Recent Results from the BESIII Experiment

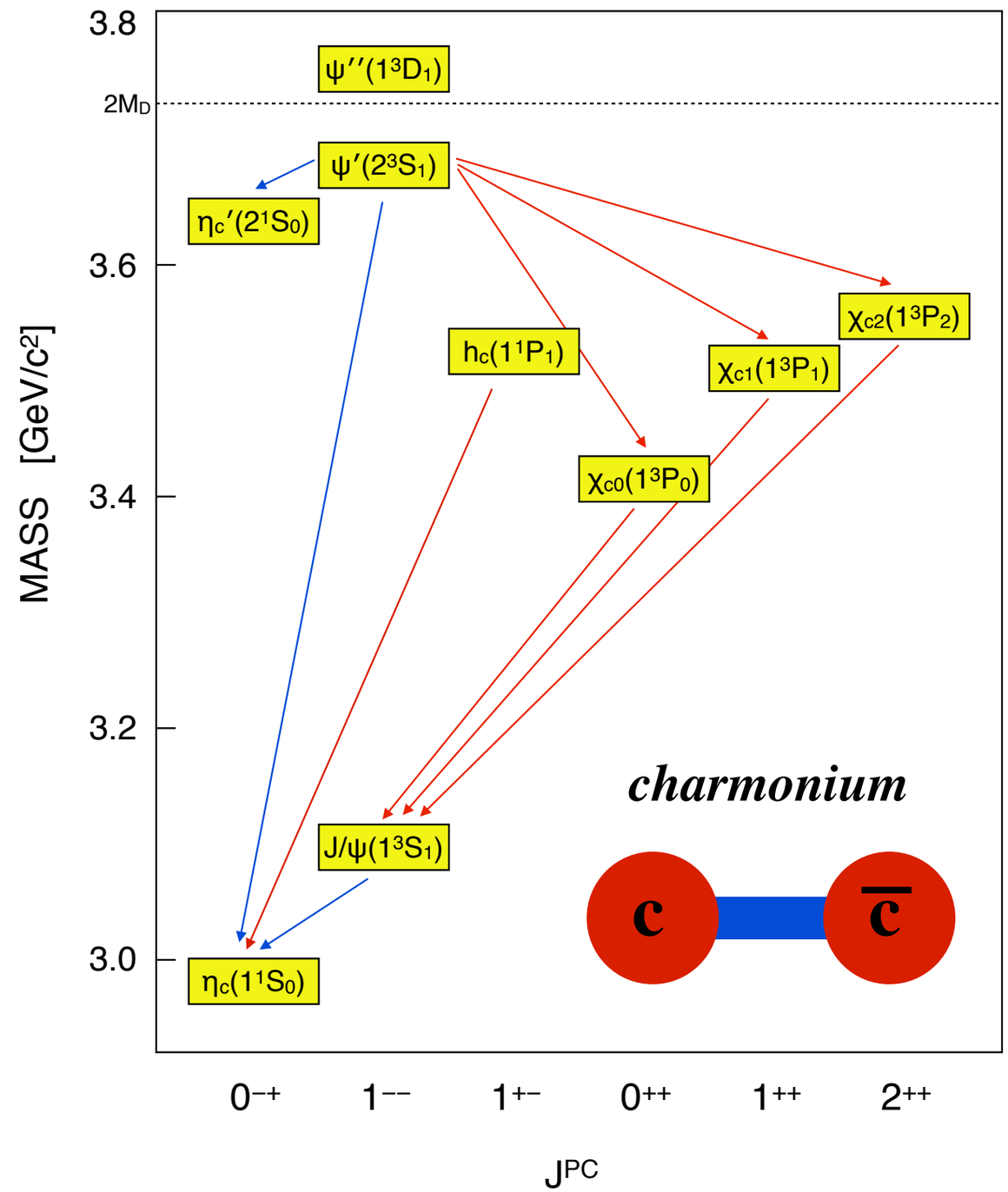
Ryan Mitchell
Indiana University
Miami 2011
December 17, 2011

Introduction to the BESIII Experiment

The primary goal of BESIII: Use e^+e^- collisions to produce charmonium states, then use their properties and their decays to learn about the strong force.

(and the properties and the decays of their decay products, etc.)

accelerator



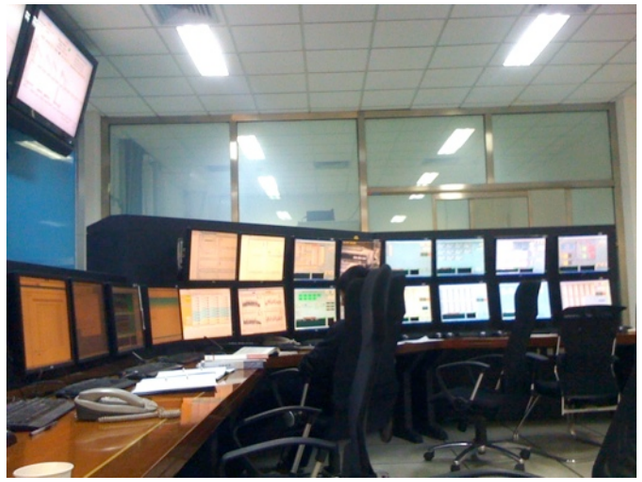
QCD

phenomenology and theory

Introduction to the BESIII Experiment

accelerator

detector



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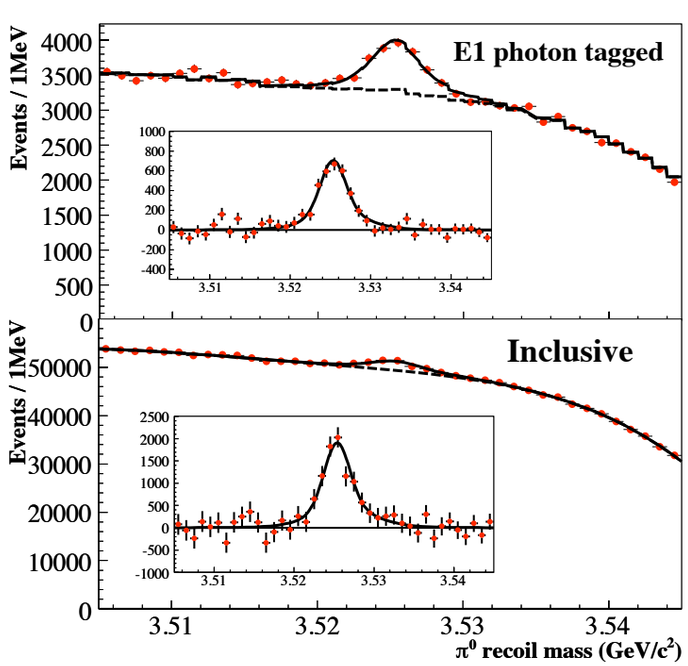
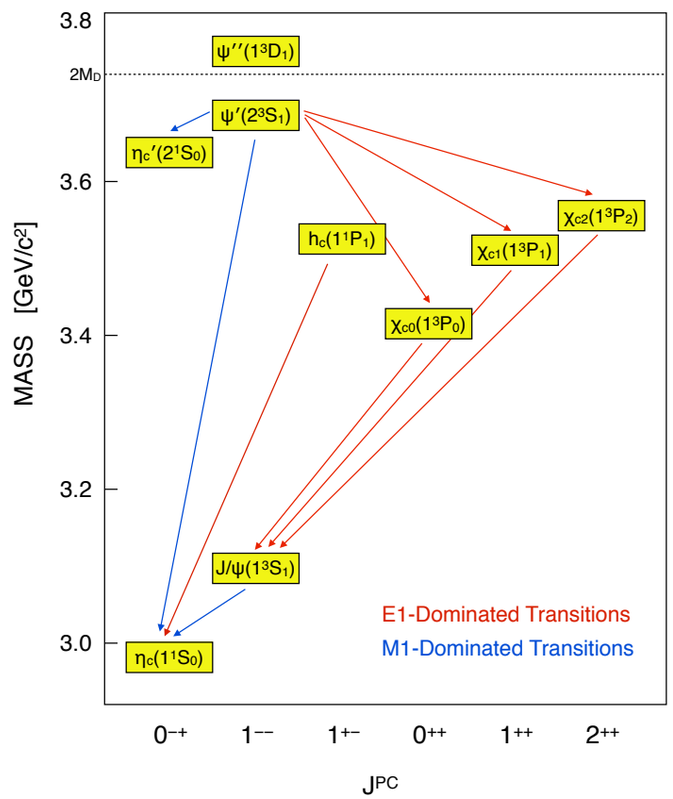


analysis



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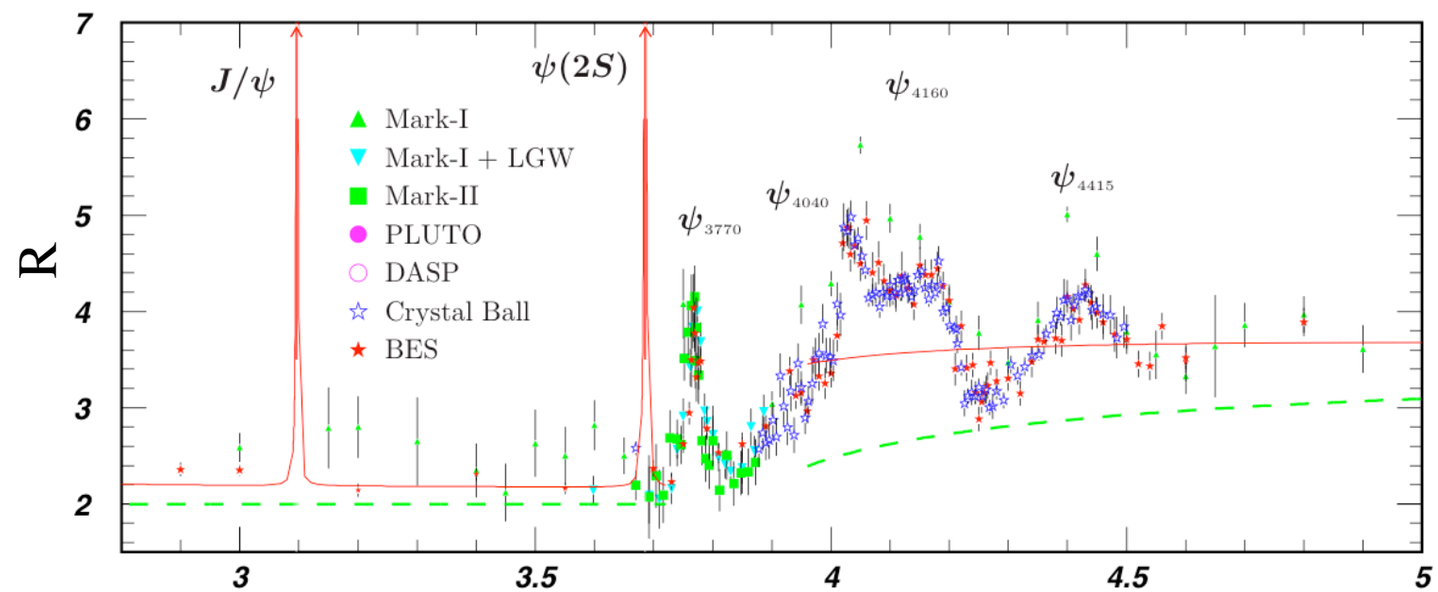
BEPCII:
Institute for High Energy Physics
Beijing, China

Collide e^+e^- in the τ-charm region:



e^+e^- Center of Mass Energy

First collisions: March 2008

Record luminosity: $\sim 6 \times 10^{32}\ cm^{-2}s^{-1}$
(~10× CESRc and ~50× BEPC)

Introduction to the BESIII Experiment

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aerial view of BEPCII at IHEP

to Beijing

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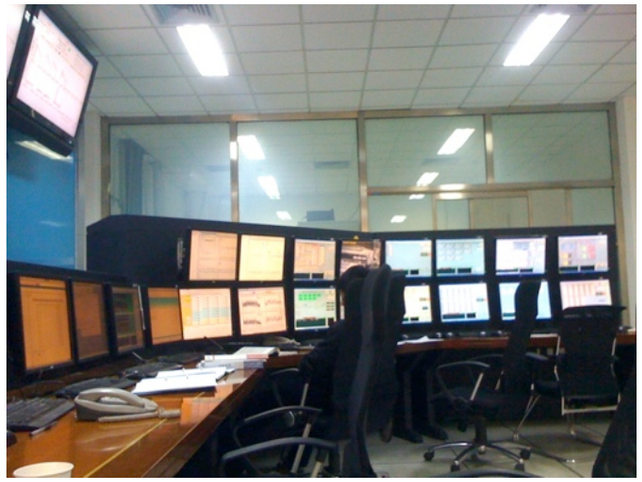
detector



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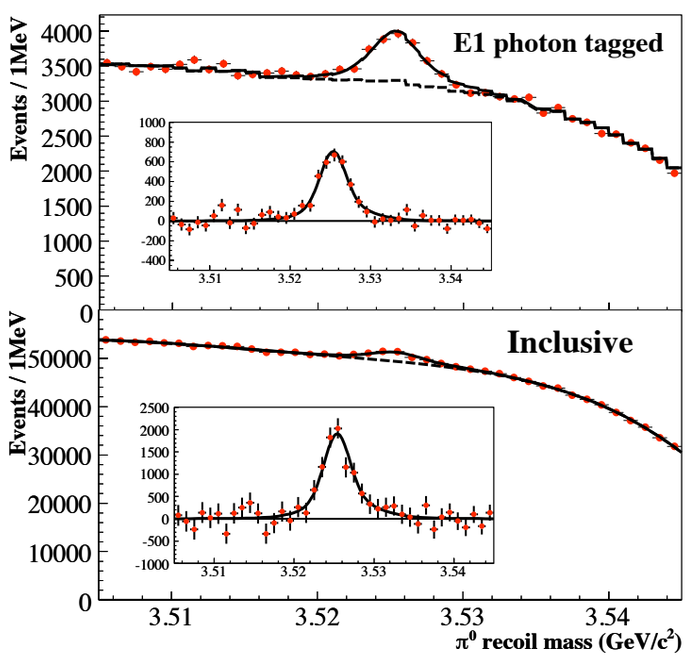

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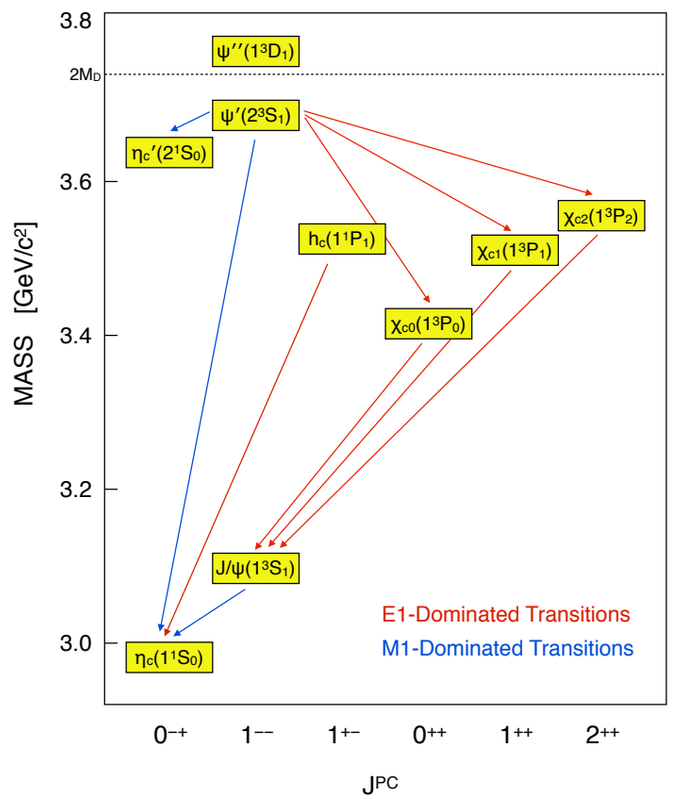

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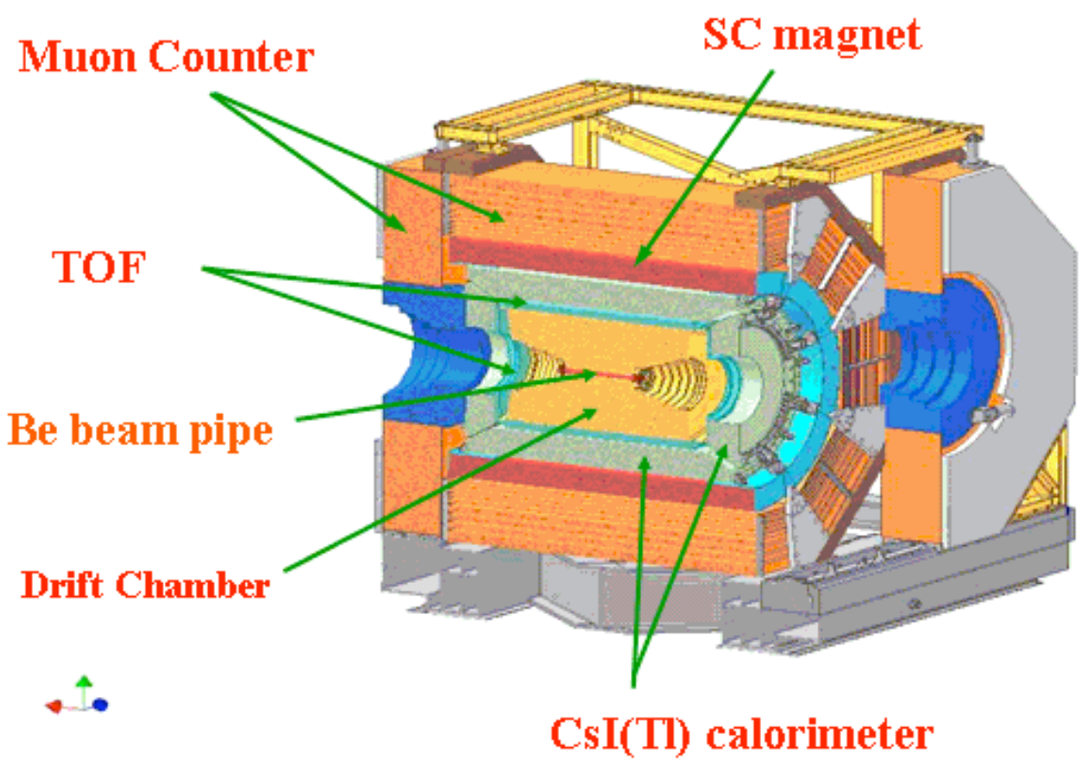
The BESIII Detector



Excellent tracking and calorimetry with a uniform acceptance:

tracks: $\sigma_p/p \sim 0.6\%$ at 1 GeV/c

photons: $\sigma_E/E \sim 2.5\%$ at 1 GeV

detector

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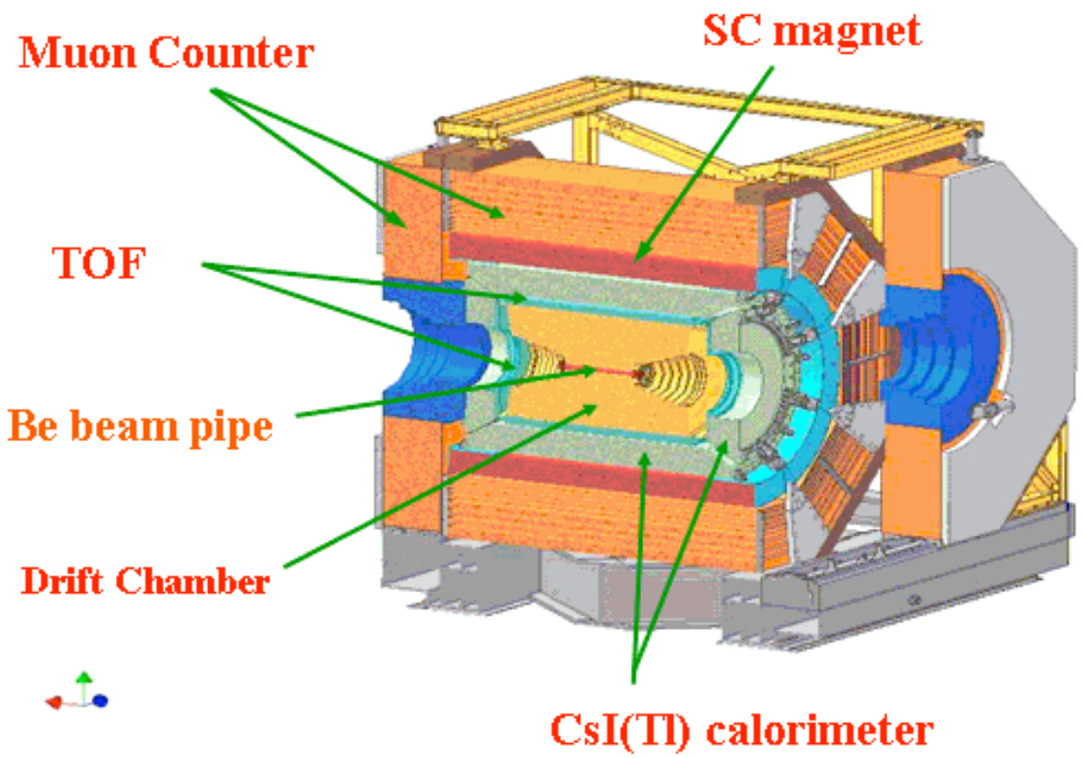
The BESIII Detector



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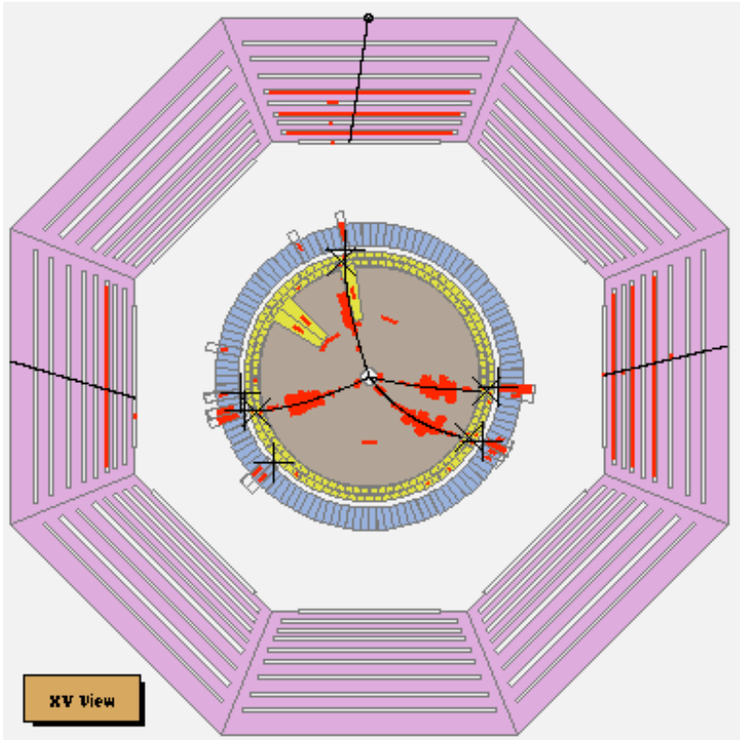
First Hadronic Event:
July 2008



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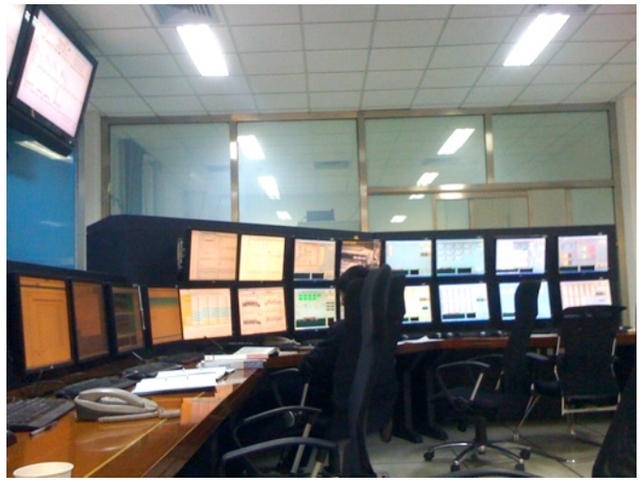

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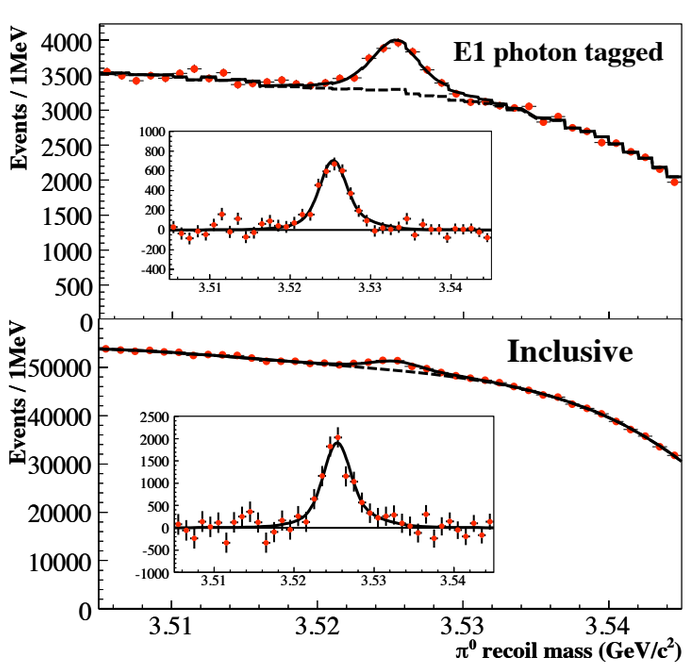

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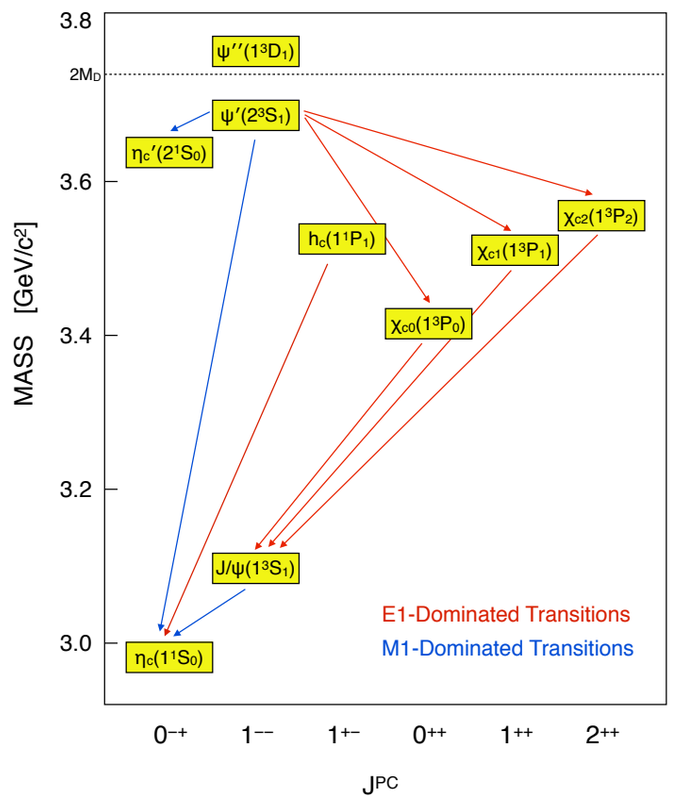

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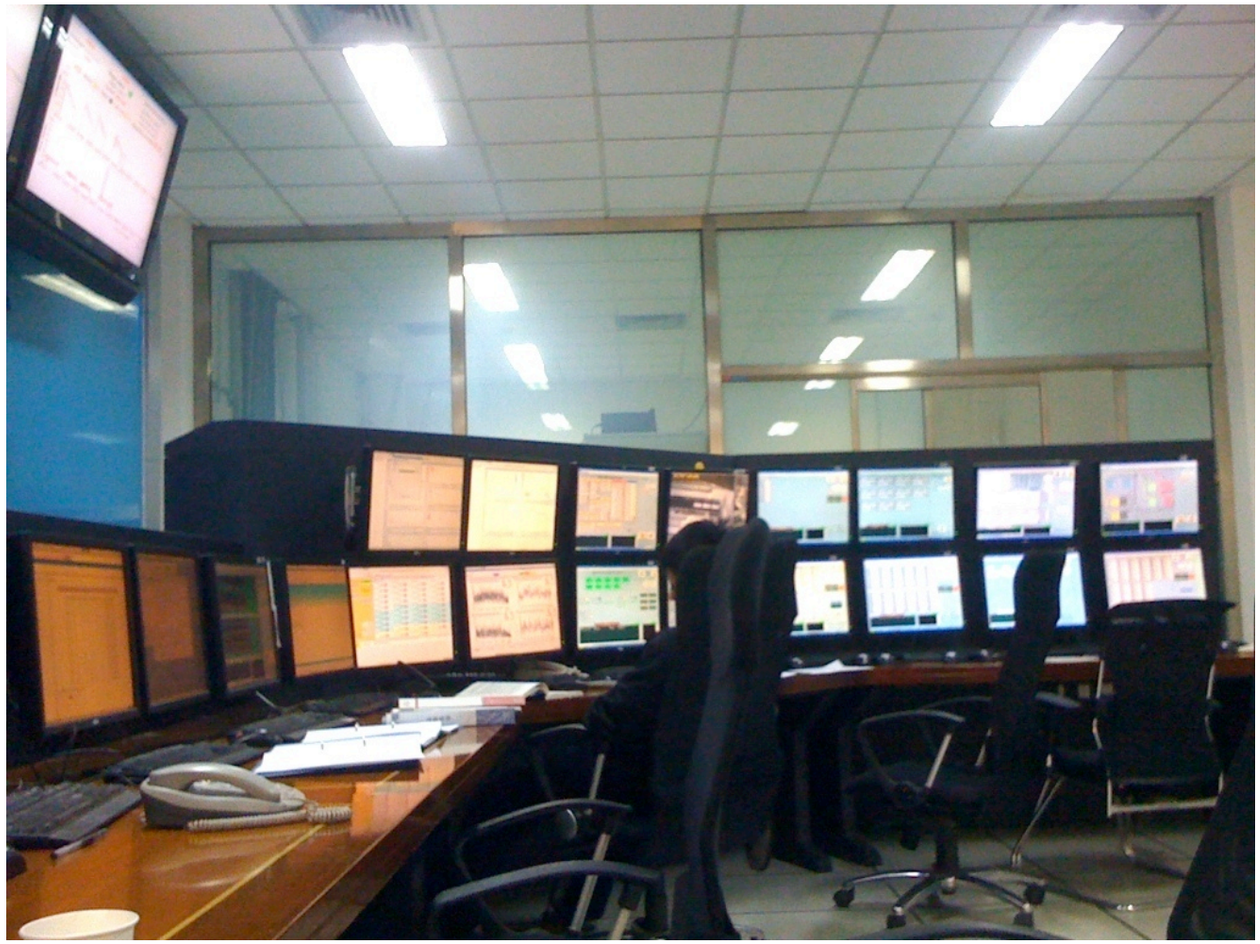

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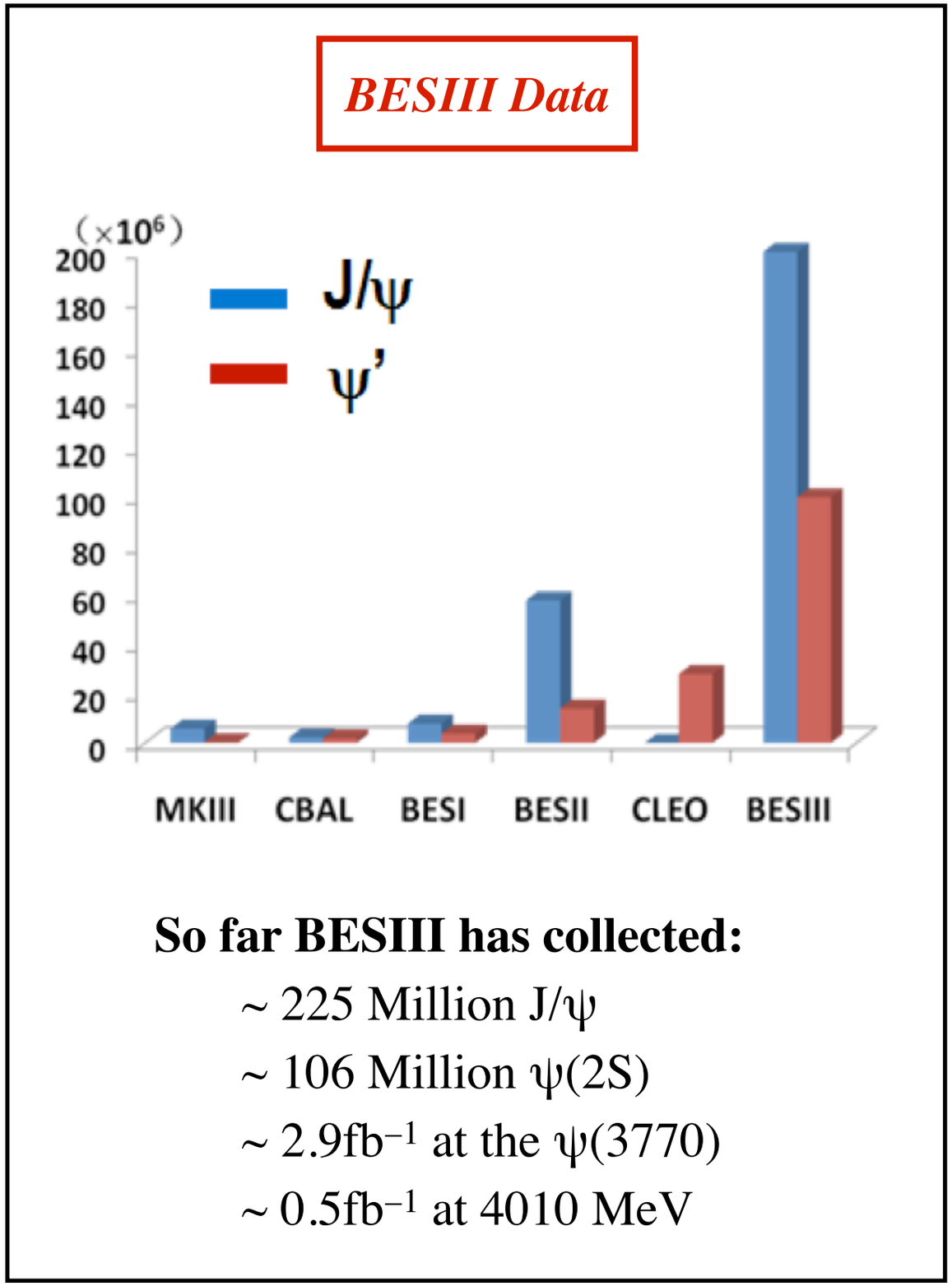

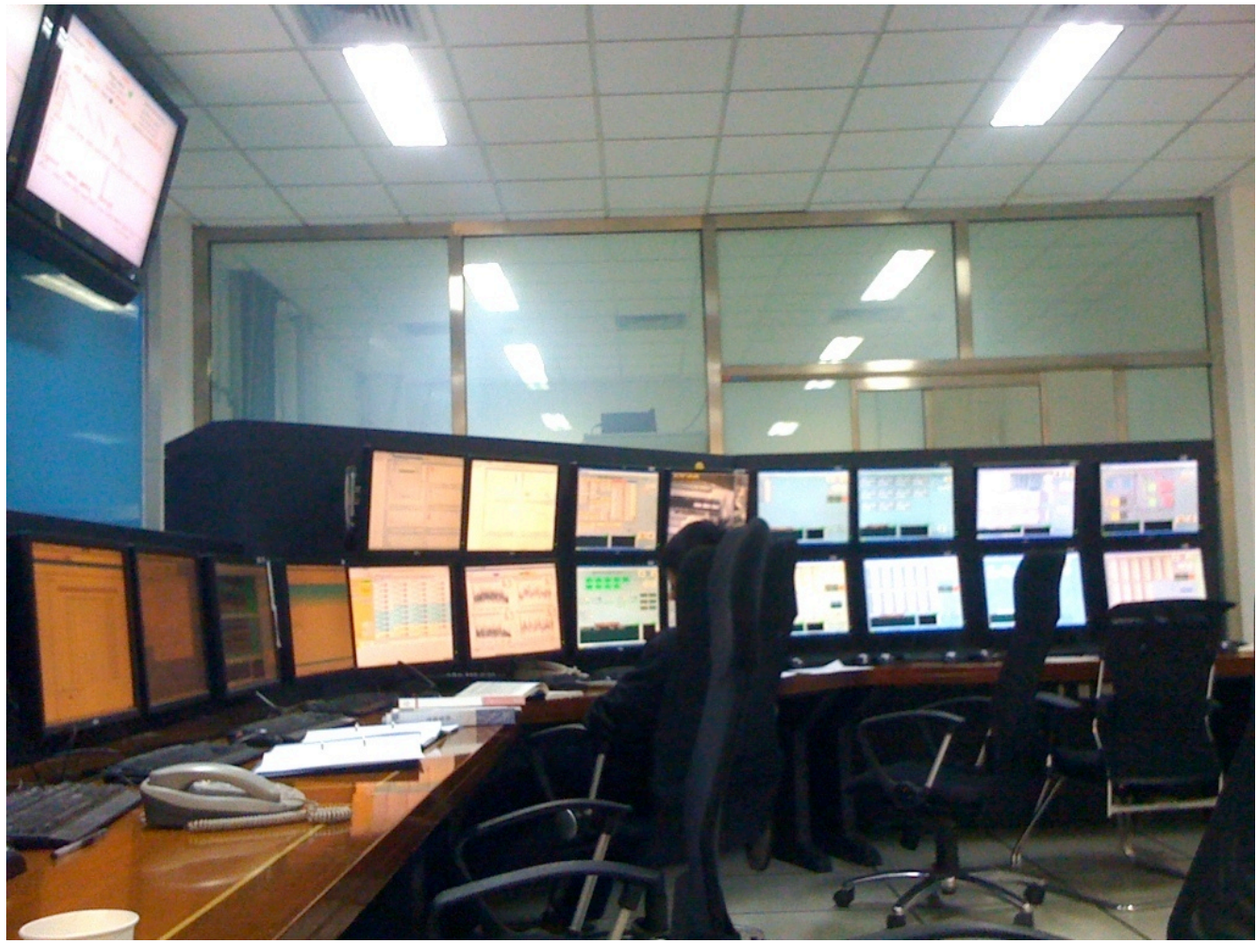

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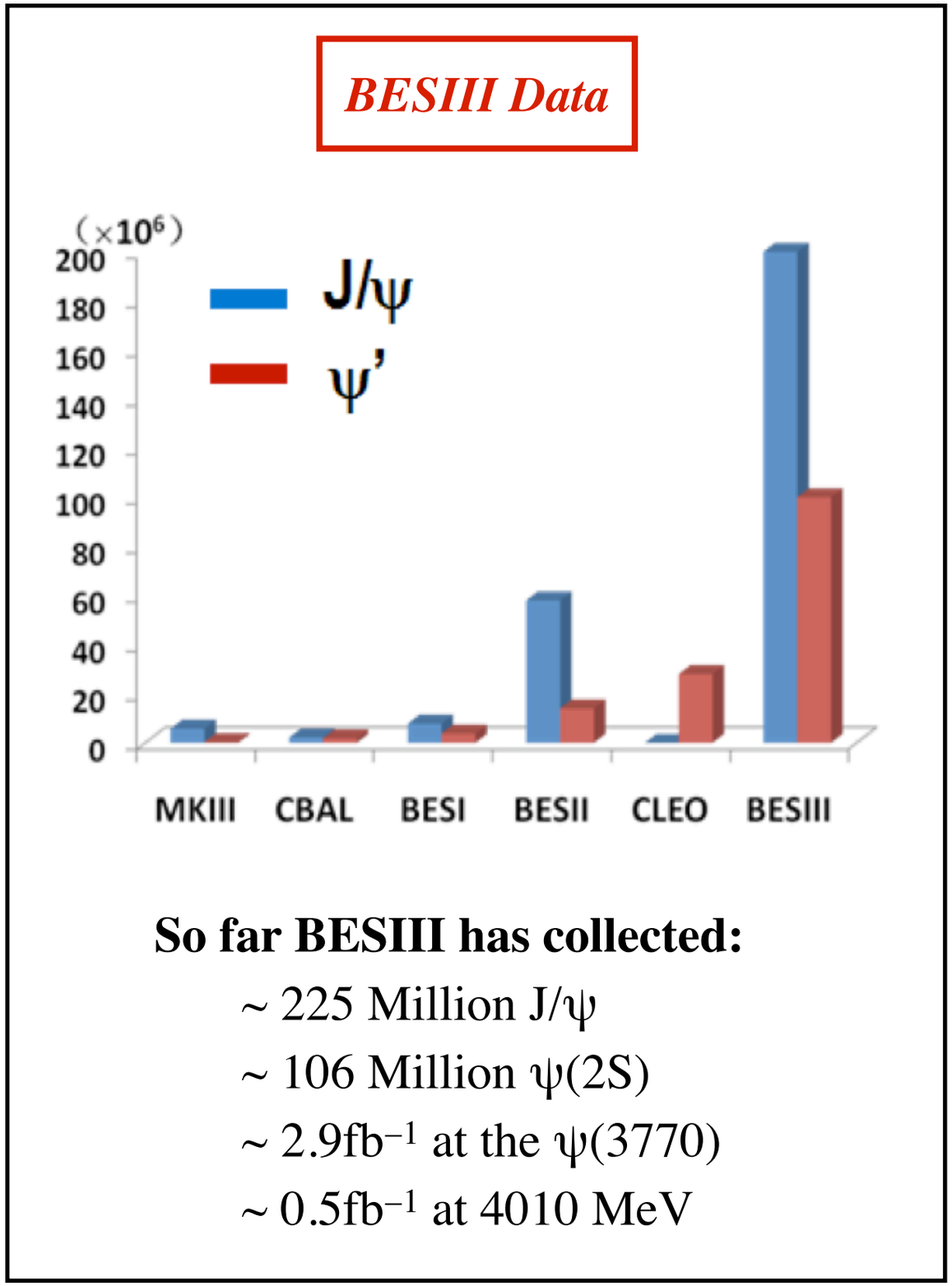

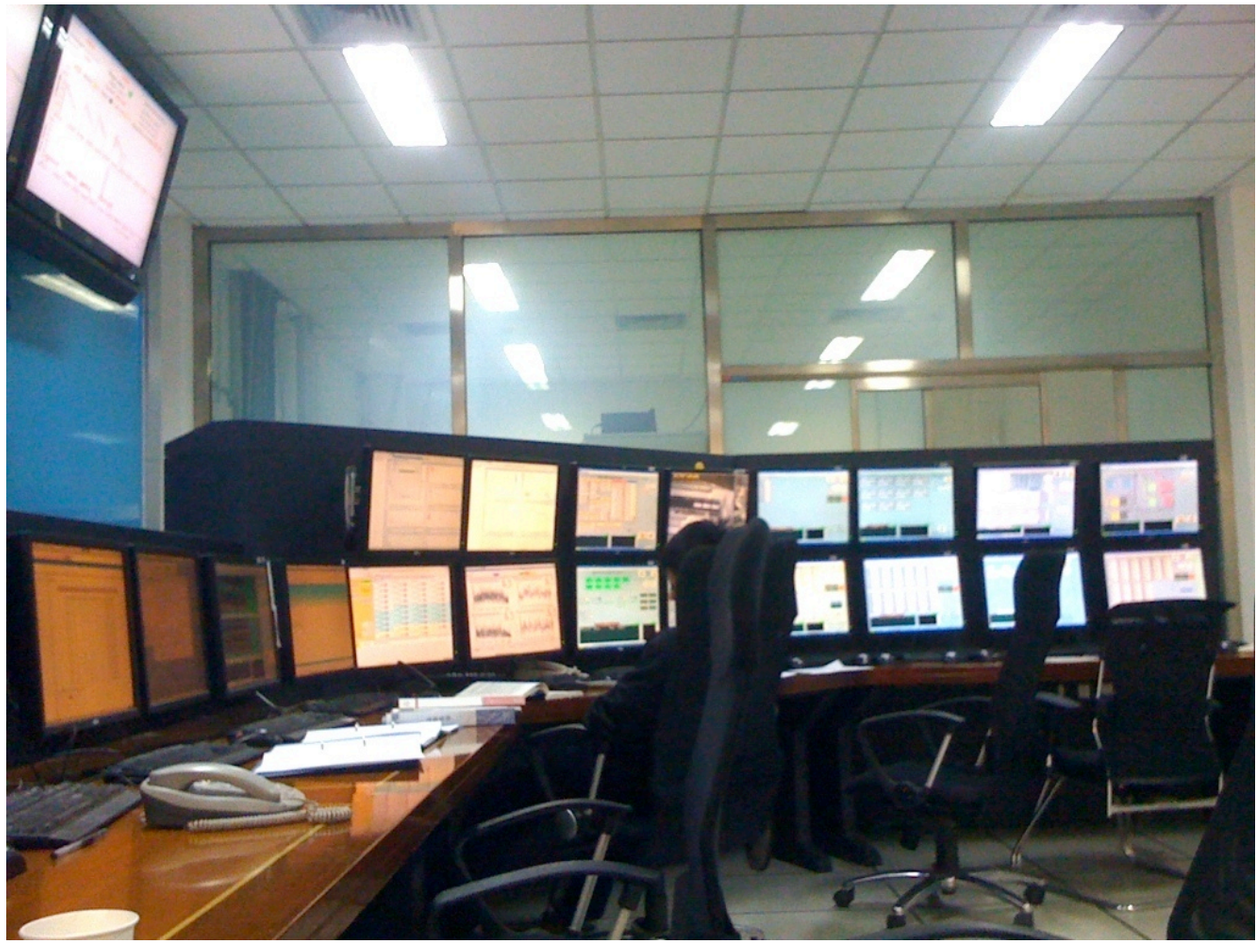

data

BESIII will also collect:

more J/ψ, ψ(2S), ψ(3770)

+ data at higher energies

(for XYZ searches and D_s physics...)

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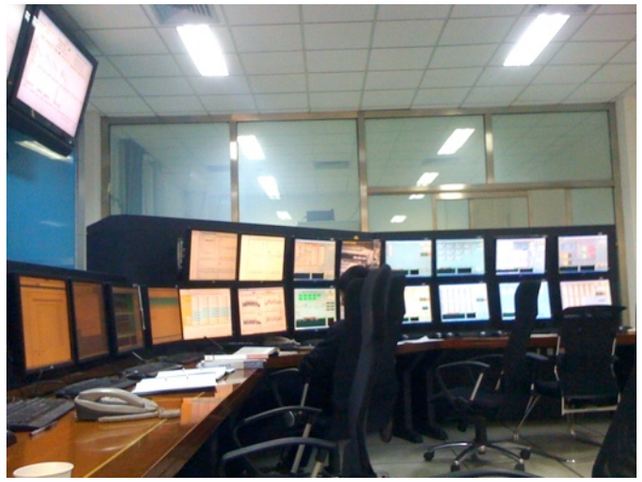

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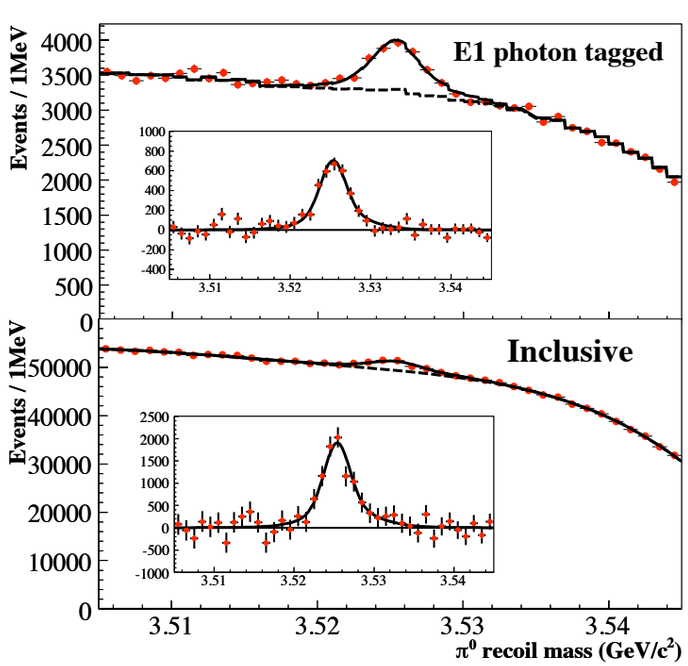

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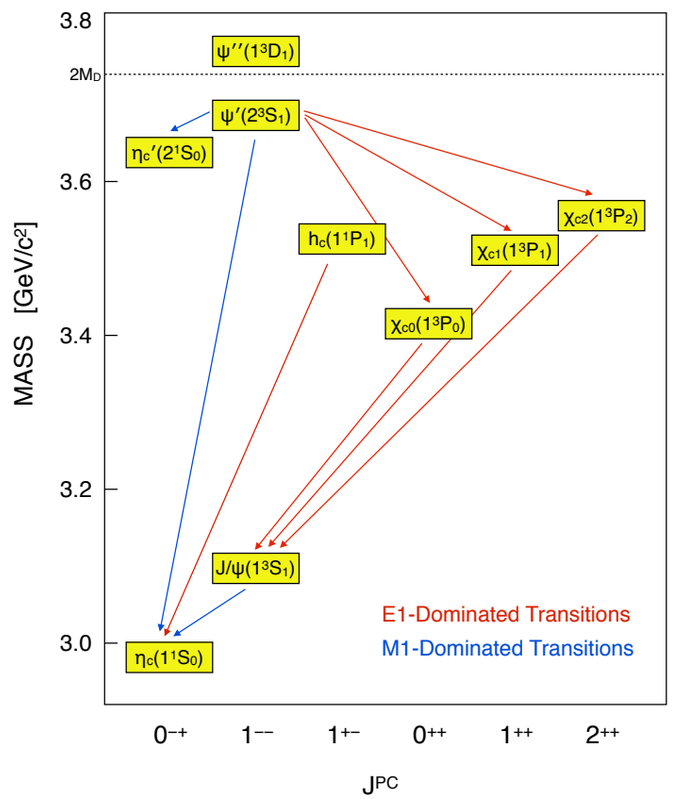

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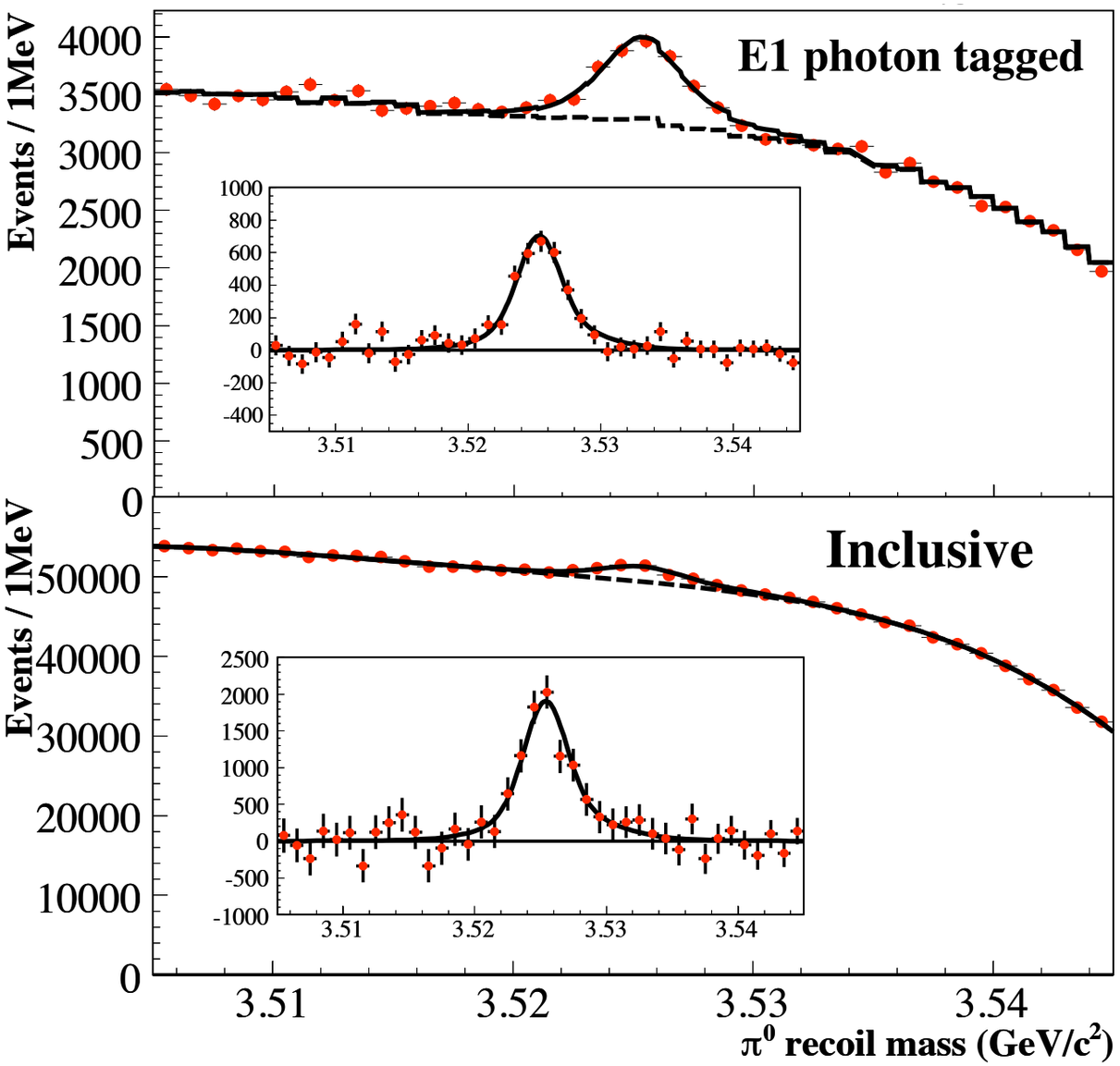

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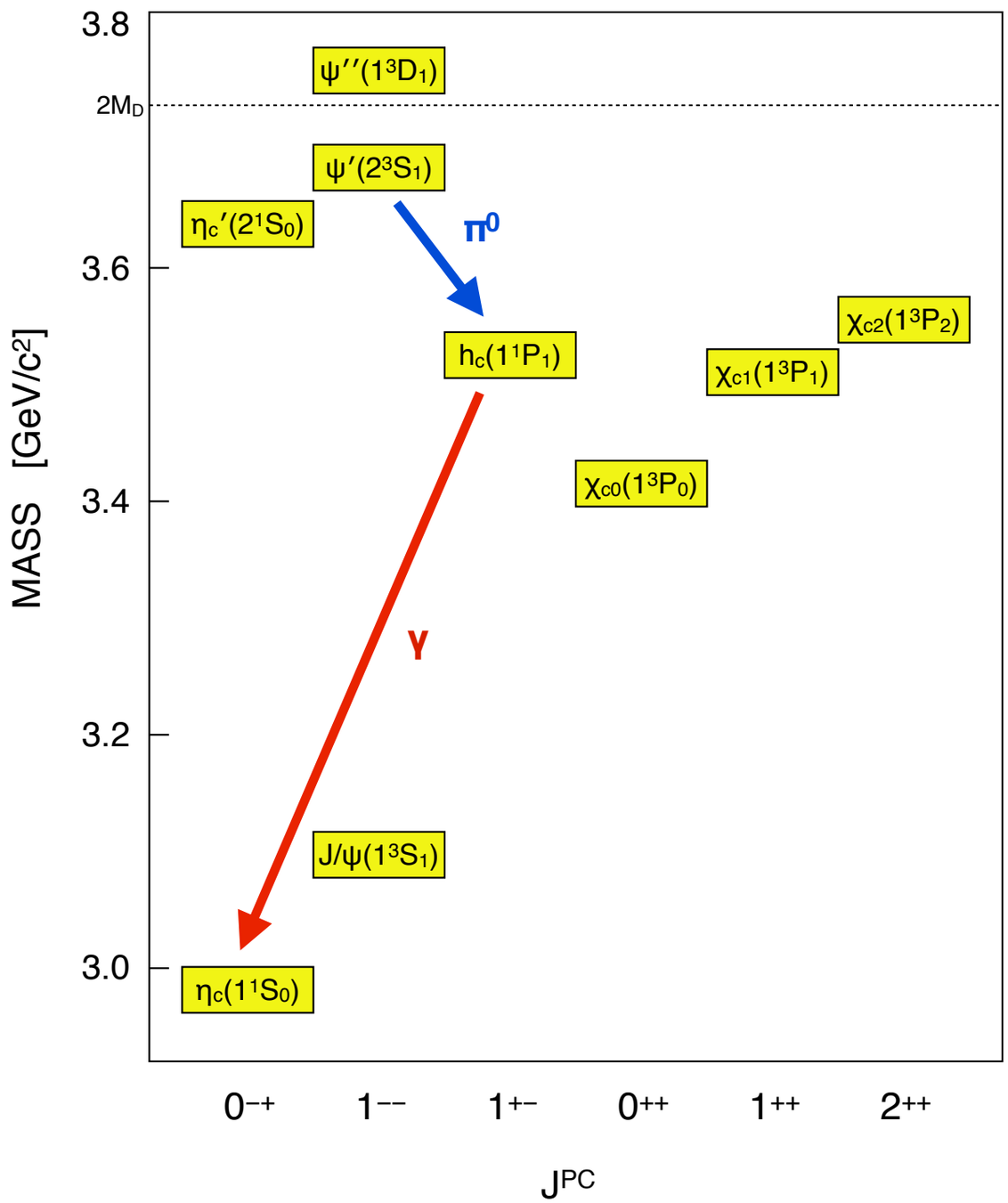
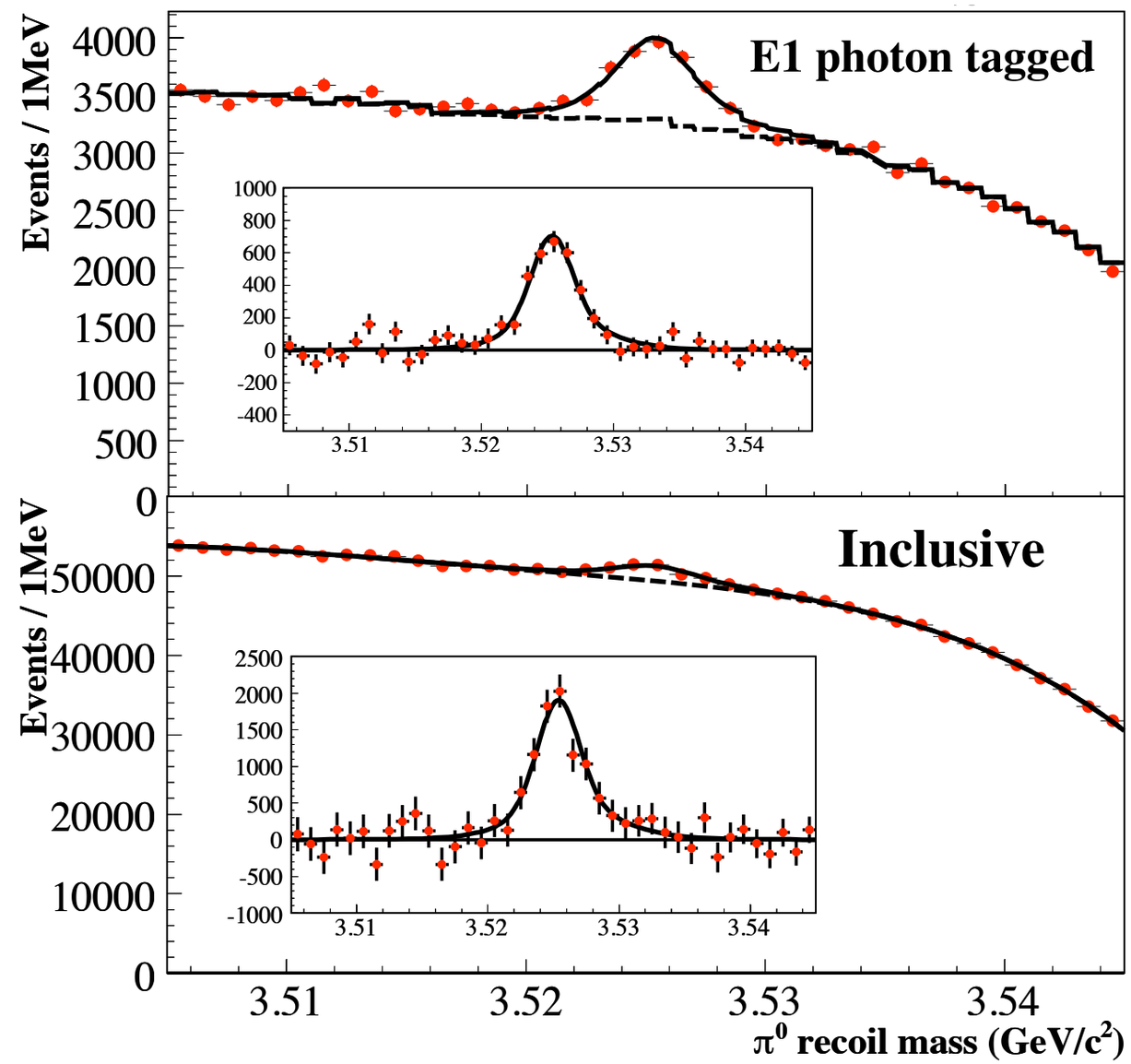


For example:

Properties of the h_c *(PRL 104, 132002 (2010))*



analysis

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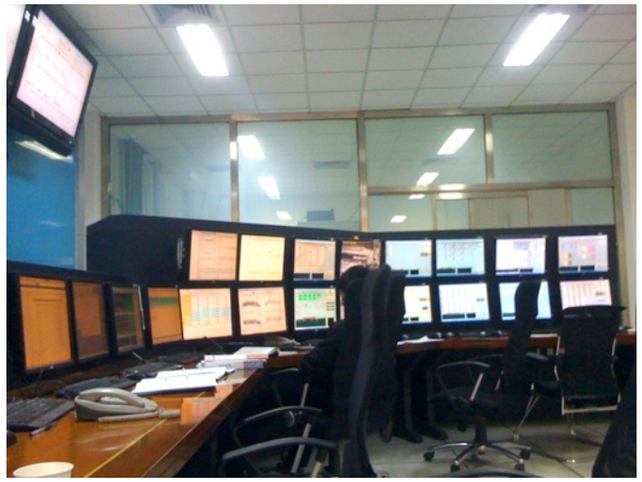

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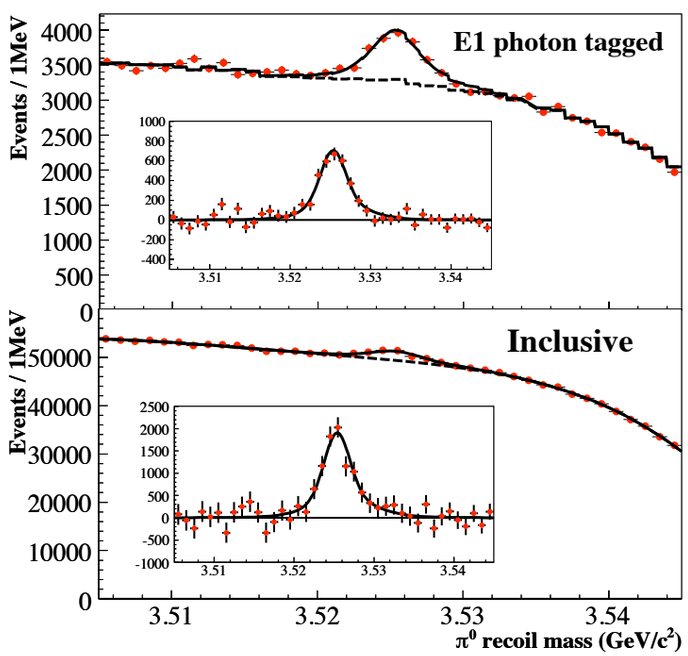

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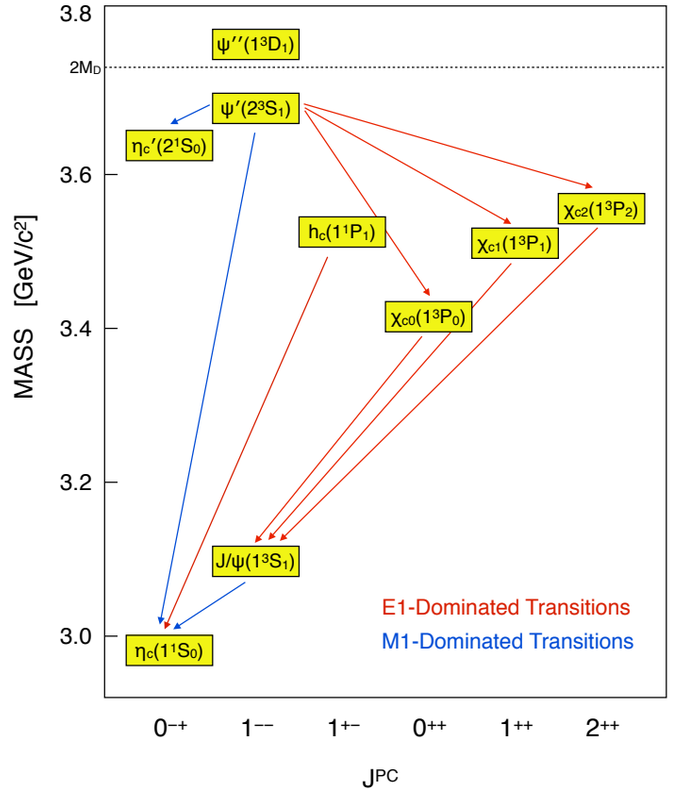

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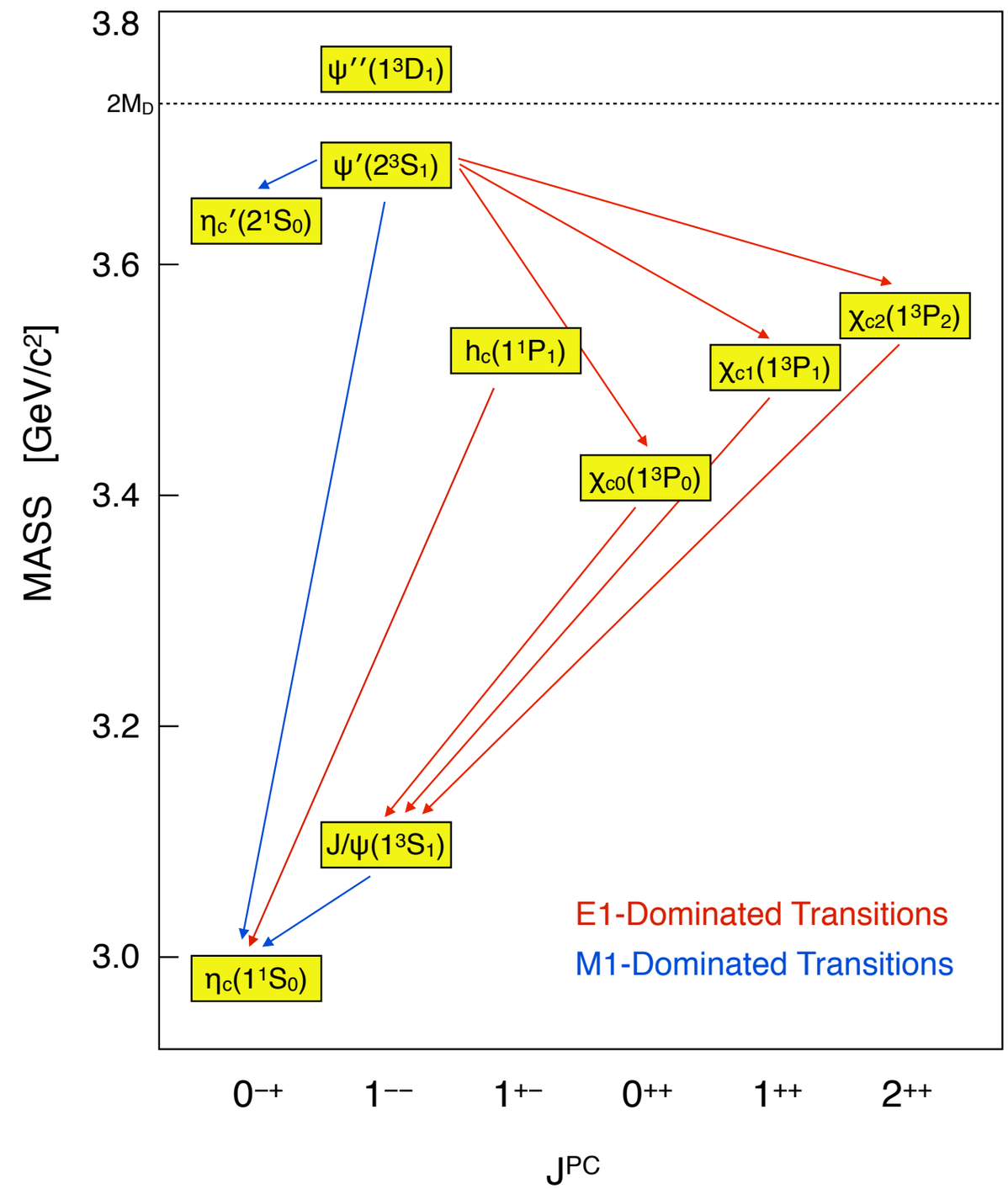

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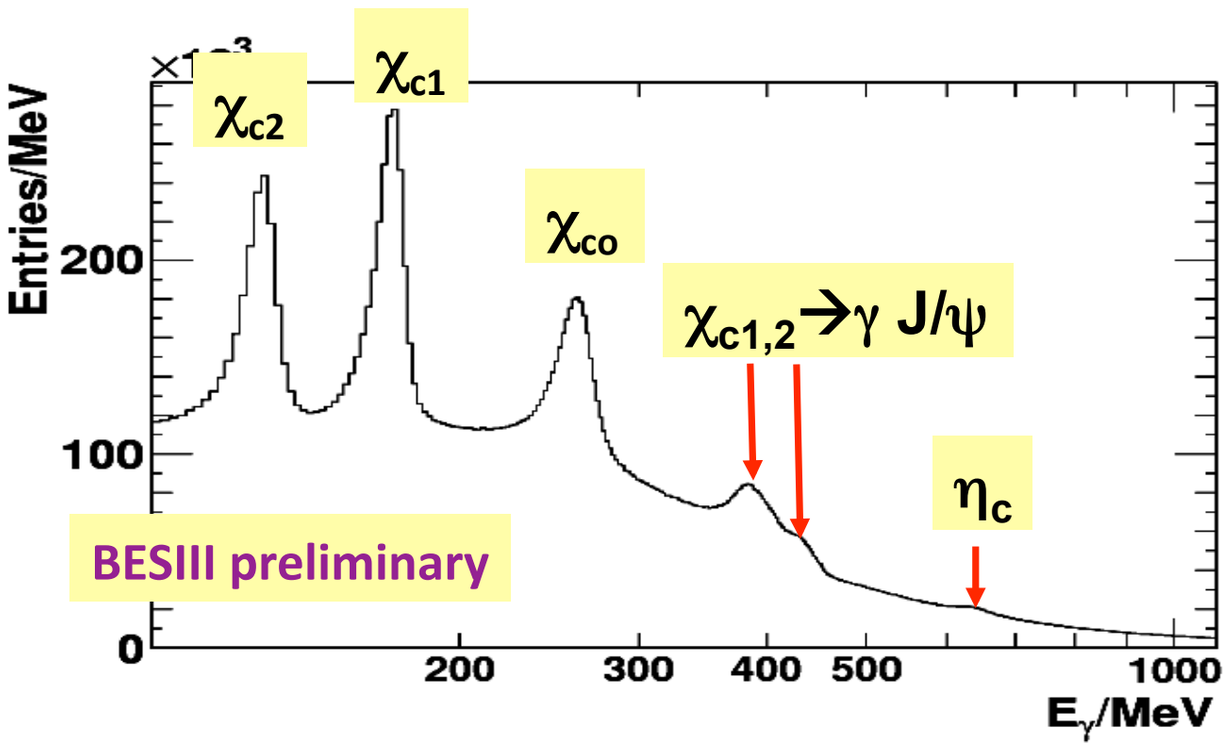
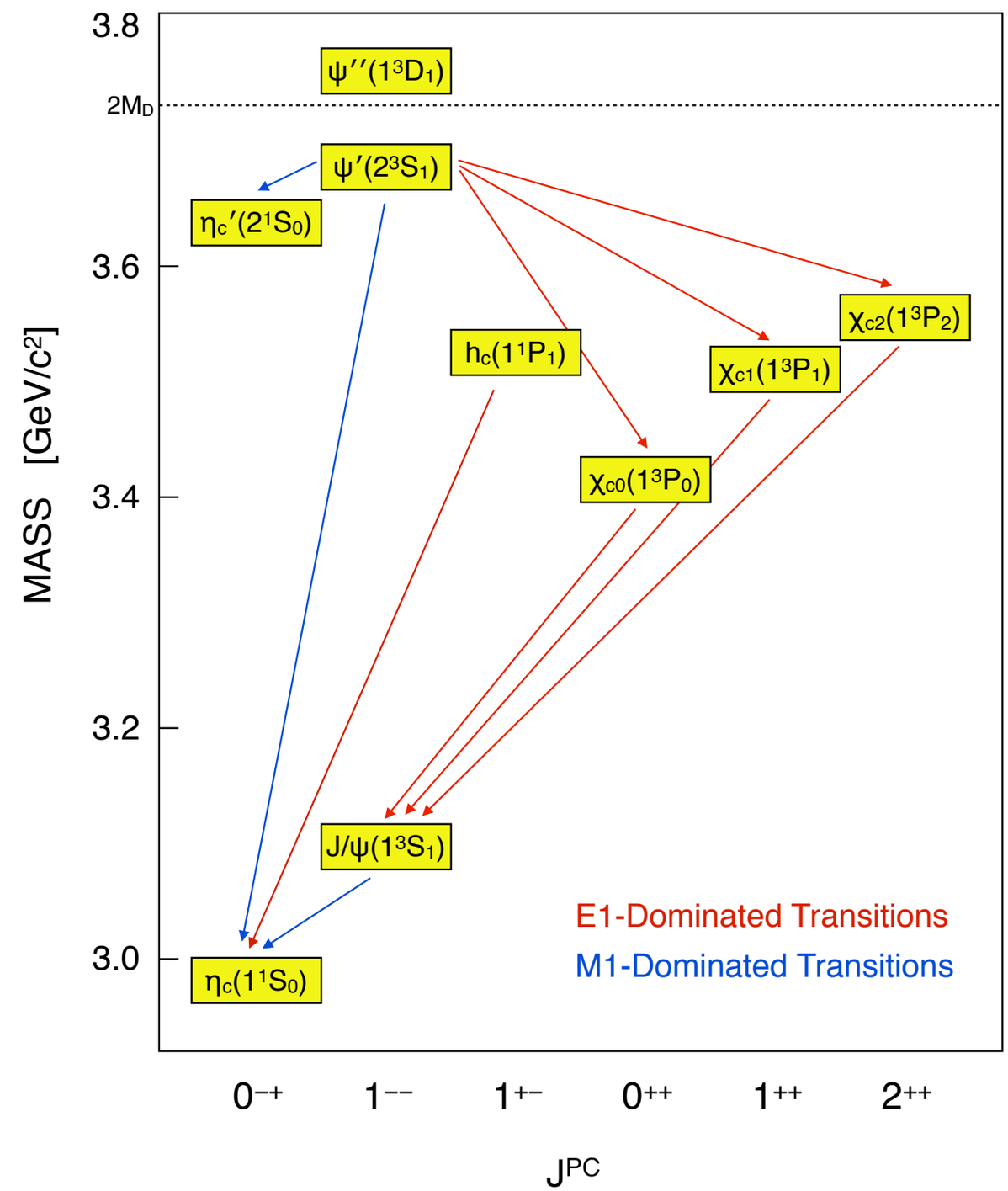


photons from ψ(2S) decays



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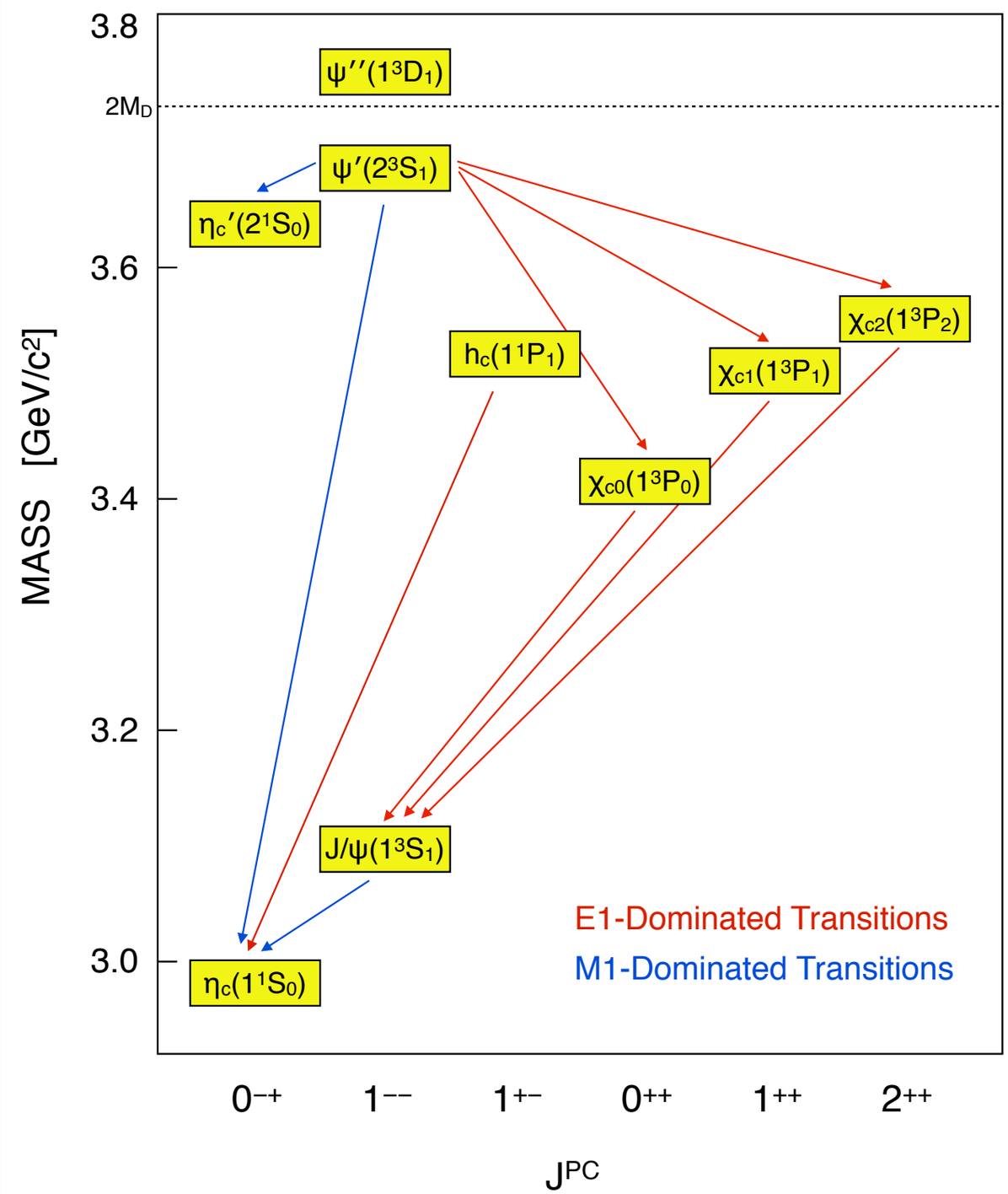
Introduction to the BESIII Experiment

A Selection of Recent Results from BESIII:

- **Light Quark States**
  - X(1860) in $J/\psi \to \gamma(pp)$ *(Chinese Physics C 34, 4 (2010) and NEW: arXiv:1112.0942)*
  - X(1835) in $J/\psi \to \gamma(\eta'\pi^+\pi^-)$ *(PRL 106, 072002 (2011))*
  - X(1870) in $J/\psi \to \omega(\eta\pi^+\pi^-)$ *(PRL 107, 182001 (2011))*
  - $a_0(980) - f_0(980)$ mixing *(PRD 83, 032003 (2011))*
  - $\eta' \to \eta\pi^+\pi^-$ matrix element *(PRD 83, 012003 (2011))*
- **Charmonium Decays**
  - $\psi(2S) \to \gamma\pi^0, \gamma\eta, \gamma\eta'$ *(PRL 105, 261801 (2010))*
  - $\chi_{cJ} \to \pi^0\pi^0, \eta\eta$ *(PRD 81, 052005 (2010))*
  - $\chi_{cJ} \to \gamma\rho, \gamma\omega, \gamma\phi$ *(PRD 83, 112005 (2011))*
  - $\chi_{cJ} \to 4\pi^0$ *(PRD 83, 012006 (2011))*
- **Charmonium Spectroscopy and Transitions**
  - Mass and width of the η_c *(arXiv:1111.0398)*
  - Properties of the h_c *(PRL 104, 132002 (2010))*
  - Multipoles in $\psi(2S) \to \gamma\chi_{c2}$ *(arXiv:1110.1742)*
- **Open Charm**
  - results very soon
- **Charmonium Above Open Charm Threshold**
  - results a little later



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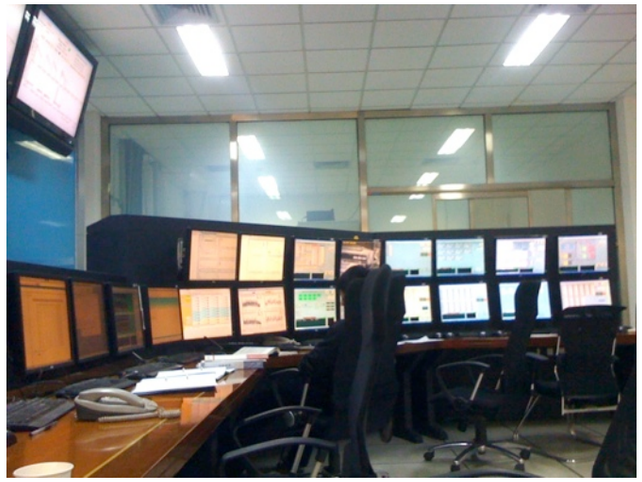
Introduction to the BESIII Experiment

accelerator

detector



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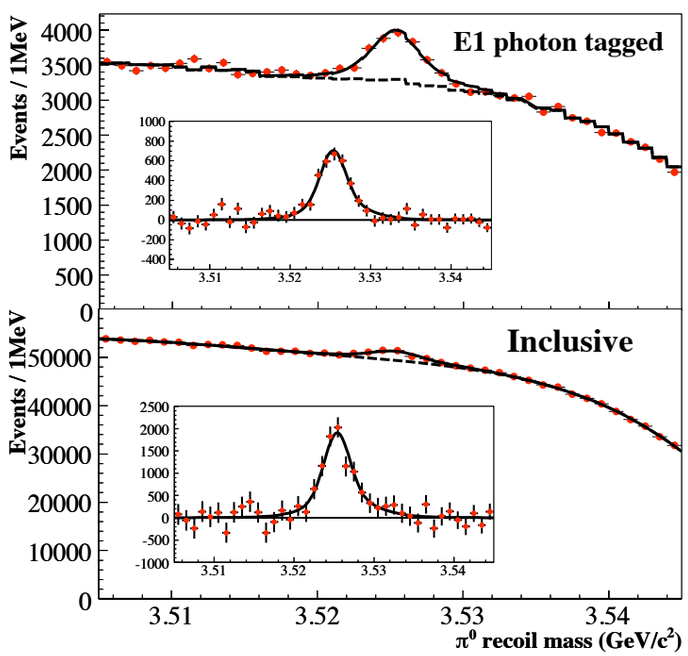
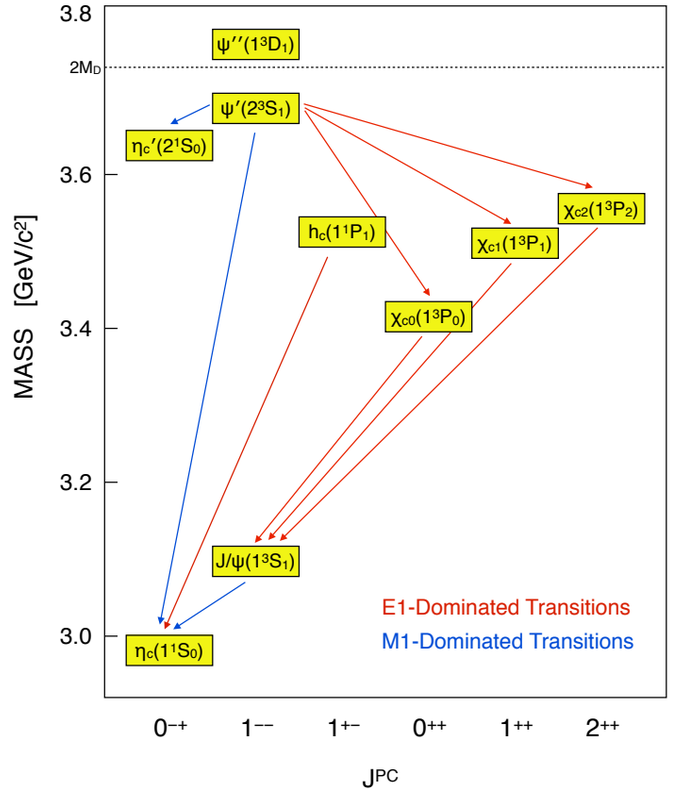


analysis



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phenomenology and theory

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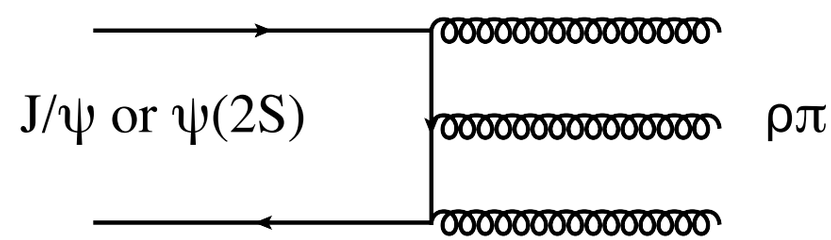
phenomenology and theory

Introduction to the BESIII Experiment

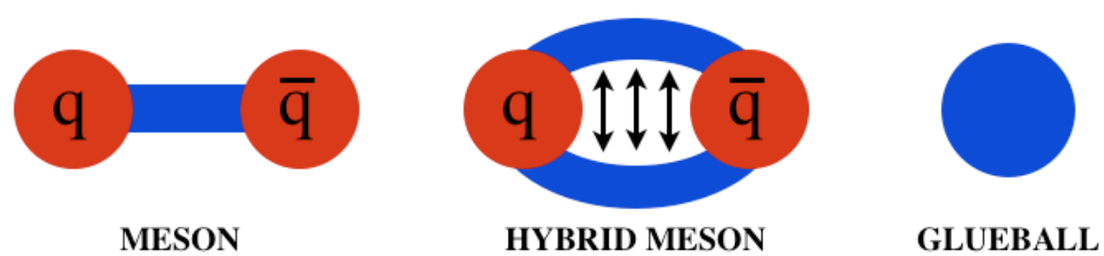
- **Quantitative Comparisons with Lattice QCD**
  - *e.g.:*
    - charmonium masses
    - radiative transitions
    - open charm decay constants

- **Decay Dynamics**
  - *e.g.:*
    - the "ϱπ puzzle"

$$\frac{B(\psi(2S) \to \rho\pi)}{B(J/\psi \to \rho\pi)} << 12\%$$



- **The Structure of Mesons**
  - *e.g.:*
    - gluonic excitations?



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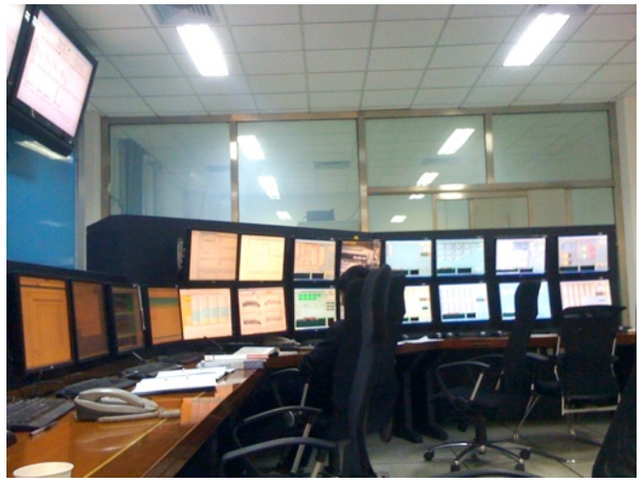

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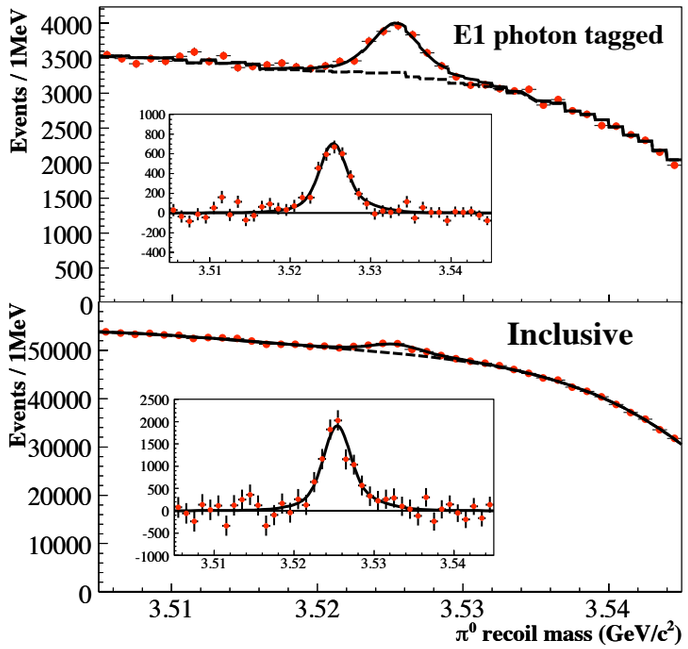

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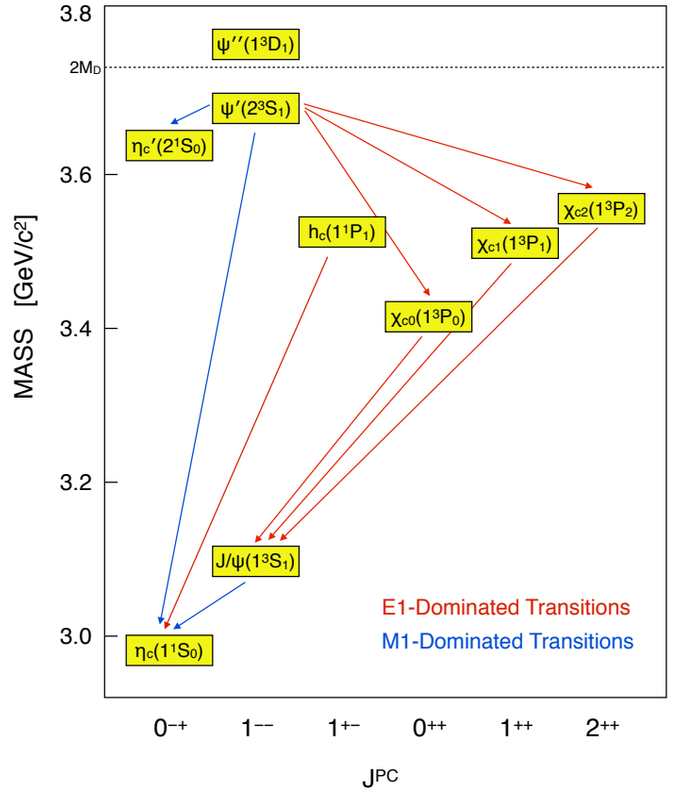

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QCD

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A Few Highlights from the BESIII Experiment

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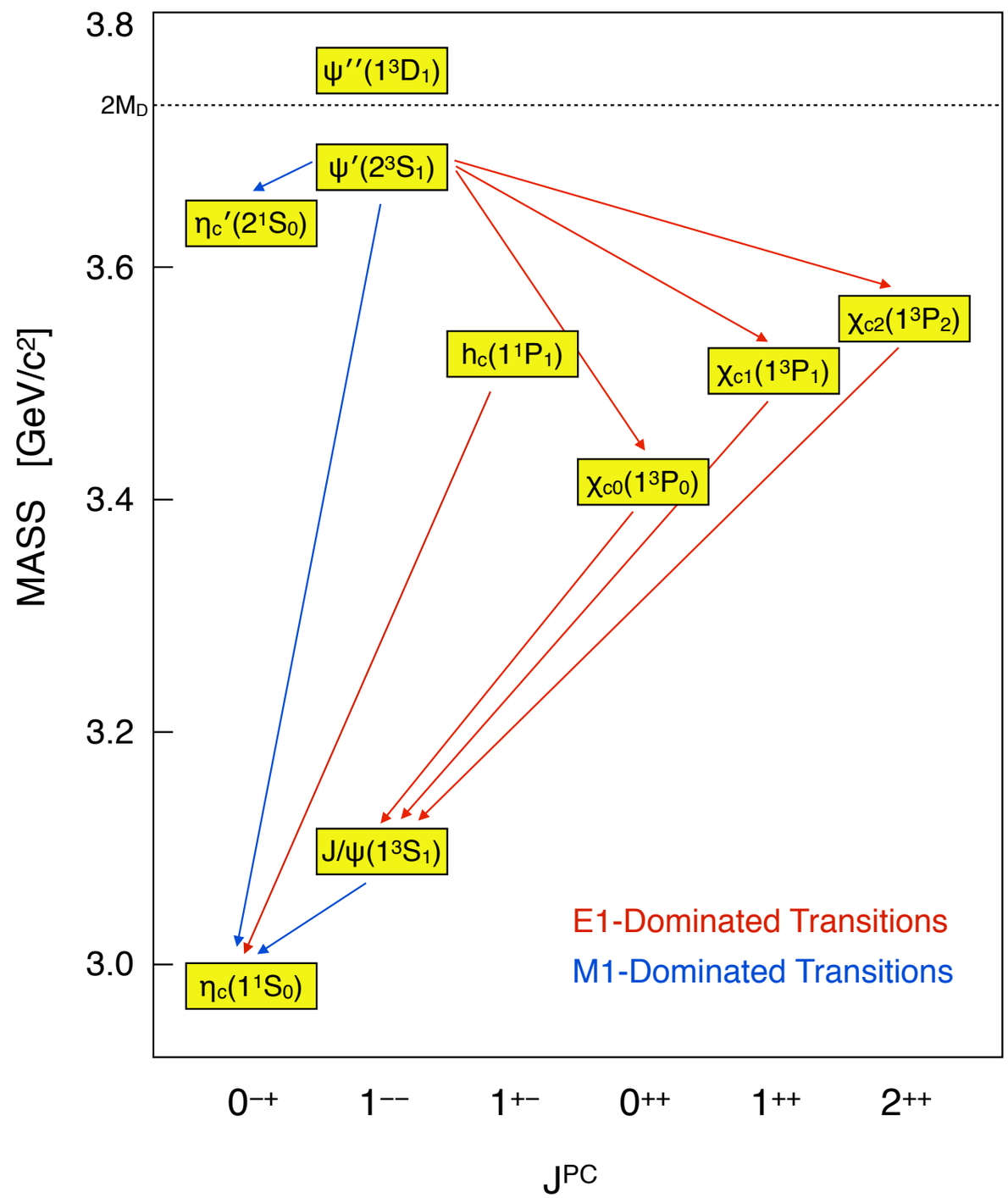

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Study of Light Quark States

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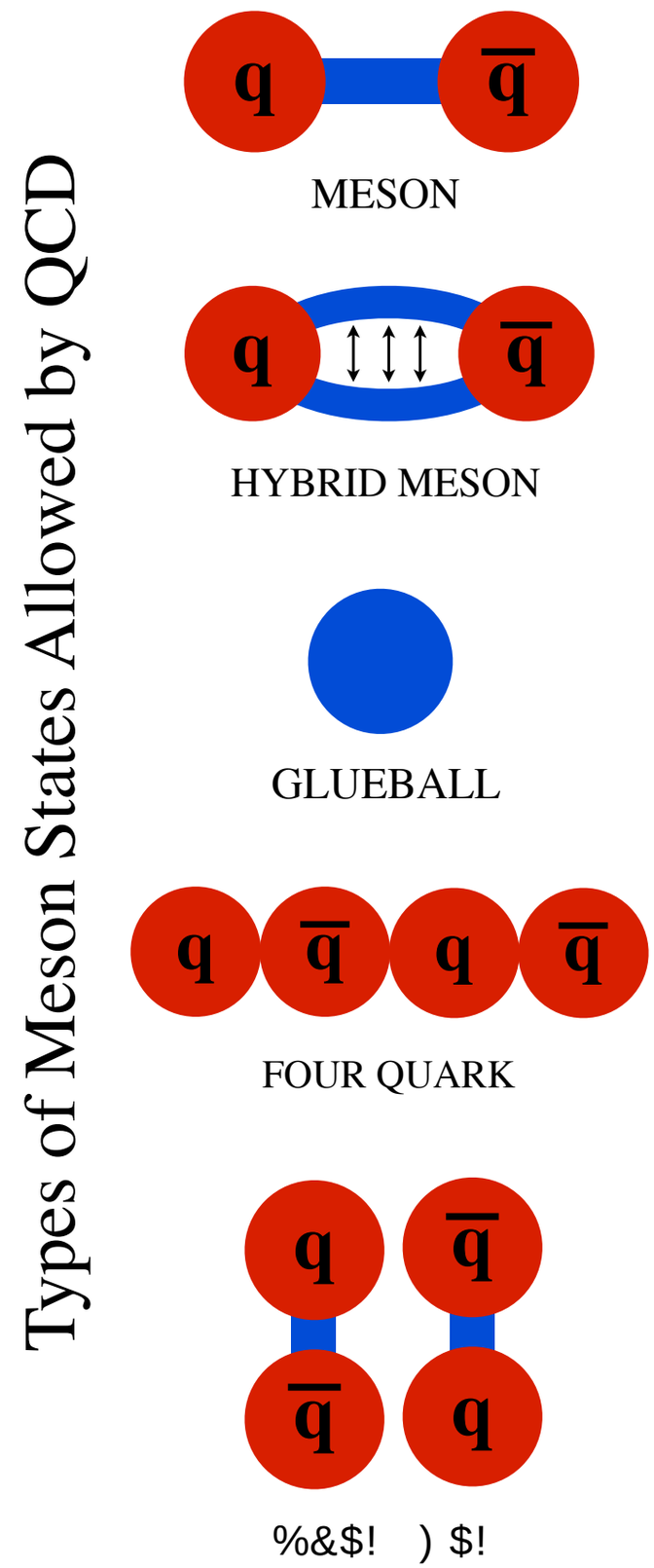


The "X(1860)" in $J/\psi \to \gamma(p\bar{p})$ at BESIII

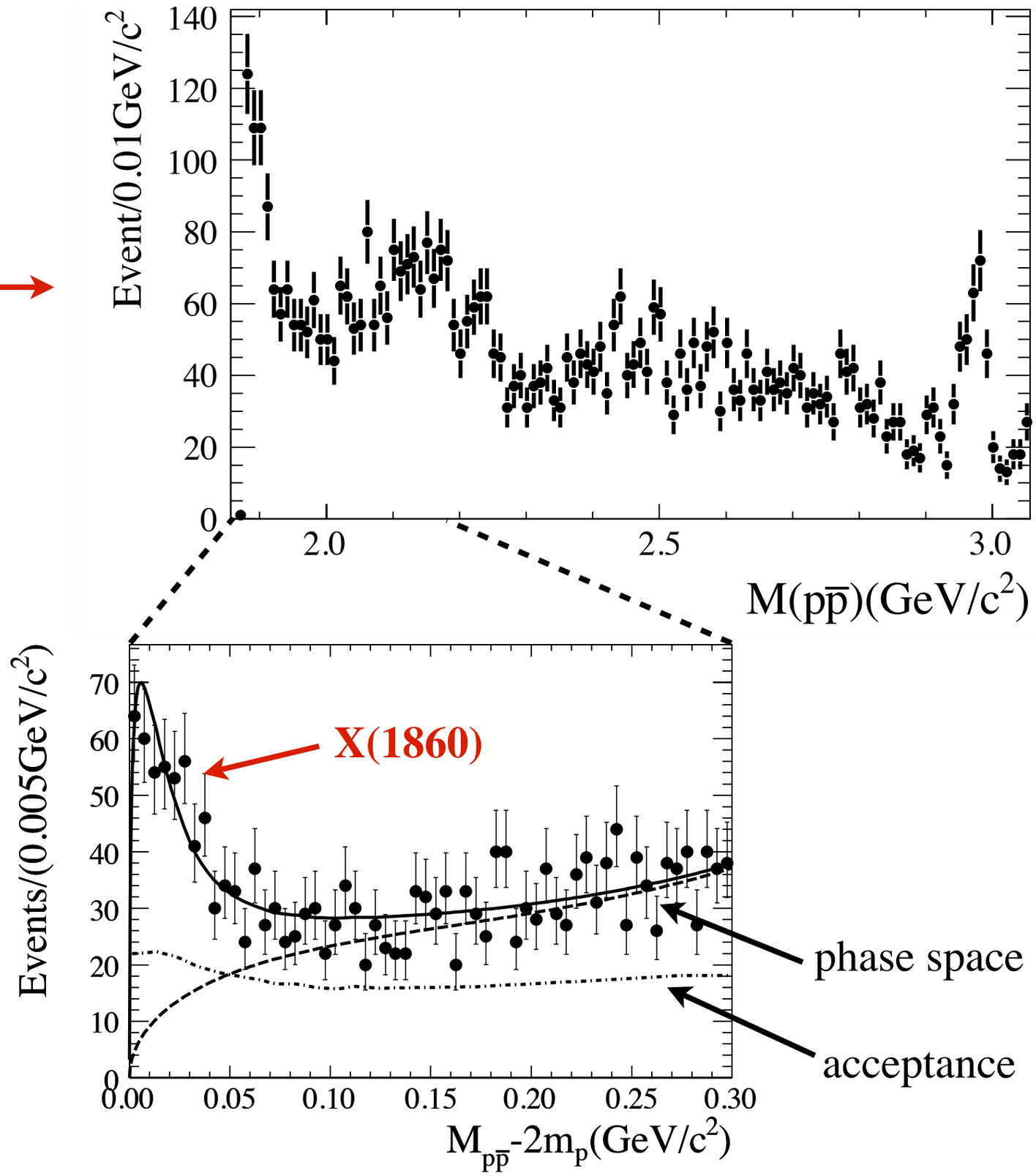
- First observed by BESII

- **Now confirmed by BESIII in**
  $\psi(2S) \to \pi^+\pi^- J/\psi$
  $J/\psi \to \gamma p\bar{p}$
  using 106 million $\psi(2S)$ decays

- Also recently confirmed by CLEO-c (with lower statistics) in the same reaction

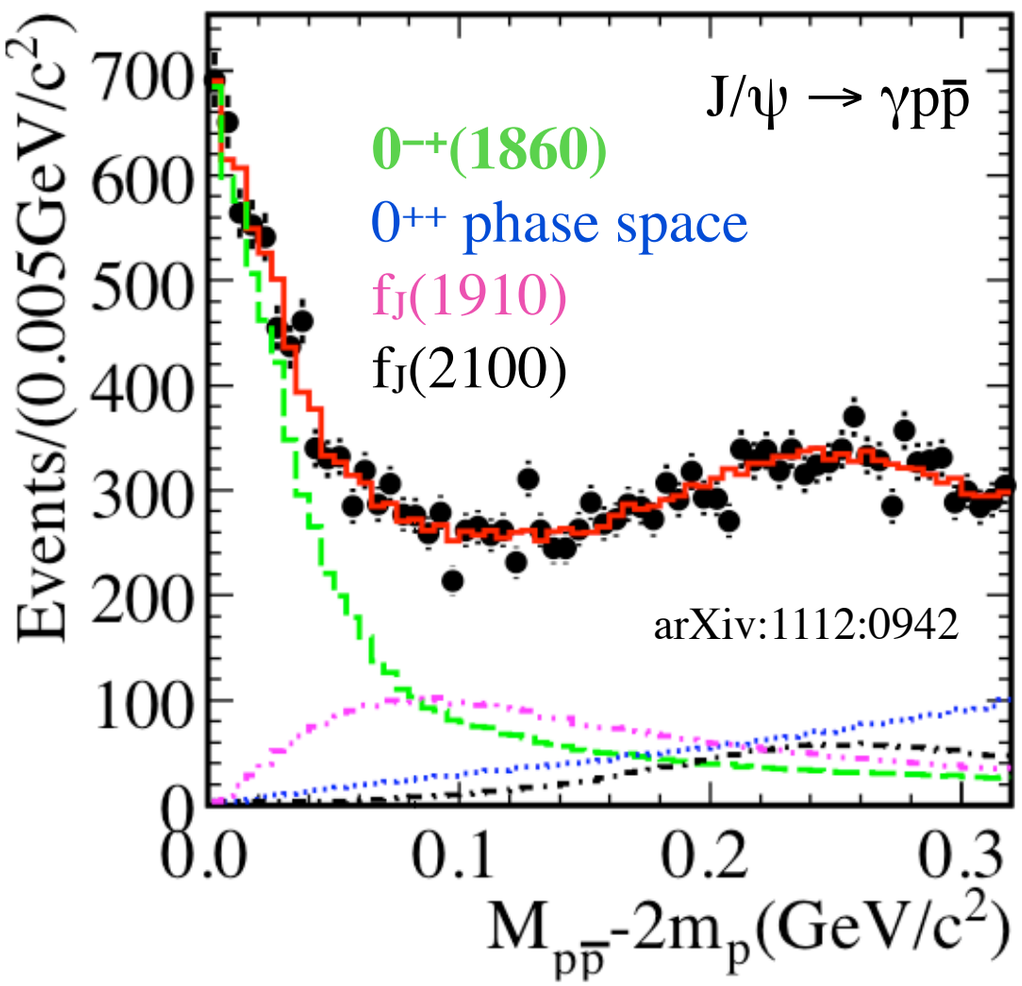
- No clear evidence in:
  - *$\psi(2S) \to \gamma p\bar{p}$ (BESII)*
  - $J/\psi \to \omega p\bar{p}$ (BESII)
  - $J/\psi \to \pi^0 p\bar{p}$ (BESIII)
  - $\Upsilon(1S) \to \gamma p\bar{p}$ (CLEO III)
  - etc.

- **Possibly baryonium?**

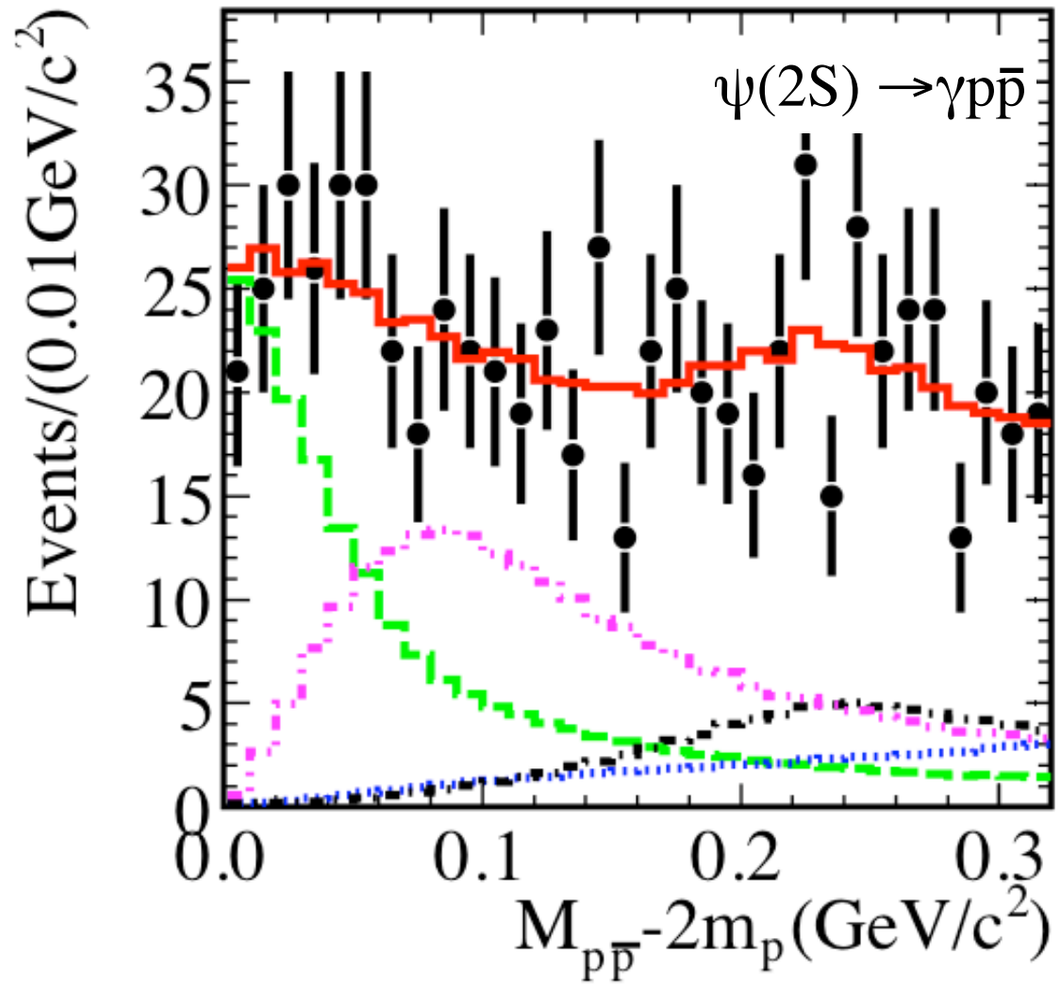


J^{PC} of the "X(1860)" *(NEW)*

perform amplitude analyses using decay angular distributions…



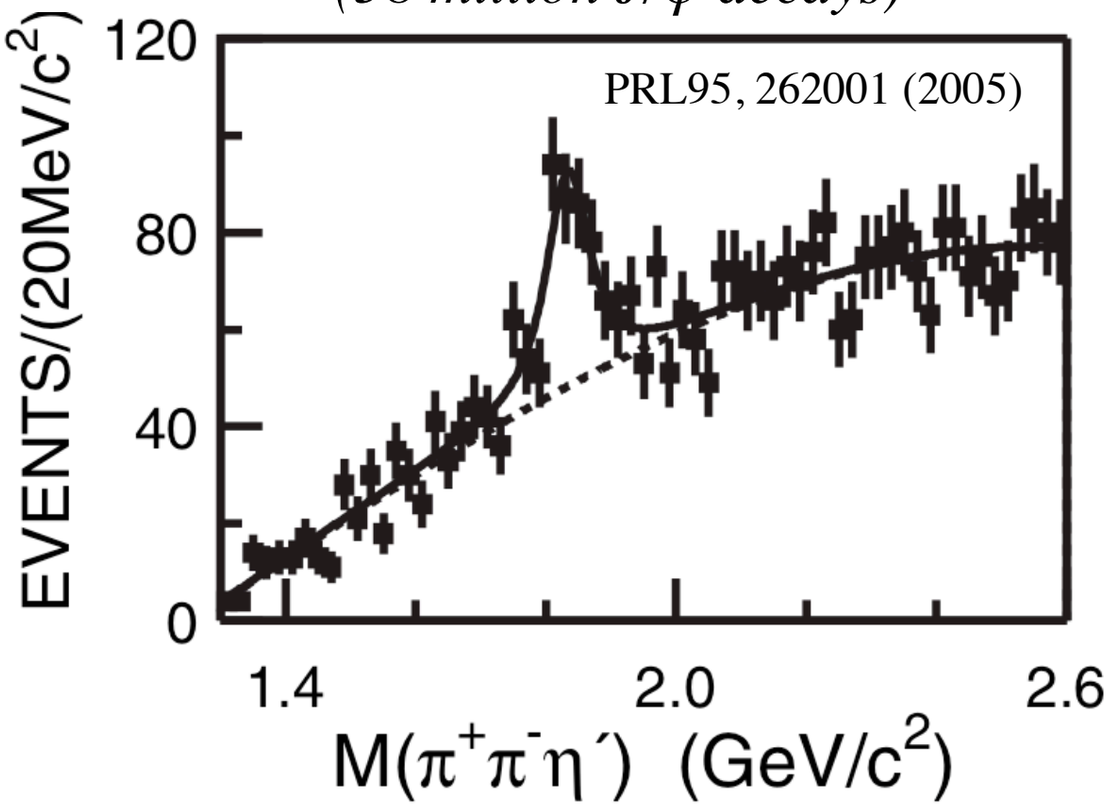
"X(1860)" has **J^{PC} = 0^{-+}**



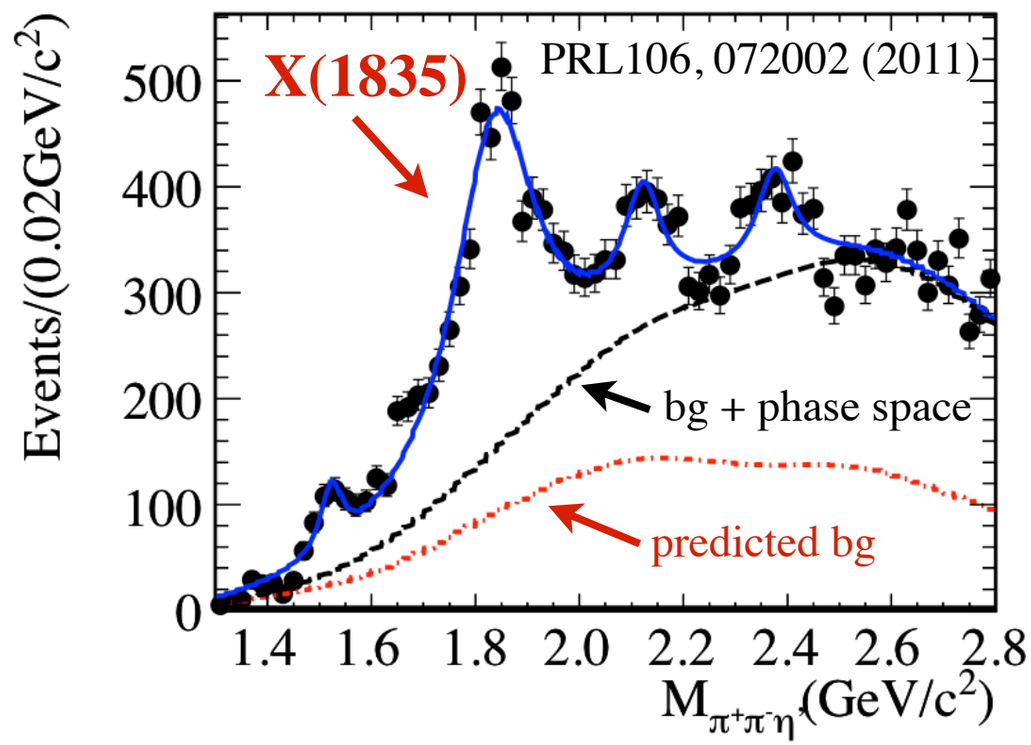
"X(1860)" is now seen in ψ(2S) decays
(~5% of J/ψ decays)

The "X(1835)" in $J/\psi \to \gamma(\eta'\pi^+\pi^-)$ at BESIII

First observed by BESII:
(58 million J/ψ decays)



Confirmed by BESIII:
(225 million J/ψ decays)



But with surprises:

Rich Substructure!

(an amplitude analysis could help with interpretation)

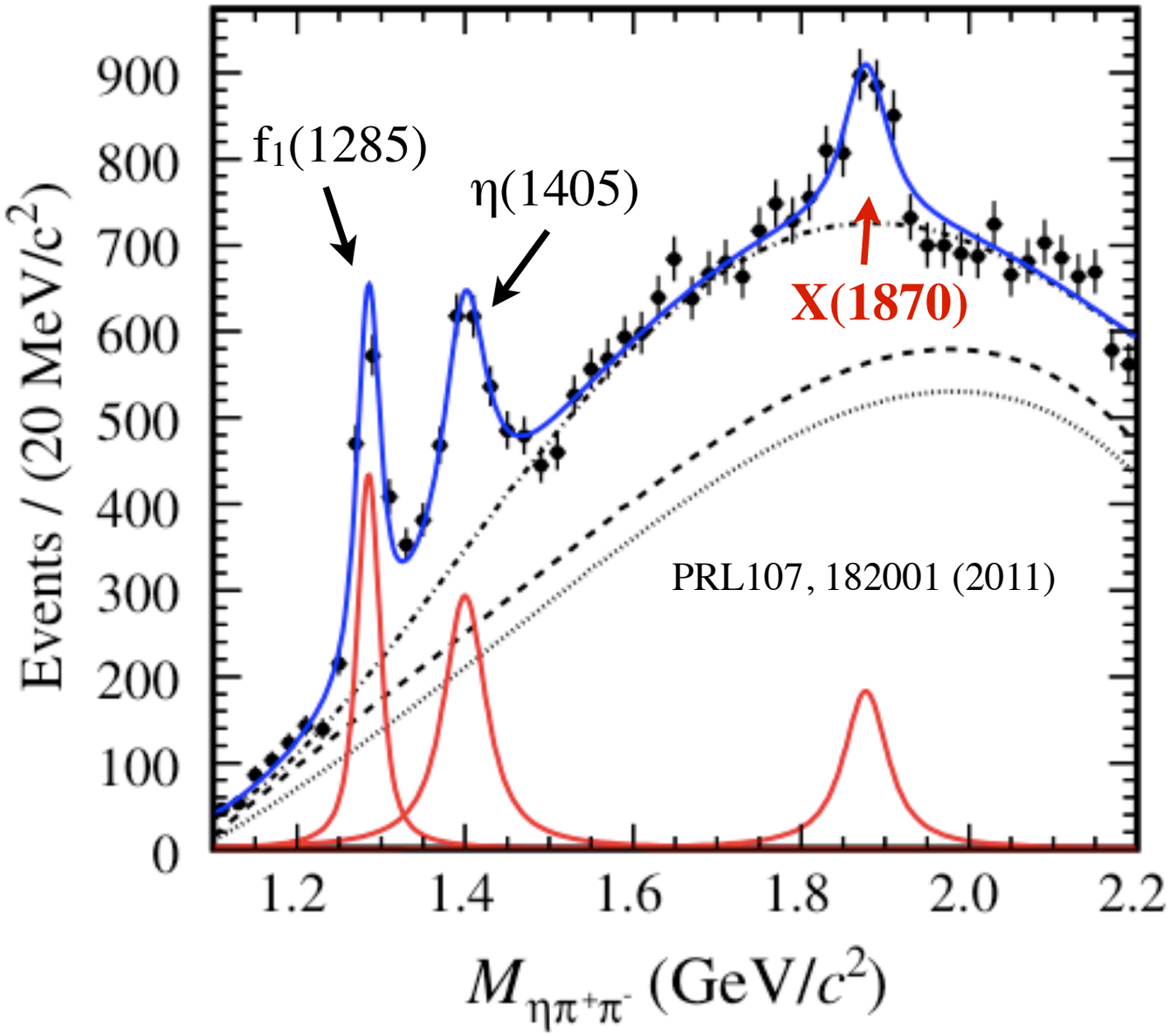
resonance	$M(\text{ MeV}/c^2)$	$\Gamma(\text{ MeV}/c^2)$	N_{event}
$f_1(1510)$	1522.7 ± 5.0	48 ± 11	230 ± 37
$X(1835)$	1836.5 ± 3.0	190.1 ± 9.0	4265 ± 131
$X(2120)$	2122.4 ± 6.7	84 ± 16	647 ± 103
$X(2370)$	2376.3 ± 8.7	83 ± 17	565 ± 105

The "X(1870)" in $J/\psi \to \omega(\eta\pi^+\pi^-)$ at BESIII

- One more surprise...
- Look at $M(\eta\pi^+\pi^-)$ from

  $J/\psi \to \omega(\eta\pi^+\pi^-)$

  after selecting $a_0^\pm \to \eta\pi^\pm$
- A new signal appears at a mass of **1870 MeV/c²** with a width of **~80 MeV/c²**!



⇒ ***In general, amplitude analyses will be needed to learn more about these new states... and then we need a global comparison between experiment and theory...***

Study of Charmonium Decays

A Selection of Recent Results from BESIII:

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  - $\chi_{cJ} \to \gamma\varrho, \gamma\omega, \gamma\phi$ *(PRD 83, 112005 (2011))*
  - $\chi_{cJ} \to 4\pi^0$ *(PRD 83, 012006 (2011))*
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  - results very soon
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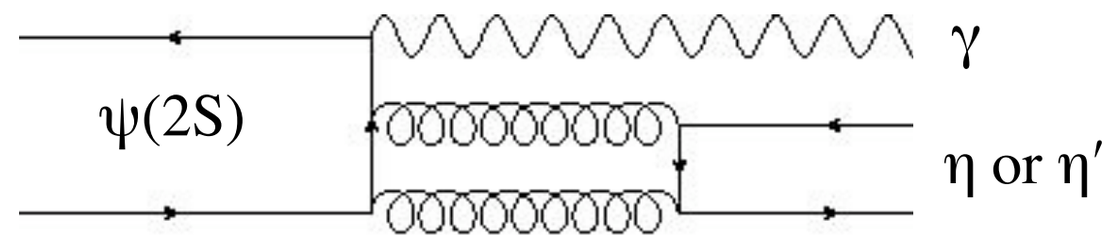
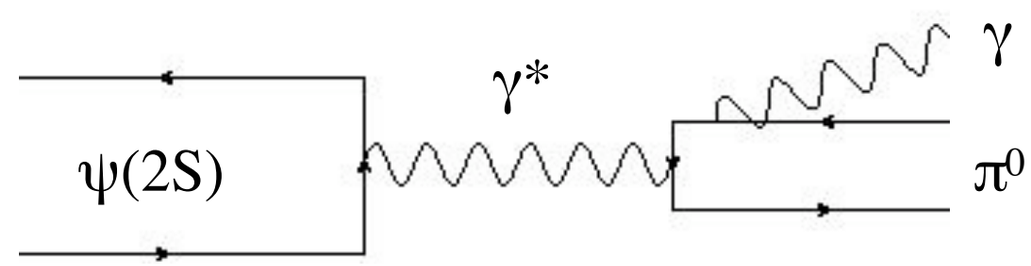
  - results a little later

$\psi(2S) \to \gamma\eta^{(\prime)}$



⇒ ideally, study the η–η' mixing angle, but $\psi(2S) \to \gamma\eta$ is anomalously suppressed...

$\psi(2S) \to \gamma\pi^0$



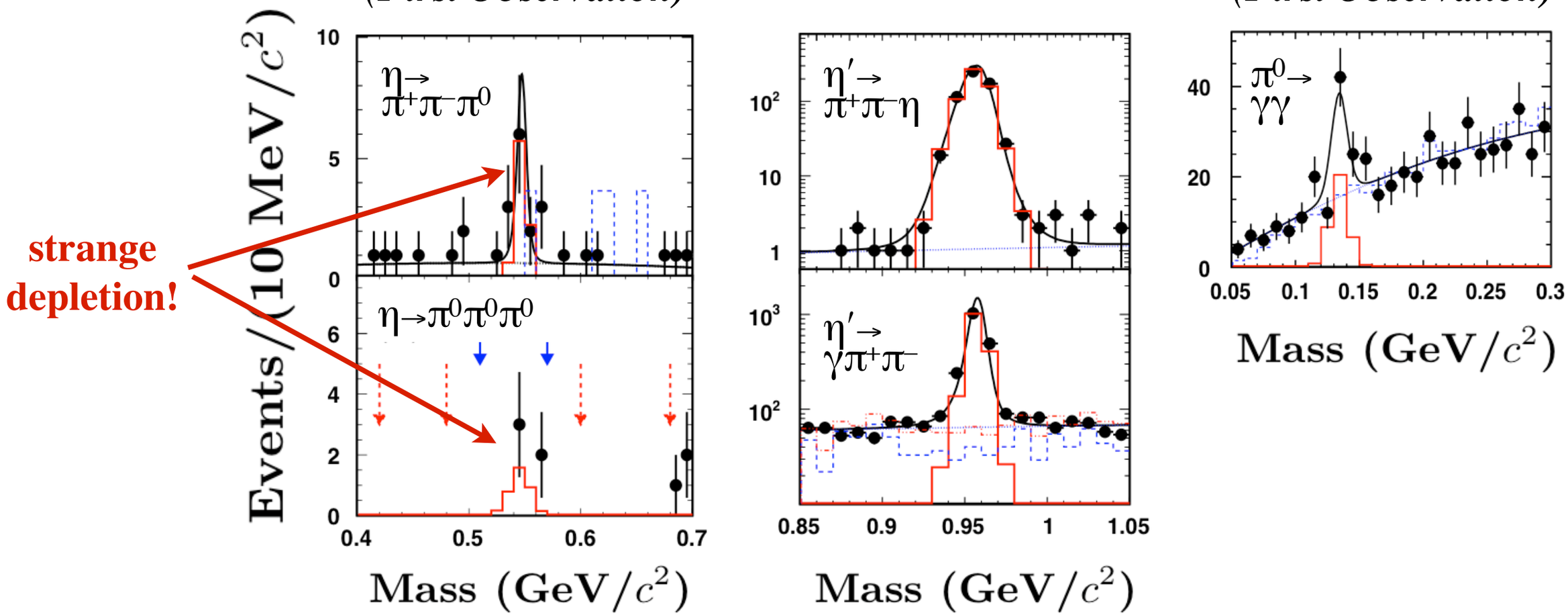
⇒ possibly study the $\gamma^* - \gamma - \pi^0$ form factor for timelike γ^*

Analysis of $\psi(2S) \to \gamma(\pi^0,\eta,\eta')$ at BESIII

$\psi(2S) \to \gamma\eta$
(First Observation)

$\psi(2S) \to \gamma\eta'$

$\psi(2S) \to \gamma\pi^0$
(First Observation)



Mode	BESIII	Combined BESIII	PDG
$\psi' \to \gamma\pi^0$	$1.58 \pm 0.40 \pm 0.13$	$1.58 \pm 0.40 \pm 0.13$	≤ 5
$\psi' \to \gamma\eta(\pi^+\pi^-\pi^0)$	$1.78 \pm 0.72 \pm 0.17$	$1.38 \pm 0.48 \pm 0.09$	≤ 2
$\to \gamma\eta(\pi^0\pi^0\pi^0)$	$1.07 \pm 0.65 \pm 0.08$		
$\psi' \to \gamma\eta'(\pi^+\pi^-\eta)$	$120 \pm 5 \pm 8$	$126 \pm 3 \pm 8$	121 ± 8
$\to \gamma\eta'(\pi^+\pi^-\gamma)$	$129 \pm 3 \pm 8$		

(Branching fractions in units of 10^{-6})

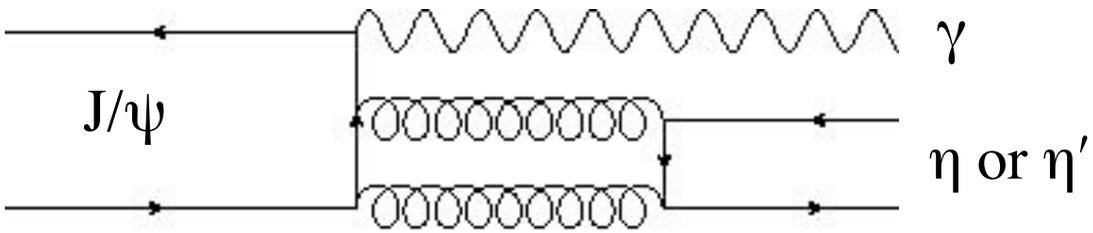
The Suppression of $\psi(2S) \to \gamma\eta$?

- **For J/ψ,**

$$\frac{B(J/\psi \to \gamma\eta)}{B(J/\psi \to \gamma\eta')} = \mathbf{(21.1 \pm 0.9)\ \%}$$

consistent with other measurements of the η–η' mixing angle.

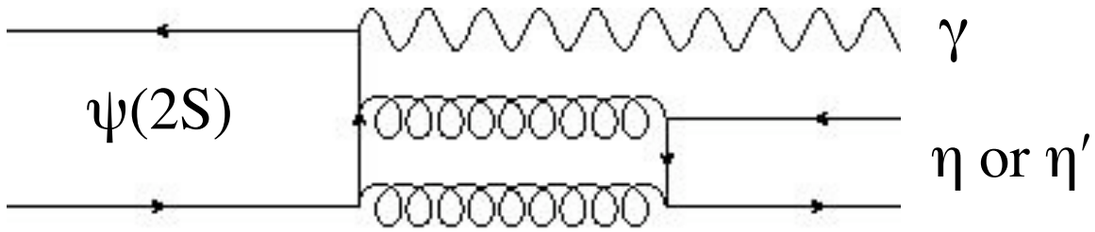
$J/\psi \to \gamma\eta^{(\prime)}$



- **But for ψ(2S),**

$$\frac{B(\psi(2S) \to \gamma\eta)}{B(\psi(2S) \to \gamma\eta')} = \mathbf{(1.10 \pm 0.38 \pm 0.07)\ \%}$$

$\psi(2S) \to \gamma\eta^{(\prime)}$



- **Why the difference?**
  - **interference with the continuum?**
  - **contributions of other processes?**
  - **something related to the "ϱπ puzzle?"**

Study of Charmonium Spectroscopy

A Selection of Recent Results from BESIII:

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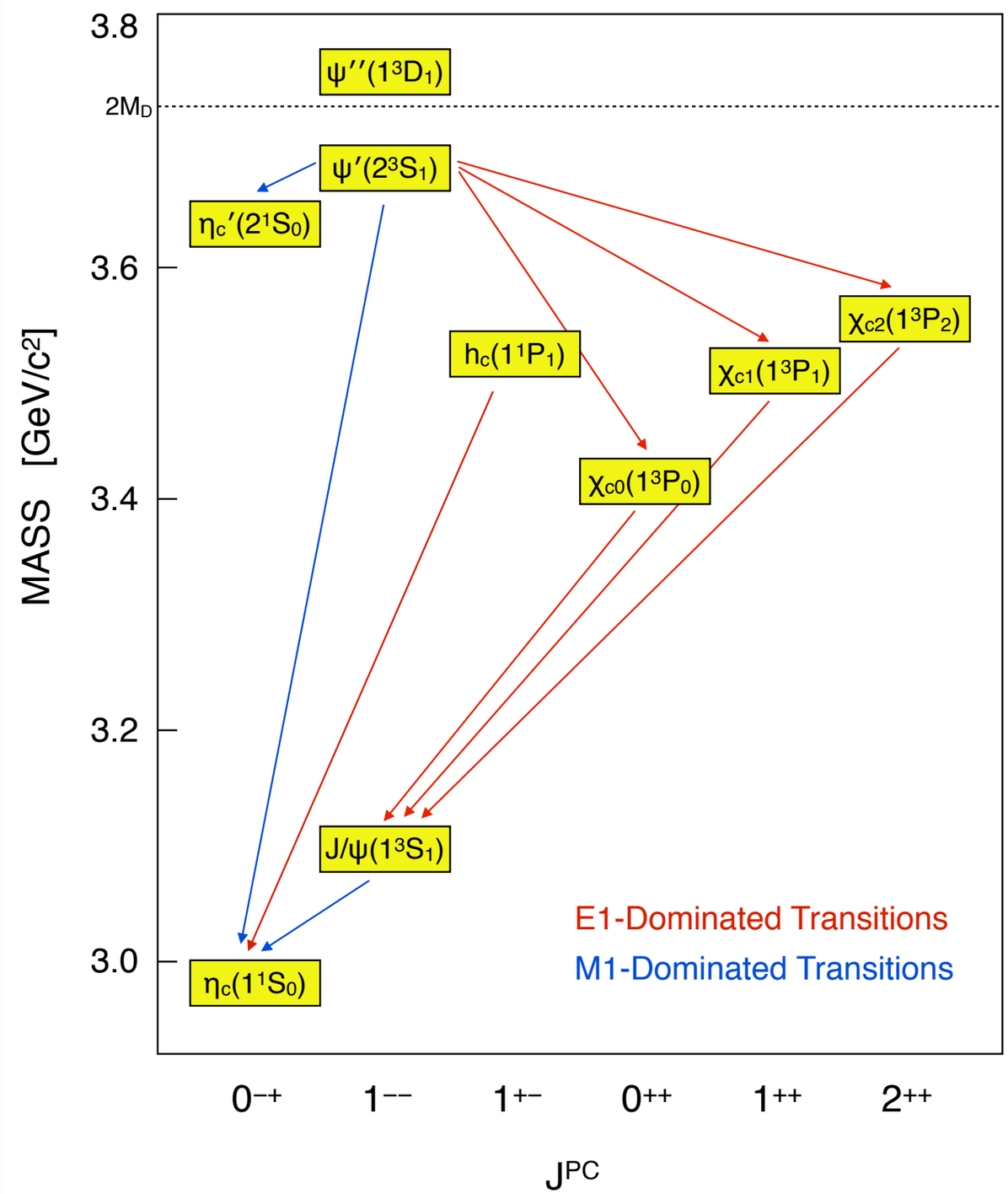
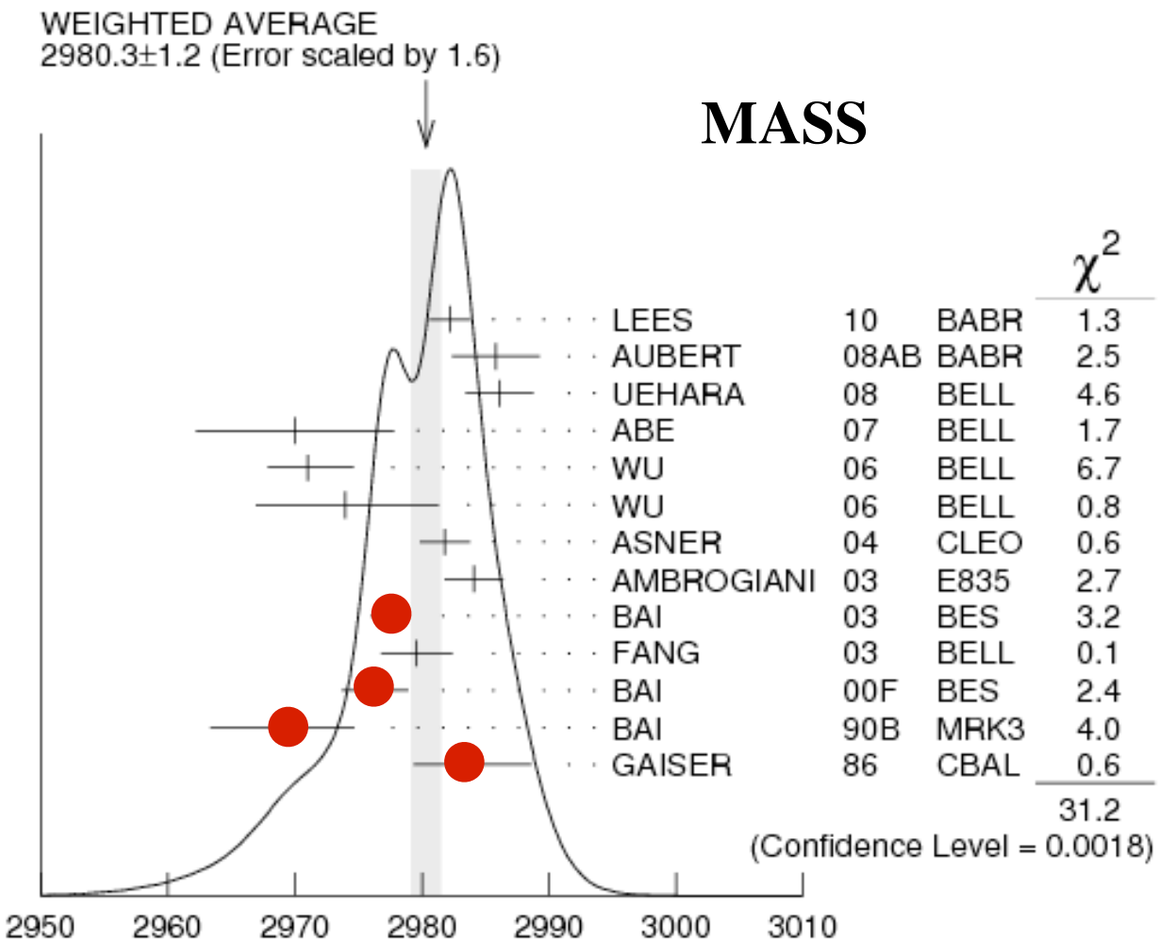
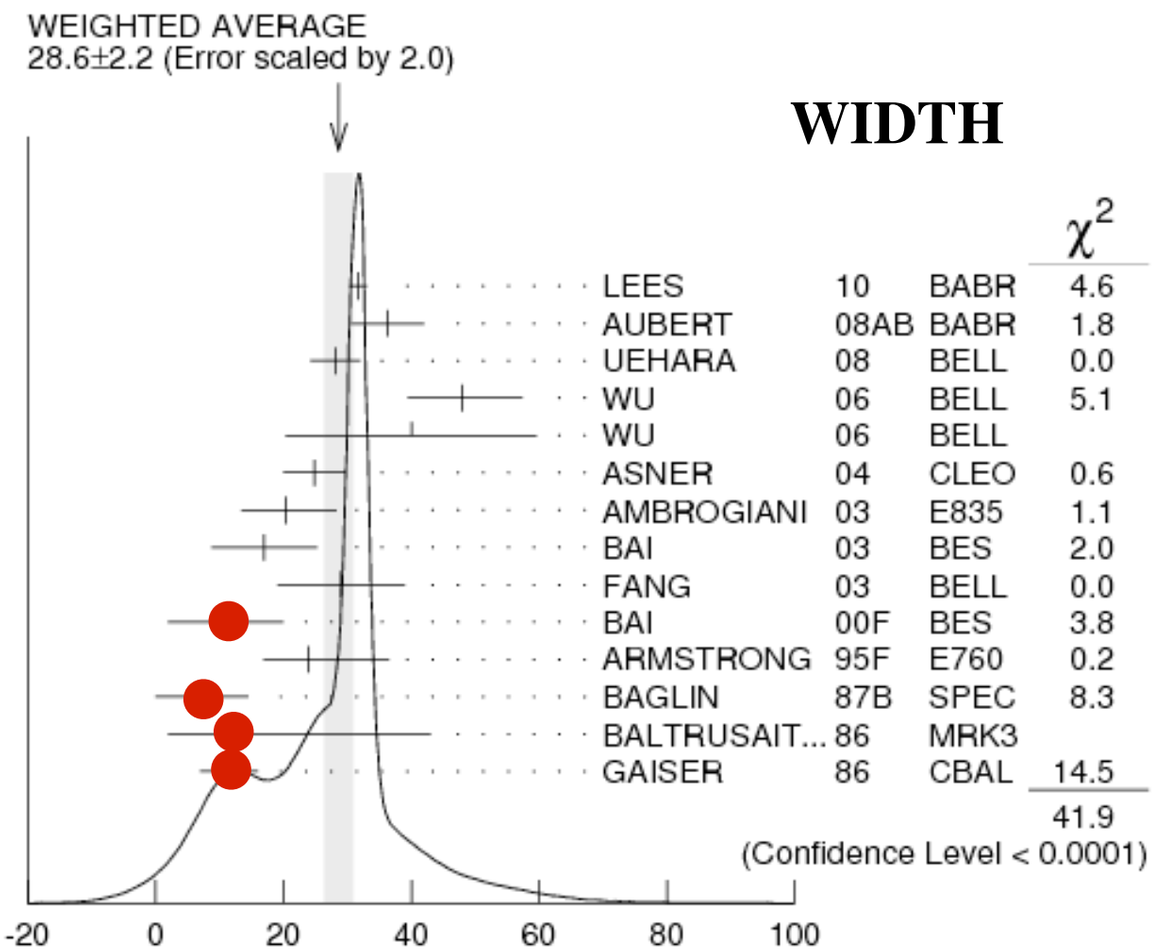


Measuring the Mass of the $\eta_c(1S)$

the $\eta_c(1S)$ is the ground state of the charmonium system, but its properties are not well-known:

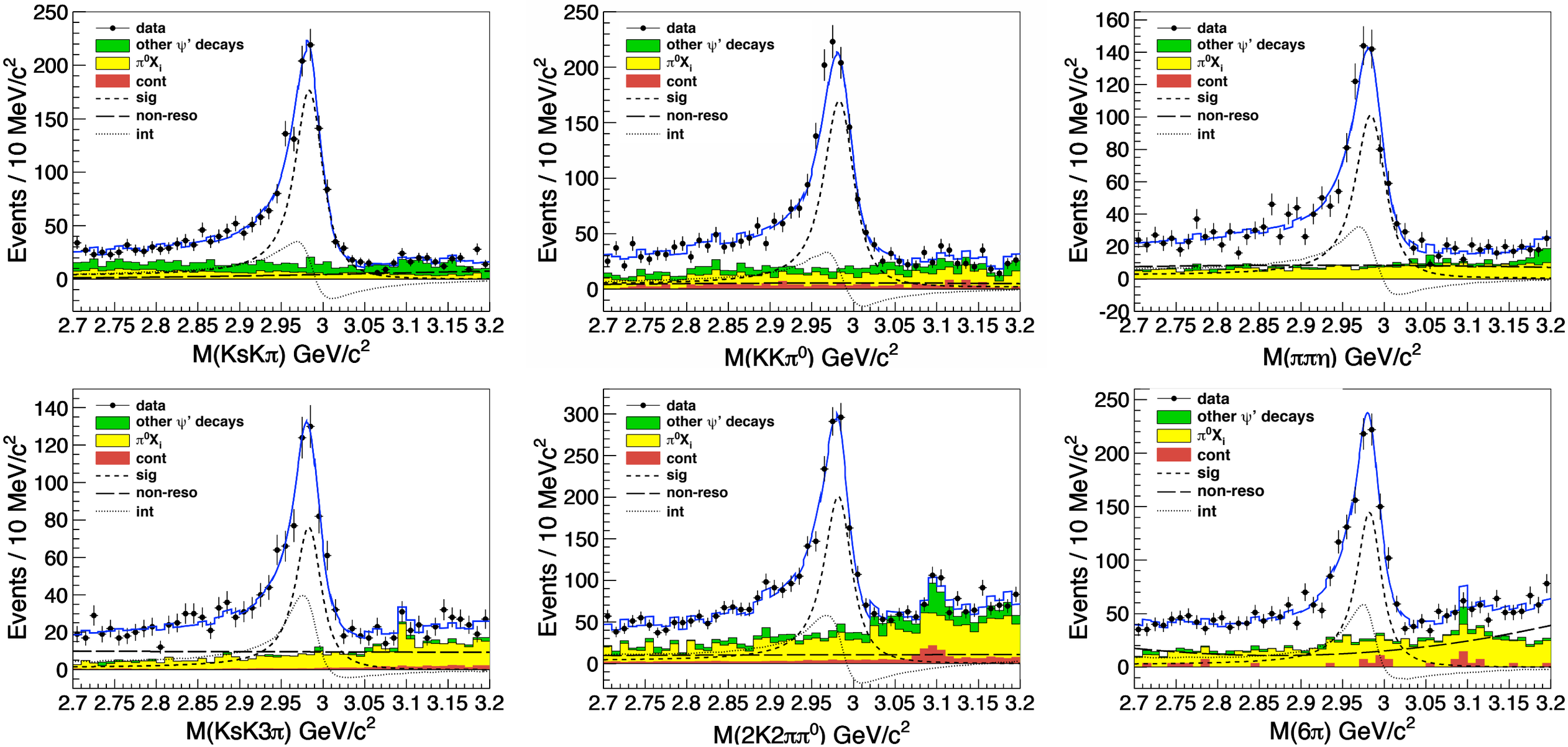




some of the problem appears to stem from measurements using $\psi(1S,2S) \rightarrow \gamma\eta_c(1S)$*...*

Measuring the Mass of the $\eta_c(1S)$

BESIII observed a shift in mass due to a distortion of the $\psi(2S) \rightarrow \gamma\eta_c(1S)$ lineshape…



Attributing the distortion to interference with non-resonant radiative decays…

M = 2984.3 ± 0.6 ± 0.6 MeV and **Γ = 32.0 ± 1.2 ± 1.0 MeV**

Study of Open Charm

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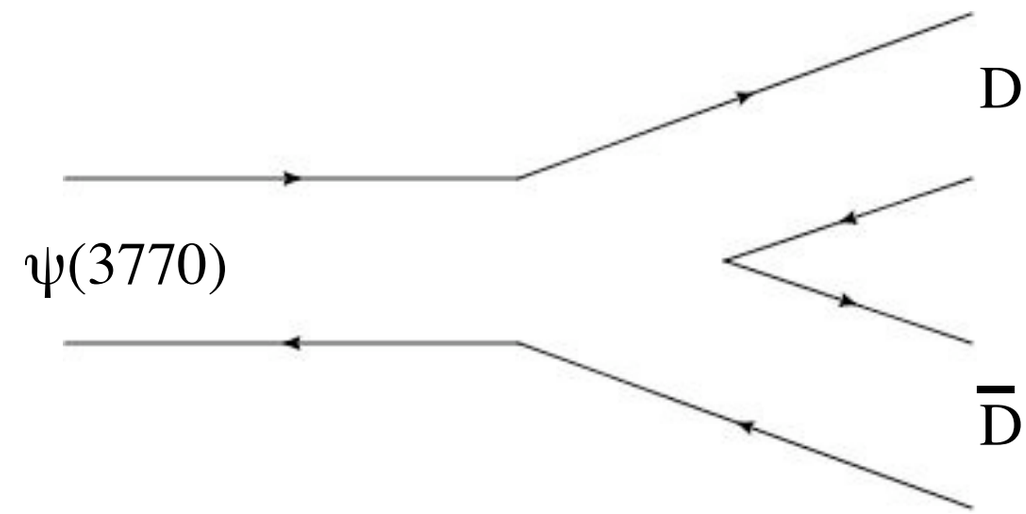
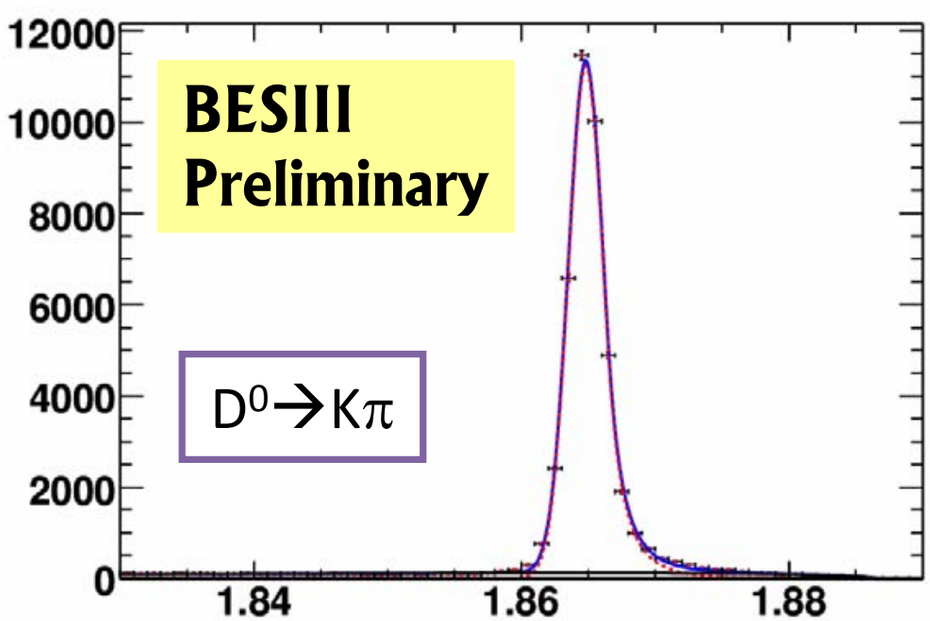
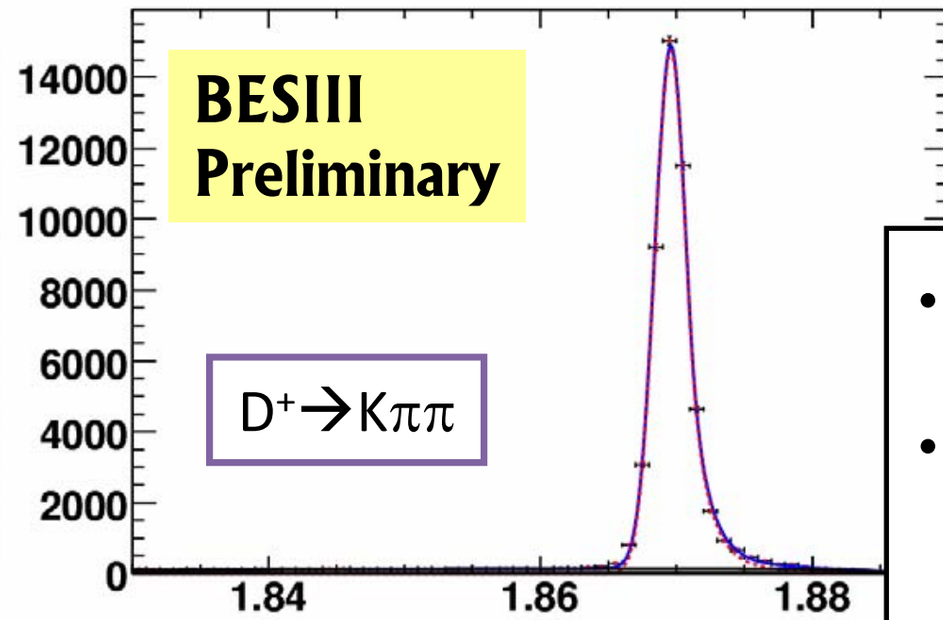


- Use $\psi(3770) \to D\bar{D}$ to produce two quantum correlated D mesons (almost) at rest.
- "Tag" one D meson to learn about the other.
- Powerful tool for studying:
  - mixing and CP violation
  - hadronic decays (e.g. Dalitz analyses)
  - semileptonic decays (form factors)
  - leptonic decays (decay constants)
  - etc.
- ***BESIII has ~2.9fb^{-1} (~3× CLEO)***

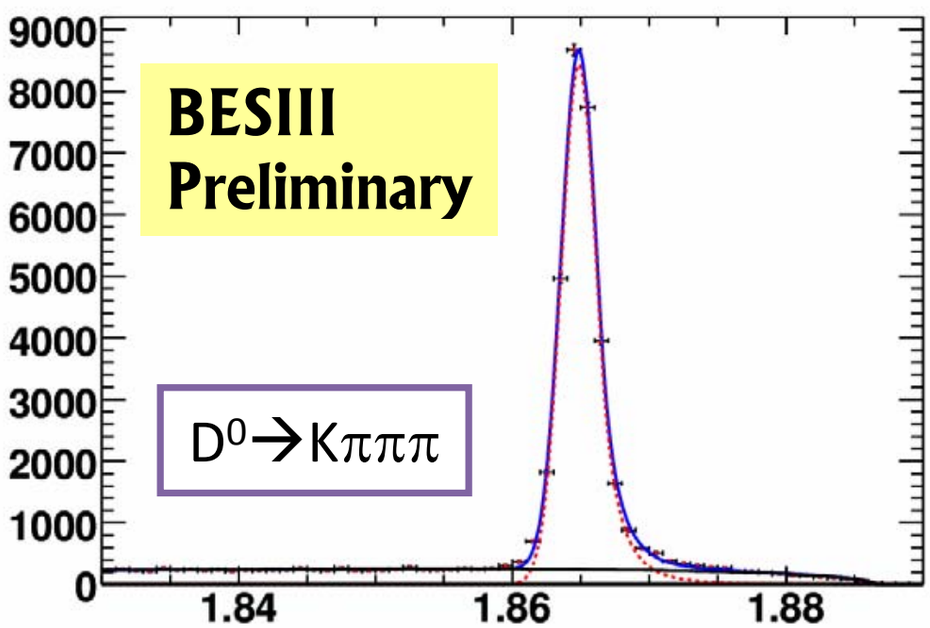
Open Charm at BESIII

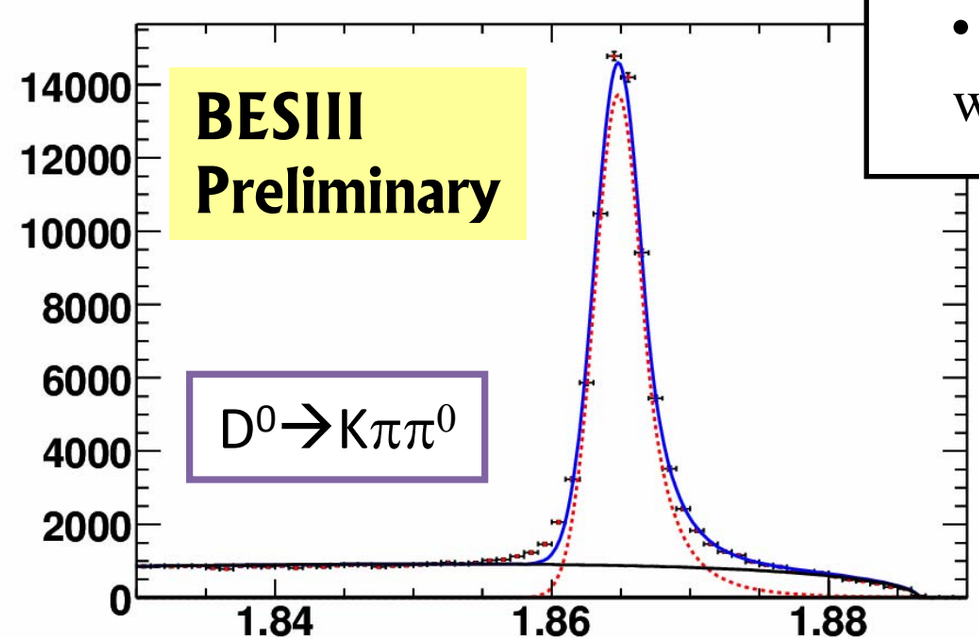
Examples of a few D-tag modes...





- very clean
- excellent resolution
  - ~1.3 MeV for pure charged
  - ~1.9 MeV with a π^0





$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

(using only 420 pb^{-1}...)

Study of Charmonium Above Open Charm Threshold

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the spectrum of charmonium states above open charm threshold is richer than once thought…

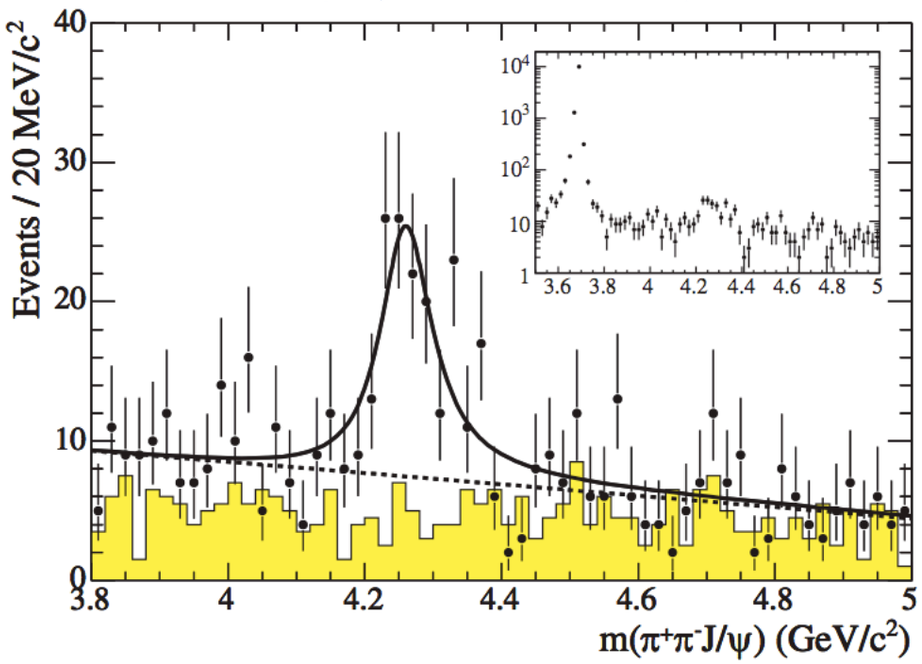
State	m (MeV)	Γ (MeV)
$X(3872)$	3871.52 ± 0.20	1.3 ± 0.6 (<2.2)
$X(3915)$	3915.6 ± 3.1	28 ± 10
$X(3940)$	3942^{+9}_{-8}	37^{+27}_{-17}
$G(3900)$	3943 ± 21	52 ± 11
$Y(4008)$	4008^{+121}_{-49}	226 ± 97
$Z_1(4050)^+$	4051^{+24}_{-43}	82^{+51}_{-55}
$Y(4140)$	4143.4 ± 3.0	15^{+11}_{-7}
$X(4160)$	4156^{+29}_{-25}	139^{+113}_{-65}
$Z_2(4250)^+$	4248^{+185}_{-45}	177^{+321}_{-72}
$Y(4260)$	4263 ± 5	108 ± 14
$Y(4274)$	$4274.4^{+8.4}_{-6.7}$	32^{+22}_{-15}
$X(4350)$	$4350.6^{+4.6}_{-5.1}$	$13.3^{+18.4}_{-10.0}$
$Y(4360)$	4353 ± 11	96 ± 42
$Z(4430)^+$	4443^{+24}_{-18}	107^{+113}_{-71}
$X(4630)$	4634^{+9}_{-11}	92^{+41}_{-32}
$Y(4660)$	4664 ± 12	48 ± 15
$Y_b(10888)$	10888.4 ± 3.0	$30.7^{+8.9}_{-7.7}$

arXiv:1010.5827 [hep-ex]

The Y(4260) and Y(4360) States

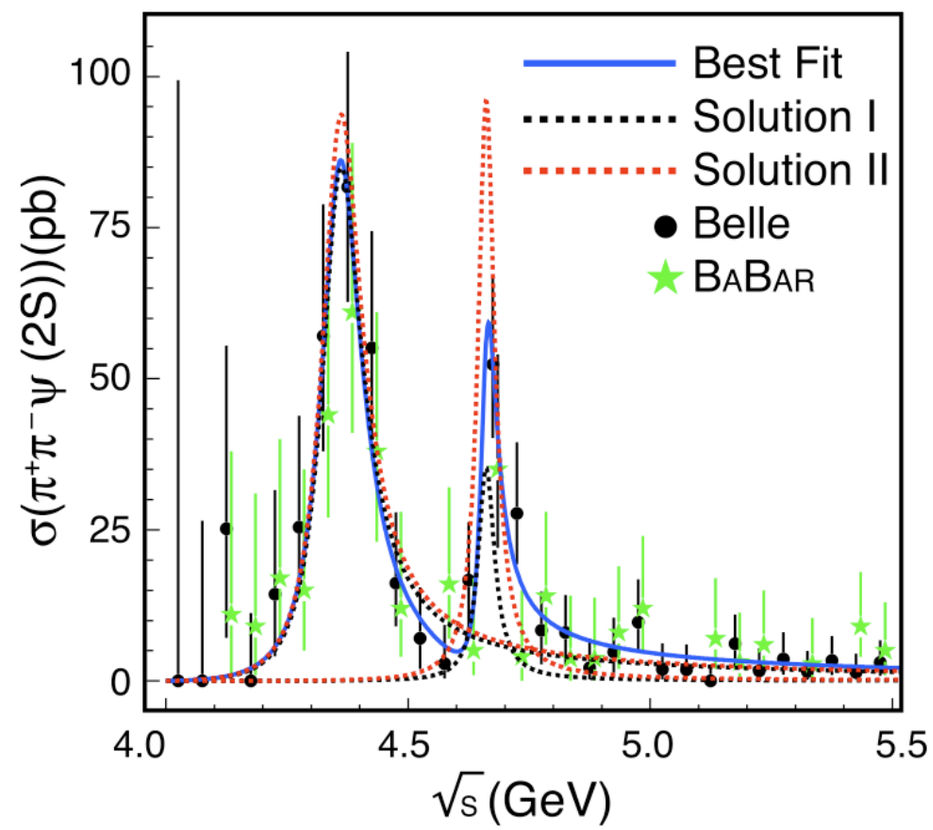
potential hybrid meson states discovered in ISR at Belle and BaBar...

*Discovery of the Y(4260) by **BaBar***



PRL 95, 142001 (2005)

*The Y(4360) in **$\pi^+\pi^-\psi(2S)$** at Belle/BaBar*



arXiv:1010.5827 [hep-ex]

These states could be produced directly at BESIII.

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  - results a little later

- BESIII is now fully operational and many analyses are underway *(as well as many systematic studies)*

- BESIII has already made many contributions beyond the reach of CLEO-c

- Many more results are on their way! *(including analyses of open charm)*