# BES Experiment at BEPCII

**Third Workshop on Hadron Physics in China and Opportunities in US**

August 8- August 11, 2011, Weihai, Shandong, China


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*Aug. 8, 2010*

*For the BES Collaboration*

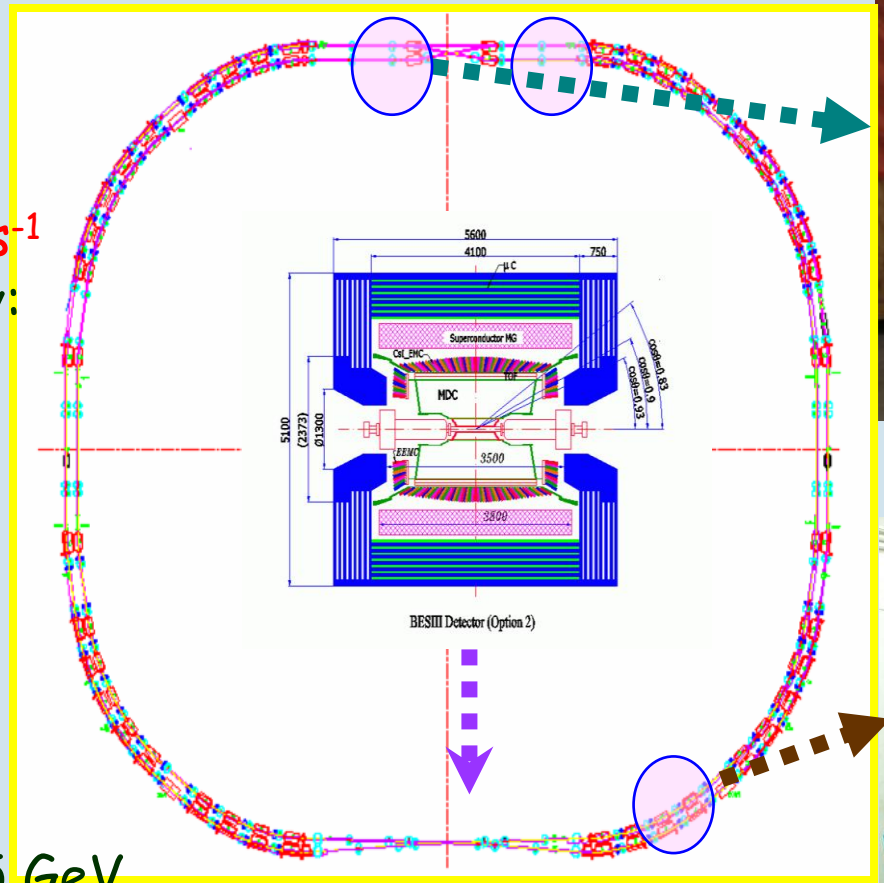
# OUTLINE

- BEPCII/BESIII
- Physics results
  - Light hadron
  - Charmonium
  - Charm
- Summary

# BEPCII: a high luminosity double-ring collider

Beam energy:
1.0-2.3GeV
Luminosity:
$1\times10^{33}$ $cm^{-2}s^{-1}$
Optimum energy:
1.89 GeV
No. of bunches:
93
Bunch length:
1.5 cm
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

22 mrad crossing angle

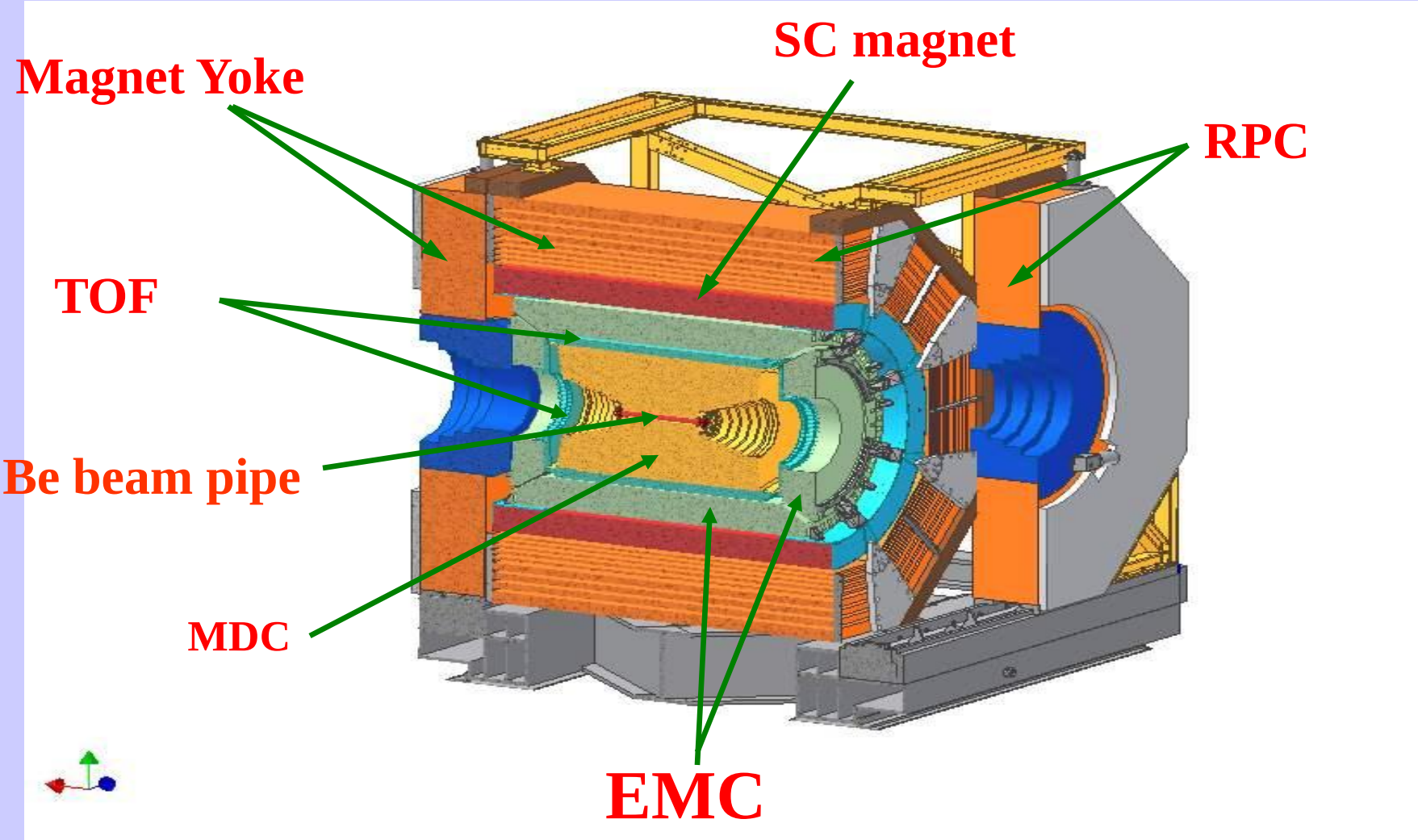



SC RF

Beam magnets

Use many bunches and SC mini-beta.

# BESIII Detector



# BESIII Detector

Berylium beam pipe

Small-celled, helium-based MDC:

- $|\cos\theta| < 0.83$ (all 43 layers), $< 0.93$ (20 layers)
- $\sigma_p/p = 0.58$ % at 1 GeV/c; dE/dx resol = 6% at 1 GeV/c (hadron)

TOF (2 layers in barrel; 1 layer endcap)

- $\sigma_T = 80$ ps barrel (Bhabha); $\sigma_T = 100$ ps endcap

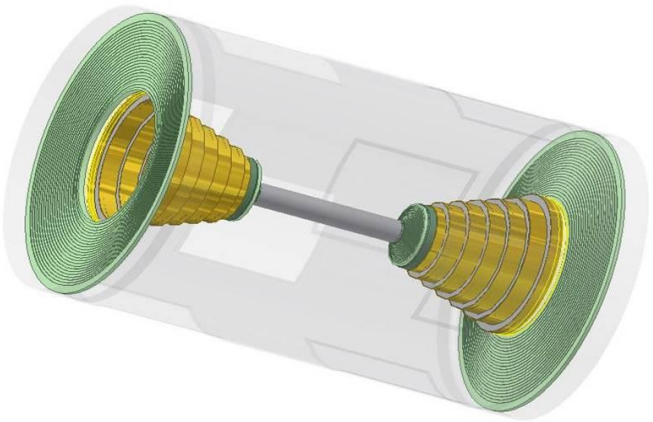
EMC

- crystal length: 28 cm (15 $X_0$)
- energy: 2.5%, space 0.6 cm at 1 GeV

Superconducting Magnet – 1 T

Muon Counter

- 9 layers of RPCs in barrel; 8 in endcap



# Data taking at BESIII

- So far BESIII has collected :
  - 2009: 225 Million J/ψ
  - 2009: 106 Million ψ'(~4 ×CLEO-c)
  - **2010-11: 2.9 $fb^{-1}$ ψ(3770) (~3.5×CLEO-c )**
  - **May 2011: 0.5$fb^{-1}$ @4010 MeV (one month) for Ds and XYZ spectroscopy**

- BESIII will also collect:
  - more J/ψ, ψ', ψ(3770)
  - data at higher energies （for XYZ searches, R scan and Ds physics）

| Year | Running Plan |
|---|---|
| 2012 | J/ψ: 1 billion / ψ(2S): 0.5 billion (approved) |
| 2013 | 4170 MeV: Ds decay<br>R scan (E > 4 GeV) |
| 2014 | ψ(2S)/τ /<br>R scan (E > 4 GeV) |
| 2015 | ψ(3770): 5-10 $fb^{-1}$<br>(our final goal) |

**Red: to be approved by BESIII Collaboration**

# Light Hadron(see Yajun's talk for detail)

- $p\bar{p}$ mass thereshould enhancement
- X(1835)
- $a^0(980)$ – $f^0(980)$ mixing
- $J/\psi \rightarrow \omega\pi^+\pi^-\eta$

# $\bar{p}p$ threshold enhancement @BESII

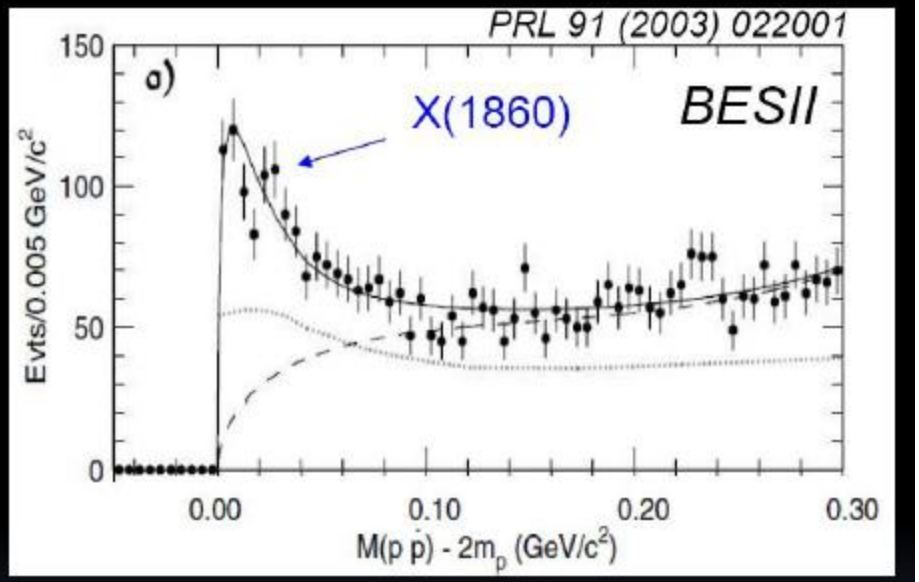
$$J/\psi \to \gamma p\bar{p}$$

- If fitted with a S-wave resonance

  **$M = 1859^{+3}_{-10}{}^{+5}_{-25}$ MeV/c²**

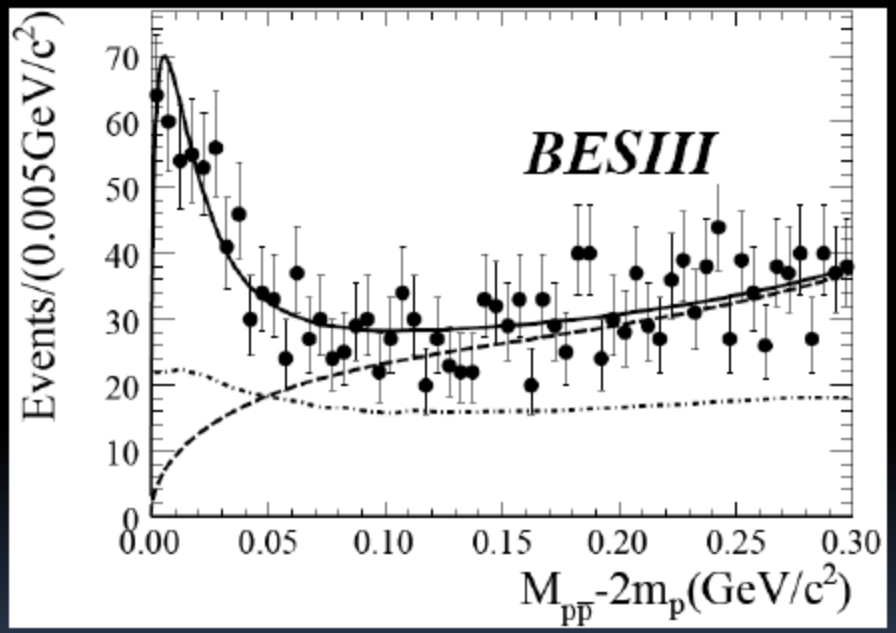
  **$\Gamma < 30$ MeV/c² (90% CL)**

- Theoretical speculation:
  - $\bar{p}p$ bound state?
  - FSI effect?
  - … …



# $p\bar{p}$ threshold enhancement @BESIII

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



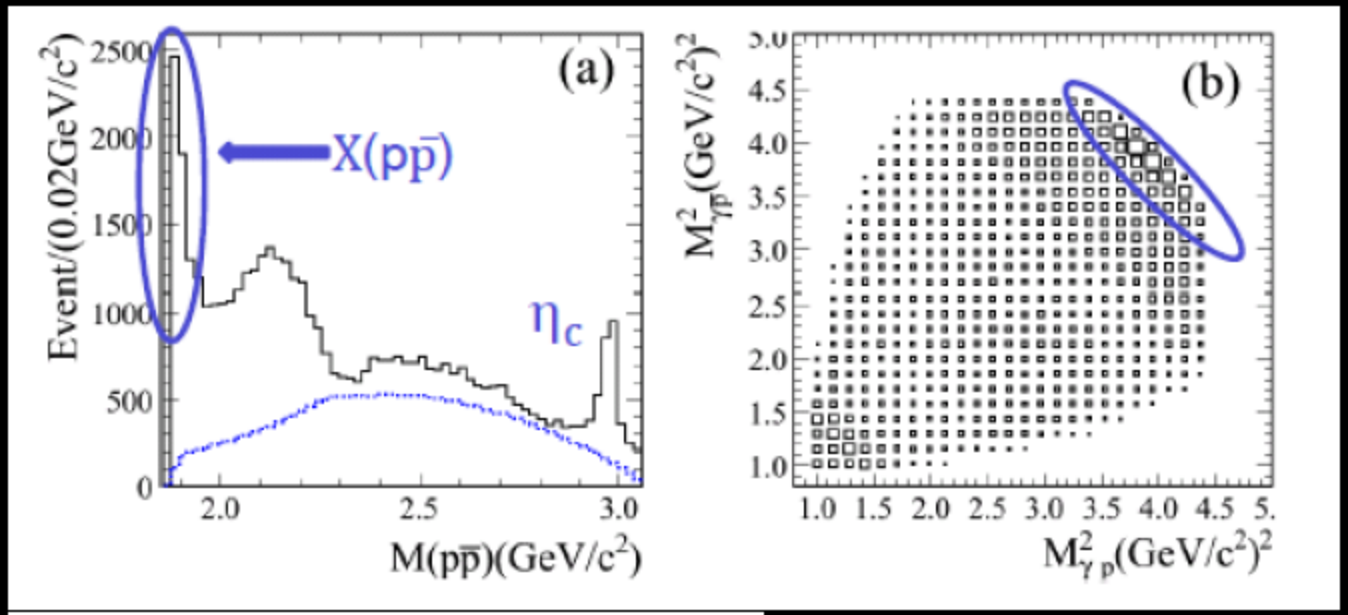

$M = 1861\,^{+6}_{-13}\,^{+7}_{-26}$ MeV/c²

$\Gamma < 38$ MeV/c² (90% CL)

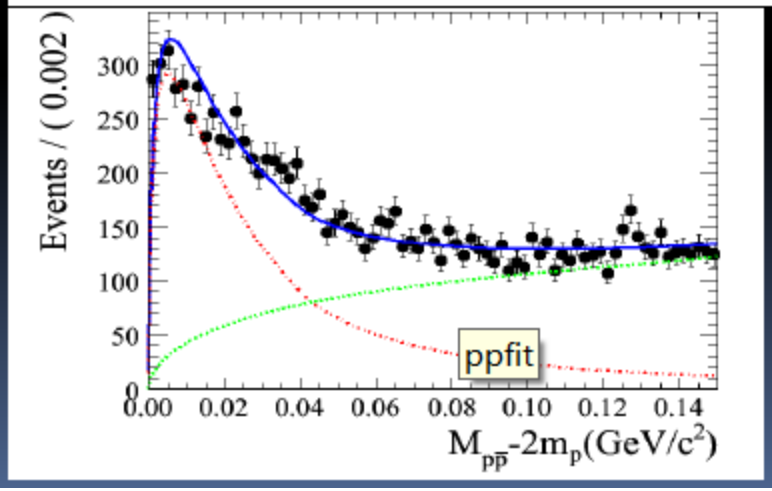
Chinese Physics C 34(2010)421

**Consistent observation by BESIII !**

# $p\bar{p}$ threshold enhancement @BESIII




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




Fit result:

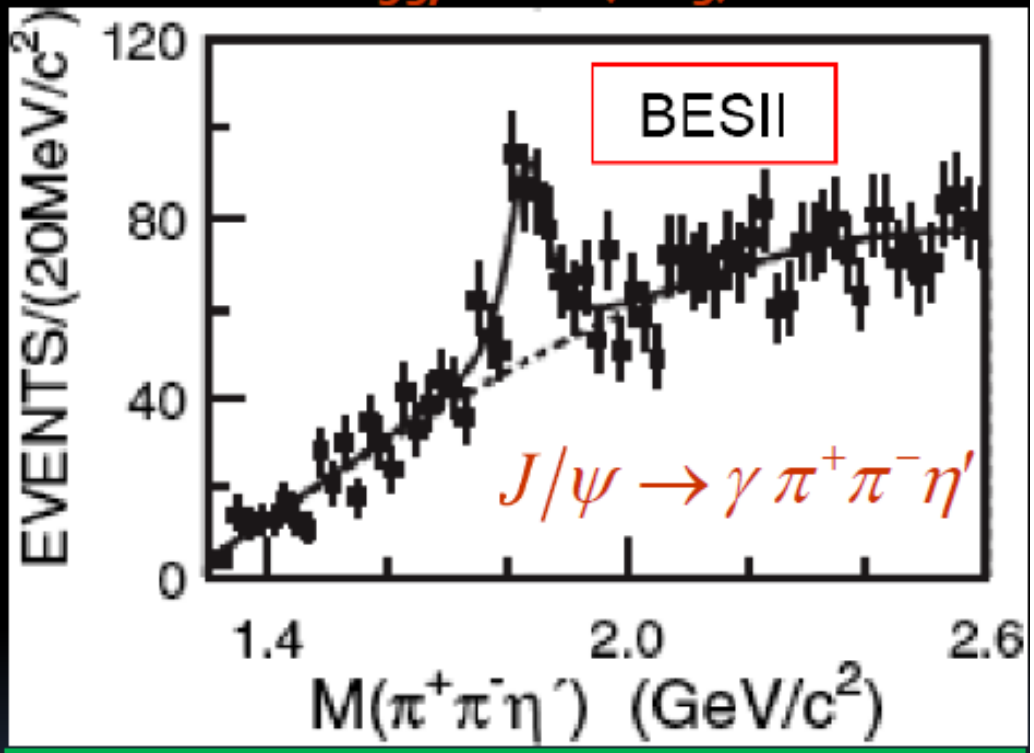
Mass=$1861.6 \pm 0.8 MeV/c^2$

$\Gamma < 8$ MeV(90%CL)

# X(1835) at BESII

- The X(1860) should be detected in other decay modes.
- G.J. Ding and M.L. Yan suggest $\eta'\pi\pi$ to be a favorable mode. (PR C72, 015208 (2005))
  - there is gluon content in $p\bar{p}$
  - $\eta'$ has strong coupling to gluons
- Confirmation of X(1835) is necessary with BESIII ~225M $J/\psi$ data sample

PRL 95,262001(2005)



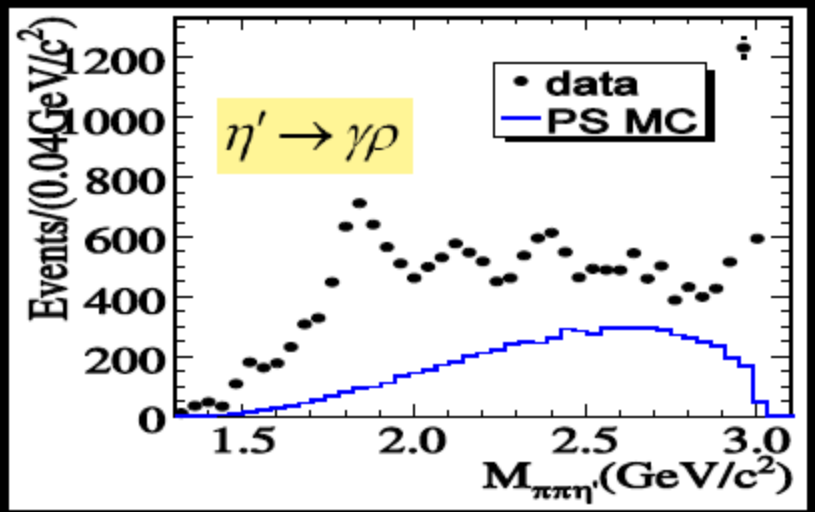

$M = 1833.7 \pm 6.1 \pm 2.7$ MeV/c$^2$

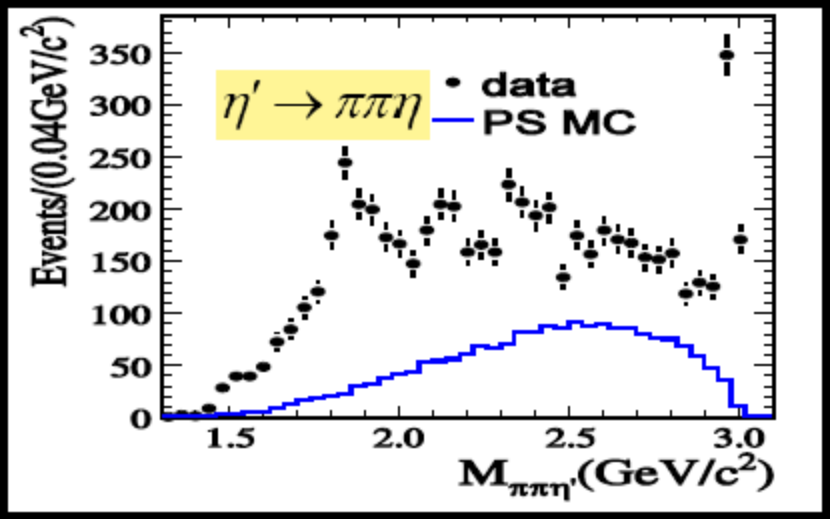
$\Gamma = 67.7 \pm 20.3 \pm 7.7$ MeV/c$^2$

$B(J/\psi \to \gamma X) \times B(X \to \pi^+\pi^-\eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$

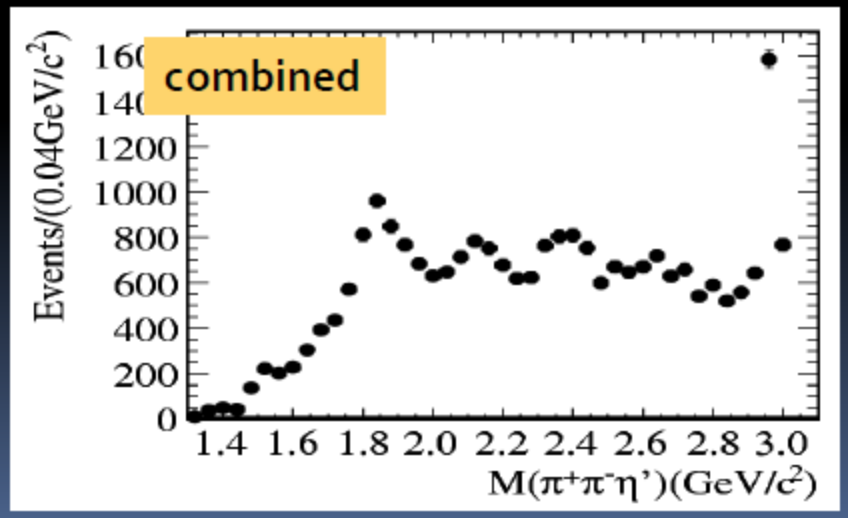
sig. = $7.7\sigma$

# X(1835) at BESIII




X(1835) confirmed by BESIII

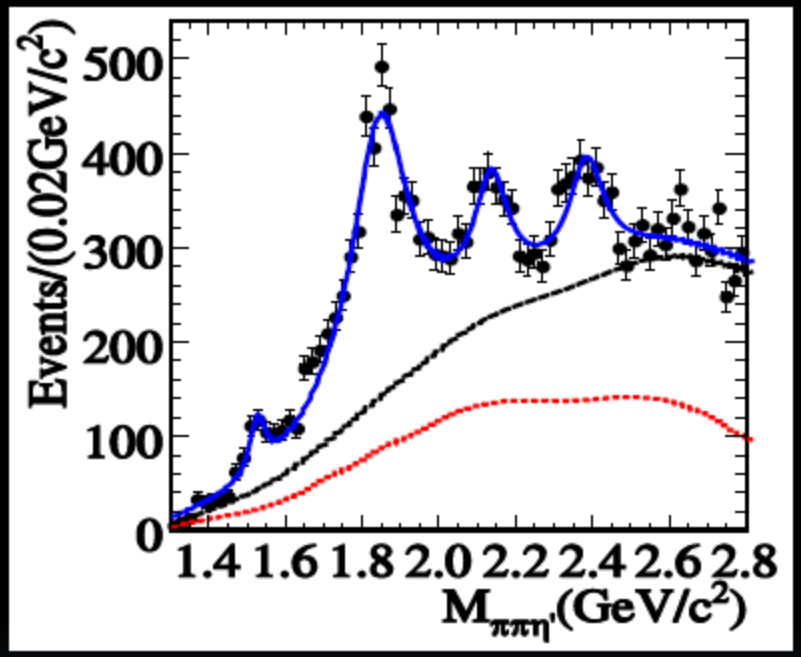



- Two additional structures are observed around 2.1 GeV and 2.3 GeV
- Maybe exist f1(1510)

PRL 106, 072002 (2011)

# Fitting results

Red line: Contribution of ①+②
Black line: Total background

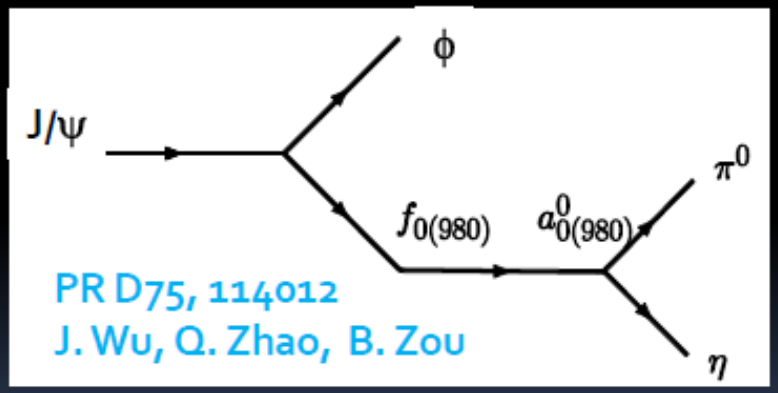



- Fitted with four resonances
- Three bkg components
  - ① $\eta'$ sideband
  - ② $J/\psi \to \pi^0\pi^+\pi^-\eta'$
  - ③ Phase Space

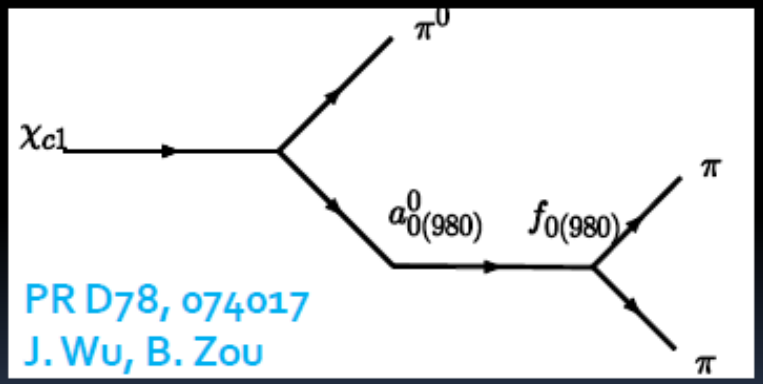
| Resonance | M( MeV/c²) | Γ( MeV/c²) | Stat.sig. |
|---|---|---|---|
| X(1835) | $1836.5 \pm 3.0^{+5.6}_{-2.1}$ | $190.1 \pm 9.0^{+38}_{-36}$ | >20σ |
| X(2120) | $2122.4 \pm 6.7^{+4.7}_{-2.7}$ | $83 \pm 16^{+31}_{-11}$ | 7.2σ |
| X(2370) | $2376.3 \pm 8.7^{+3.2}_{-4.3}$ | $83 \pm 17^{+44}_{-6}$ | 6.4σ |

# $a_0(980)$ - $f_0(980)$ mixing

- Light scalar mesons $f_0$ and $a_0$ are still controversial.
- Described as quark-antiquarks, four quarks, KK-bar molecule, qq-bar g hybrids, etc.
- Study of mixing important to clarify their nature.
- $J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi$ and $\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0$ provide complementary information:




PR D75, 114012
J. Wu, Q. Zhao, B. Zou




PR D78, 074017
J. Wu, B. Zou

$$\xi_{fa}(s) = \frac{d\Gamma_{X\to Yf_0(980)\to Ya_0(980)\to Y\pi^0\eta(s)}}{d\Gamma_{X\to Yf_0(980)\to Y\pi\pi(s)}}$$

$$\xi_{af}(s) = \frac{d\Gamma_{X\to Ya_0(980)\to Yf_0(980)\to Y\pi\pi(s)}}{d\Gamma_{X\to Ya_0(980)\to Y\pi^0\eta(s)}}$$

**Mixing intensity**

# $a_0(980)$ – $f_0(980)$ mixing

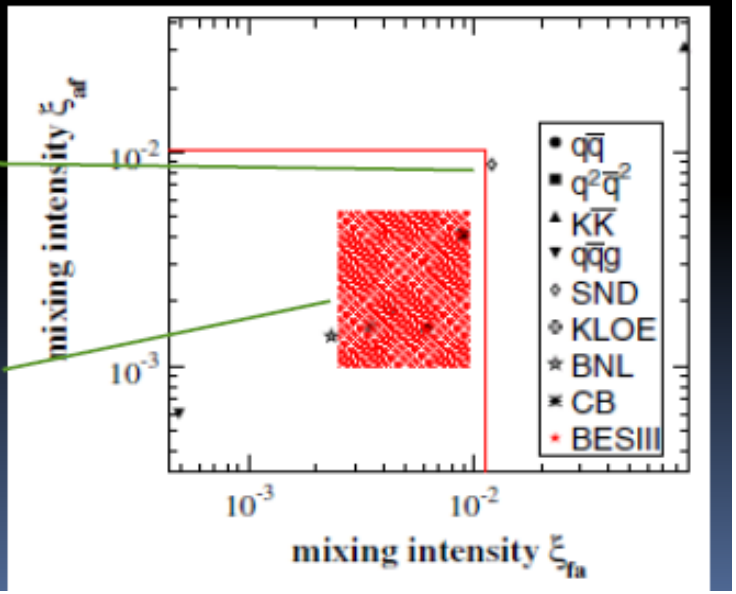
- **Mixing intensity**

✸ $\xi_{fa}$= (0.60±0.20(stat.)±0.12(sys.)±0.26(para)%
(<1.1% @90% C.L.)

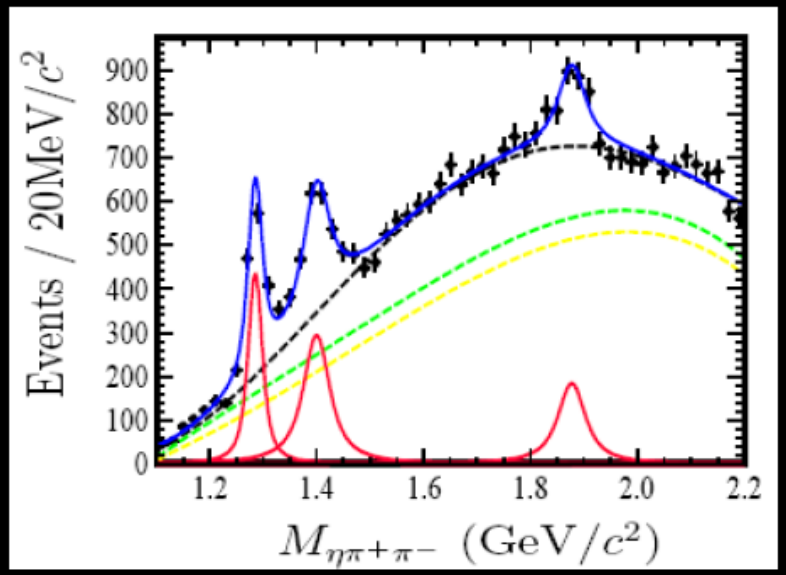
✸ $\xi_{af}$= (0.31±0.16(stat.)±0.14(sys.)±0.03(para)%
(<1.0% @90% C.L.)

our upper limit

our measurement



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




**Fitted result of X(1870):**

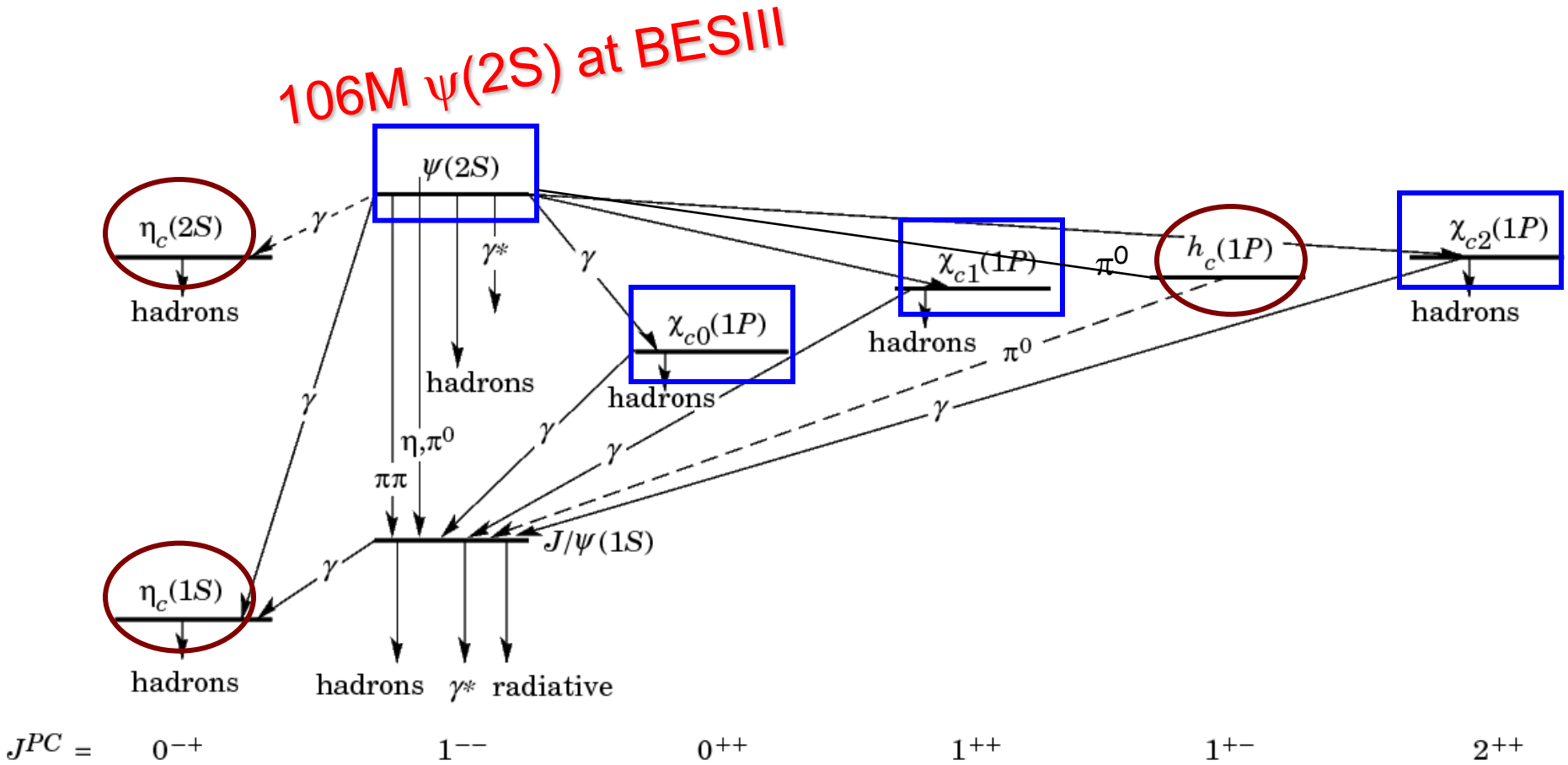
- M = (1877.3 ± 6.3) MeV/$c^2$
- Γ = (57 ± 12) MeV/$c^2$
- Significance: 7.1σ

- The fit is performed under the assumption that the interference between the resonances and background can be ignored.
- Current results cannot settle down whether X(1870) is actually $\eta_2(1870)$ (Γ =225 ± 14 MeV/$c^2$) or a new resonance.

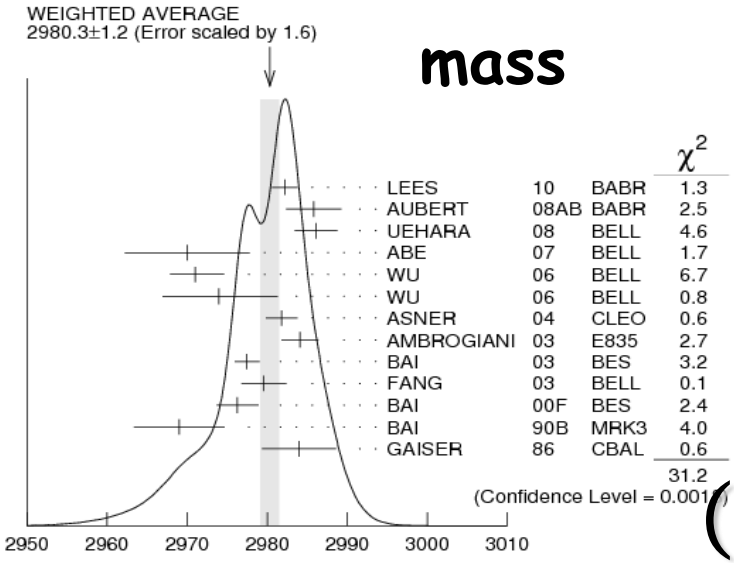
# Charmonium

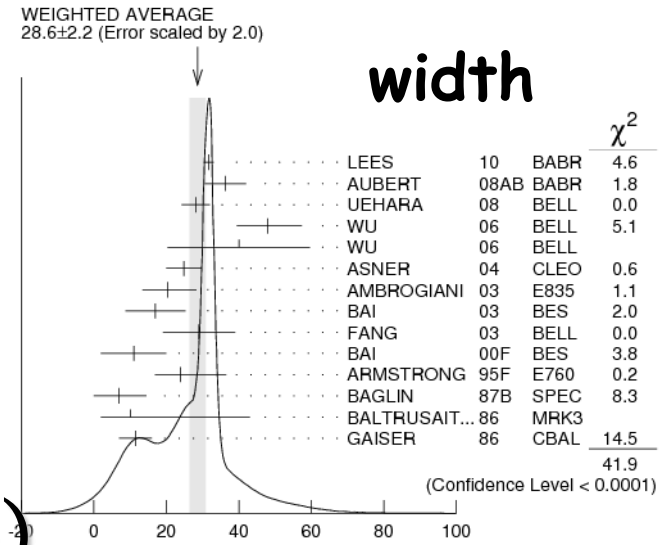
- Spectrum: $\eta_c$, $h_c$, $\eta'_c$
- $\psi' \to \gamma P$
- $\chi_{cJ} \to \gamma V$
- $\chi_{cJ} \to VV$

# Charmonium spectrum below open charm threshold

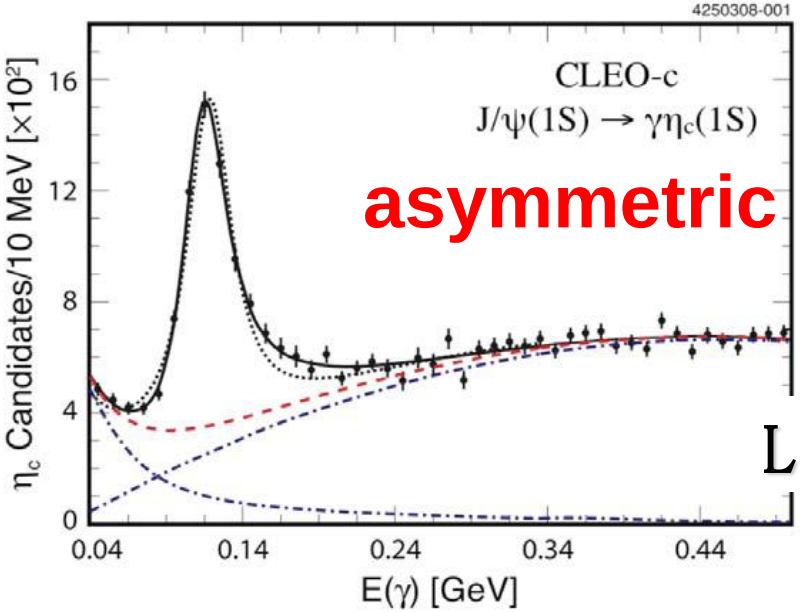


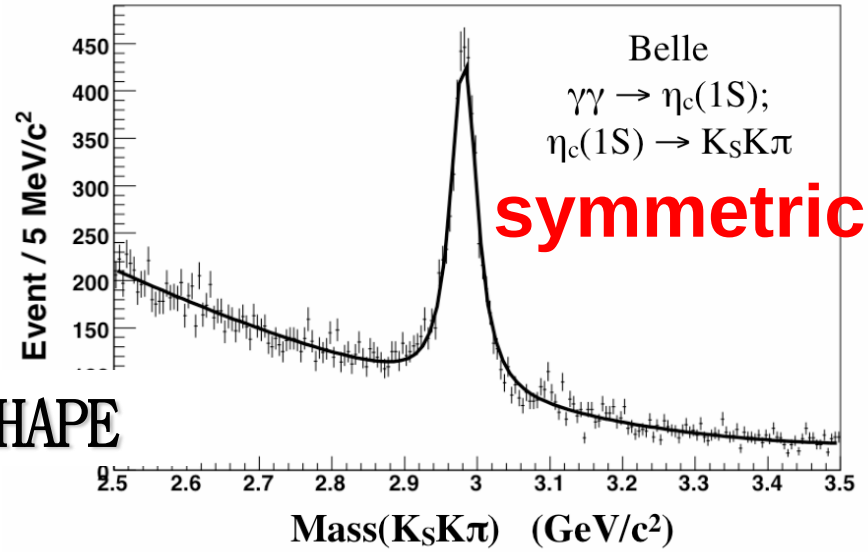
# $\eta_c$, the lightest charmonium state




PDG (2010)

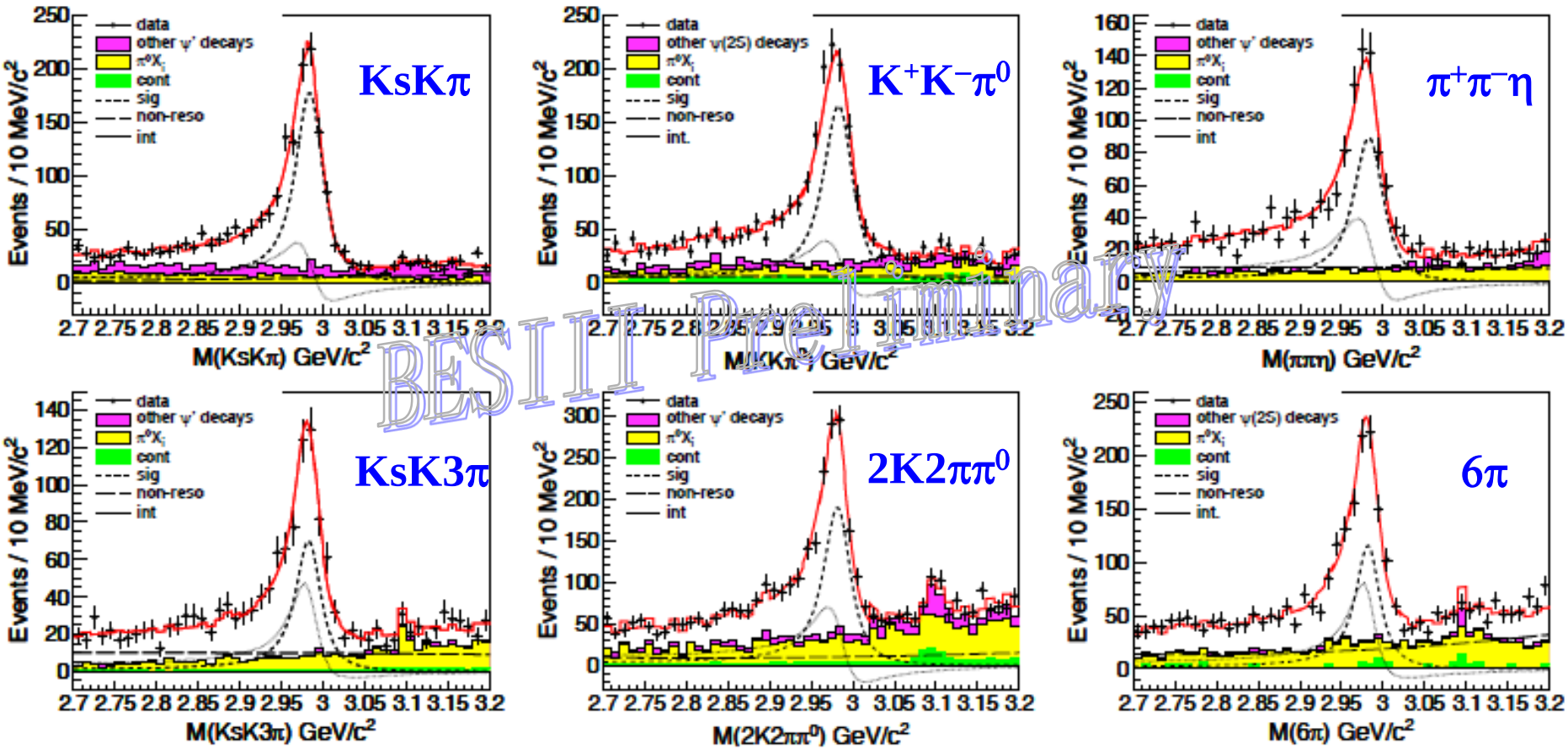



LINESHAPE

(IHEP)

# $\eta_c$ resonance parameters from $\psi' \to \gamma\eta_c$



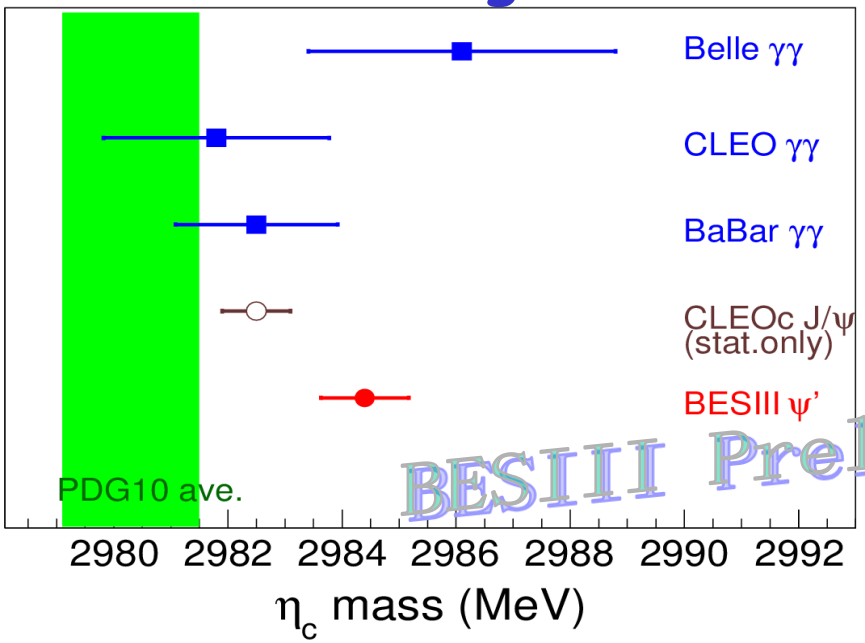

Simultaneous fit with modified Breit-Wigner (hindered M1) with considering **interference** between $\eta_c$ and non-$\eta_c$ decays

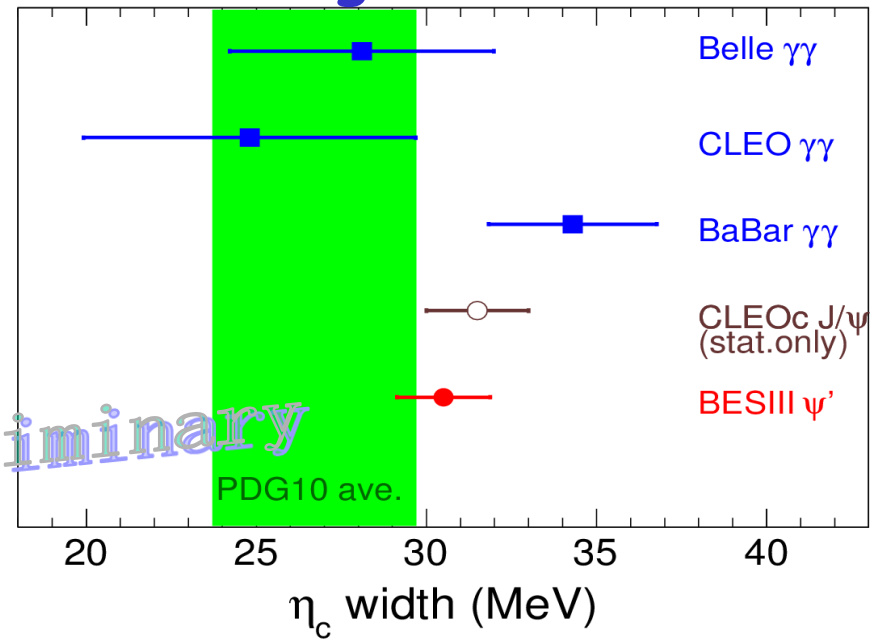
# Mass and Width of $\eta_c$

***BESIII preliminary***

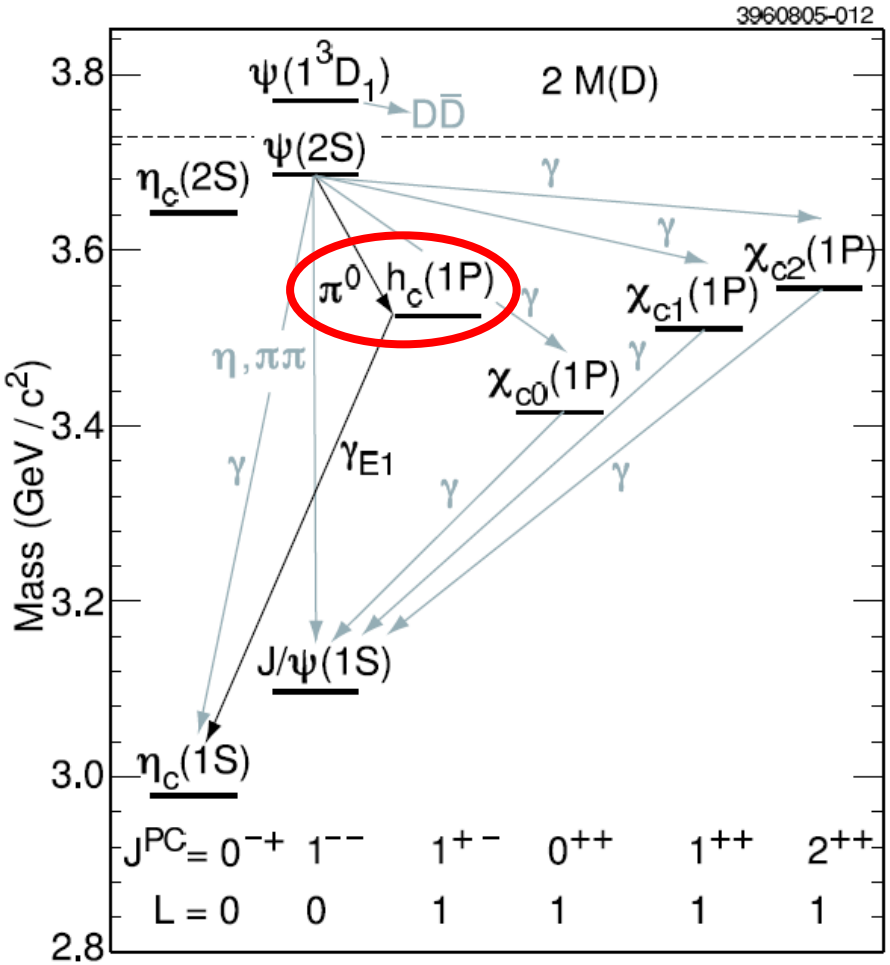
- **mass = $2984.4 \pm 0.5_{stat} \pm 0.6_{syst}$ MeV/$c^2$**
- **width = $30.5 \pm 1.0_{stat} \pm 0.9_{syst}$ MeV**
- **$\phi = 2.35 \pm 0.05_{stat} \pm 0.04_{syst}$ rad**

**The world average in PDG2010 was using earlier results.**



# $h_c(^1P_1)$, singlet 1P wave state



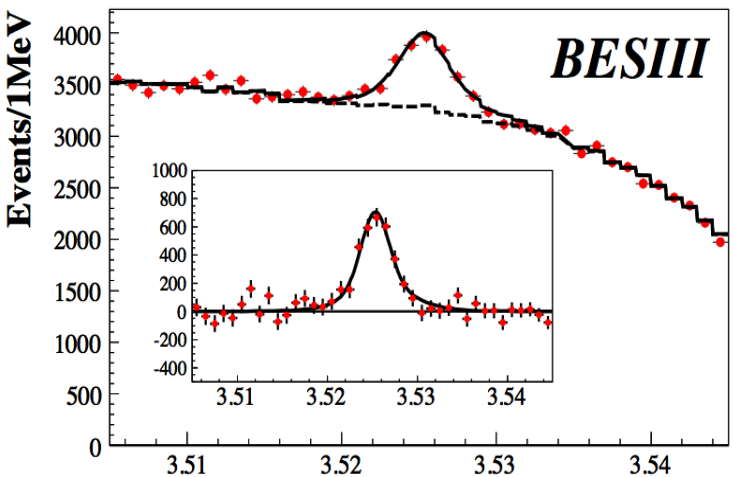

- Predicted for a long time
- Hyperfine splitting of 1P states (spin-spin)
- iso-spin forbidden transition $\psi' \to \pi^0 h_c$
- Mass and product Brs from CLEO-c [PRL101,182003(2008)]

| | Inclusive | Exclusive |
|---|---|---|
| Counts | $1146 \pm 118$ | $136 \pm 14$ |
| Significance | $10.0\sigma$ | $13.2\sigma$ |
| $M(h_c)$ (MeV) | $3525.35 \pm 0.23 \pm 0.15$ | $3525.21 \pm 0.27 \pm 0.14$ |
| $\mathcal{B}_1 \times \mathcal{B}_2 \times 10^4$ | $4.22 \pm 0.44 \pm 0.52$ | $4.15 \pm 0.48 \pm 0.77$ |

# Observe $h_c$ in inclusive reaction

**E1-tagged $\psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma \eta_c$**

**PRL 104, 132002 (2010)**




$M(h_c)=3525.40 \pm 0.13$MeV

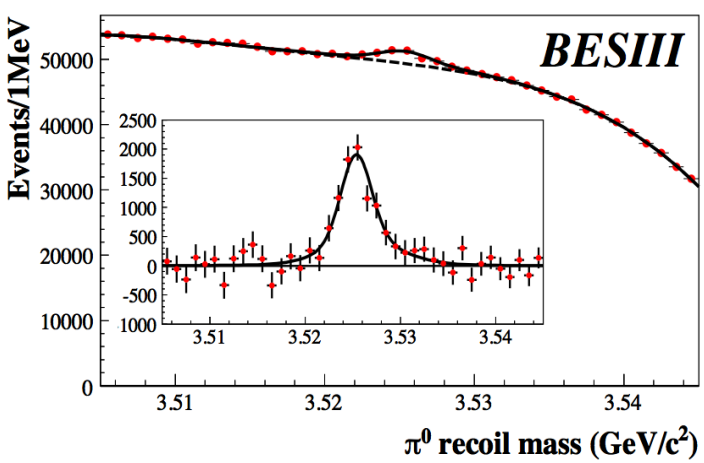
$N(h_c)= 3679 \pm 319$

$\Gamma(h_c) = 0.73 \pm 0.45$MeV

prediction. Consistent with CLEO-c result:$3525.35 \pm 0.23$ and theoretical

**First observation**

**Inclusive $\psi' \rightarrow \pi^0 h_c$**




$N(h_c) = 10353 \pm 1097$

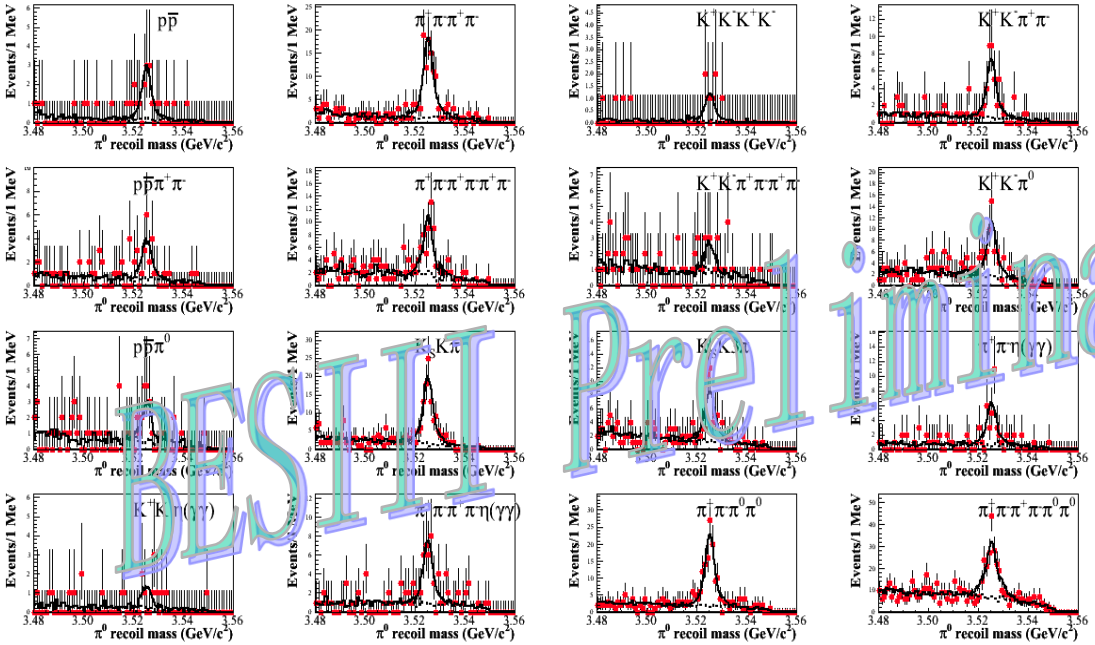
$B(\psi' \rightarrow \pi^0 h_c)=(8.4 \pm 1.3) \times 10^{-4}$

$B(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7)\%$

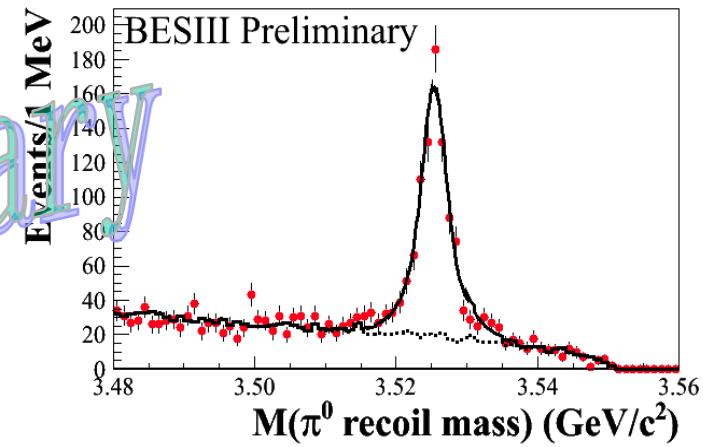
Consistent with CLEO-c result:

$Br(\psi' \rightarrow \pi^0 h_c) \times Br(h_c \rightarrow \gamma \eta_c)= (4.22 \pm 0.44 \pm 0.52) \times 10^{-4}$

# Observe $h_c$ in exclusive reaction




**Summed $\pi^0$ recoil mass**




**BESIII Preliminary**

**Simultaneous fit to $\pi^0$ recoiling mass**

**$M(h_c)$ = 3525.31±0.11±0.15 MeV/$c^2$**

**$\Gamma(h_c)$ = 0.70±0.28±0.25 MeV**

**N = 832±35**

**$\chi\chi^2$/d.o.f. = 32/46**

**Consistent with**

**BESIII inclusive results**

PRL104,132002(2010)

**and**

**CLEO-c exlusive results**

**$M(h_c)$=3525.21±0.27±0.14 MeV/$c^2$**

**N = 136±14**

PRL101, 182003(2008)

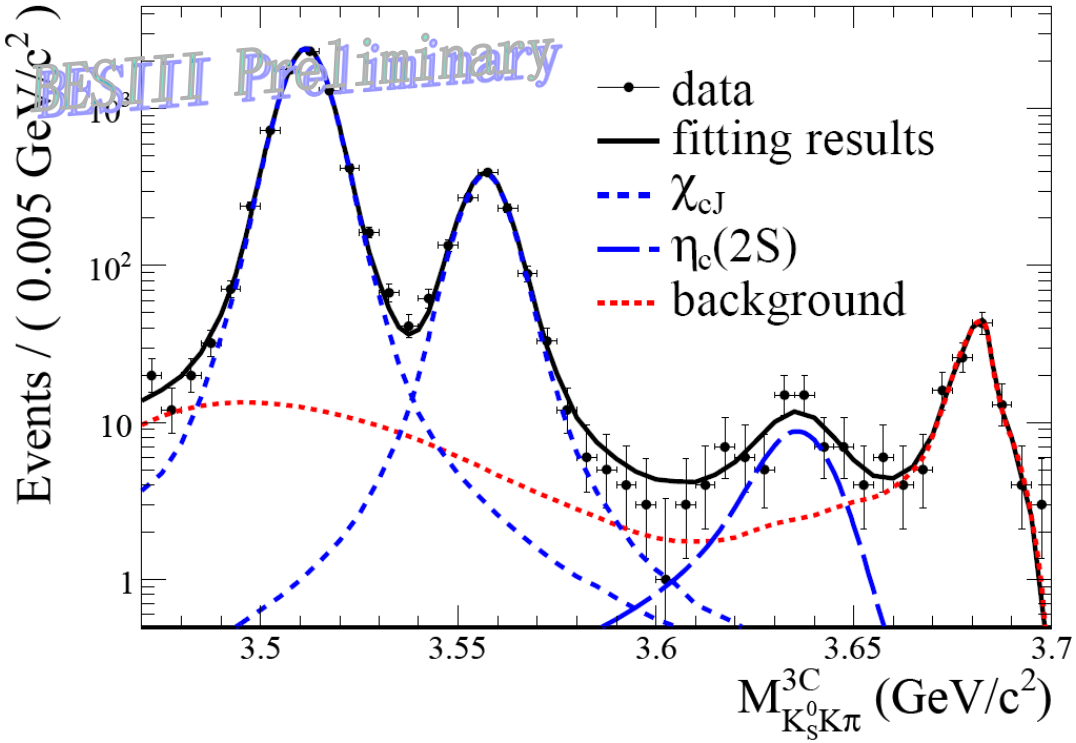
# $\eta_c(2S)$ (never confirmed in M1 transition)

- First "observation" by Crystal Ball in 1982 (M=3.592GeV, Br=0.2%-1.3% from $\psi' \to \gamma X$, never confirmed. Experimental challenge for **50MeV photon**.)
- Published results about $\eta_c(2S)$ observation:

| Experiment | $M$ [MeV] | $\Gamma$ [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] | $3638 \pm 4$ | $14 \pm 7$ | — |

- Combined with the results based on two-photon processes from BaBar and Belle reported at ICHEP 2010, the world average $\Gamma(\eta_c(2S))=12 \pm 3$ MeV
- Decay mode studied: $\psi' \to \gamma \eta_c(2S) \to \gamma K_s K \pi$ ($K^+K^- \pi^0$ etc. in progress), better chance with 106M $\psi'$ data at BESIII.

# Simultaneous fit of $\eta_c(2S)$ and $\chi_{cJ}$




- $N(\eta_c(2S)) = 50.6 \pm 9.7$
- Pure statistical significance more than $6\sigma$
- Significance with systematic variations not less than $5\sigma$
- $\chi^2/ndf=0.9$

- $\eta_c(2S)$ signal: modified BW (M1) with fixed width. (The resolution is extrapolated from $\chi_{cJ}$)
- $\chi_{cJ}$ signal: MC shape smeared with Gaussian.
- BG from $e^+ e^- \to K_s K \pi$(ISR), $\psi' \to K_s K \pi$ (FSR), $\psi' \to \pi^0 K_s K \pi$, : are measured from data.

# Preliminary measurements from $\psi' \to \gamma\eta_c(2S) \to \gamma K_S K\pi$

- $M(\eta_c(2S)) = 3638.5 \pm 2.3_{stat} \pm 1.0_{sys}$ (MeV/$c^2$)
- $Br(\psi' \to \gamma\eta_c(2S) \to \gamma K_S K\pi) = (2.98 \pm 0.57_{stat} \pm 0.48_{sys}) \times 10^{-6}$

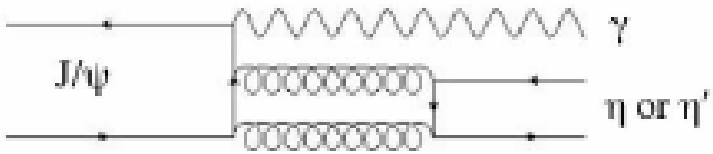
$Br(\eta_c(2S) \to KK\pi) = (1.9 \pm 0.4 \pm 1.1)\%$ from BaBar

- $Br(\psi' \to \gamma\eta_c(2S)) = (4.7 \pm 0.9_{stat} \pm 3.0_{sys}) \times 10^{-4}$

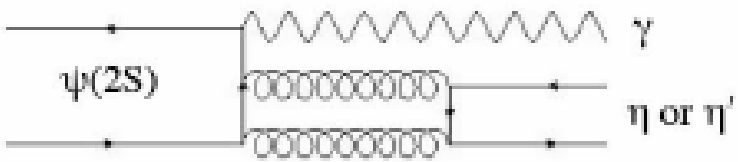
CLEO-c: $<7.6\times10^{-4}$ (PRD81,052002(2010))
Potential model: $(0.1–6.2)\times10^{-4}$ (PRL89,162002(2002))

# $\psi' \to \gamma\, P(\pi^0, \eta, \eta')$, arise surprises

$V \to \gamma\, P$ are important tests for various mechanisms: Vector meson Dominance Model (VDM); Couplings & form factor; Mixing of $\eta$-$\eta'$(-$\eta_c$); FSR by light quarks; 12% rule and "$\rho\ \pi$ puzzle".




VS




**theory**

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

LO-pQCD

$\Downarrow$

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

PRP 112,173 (1984)

**experiment**

CLEO-c: $J/\psi$, $\psi'$, $\psi''$ $\to \gamma\, P$

$R_{J/\psi} = (21.1 \pm 0.9)\%$

No Evidence for $\psi' \to \gamma\, \pi^0$ or $\gamma\, \eta$

$Br(\psi' \to \gamma\eta') = (1.19 \pm 0.09)\%$

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

$\Downarrow$

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

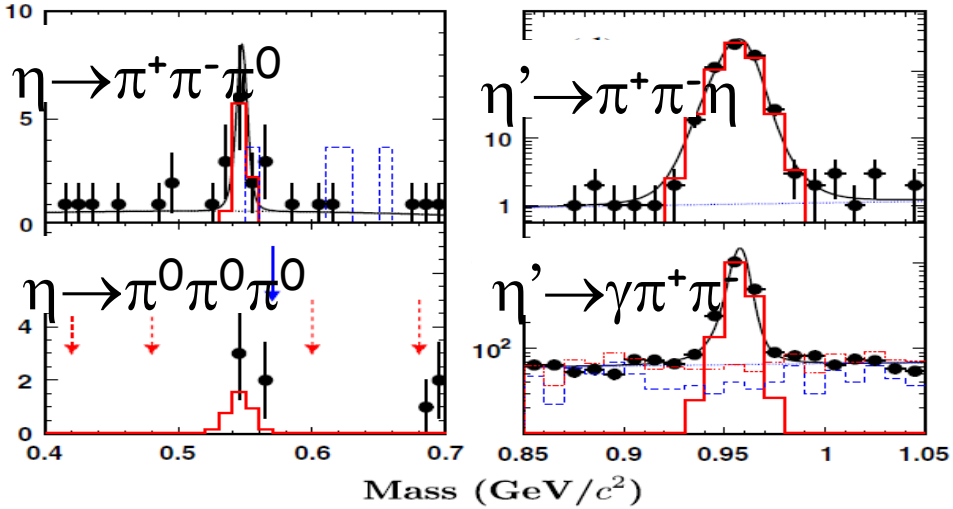
PRD 79, 111101 (2009)

# $\psi' \to \gamma P$ at BESIII

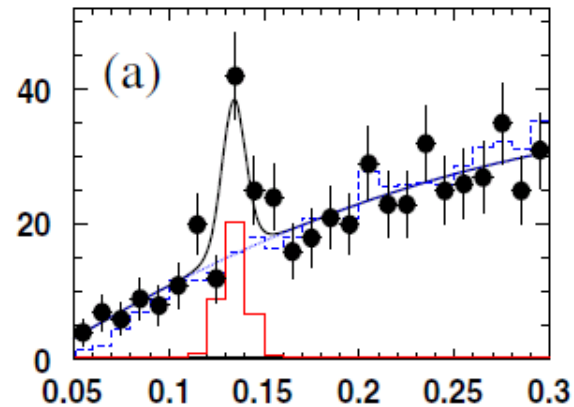
PRL 105, 261801 (2010)

$\psi' \to \gamma\eta$
(First observation)

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




$\psi' \to \gamma\pi^0$
(First observation)



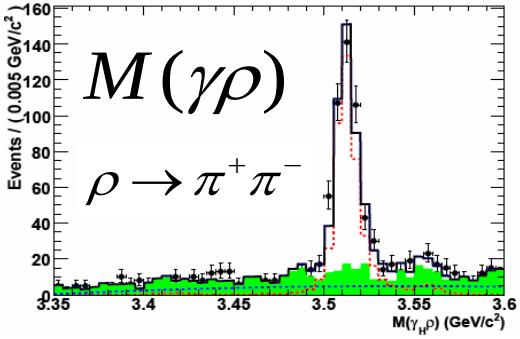

$R_{\psi'} = 1.10 \pm 0.38 \pm 0.07\% \ll R_{J/\psi}$

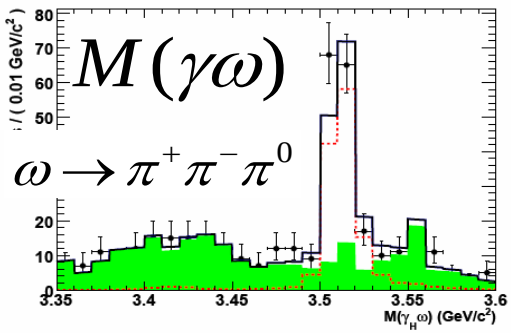
| Mode | $B(\psi')$ [$\times 10^{-6}$] | $B(J/\psi)$ [$\times 10^{-4}$] | Q (%) |
|---|---|---|---|
| $\gamma\pi^0$ | 1.58±0.42 | 0.35±0.03 | 4.5 ± 1.3 |
| $\gamma\eta$ | 1.38±0.49 | 11.04±0.34 | 0.13 ± 0.04 |
| $\gamma\eta'$ | 126±9 | 52.8±1.5 | 2.4 ± 0.2 |

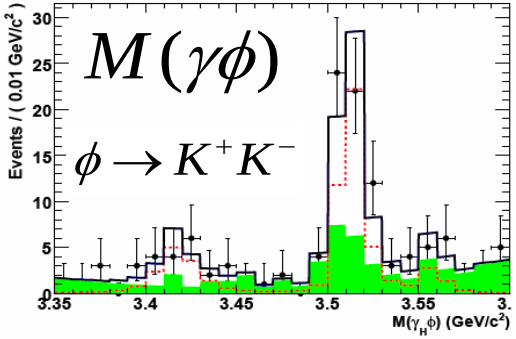
*Possible interpretation: Q. Zhao*, Phys. Lett. B697, 52 (2011)

# $\chi_{cJ} \to \gamma\ V(\rho,\omega,\phi)$

**prediction by pQCD much lower than experiment**




| 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 | $228 \pm 13 \pm 16$ |
| $\chi_{c2} \to \gamma\rho^0$ | $< 50$ | 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 | $69.7 \pm 7.2 \pm 5.6$ |
| $\chi_{c2} \to \gamma\omega$ | $< 7.0$ | 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 | $25.8 \pm 5.2 \pm 2.0$ |
| $\chi_{c2} \to \gamma\phi$ | $< 13$ | 1.1 | 3.3 | 6.5 | <8.1 |

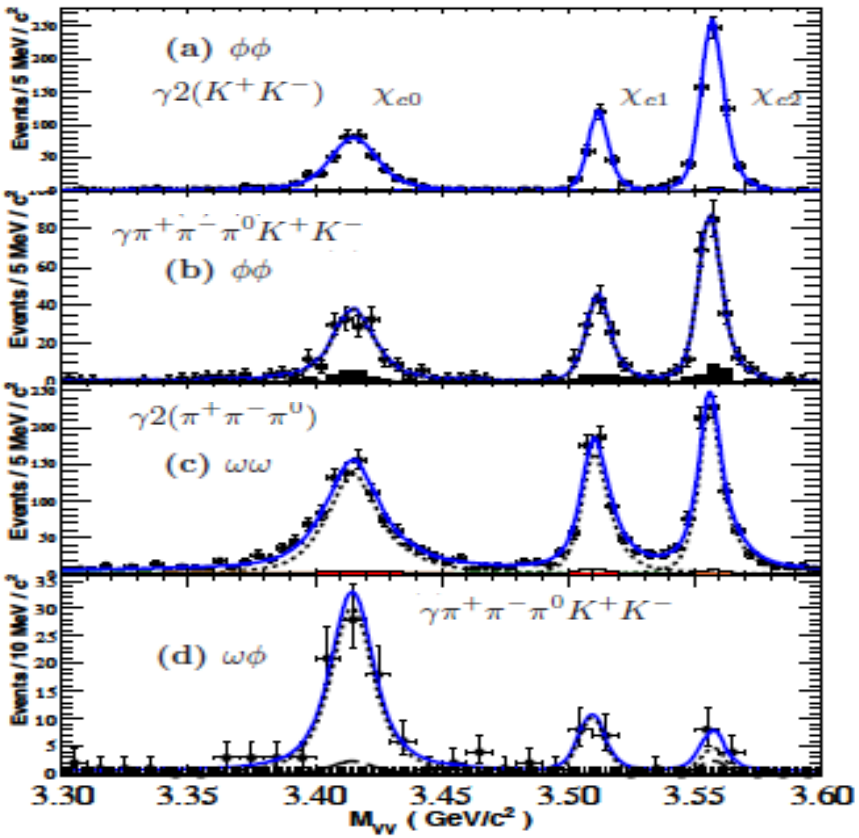
**First observation**

**Longitudinal polarization dominant!**

Phys. Rev. D 83, 112005 (2011)

# $\chi_c \to VV(V=\omega,\ \phi)$, suppressed decays

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




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

First observation

Evidence

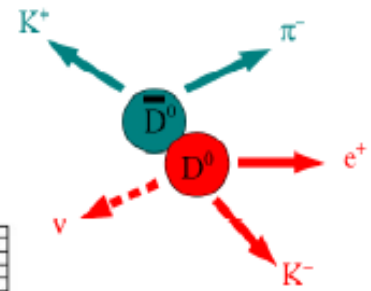
Accepted by PRL

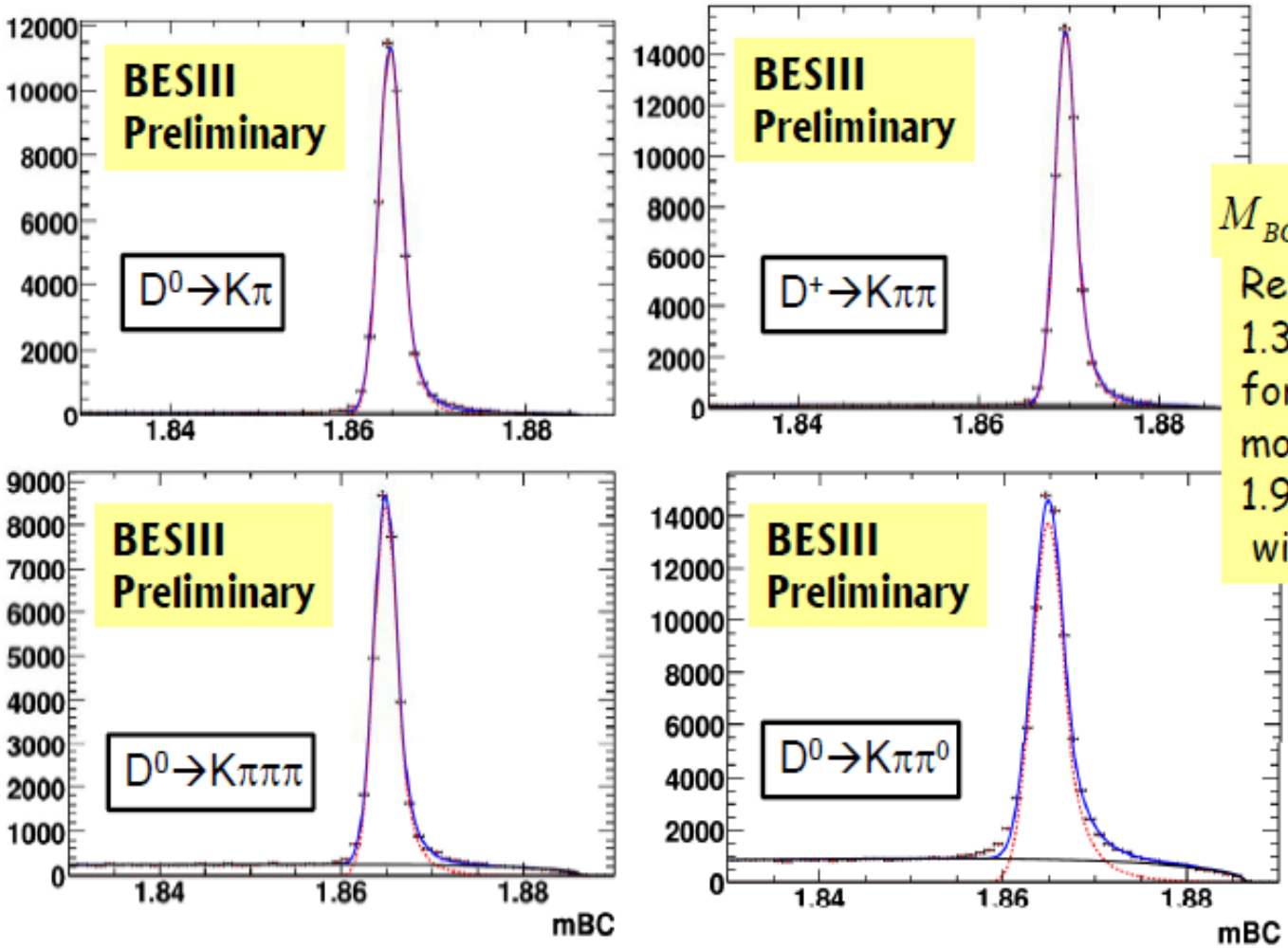
# Charm (many ongoing analysis)

- Purely leptonic decays
  - $f_D$ and $f_{Ds}$ decay constants
- Semileptonic decays
  - |Vcs| and |Vcd| CKM matrix elements, form factor
- Absolute branching fractions
- CP or T violation
- D-D mixing
  - Exploiting quantum correlations @ the ψ(3770)
- XYZ search
- other……

# Clean single tag at BESIII

@ψ(3770) with 420pb$^{-1}$ first clean single tagging sample:

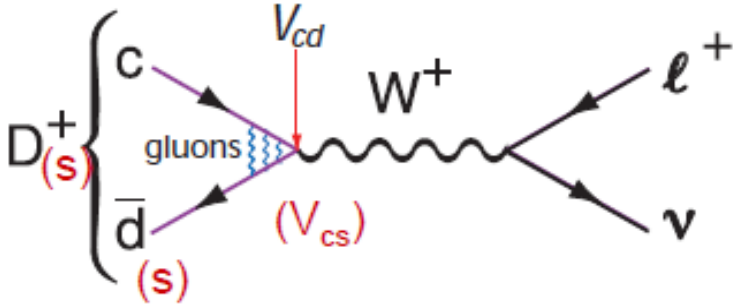



$$M_{BC} = \sqrt{E_{beam}^2 - |p_D|^2}$$

Resolution:
1.3 MeV
for pure charged modes;
1.9 MeV for modes with one $\pi^0$.

# Leptonic decay

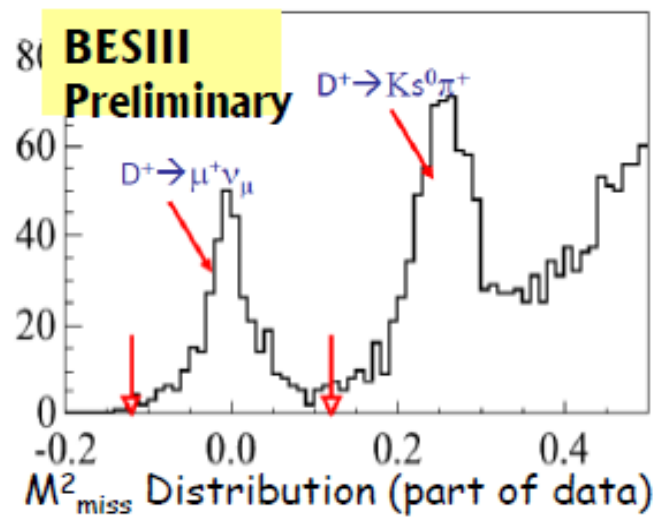



- Clean way to measure $f_{D+}$ and $f_{Ds}$ in SM
- Good agreement between expt. $f_{D+}$ and LQCD calculations
- ~1.6σ difference between expt. $f_{Ds}$ and LQCD calculations

PhysRevD.82.114504

$$\Gamma(D_q^+ \to l^+\nu) = \frac{G_F^2}{8\pi} f_{D_q}^2 \, |V_{cq}|^2 \, m_l^2 \left(1 - \frac{m_l^2}{m_{D_q}^2}\right)^2 m_{D_q} \quad (q = d, s)$$

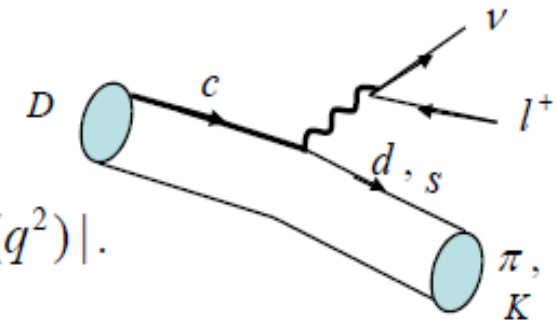
- Two ongoing measurements at BESIII:
  - $D^+ \to \mu^+\nu$
  - $D_s \to \mu^+\nu$



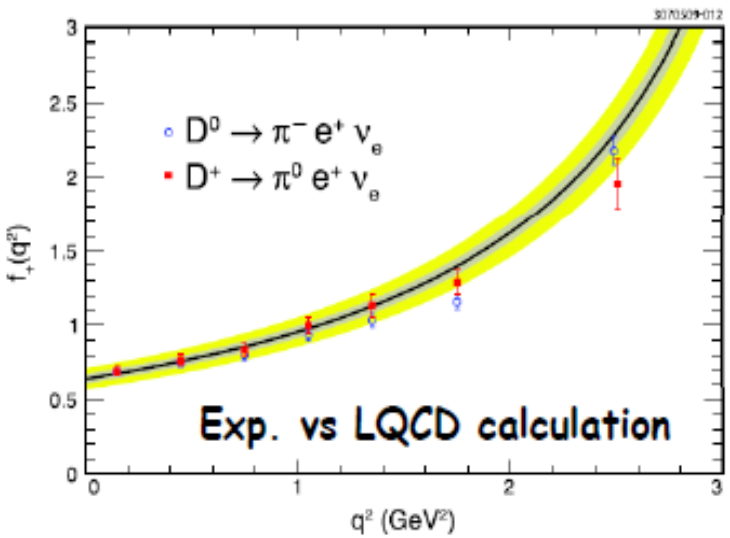
# Semi-leptonic decay

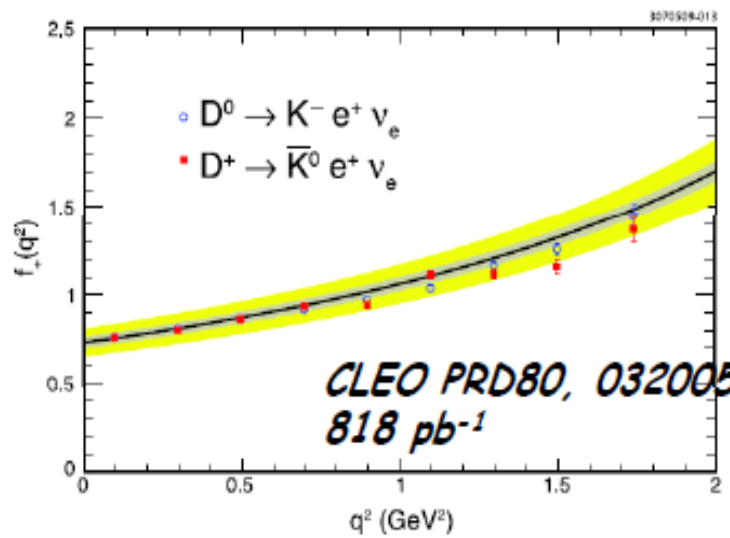
For pseudo-scalar meson:

$$\frac{d\Gamma(D \to K(\pi)e\upsilon)}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cs(d)}|^2 \, p_{K(\pi)}^3 \, |f_+^{K(\pi)}(q^2)|.$$




$D \to \pi \; l^+\nu, \quad D \to K \; l^+\nu$



# Semi-leptonic decay

- Three ongoing measurements:
  - $D^0 \to K^-/\pi^-\ e^+\nu$
  - $D^+ \to \pi^0/\eta\ e^+\nu$,
  - $D^+ \to \omega/\phi\ e^+\nu$, $\omega \to \pi^+\pi^-\pi^0$ , $\phi \to K^+K^-$
- Motivation:
  - Measure form factors and check theory
  - Test iso-spin symmetry in $D^0/D^+ \to \pi^+/\pi^0 e^+\nu$
  - Branching fraction measurements (larger error for PDG value of $D^+ \to \omega e^+\nu$, and only upper limit for $D^+ \to \phi e^+\nu$. can help studying $\omega$–$\phi$ mixing. )

# CPV in D decay at BESIII

Direct CP violation in D decays is expected to be small in SM.

For CF and DCS decays direct CP violation requires New Physics.
Exception: $D^{\pm}\to K_{S,L}\pi^{\pm}$ with $A_{CP}=-3.3\times10^{-3}$.

For Singly Cabibbo Suppressed (SCS) decays SM CPV could reach $10^{-3}$.

$$A_{CP}=\frac{\Gamma(D\to f)-\Gamma(\bar{D}\to\bar{f})}{\Gamma(D\to f)+\Gamma(\bar{D}\to\bar{f})}$$

D.S.Du , EPJC5,579(2007)
Y. Grossman et al
PRD75, 036008(2007)

**Best limits:**

Belle: $D^0\to K^+K^-,\pi^+\pi^-$
$A_{CP}(K^+K^-)=(0.43\pm0.30\pm0.11)\%$
$A_{CP}(\pi^+\pi^-)=(0.43\pm0.52\pm0.12)\%$

BABAR: $D^+\to K_S\pi^+$
$A_{CP}(K_S\pi^+)=(-0.44\pm0.13\pm0.10)\%$

CLEO-c : Ks $\pi^+\pi^0$
$A_{CP}(K_S\pi^+\pi^0)=(0.3\pm0.9\pm0.3)\%$

At BESIII, CP asymmetry can be tested with $10^{-3}$ sensitivity for many final states.

# CP Violation with T-Odd Correlation

- Form T-odd correlation and difference of asymmetries
  - Look for T-violation assuming CPT invariance (Bigi hep-ph/0107102)
  - D meson four body decays
  - D→ KsKππ, KKππ

$$C_T \equiv \langle \vec{p}_{K^+} \cdot (\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}) \rangle$$

$$\bar{C}_T \equiv \langle \vec{p}_{K^-} \cdot (\vec{p}_{\pi^-} \times \vec{p}_{\pi^+}) \rangle$$

$$A_T = \frac{\Gamma_{D^0}(C_T>0) - \Gamma_{D^0}(C_T<0)}{\Gamma_{D^0}(C_T>0) + \Gamma_{D^0}(C_T<0)} \quad \text{and} \quad \bar{A}_T = \frac{\Gamma_{\bar{D}^0}(-\bar{C}_T>0) - \Gamma_{\bar{D}^0}(-\bar{C}_T<0)}{\Gamma_{\bar{D}^0}(-\bar{C}_T>0) + \Gamma_{\bar{D}^0}(-\bar{C}_T<0)}$$

- If T violation:

$$\mathcal{A}_T = \frac{A_T - \bar{A}_T}{2} \neq 0$$

- Ongoing analysis:
  - Look into $D^{+/-}$→ KsKππ, KKππ$^0$

# Other topics on charm

- Dalitz plot analysis ($D^0 \to K\pi\pi^0$, $D^+ \to K^0_s\pi\pi^0$, $D^0 \to K\pi\eta$, $D^+ \to KK\pi$) :
  - Study the $K\pi$ system, search for the low mass scalar resonance $\kappa$
- $\psi(3770)$ cross section measurement
- $\psi(3770)$ line shape measurement
- …

# Summary

- Both $p\bar{p}$ threshold enhancement and X(1835) are confirmed at BESIII
- A new process is observed in $J/\psi \to \omega X(1870) \to \omega\eta\pi^+\pi^-$.
- a0(980) –f0(980) mixing is measured
- $\eta_c$ resonance parameters are measured with higher precision, $h_c$ inclusive and exclusive decays are studied. $\eta_c(2S)$ are confirmed in M1 transition for the first time
- $\psi' \to \gamma$ P, $\chi_{cJ} \to \gamma$ V and $\chi_{cJ} \to$ VV are measured and many new decay modes are observed for the first time.
- Large $\psi(3770)$ data and unique data @4.01GeV are available and many studies are ongoing.
- More exciting/interesting results are upcoming

**Thank you!**

# Backup Slides