Overview of the BESIII results

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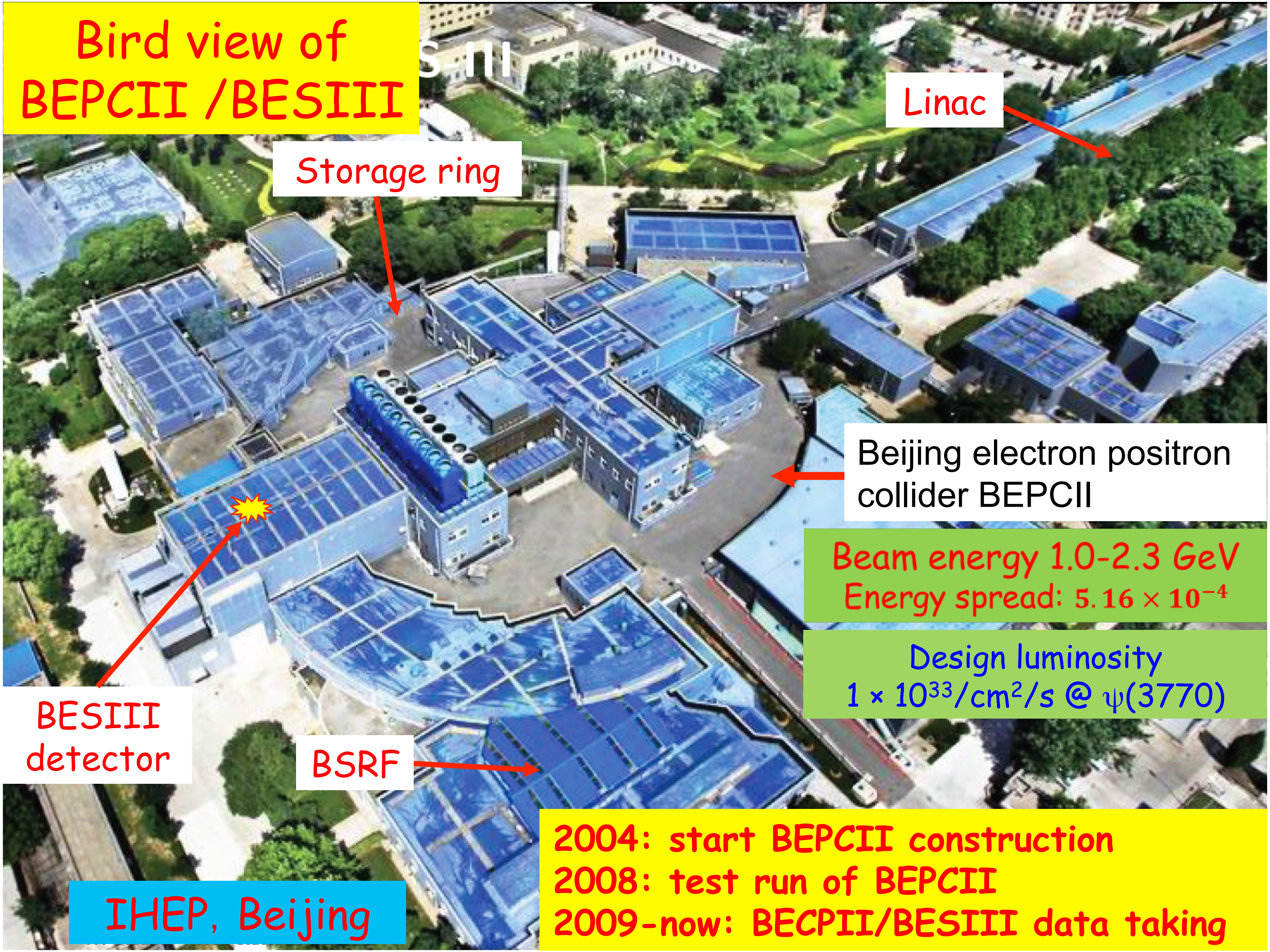
For BESIII Collaboration

Institute of High Energy Physics

Meson2012, 31st May-5th June, Krakow, Poland

Outline

- Status of BEPCII/BESIII
- Highlight of BESIII results
  - Light hadrons spectroscopy
  - Charmonium transitions and decays
  - Charm decays
- Summary


Bird view of
BEPCII /BESIII
Storage ring
Linac
Beijing electron positron collider BEPCII
Beam energy 1.0-2.3 GeV
Energy spread: 5.16×10^{-4}
Design luminosity
$1 \times 10^{33}/cm^2/s$ @ $\psi(3770)$
BESIII detector
BSRF
IHEP, Beijing
2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII data taking

The BESIII Detector

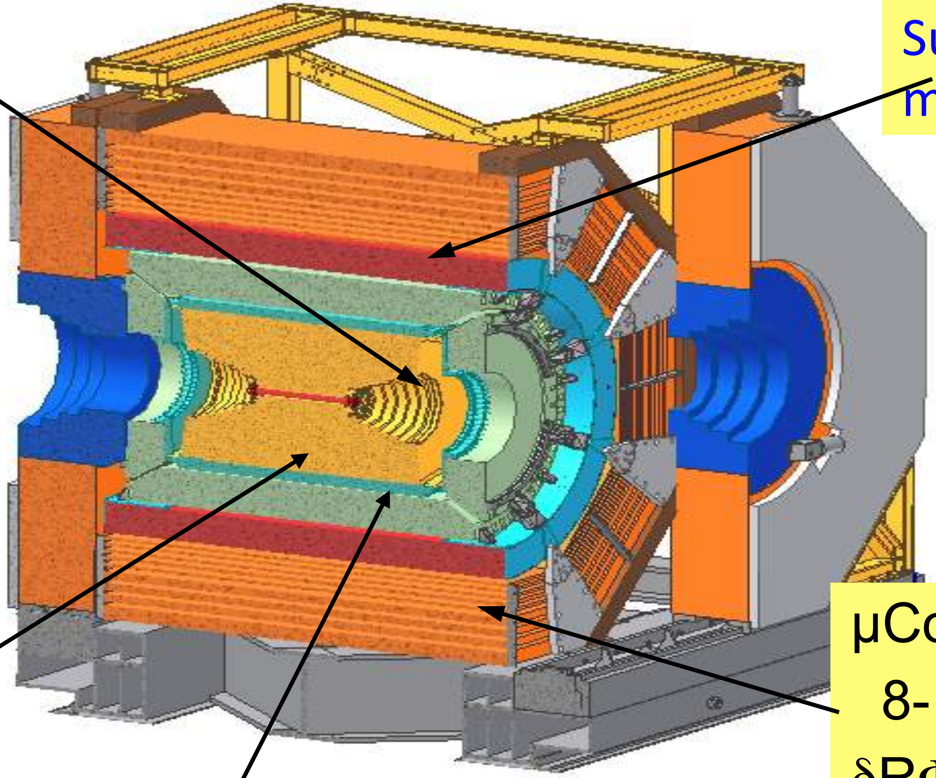
NIM A614, 345 (2010)

Drift Chamber (MDC)

$\sigma P/P$ ($^0/_0$) = 0.5%(1GeV)

$\sigma_{dE/dx}$ ($^0/_0$) = 6%

Super-conducting magnet (1.0 tesla)



Time Of Flight (TOF)

σ_T: 90 ps Barrel

110 ps endcap

μCounter

8- 9 layers RPC

$\delta R\Phi$=1.4 cm~1.7 cm

EMC: $\sigma E/\sqrt{E}$($^0/_0$) = 2.5 % (1 GeV)

(CsI) $\sigma_{z,\phi}$(cm) = 0.5 - 0.7 cm/$\sqrt{E}$

The BESIII Collaboration

http://bes3.ihep.ac.cn

US (6)
Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Europe (11)
Germany: Univ. of Bochum, Univ. of Giessen, GSI
Univ. ofJohannes Gutenberg
Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino， Frascati Lab
Netherland： KVI/Univ. of Groningen
Turkey: Turkey Accelerator Center

Korea (1)
Seoul Nat. Univ.

Japan (1)
Tokyo Univ.

Pakistan (1)
Univ. of Punjab

China(30)
IHEP, CCAST, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.
Univ. of South China, GUCAS.

>300 physicists
50 institutions from 10 countries

BESIII commissioning

- **July 19, 2008: first e^+e^- collision event in BESIII**
- **Nov. 2008: ~ 14M $\psi(2S)$ events for detector calibration**
- **2009: 106M $\psi(2S)$ 4×CLEOc**
  225M J/ψ 4×BESII
- **2010: 900 pb^{-1} $\psi(3770)$**
- **2011: 2000 pb^{-1} $\psi(3770)$**
  470 pb^{-1} @ 4.01 GeV

  3.5×CLEOc (2010 and 2011 $\psi(3770)$)
- **2012: tau mass measurement**
  $\psi(2S)$: 0.3 billion; J/ψ: from ~April 1

World's largest samples of J/ψ, $\psi(2S)$ and ψ (3770) (and still growing)

Peak luminosity reached 6.5 X 10^{32} @3770 MeV

Physics Programs @ BESIII

Light hardron physics

-meson & baryon spectroscopy
-threshold effects
-multiquark states
-glueballs & hybrids
-two-photon physics
-form-factors

Charm physics:

- (semi-)leptonic form factors
- *f_D & f_{Ds} decay constants.*
- CKM matrix: V_{cd} , V_{cs}
- *D^0-D^0 mixing and CPV*
- strong phases

QCD & τ -physics:

- precision *R-measurement*
- τ mass / τ decays

Charmonium physics:

- precision spectroscopy
- transitions and decays

XYZ meson physics:

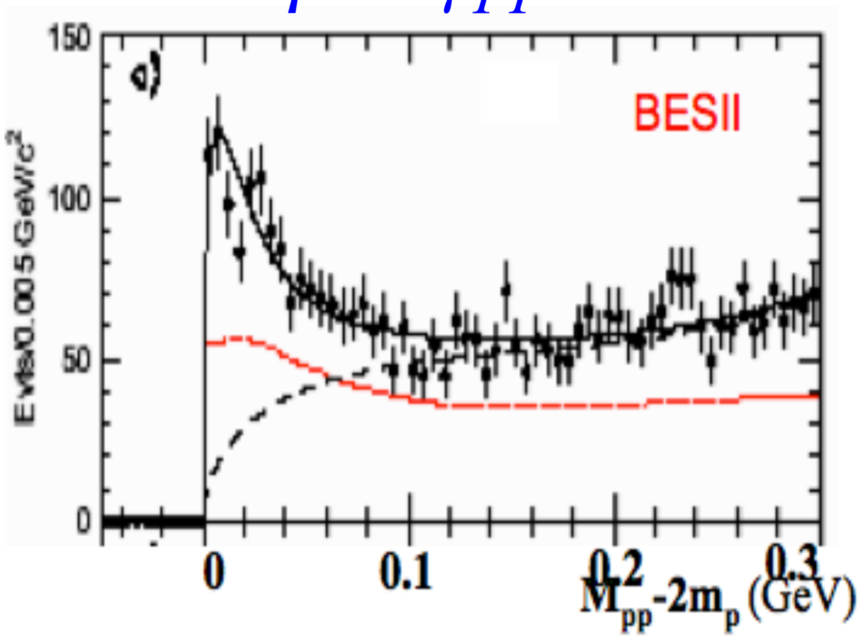
-Y(4260)ππh_c decays

Recent Results on Light Hadron Spectroscopy

- $p\bar{p}$ mass threshold structure in $J/\psi \to \gamma p\bar{p}$
- X(1835) and two new structures in $J/\psi \to \gamma\pi^+\pi^-\eta'$
- η(1405) in $J/\psi \to \gamma f_0(980)\pi^0, f_0(980) \to 2\pi$
- PWA of $J/\psi \to \gamma\eta\eta$
- PWA of $J/\psi \to \gamma\omega\phi$

Observation of X($p\bar{p}$) @ BESII

$J/\psi \rightarrow \gamma p\bar{p}$



$$M = 1859 \,^{+3}_{-10}\,^{+5}_{-25}\ \text{MeV}/c^2$$

$$\Gamma < 30\ \text{MeV}/c^2\ (90\%\ \text{CL})$$

PRL 91 (2003) 022001

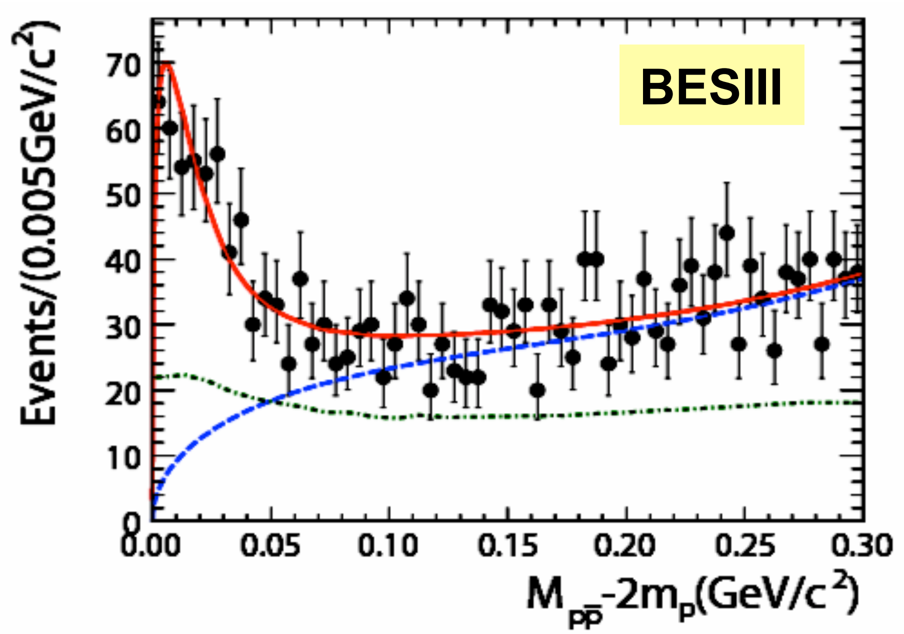
Theoretical interpretation:

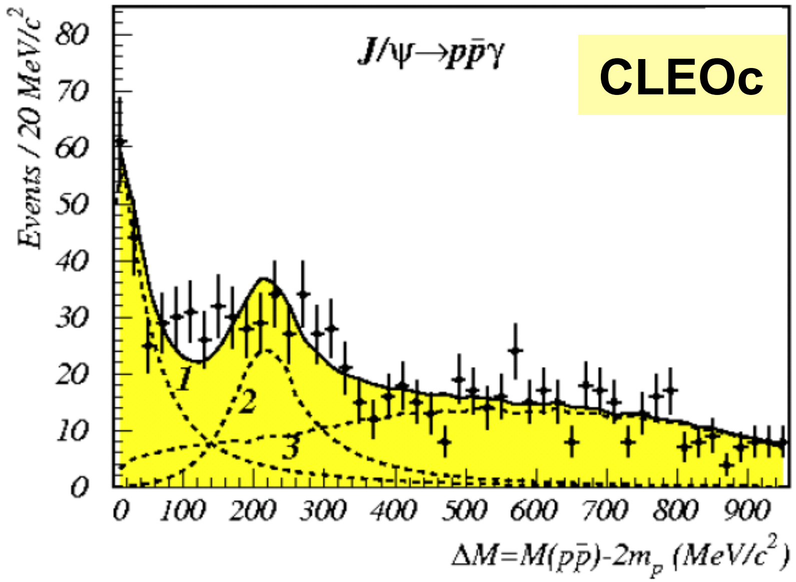
- conventional meson?
- $p\bar{p}$ bound state/multiquark
- glueball
- Final state interaction (FSI)
- …

Confirmation @ BESIII and CLEOc

Fit with one resonance at BESII did:

$\psi' \to \pi^+\pi^- J/\psi, J/\psi \to \gamma p\bar{p}$





$M=1861\ ^{+6}_{-13}\ ^{+7}_{-26}$ MeV/c^2

$\Gamma < 38$ MeV/c^2 (90% CL)

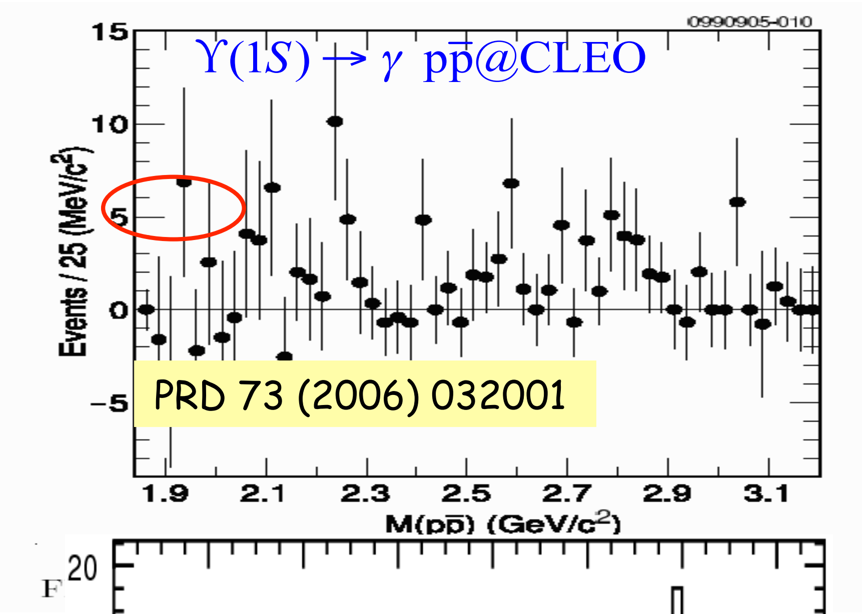
$M(R_{thr}) = 1861^{+6}_{-16}$ (MeV), $\Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV),

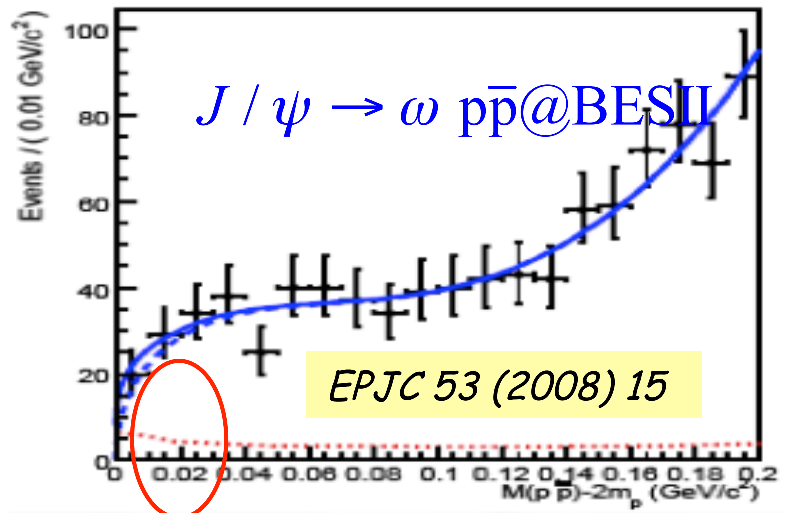
$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}$

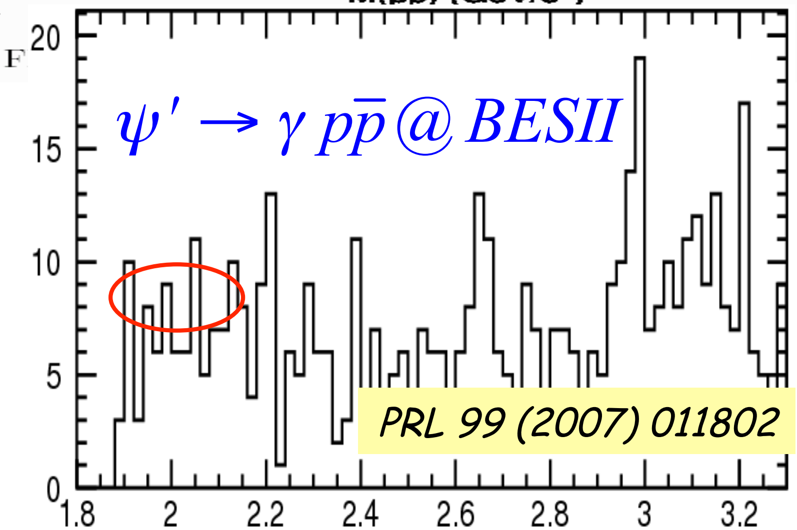
Chinese Physics C 34, 421 (2010)

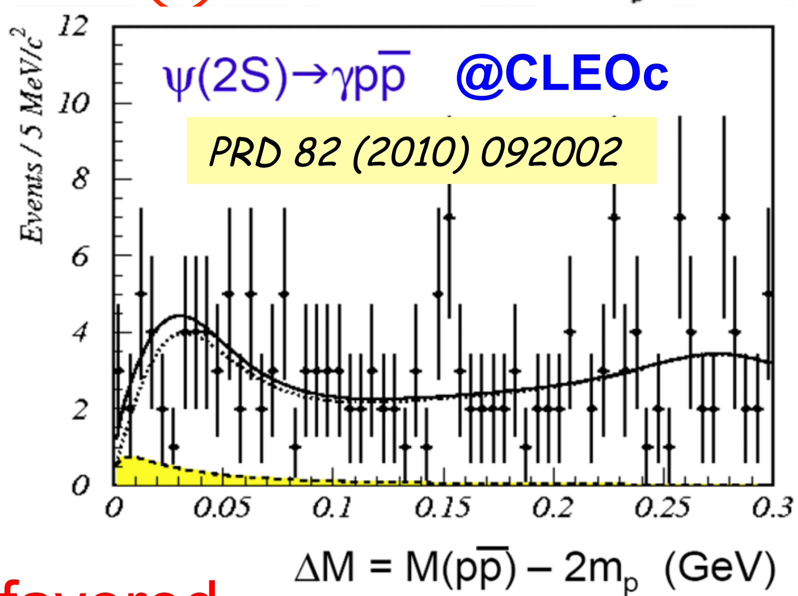
PRD 82, 092002(2010)

Several non-observations





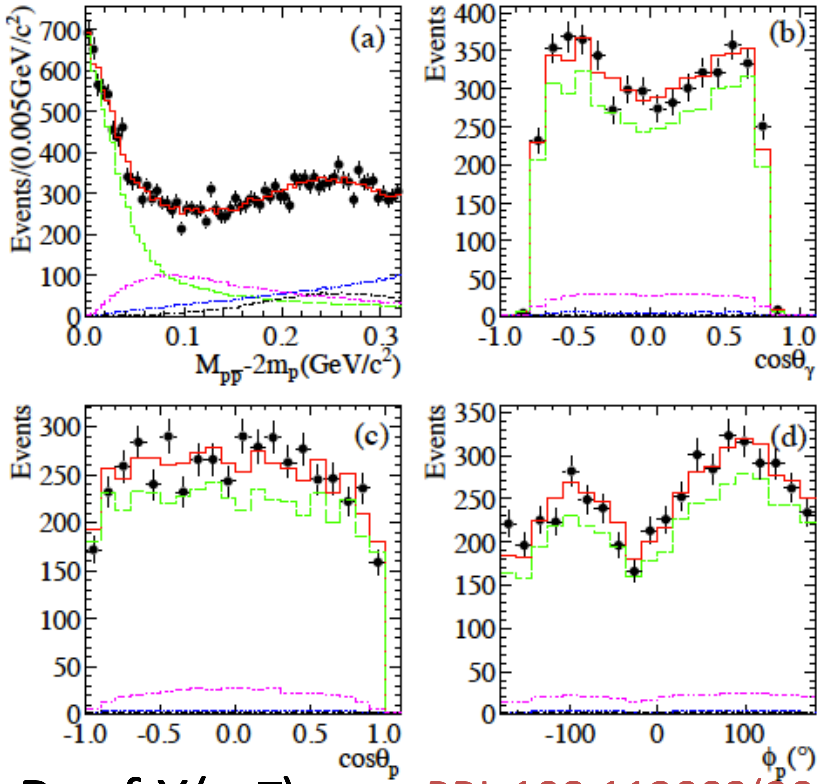




Pure FSI interpretation is disfavored

PWA of $J/\psi \to \gamma p\bar{p}$ @BESIII

- PWA of J/ψ->γpp̄ was first performed
  - The fit with a BW and S-wave FSI(I=0) factor can well describe ppb mass threshold structure.
  - It is much better than that without FSI effect, and Δ2lnL=51 (7.1σ)
  - Different FSI models→Model dependent uncertainty



PRL 108,112003(2012)

- Spin-parity, mass, width and B.R. of X(pp̄):

$J^{pc} = 0^{-+}$ → >6.8σ better than other J^{pc} assignments.

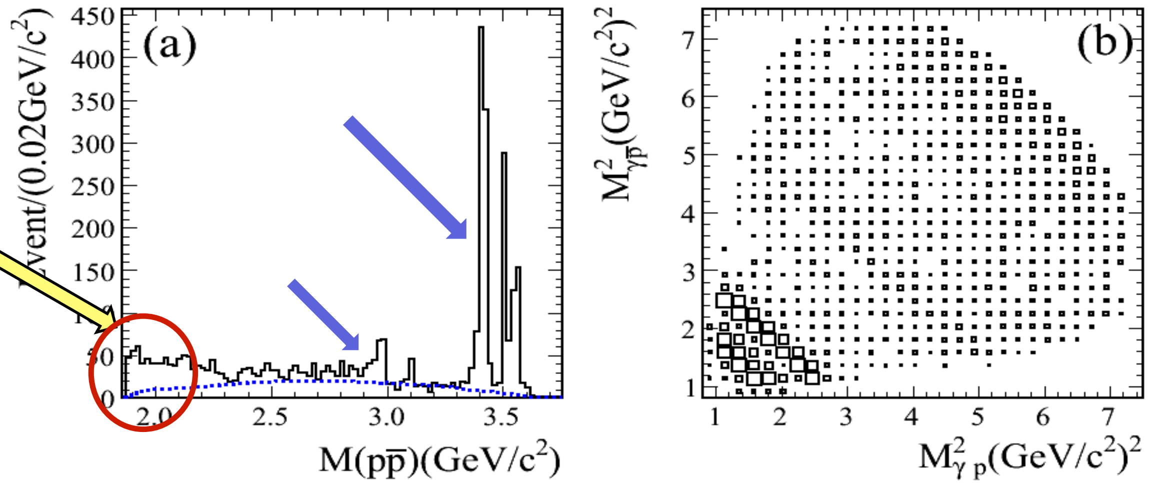
$$M = 1832^{+19}_{-5}(\mathrm{stat})^{+18}_{-17}(\mathrm{syst}) \pm 19(\mathrm{mod})\mathrm{MeV}/c^2$$

$$\Gamma = 13 \pm 20(\mathrm{stat})^{+11}_{-33}(\mathrm{syst}) \pm 4(\mathrm{mod})\mathrm{MeV}/c^2 \text{ or } \Gamma < 76\mathrm{MeV}/c^2 \text{ @}90\%\, C.L.$$

$$B(J/\psi \to \gamma X(p\bar{p}))B(X(p\bar{p}) \to p\bar{p}) = (9.0^{+0.4}_{-1.1}(\mathrm{stat})^{+1.5}_{-5.0}(\mathrm{syst}) \pm 2.3(\mathrm{mod})) \times 10^{-5}$$

Mp$\bar{p}$ threshold structure of $\psi' \to \gamma p\bar{p}$ @BESIII

Obviously different line shape of p$\bar{p}$ mass spectrum near threshold from that in J/ψ decays



PWA results:

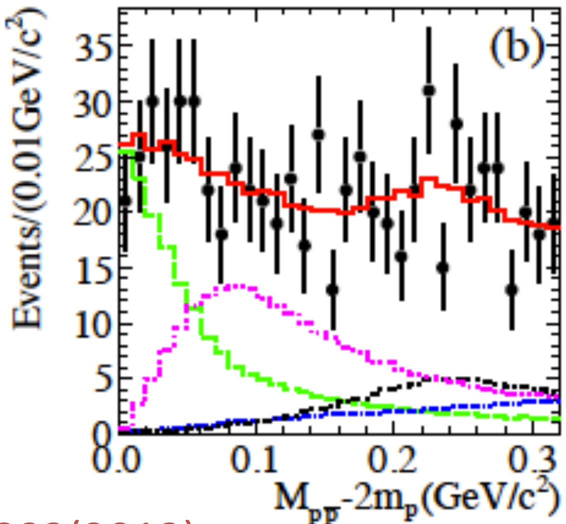
- Significance of X(p$\bar{p}$) is > 6.9σ.
- The production ratio R: first measurement

$$R = \frac{B(\psi' \to \gamma X(p\bar{p}))}{B(J/\psi \to \gamma X(p\bar{p}))}$$

$$= (5.08^{+0.71}_{-0.45}(stat)^{+0.67}_{-3.58}(syst) \pm 0.12(mod))\%$$

- It is suppressed compared with “12% rule”.

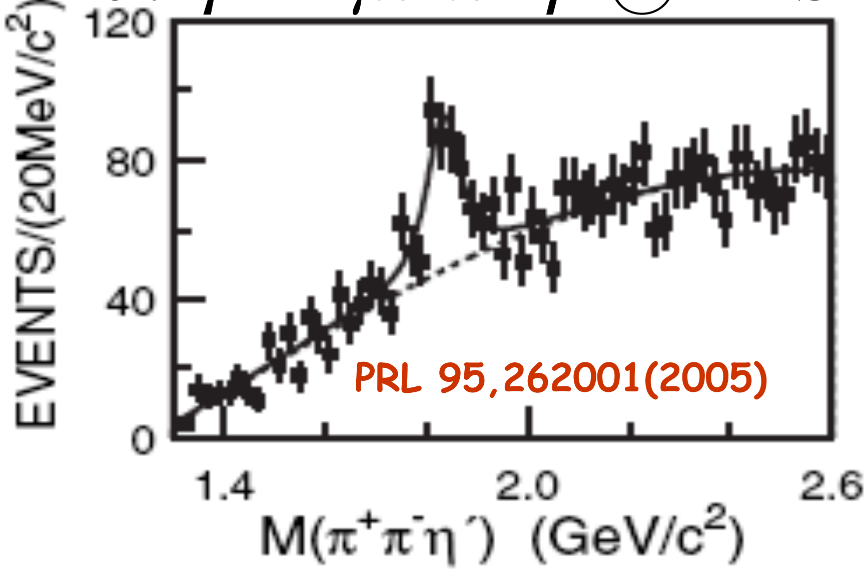
PWA Projection:



PRL 108,112003(2012)

Observation of X(1835) at BESII

$J/\psi \to \gamma\pi^+\pi^-\eta'$ @ BESII



BESII results(Statistical significance~7.7σ):

$M = 1833.7 \pm 6.1(stat) \pm 2.7(syst)\text{MeV}/c^2$

$\Gamma = 67.7 \pm 20.3(stat) \pm 7.7(stat)\text{MeV}/c^2$

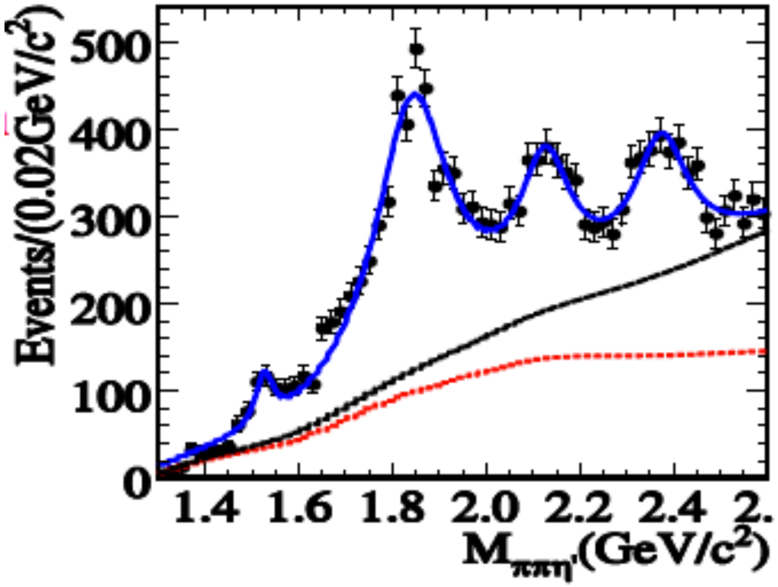
$B(J/\psi \to \gamma X(1835))B(X(1835) \to \pi^+\pi^-\eta')$

$= (2.2 \pm 0.4(\text{stat}) \pm 0.4(\text{syst})) \times 10^{-4}$

Theoretical interpretation:

- $p\bar{p}$ bound state
- η excitation
- ….
- Whether are X($p\bar{p}$) and X(1835) from the same source?

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

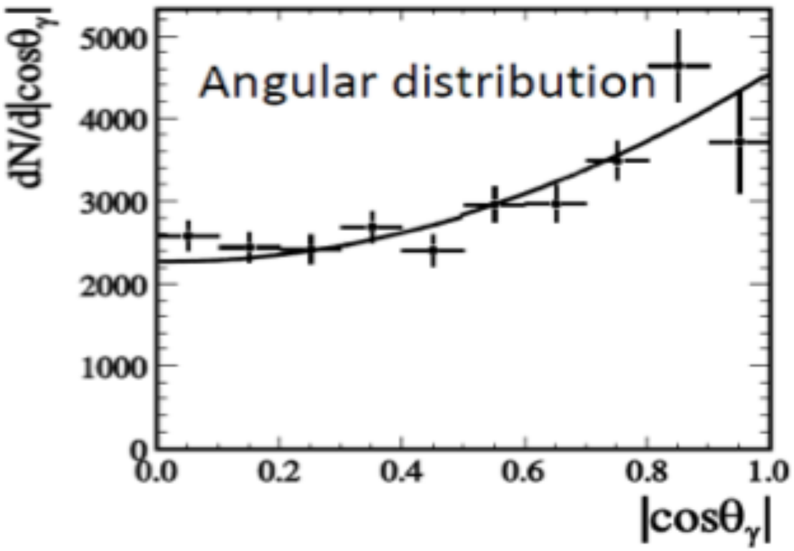


PRL 106, 072002 (2011)

resonance	M(MeV/c^2)	Γ(MeV/c^2)	significance
X(1835)	1836.5 ± 3.0	190.1 ± 9.0	$>> 20\sigma$
X(2120)	2122.4 ± 6.7	84 ± 16	$> 7.2\sigma$
X(2370)	2376.3 ± 8.7	83 ± 17	$> 6.4\sigma$

For the X(1835):

$$BR(J/\psi \to \gamma X(1835)) \bullet BR(X(1835) \to \pi^+\pi^-\eta')$$
$$= (2.87 \pm 0.09(stat)^{+0.49}_{-0.52}(syst)) \times 10^{-4}$$

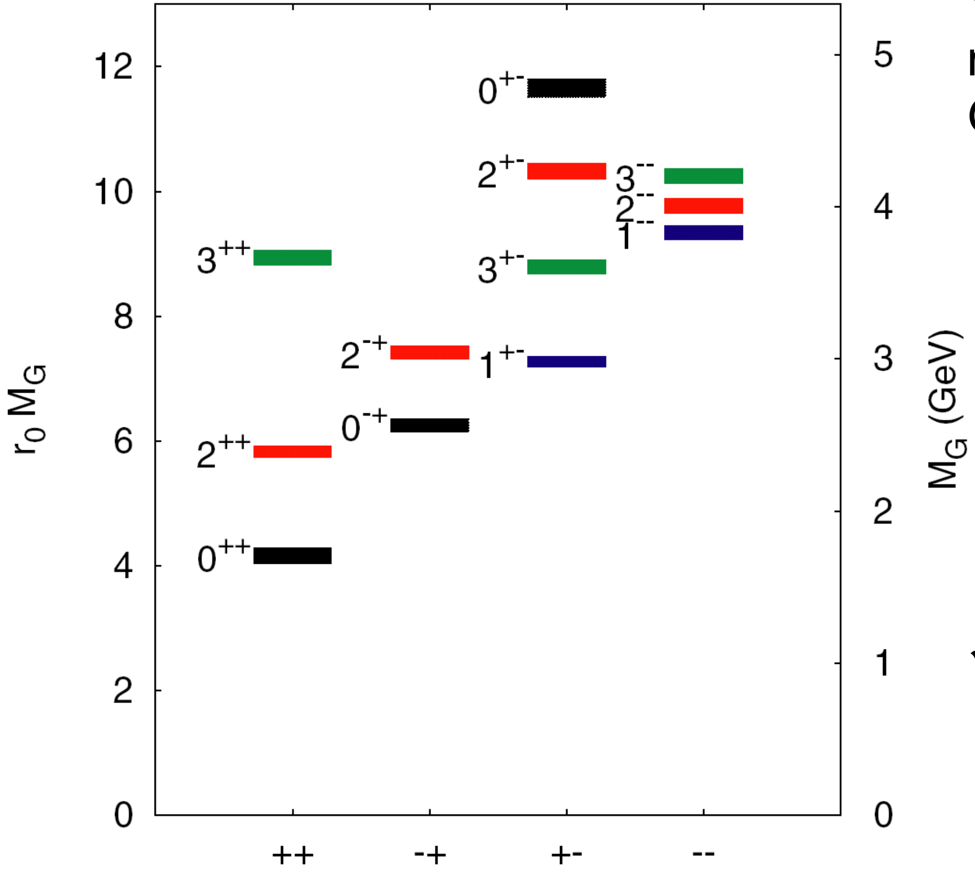


The polar angle of the photon in J/psi center of mass system is consistent with expectation for a pseudoscalar

PWA is needed, inference among the resonances needs to be considered.

Why are X(2120)/X(2370) interesting?

PRD73,014516(2006) Y.Chen et al



✓It is the first time in J/ψ radiative decays resonant structures are observed in the 2.4 GeV/c^2 region,

it is interesting since:

LQCD predicts that the lowest lying pseudoscalar glueball: around 2.4 GeV/c^2.

J/ψ-->γππη' decay is a good channel for finding 0^{-+} glueballs.

✓Nature of X(2120)/X(2370)

pseudoscalar glueball ?

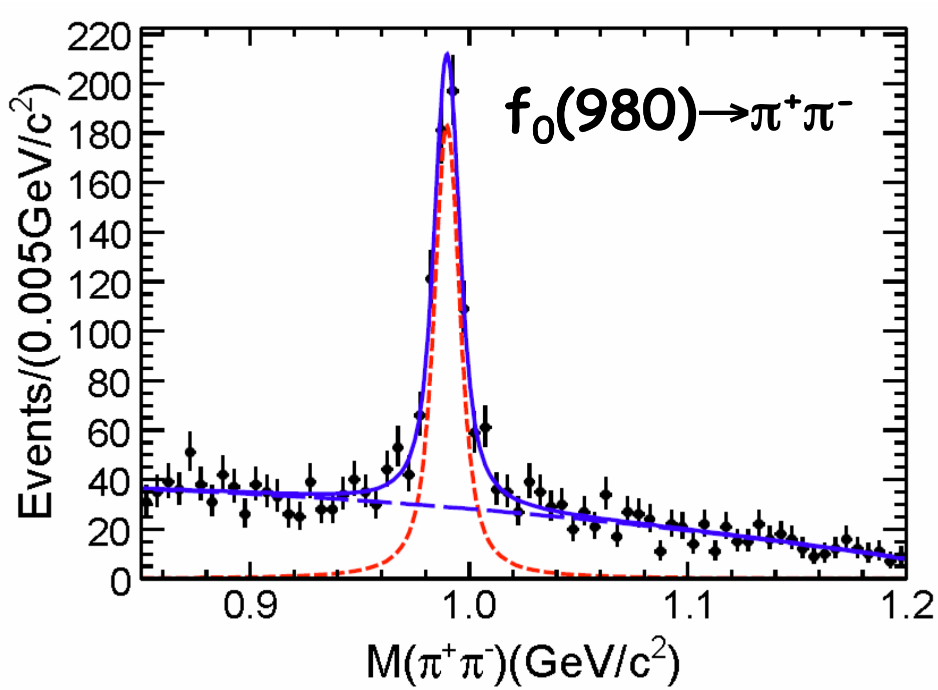
η/η' excited states?

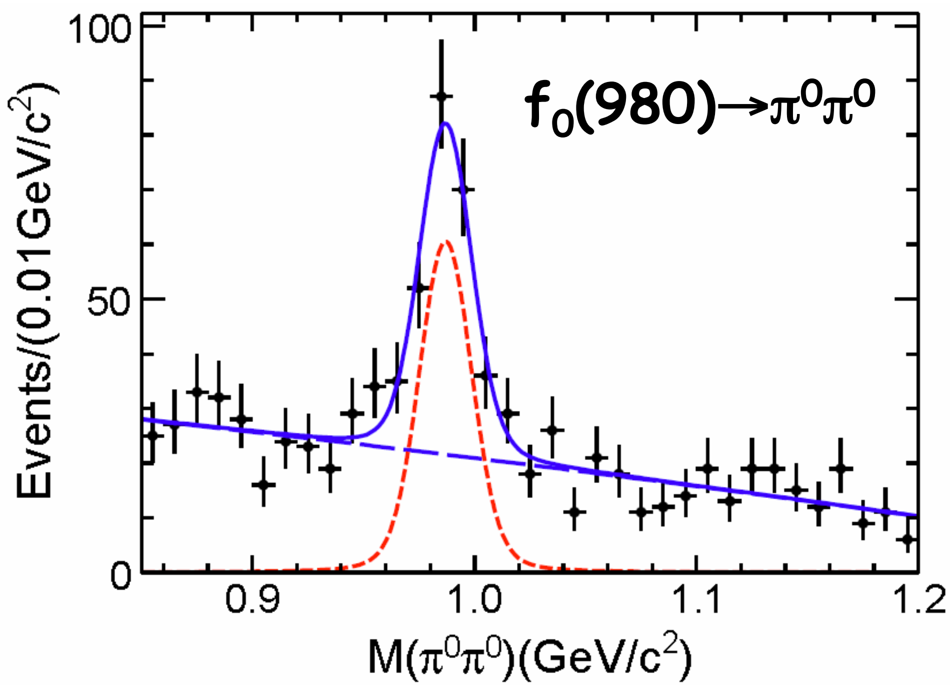
ΔΔ bound state?

……

PRD82,074026,2010 (J.F. Liu, G.J. Ding and M.L.Yan)
PRD**83:114007,2011** (J.S. Yu, Z.-F. Sun, X. Liu, Q. zhao),
and more…

Anomalous line shape of $f_0(980)$ in $J/\psi \to \gamma 3\pi$





$M = 989.9 \pm 0.4 \mathrm{MeV}/c^2$
$\Gamma = 9.5 \pm 1.1\ \mathrm{MeV}/c^2$

$M = 987.0 \pm 1.4 \mathrm{MeV}/c^2$
$\Gamma = 4.6 \pm 5.1\ \mathrm{MeV}/c^2$

PRL 108, 182001 (2012)

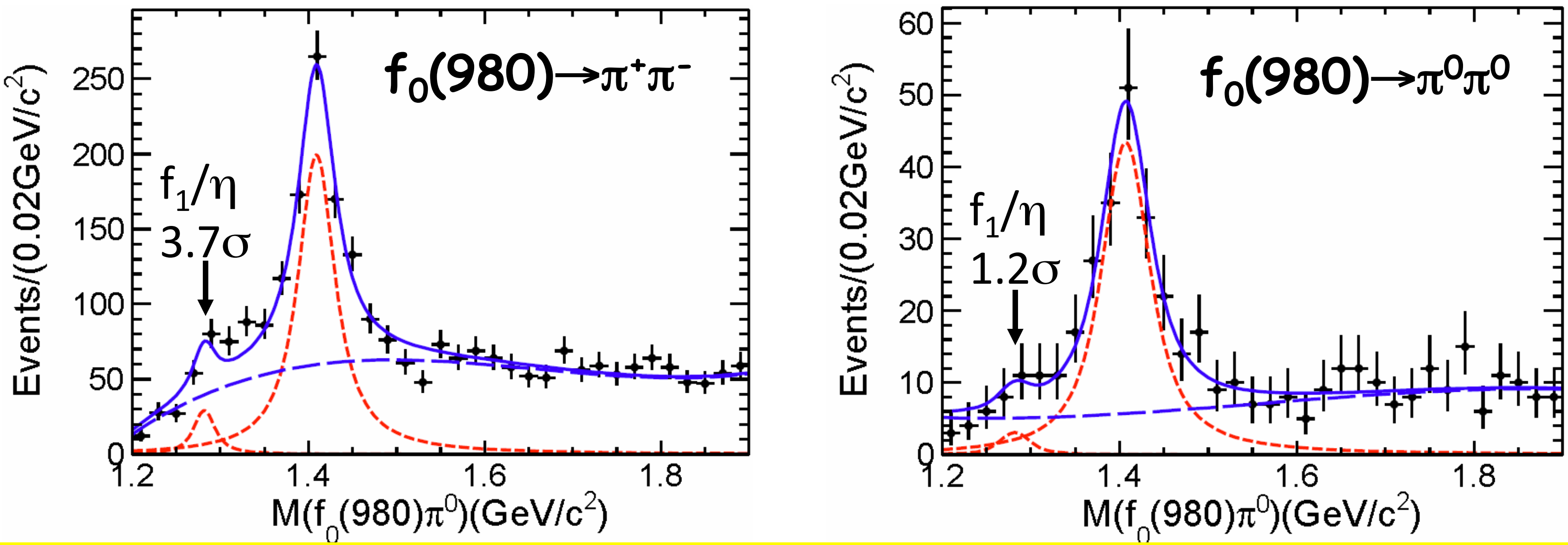
Surprising result:

very narrow $f_0(980)$ width: <11.8 MeV/c^2@90% C.L.

much narrower than the world average (PDG 2010: 40-100 MeV/c^2)

A possible explanation is KK^* loop, Triangle Singularity (TS) (J.J. Wu et al, PRL 108, 081803(2012))

$\eta(1405)$ in $J/\psi \to \gamma f_0(980)\pi^0$, $f_0(980) \to 2\pi$



First observed: $\eta(1405) \to f_0(980)\pi^0$ (Large isospin breaking):

$$\frac{BR(\eta(1405) \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{BR(\eta(1405) \to a_0(980)\pi^0 \to \pi^0\pi^0\eta)} \approx (17.9 \pm 4.2)\%$$

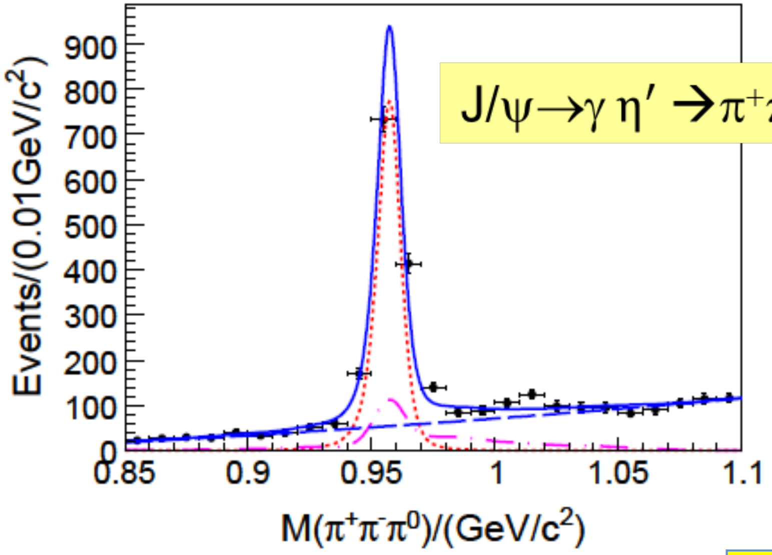
$\vee$

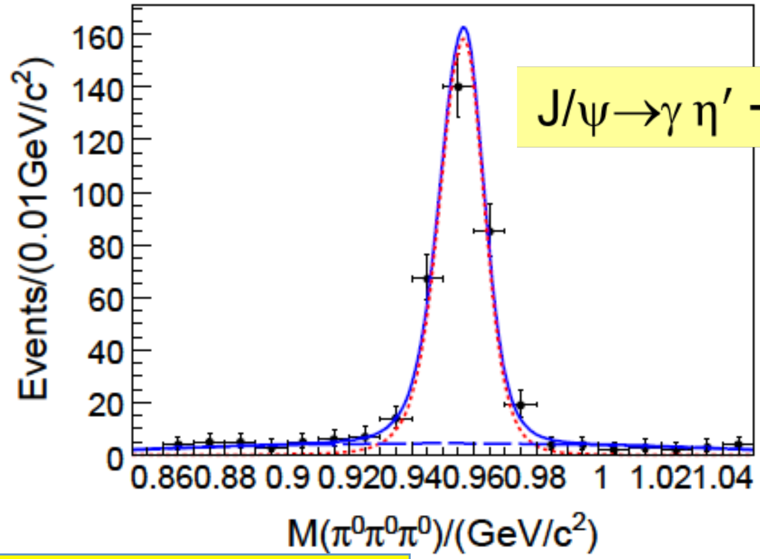
$$\xi_{af} = \frac{Br(\chi_{c1} \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{Br(\chi_{c1} \to a_0(980)\pi^0 \to \eta\pi^0\pi^0)} < 1\% (90\% \; C.L.)$$

PRD, 83(2100)032003

a_0-f_0 mixing alone can not explain the branching ratio of $\eta(1405)$

New results on η'→3π





PRL 108, 182001 (2012)

New results:

$Br(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15 \pm 0.39) \times 10^{-3}$ (PDG2010: $(3.6^{+1.1}_{-0.93}) \times 10^{-3}$)

$Br(\eta' \to \pi^0\pi^0\pi^0) = (3.56 \pm 0.22 \pm 0.34) \times 10^{-3}$ (PDG2010: $(1.68 \pm 0.22) \times 10^{-3}$)

For the decay $\eta' \to \pi^0\pi^0\pi^0$, it is two times larger than the world average value.

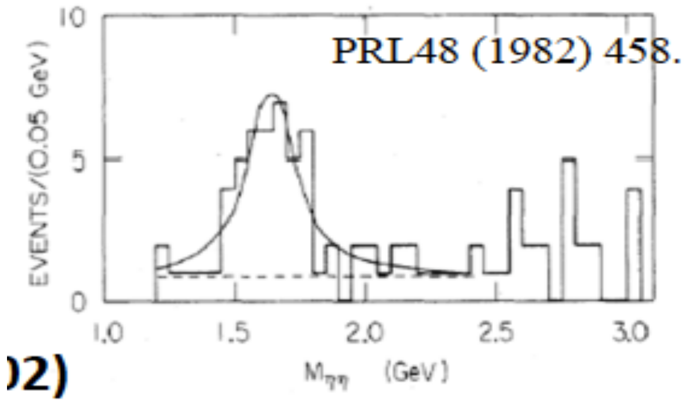
Comparison: Isospin violations in η'→πππ :

$$\frac{BR(\eta' \to \pi^+\pi^-\pi^0)}{BR(\eta' \to \pi^+\pi^-\eta)} \approx 0.9\%, \quad \frac{BR(\eta' \to \pi^0\pi^0\pi^0)}{BR(\eta' \to \pi^0\pi^0\eta)} \approx 1.6\%$$

Study of ηη system

- **First observed $f_0(1710)$ from J/ψ radiative decays to ηη by Crystal Ball in 1982.**
- **LQCD predicts:**

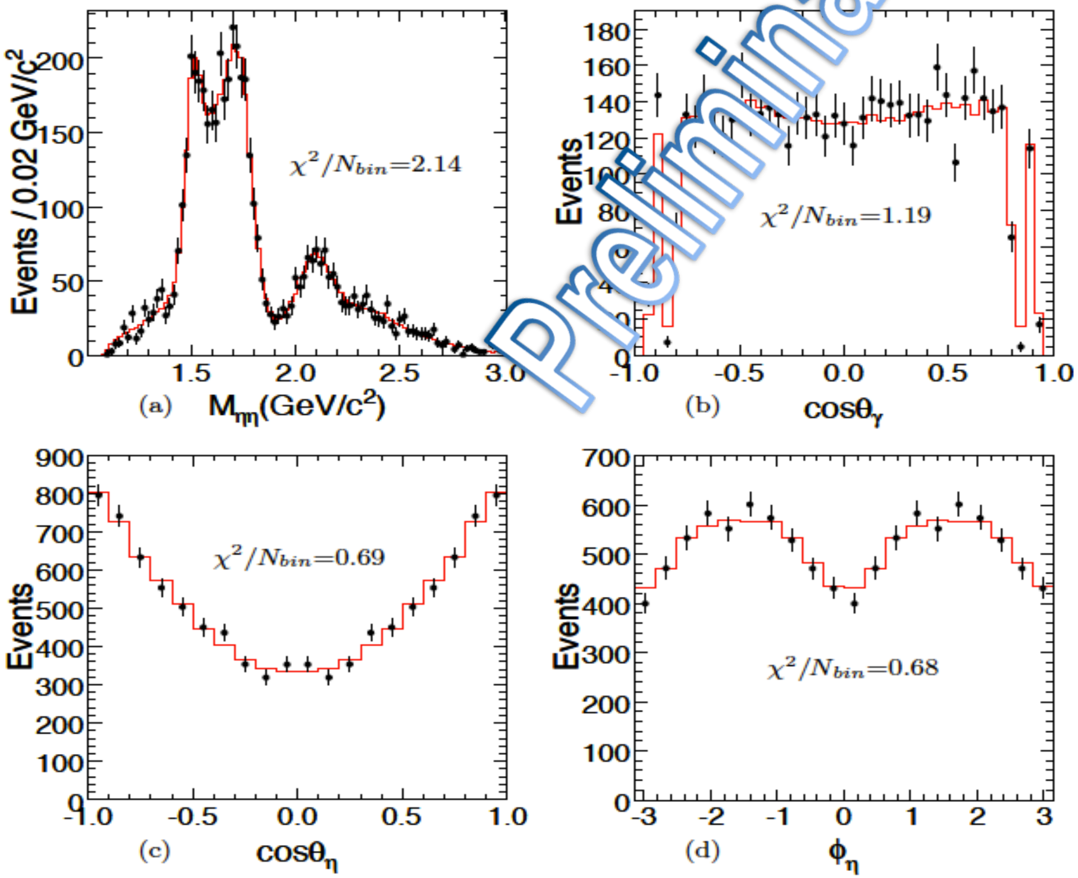
0^{++} : 1710 ± 50 ± 80



- **Crystal Barrel Collaboration (2002) analyzed the three final states $\pi^0\pi^0\pi^0$, $\eta\pi^0\pi^0$ and $\pi^0\eta\eta$ with K matrix formalism. Found a 2^{++} (~1870), but no $f_0(1710)$.**
- **E835 (2006): ppbar → $\pi^0\eta\eta$, found $f_0(1500)$ and $f_0(1710)$.**
- **WA102 and GAMS all identified $f_0(1710)$ in ηη.**

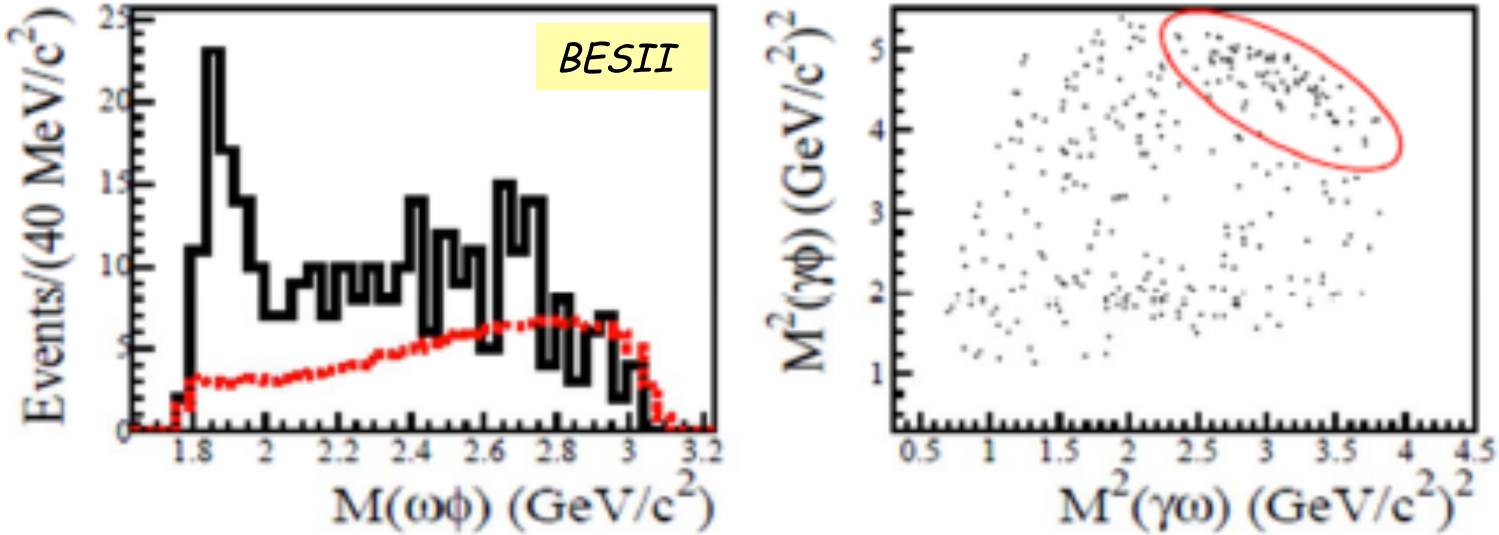
Preliminary PWA results of J/ψ->γηη @BESIII

Resonance	Mass(MeV/c^2)	Width(MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+20}_{-15-74}	$136^{+41+8}_{-26-100}$	$(1.61^{+0.29+0.41}_{-0.32-1.28}) \times 10^{-5}$	8.2 σ
$f_0(1710)$	1759^{+6+14}_{-6-25}	172^{+10+31}_{-10-15}	$(2.35^{+0.07+1.23}_{-0.07-0.72}) \times 10^{-4}$	25.0 σ
$f_0(2100)$	2081^{+13+23}_{-13-34}	273^{+27+65}_{-24-18}	$(9.99^{+0.57+5.52}_{-0.52-2.21}) \times 10^{-5}$	13.9 σ
$f_2'(1525)$	1513^{+5+3}_{-5-10}	$75^{+12[illegible]15}_{[illegible]}$	$(3.41^{+0.43+1.22}_{-0.50-1.23}) \times 10^{-5}$	11.0 σ
$f_2(1810)$	1822^{+29+61}_{-24-54}	$229^{[illegible]}_{[illegible]2-15}$	$(5.38^{+0.60+3.31}_{-0.67-2.24}) \times 10^{-5}$	6.4 σ
$f_2(2340)$	$2362^{+31+139}_{-30-59}$	$33[illegible]^{[illegible]+16}_{[illegible]4-99}$	$(5.58^{+0.61+1.93}_{-0.65-1.81}) \times 10^{-5}$	7.6 σ

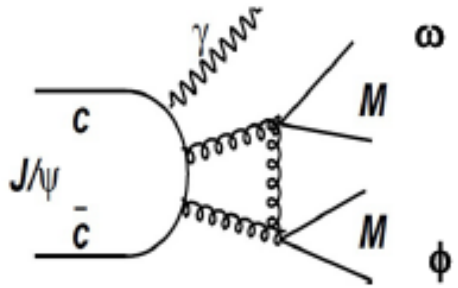


- **$f_0(1710)$ and $f_0(2100)$ are dominant scalars**
- **$f_0(1500)$ exists (8.2 σ)**
- **$f_2'(1525)$ is the dominant tensor**

$M_{\omega\Phi}$ threshold enhancement in J/ψ->γωΦ



PRL 96(2006) 162002



For X(1810):

$$M = 1812^{+19}_{-26} \pm 18\,\mathrm{MeV/c^2}$$

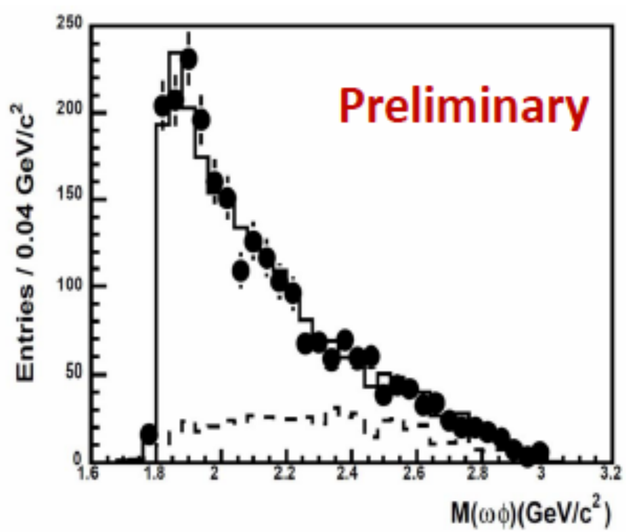
$$\Gamma = 105 \pm 20 \pm 28\,\mathrm{MeV/c^2}$$

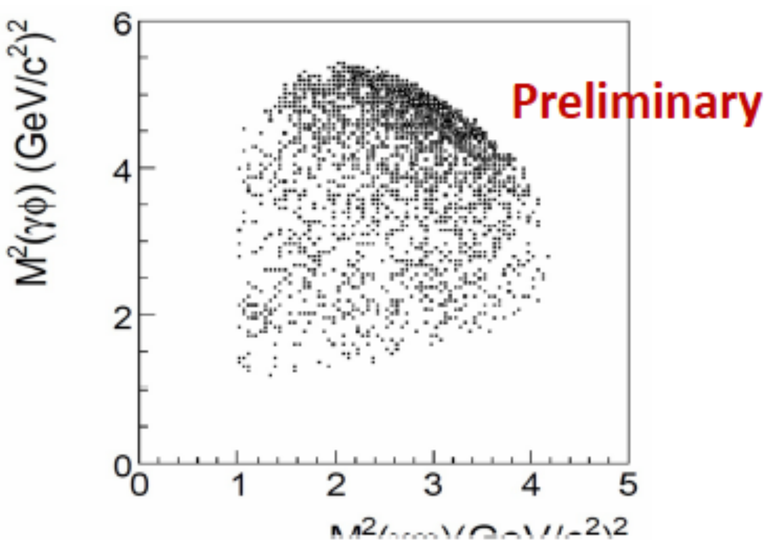
J^{pc} favors 0^{++} over 0^{-+} and 2^{++}

$J/\psi \to \gamma\omega\phi$ **(DOZI)**

Preliminary PWA results of J/ψ->γωΦ @BESIII

Resonance	J^{PC}	$M(MeV/c^2)$	$\Gamma(MeV/c^2)$	Events	ΔS	Δndf	Significance
$X(1810)$	0^{++}	1795 ± 7	95 ± 10	1319 ± 52	783	4	$> 30\sigma$
$f_2(1950)$	2^{++}	1944	472	665 ± 40	211	2	$> 10\sigma$
$f_0(2020)$	0^{++}	1992	442	715 ± 45	100	2	$> 10\sigma$
$\eta(2225)$	0^{-+}	2240	190	70 ± 30	23	2	6.4σ
phase space	0^{-+}	2400	5000	319 ± 24	45	2	$> 8\sigma$



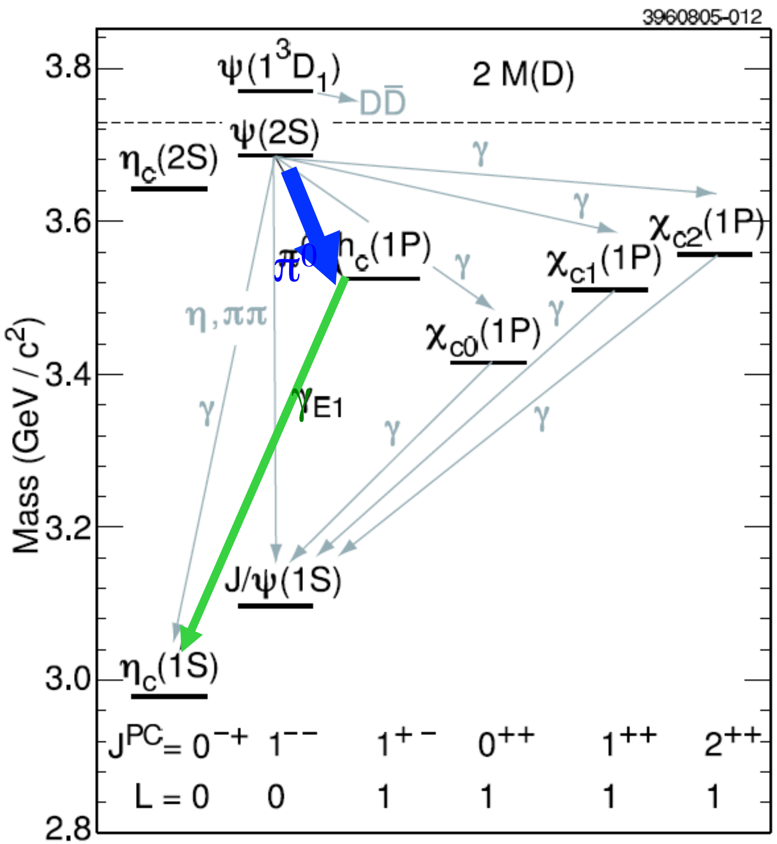


Is X(1810) the f0(1710)/f0(1790) or new state?

Recent results on Charmonium spectroscopy

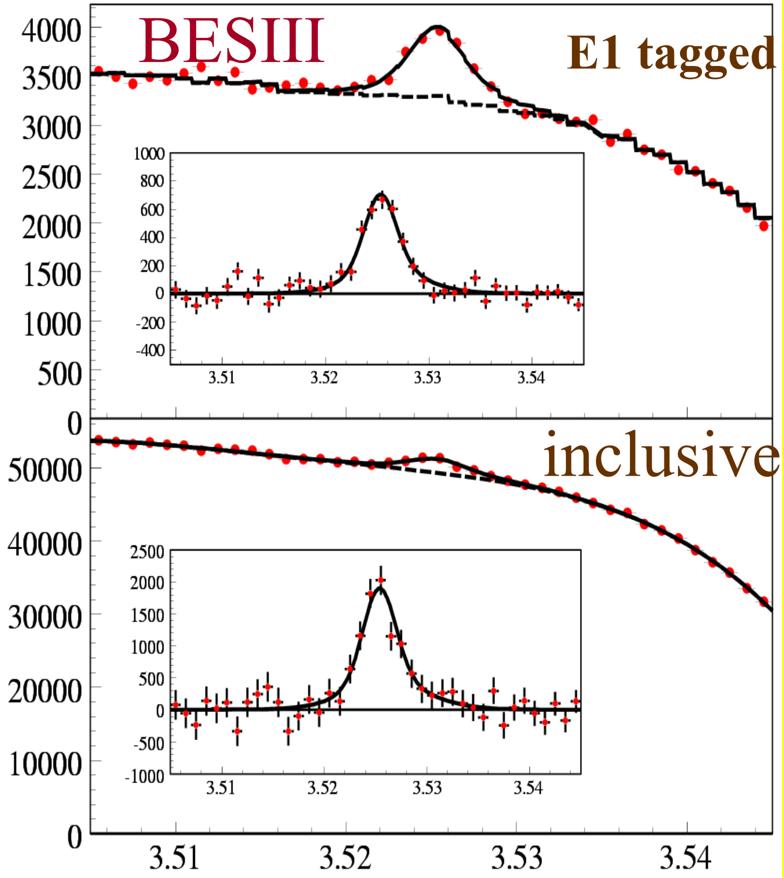
- Properties of h_c
- Mass and width of η_c
- Observation evidence of $\psi'\to\gamma\eta_c(2S)$
- First observation of $\psi'\to\gamma\gamma J/\psi$
- Multipole in $\psi'\to\gamma\chi_{c2}$

Property of h_c



- First evidence:
  E835 in $pp \rightarrow h_c \rightarrow \gamma\eta_c$ (PRD72,092004(2005))
- CLEO-c observed h_c in $ee \rightarrow \psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$
  $\Delta M_{hf}(1P)=0.08\pm0.18\pm0.12$ MeV/c^2
  (PRL104,132002(2010))
- Study isospin forbidden transition:
  $$B(\psi' \rightarrow \pi^0 h_c)$$
- Measure as well the E1 transition:
  $$B(h_c \rightarrow \gamma\eta_c)$$
- $M(h_c)$ gives access to hyperfine splitting of 1P states:
  $\Delta M_{hf}(1P)=M(h_c)-1/9(M(\chi_{c0})+3M(\chi_{c1})+5M(\chi_{c2}))$

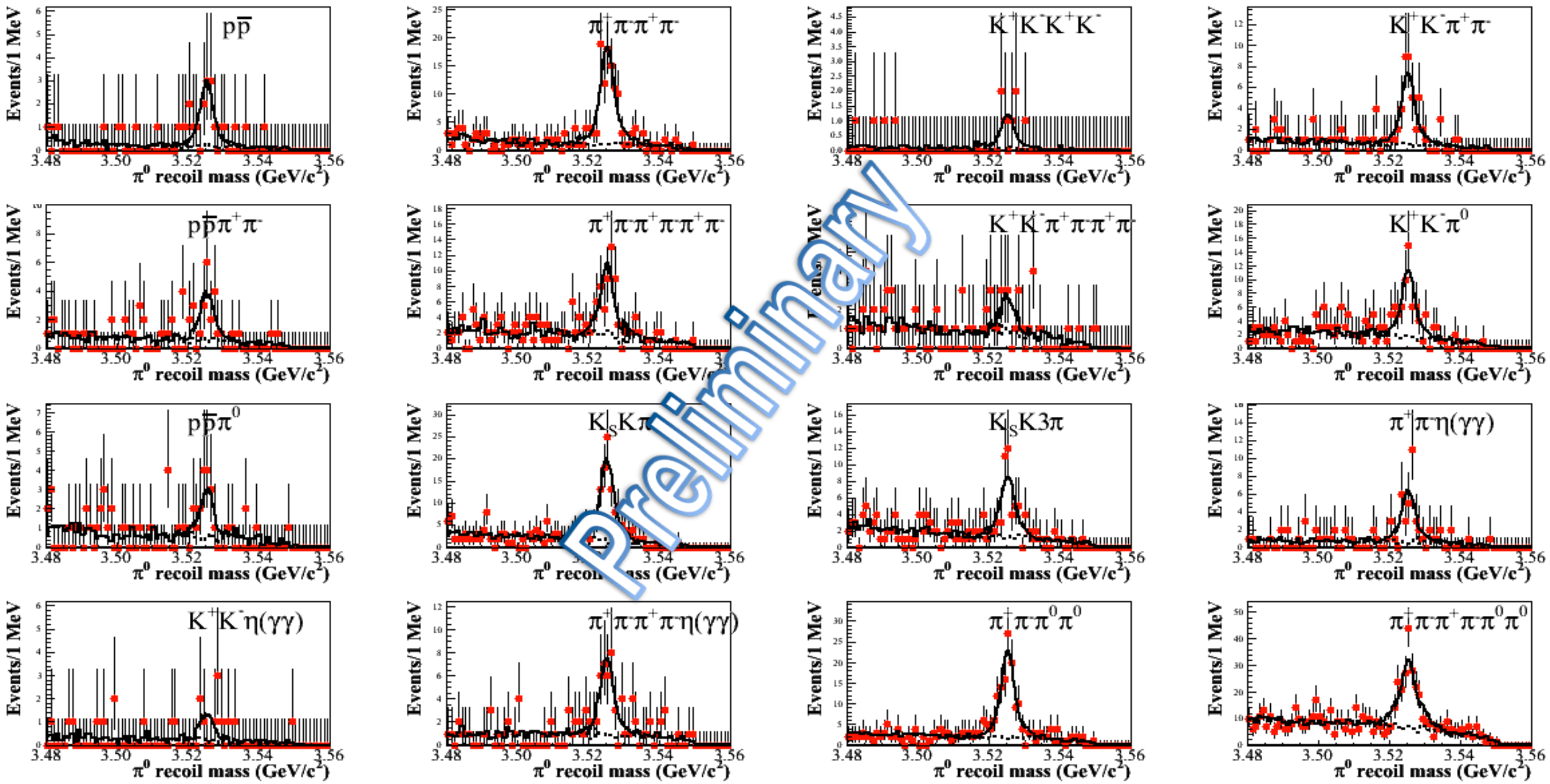
$\psi' \rightarrow \pi^0 h_c$ @ BESIII



PRL104, 132002, (2010)

- Select inclusive π^0 ($\psi' \rightarrow \pi^0 h_c$)
- Select E1-photon in $h_c \rightarrow \gamma\eta_c$ (w/o E1 tagged)
- E1-tagged selection gives
  $M(h_c)$=3525.40±0.13 ±0.18MeV
  ($\Delta M_{hf}(1P)$=0.10±0.13±0.18MeV/c^2)
  $\Gamma(h_c)$=0.73±0.45 ±0.28MeV (first measurement)
  (<1.44MeV at 90% CL)
  $Br(\psi' \rightarrow \pi^0 h_c) \times Br(h_c \rightarrow \gamma\eta_c)$= $(4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$
- E1-untagged selection gives
  $Br(\psi' \rightarrow \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$
- Combining branching fractions leads to
  $Br(h_c \rightarrow \gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$
  (first measurement)

$\psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$, η_c exclusive decays @ BESIII



Simultaneous fit to π^0 recoiling mass
χ^2/d.o.f. = 32/46
Mass = **3525.31 ± 0.11 ± 0.15** MeV/c^2
Width = **0.70 ± 0.28 ± 0.25** MeV

Consistent with BESIII inclusive results PRL104,132002(2010)

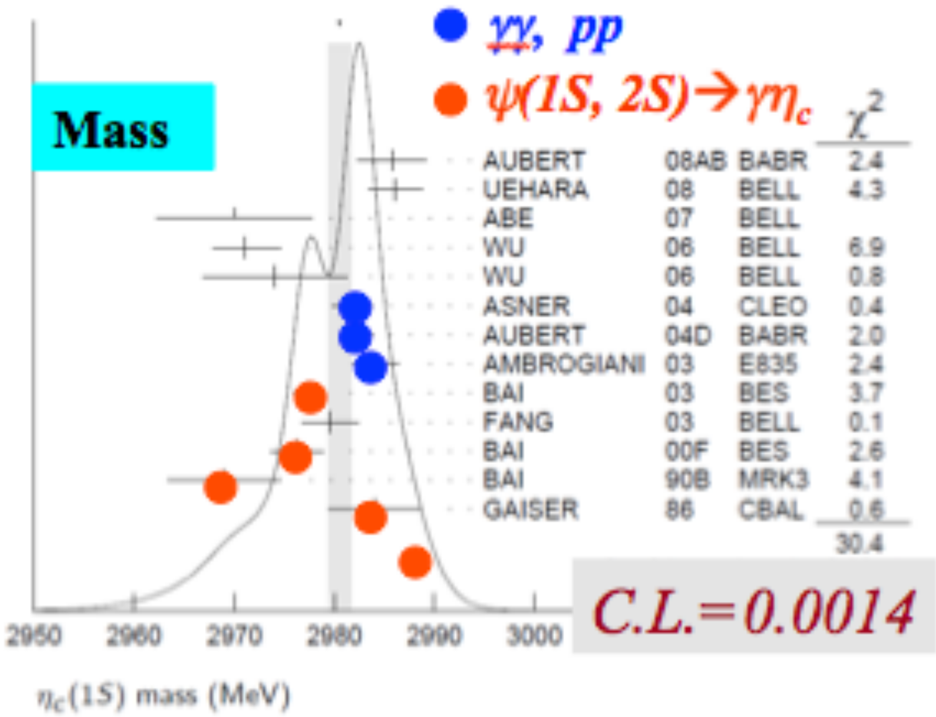
CLEOc exlusive results
$M(h_c)$=3525.21±0.27±0.14 MeV/c^2
N = 136±14
PRL101, 182003(2008)

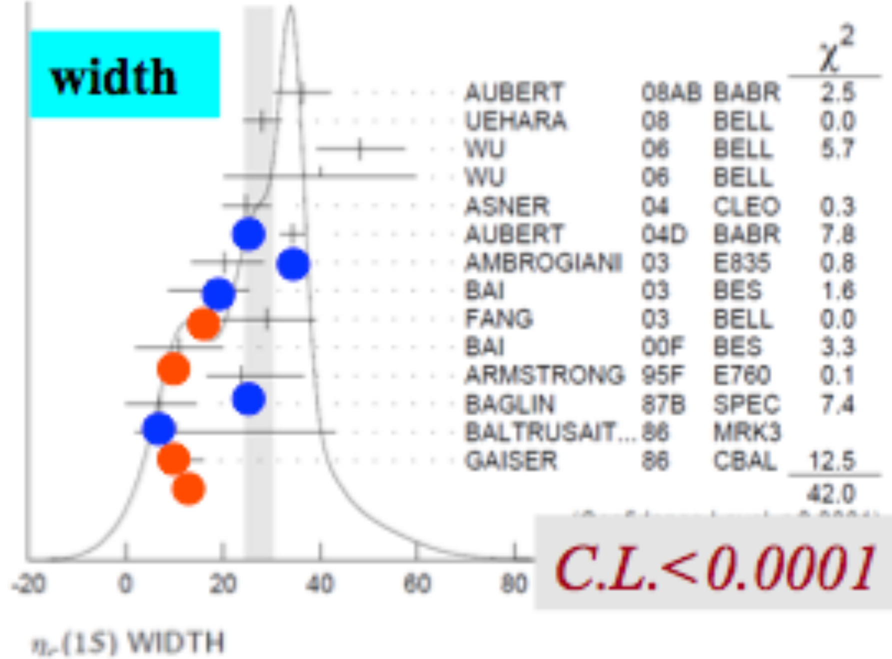
$\eta_c(1S)$

- The lowest lying S-wave spin singlet charmonium, discovered in 1980 by MarkII
- Parameters:

J/ψ, ψ' radiative transition: M ~ 2978.0MeV/c^2, Γ ~ 10MeV

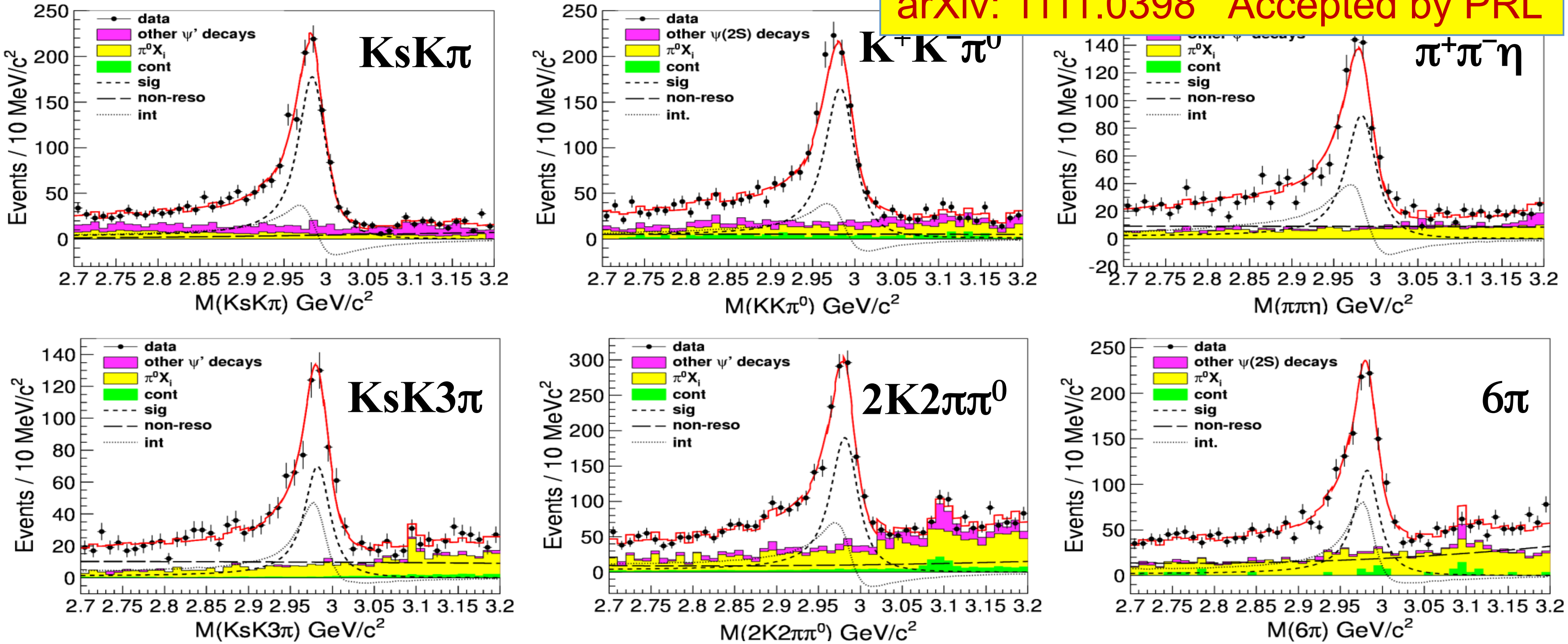
$\gamma\gamma$ process: M = 2983.1±1.0 MeV/c^2, Γ = 31.3±1.9 MeV





$\psi' \rightarrow \gamma\eta_c$, $\eta_c \rightarrow$ exclusive decays @ BESIII

arXiv: 1111.0398 Accepted by PRL



Interference with non-resonant is significant !

Relative phase ϕ values from each mode are consistent within 3σ,

➔ use a common phase value in the simultaneous fit.

M: **2984.4 ± 0.5 ± 0.6** MeV

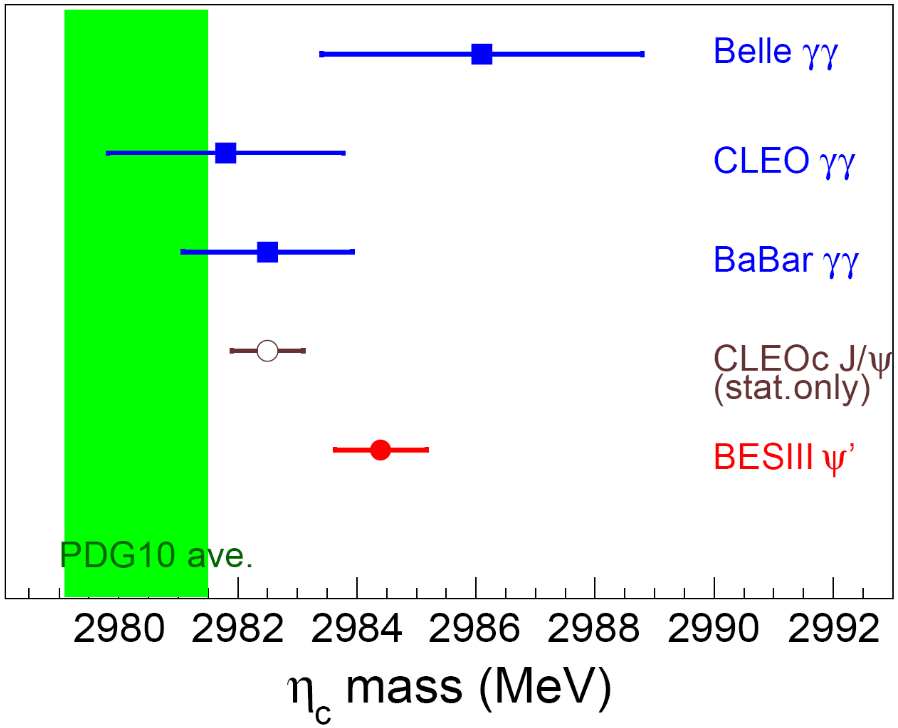
Γ: **30.5 ± 1.0 ± 0.9** MeV

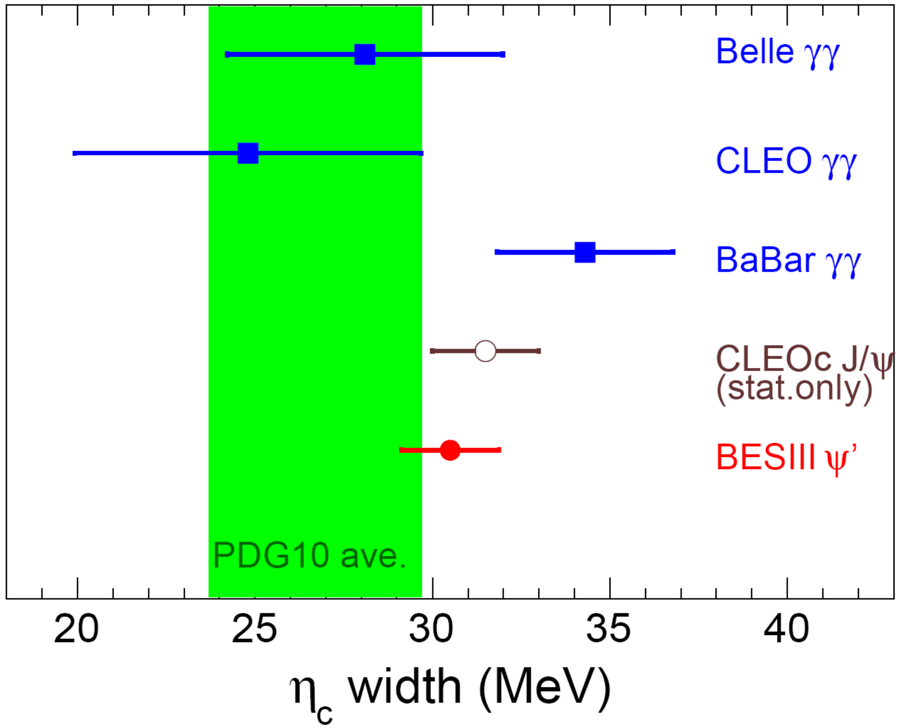
ϕ: **2.35 ± 0.05 ± 0.04** rad

BESIII arXiv:1111:0398 accepted by PRL

Comparison of the mass and width for η_c

The world average in PDG2010 was using earlier measurements





Hyperfine splitting: $\Delta M(1S)$ = **112.6 ± 0.8** MeV

Consistent with B factory results in other production mechanisms.
Agree with lattice QCD calculations of the charmonium hyperfine splitting

$\eta_c(2S)$

Crystal Ball's "first observation" of $\psi' \to \gamma X$ (M=3.592, B=0.2%-1.3%) never been confirmed. *PRL 48 70 (1982)*

"Seen" $\eta_c(2S)$ from inclusive photon spectrum of ψ' decays.
Branch ratios and parameters are far from modern measurements.

Observed in different processes other than radiative transition

Experiment	M [MeV]	Γ [MeV]	Process
Belle [1]	$3654 \pm 6 \pm 8$	—	$B^\pm \to K^\pm \eta_c(2S), \eta_c(2S) \to K_S K^\pm \pi^\mp$
CLEO [2]	$3642.9 \pm 3.1 \pm 1.5$	$6.3 \pm 12.4 \pm 4.0$	$\gamma\gamma \to \eta_c(2S) \to K_S K^\pm \pi^\mp$
BaBar [3]	$3630.8 \pm 3.4 \pm 1.0$	$17.0 \pm 8.3 \pm 2.5$	$\gamma\gamma \to \eta_c(2S) \to K_S K^\pm \pi^\mp$
BaBar [4]	$3645.0 + 5.5^{+4.9}_{-7.8}$	—	$e^+e^- \to J/\psi c\bar{c}$
PDG [5]	3638 ± 4	14 ± 7	—

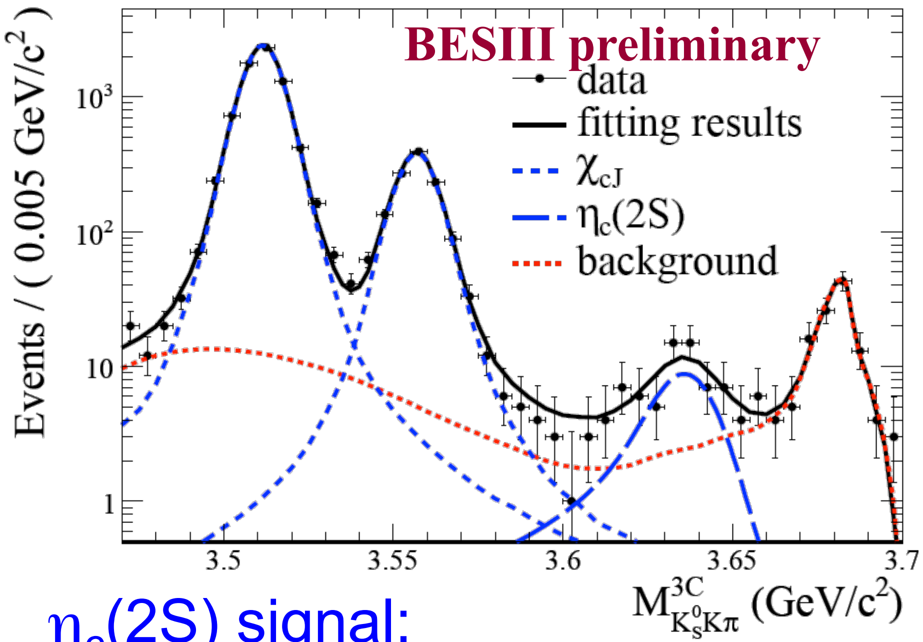
M1 transition $\psi' \to \gamma\eta_c(2S)$

CLEO found no signals in 25M ψ'.

$BF(\psi' \to \gamma\eta_c(2S)) < 7.6\times10^{-4}$ CLEO: PRD 81 052002 (2010)

Experimental challenge : search for photons of 50 MeV

Observation of $\psi' \rightarrow \gamma\eta_c(2S) \rightarrow \gamma (K_s K\pi)$ @BESIII



$\eta_c(2S)$ signal:

$$(E_\gamma^3 \times BW(m) \times damping(E_\gamma)) \otimes Gauss(0,\sigma)$$

M1 transition

$$\frac{E_0^2}{E_\gamma E_0 + (E_\gamma - E_0)^2}$$

Width fixed to 12 MeV (world ave.)

Events: 50.6±9.7; Significance >6.0σ!

Mass = 3638.5±2.3±1.0 MeV/c^2

$Br(\psi' \rightarrow \gamma\eta_c(2S) \rightarrow \gamma K_s K\pi)$

=(2.98±0.57±0.48)×10^{-6}

$Br(\eta_c(2S) \rightarrow KK\pi)$=(**1.9±0.4±1.1**)%

BaBar: PR D78 012006 (2008)

$Br(\psi' \rightarrow \gamma\eta_c(2S))$

= (4.7±0.9±3.0)×10^{-4}

CLEO-c: <**7.6*10^{-4}**

PRD81 052002 (2010)

Potential model predicts

(0.1~ 6.2)*10^{-4}

PRL 89 162002 (2002)

$\psi' \to \gamma\gamma J/\psi$

- Two photon transitions are well known in excitations of molecules, atomic hydrogen, and positronium.

  *[F. Bassani etal, PRL **39**, 1070 (1977);A. Quattropani etal, PRL **50**, 1258 (1983)]*

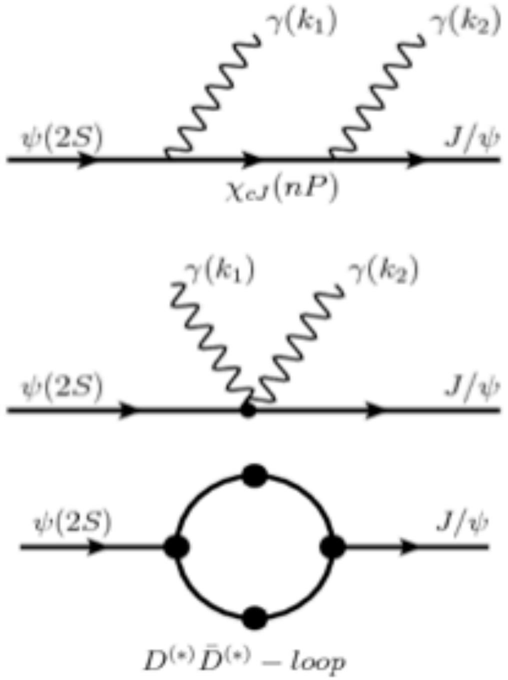
- Never been observed in the quarkonium system.

  CLEOc: upper limit of $Br(\psi' \to \gamma\gamma J/\psi)$ is 1×10^{-3} (PRD 78,011102(2008))

- Observation helpful to understand heavy quarkonium spectrum & strong interaction

Theoretically:

- Potential models give discrete spectra ($\psi(2S) \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi$)
- Possibility of testing the hadron-loop effect
- Coupled channel: **the hadron-loop effect also may play a important role in the continuous spectra**

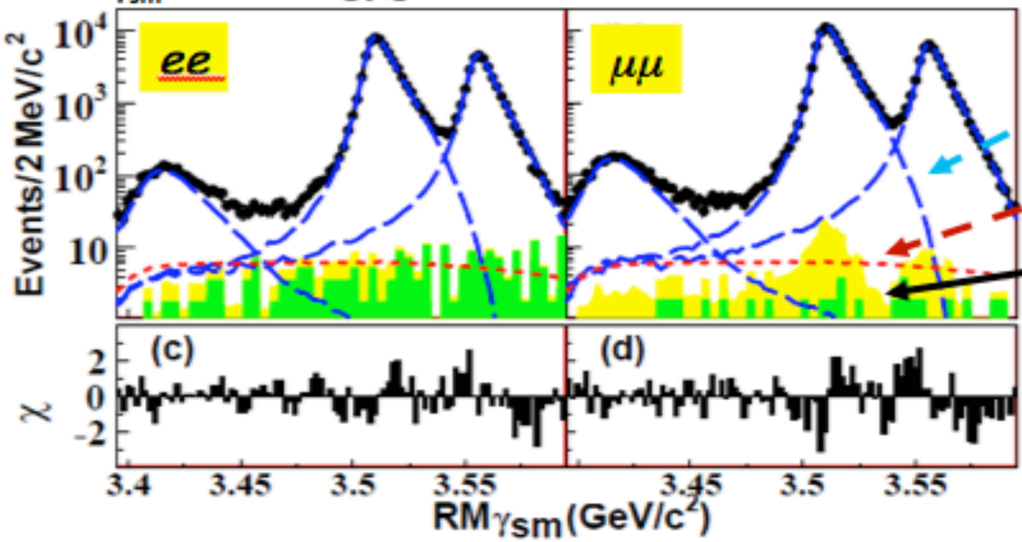


First evidence of ψ' ->γγJ/ψ @BESIII

arXiv: 1204.0246

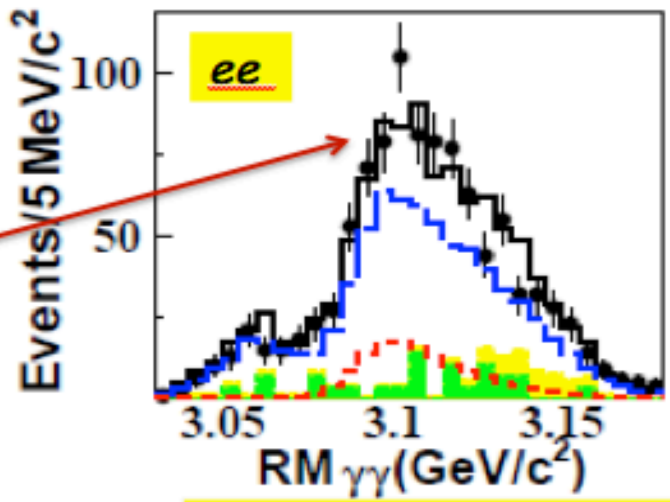
- Select $\psi(2S) \to \gamma\gamma J/\psi$, $J/\psi \to e^+e^-$ and $\mu^+\mu^-$ events

γ_{sm} - low energy gamma



- the χ_{cJ} components: double E1 scaling
- yields of the two-photon events
- continuum(green)+ ψ'-decay BG(yellow)

- Global fit of the two-photon process and cascade χ_{cJ} processes
- See **clear excess** over BG + continuum

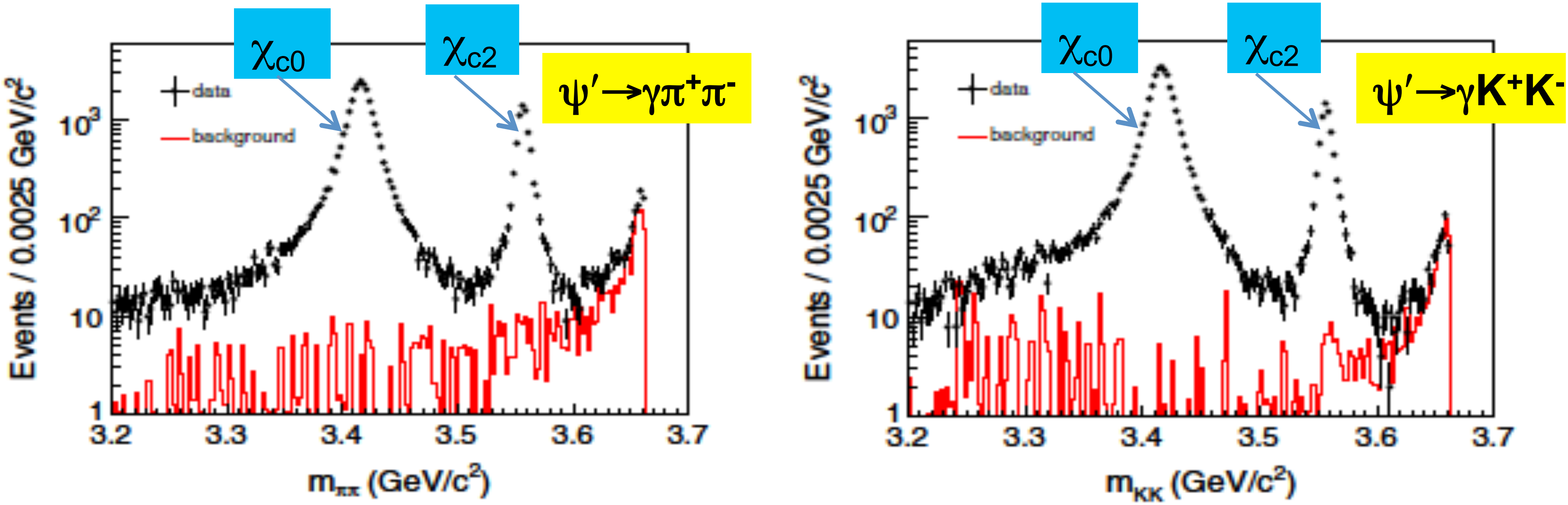


3.44<RM(γ_{sm})<3.48GeV

- $Br(\psi' \to \gamma\gamma J/\psi) = (3.3 \pm 0.6^{+0.8}_{-1.1}) \times 10^{-4}$ (both *ee* and $\mu\mu$)
- **Significance : 3.8σ including systematics**
- $Br(\psi' \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma J/\psi)$ are also measured

Higher-order Multipole in $\psi' \to \gamma\chi_{c2}$, $\chi_{c2} \to \pi^+\pi^-, K^+K^-$

- $\psi' \to \gamma\chi_{c2}$ is dominated by electric dipole (E1) transition, but expect some magnetic quadrupole component (M2).
- M2 amplitude provides sensitivity to charm quark anomalous magnetic moment κ : $\mathrm{M2} = 0.029(1+\kappa)$
- Use large clean samples of $\chi_{c2} \to \pi^+\pi^-$ and $\chi_{c2} \to K^+K^-$; χ_{c0} samples used as control since M2 = 0.



Higher-order Multipole in $\psi' \to \gamma\chi_{c2}$, $\chi_{c2} \to \pi^+\pi^-, K^+K^-$

PRD84, 092006 (2011)

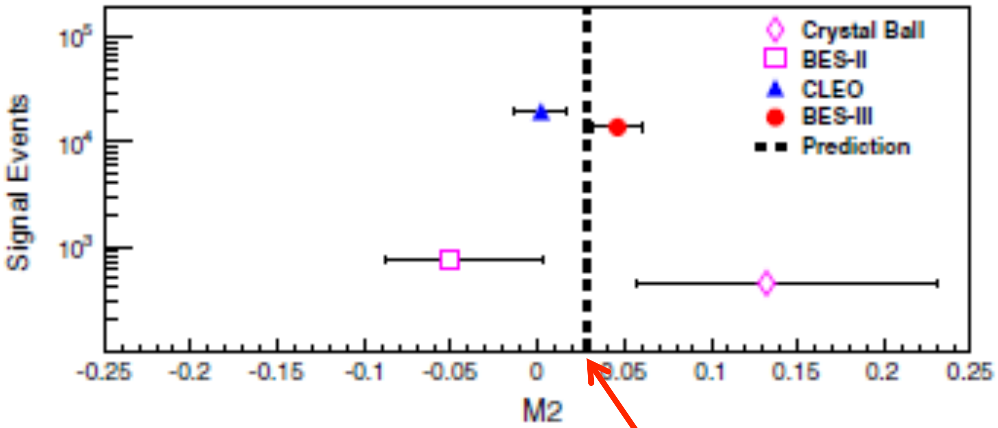
- Extract M2 using fit to full angular distribution

Evidence of M2 contribution:

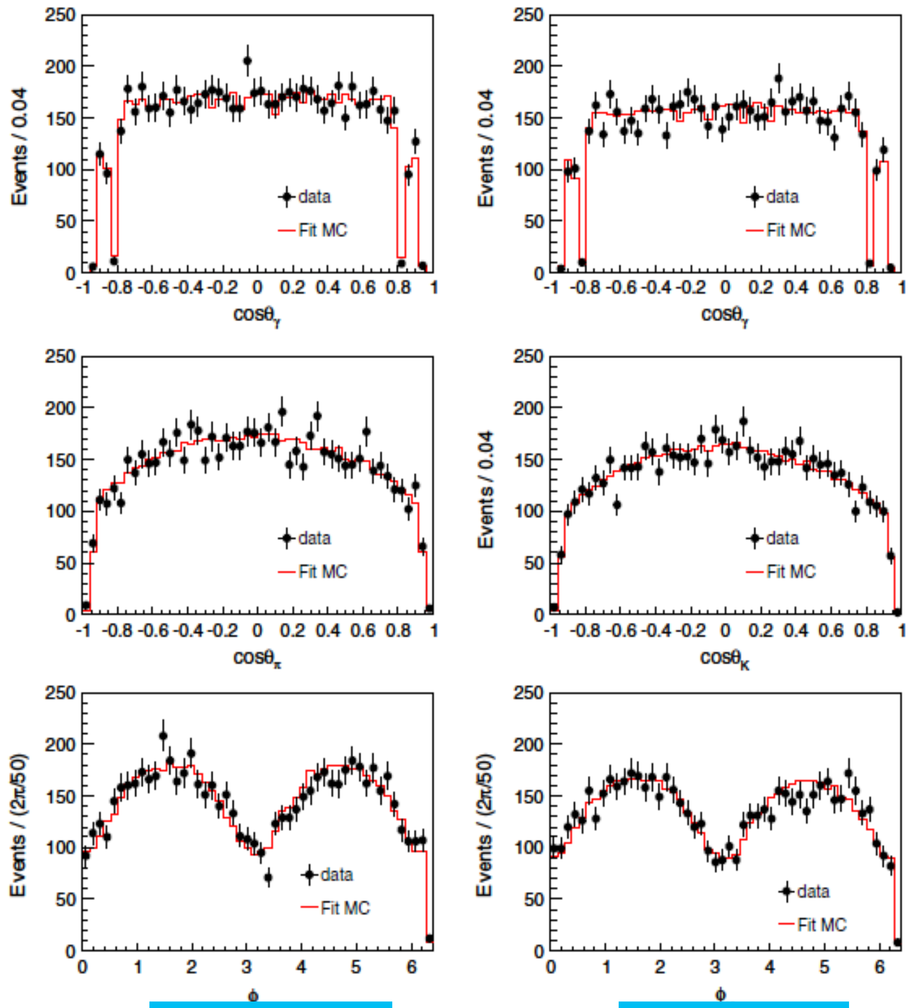
$$M2 = 0.046 \pm 0.010 \pm 0.013,$$
$$E3 = 0.015 \pm 0.008 \pm 0.018,$$

4.4σ

- Significant signal for M2 amplitude that is consistent with κ =0



M(c) = 1.5 GeV and κ = 0



$\chi_{c2} \to \pi^+\pi^-$,

$\chi_{c2} \to K^+K^-$

Recent results on Charmonium Decays

- $\psi' \rightarrow \gamma\pi^0, \gamma\eta, \gamma\eta'$
- Search for $\eta_c(2S) \rightarrow VV$
- χ_{cJ} decays

ψ'→γ P(π⁰,η,η'), arise surprises

ψ' →γ P are important tests for various mechanisms:

Vector meson Dominance Model (VDM); Couplings & form factor;
Mixing of η-η′(-η_c); FSR by light quarks; 12% rule and "ρ π puzzle".

theory

experiment

$$R_{(c\bar{c})} = \frac{Br((c\bar{c})\to\gamma\eta)}{Br((c\bar{c})\to\gamma\eta')}$$

LO-pQCD

⇓

$$R_{\psi'} \simeq R_{J/\psi}$$

PRP 112,173 (1984)

CLEO-c: J/ψ, ψ', ψ'' →γ P

$R_{J/\psi}$ = (21.1± 0.9)%

No Evidence for ψ' →γ π^0 or γ η

Br(ψ′→γη′)=(1.19 ± 0.09)%

$R_{\psi'}$ < 1.8% at 90% CL

⇓

$R_{\psi'}$ << $R_{J/\psi}$

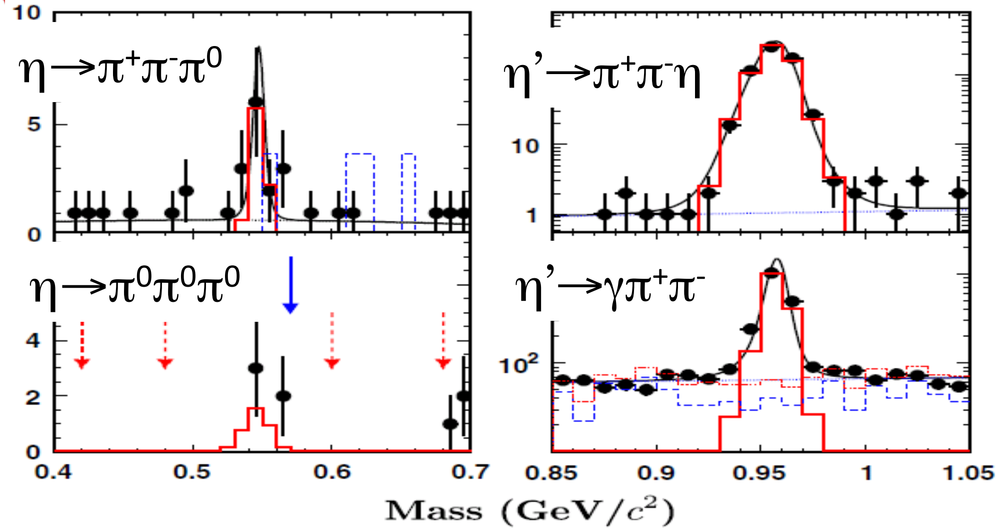
PRD 79, 111101 (2009)

$\psi' \to \gamma P(\pi^0, \eta, \eta')$ @ BESIII

$\psi' \to \gamma\eta$

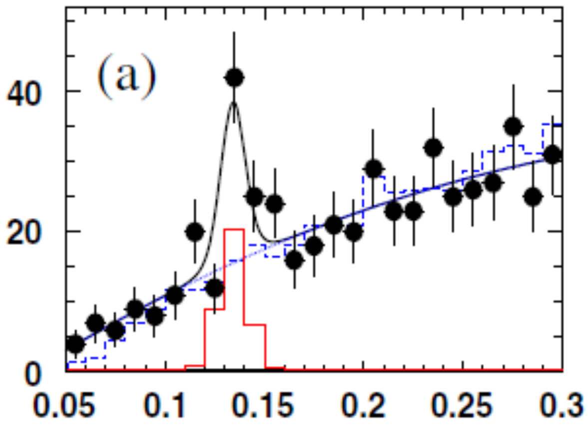
(First evidence 4.3σ)

$\psi' \to \gamma\eta'$



$\psi' \to \gamma\pi^0$

(First evidence 4.6 σ)



Mode	$B(\psi')$ $[\times 10^{-6}]$	$B(J/\psi)$ $[\times 10^{-4}]$ (PDG)	Q (%)
$\gamma\pi^0$	1.58±0.42	0.35±0.03	4.5 ± 1.3
$\gamma\eta$	1.38±0.49	11.04±0.34	0.13 ± 0.04
$\gamma\eta'$	126±9	52.8±1.5	2.4 ± 0.2

$R_{\psi'} = (1.10 \pm 0.38 \pm 0.07)\% \ll R_{J/\psi}$

PRL105, 261801, (2010)

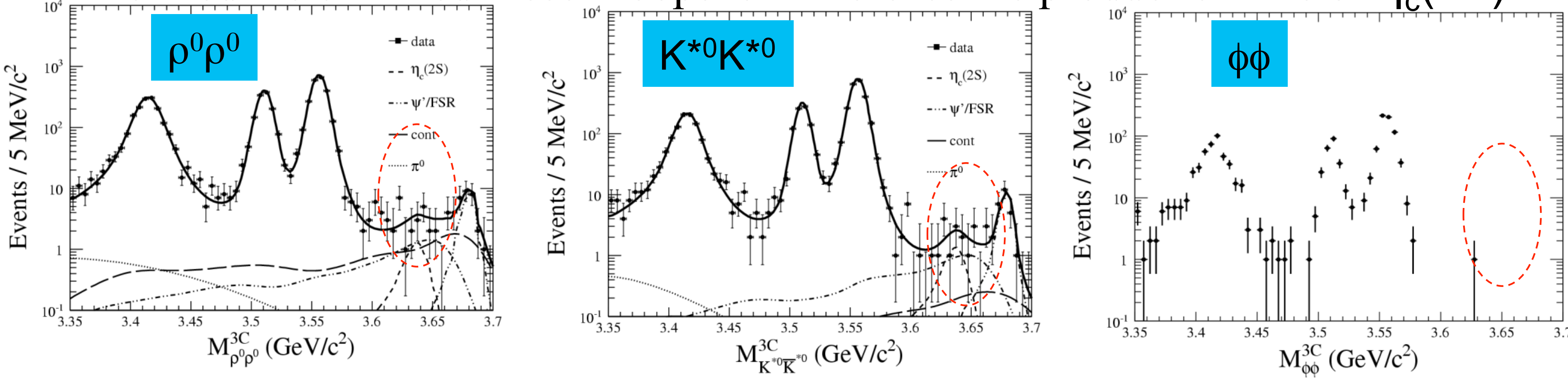
Search for $\eta_c(2S) \rightarrow VV$

Test for the 'intermediate charmed meson loops':

PRD84, 091102R (2011)

$\eta_c(2S) \rightarrow VV$ is highly suppressed by the helicity selection rule.

'intermediate charmed meson loops' can increase the production rate of $\eta_c(2S) \rightarrow VV$.



	$Br(\psi' \rightarrow \gamma\eta_c(2S) \rightarrow \gamma VV$ (10^{-7})	$Br(\eta_c' \rightarrow VV)$ (10^{-3}) (using BESIII BF($\psi' \rightarrow \gamma\eta_c(2S)$))	$Br(\eta_c' \rightarrow VV)$ (10^{-3}) Theory: (arXiv:1010.1343)
$\rho^0\rho^0$	<12.7	<3.1	6.4 ~ 28.9
$K^{*0}K^{*0}$	<19.6	<5.4	7.9 ~ 35.8
$\phi\phi$	< 7.8	<2.0	2.1 ~ 9.8

- ***No signals observed in $\eta_c(2S) \rightarrow \rho\rho$, $K^{*0}K^{*0}$, $\phi\phi$;***
- ***more stringent UL's are set.***

χ_{cJ} study at BESIII

The χ_{cJ} decays provide good place to:

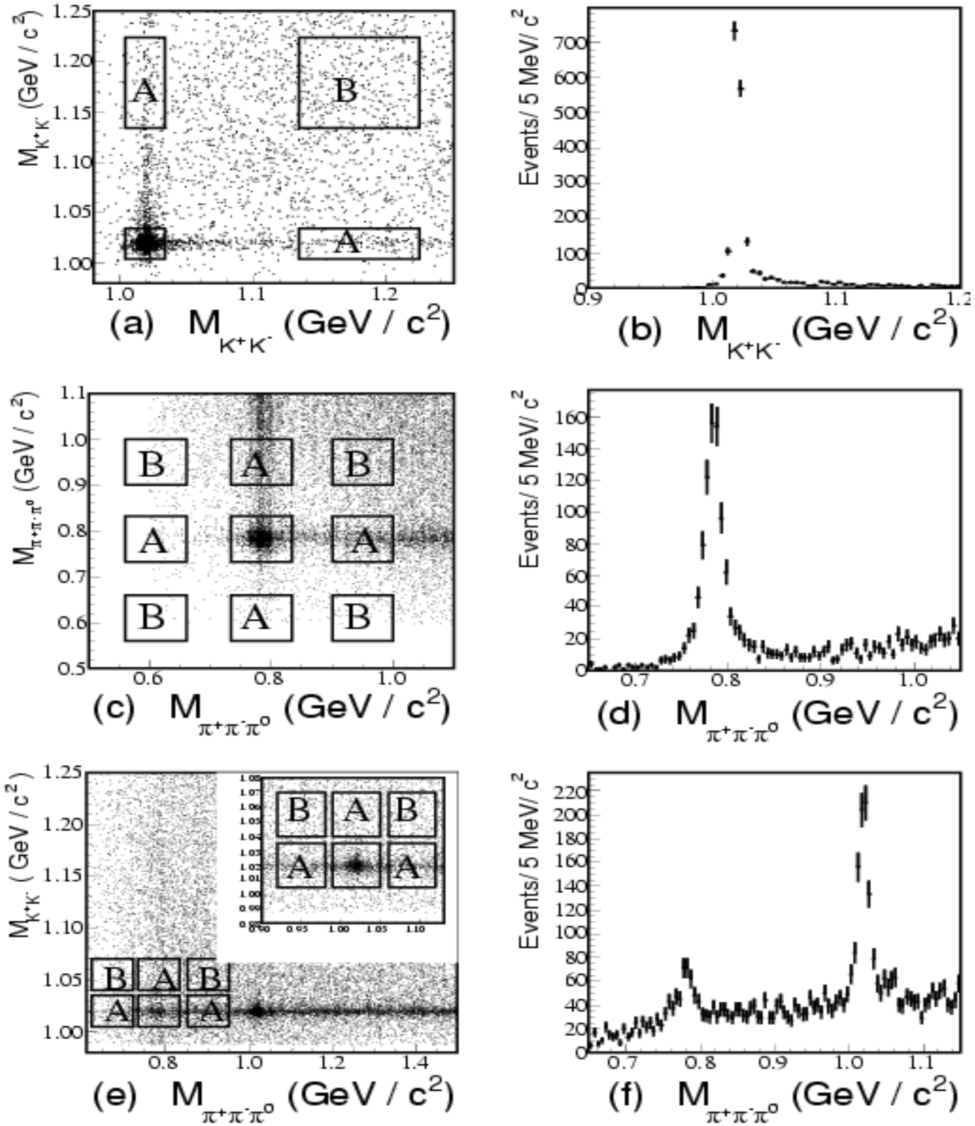
- **Study gluonium: $\chi_c \rightarrow gg \rightarrow (qq)(qq)$**
  C. Amsler and F. E. Close,Phys. Rev. D 53, 295 (1996).
- **Test the Color Octet Mechanism(COM)**
  G. T. Bodwin *et al*., Phys Rev. Lett. D51, 1125 (1995).
  H.-W. Huang and K.-T. Chao, Phys. Rev. D54, 6850 (1996).
  J. Bolz *et al*., Eur. Phys. J. C 2, 705 (1998).

- **First measurement of $\chi_{cJ} \rightarrow \omega\phi$, $\omega\omega$, $\phi\phi$**
- **First measurement of $\chi_{cJ} \rightarrow \gamma\phi$**

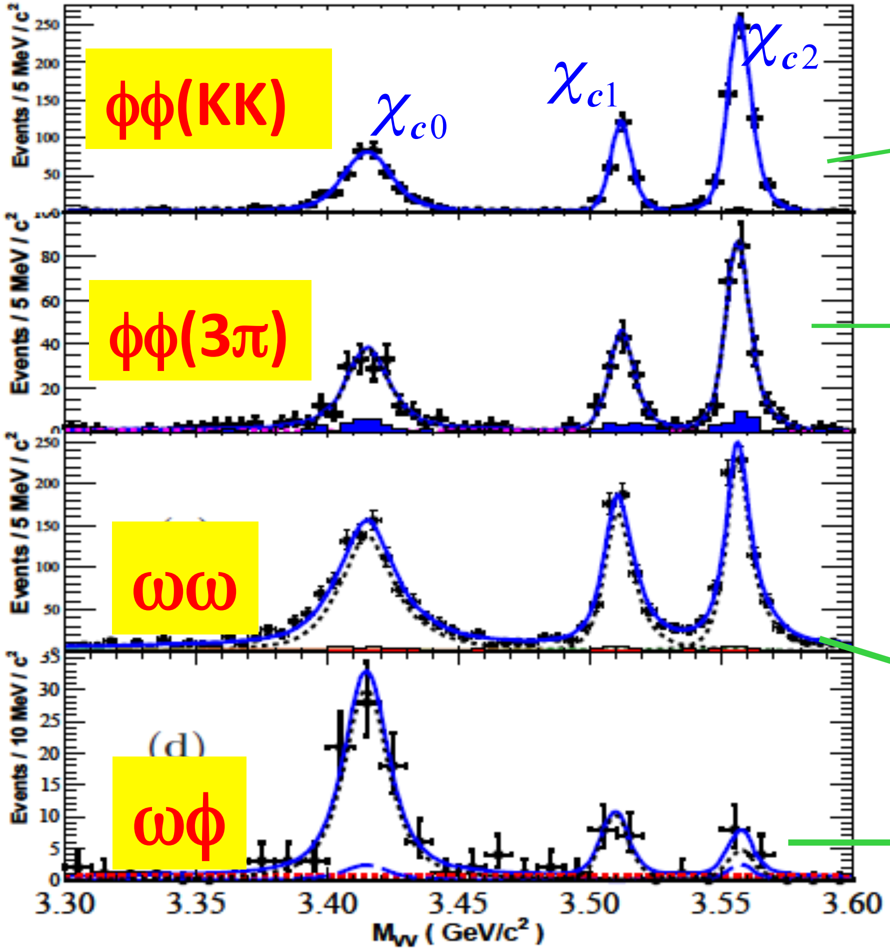
$\chi_{cJ} \rightarrow VV$ (V: ω, ϕ)

- $\chi_{cJ} \rightarrow \phi\phi$ and $\chi_{cJ} \rightarrow \omega\omega$ are Singly OZI suppressed
- $\chi_{c1} \rightarrow \phi\phi$ and $\chi_{c1} \rightarrow \omega\omega$ is suppressed by helicity selection rule.
- $\chi_{cJ} \rightarrow \phi\omega$ is doubly OZI suppressed, not measured yet

PRL107, 091803 (2011)



$\chi_{cJ} \rightarrow$ VV(V: ω, ϕ)



Mode	N_{net}	ϵ (%)	$\mathcal{B}(\times 10^{-4})$
$\chi_{c0} \to \phi\phi$	433 ± 23	22.4	$7.8 \pm 0.4 \pm 0.8$
$\chi_{c1} \to \phi\phi$	254 ± 17	26.4	$4.1 \pm 0.3 \pm 0.4$
$\chi_{c2} \to \phi\phi$	630 ± 26	26.1	$10.7 \pm 0.4 \pm 1.1$
$\to 2(K^+K^-)$			
$\chi_{c0} \to \phi\phi$	179 ± 16	1.9	$9.2 \pm 0.7 \pm 1.0$
$\chi_{c1} \to \phi\phi$	112 ± 12	2.3	$5.0 \pm 0.5 \pm 0.6$
$\chi_{c2} \to \phi\phi$	219 ± 16	2.2	$10.7 \pm 0.7 \pm 1.2$
$\to K^+K^-\pi^+\pi^-\pi^0$			
Combined:			
$\chi_{c0} \to \phi\phi$	—	—	$8.0 \pm 0.3 \pm 0.8$
$\chi_{c1} \to \phi\phi$	—	—	$4.4 \pm 0.3 \pm 0.5$
$\chi_{c2} \to \phi\phi$	—	—	$10.7 \pm 0.3 \pm 1.2$
$\chi_{c0} \to \omega\omega$	991 ± 38	13.1	$9.5 \pm 0.3 \pm 1.1$
$\chi_{c1} \to \omega\omega$	597 ± 29	13.2	$6.0 \pm 0.3 \pm 0.7$
$\chi_{c2} \to \omega\omega$	762 ± 31	11.9	$8.9 \pm 0.3 \pm 1.1$
$\to 2(\pi^+\pi^-\pi^0)$			
$\chi_{c0} \to \omega\phi$	76 ± 11	14.7	$1.2 \pm 0.1 \pm 0.2$
$\chi_{c1} \to \omega\phi$	15 ± 4	16.2	$0.22 \pm 0.06 \pm 0.02$
$\chi_{c2} \to \omega\phi$	< 13	15.7	< 0.2
$\to K^+K^-\pi^+\pi^-\pi^0$			

Evidence

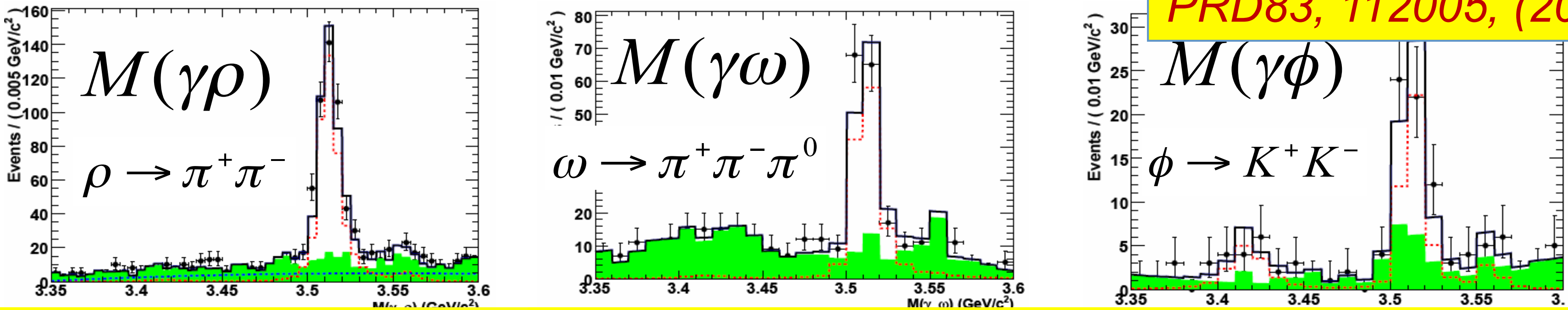
First observation

Long distance transitions could contribute via the intermediate meson loops.

PRD81 014017 (2010) , PRD81 074006 (2010)

$\chi_{cJ} \to \gamma$ V (V:ρ,ω,φ)

PRD83, 112005, (2011)



Branching fractions for χ_{cJ} radiative decays to a vector meson (In units of 10^{-6})

Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]	BESIII
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0	<10.5
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42	228±13±22
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38	<20.8
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22	<12.9
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7	69.7±7.2±6.6
$\chi_{c2} \to \gamma\omega$	< 7.0	0.5	1.5	4.2	<6.1
$\chi_{c0} \to \gamma\phi$	< 6.4	0.46	1.3	0.03	<16.2
$\chi_{c1} \to \gamma\phi$	< 26	3.6	11	11	25.8±5.2±2.3
$\chi_{c2} \to \gamma\phi$	< 13	1.1	3.3	6.5	<8.1

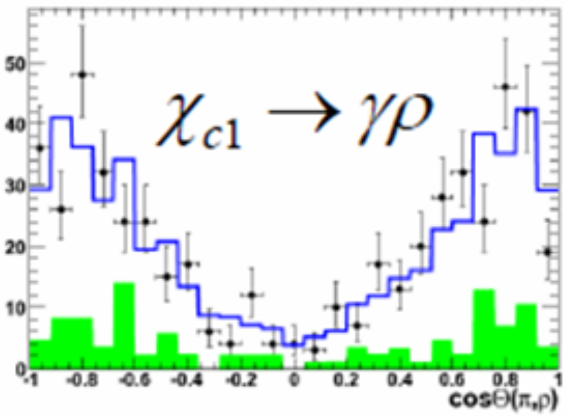
First observation

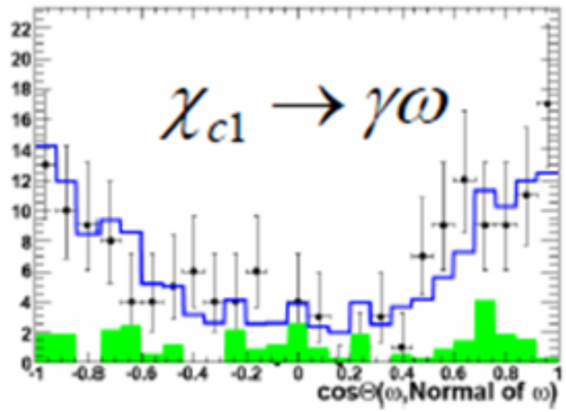
prediction by pQCD much lower than experiment

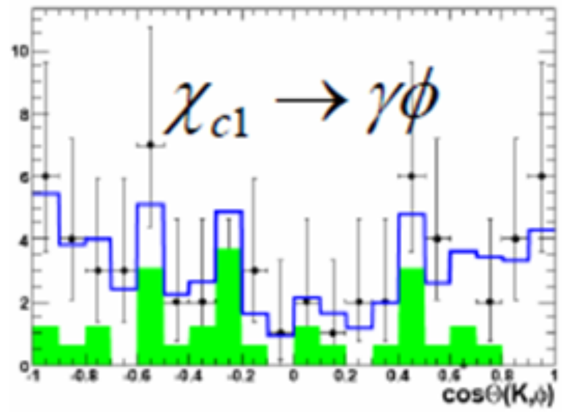
Polarization of $\chi_{cJ} \to \gamma V$ (V: ρ,ω,ϕ)

Longitudinal polarization (f_L); Transverse polarization (f_T); Helicity angle (θ)

$$\frac{d\Gamma}{\Gamma d\cos\theta} \propto (1-f_T)\cos^2\theta + \frac{1}{2} f_T \sin^2\theta \qquad f_T = \frac{|A_T|^2}{|A_T|^2 + |A_L|^2}$$







$f_T = 0.158 \pm 0.034^{+0.015}_{-0.014}$ $\quad$ $f_T = 0.247^{+0.090+0.044}_{-0.087-0.026}$ $\quad$ $f_T = 0.29^{+0.13+0.10}_{-0.12-0.09}$

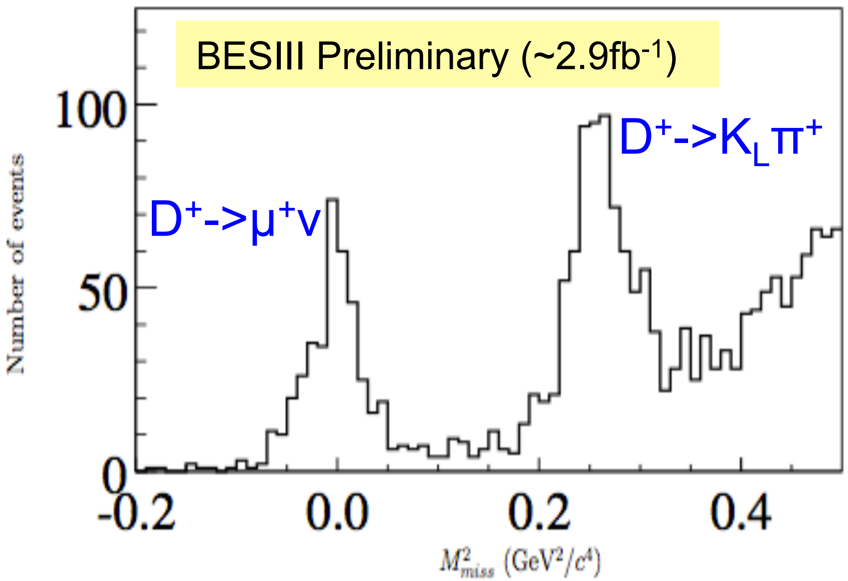
Longitudinal polarization dominates, consistent with theoretical prediction

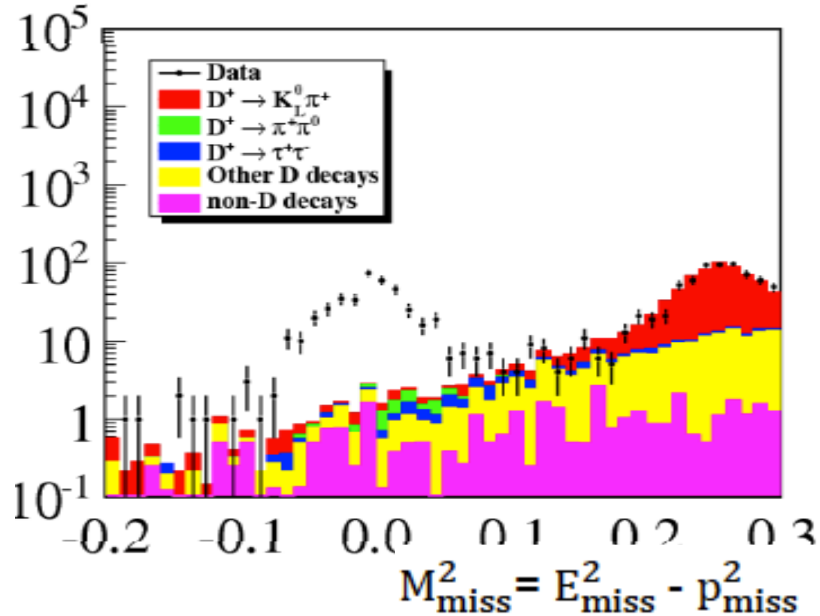
PRD83, 112005, (2011)

Recent results on D analysis

- Leptonic Decays
- Semi-leptonic Decays
- Search for D0->γγ

Preliminary results of $D^+ \to \mu^+\nu$ @BESIII





Results: $N(D^+ \to \mu^+\nu) = 377.3 \pm 19.4$

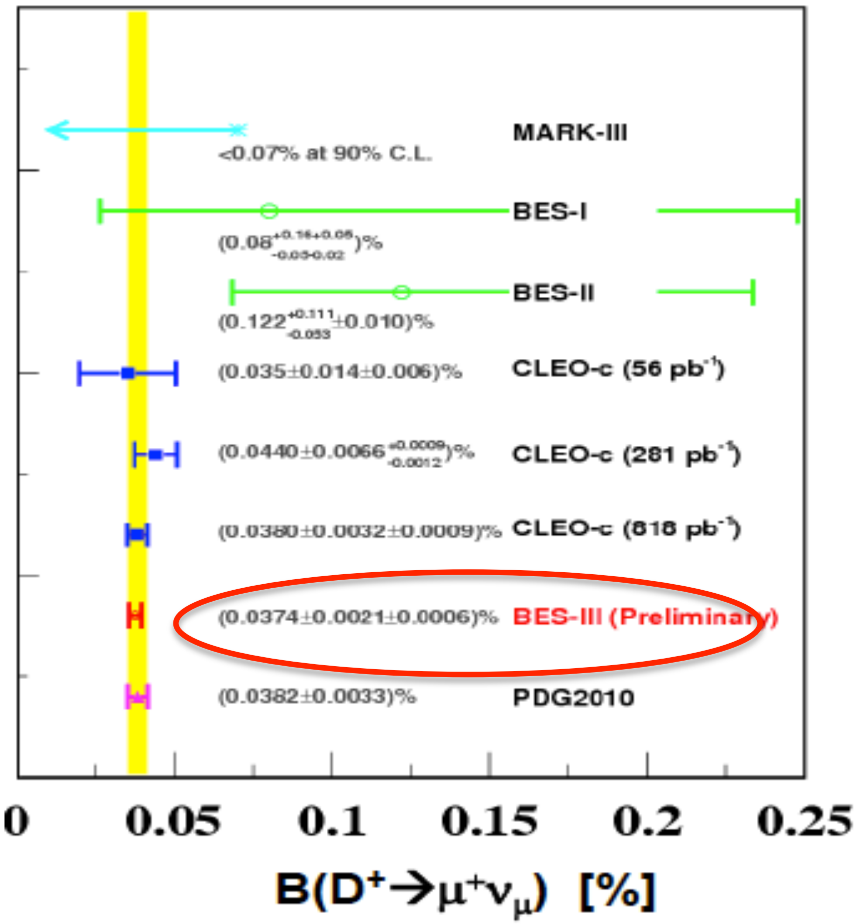
$BF(D^+ \to \mu^+\nu) = (3.74 \pm 0.21 \pm 0.06) \times 10^{-4}$

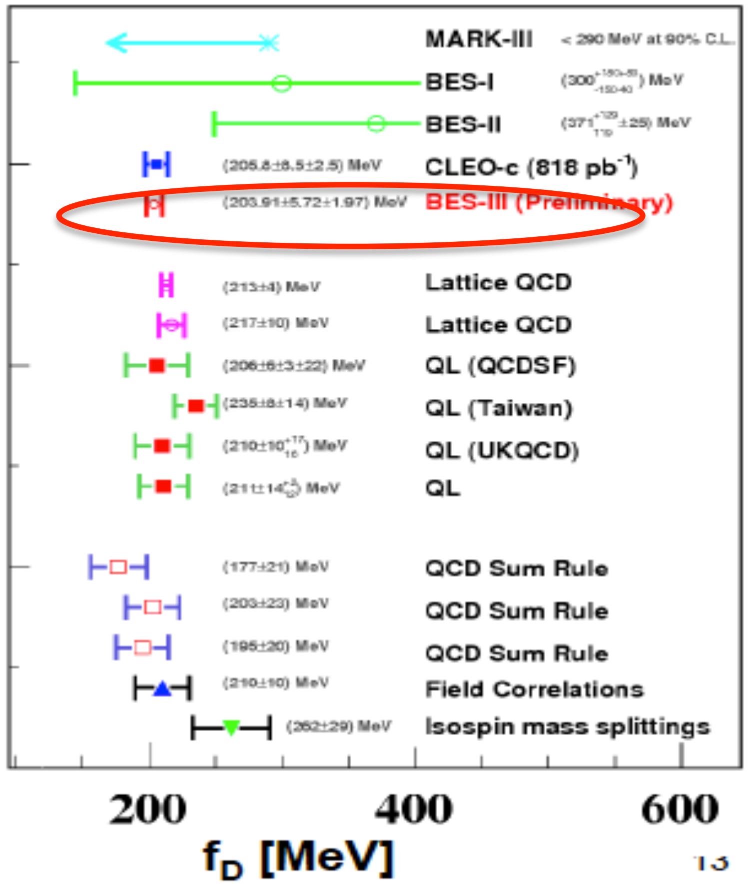
$$\Gamma(D^+ \to l^+\upsilon_l) = \frac{G_F^2 f_{D^+}^2}{8\pi} |V_{cd}|^2 m_l^2 m_{D^+} (1 - \frac{m_l^2}{m_{D^+}^2})^2$$

$f_{D+} = (203.91 \pm 5.72 \pm 1.97)$ MeV

$|V_{cd}| = (0.222 \pm 0.006 \pm 0.005)$

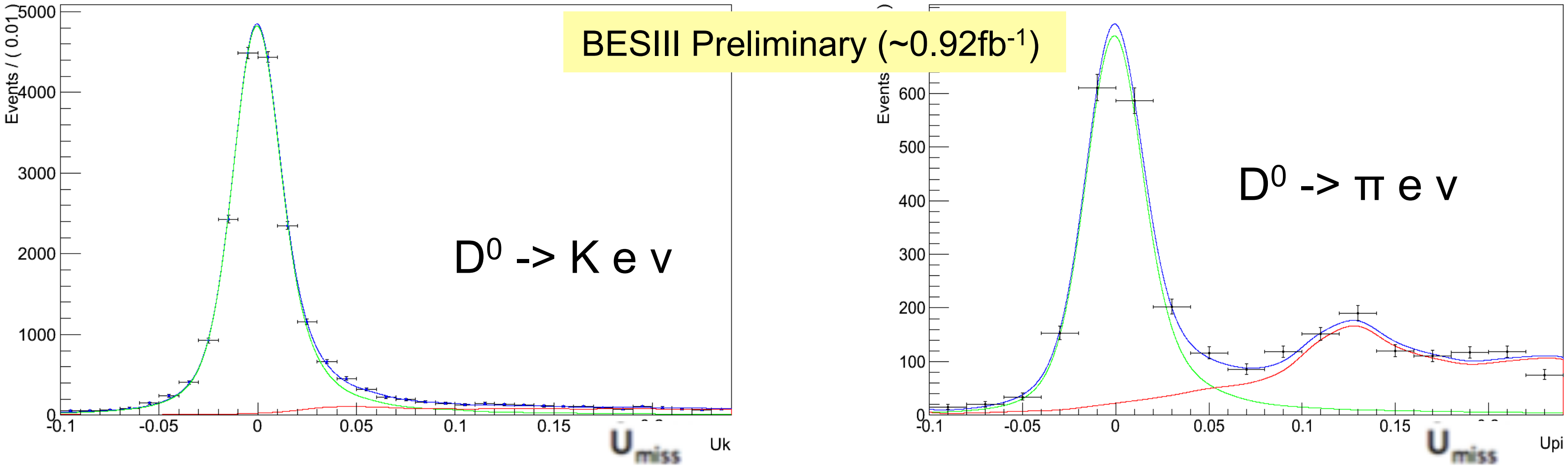
Comparison of $B(D^+ \rightarrow \mu^+\nu)$ & f_D





- The most precise measurement is provided by BESIII
- the error is still dominated by statistics, needing more data taken at 3773 GeV to reduce it.

Semi-leptonic Decays @BESIII

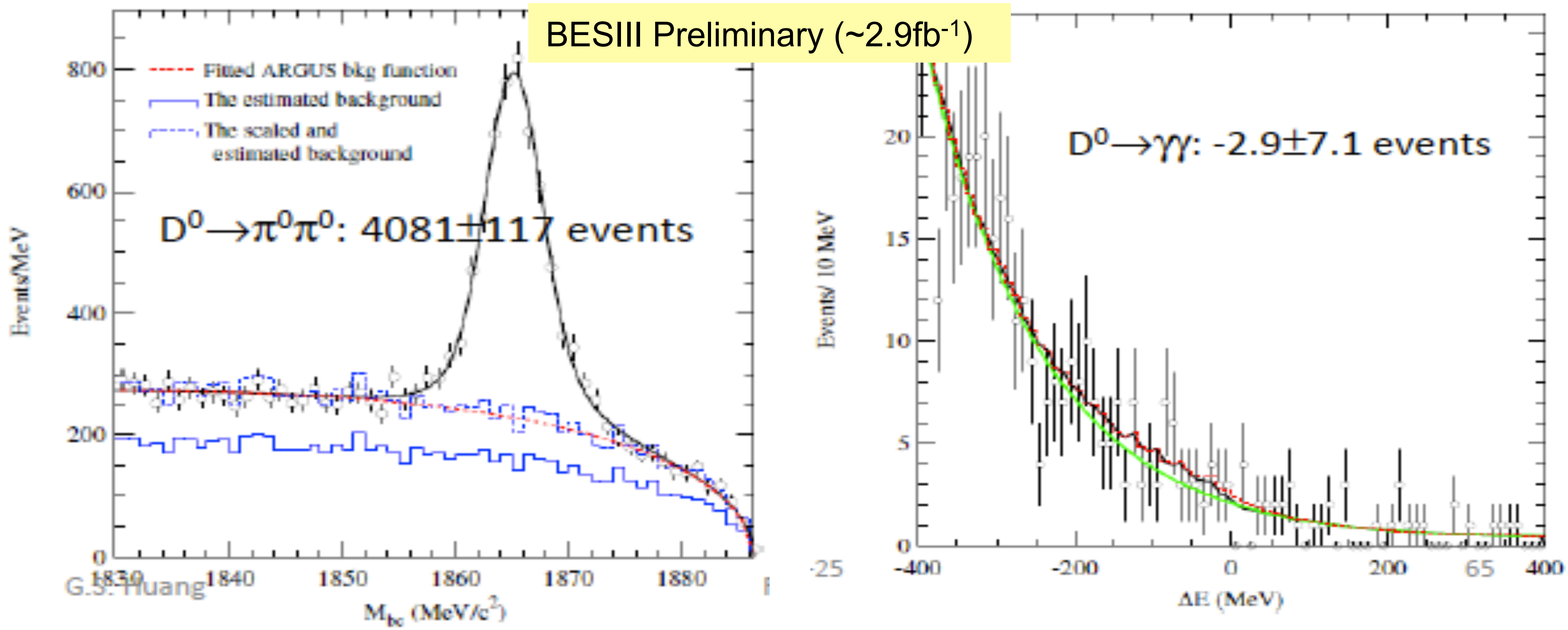


Mode	measured branching fraction(%)	PDG	CLEOc
$\bar{D}^0 \to K^+e^-\bar{\nu}$	3.542 ±0.030±0.067	3.55 ±0.04	3.50 ±0.03 ±0.04
$\bar{D}^0 \to \pi^+e^-\bar{\nu}$	0.288 ±0.008±0.005	0.289 ±0.008	0.288 ±0.008±0.003

- Systematics are preliminary
- Will improve using full (3X) data set in the near future
- Form factor measurement is ongoing

Search for D0->γγ

- Forbidden FCNC transition (c ->u+γ);
- SM prediction: Br(D0->γγ)~10^{-8} or less;
- Results presented in Br(D_0->γγ)/Br(D_0->$\pi^0\pi^0$) < 5.8 x 10^{-3} @ 90% CL, Br(D_0->γγ) < 4.6 x 10^{-6} @ 90% CL(preliminary);
- PDG 2.7 x 10^{-5}, CLEO-c preli. 8.63 x 10^{-6}, BaBar 2.2 x 10^{-6}



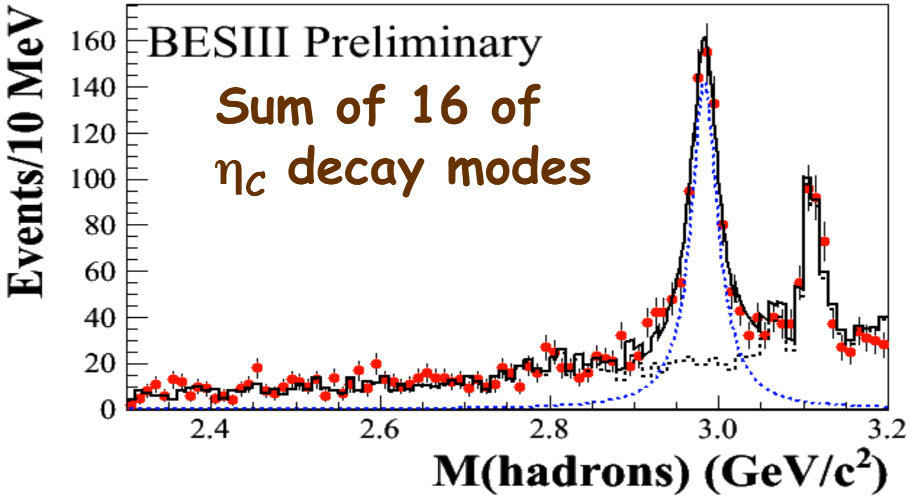
Summary

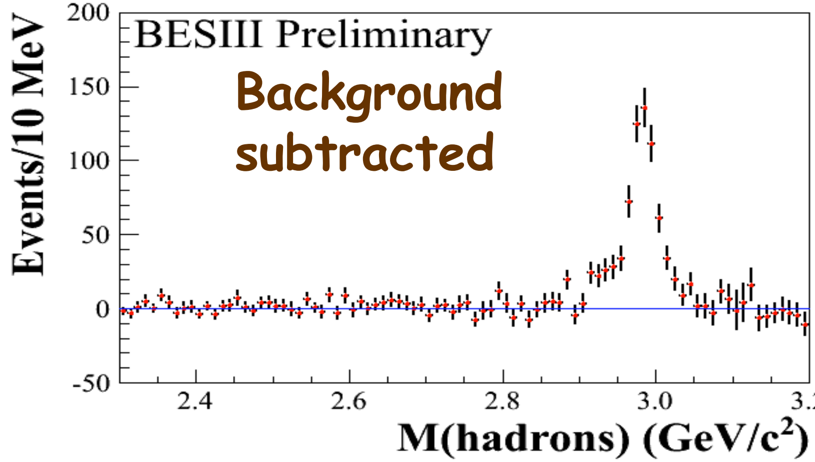
- BESIII has been successfully operated since 2008:
  - World largest data sample of J/ψ, ψ', ψ(3770), ψ(4040) already collected, more data in future ($D_s^{*+}D_s^-$ at 4170MeV coming soon).
- A lot of results have been obtained:
  - Light quark states:
    - confirmation the enhancement at pp threshold in J/ψ->γpp, Jpc =0-+.
    - confirmation X(1835) with two new structures in J/ψ->γππη'.
    - First observation: η(1405)->f_0(980)π^0 (isospin breaking).
    - ωφ threshold enhancement in J/ψ->γωφ
    - ηη system in J/ψ->γηη
  - Charmonium transitions and decays:
    - Precision measurements of h_C and η_C(1S) properties.
    - first observation of η_c(2S) in ψ'->γηc(2S) decay.
    - First evidence of ψ' ->γγJ/ψ.
    - χ_{cJ}->ωϕ , ωω, ϕϕ, γϕ.
  - Charm decays:
    - $D^+ \to \mu^+ v$, $D^0 \to K/\pi\ e\ v$, $D^0 \to \gamma\gamma$.
- Expect many more results from BESIII in the future

Thank you

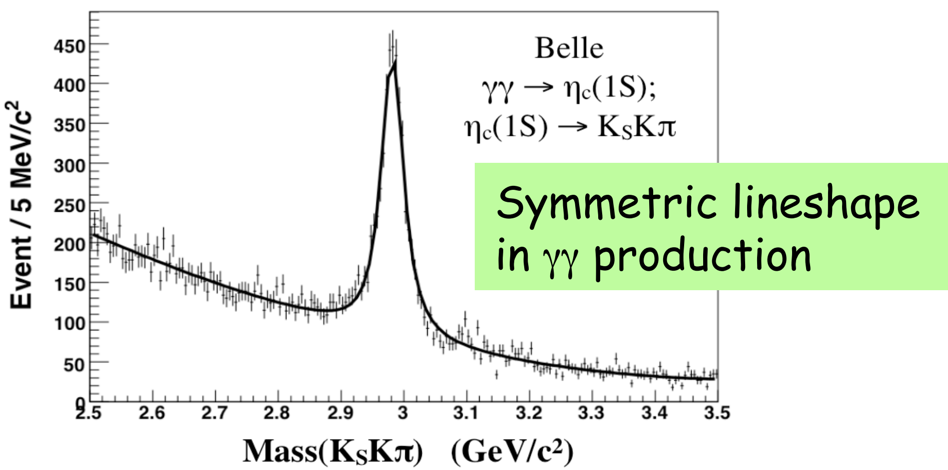
Backup

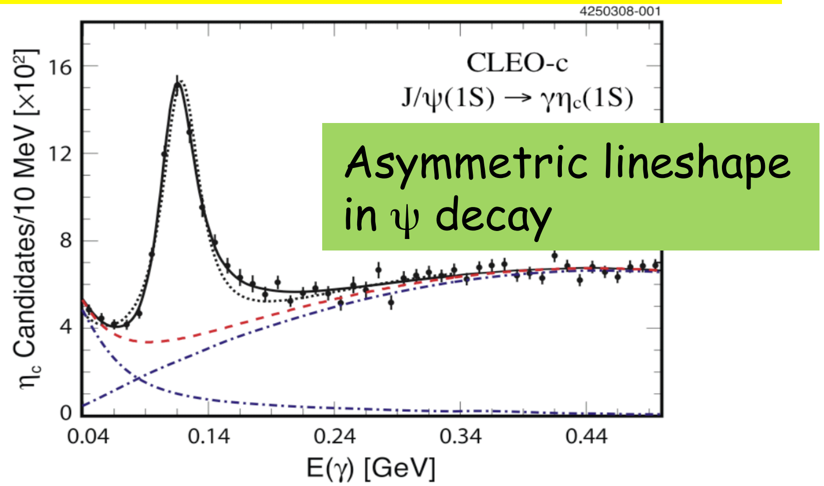
η_c lineshape from $\psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma\eta_c$





The η_c lineshape is not distorted in the $h_c \rightarrow \gamma\eta_c$, non-resonant bkg is small. This channel will be best suited to determine the η_c resonance parameters.

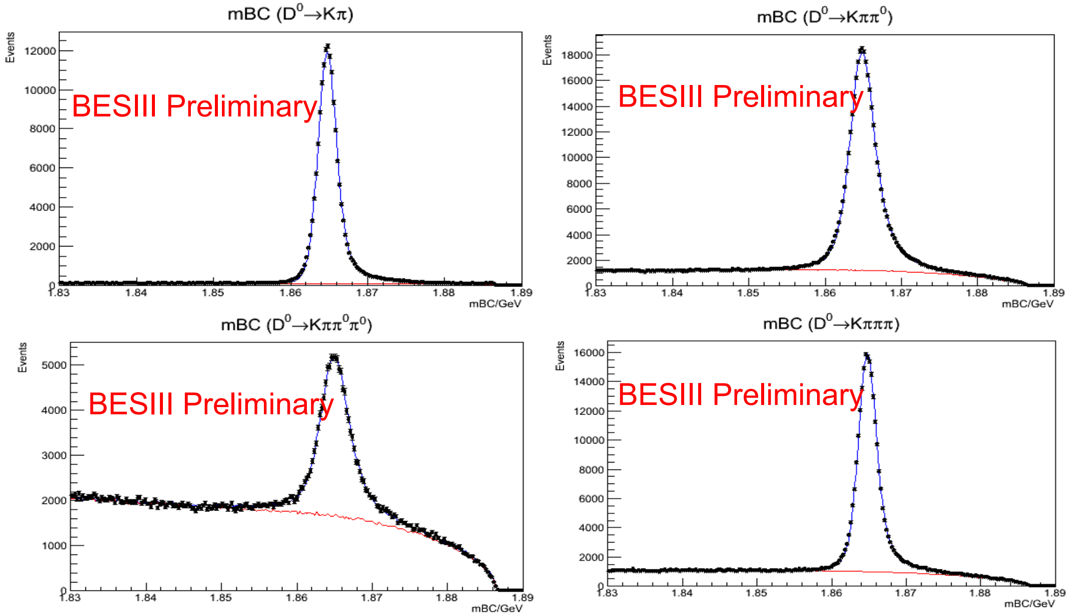




Tag Mode Reconstruction

- Four tag modes picked
- Best tag mode based minimum ΔE

$$\Delta E \equiv E - E_{beam}$$



BESIII Preliminary

Mode	Data Yield	Fraction of All Tags (%)	Tag Efficiency(%)
$D^0 \to K^-\pi^+$	159,929 ± 413	20.7	62.08±0.07
$D^0 \to K^-\pi^+\pi^0$	323,348 ± 667	41.8	33.56±0.03
$D^0 \to K^-\pi^+\pi^0\pi^0$	78,467 ± 480	10.1	14.93±0.04
$D^0 \to K^-\pi^+\pi^-\pi^+$	211,910 ± 550	27.4	36.80±0.04

Is the X(1835) from the same source of X(pp̄)?

- The mass of X(pp̄) is consistent with X(1835)

- The width of X(pp̄) is much narrower.

  Possible reasons:

  – X(pp̄) and X(1835) come from different sources

  – Interference effect in J/ψ->γππη' process should not be ignored in the determination of the X(1835) mass and width

  – There may be more than one resonance in the mass peak around 1.83GeV in J/ψ->γππη' decays.