Review of Light Hadron Spectra at BESIII

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(on behalf of BESIII Collaboration)

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Moriond QCD and High Energy Interactions
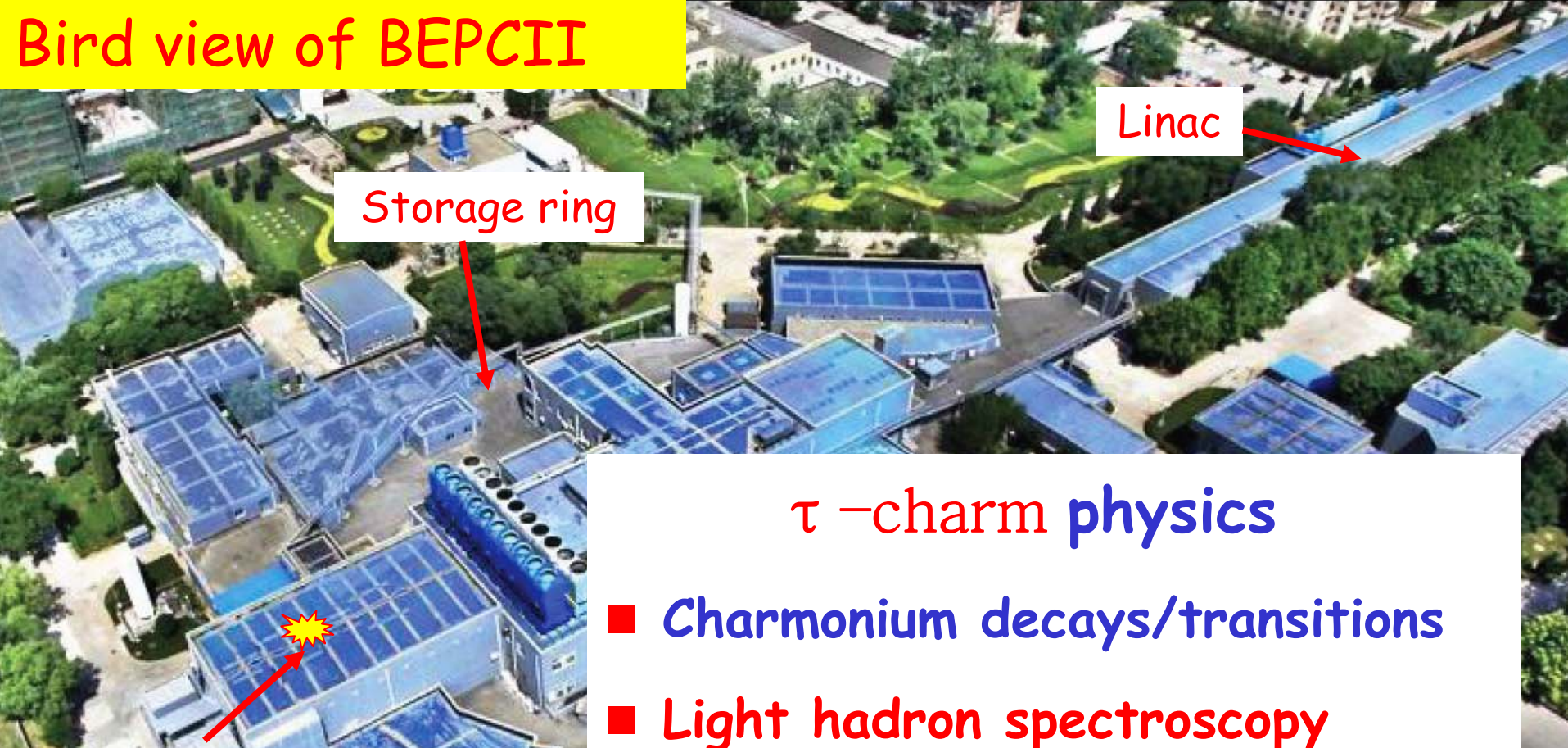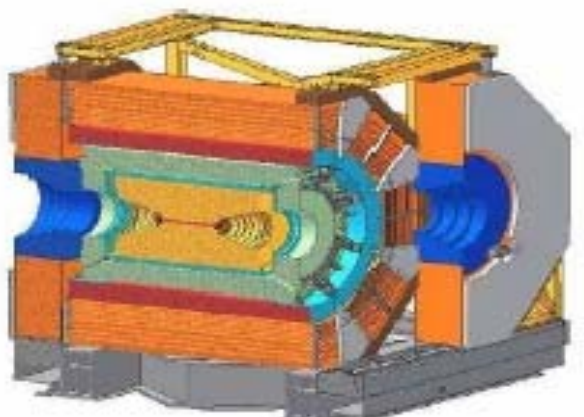
March 9th - March 16th 2013

OUTLINE

- **Introduction**

- **Latest results on hadron spectroscopy**

- **Summary and prospects**
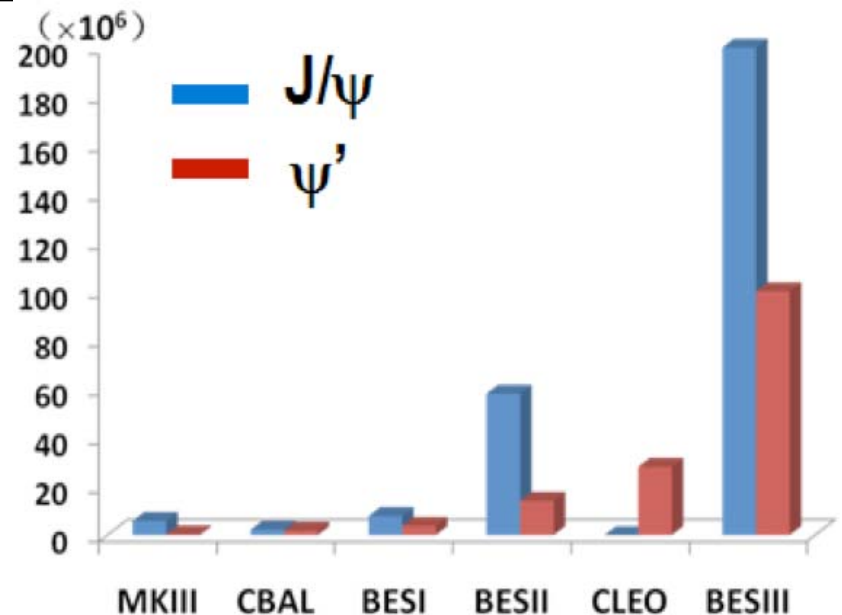
Bird view of BEPCII

Linac

Storage ring

BESIII at BEPCII

$\tau -$charm **physics**

- ■ **Charmonium decays/transitions**
- ■ **Light hadron spectroscopy**
  - ● …
  - ● η **and** η' **physics**
- ■ **Charm physics**
- ■ τ **physics**

J/ψ and ψ' Data samples

- **So far BESIII has collected :**
  - **2009: 106 Million ψ'**
  - **2012: 0.4 Billion ψ'**

  - **2009: 225 Million J/ψ**
  - **2012: 1 Billion J/ψ**

**The results in this talk are based on the data sample of 106M ψ' events and 225M J/ψ events**

Latest results on hadron spectroscopy

- ✓ **Confirmation of p $\bar{\text{p}}$ mass threshold enhancement**
- ✓ **Confirmation of X(1835) and observation of two new structures**
- ✓ **X(1870) in J/$\psi \to \omega$X, X$\to$a$_0$(980)π**
- ✓ **X(1840) in J/$\psi \to \gamma 3(\pi^+\pi^-)$**
- ✓ **M$\omega\phi$ threshold enhancement in J/$\psi \to \gamma \omega \phi$**
- ✓ **N* baryons in $\psi' \to$ p $\bar{\text{p}}\eta$, p $\bar{\text{p}}\pi^0$ decays**

Confirmation of p p̄ mass threshold enhancement

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

M=1859 $^{+3}_{-10}$ $^{+5}_{-25}$ MeV/c^2
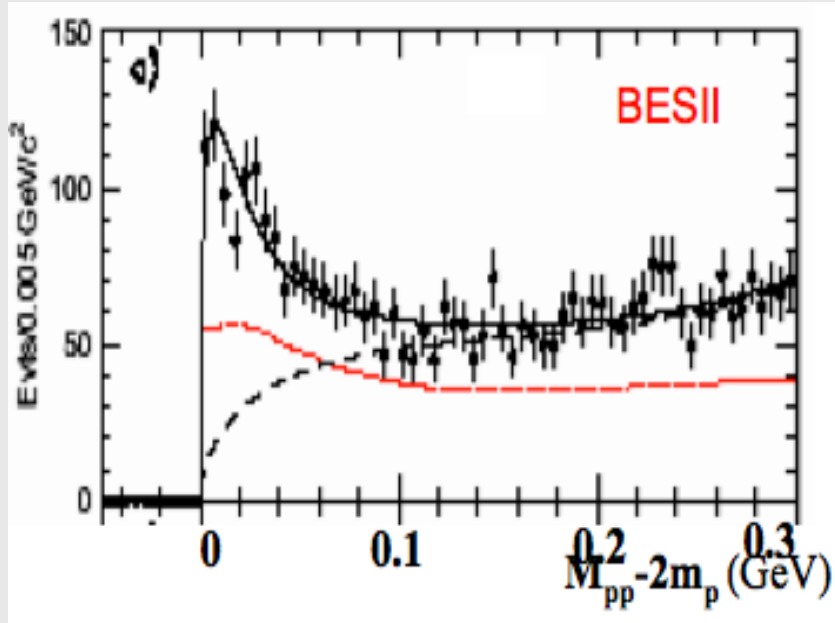
Γ < 30 MeV/c^2 (90% CL)

PRL 91 (2003) 022001

Theoretical interpretation:

➢ conventional meson?

➢ ppbar bound state/multiquark
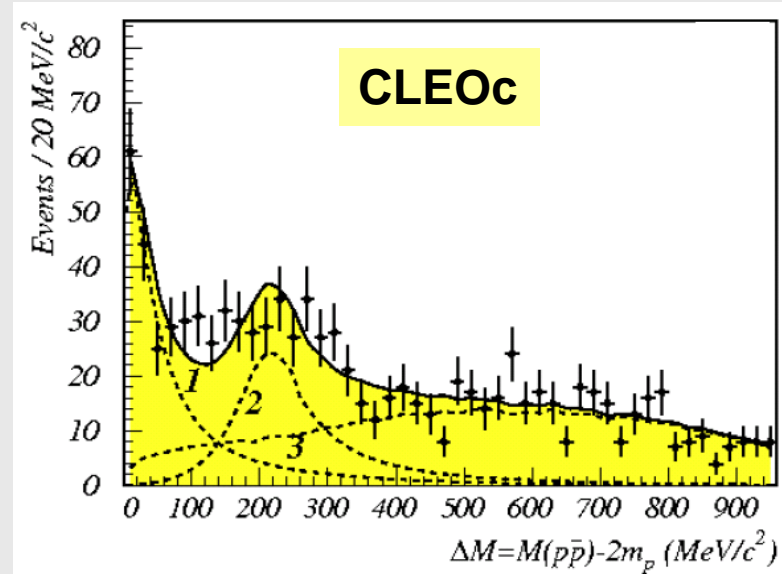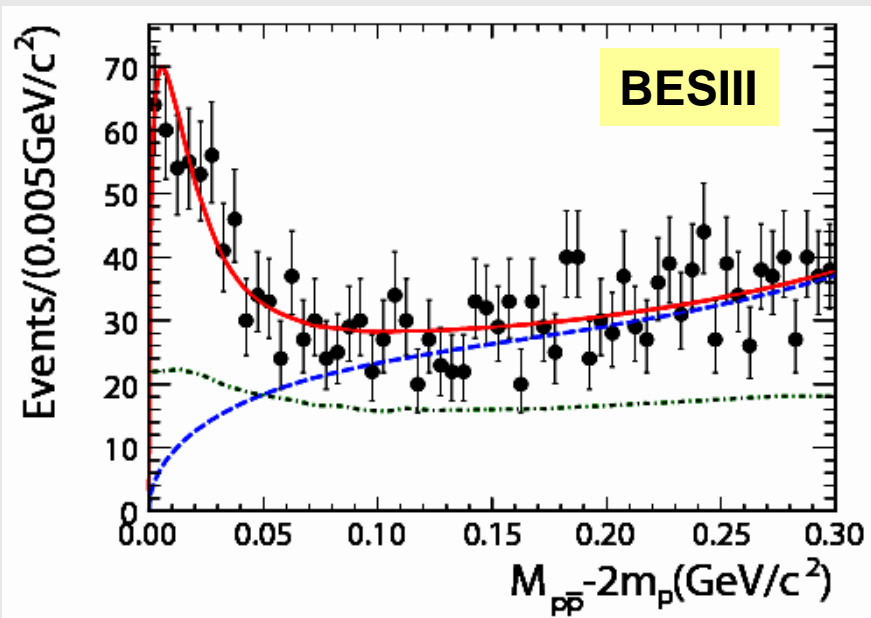
➢ glueball

➢ Final state interaction (FSI)

➢ ...

6

Fit with one resonance at BESII did:

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

BESIII

CLEOc

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

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

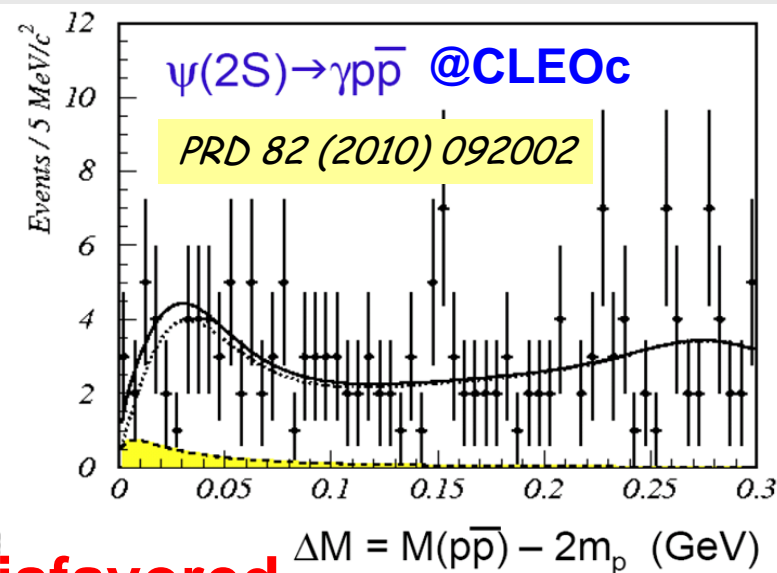$M(R_{thr}) = 1861^{+6}_{-16}$ (MeV), $\quad \Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV),

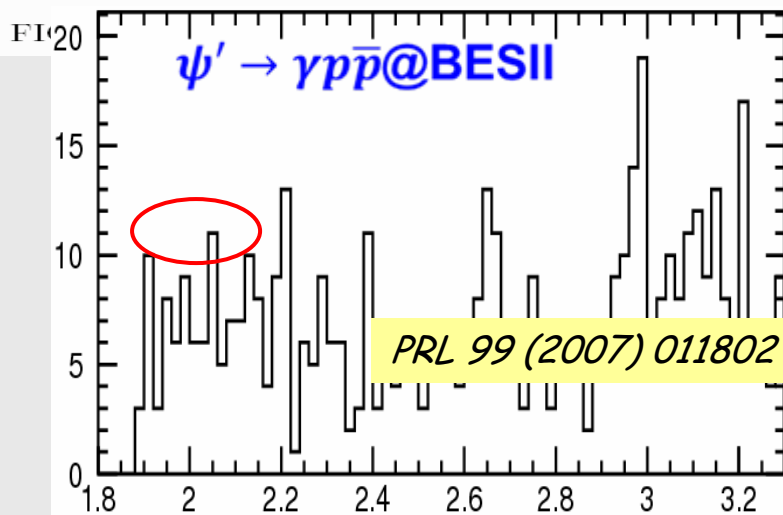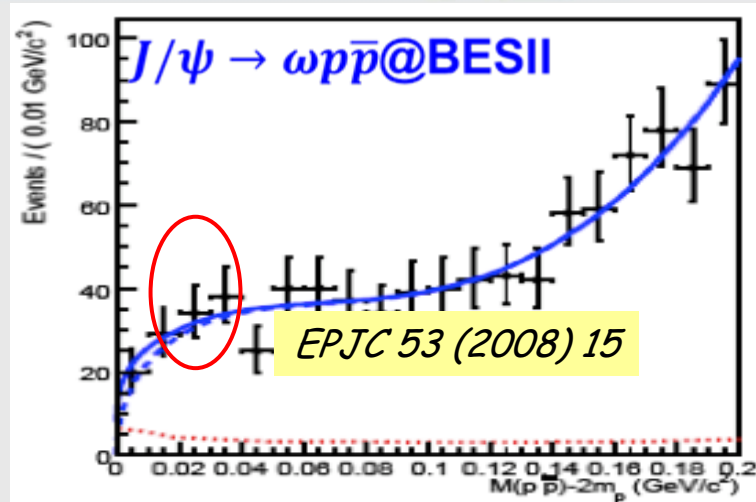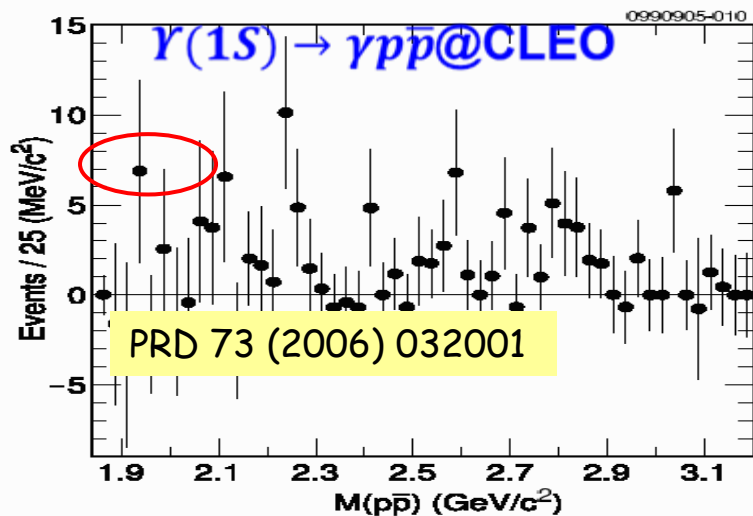$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}$

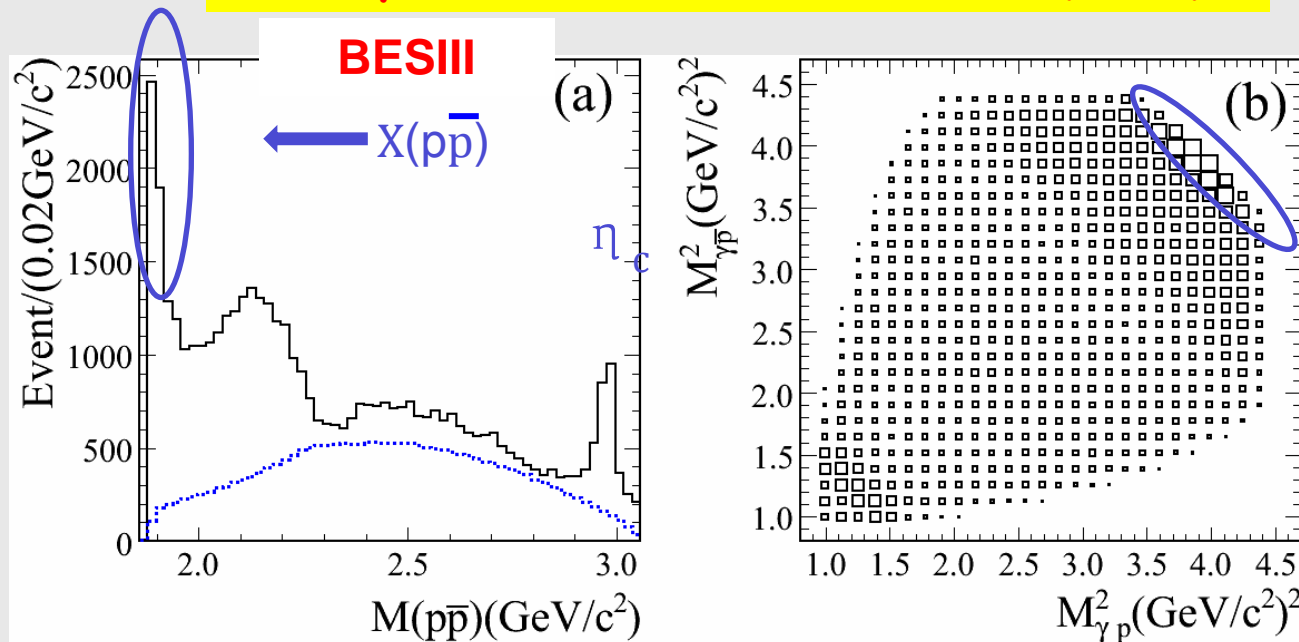Chinese Physics C 34, 421 (2010)   PRD 82, 092002(2010)

7

Pure FSI interpretation is disfavored

PWA on the p p̄ mass threshold structure in $J/\psi \to \gamma p\bar{p}$

- **Evident narrow ppbar mass threshold enhancement in J/ψ decays.**
- **Partial Wave Analysis (PWA):**
  - Concentrate on dealing with the $p\bar{p}$ mass threshold structure, especially to determine the J^{PC}.
  - Convariant tensor amplitudes (S. Dulat and B. S. Zou, Eur.Phys.J A 26:125, 2005).
  - Include the Juich-FSI effect (A. Sirbirtsen et al. Phys.Rev.D 71:054010, 2005). 9
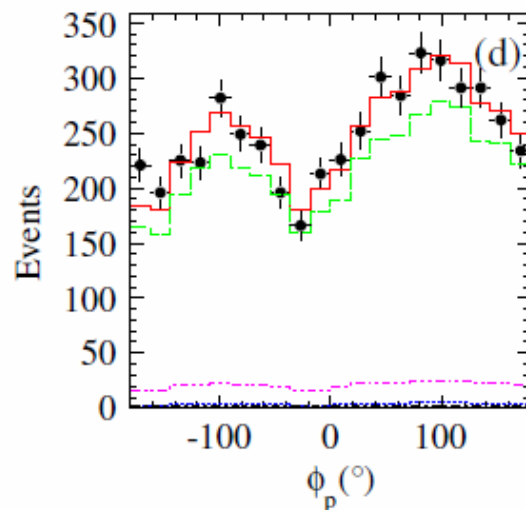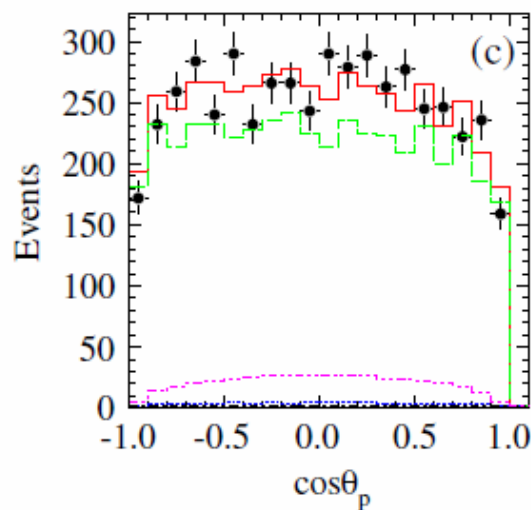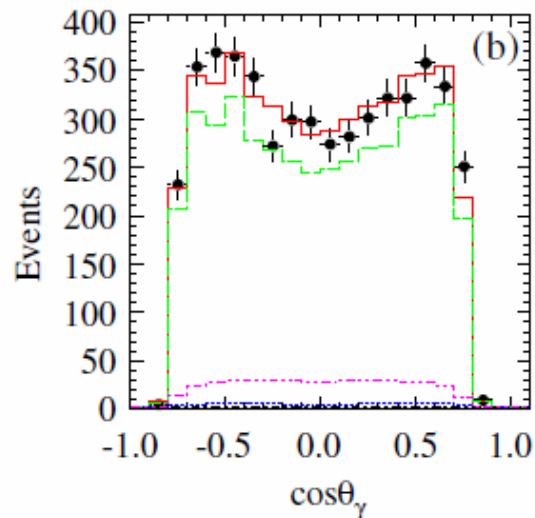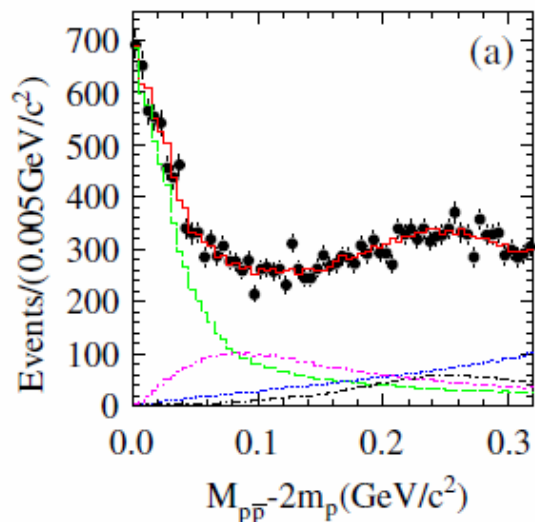
- The fit with a BW and S-wave FSI(I=0) factor can well describe ppb mass threshold structure

- It is much better than that without FSI effect (~7 σ)

10

- **PWA results are carefully checked from different aspects:**
  - **Contribution of additional resonances**
  - **Solution with different combinations**
  - **Different background levels and fitting mass ranges**
  - **Different BW formula**

  All uncertainties are considered as systematic errors

- **Different FSI models → Model dependent uncertainty**

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

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

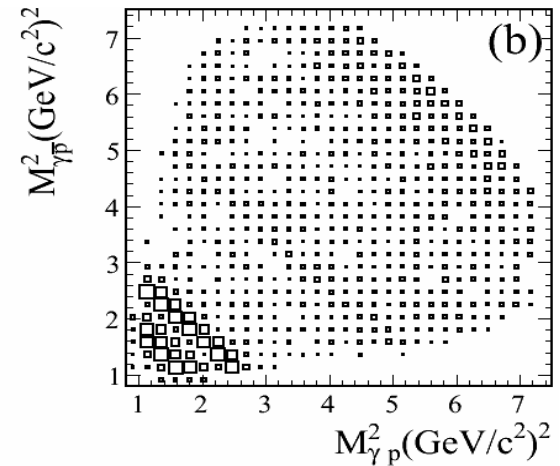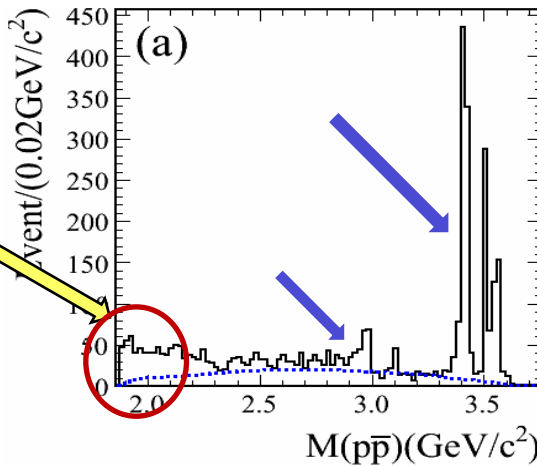| Resonance	Mass(MeV/c²)	Width(MeV/c²)
X(ppbar)	$1832^{+19}_{-5}{}^{+18}_{-17} \pm 19(\text{model})$	$13 \pm 39^{+10}_{-13} \pm 4(\text{model})$

$$BR[J/\psi \rightarrow \gamma X(p\bar{p})]BR[X(p\bar{p}) \rightarrow p\bar{p}] = [9.0^{+0.4}_{-1.1}(\text{stat})^{+1.5}_{-5.0}(\text{syst}) \pm 2.3(\text{model})] \times 10^{-5}$$

Obviously different line shape of ppbar mass spectrum near threshold from that in J/ψ decays

(a) Event/(0.02GeV/c^2) vs M(p$\bar{p}$)(GeV/c^2)

(b) $M^2_{\gamma\bar{p}}$(GeV/c^2)^2 vs $M^2_{\gamma p}$(GeV/c^2)^2

PWA results:

- Significance of X(ppbar) is > 6.9 σ .

- The production ratio R: **first measurement**
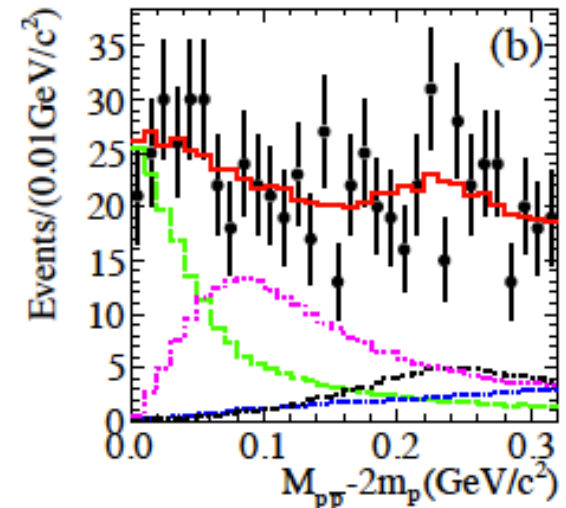
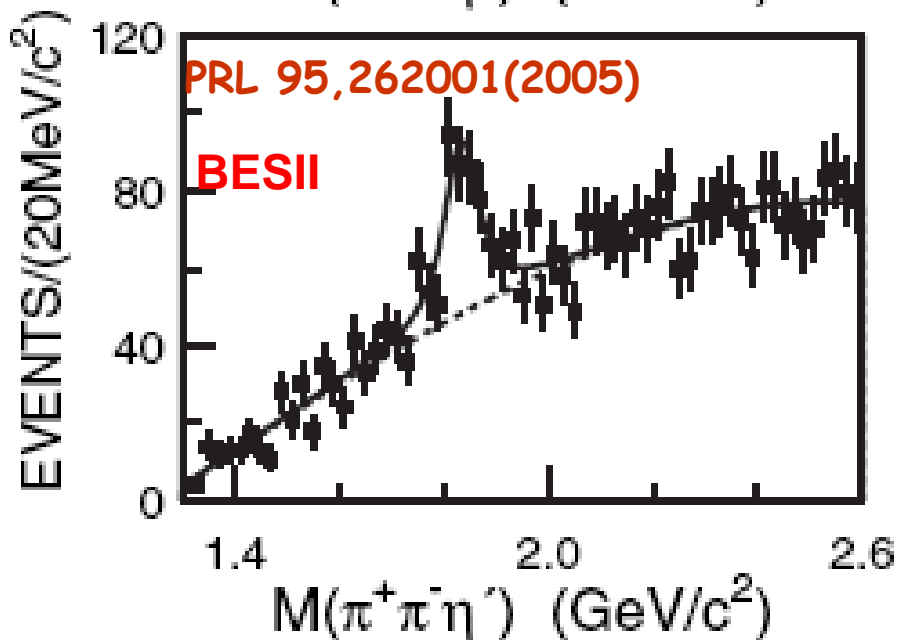$$R = \frac{B(\psi' \to \gamma X(p\bar{p}))}{B(J/\psi \to \gamma X(p\bar{p}))}$$

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

- It is suppressed compared with "12% rule".

PWA Projection:

(b) Events/(0.01GeV/c^2) vs $M_{p\bar{p}} - 2m_p$ (GeV/c^2)

PRL 108,112003(2012)

PRL 95,262001(2005)

BESII

EVENTS/(20MeV/c^2)

M($\pi^+\pi^-\eta'$) (GeV/c^2)

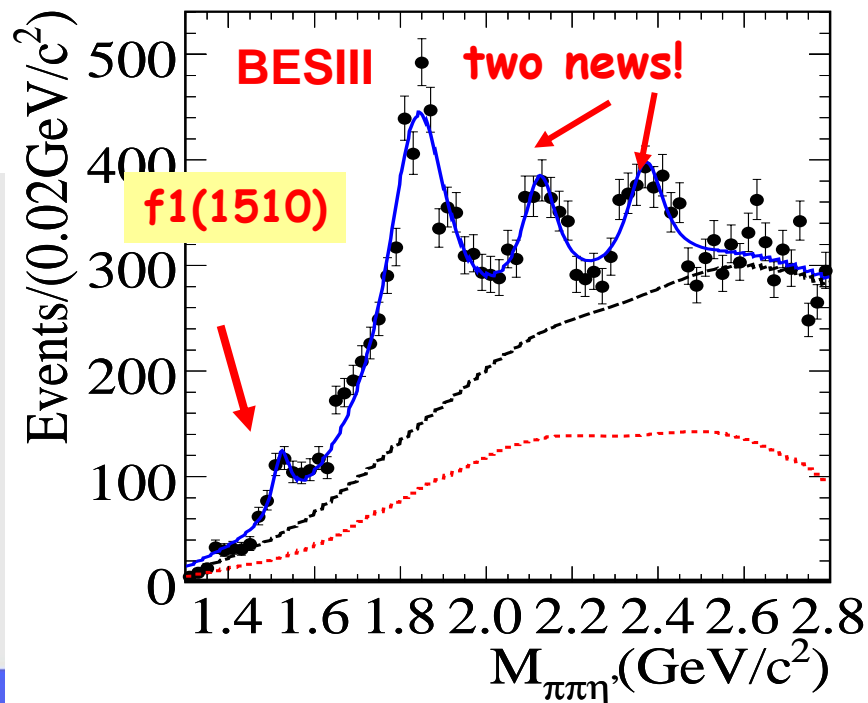$BESII\ result(\text{Stat. sig.} \sim 7.7\sigma):$

$M = 1833.7 \pm 6.1(stat) \pm 2.7(syst)MeV$

$\Gamma = 67.7 \pm 20.3(stat) \pm 7.7(syst)MeV$

PRL 106, 072002(2011)

BESIII two news!

f1(1510)

Events/(0.02GeV/c^2)

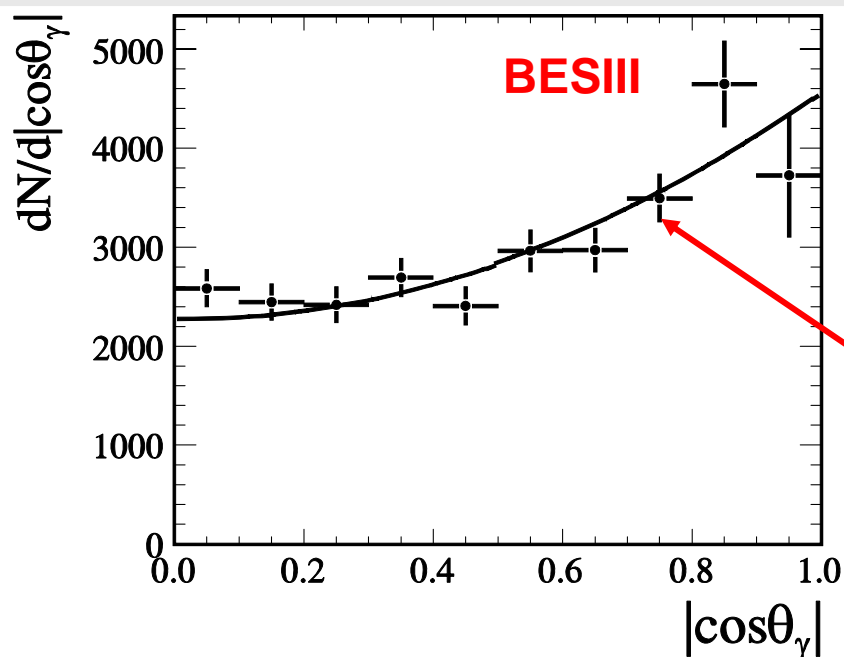M$_{\pi\pi\eta'}$(GeV/c^2)

J/$\psi\rightarrow\gamma\eta'\pi^+\pi^-$

$\eta'\rightarrow\eta\pi+\pi^-$

$\eta'\rightarrow\gamma\rho$

Confirmation of X(1835) and Observation of two new structures

BESIII fit results:

Resonance	M(MeV/c^2)	Γ(MeV/c^2)	Stat.Sig.
X(1835)	$1836.5 \pm 3.0^{+5.6}_{-2.1}$	$190.1 \pm 9.0^{+38}_{-36}$	>20 σ
X(2120)	$2122.4 \pm 6.7^{+4.7}_{-2.7}$	$83 \pm 16^{+31}_{-11}$	7.2 σ
X(2370)	$2376.3 \pm 8.7^{+3.2}_{-4.3}$	$83 \pm 17^{+44}_{-6}$	6.4 σ

PWA is needed to understand these structures.

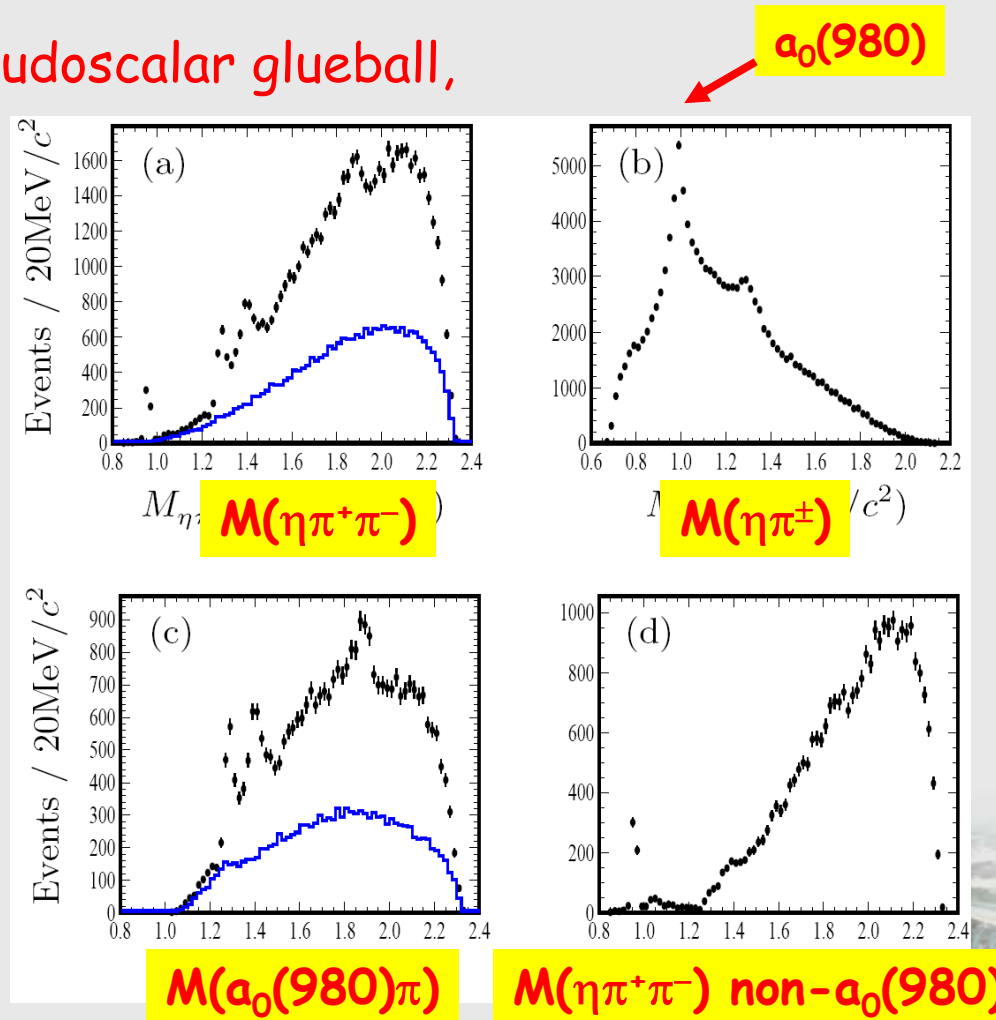**X(1835) consistent with 0^{-+}**

X(1870) in $J/\psi \to \omega X$, $X \to a_0(980)\pi$
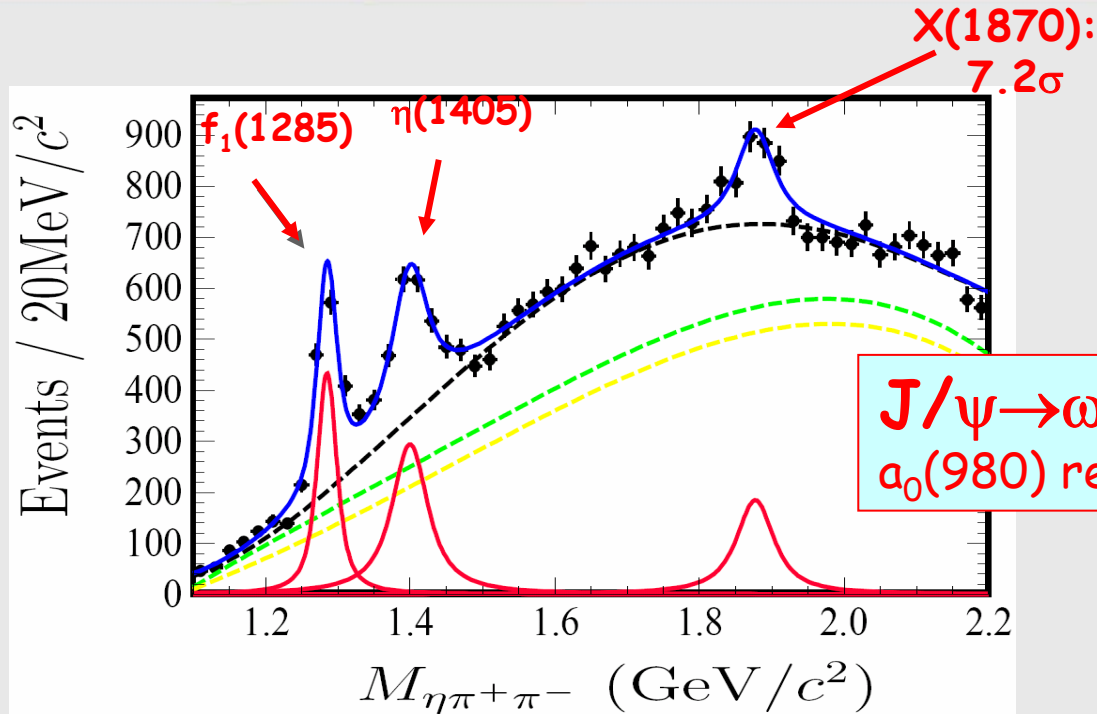
✓ X(1835) observed at BESII and then confirmed at BESIII in
$J/\psi \to \gamma \pi^+\pi^-\eta'$

✓ theoretical interpretations: pseudoscalar glueball,
η/η' excited states ..

✓ study of its production in hadronic decays

✓ to our surprise, we observed a new structure around 1.87 GeV

PRL 107, 182001(2011)

BESIII

$a_0(980)$

(a) $M(\eta\pi^+\pi^-)$

(b) $M(\eta\pi^\pm)$

(c) $M(a_0(980)\pi)$

(d) $M(\eta\pi^+\pi^-)$ non-$a_0(980)$

X(1870) in $J/\psi \to \omega X$, $X \to a_0(980)\pi$

X(1870): 7.2σ

$f_1(1285)$ η(1405)

$J/\psi \to \omega\eta\pi^+\pi^-$,
$a_0(980)$ reconstructed in $\eta\pi^\pm$

Identification of X(1870): 0⁻⁺(?) It is X(1835)? Need PWA!

BR($J/\psi \to \omega X$, $X \to a_0^\pm(980)\pi^\mp$)

Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	Branch ratio (10^{-4})
$f_1(1285)$	$1285.1 \pm 1.0^{+1.6}_{-0.3}$	$22.0 \pm 3.1^{+2.0}_{-1.5}$	$1.25 \pm 0.10^{+0.19}_{-0.20}$
$\eta(1405)$	$1399.8 \pm 2.2^{+2.8}_{-0.1}$	$52.8 \pm 7.6^{+0.1}_{-7.6}$	$1.89 \pm 0.21^{+0.21}_{-0.23}$
$X(1870)$	$1877.3 \pm 6.3^{+3.4}_{-7.4}$	$57 \pm 12^{+19}_{-4}$	$1.50 \pm 0.26^{+0.72}_{-0.36}$

X(1840) in $J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
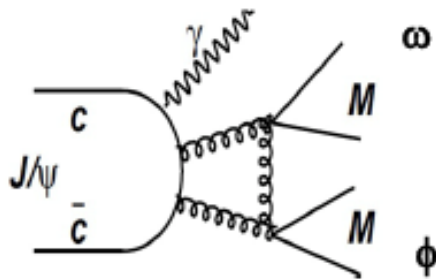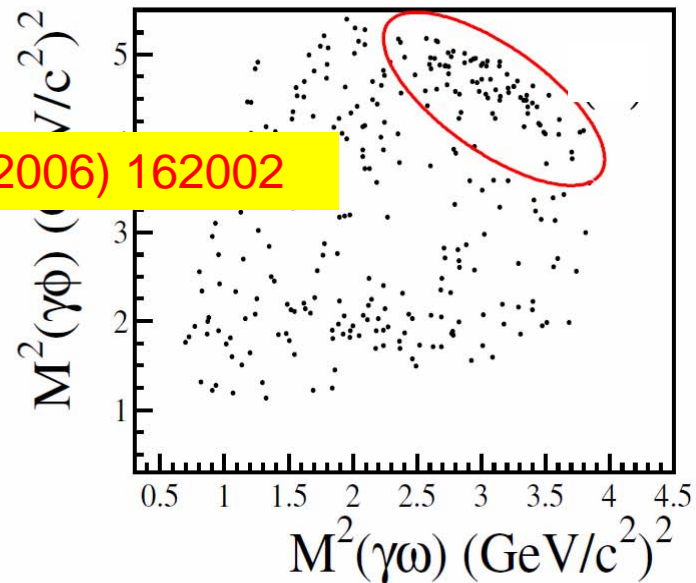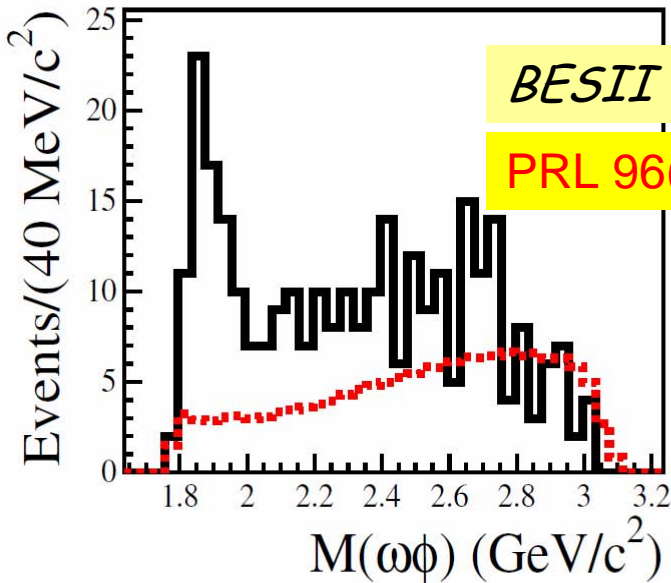
Preliminary results
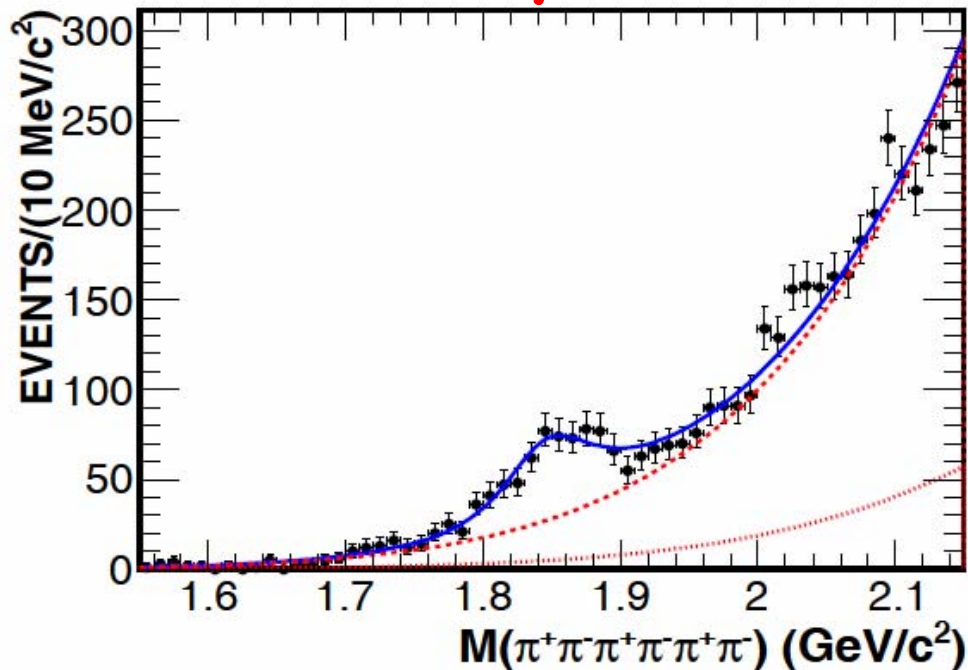
A peak around 1.84 GeV is observed !

$M = 1842.2 \pm 4.2^{+6.9}_{-1.8}$ MeV

$\Gamma = 83 \pm 14 \pm 11$ MeV

- Its mass is consistent with that of X(1835), but the width is much smaller than $\Gamma_{x(1835)} = 190.1 \pm 9.0^{+38}_{-36}$ MeV
- Most likely to be a new decay mode of X(1835)

BESII

PRL 96(2006) 162002

$J/\psi \to \gamma\omega\phi$ **(DOZI)**
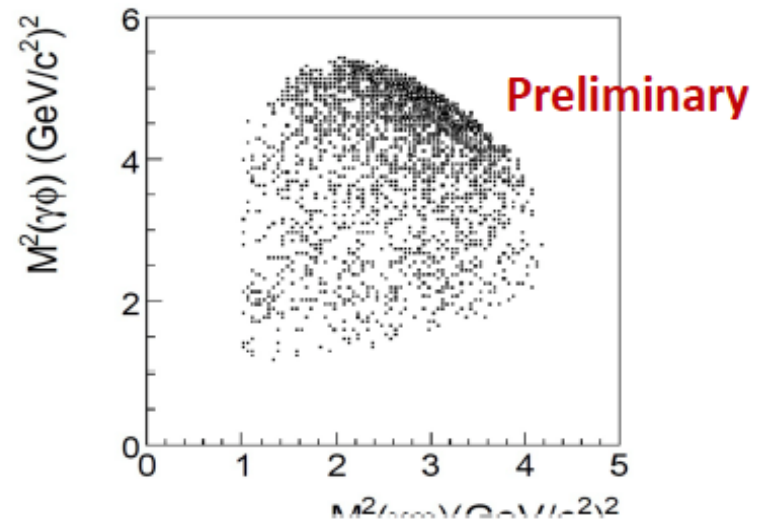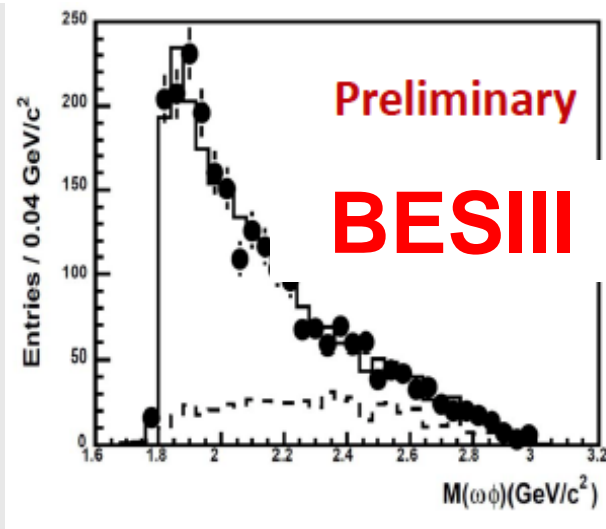
For X(1810):

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

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

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

18

Preliminary PWA results of J/$\psi \rightarrow \gamma \, \omega \, \phi$

| Resonance	J^{PC}	M(MeV/c^2)	Γ(MeV/c^2)	Events	$\Delta \mathcal{S}$	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	$> 10\sigma$
η(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?

Observation of two N* baryons in $\psi' \to \pi^0 p \bar{p}$ decay

- **Non-relativistic quark model is successful in interpreting of the excited baryons**

- **Predicted more excited stated ("missing resonance problem")**

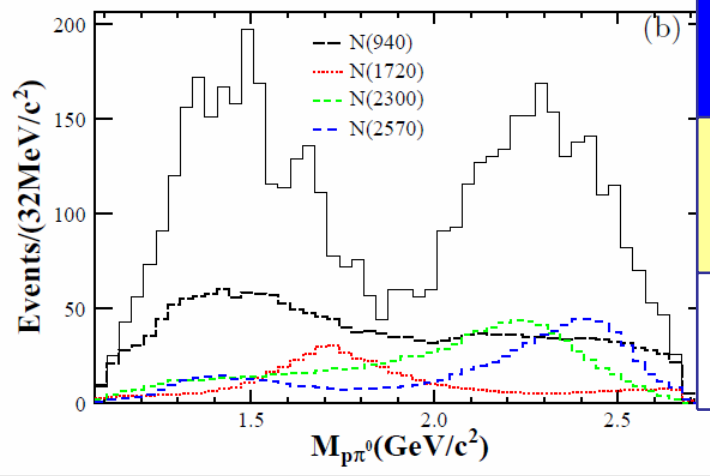- **J/ψ (ψ') decays offers an window to search for the missing resonance**

arXiv:1207.0223
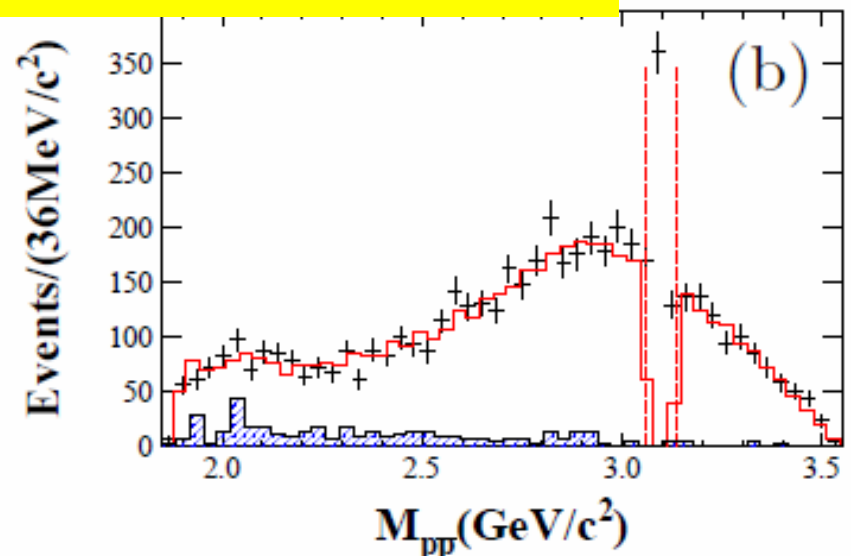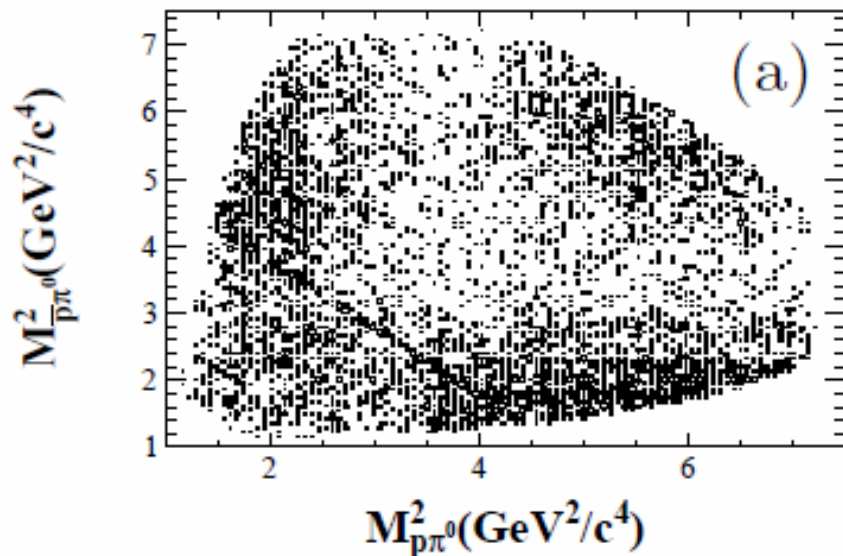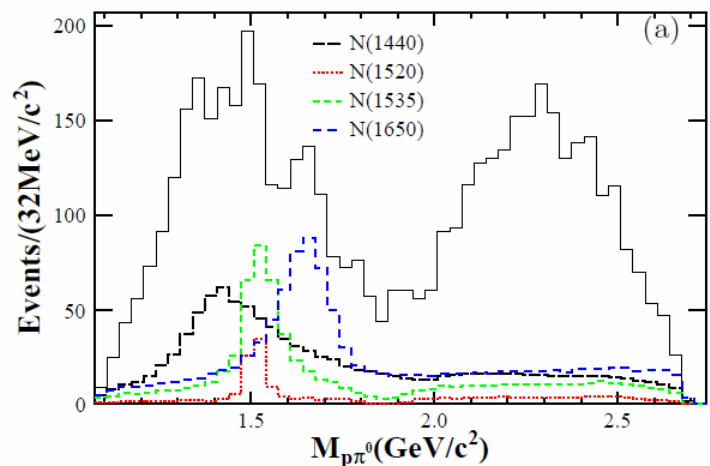
Resonance	$M(\text{MeV}/c^2)$	$\Gamma(\text{MeV}/c^2)$	ΔS	ΔN_{dof}	C.L.
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	4	12.2σ
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94-44}$	55.6	6	9.6σ
$N(2300)$	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$	120.7	4	15.0σ
$N(2570)$	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}	78.9	6	11.7σ

Two new baryonic excited states are observed !   arXiv:1207.0223

Resonance	M(MeV/c²)	Γ(MeV/c²)
N(2300)	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$
N(2570)	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}

21

Preliminary results on N* baryon in ψ'→ηp p̄ decay

BESIII Preliminary

Dalitz plot data

dalitz plot of fit result
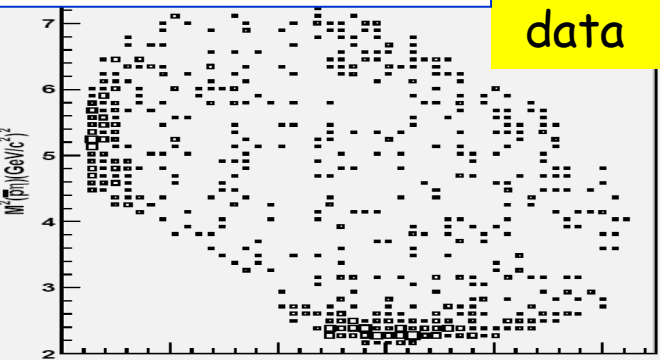
Dalitz plot MC fit
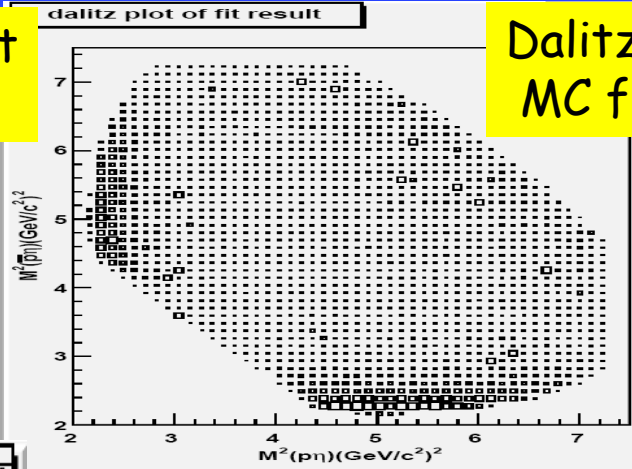
A full PWA is performed.

Background clean!

N(1535)

N(1535) is 1/2⁻

M(pη)

M(pp̄)
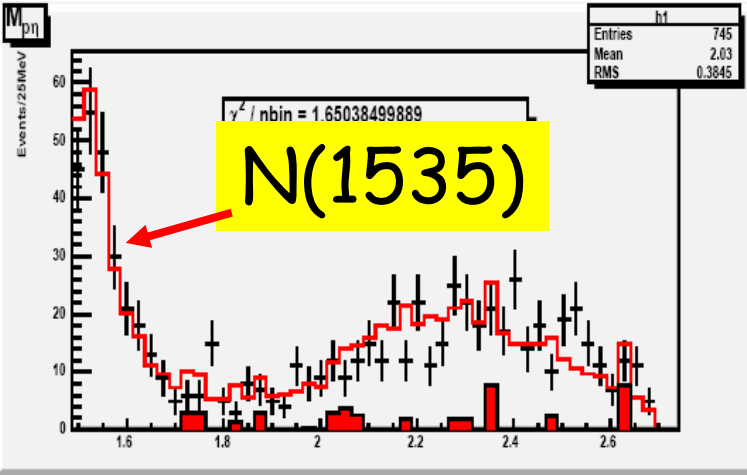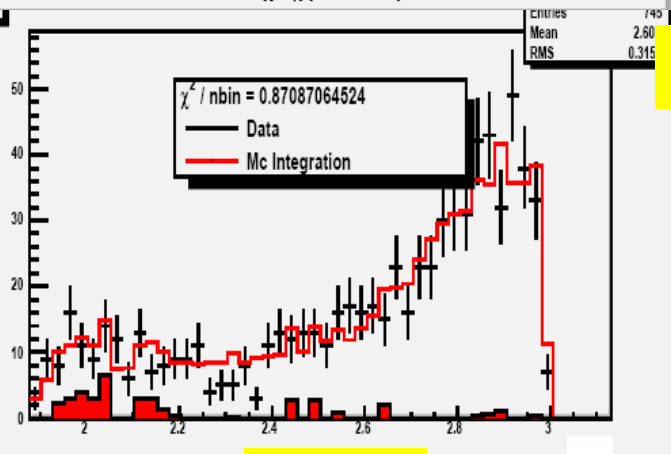
Mass:
$$1.524^{+0.005+0.010}_{-0.005-0.004}\text{GeV}$$

Width:
$$0.130^{+0.027+0.061}_{-0.027-0.014}\text{ GeV}$$

Br(ψ'→ppη)=(6.6±0.2±0.6)×10⁻⁵

Br(ψ'→N(1535)p)×Br(N(1535)→pη+c.c.)
$$= 5.5^{+0.3+7.4}_{-0.3-1.1}\times10^{-5}$$

PDG2010: (6.0±1.2)×10⁻⁵

- **Huge data samples collected for charmonium decays at BESIII. A lot of results have been obtained,**

  - ✓ Confrimation of the p $\bar{p}$ mass threshold enhancement

  - ✓ Confirmation of X(1835) and observation of two new structures X(2120) and X(2370)

  - ✓ Observation of new structure X(1870) in $J/\psi \rightarrow \omega\pi\pi\eta$

  - ✓ ……

- **1 billion J/psi events were taken at BESIII**

- **We expect rich physics results in the coming years from BESIII !**

Thanks!