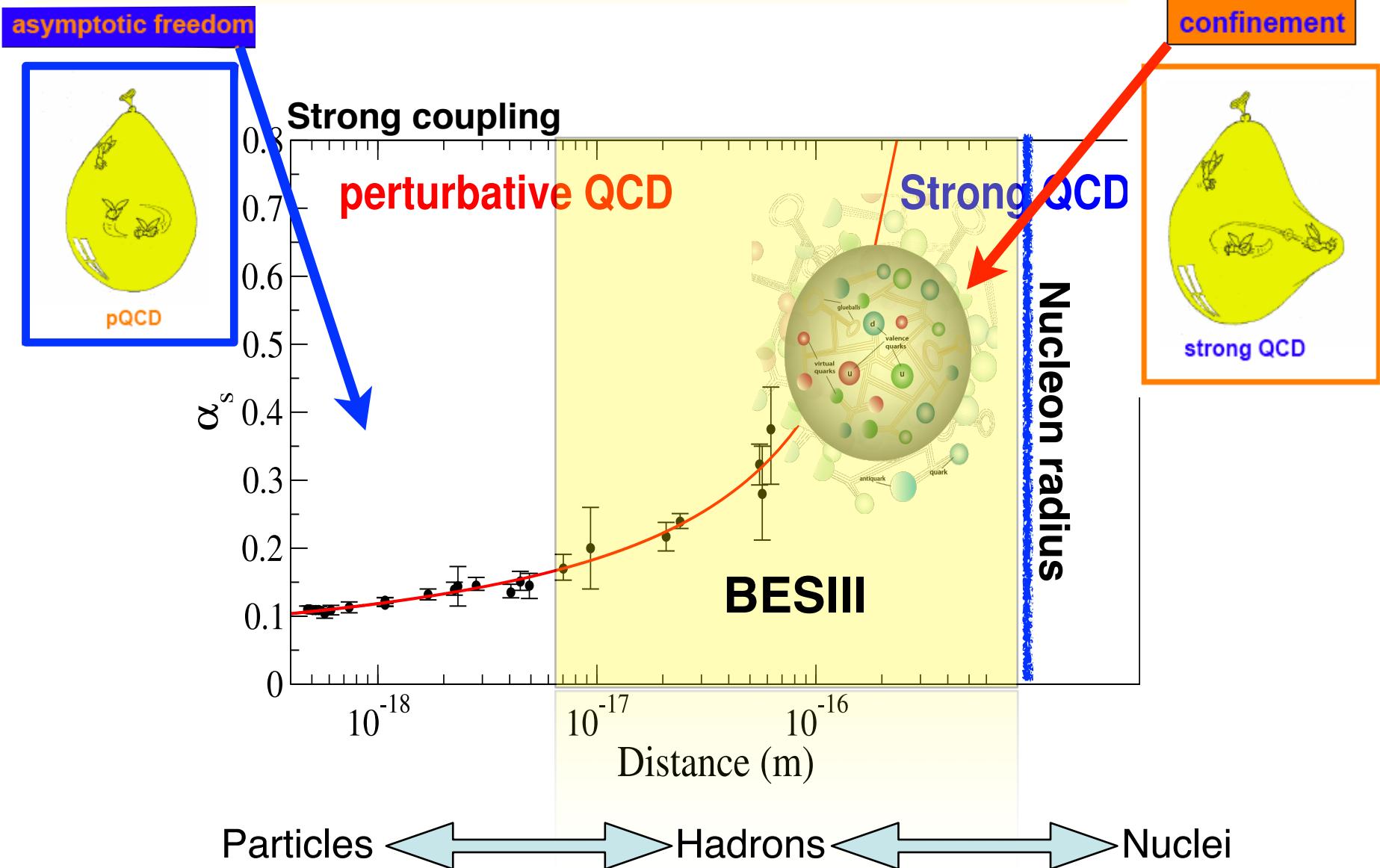
## “XYZ states at BESIII”

Johan Messchendorp (KVI-CART/University of Groningen)  
on behalf of the **BESIII Collaboration**

# The dynamics of QCD!



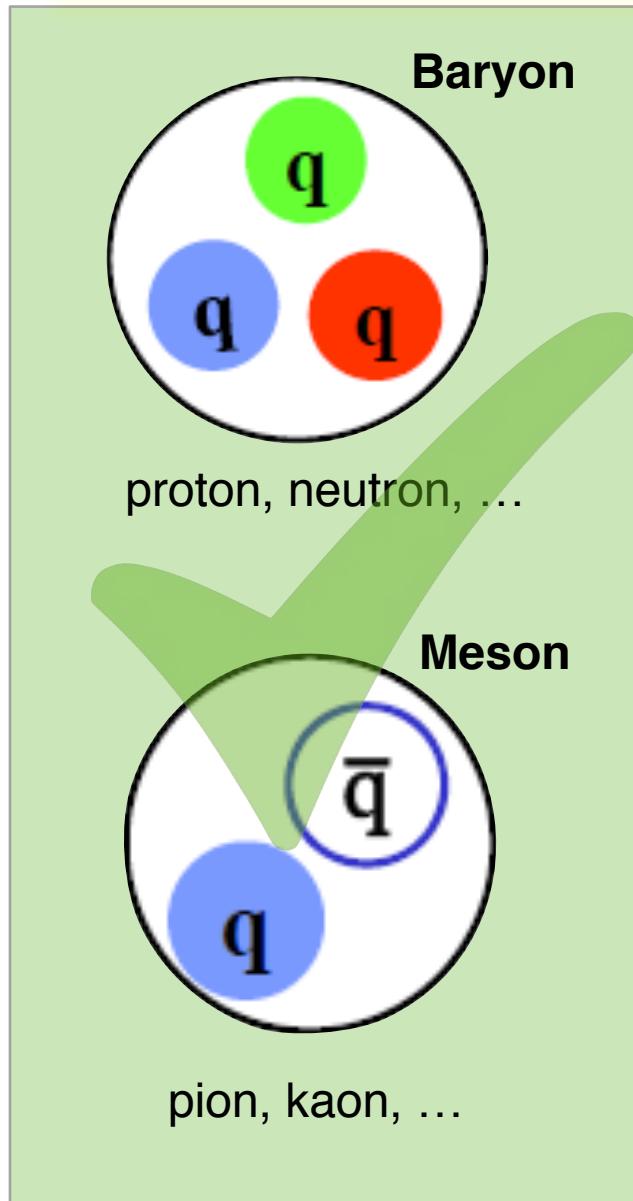
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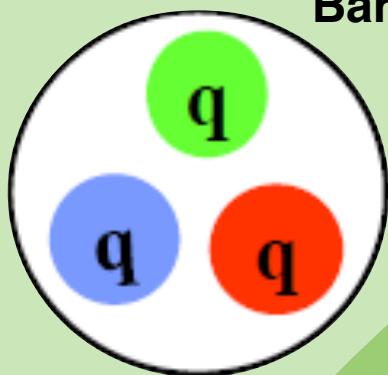
# Ordinary versus “exotic” matter

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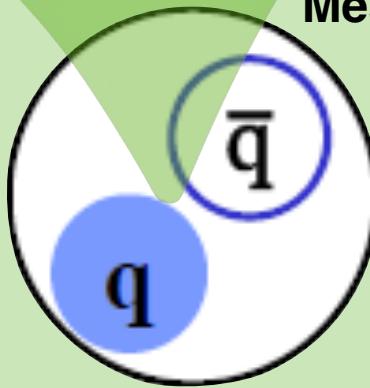


# Ordinary versus “exotic” matter



Baryon

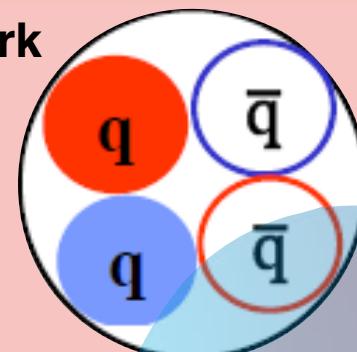
proton, neutron, ...



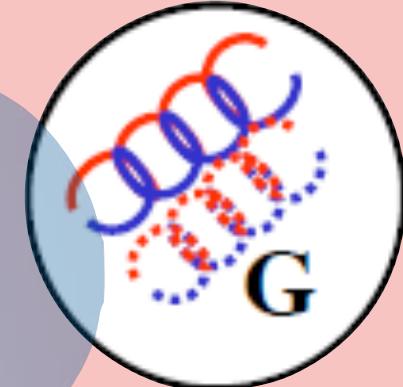
Meson

pion, kaon, ...

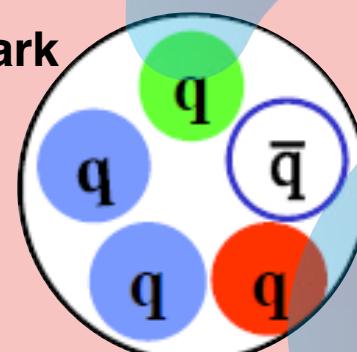
Tetraquark



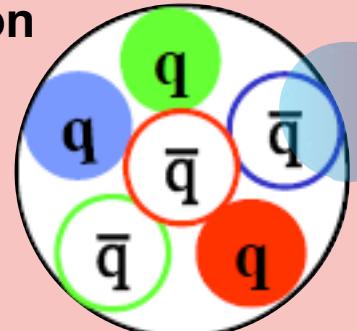
Glueball



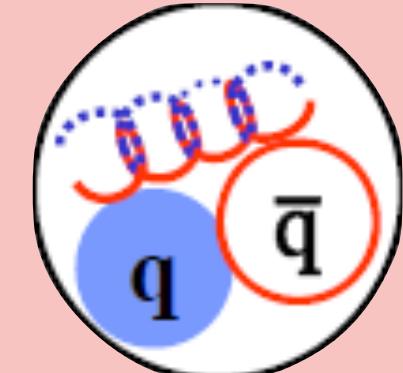
Pentaquark



Hybrid



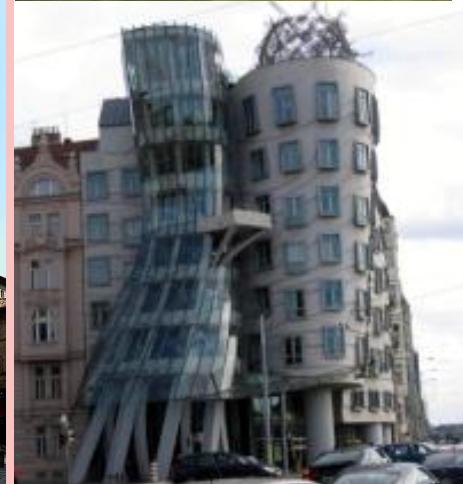
Dibaryon



# Ordinary versus “exotic” matter

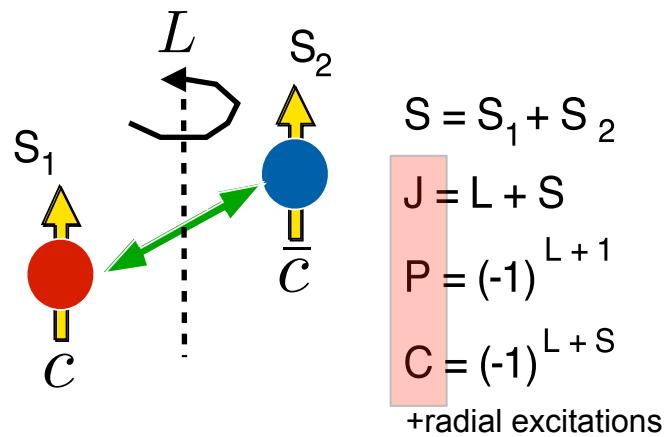


“ordinary matter”

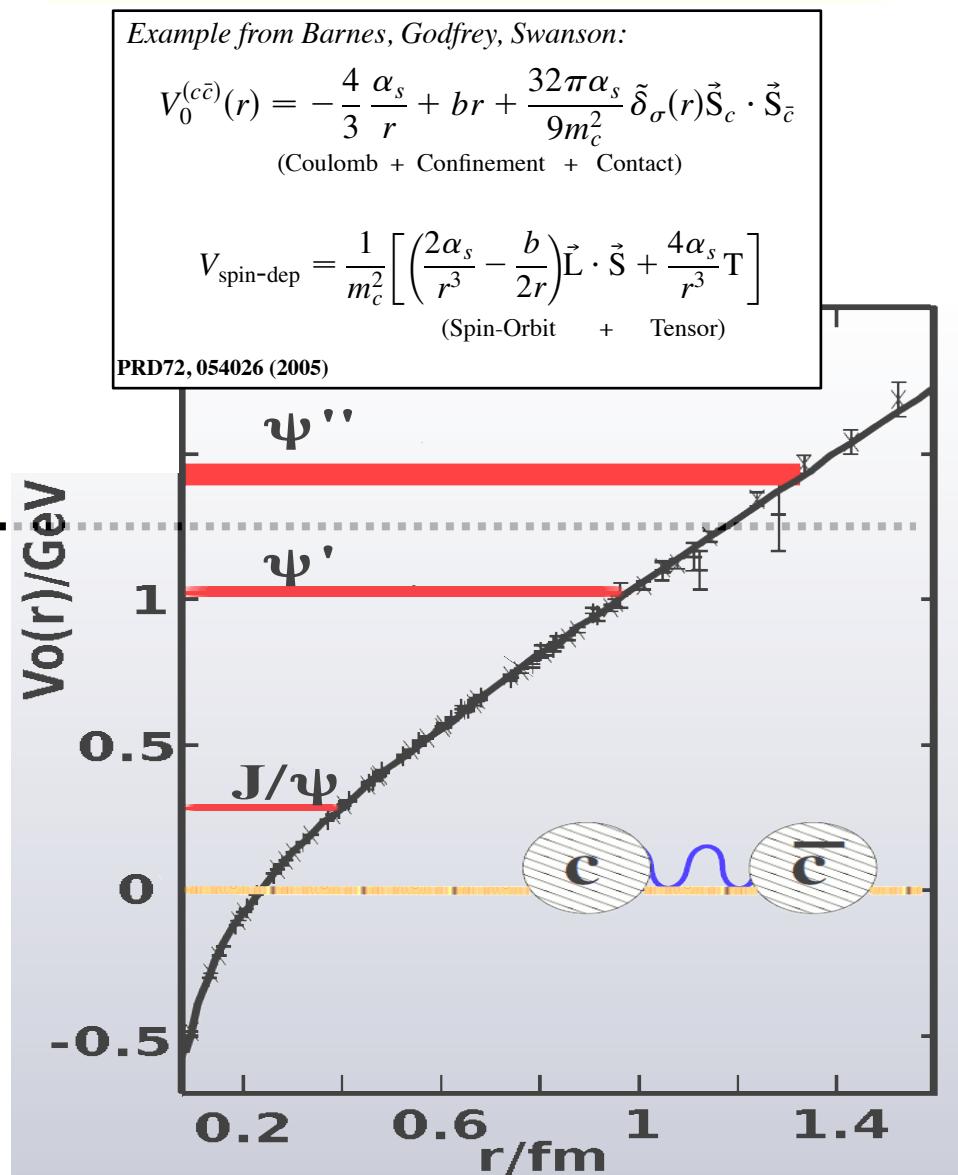
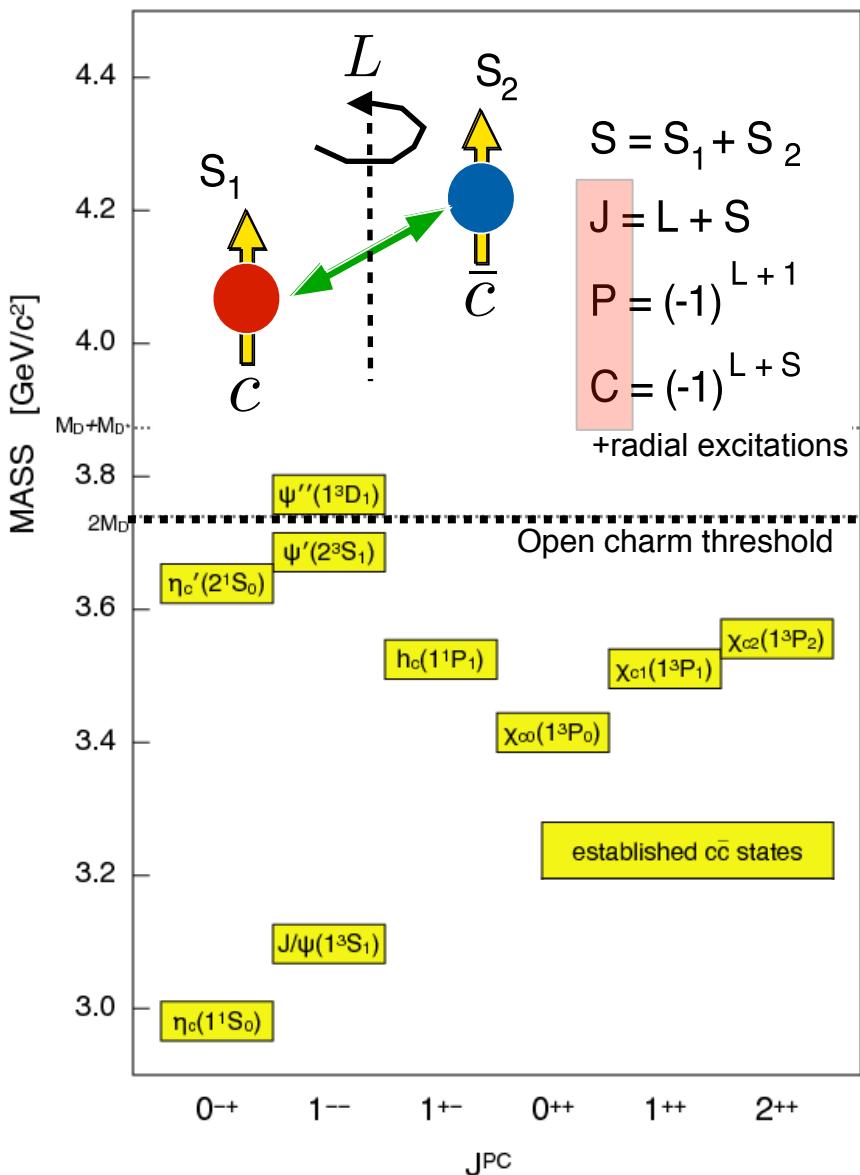


“matter at extremes”

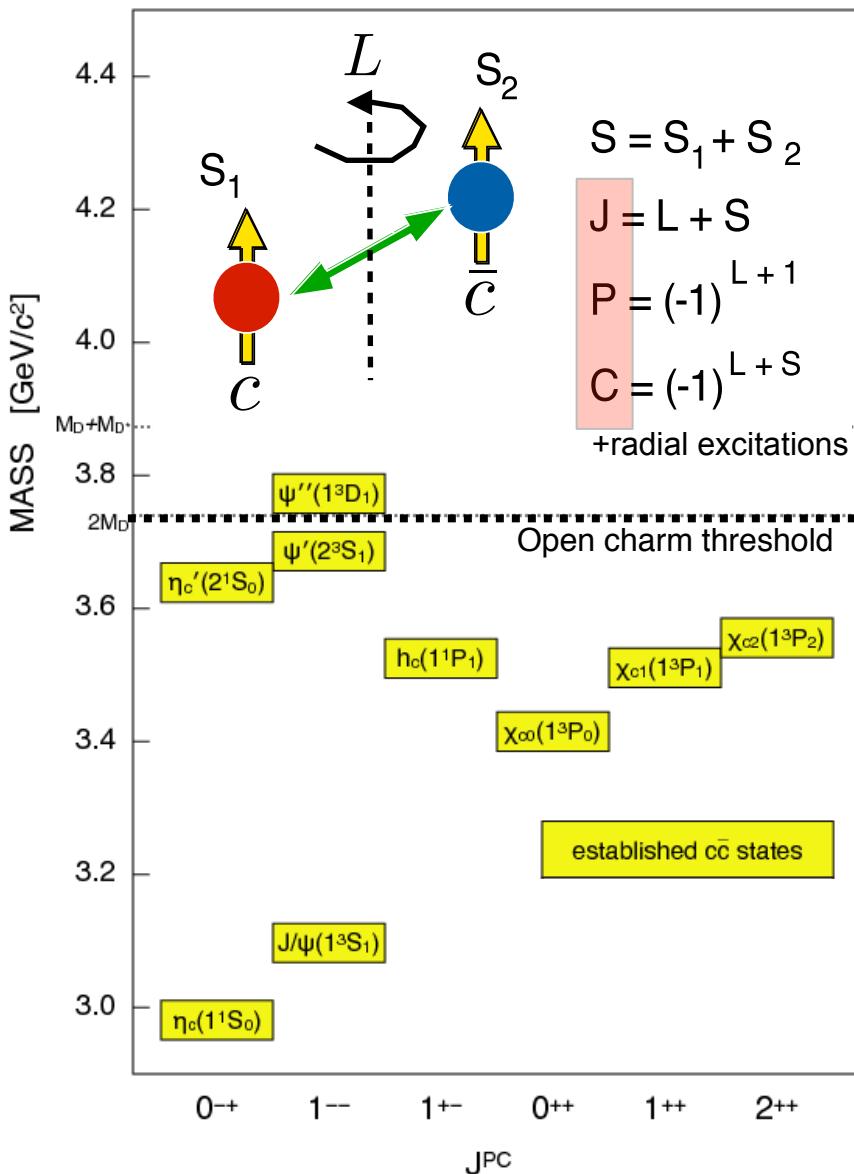
# Charmonium - the “positronium” of QCD



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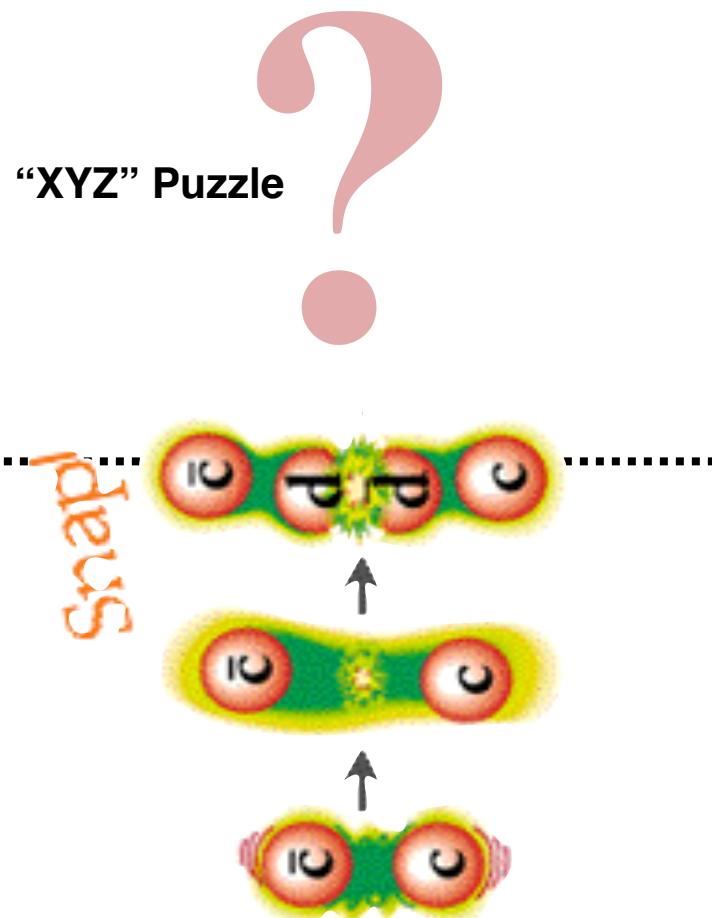
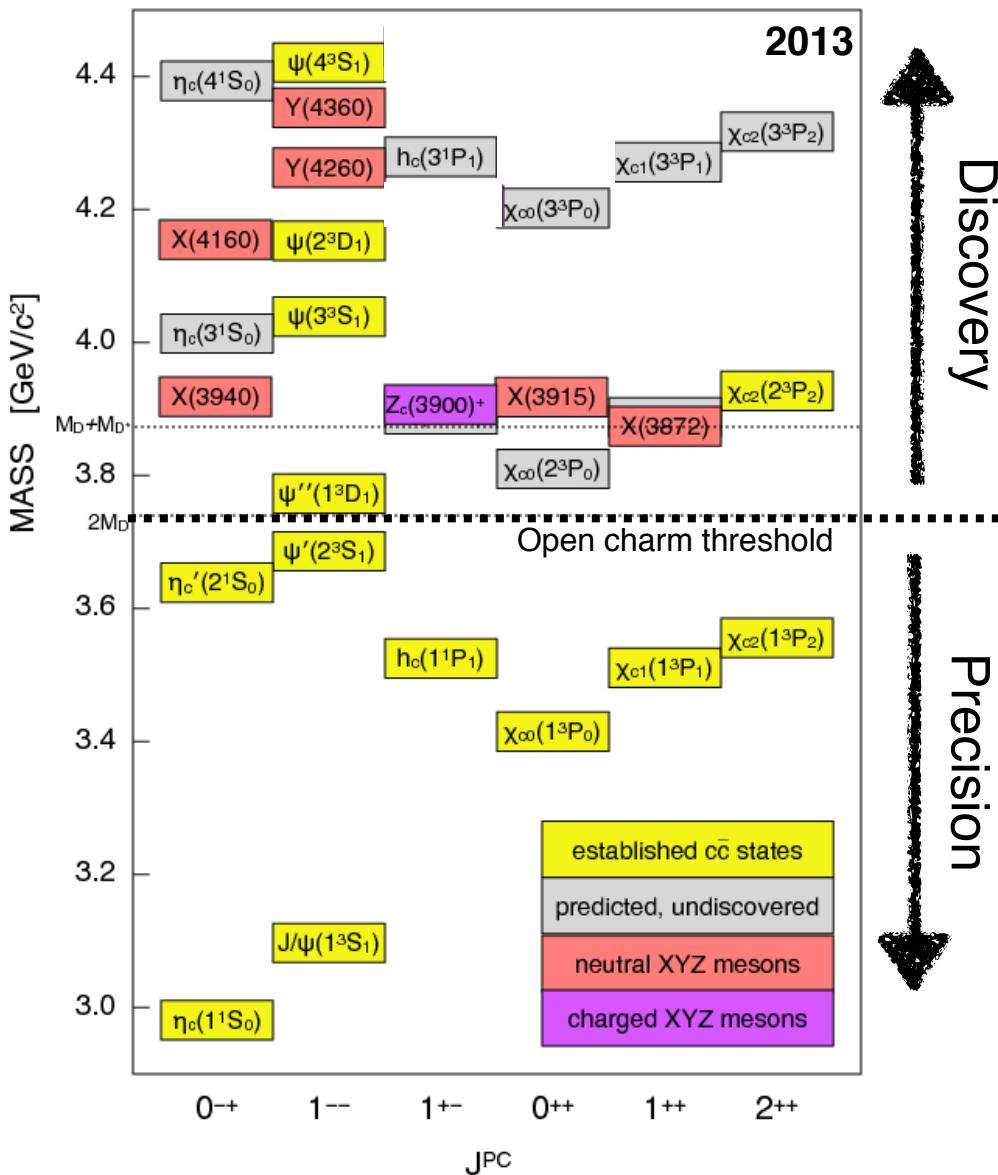


# Charmonium - the “positronium” of QCD

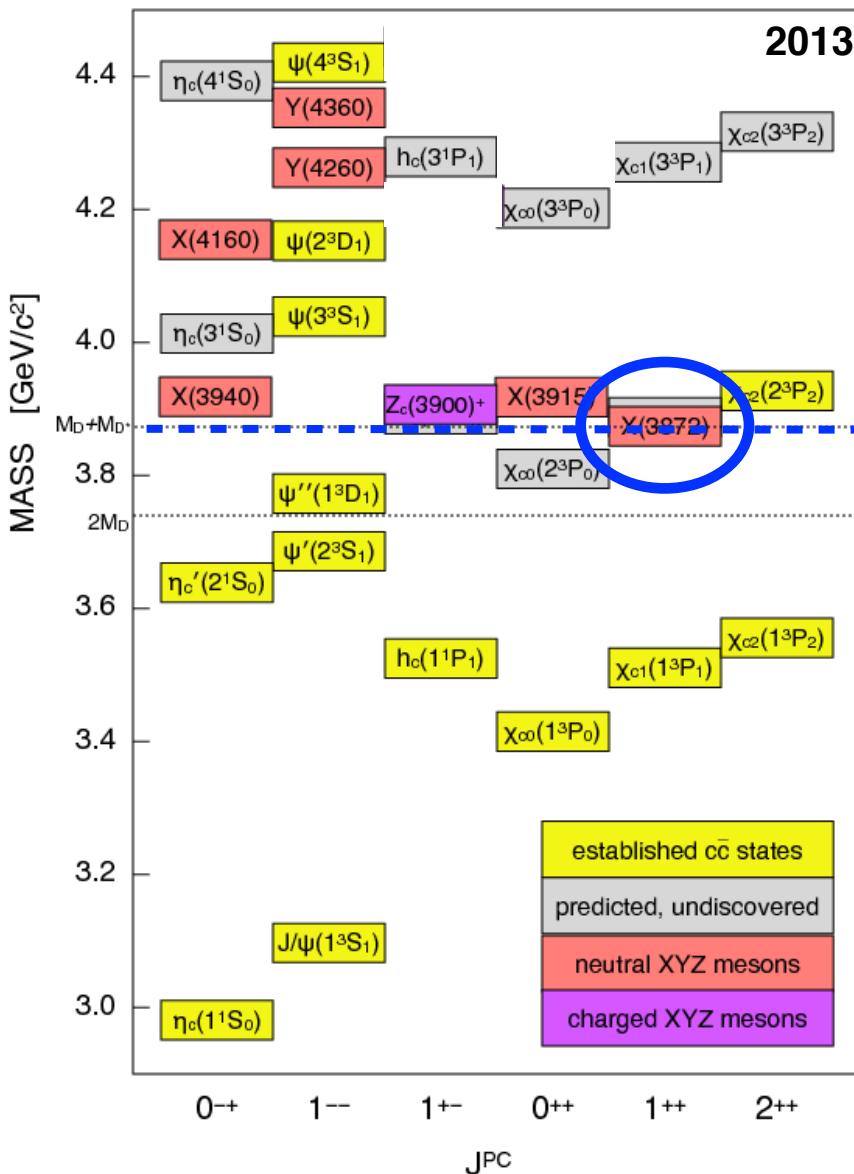


- Symmetric  $e^+e^-$  collider:
  - $\sqrt{s} = 2.0 - 4.6 \text{ GeV}$
- Design luminosity:
  - $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$  (at  $\psi(3770)$ , achieved in 04/2016)
- Data taking started in 2009

# Charmonium-like particles - terra incognita



# X(3872) - “Poster Boy” of a new era!



Discovered by Belle [PRL91, 262001 (2003)]

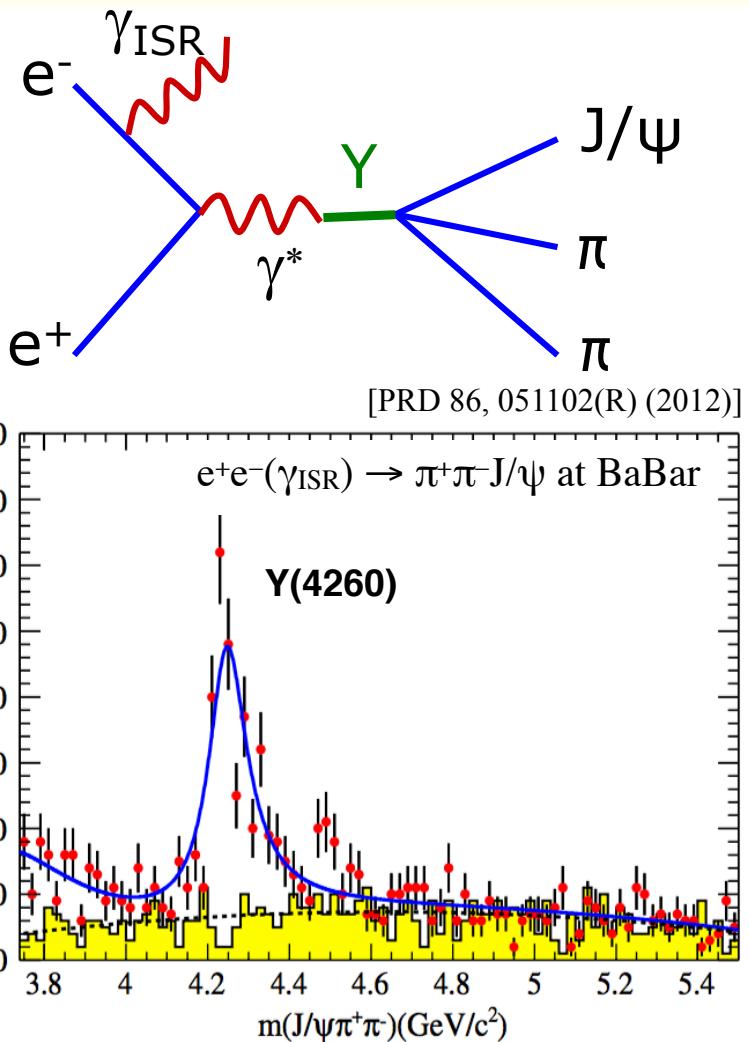
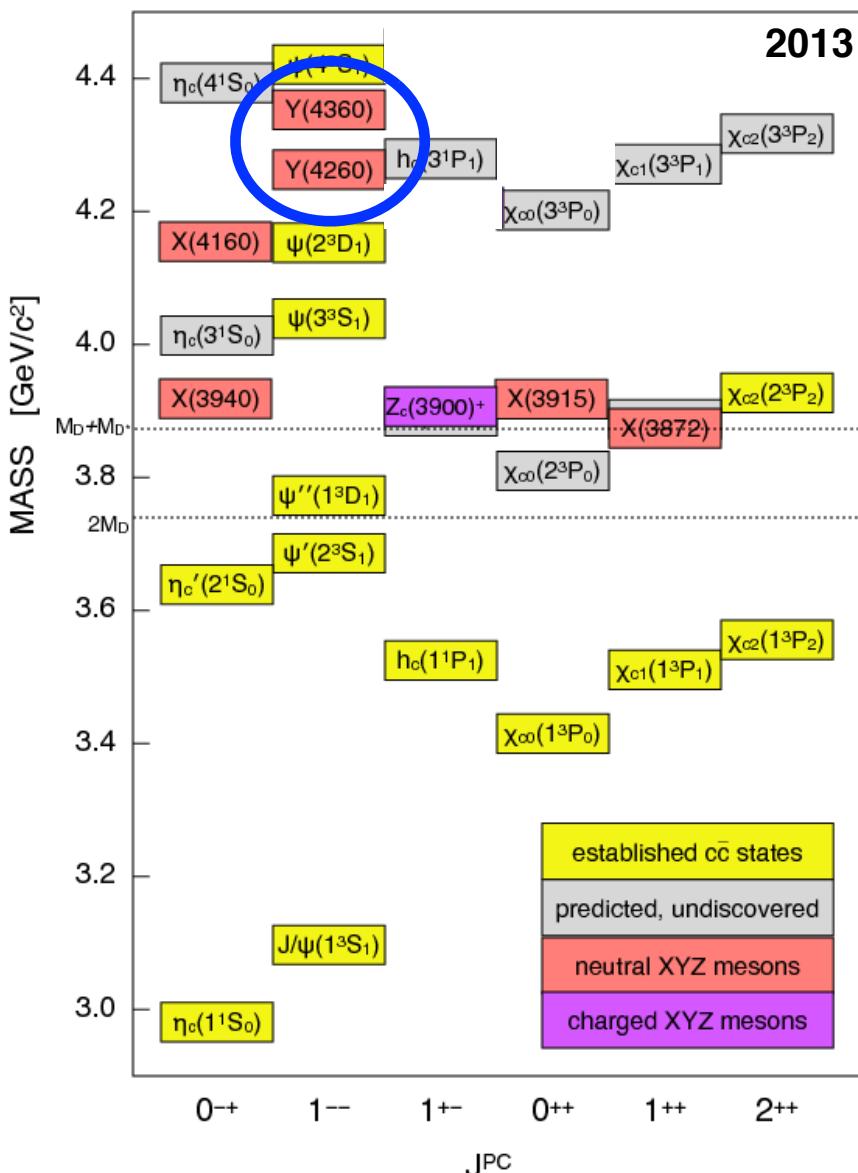
Surprisingly narrow:  $\Gamma < 1.2 \text{ MeV}$

Suspiciously close to  $D\bar{D}^*$  threshold:  
 $\Delta E = -0.13 \pm 0.40 \text{ MeV}$

Large isospin breaking:  
 $B(X \rightarrow \rho J/\Psi) \approx B(X \rightarrow \omega J/\Psi)$

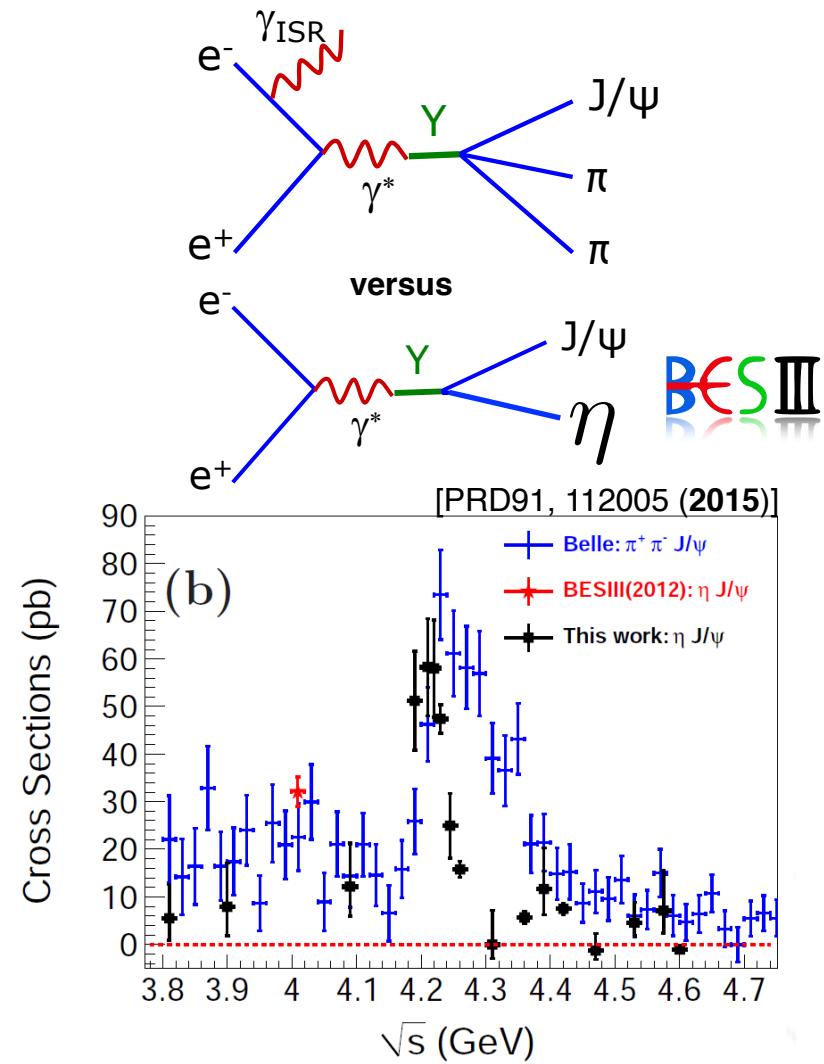
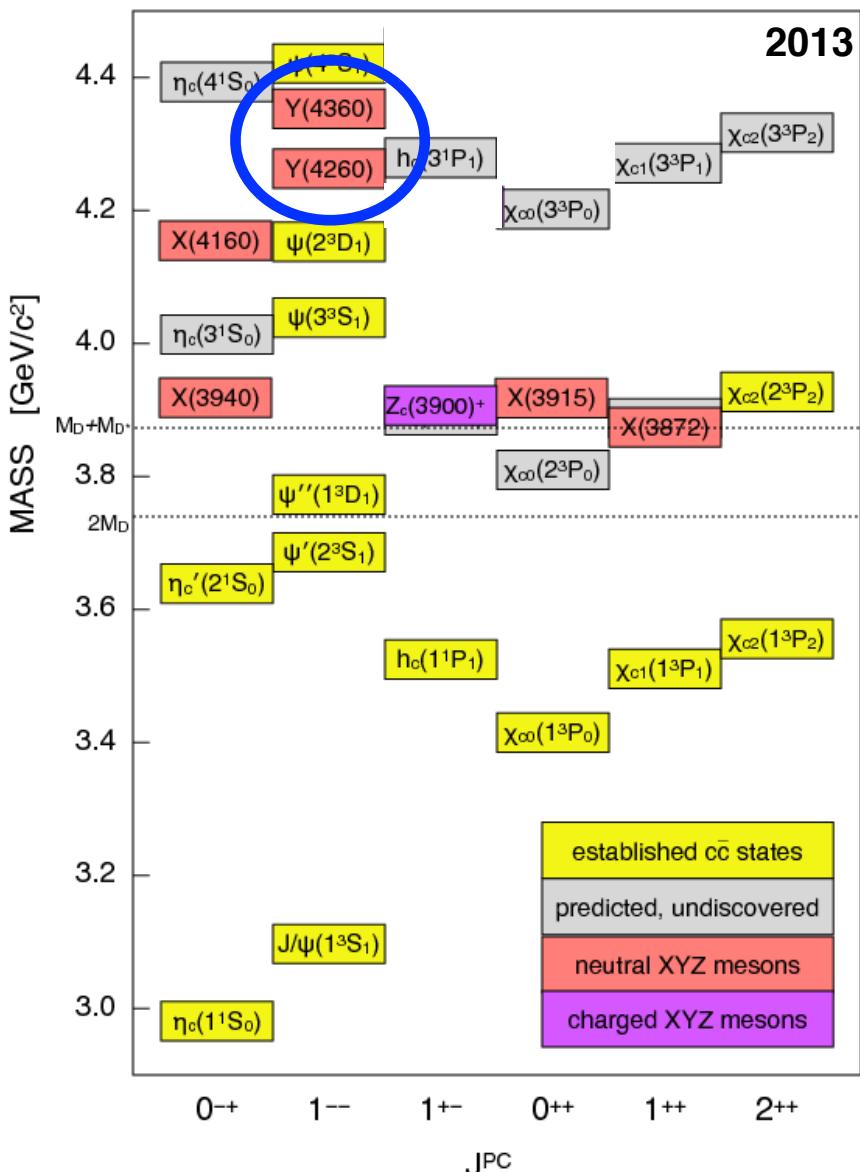
Seen by \*many\* experiments, including  
 BESIII; more later! [PRL112, 092001 (2014)]

# The mysterious "Y" states: Y(4260, 4360)



**Y states do not fit charmonium:  
“wrong mass”, small coupling DD**

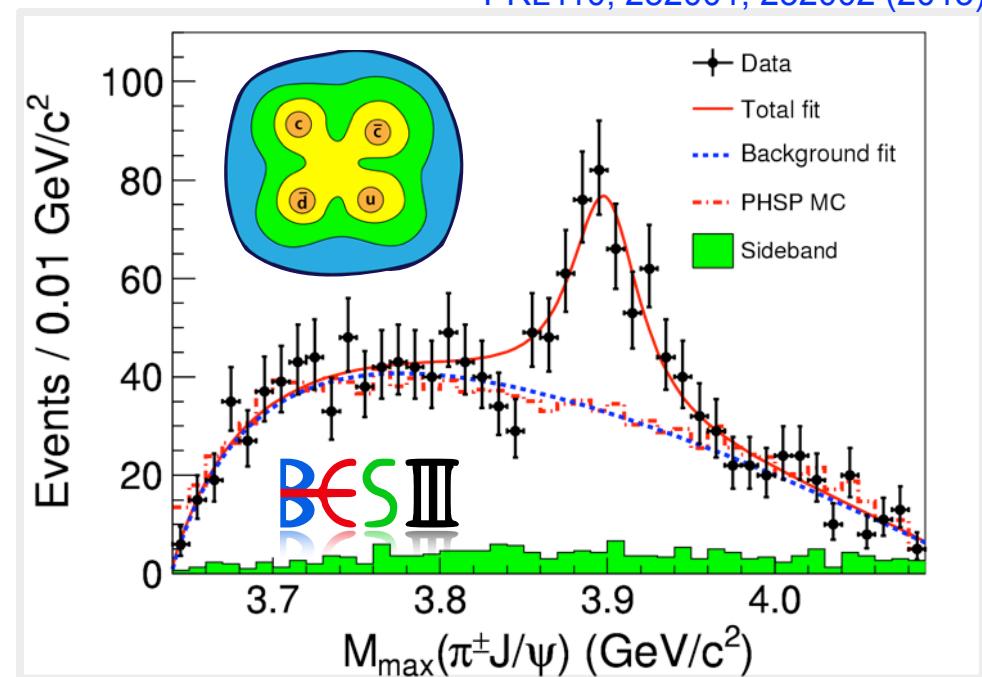
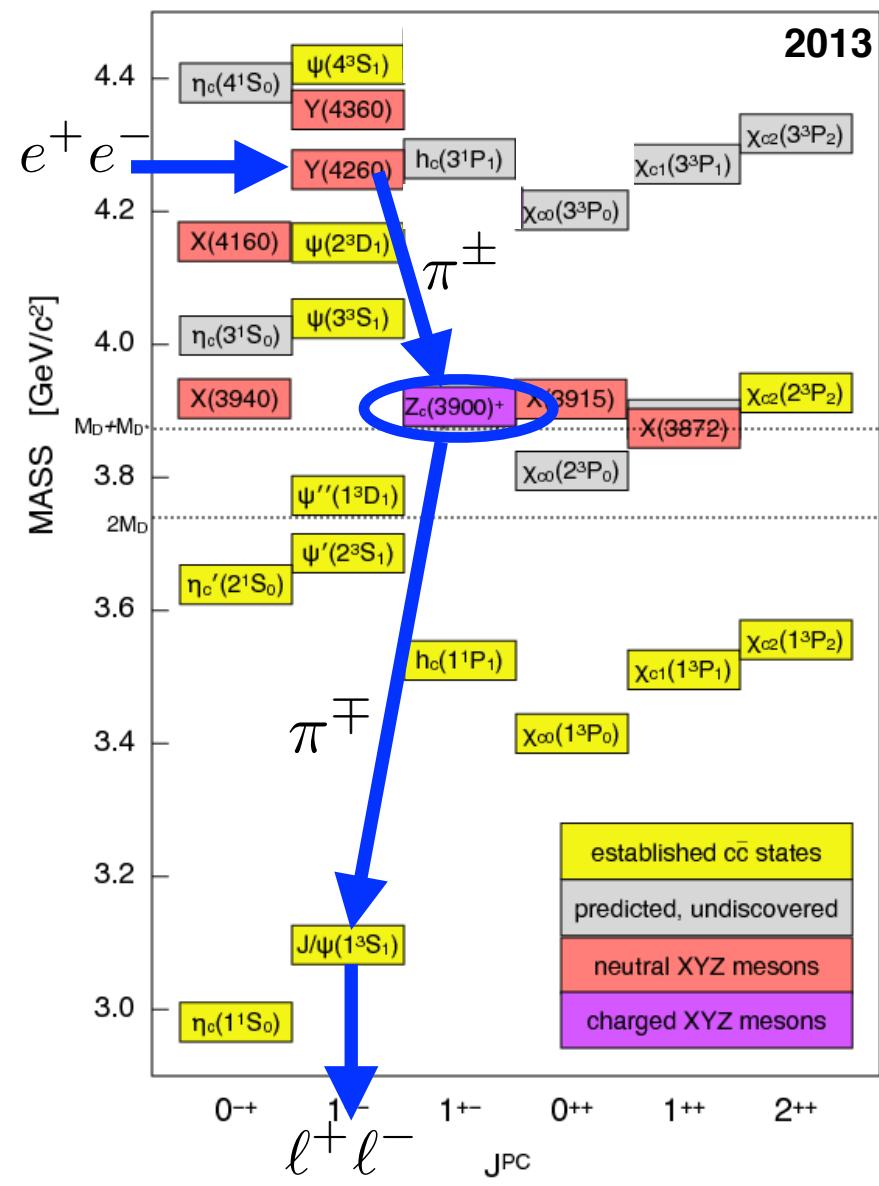
# The mysterious "Y" states: Y(4260, 4360)



Existence of a rich Y-spectrum?

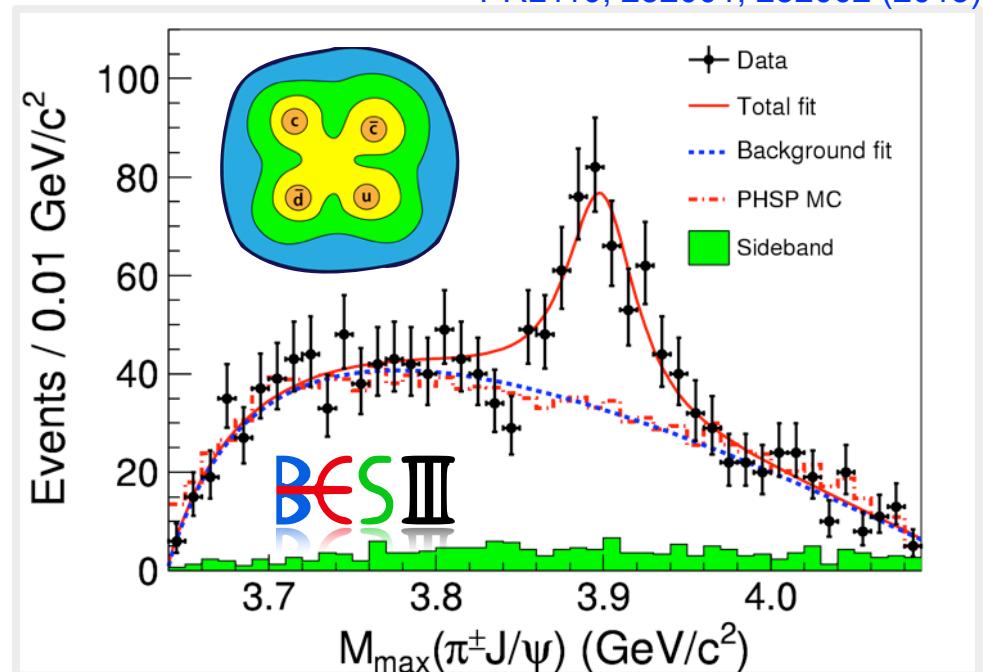
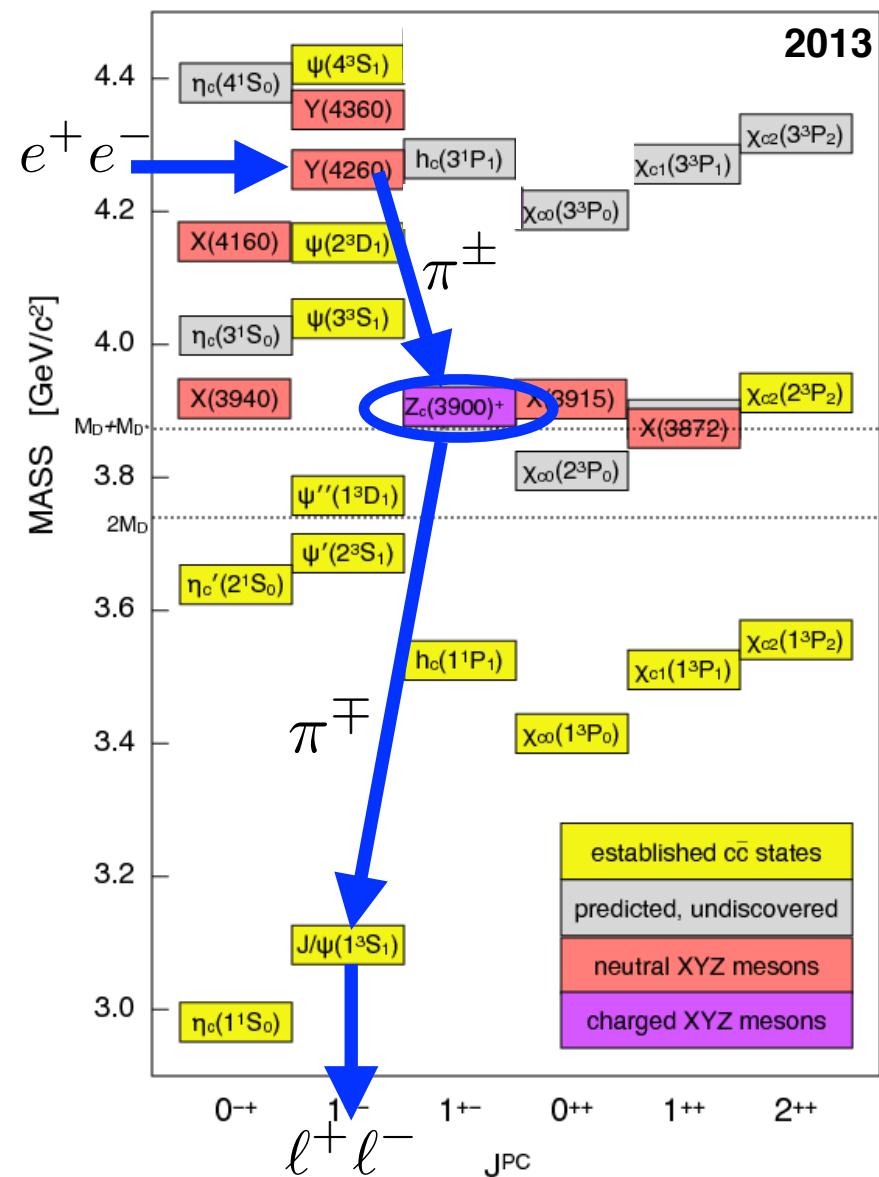
# Z(3900) - breakthrough by BESIII!

PRL110, 252001, 252002 (2013)



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PRL110, 252001, 252002 (2013)



A charged and charmonium-rich state

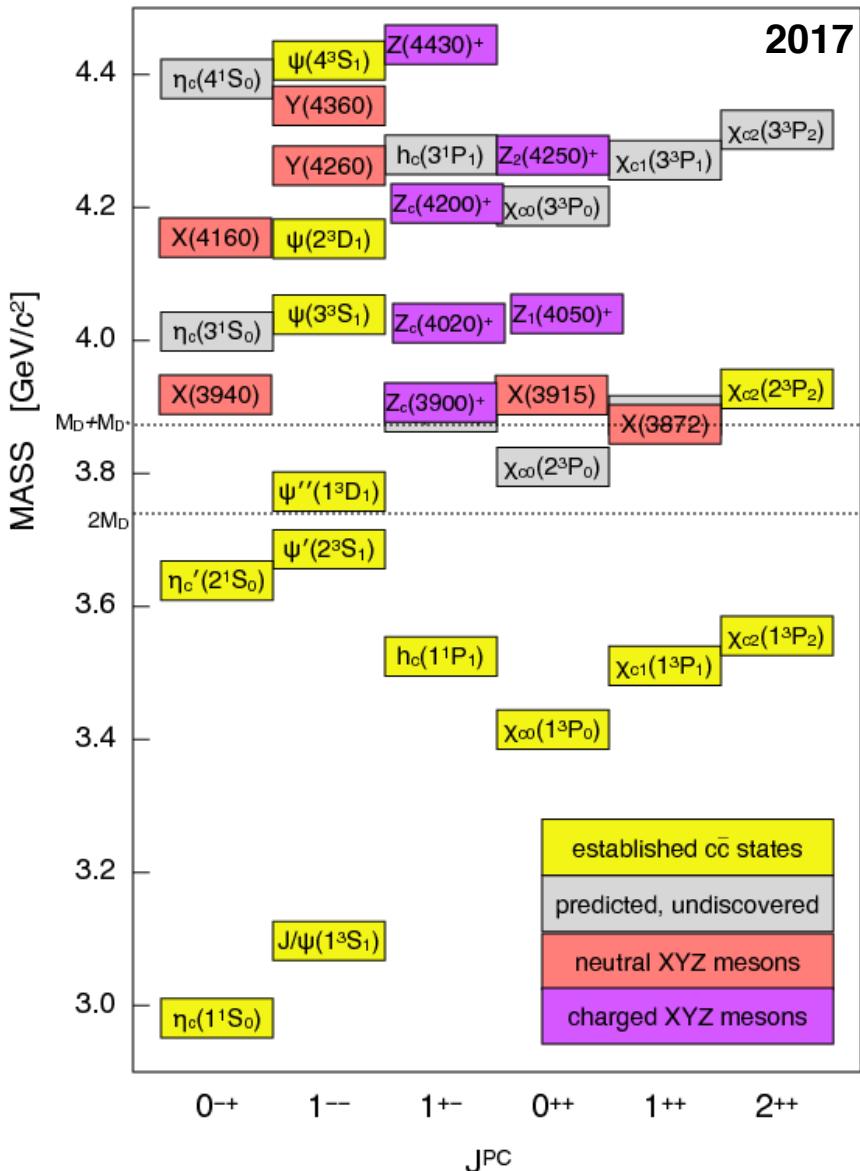
At least 4 quarks involved

Confirmed by Belle and CLEO-c data

Spin-parity  $1^+$ : [BESIII, PRL119, 072001 (2017)]

More Z states discovered afterwards!

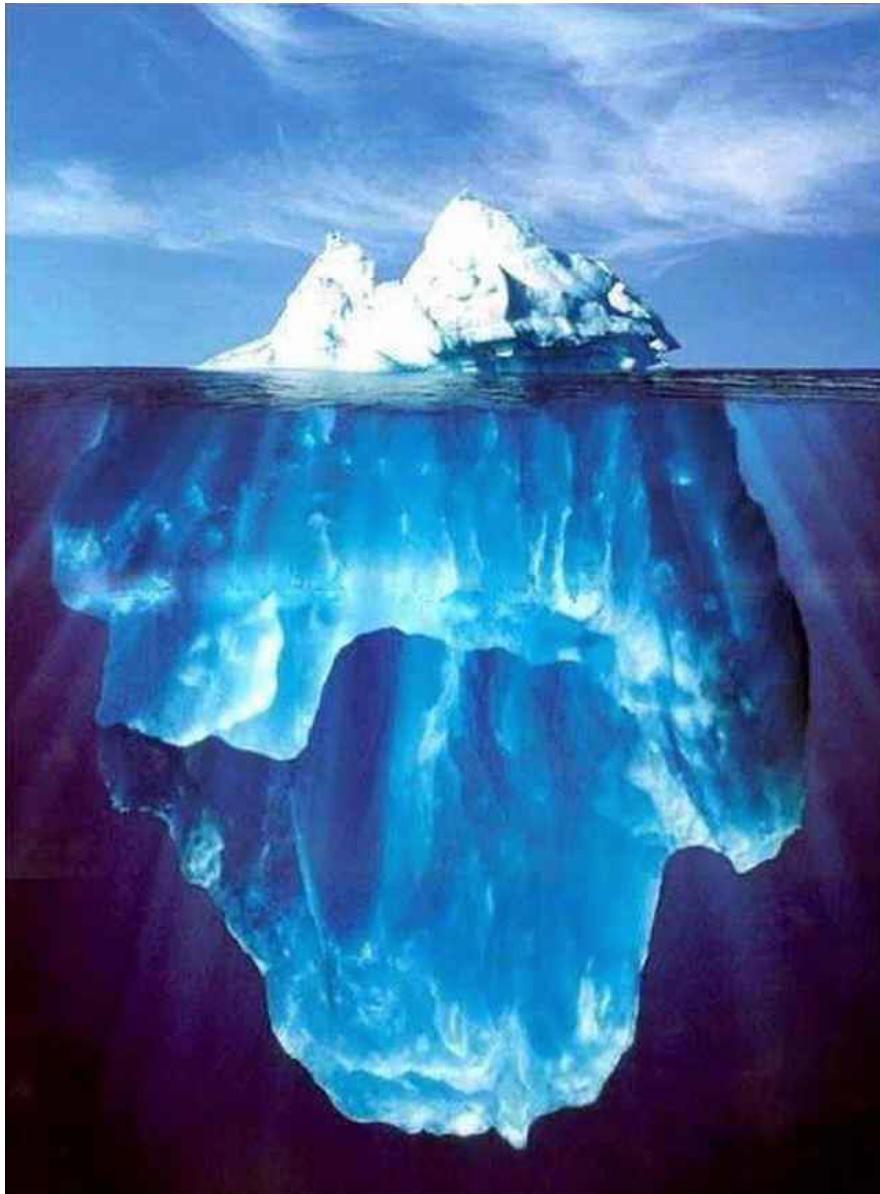
# Z(3900) and beyond...



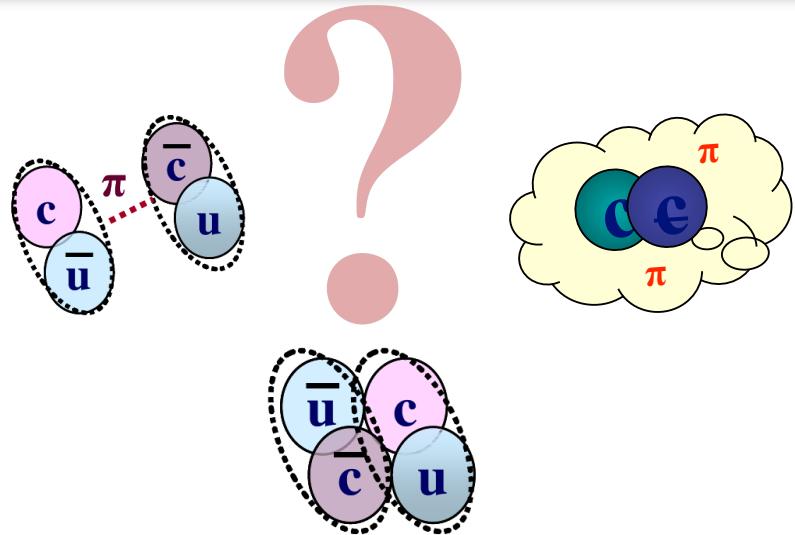
- $Z_c(3900)$ : PRL110, 252001 (2013)
- $Z_c(4040)$ : PRL112, 132001 (2014)
- $Z_c(3885)$ : PRL112, 022001 (2014)
- $X(3872)$ : PRL112, 092001 (2014)
- $Z_c(4020)^0$ : PRL113, 212002 (2014)
- $X(3823)$ : PRL115, 011803 (2015)
- $Z_c(3900)^0$ : PRL115, 112003 (2015)
- $Z_c(4025)^0$ : PRL115, 182002 (2015)
- $Z_c(3885)^0$ : PRL115, 222002 (2015)

**Multiplet(s) of new matter discovered!**

# Break-through! It is just the beginning...



XYZ particles: tip of the iceberg?



Internal structure?

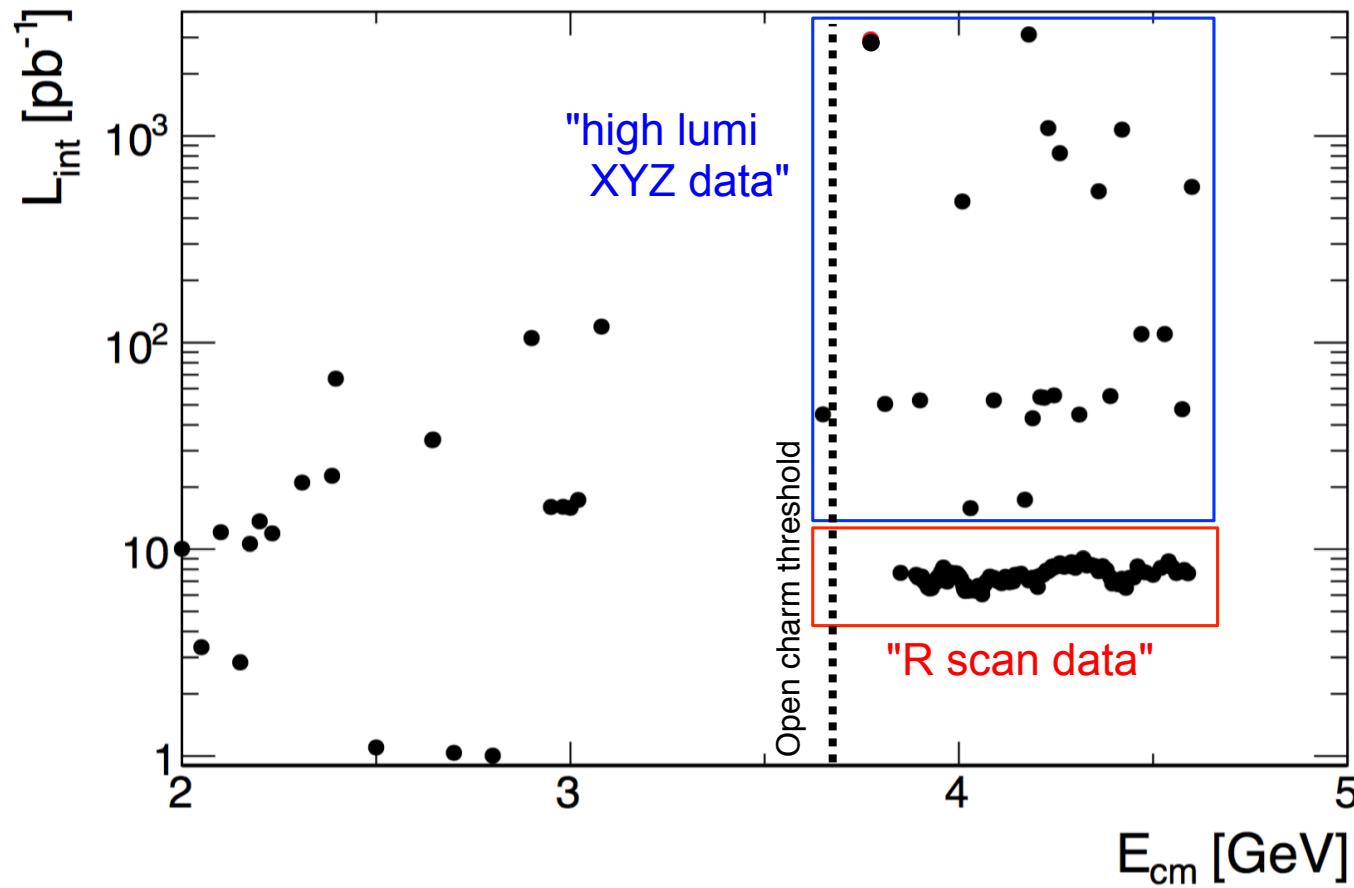
Level scheme?

Spin-parity  $J^{PC}$ ?

Width/lifetime?

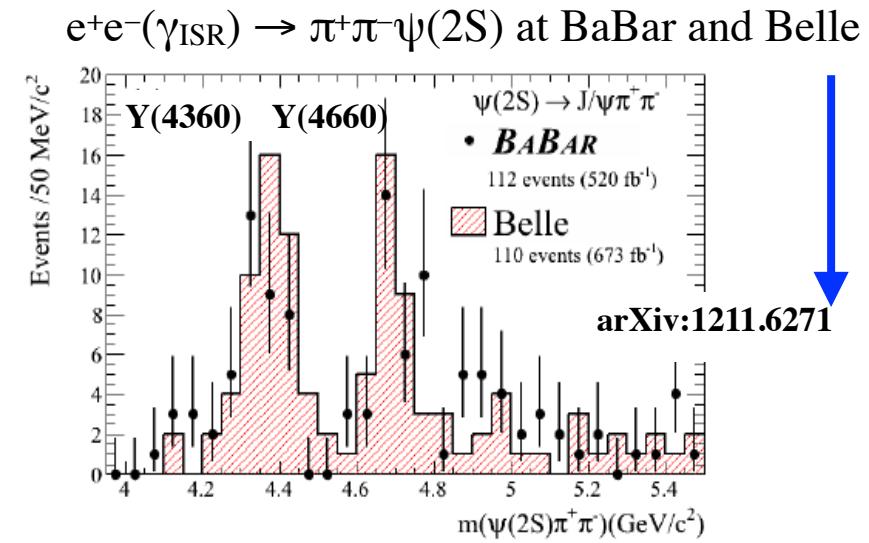
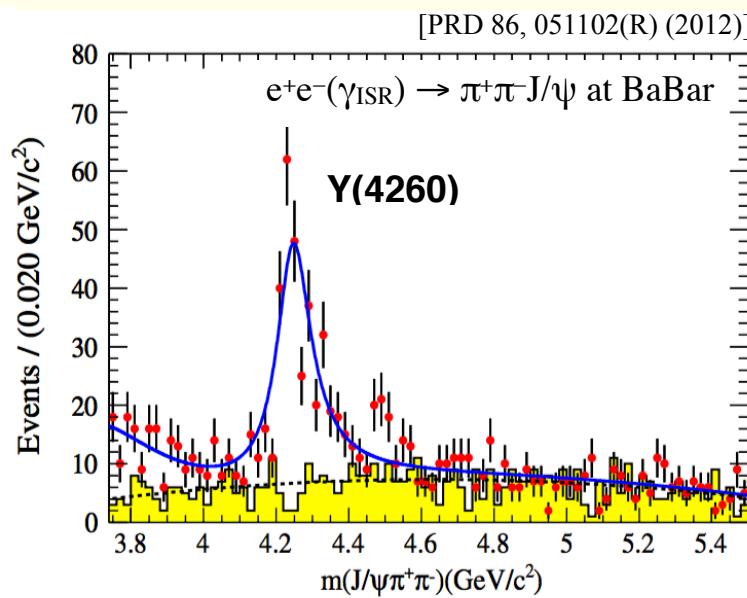
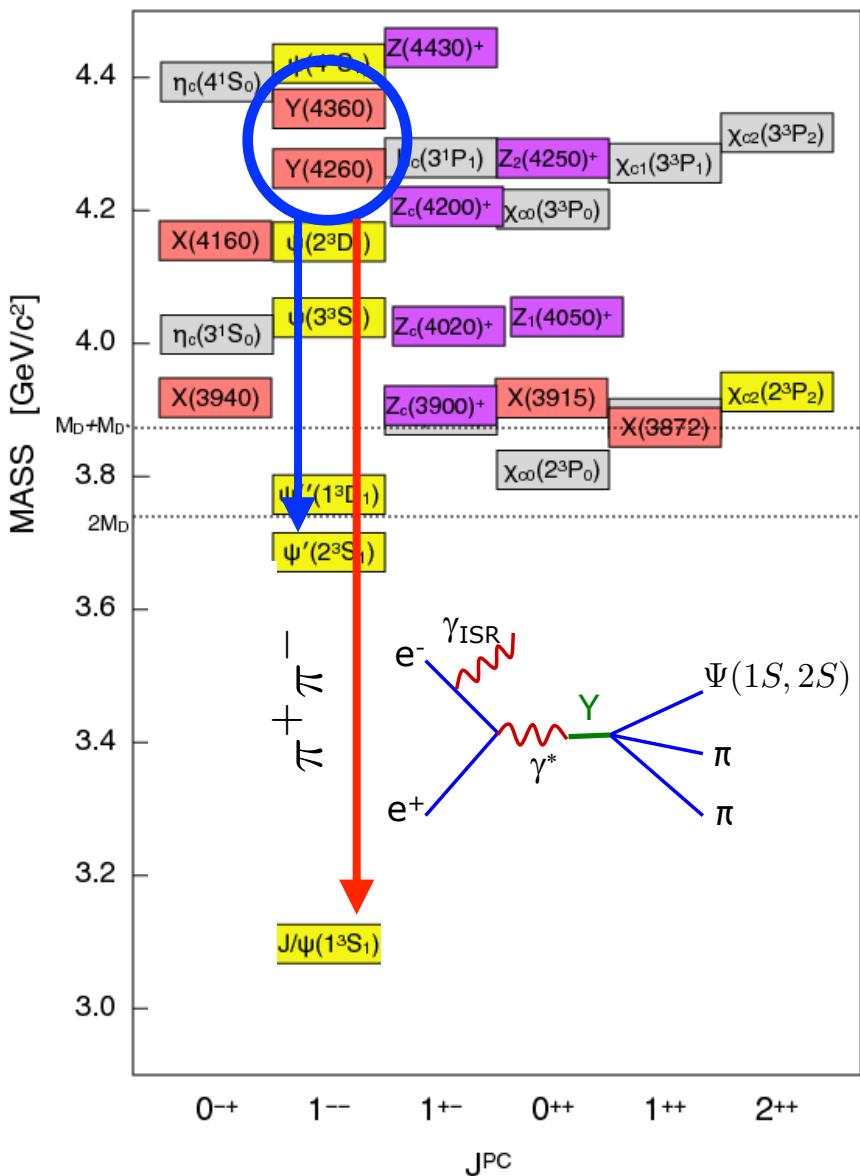
Production and decay?

# From discovery towards precision

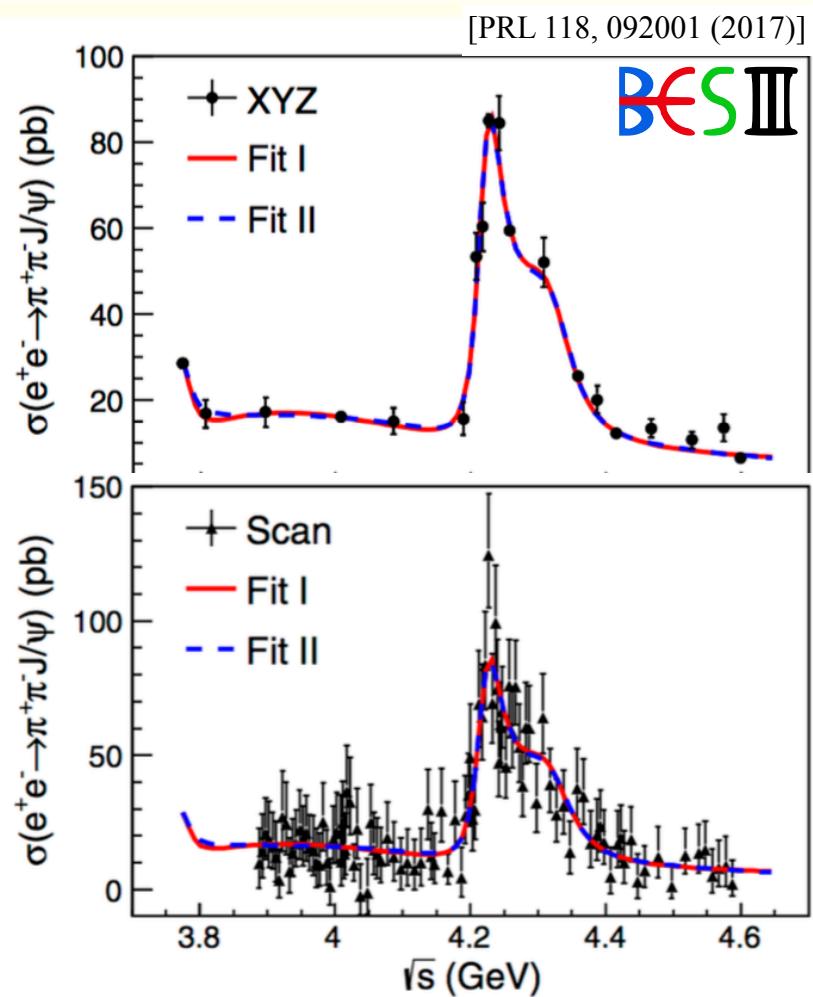
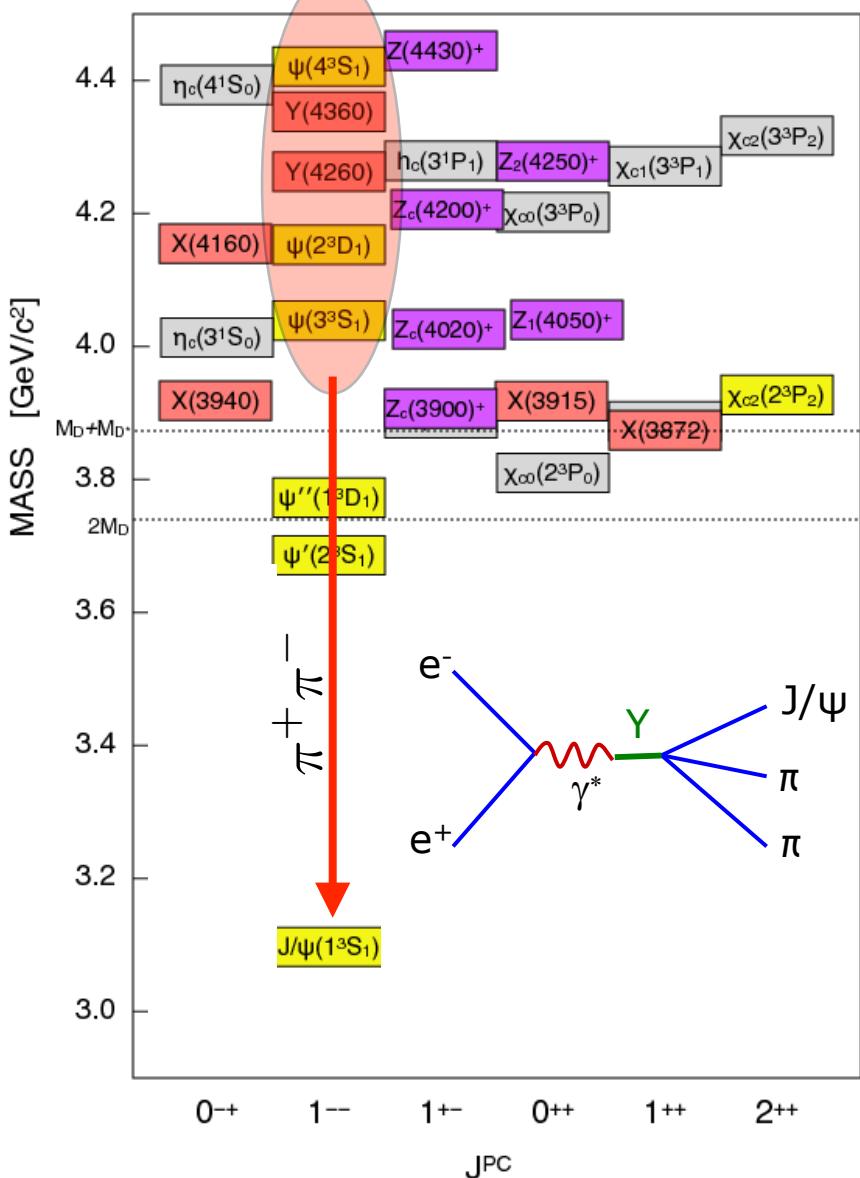


- XYZ region:  $3.8 \sim 4.6$  GeV, integrated luminosity: **12 fb $^{-1}$**
- 104 energy points between 3.85 and 4.59 GeV (*R scan*)
- ~20 energy points between 2.0 and 3.1 GeV

# "Y" spectroscopy from Belle and Babar

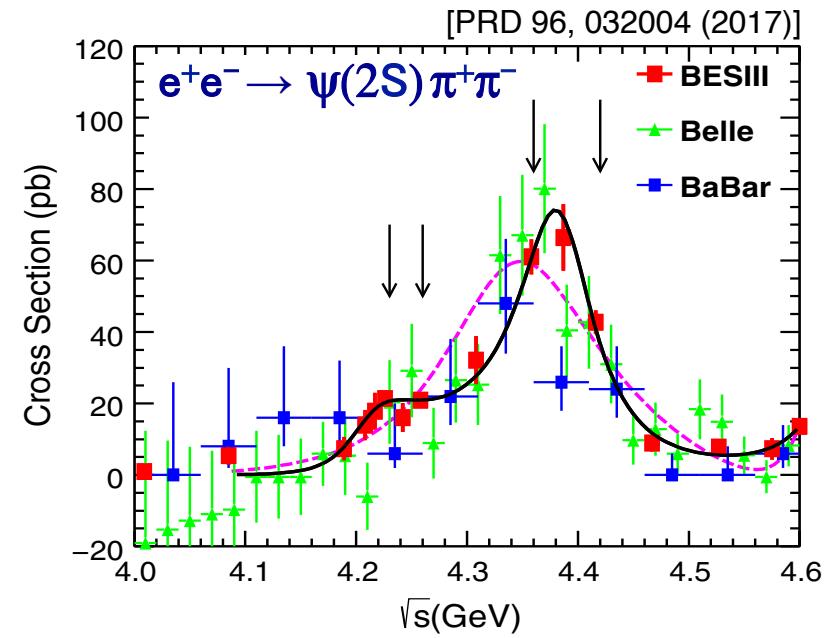
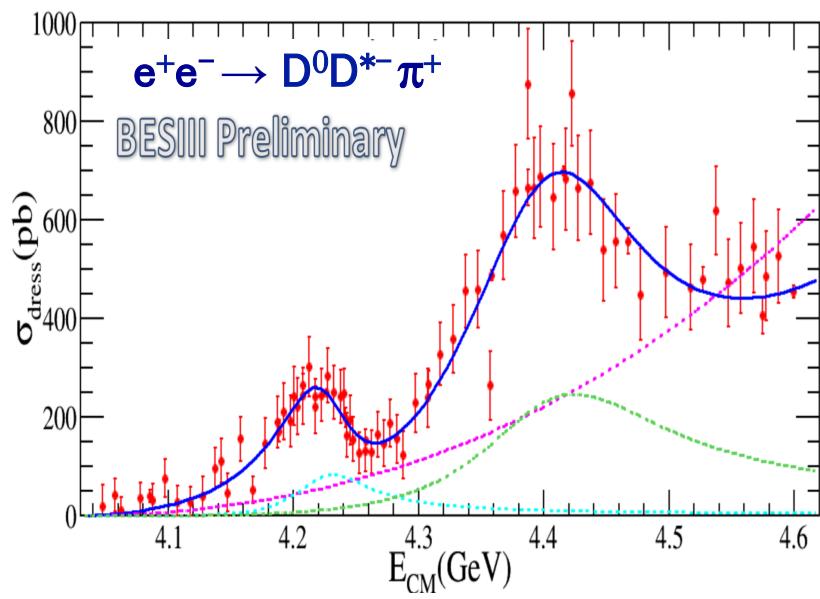
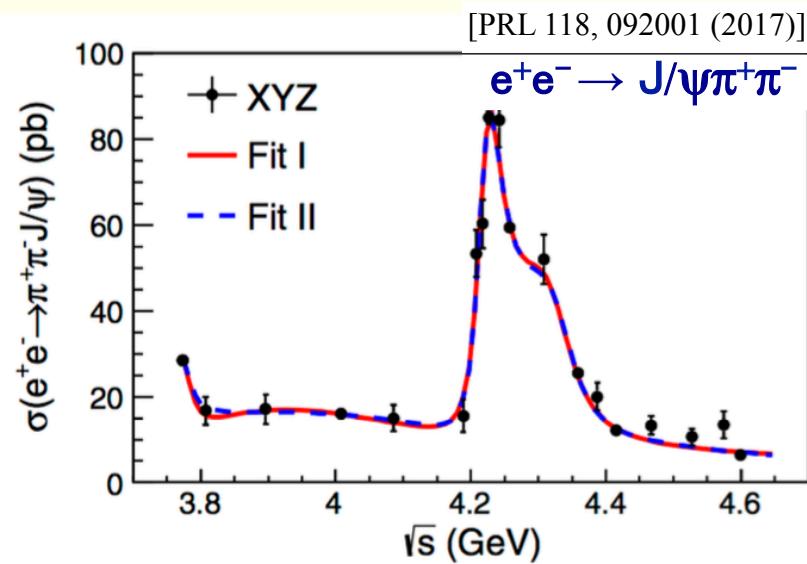
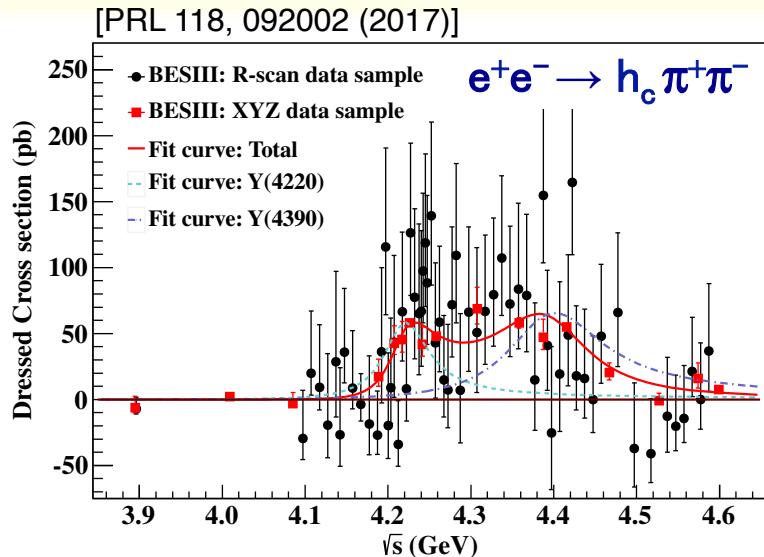


# Precision "Y" spectroscopy at BESIII

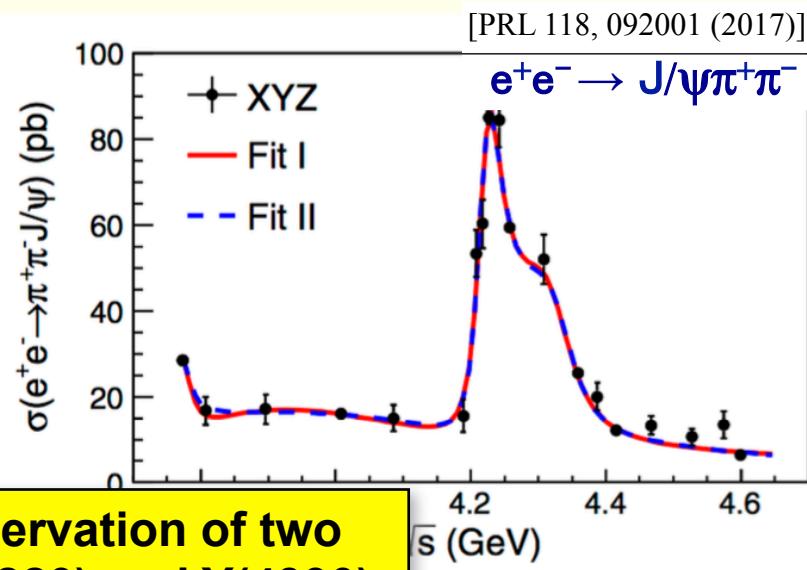
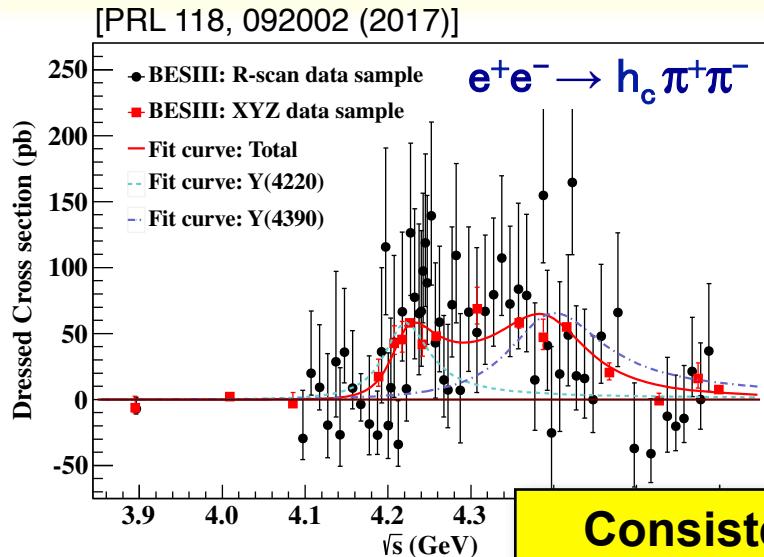


Two resonances & no  $\Upsilon(4008)$  needed

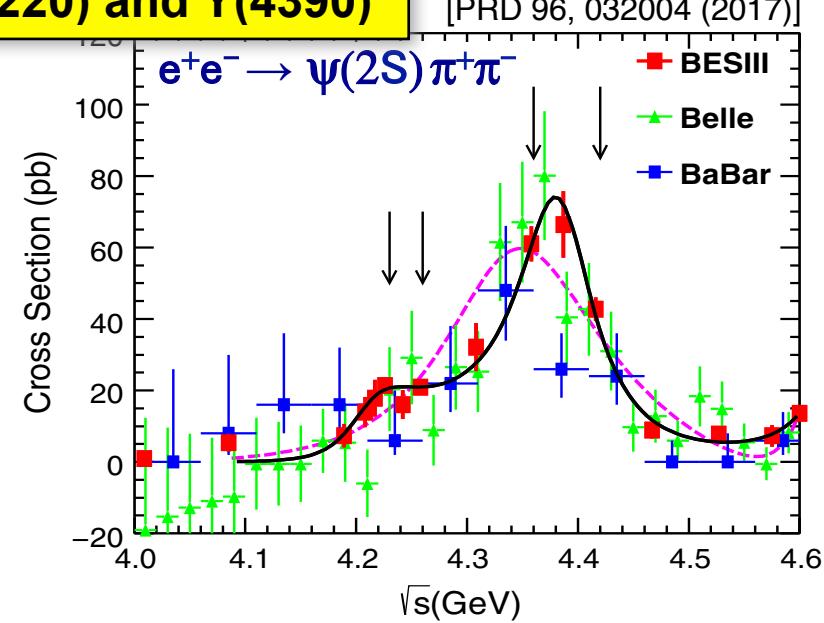
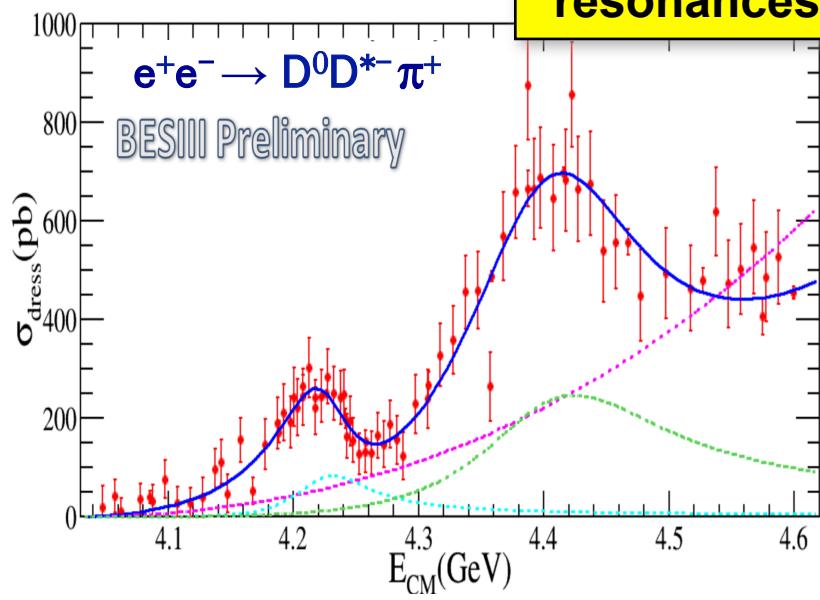
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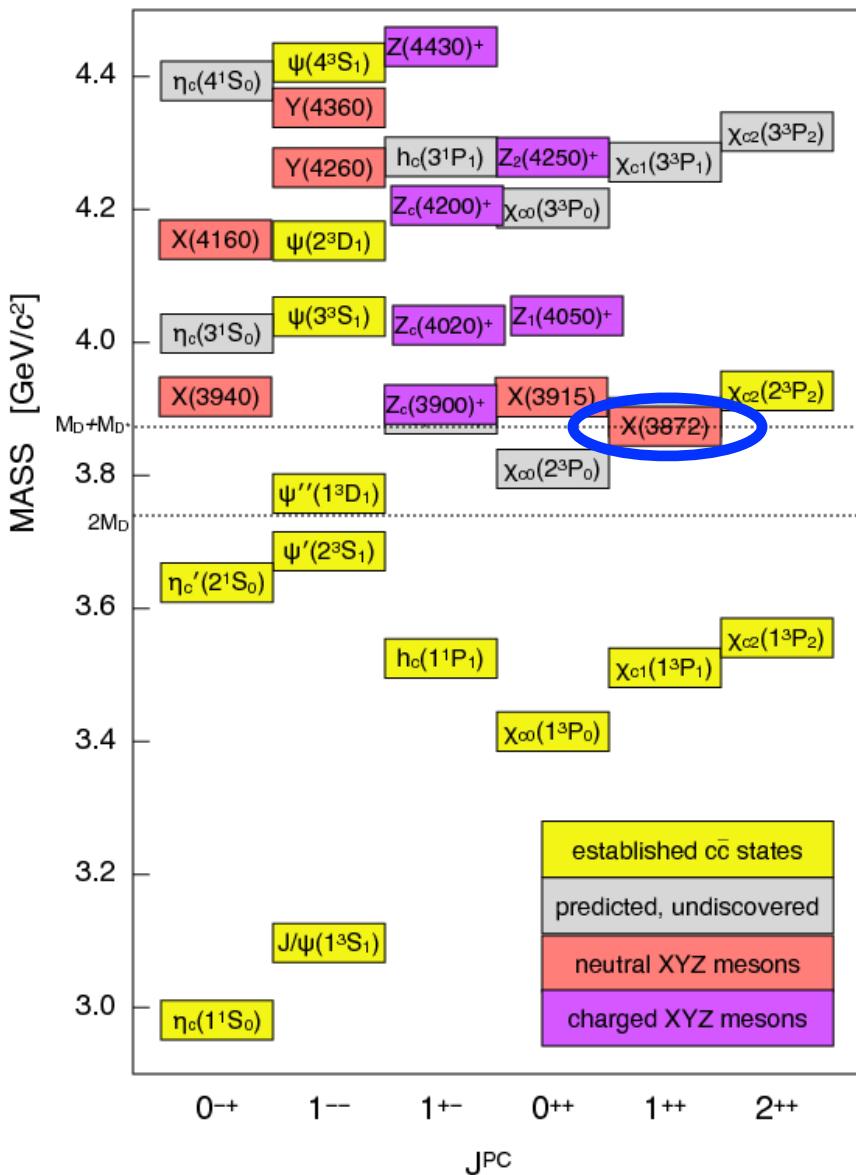
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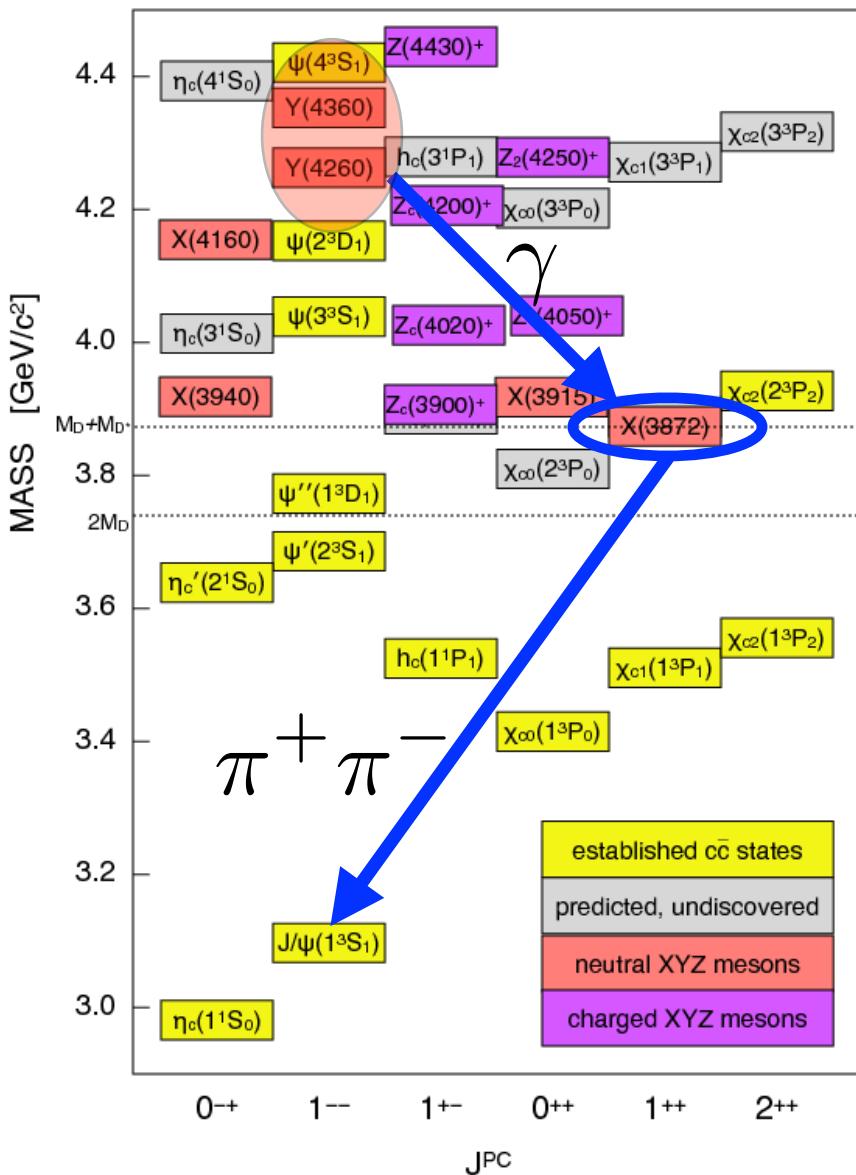
Consistent observation of two resonances: Y(4220) and Y(4390)



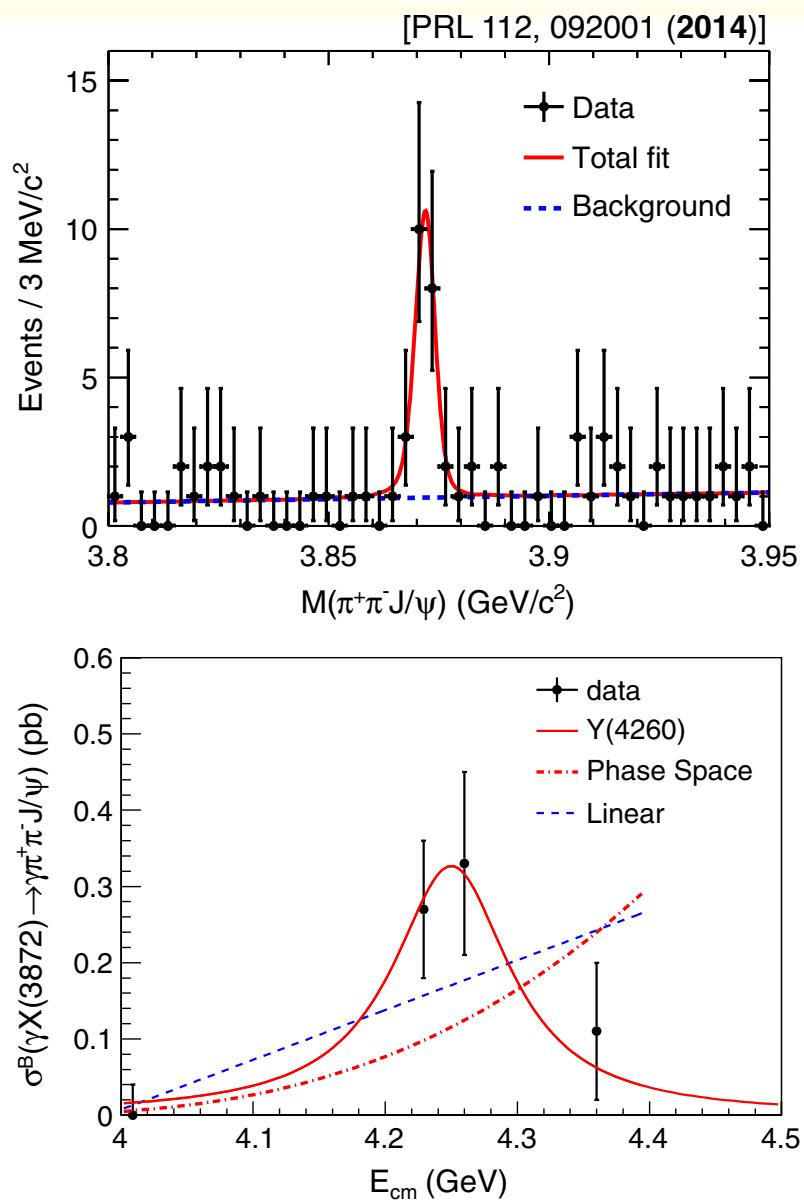
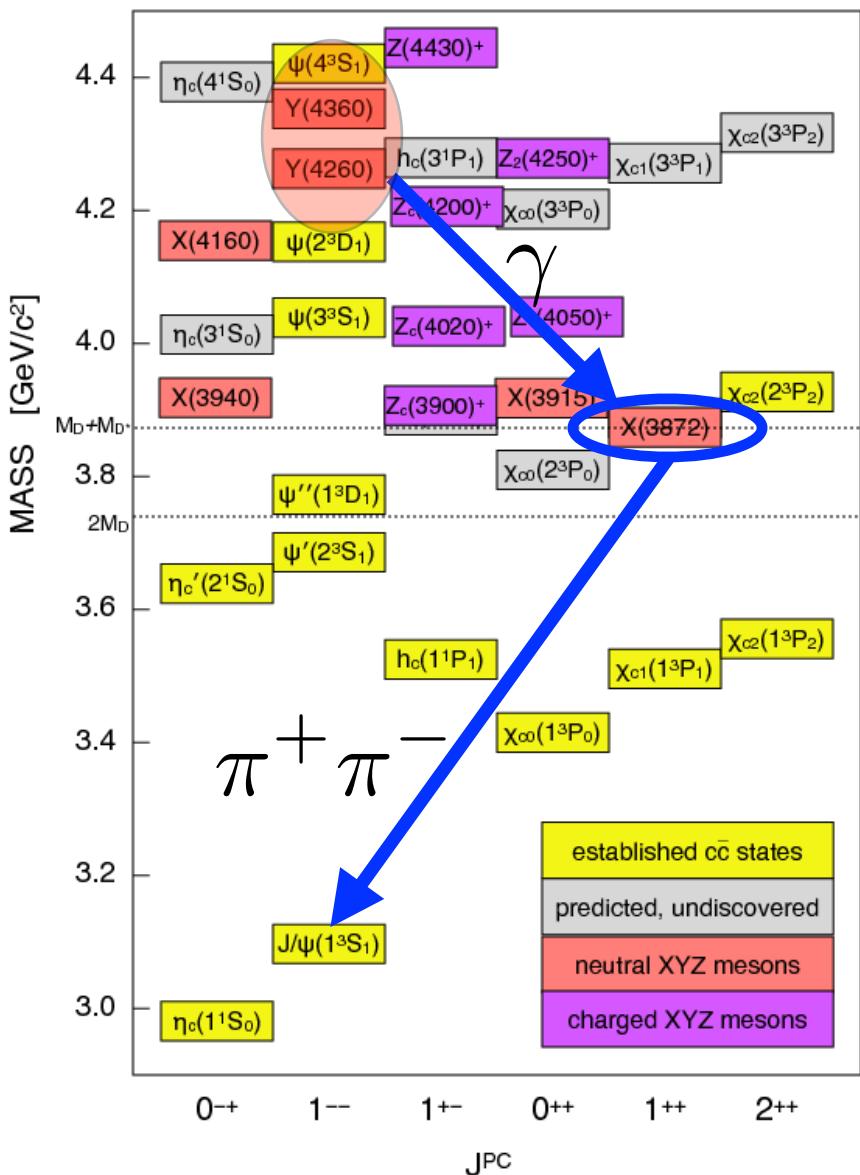
# New insights in the mysterious X(3872)



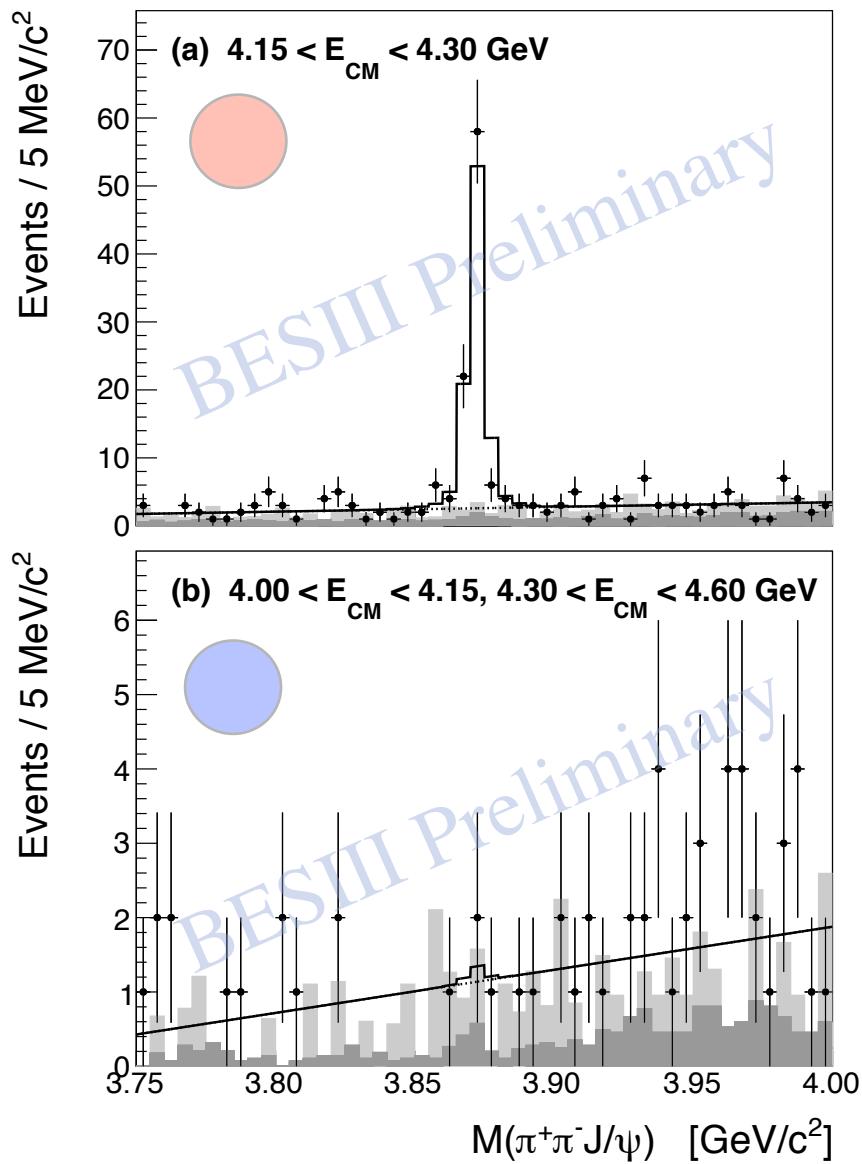
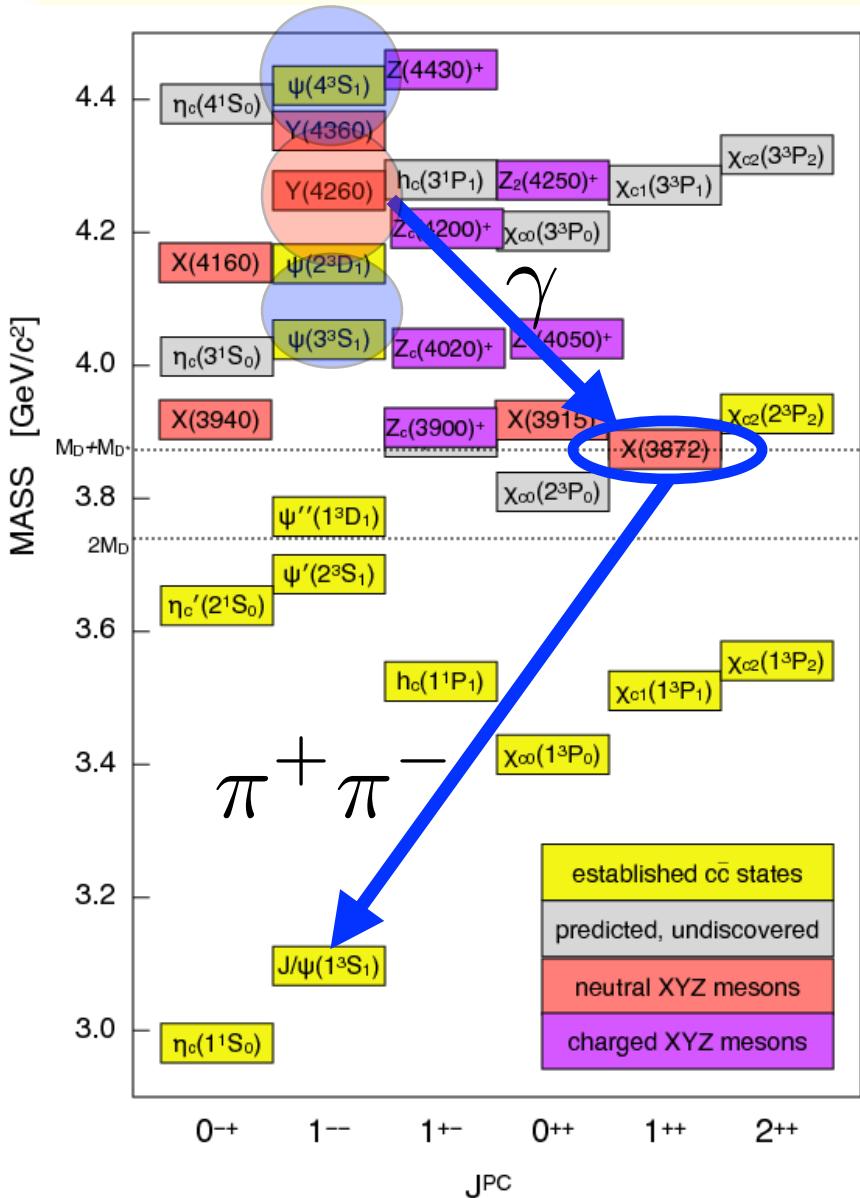
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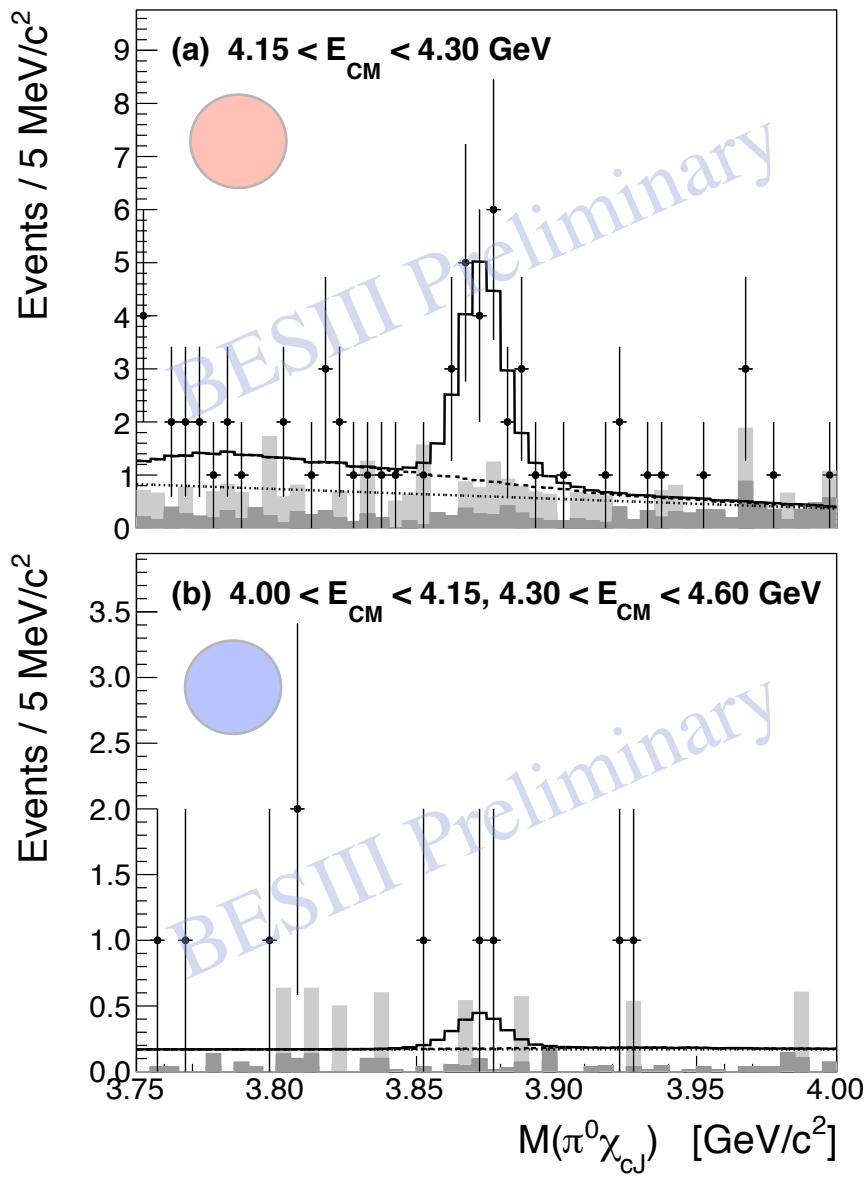
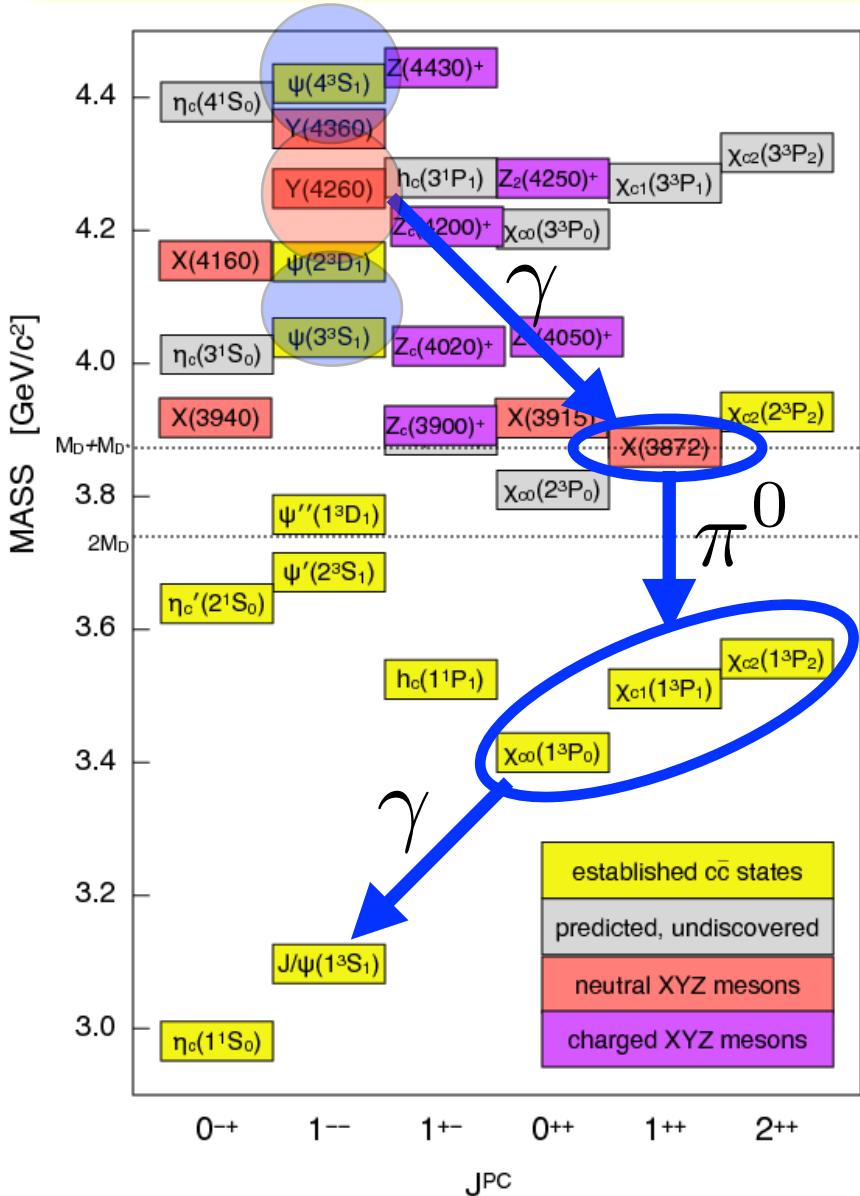
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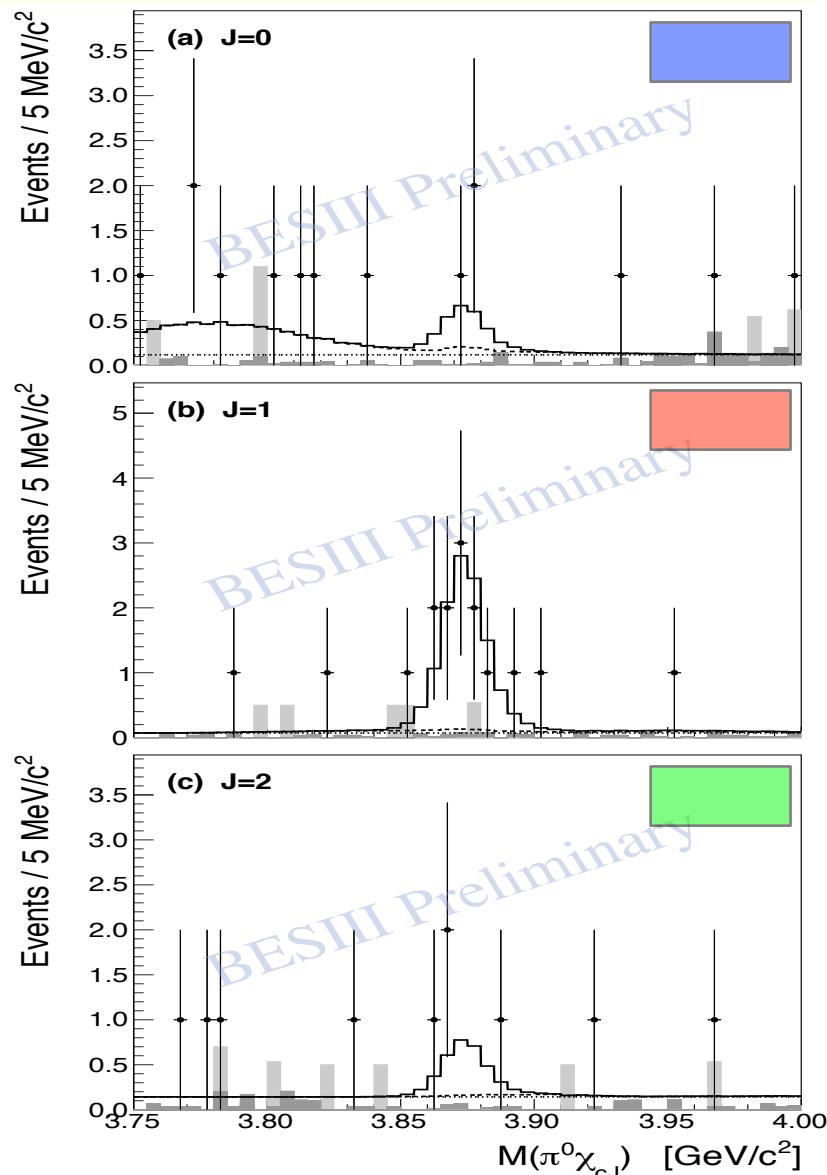
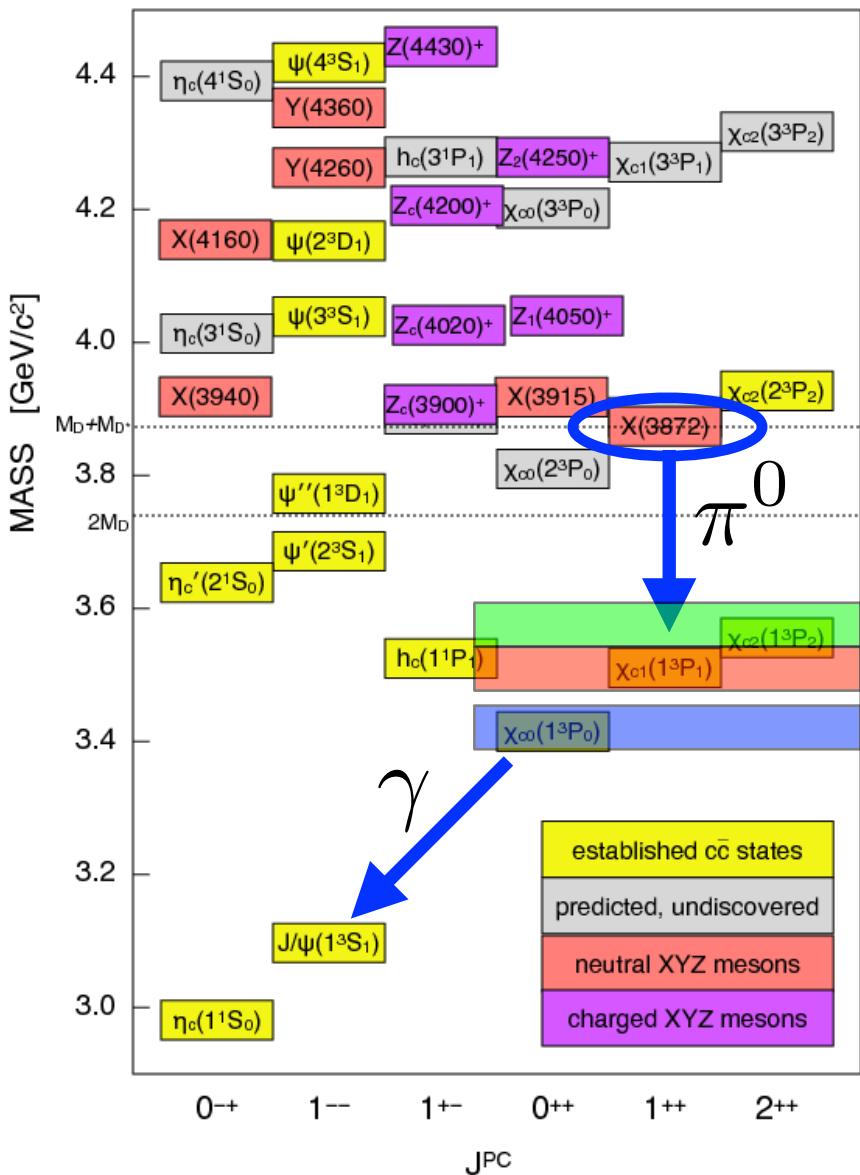
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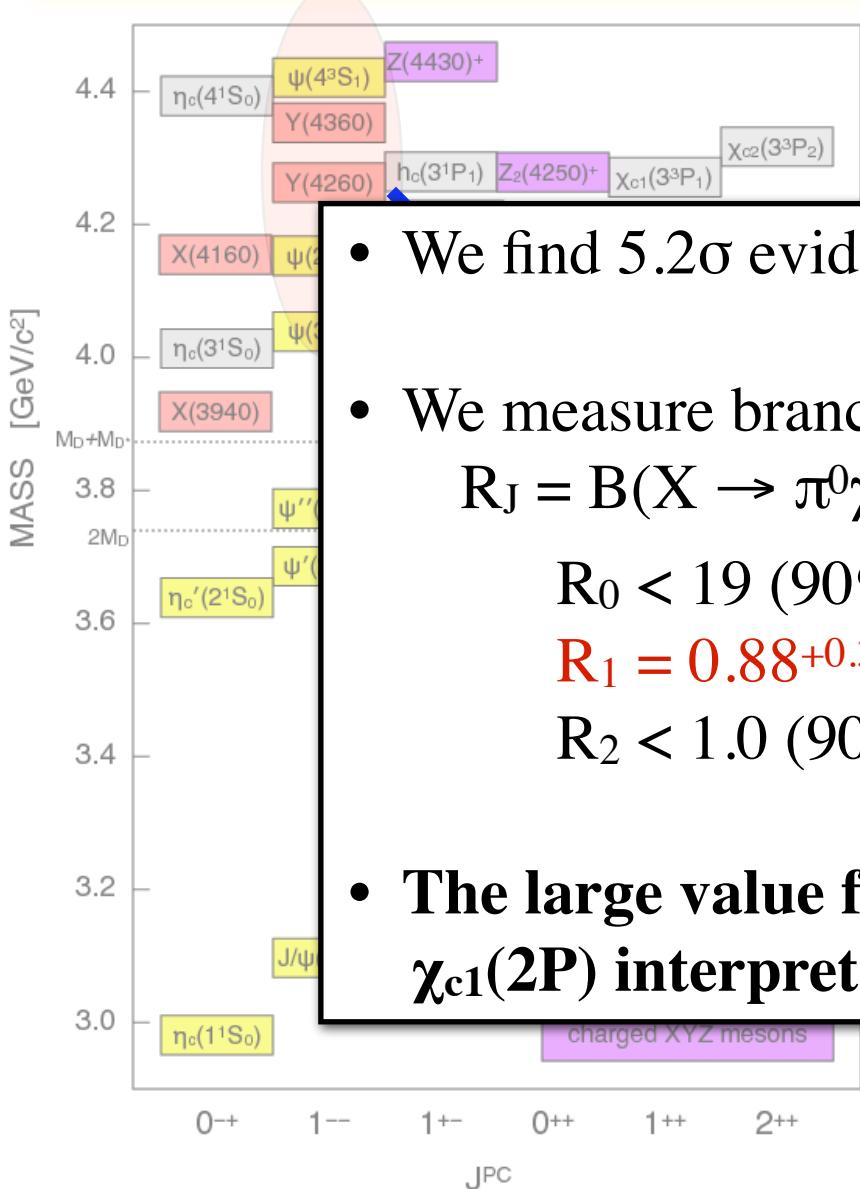
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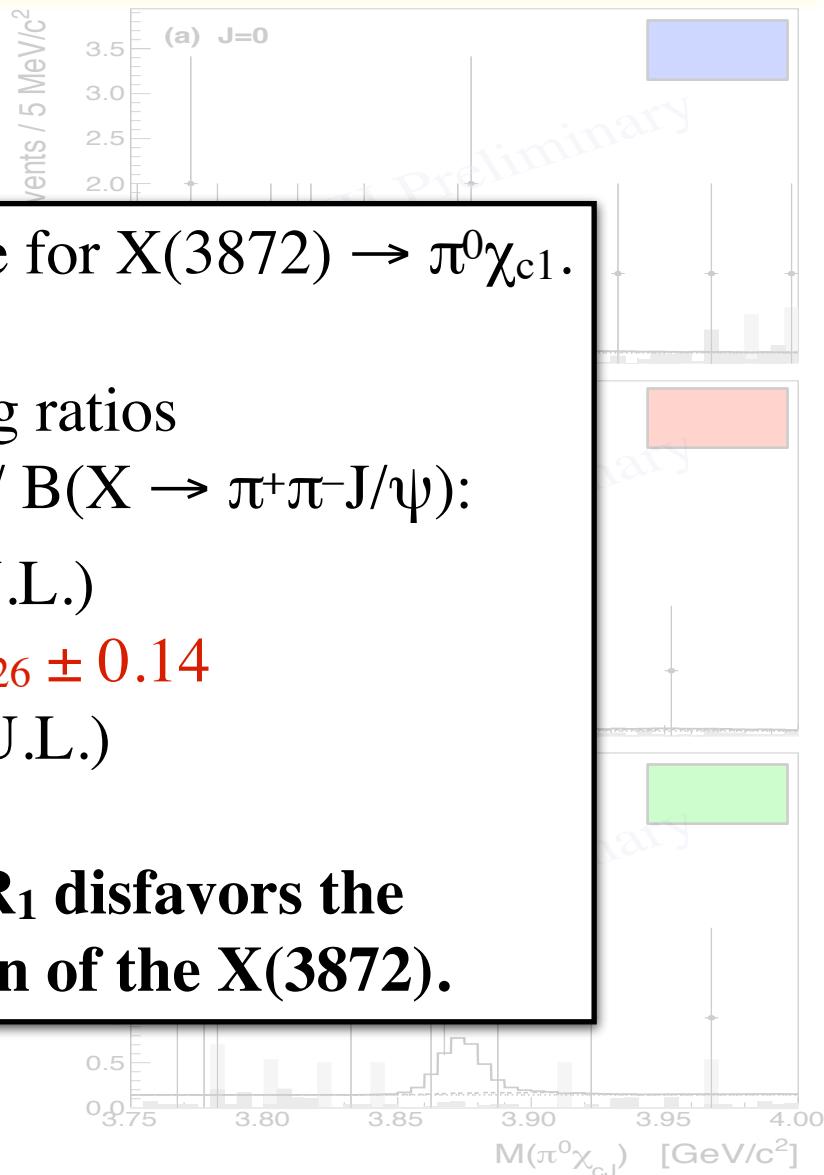
# New insights in the mysterious X(3872)



# New insights in the mysterious X(3872)



- We find  $5.2\sigma$  evidence for  $X(3872) \rightarrow \pi^0 \chi_{c1}$ .
- We measure branching ratios  
 $R_J = B(X \rightarrow \pi^0 \chi_{cJ}) / B(X \rightarrow \pi^+ \pi^- J/\psi)$ :  
 $R_0 < 19$  (90% U.L.)  
 $R_1 = 0.88^{+0.31}_{-0.26} \pm 0.14$   
 $R_2 < 1.0$  (90% U.L.)
- The large value for  $R_1$  disfavors the  $\chi_{c1}(2P)$  interpretation of the  $X(3872)$ .



# XYZ states at BESIII

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# XYZ states at BESIII

Charmonium(-like) systems revealed many insights in the dynamics of the strong force

... from the discovery of “charm” in the 70s till the recent discovery of exotic hadrons

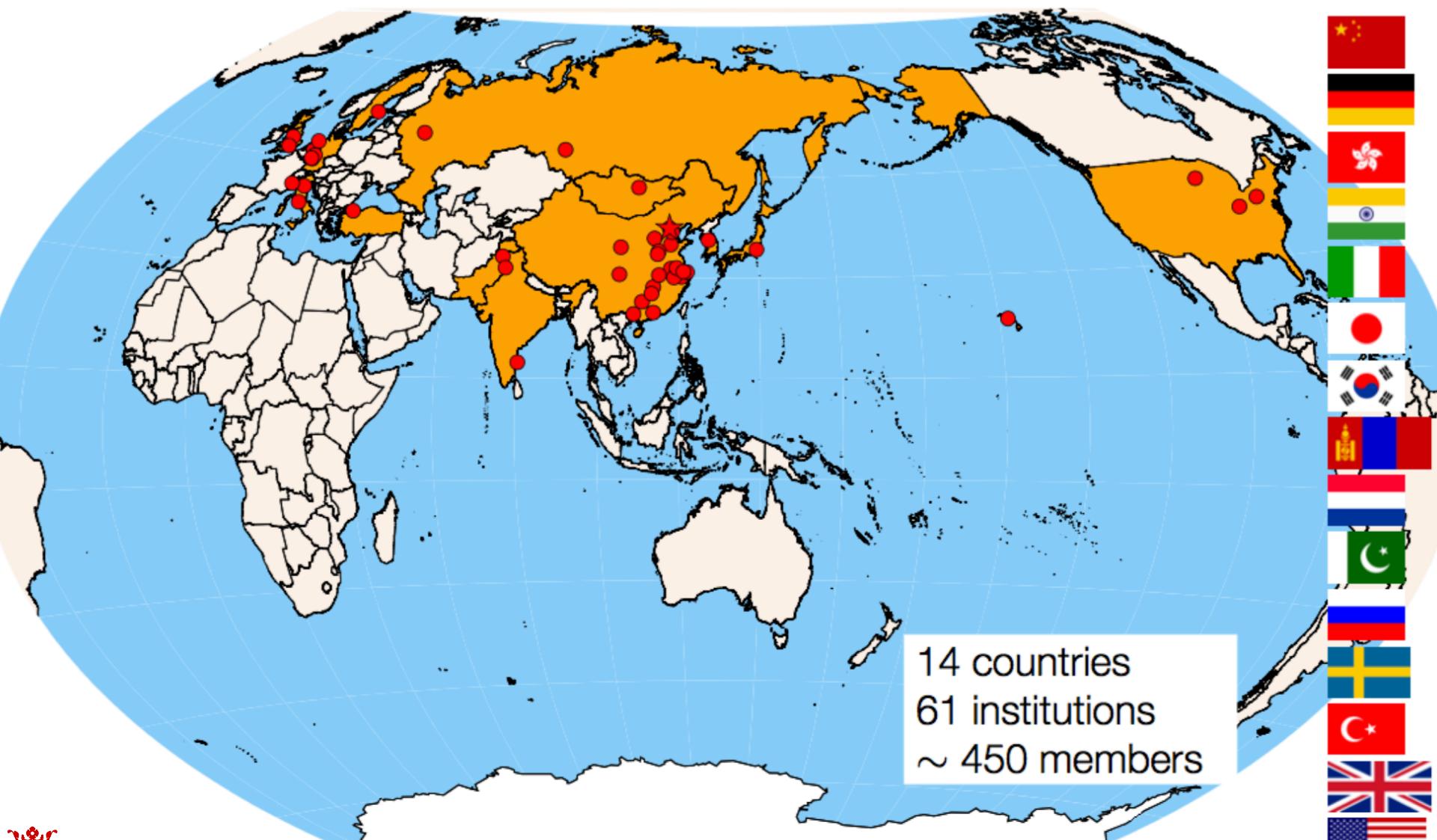
BESIII is a leading player in the field, using  $e^+e^-$  annihilation in the charmonium regime

High statistics samples have (recently) been obtained to unambiguously measure the properties of various XYZ states

...and to make new discoveries in this exciting field of hadron physics



# The BESIII Collaboration



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