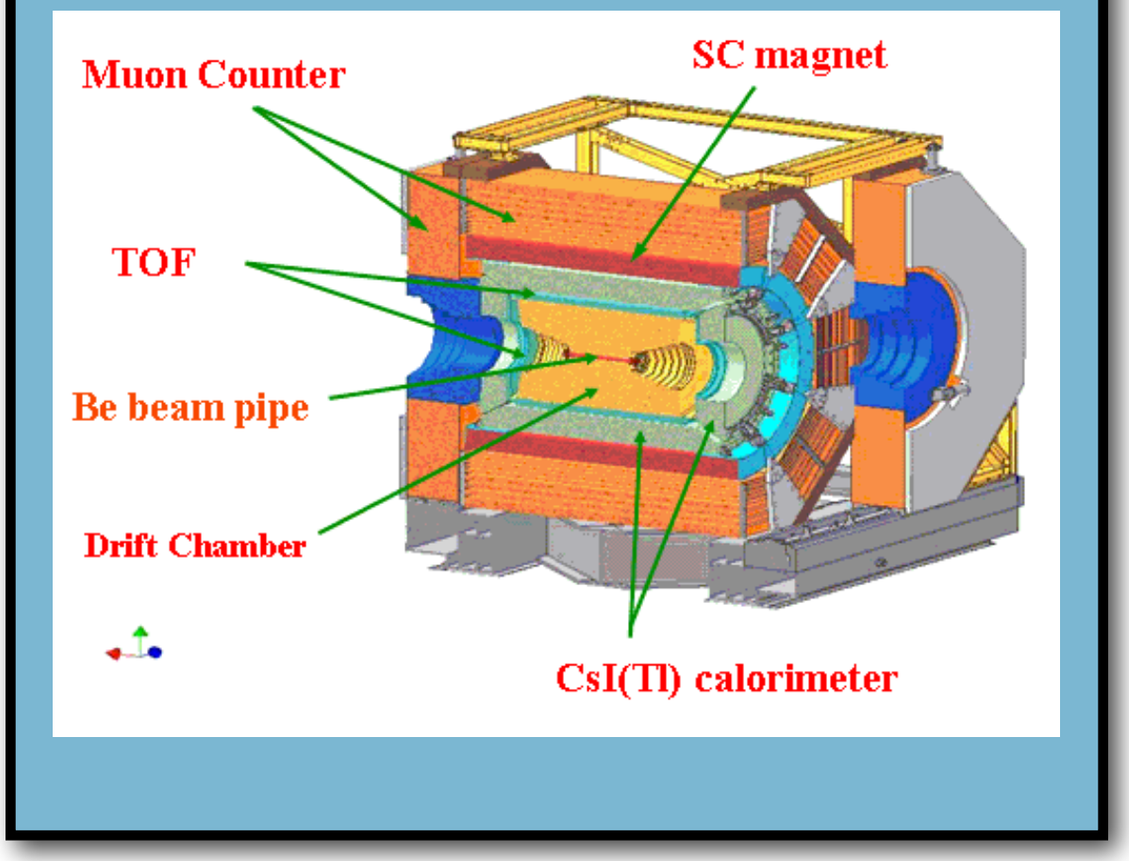
Spectroscopy at the BESIII Experiment

Ryan Mitchell
Indiana University

BEPCII: Beijing Electron Positron Collider
symmetric e^+e^-collisions at E_{CM} between 2.0 and 4.7 GeV

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



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

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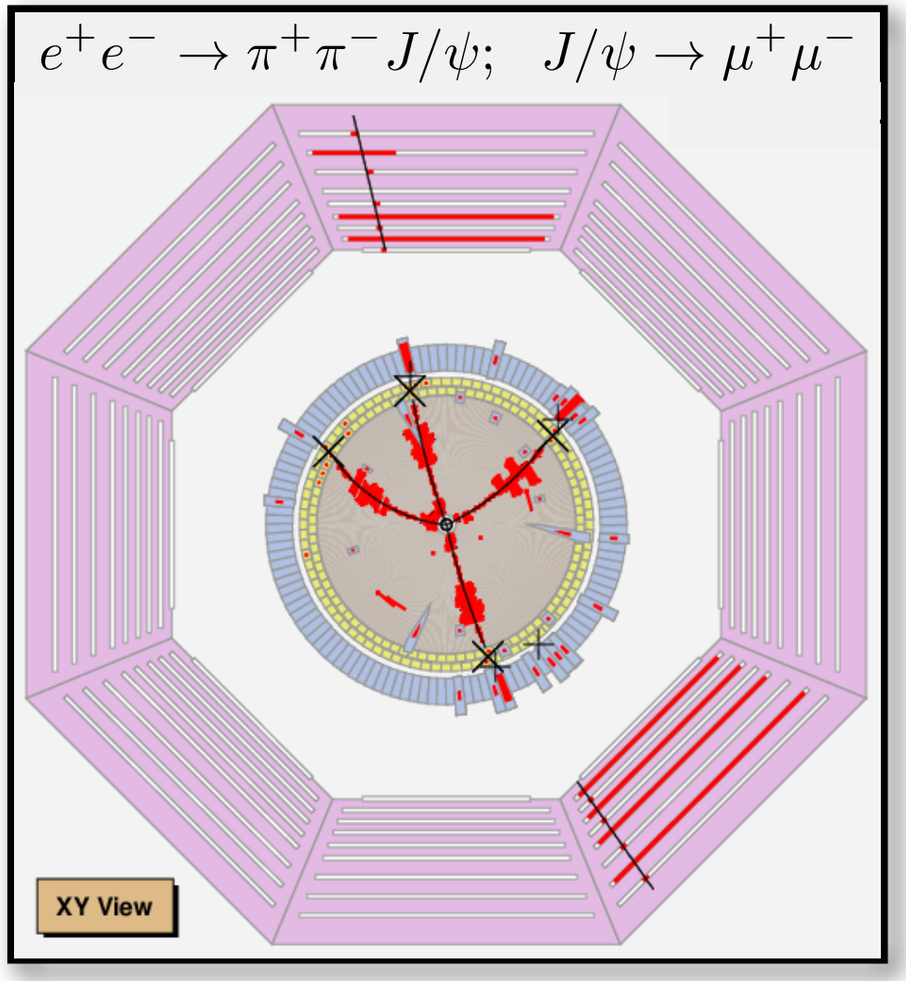

running since 2009 at the Institute of High Energy Physics in Beijing, China

BESIII Collaboration Statistics

Study of Open-Charm Decays and Radiative Transitions of the $X(3872)$

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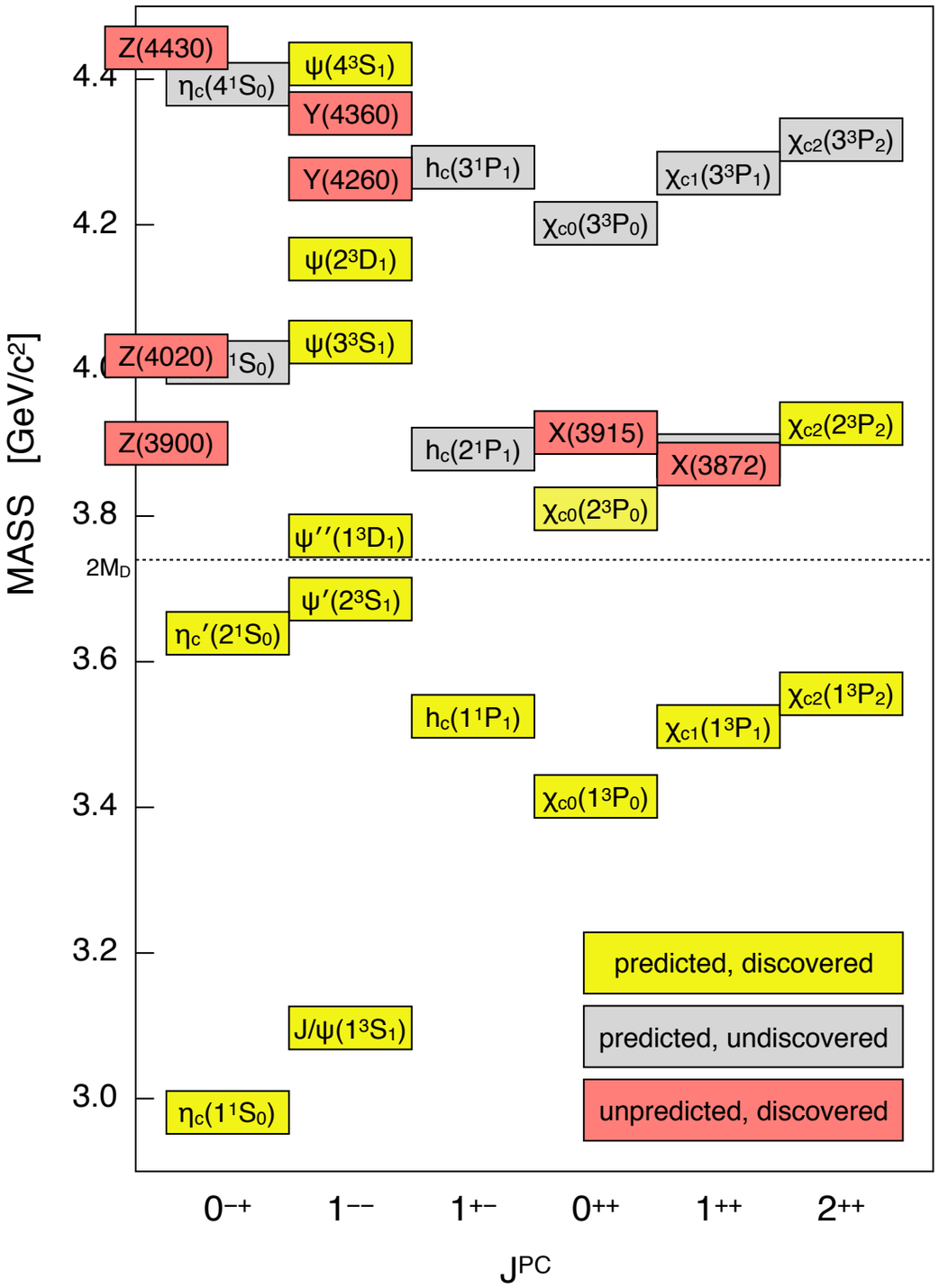
Primary Data Sets at BESIII

Charmonium Spectrum

predictions based on PRD 72, 054026 (2005)
measurements from PDG



BESIII Data Sets (primary):

(e^+e^- collisions at E_{CM} between 2.0 and 4.7 GeV)

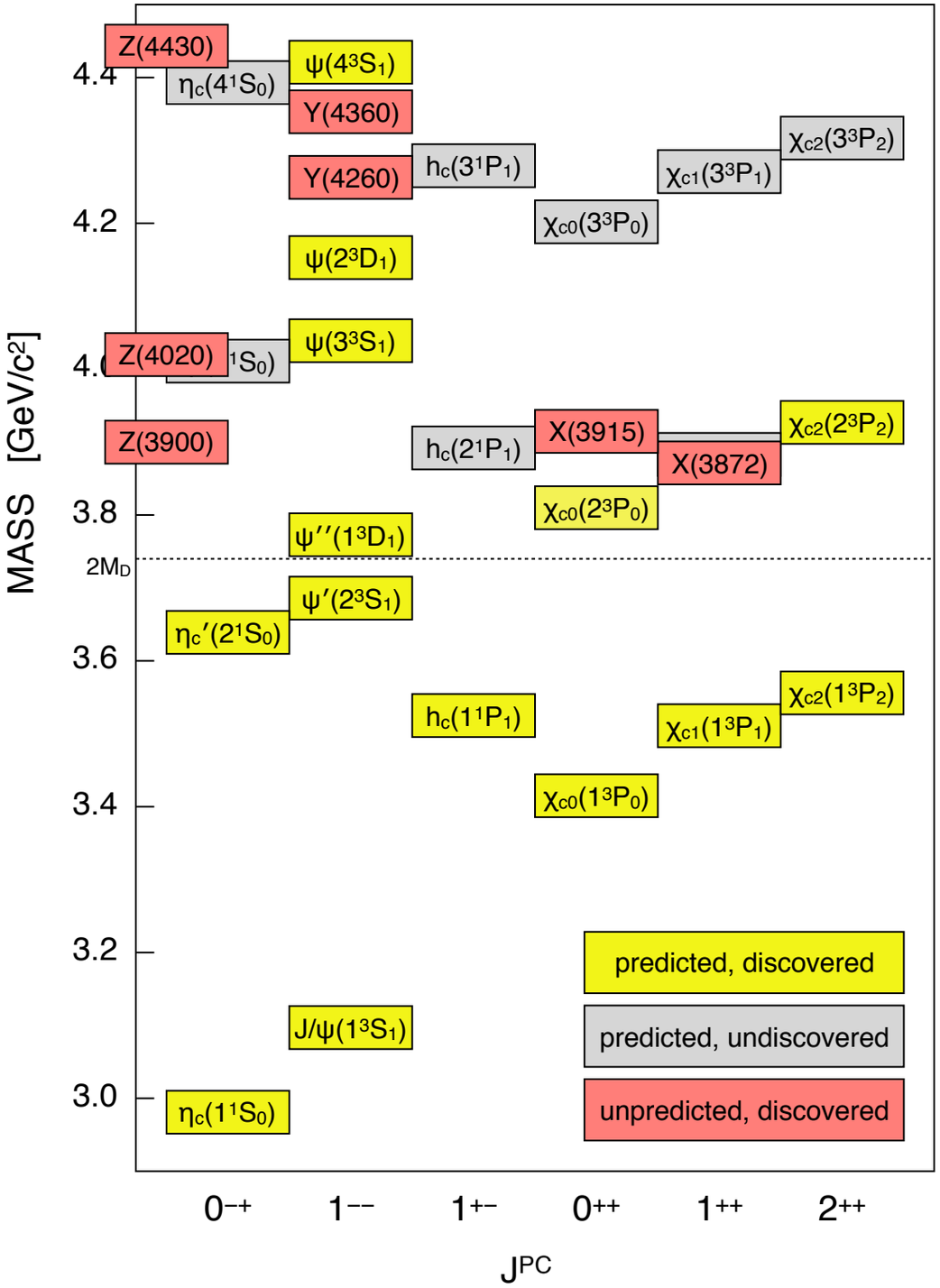
2009: 106M $\psi(2S)$
225M J/ψ
2010: 975 pb^{-1} at $\psi(3770)$
2011: 2.9 fb^{-1} *(total)* at $\psi(3770)$
482 pb^{-1} at 4.01 GeV
2012: 0.45B *(total)* $\psi(2S)$
1.3B *(total)* J/ψ
2013: 1092 pb^{-1} at 4.23 GeV
826 pb^{-1} at 4.26 GeV
540 pb^{-1} at 4.36 GeV
10 × 50 pb^{-1} scan 3.81 — 4.42 GeV
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
0.8 fb^{-1} R-scan 3.85 — 4.59 GeV
2015: R-scan 2 — 3 GeV + 2.175 GeV
2016: ~3fb^{-1} at 4.18 GeV (for D_s)
2017: 7 × 500 pb^{-1} scan 4.19 — 4.27 GeV
2018: more J/ψ *(and tuning new RF cavity)*
2019: 10B *(total)* J/ψ
8 × 500 pb^{-1} scan 4.13, 4.16, 4.29 — 4.44 GeV
2020: 5 × 500 pb^{-1} scan 4.63 — 4.70 GeV *(+ extra)*

Many topics!
spectroscopy (light and heavy), flavor physics, new physics, R scans, τ physics, etc.

Primary Data Sets at BESIII

Charmonium Spectrum

predictions based on PRD 72, 054026 (2005)
measurements from PDG



Primary Data for Spectroscopy:

Light Quark Spectroscopy

10 billion J/ψ

Precision Charmonium Physics

450 million $\psi(2S)$

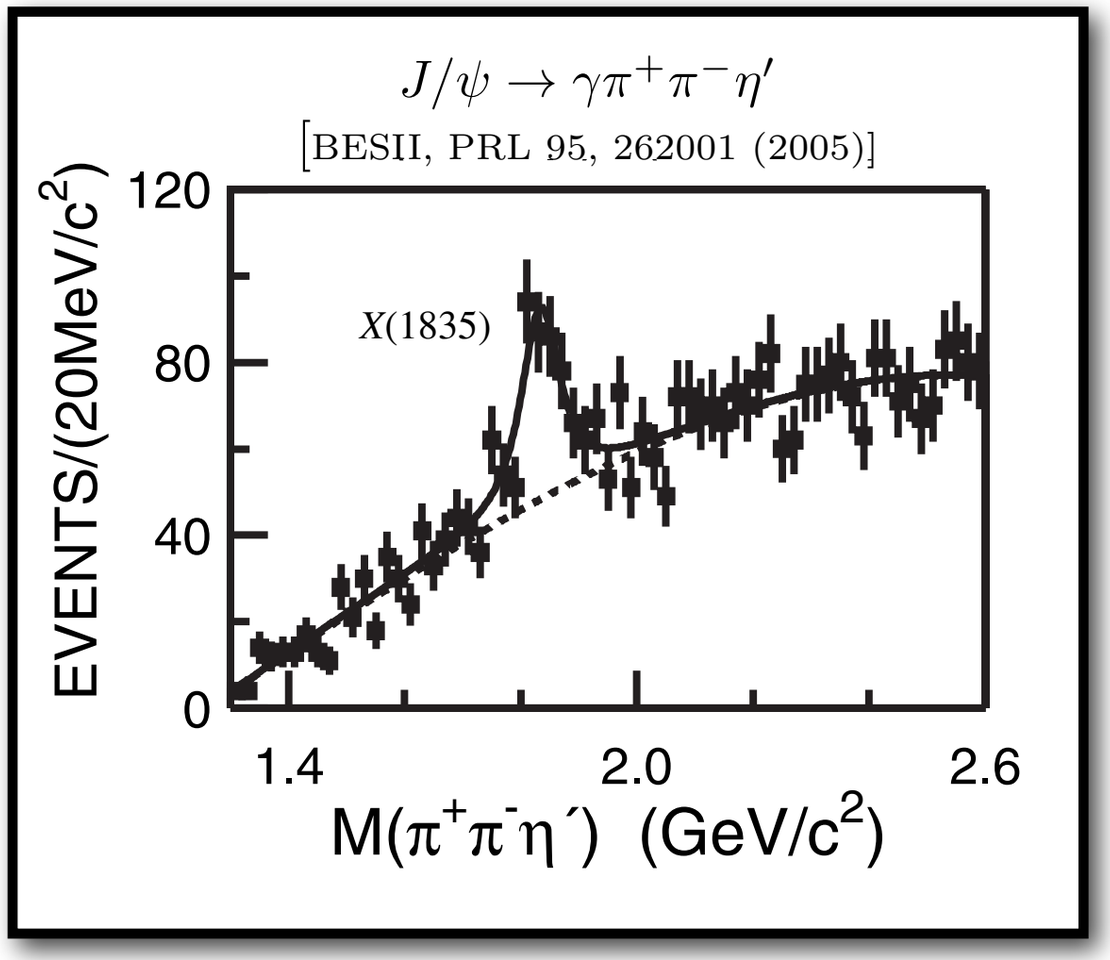
Charmonium (XYZ) Spectroscopy

≥ 500 pb^{-1} at 27 points
between 4.0 and 4.7 GeV

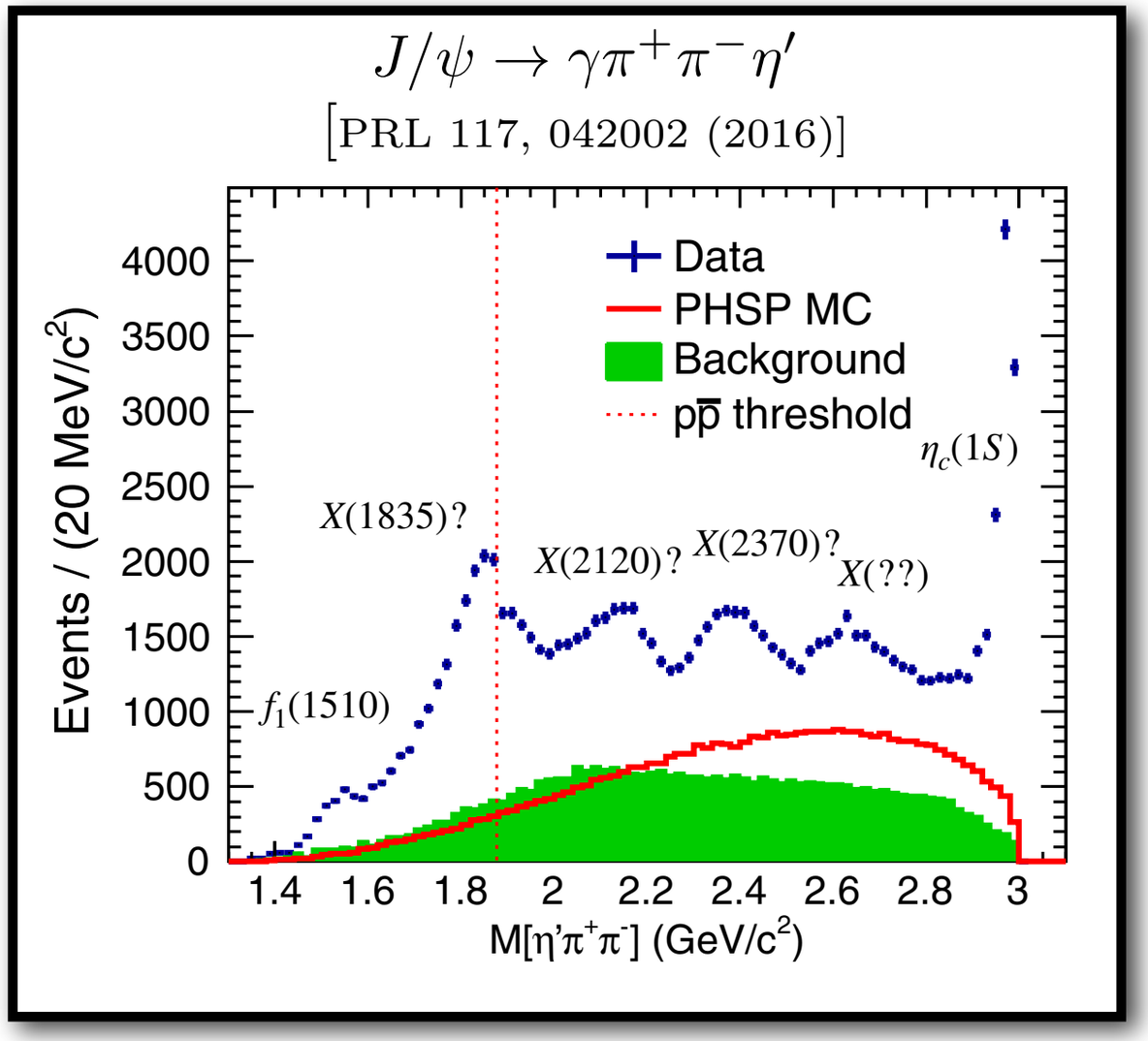
Light Quark Spectroscopy

Hundreds of light quark channels are produced in J/ψ hadronic and radiative decays.

From BESII *(with 58M J/ψ decays)…*



To BESIII *(with 1.1B J/ψ decays)…*

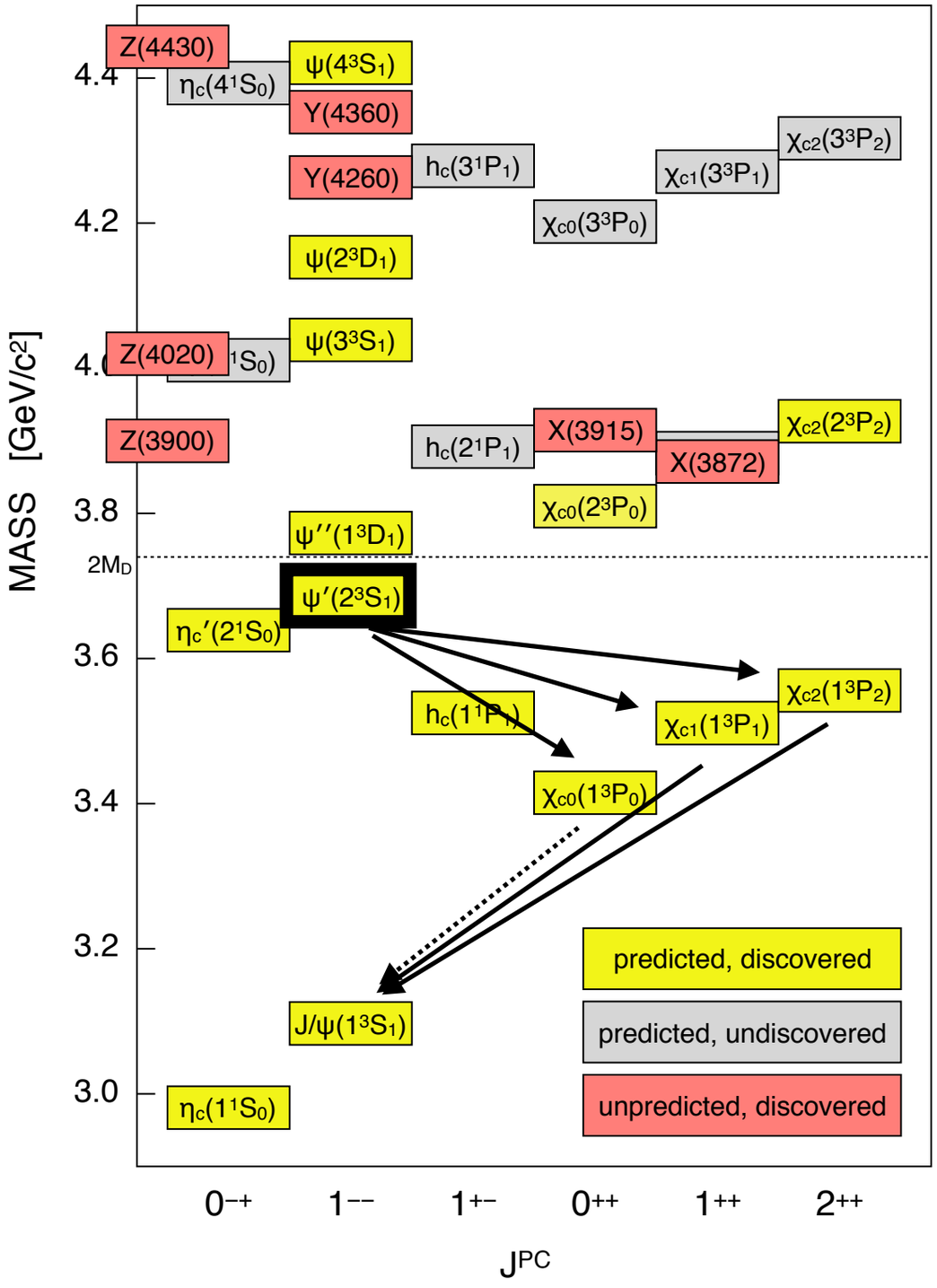


And now to 10B J/ψ decays! A "legacy" data set.

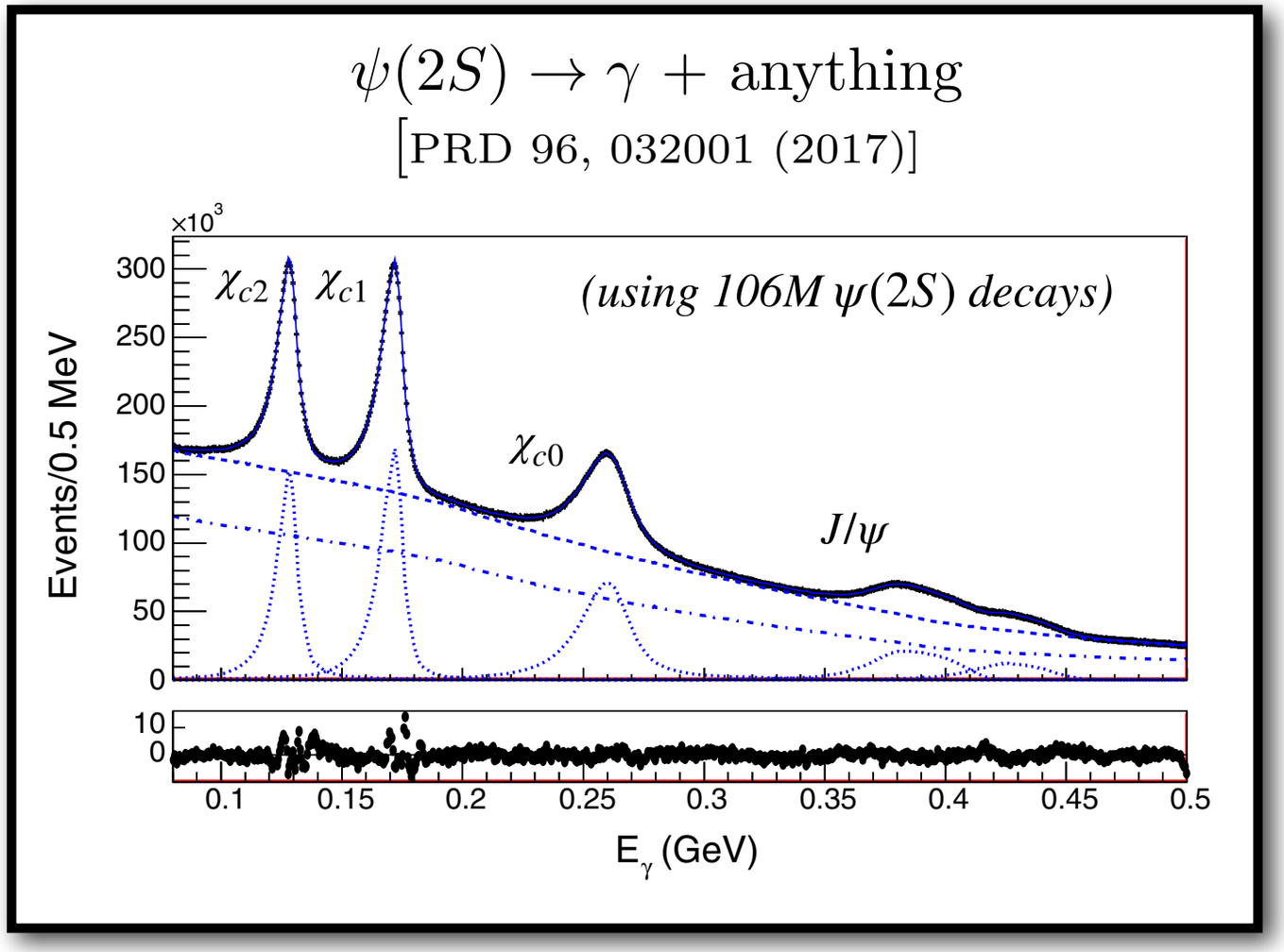
Precision Charmonium Physics

Charmonium Spectrum

predictions based on PRD 72, 054026 (2005)
measurements from PDG



The $\psi(2S)$ provides easy access to the $\eta_c(1S,2S)$, J/ψ, $h_c(1P)$, and $\chi_{cJ}(1P)$ charmonium states.



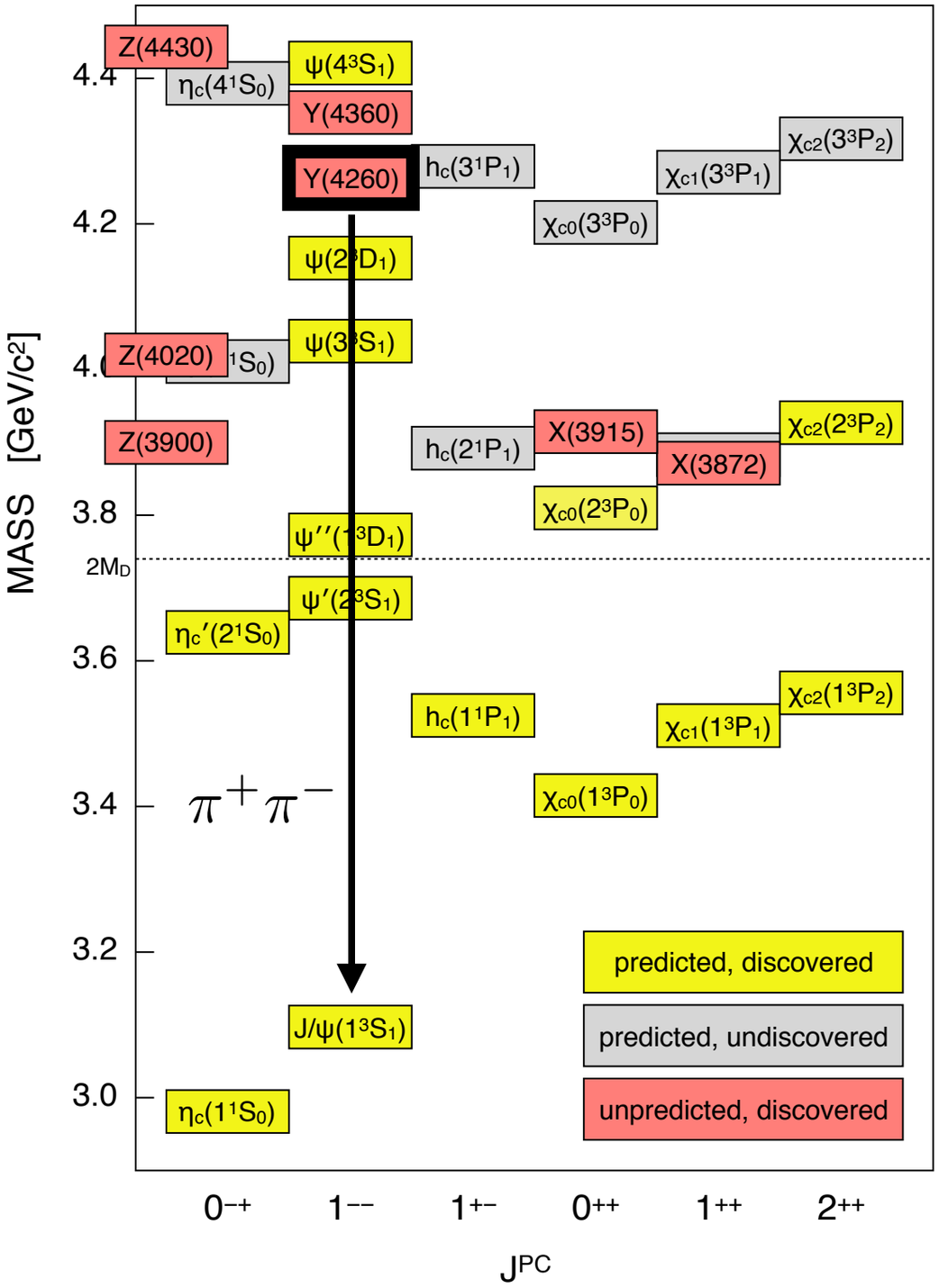
Expect 3-5B $\psi(2S)$ decays within the next several years.

precision transitions (radiative and hadronic),
precision decays, rare decays
→ tests of effective field theories (like NRQCD), etc.

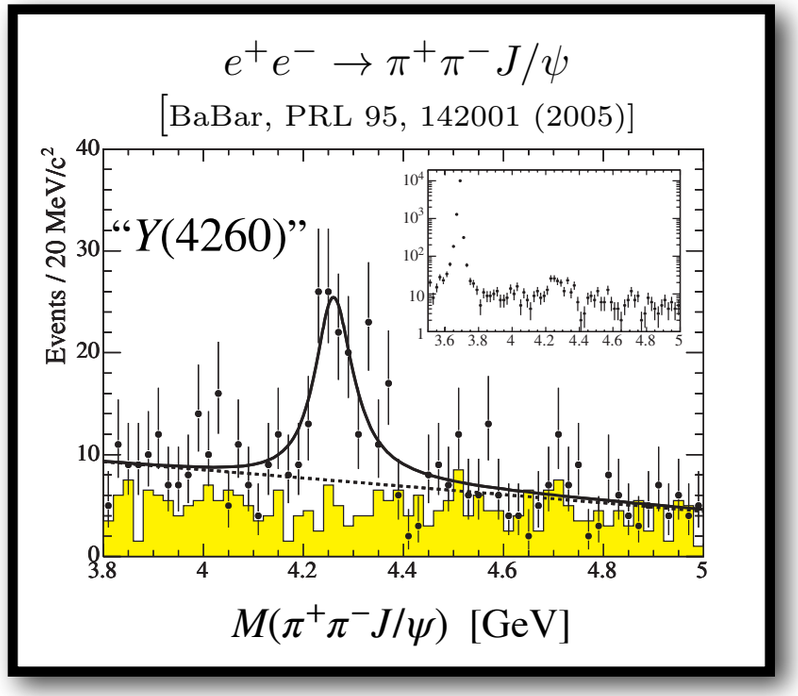
Charmonium Spectroscopy: Y States

Charmonium Spectrum

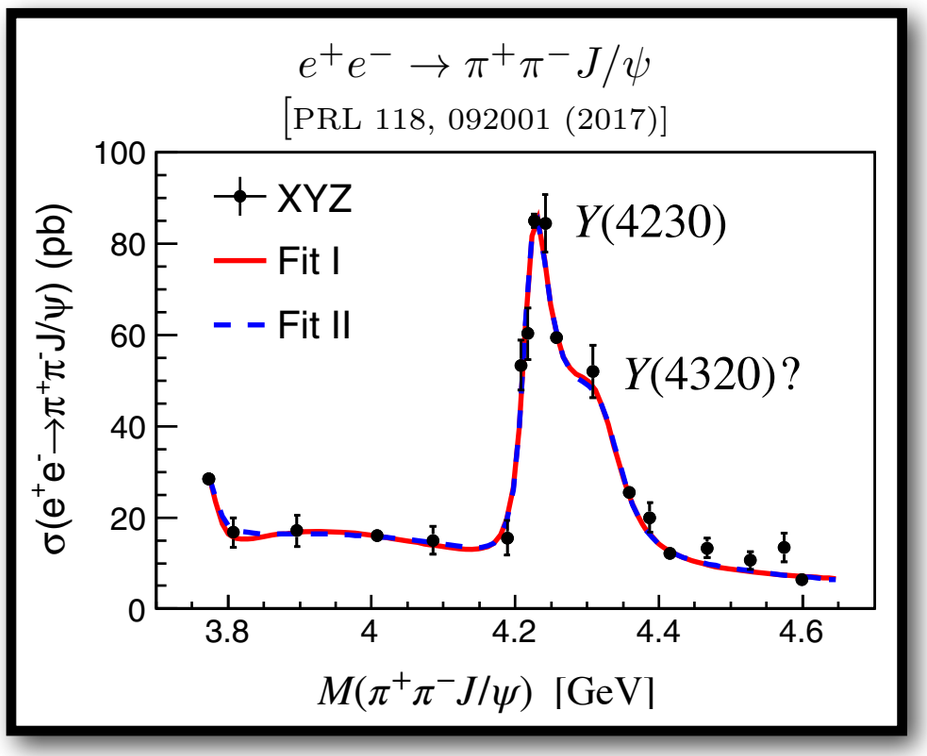
predictions based on PRD 72, 054026 (2005)
measurements from PDG



Charmonium vector states can be produced directly and scanned in e^+e^- annihilation.



Discovery of the "*Y*(4260)" by BaBar using ISR
measure a wide range of energies imprecisely

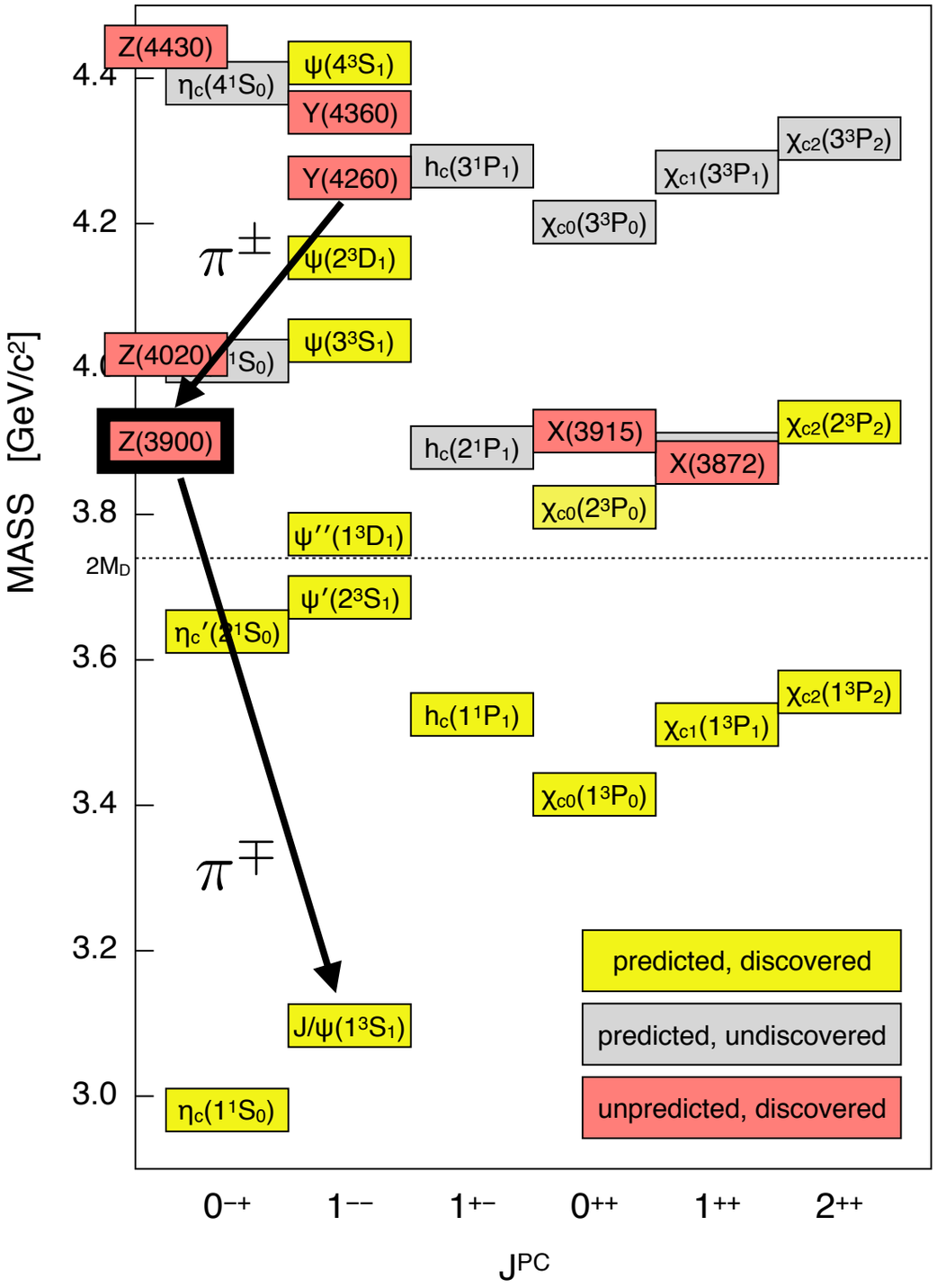


Discovery of Fine Structure at BESIII
measure narrow ranges of energy precisely

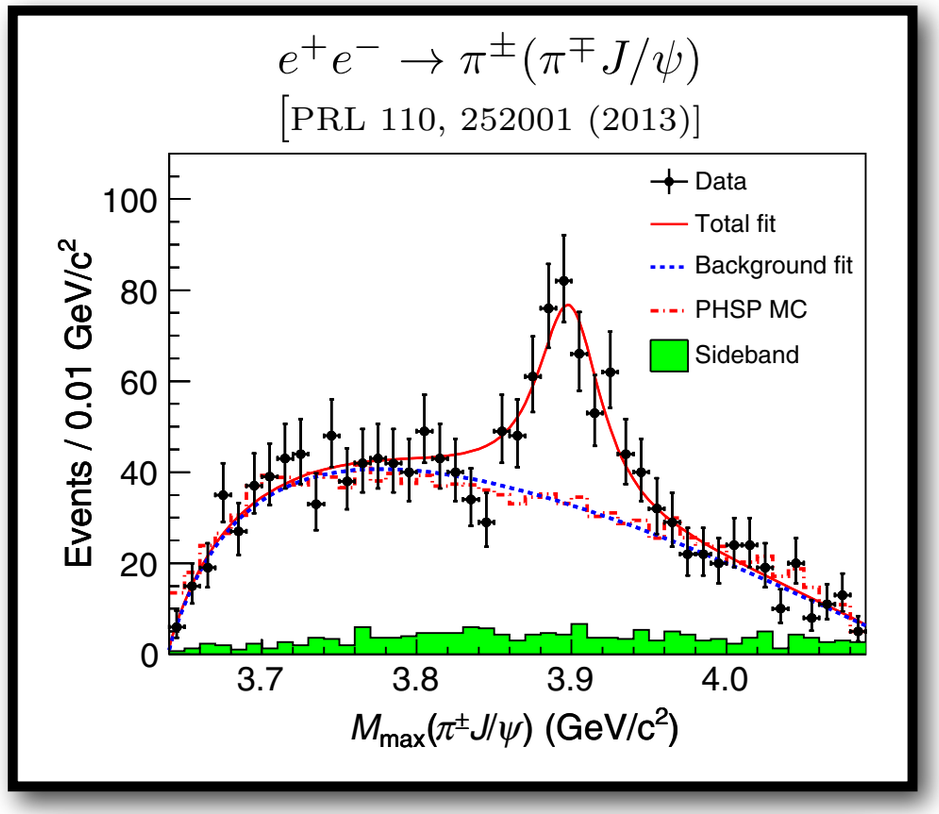
Charmonium Spectroscopy: Z States

Charmonium Spectrum

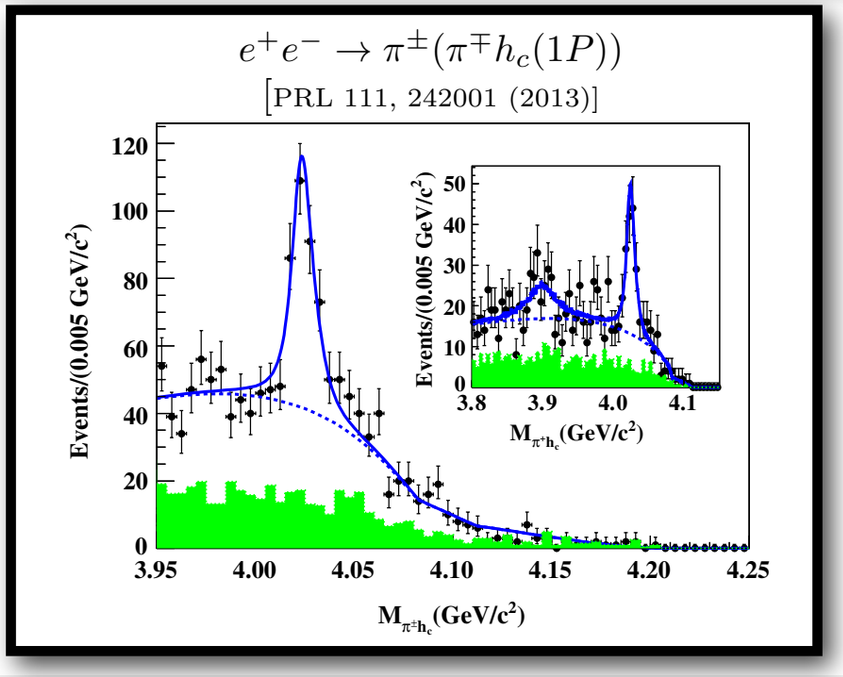
predictions based on PRD 72, 054026 (2005)
measurements from PDG



Decays of the Y states show evidence for electrically charged structures near open charm thresholds.



The $Z_c(3900)$ is near the $D\overline{D^*}$ threshold.

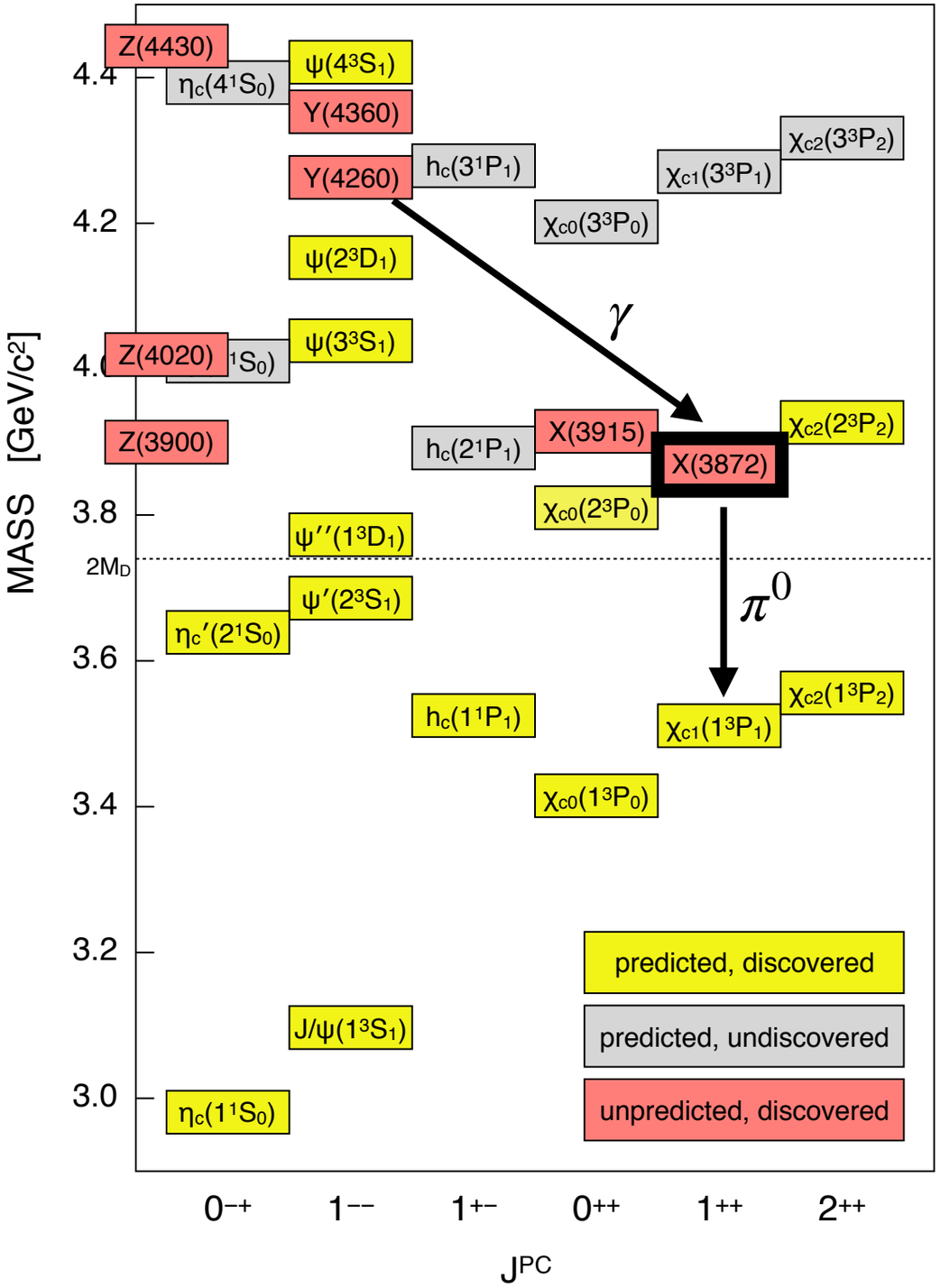


The $Z_c(4020)$ is near the $D^*\overline{D^*}$ threshold.

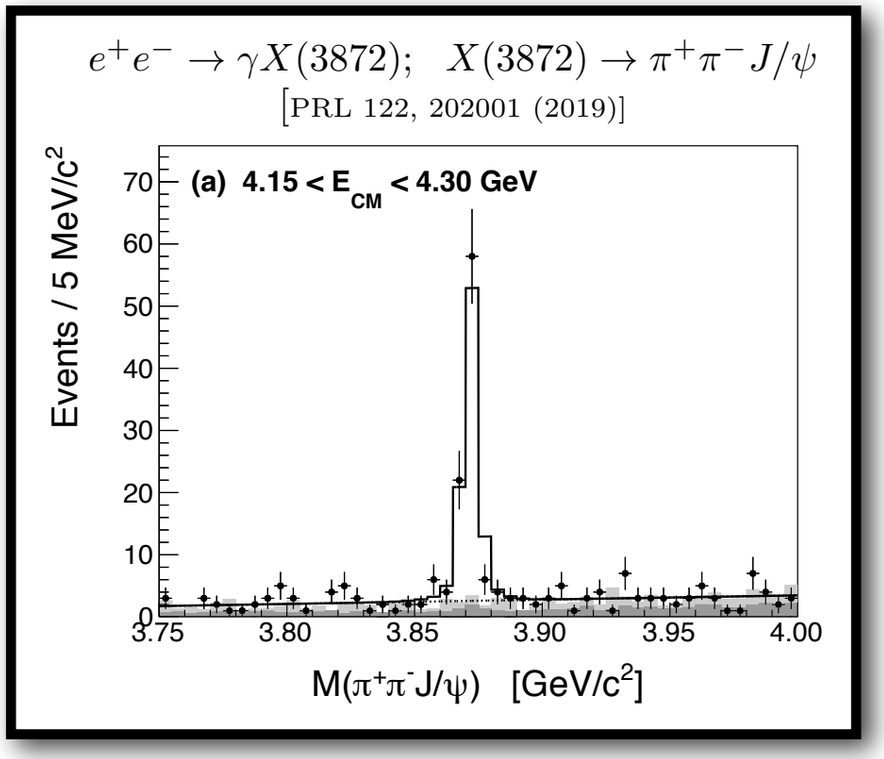
Charmonium Spectroscopy: X States

Charmonium Spectrum

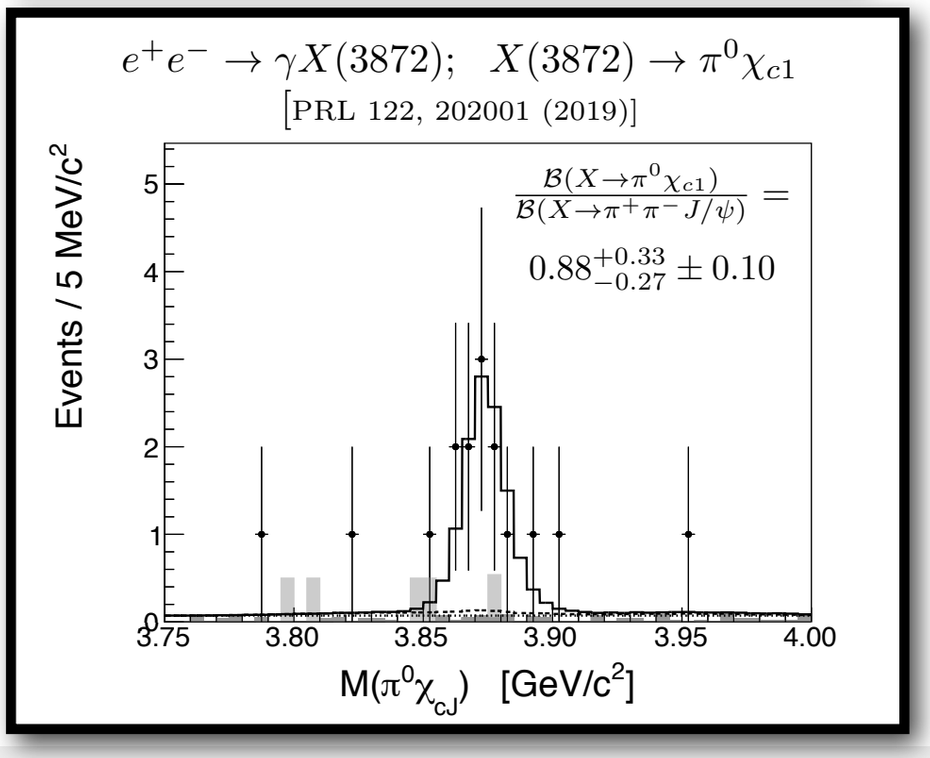
predictions based on PRD 72, 054026 (2005)
measurements from PDG



Radiative transitions from the Y states provide access to X states.



Establish the *X*(3872) is produced in radiative transitions.



Then search for new *X*(3872) decay modes.

The Future

The BESIII Experiment:

* is still extremely active — 61 publications in 2019! (https://inspirehep.net/literature/1770442)
* maximum energy will be upgraded from 4.7 to 4.9 GeV *(this summer)*
* a proposal exists for a 2× luminosity upgrade *(timing and funding is uncertain)*
* no official end date *(unofficial end date is 5-10 years from now)*

Super tau-charm factories

are being discussed in China (USTC) and Russia (BINP):

* a recent joint workshop on the two proposals:
  https://mosphys.ru/indico/event/3/overview
* luminosity expected to be $0.5 - 1.0 \times 10^{35}$ (50 -100× BEPCII)
* CDRs have been developed
* R&D is funded and active
* timeline would be ~10 years to physics, depending on funding

(concept drawing for a tau-charm factory in Hefei, China)

Tau-charm factories offer clean and complimentary environments to study both light and heavy quark spectroscopy, as well as a diverse array of other topics (flavor physics, new physics, etc.)!