Review of Light Hadron Spectra at BESIII

Shuangshi FANG

(on behalf of BESIII Collaboration)

Institute of High Energy Physics

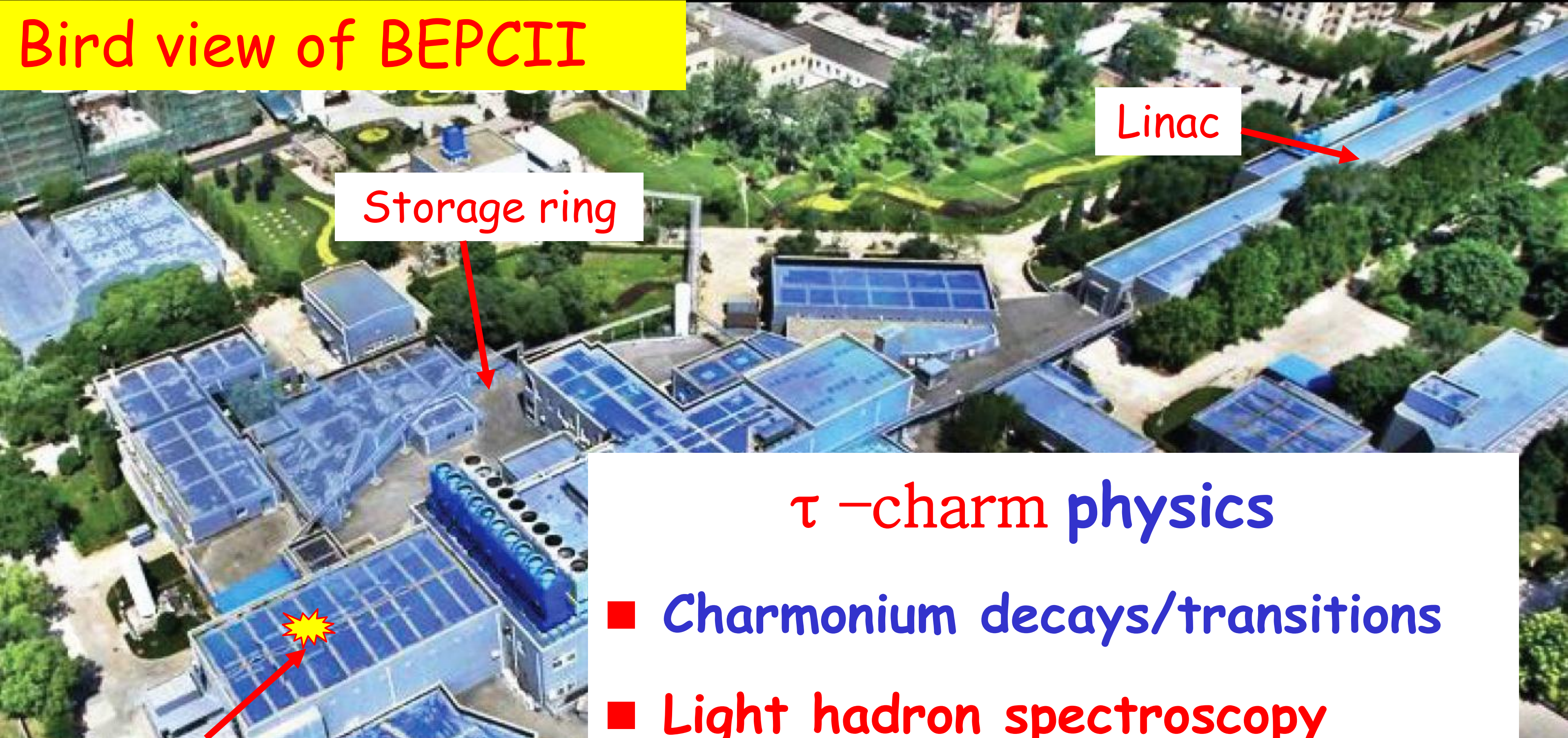
Hadron Structure and Interactions in 2012

Osaka, 16-17, November 2012

OUTLINE

- Introduction
- Latest results on hadron spectroscopy
- Summary

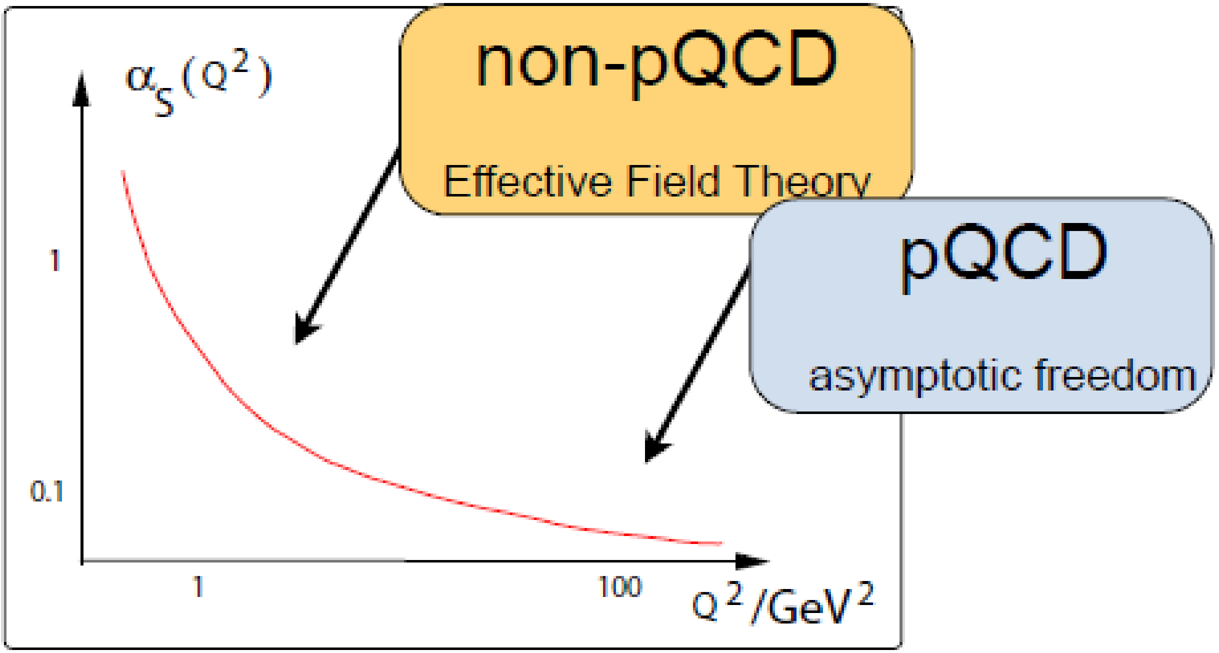
Bird view of BEPCII



τ −charm physics

- Charmonium decays/transitions
- Light hadron spectroscopy
  - …
  - η and η′ physics
- Charm physics
- τ physics

Why light hadron physics ?

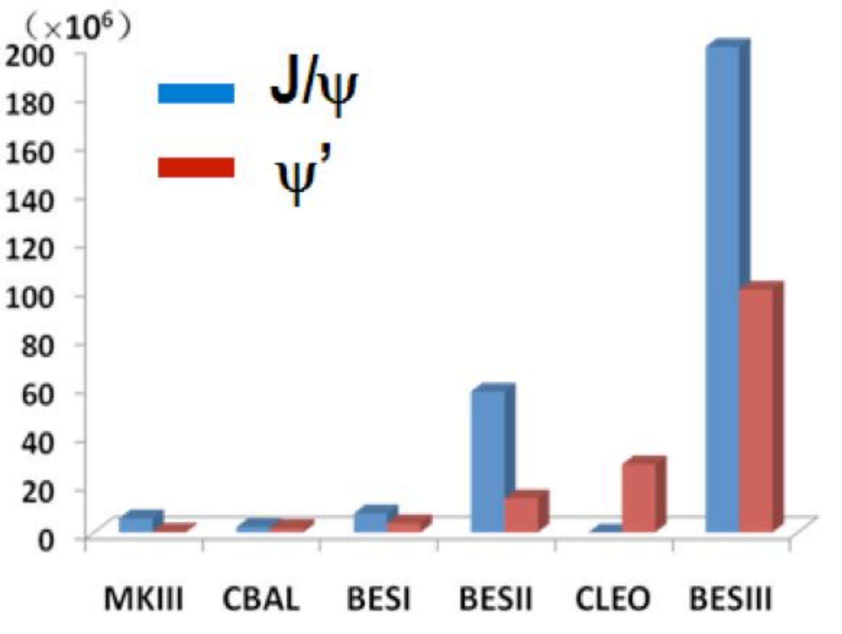


"That [intermediate distance] scale is the richest phenomenologically, and is certainly the crux region to understand...what QCD is really about. And at the heart of the subject is the hadron spectrum, in particular the spectrum built from light quarks. (...) **Without question, there is a great need... for a new round of experiments,...**"

James D. Bjorken (2000)

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



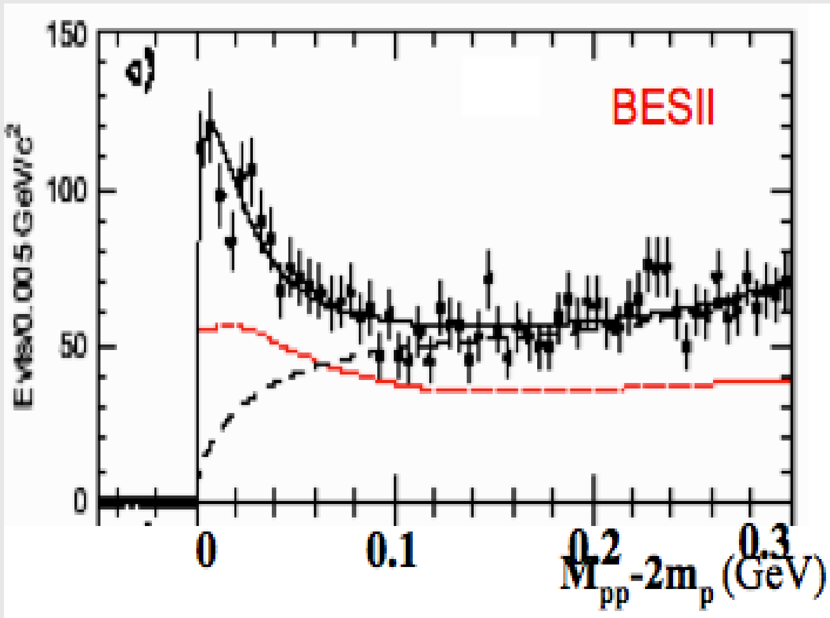
The results in this talk are based on the data sample of 106M ψ' events and 225M J/ψ events

Latest results on hadron spectroscopy

- ✓ Confirmation of $p\bar{p}$ mass threshold enhancement
- ✓ Confirmation of X(1835) and observation of two new structures
- ✓ X(1870) in $J/\psi \to \omega X$, $X \to a_0(980)\pi$
- ✓ X(1840) in $J/\psi \to \gamma 3(\pi^+\pi^-)$
- ✓ Study of ηη system
- ✓ First observation of $\eta(1405) \to f_0(980)\pi^0, f_0(980) \to \pi\pi$
- ✓ N* baryons in $\psi' \to p\bar{p}\eta$, $p\bar{p}\pi^0$ decays
- ✓ η and η' physics

Confirmation of $p\bar{p}$ mass threshold enhancement

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



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

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

PRL 91 (2003) 022001

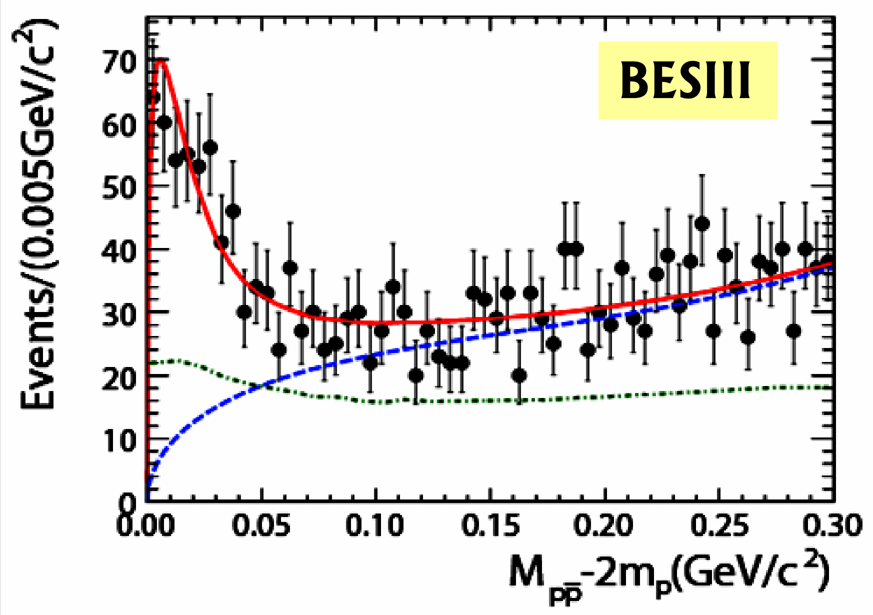
Theoretical interpretation:

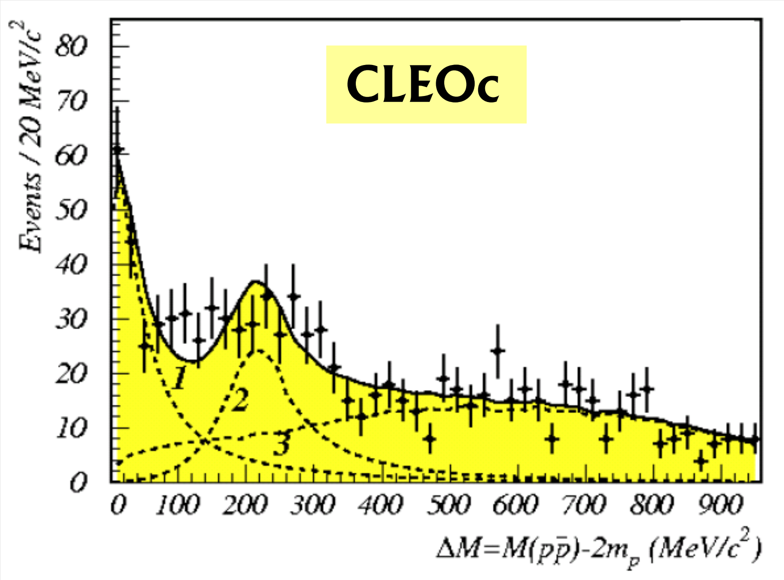
- conventional meson?
- ppbar bound state/multiquark
- glueball
- Final state interaction (FSI)
- …

Confirmation of p $\bar{p}$ mass threshold enhancement

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)

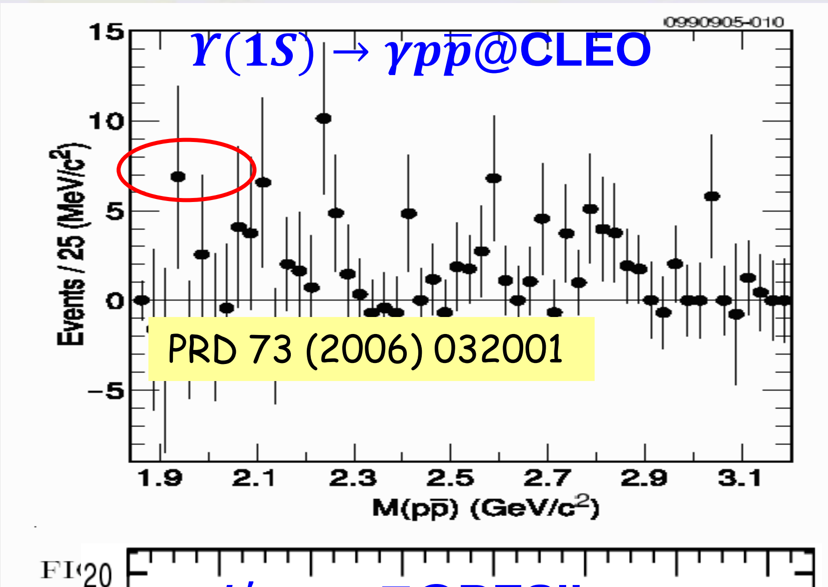
$M(R_{thr}) = 1861^{+6}_{-16}$ (MeV), $\Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV),

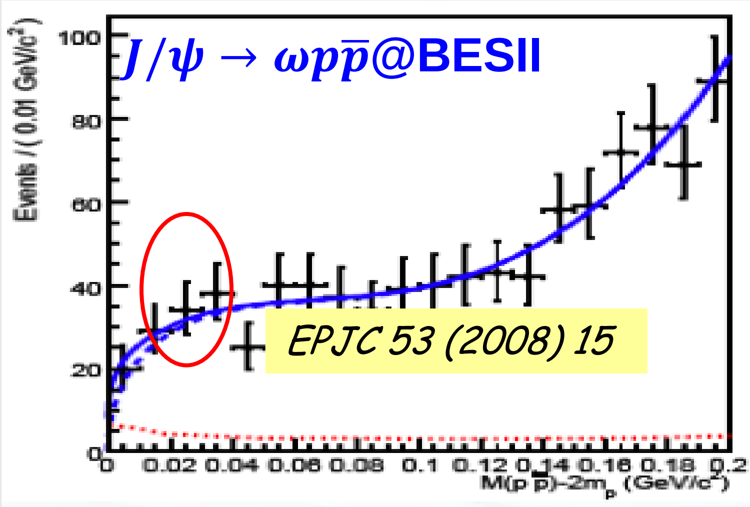
$B_1(J/\psi \to \gamma R_{thr}) \times B_2(R_{thr} \to p\bar{p}) = (5.9^{+2.8}_{-3.2}) \times 10^{-5}$

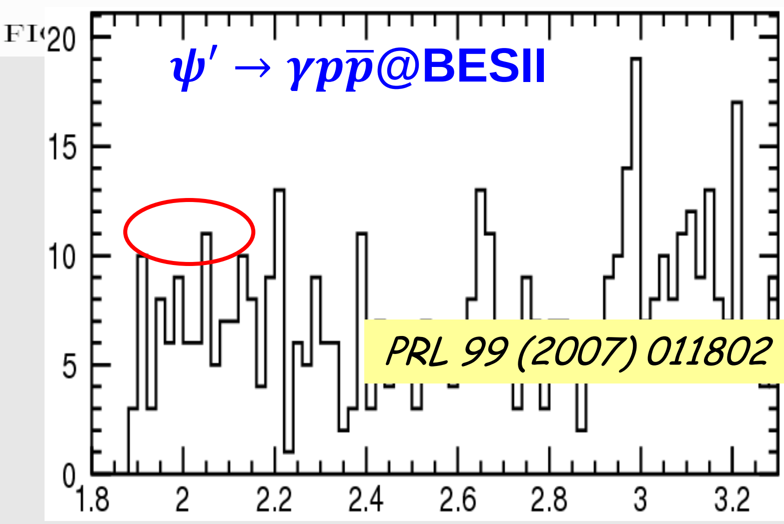
Chinese Physics C 34, 421 (2010)

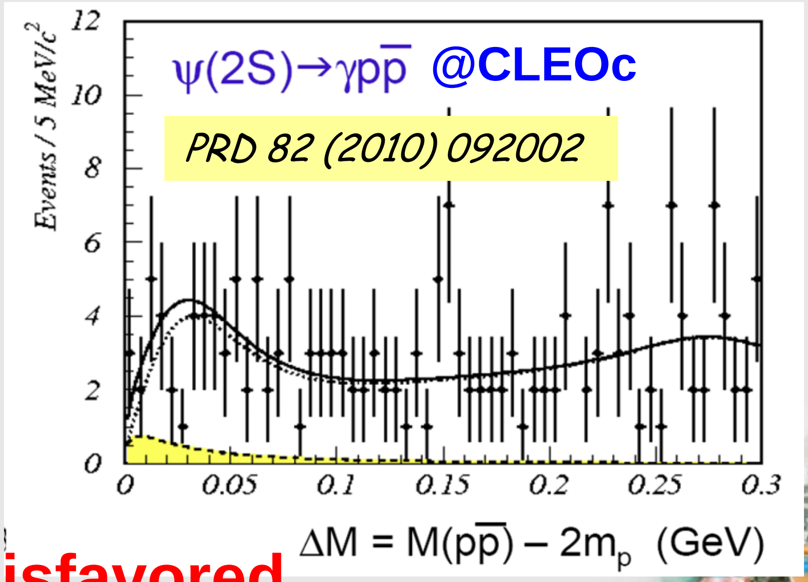
PRD 82, 092002(2010)

Several non-observations





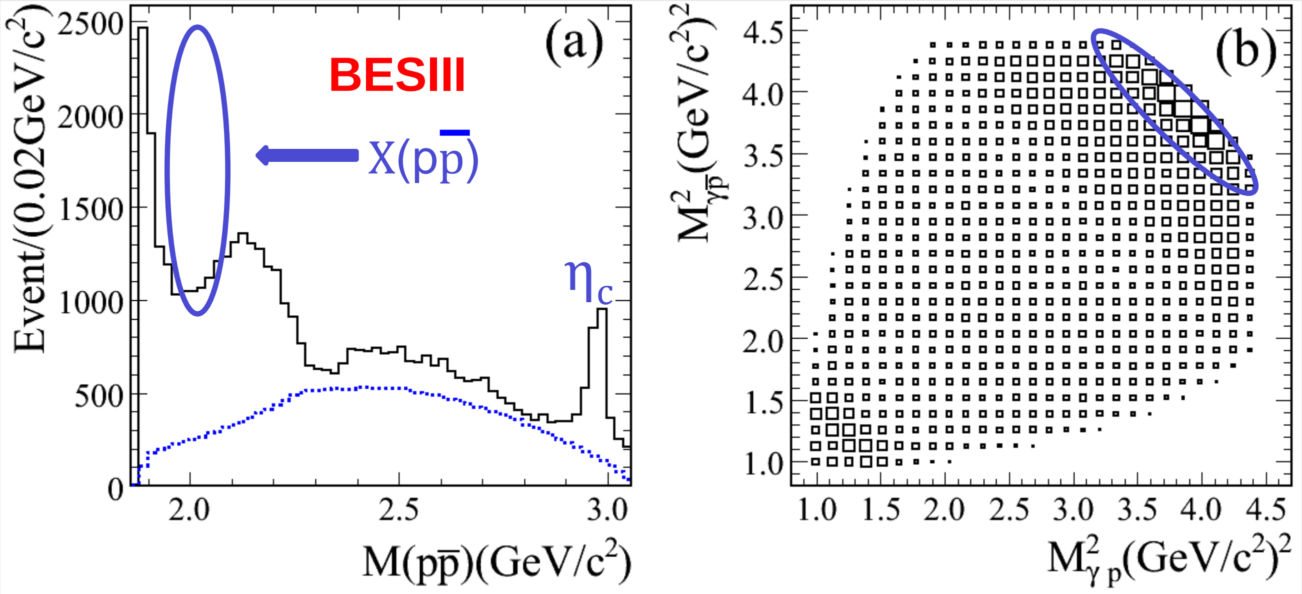




Pure FSI interpretation is disfavored

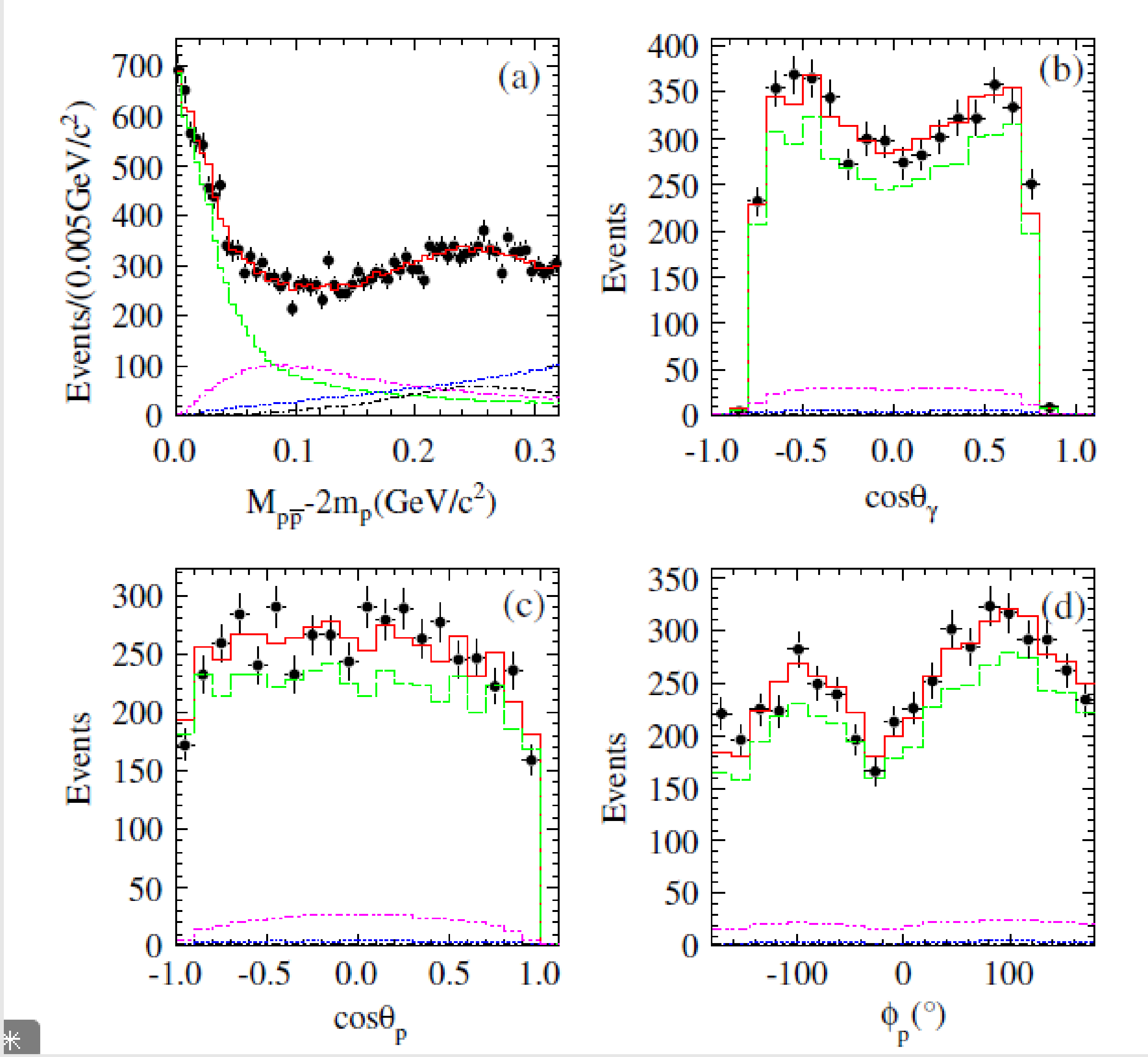
PWA on the p $\bar{p}$ mass threshold structure in $J/\psi \to \gamma p\bar{p}$

Phys. Rev. Lett. 108, 112003 (2012)



- **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).

PWA results and projections in $J/\psi \rightarrow \gamma p\bar{p}$



- 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 (~7σ)

Measurement for $X(p\bar{p})$

- 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 $X(p\bar{p})$:

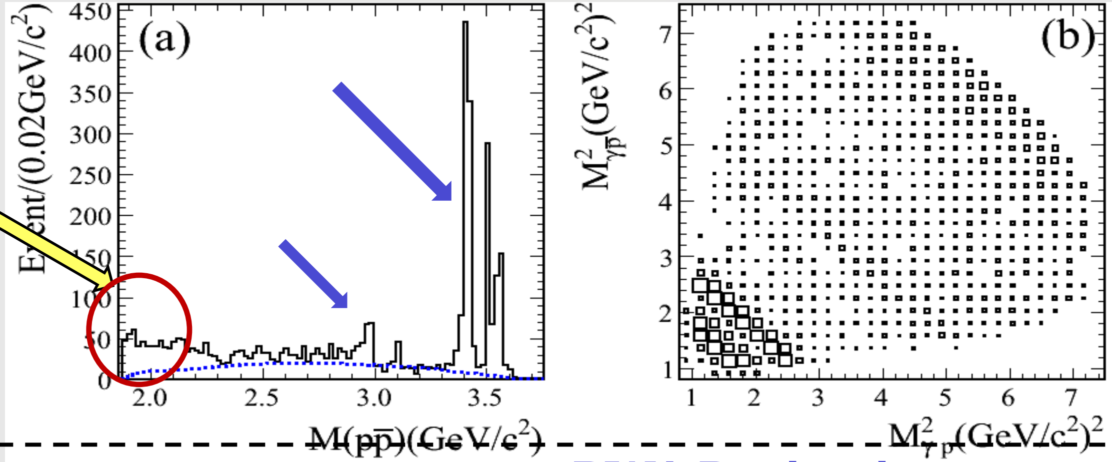
  $J^{PC}=0^{-+}$ → >6.8σ better than other J^{PC} assignments.

Resonance	Mass(MeV/c^2)	Width(MeV/c^2)
X(ppbar)	$18326.3^{+19}_{-5}{}^{+18}_{-17} \pm 19$(model)	$13 \pm 39^{+10}_{-13} \pm 4$(model)

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

M_{ppbar} threshold structure of $\psi' \to \gamma p\bar{p}$

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



PWA results:

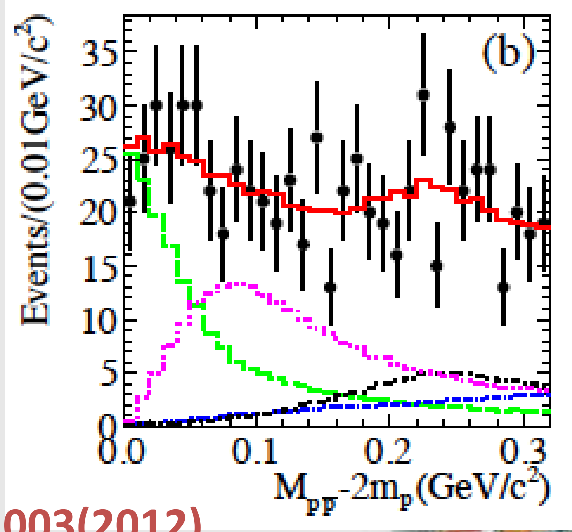
- Significance of X(ppbar) is > 6.9σ.
- The production ratio R: **first measurement**

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

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

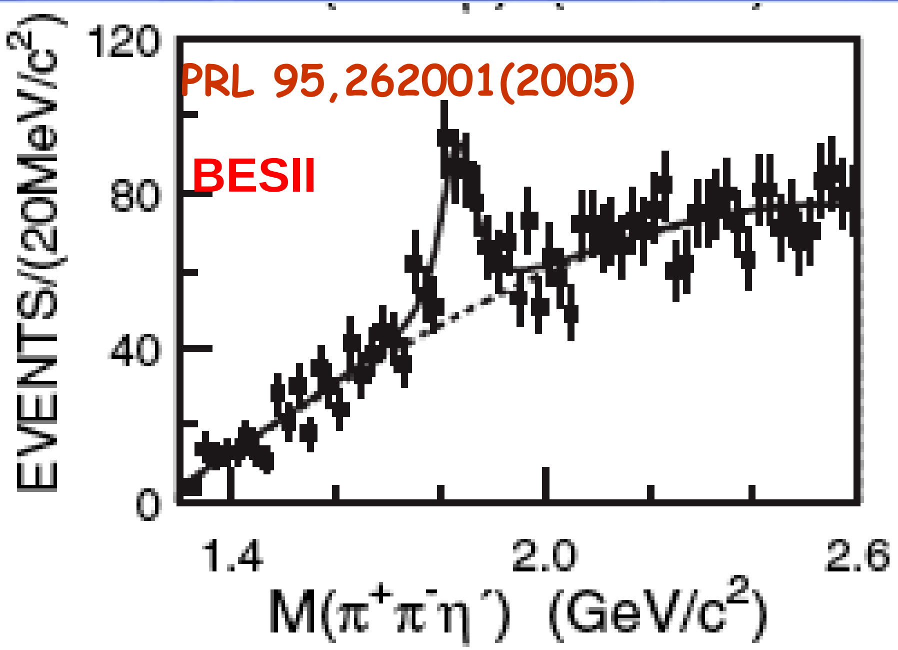
- It is suppressed compared with “12% rule”.

PWA Projection:



PRL 108,112003(2012)

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

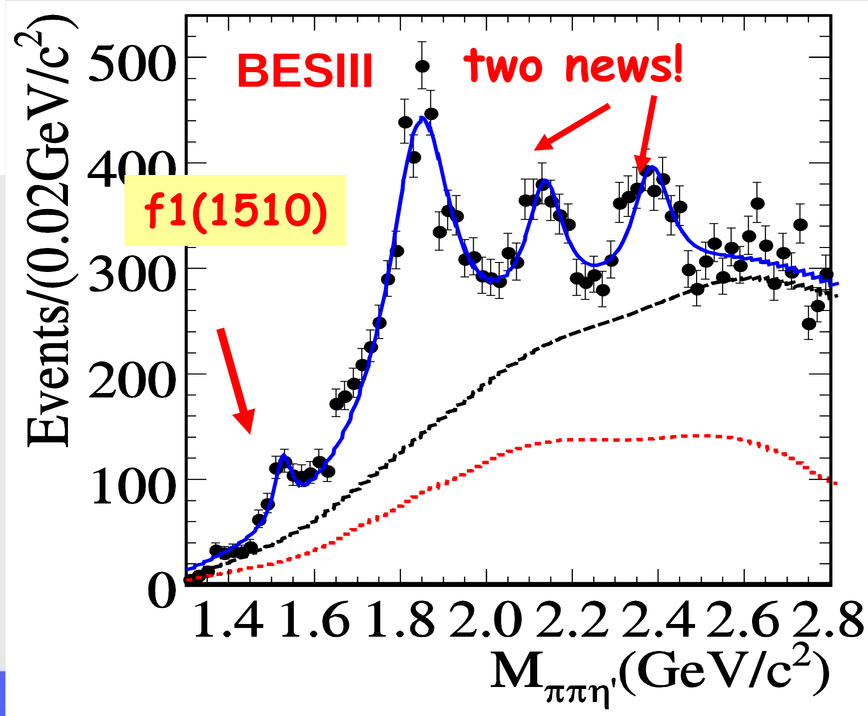


$BESII\ result$(Stat. sig. ~ 7.7σ):

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

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

PRL 106, 072002(2011)



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

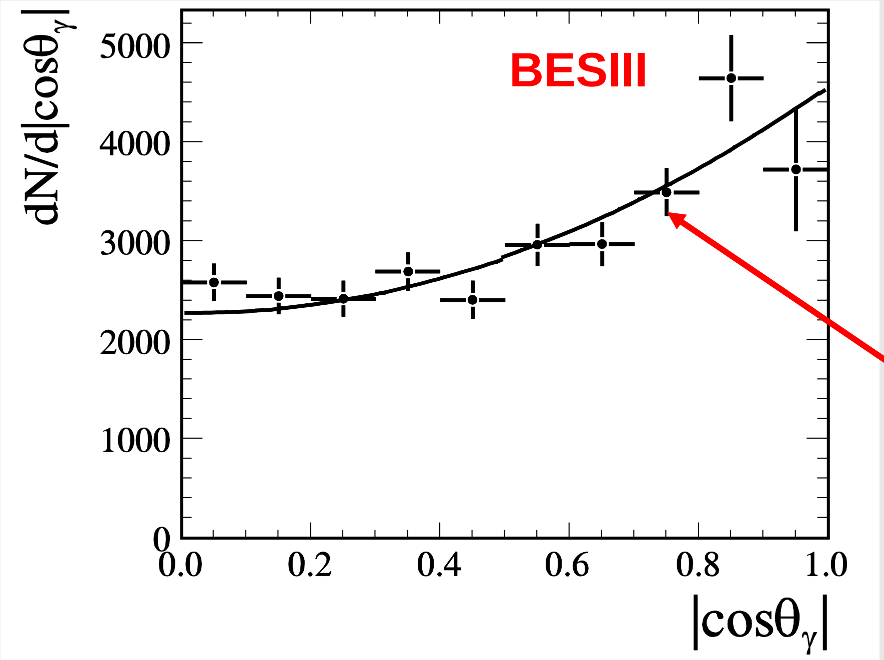
$\eta' \to \eta\pi^+\pi^-$

$\eta' \to \gamma\rho$

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

BESIII fit results:

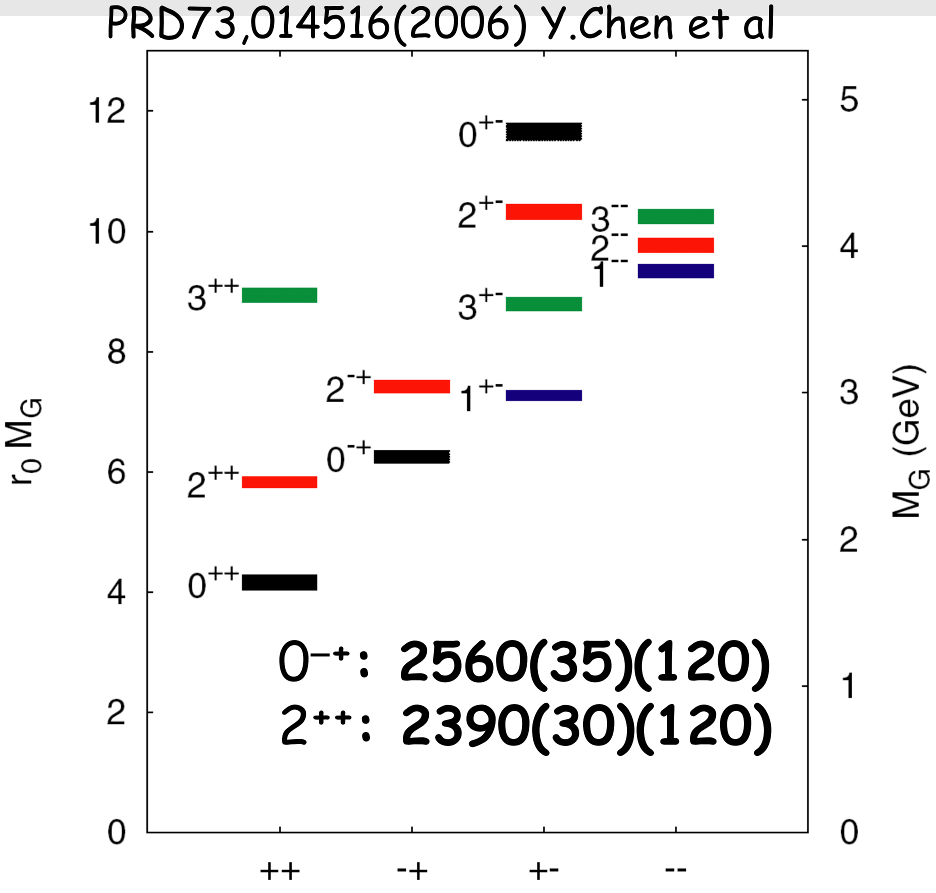
Resonance	M(MeV/c^2)	Γ(MeV/c^2)	Stat.Sig.
X(1835)	$1836.5 \pm 3.0^{+5.6}_{-2.1}$	$190.1 \pm 9.0^{+38}_{-36}$	$>20\sigma$
X(2120)	$2122.4 \pm 6.7^{+4.7}_{-2.7}$	$83 \pm 16^{+31}_{-11}$	7.2σ
X(2370)	$2376.3 \pm 8.7^{+3.2}_{-4.3}$	$83 \pm 17^{+44}_{-6}$	6.4σ



PWA is needed to understand these structures.

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

What's the nature of new structures?



✓It is the first time 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

$J/\psi \to \gamma\pi\pi\eta'$ decay is a good channel for finding 0^{-+} glueballs.

✓Nature of X(2120)/X(2370)

pseudoscalar glueball ?

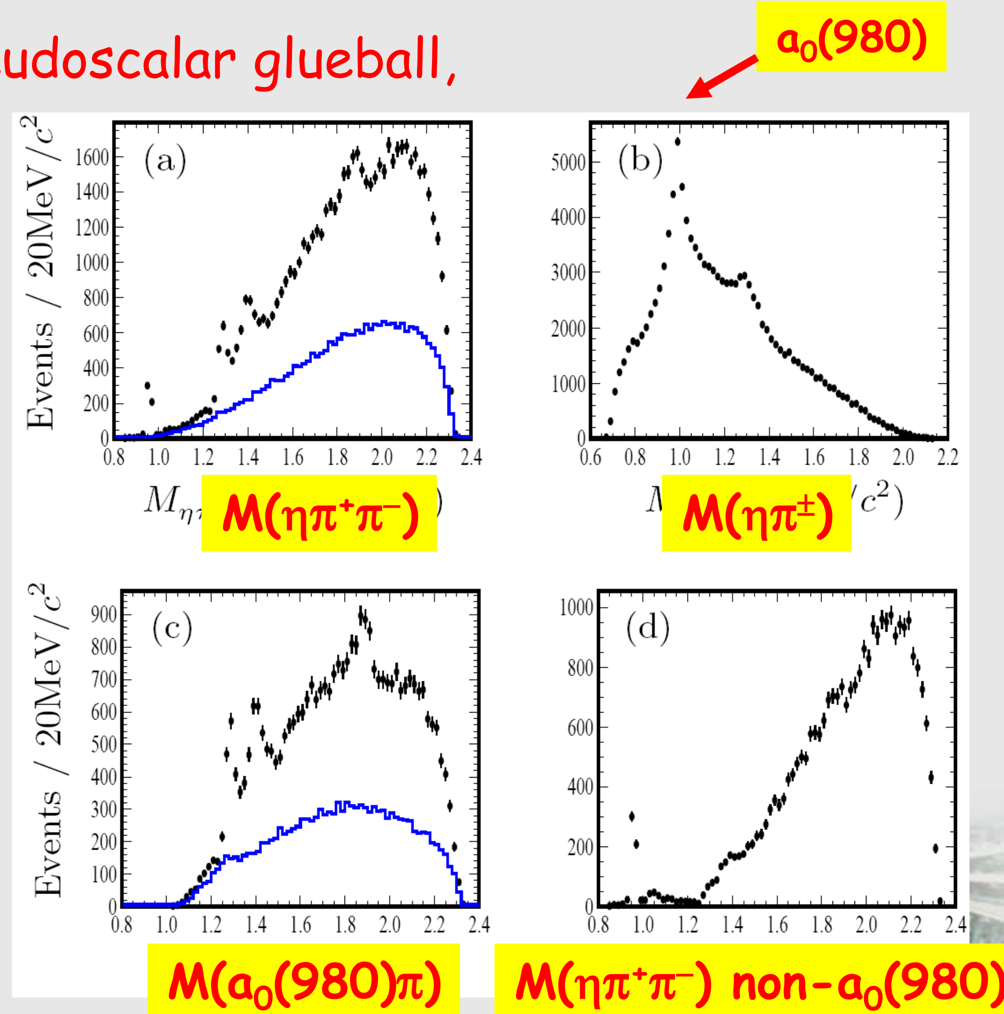
η/η' excited states?

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

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

PRL 107, 182001(2011)

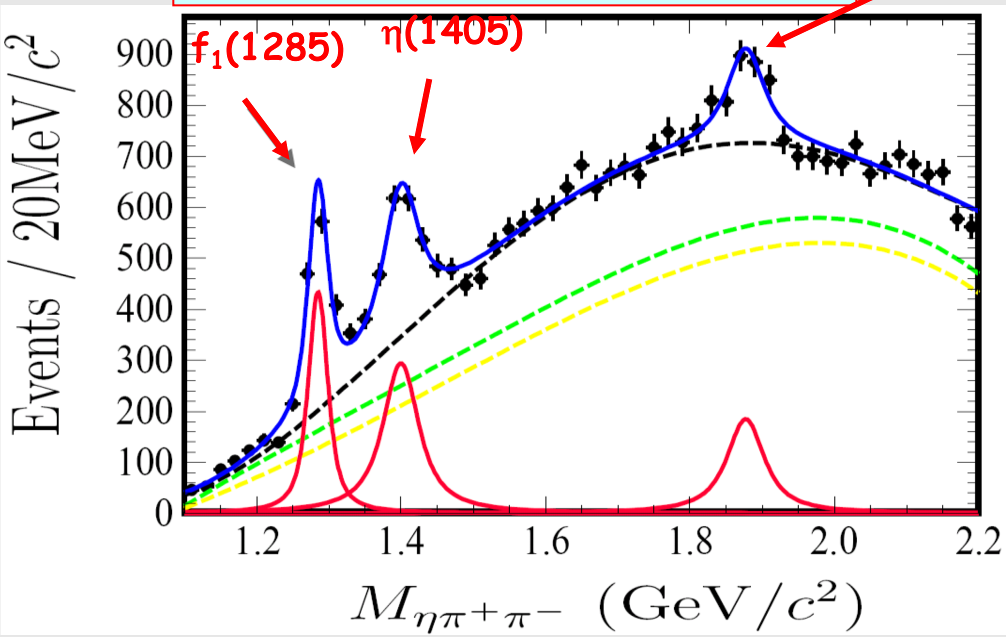
- ✓ X(1835) observed at BESII and then confirmed at BESIII in $J/\psi \to \gamma\pi^+\pi^-\eta'$
- ✓ theoretical interpretations: pseudoscalar glueball, η/η' excited states ..
- ✓ study of its production in hadronic decays
- ✓ to our surprise, we observed a new structure around 1.87 GeV



BESIII

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

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



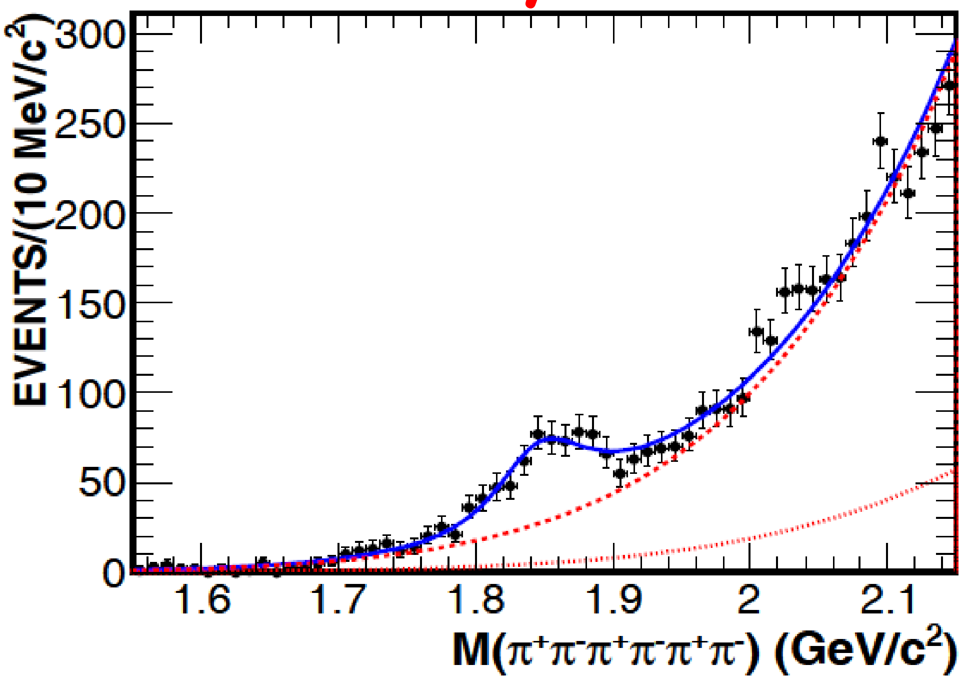
Identification of X(1870): 0^{-+}(?)
It is X(1835)?
Need PWA!

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 $J/\psi \to \gamma 3(\pi^+\pi^-)$

Preliminary results



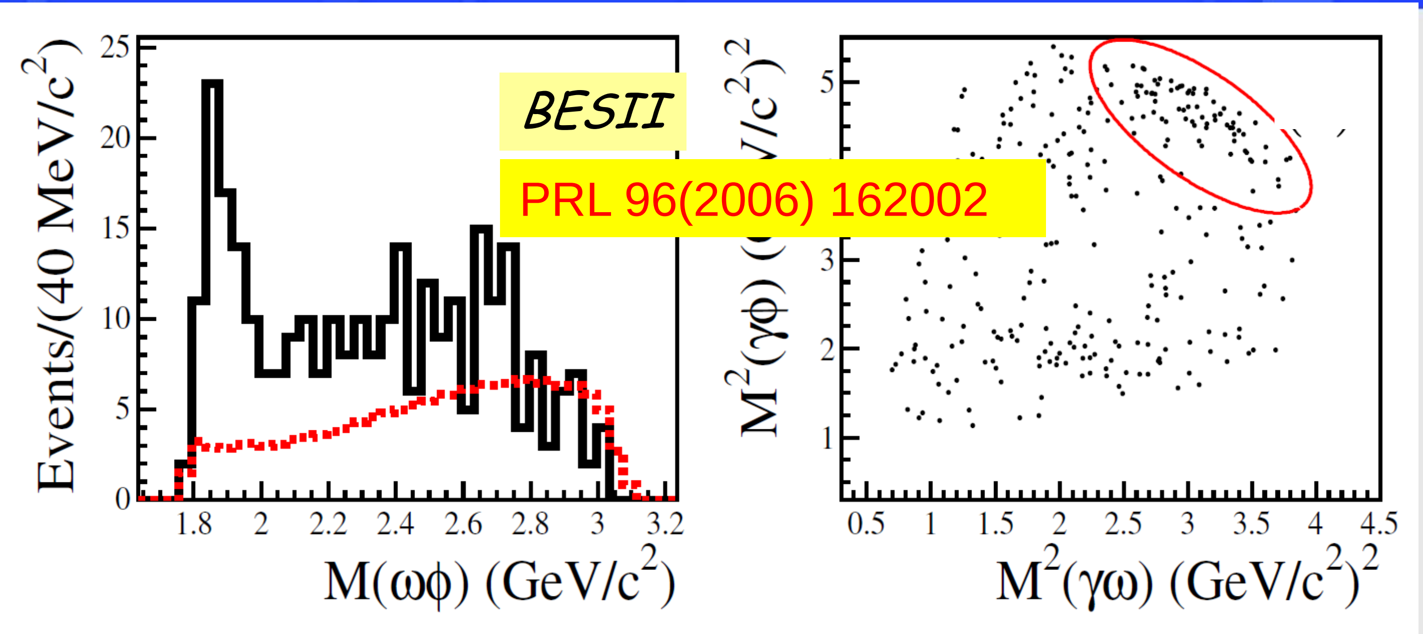
A peak around 1.84 GeV is observed !

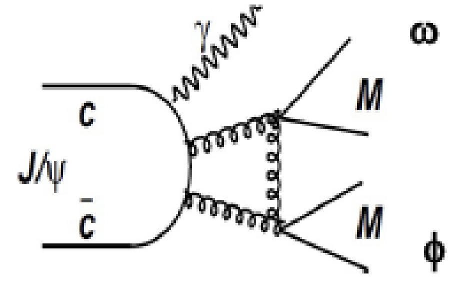
$M = 1842.2 \pm 4.2^{+6.9}_{-1.8}$ MeV

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

$M_{\omega\phi}$ threshold enhancement in $J/\psi \rightarrow \gamma\omega\phi$





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

For X(1810):

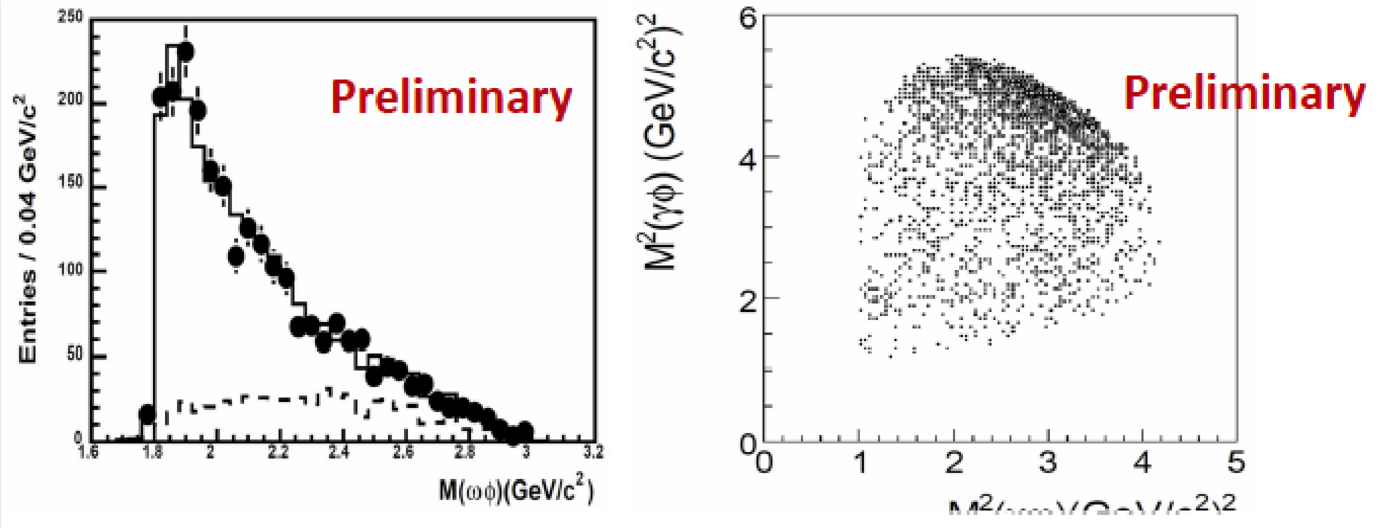
$$M = 1812^{+19}_{-26} \pm 18\ \mathrm{MeV/c^2}$$

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

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

Preliminary PWA results of J/ψ→γωφ

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	$> 8\sigma$

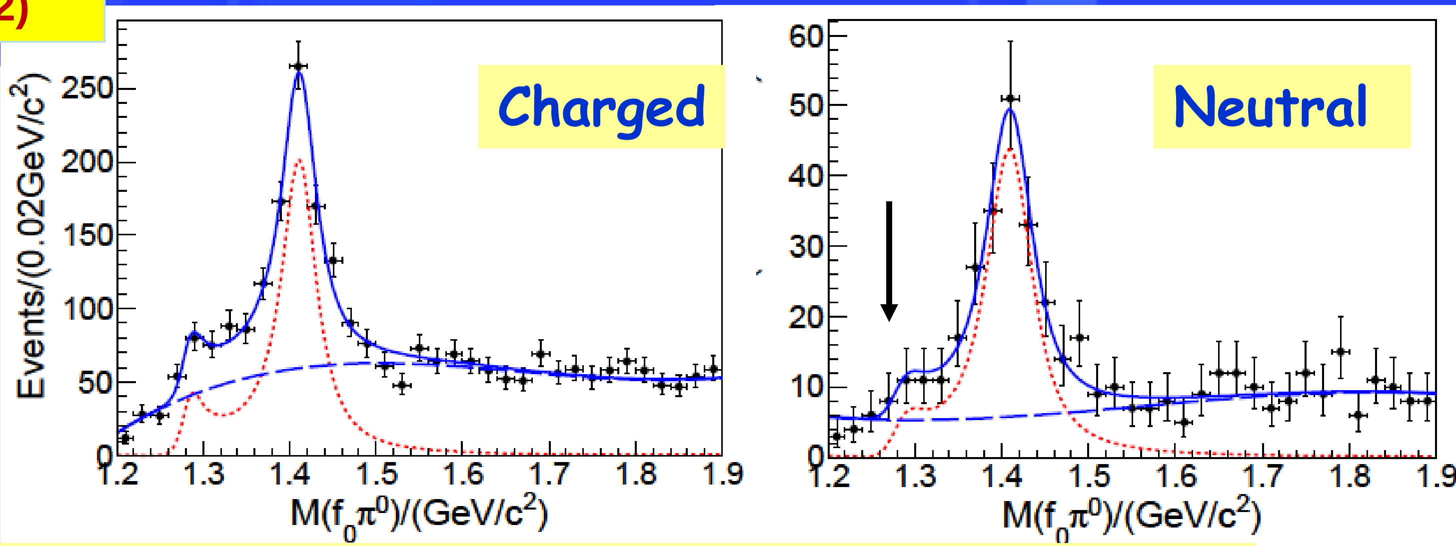


Is X(1810) the f0(1710)/f0(1790) or new state?

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

PRL 108, 182001 (2012)

Charged:
$f0(980) \to \pi^+\pi^-$
Neutral
$f0(980) \to \pi^0\pi^0$



Helicity analysis indicates that peak at 1400MeV is from $\eta(1405) \to f_0(980)\pi^0$ not from $f_1(1420)$:

First observation of $\eta(1405) \to f_0(980)\pi^0$ (isospin violated decays) and $J/\psi \to \gamma f_0(980)\pi^0$

$$Br(J/\psi \to \gamma\eta(1405) \to \gamma f_0\pi^0 \to \gamma\pi^0\pi^+\pi^-)$$
$$= (1.48 \pm 0.13(stat.) \pm 0.17(sys.)) \times 10^{-5}$$

$$Br(J/\psi \to \gamma\eta(1405) \to \gamma f_0\pi^0 \to \gamma\pi^0\pi^0\pi^0)$$
$$= (6.99 \pm 0.93(stat.) \pm 0.95(sys.)) \times 10^{-6}$$

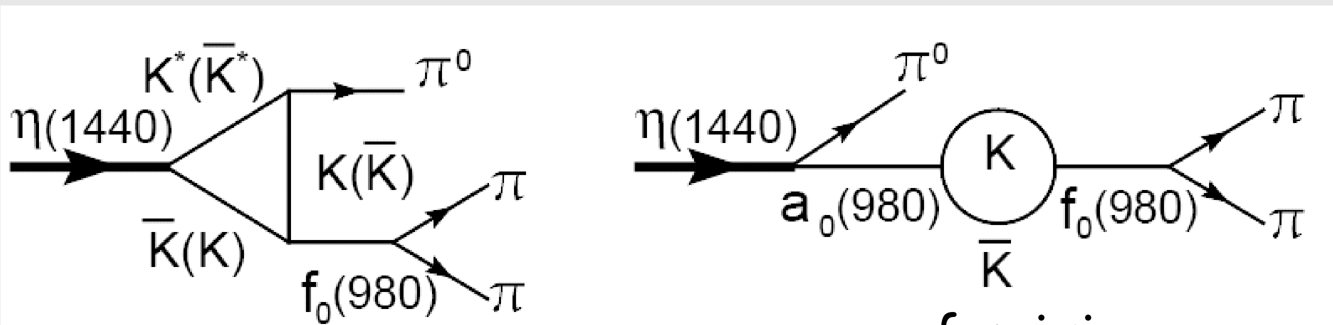
Large isospin violation in η(1405) decay

In general, magnitude of isospin violation in strong decay should be less than 1% or at 0.1% level. For example:

$$\frac{BR(\psi' \to \pi^0 J/\psi)}{BR(\psi' \to \eta J/\psi)} = 0.2 \times 10^{-2} \times \frac{|P_\pi|^3}{|P_\eta|^3}, \quad \frac{BR(\eta' \to \pi^+\pi^-\pi^0)}{BR(\eta' \to \pi^+\pi^-\eta)} = 0.8 \times 10^{-2}$$

However:

$$\frac{BR(\eta(1405) \to f_0(980)\pi^0)}{BR(\eta(1405) \to a_0(980)\pi)} \approx 25\%$$



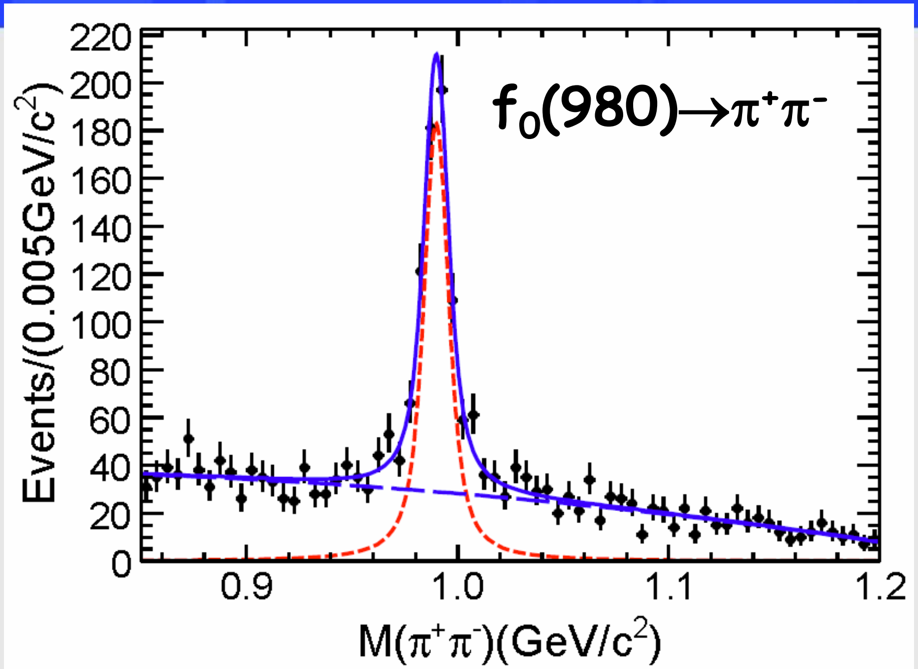
Triangle Singularity (TS)

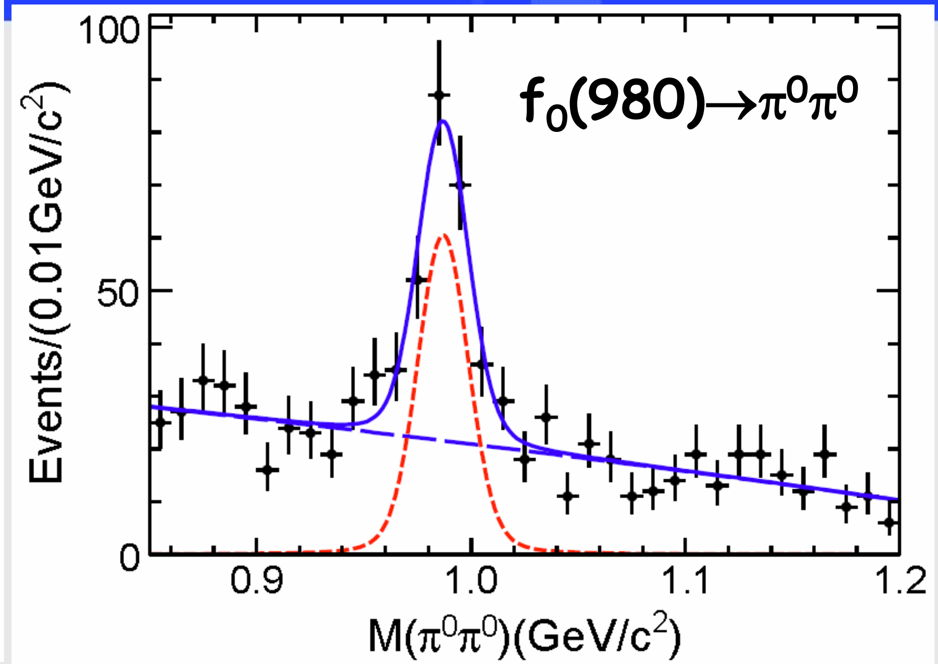
a_0—f_0 mixing

K*K pair in TS is almost on-shell, together with mixing explain the narrow $f_0(980)$, and large isospin violation.

J.J.Wu et al, PRL 108, 081803(2012)

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





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

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

Surprising result:

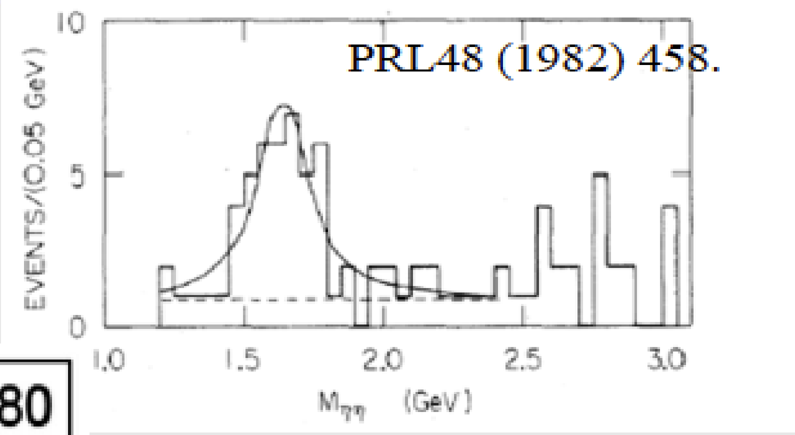
PRL 108, 182001 (2012)

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)

Study of ηη system

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



- **LQCD predicts:**

$$0^{++} : 1710 \pm 50 \pm 80$$

- **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^{++} (~1870MeV), but no $f_0(1710)$.**

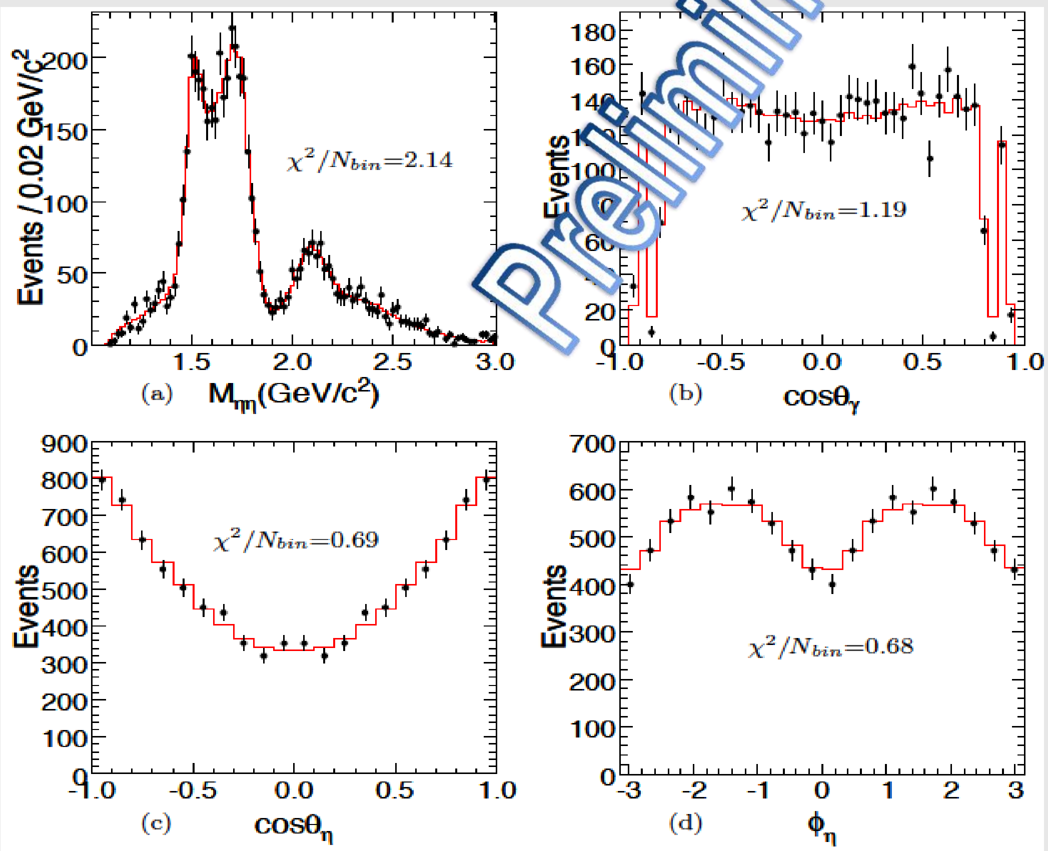
- **E835 (2006): ppbar → $\pi^0\eta\eta$, found $f_0(1500)$ and $f_0(1710)$.**

- **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}	$75^{+12+1\text{[illegible]}}_{-10\text{[illegible]}}$	$(3.41^{+0.43+1.22}_{-0.50-1.23}) \times 10^{-5}$	11.0 σ
$f_2(1810)$	1822^{+29+61}_{-24-54}	$229^{+5\text{[illegible]}+64}_{-4\text{[illegible]}-152}$	$(5.38^{+0.60+3.31}_{-0.67-2.24}) \times 10^{-5}$	6.4 σ
$f_2(2340)$	$2362^{+31+139}_{-30-59}$	$334^{+\text{[illegible]}+1\text{[illegible]}4}_{-\text{[illegible]}-\text{[illegible]}9}$	$(5.58^{+0.61+1.93}_{-0.65-1.81}) \times 10^{-5}$	7.6 σ

Preliminary

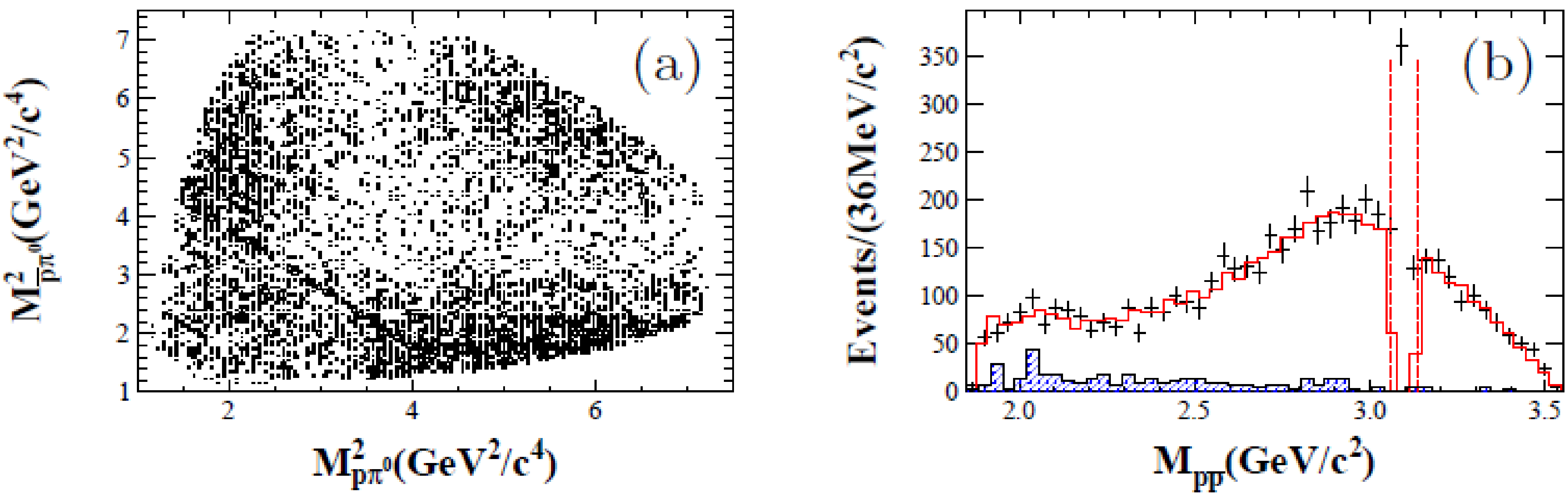


- $f_0(1710)$ and $f_0(2100)$ are dominant scalars.
- $f_0(1500)$ exists (8.2σ).
- $f_2'(1525)$ is the dominant tensor.

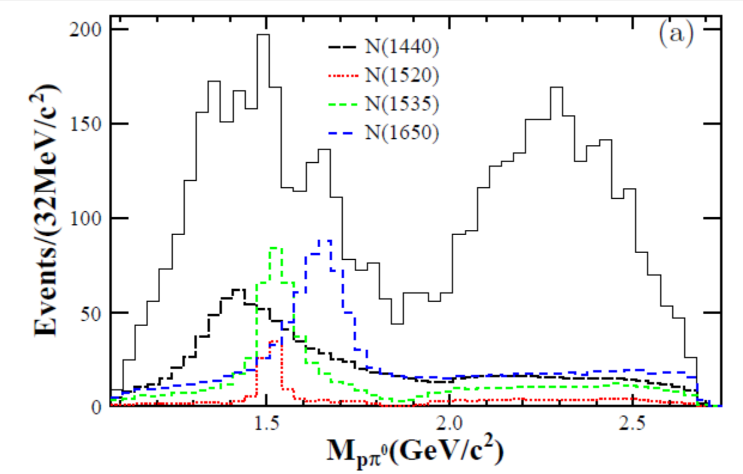
Observation of two N* baryons in $\psi' \to \pi^0 p \bar{p}$ decay

arXiv:1207.0223

- 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

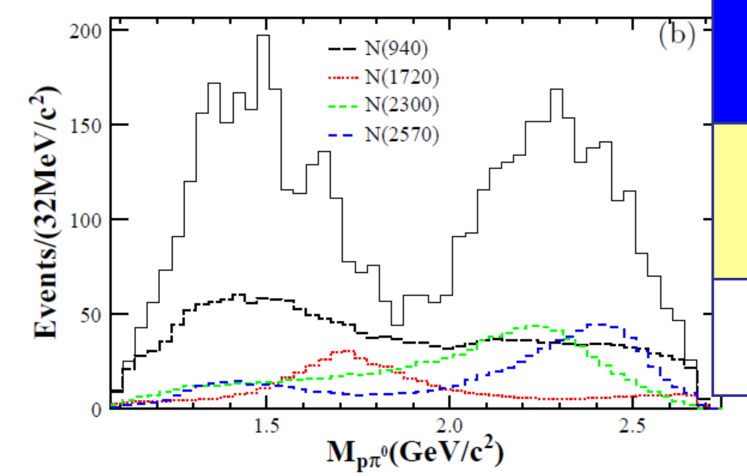


PWA results on N* baryons in $\psi' \to \pi^0 p \bar{p}$



Resonance	M(MeV/c^2)	Γ(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 !

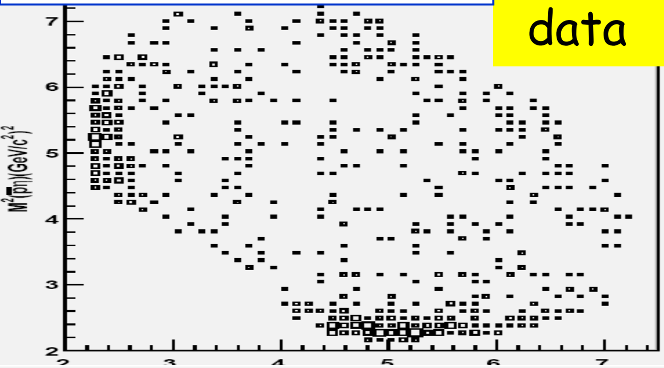


Resonance	M(MeV/c^2)	Γ(MeV/c^2)
N(2300)	$2300^{+40}_{-30}{}^{+109}_{-0}$	$340^{+30}_{-30}{}^{+110}_{-58}$
N(2570)	$2570^{+19}_{-10}{}^{+34}_{-10}$	$250^{+14}_{-24}{}^{+69}_{-21}$

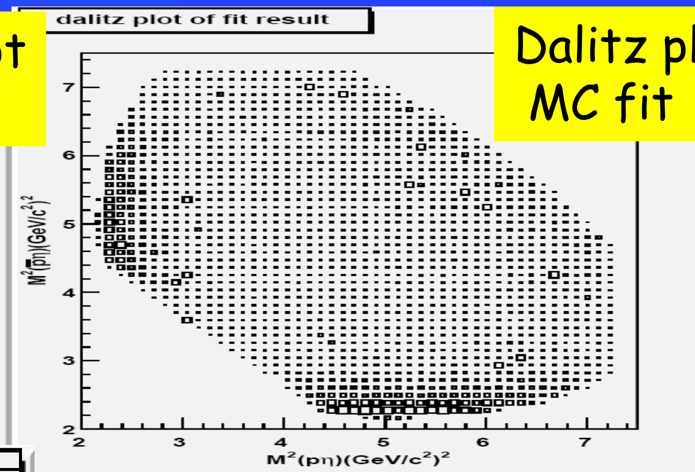
Preliminary results on N* baryon in $\psi' \to \eta p \bar{p}$ decay

BESIII Preliminary

Dalitz plot data

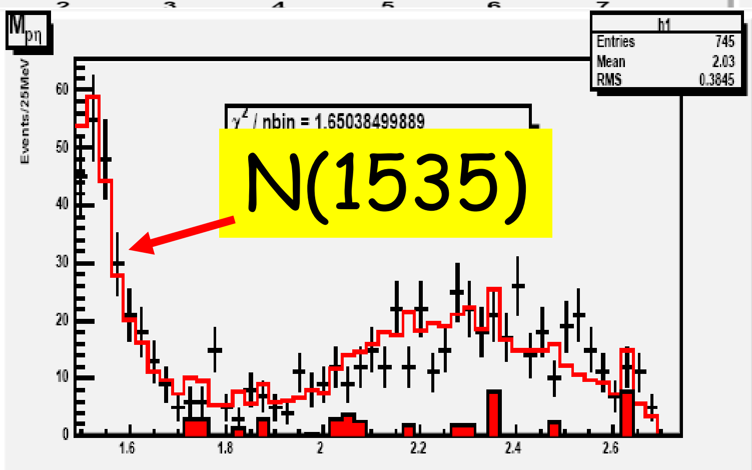


Dalitz plot MC fit

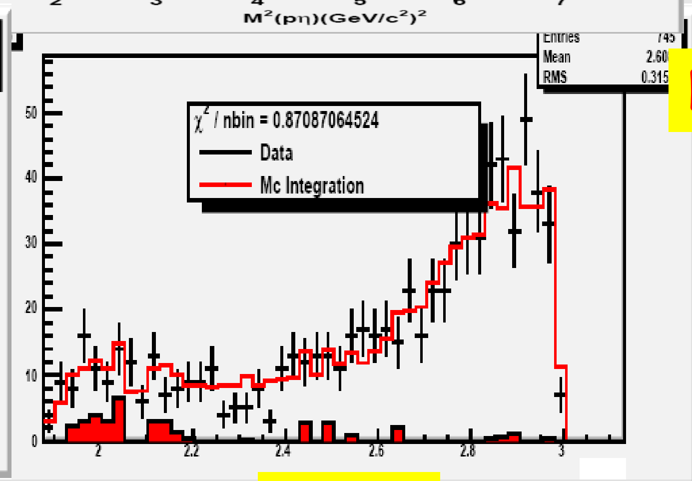


A full PWA is performed.

Background clean!



M(pη)



M($p\bar{p}$)

N(1535) is $1/2^-$

Mass:

$1.524^{+0.005+0.010}_{-0.005-0.004}$ GeV

Width:

$0.130^{+0.027+0.061}_{-0.027-0.014}$ GeV

$Br(\psi' \to pp\eta) = (6.6 \pm 0.2 \pm 0.6) \times 10^{-5}$

PDG2010: $(6.0 \pm 1.2) \times 10^{-5}$

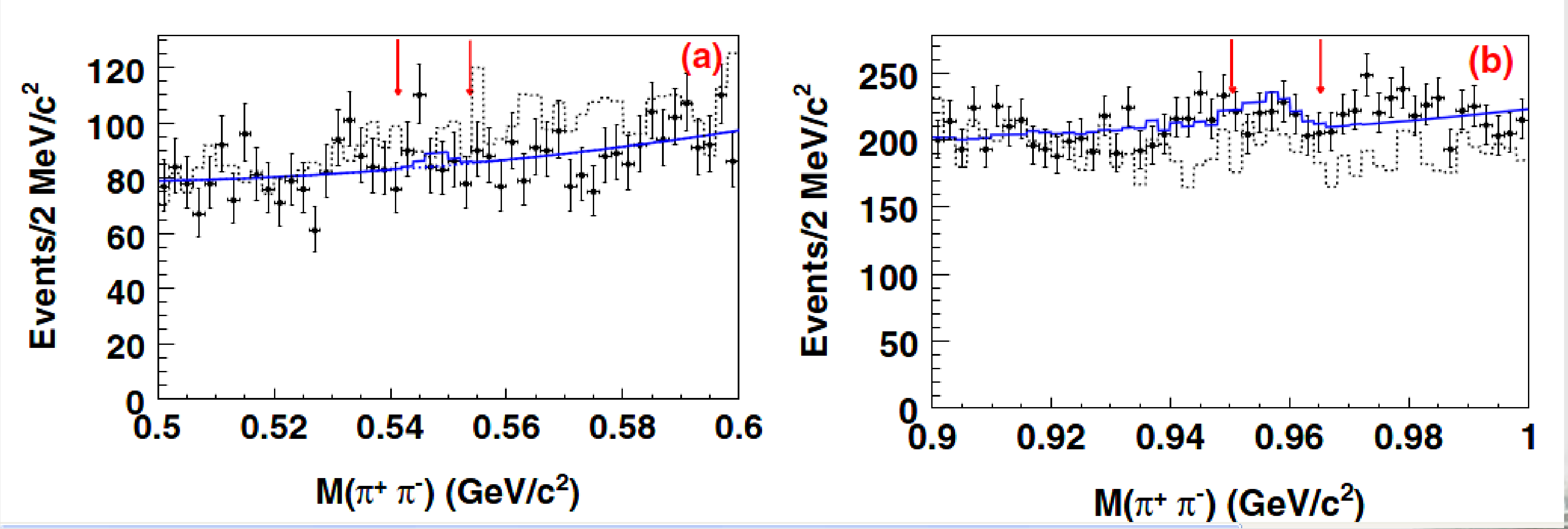
$Br(\psi' \to N(1535)p) \times Br(N(1535) \to p\eta + c.c.)$

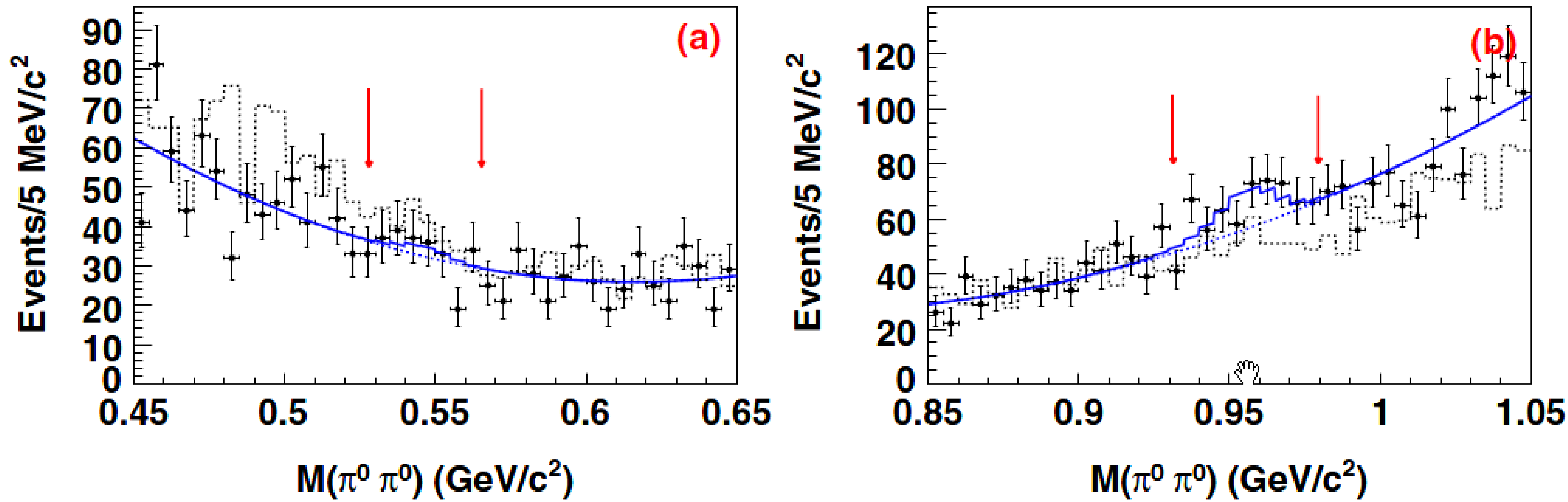
$= 5.5^{+0.3+7.4}_{-0.3-1.1} \times 10^{-5}$

Search for CP violation in $\eta/\eta' \to \pi\pi$

Phys. Rev. D84,032006(2011)

- Offer an excellent laboratory for testing P and CP invariance
- Theoretically proceed via the weak interaction at a level of 10^{-15}~10^{-27}



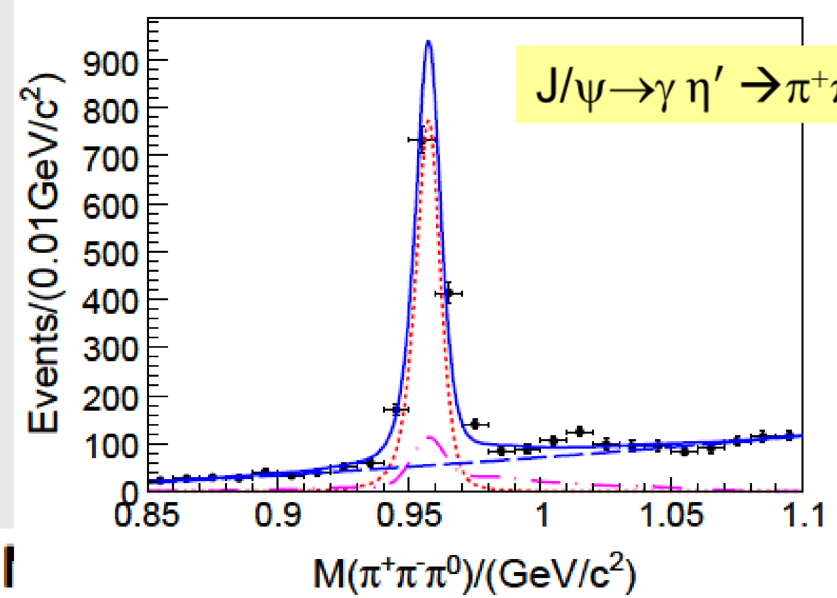


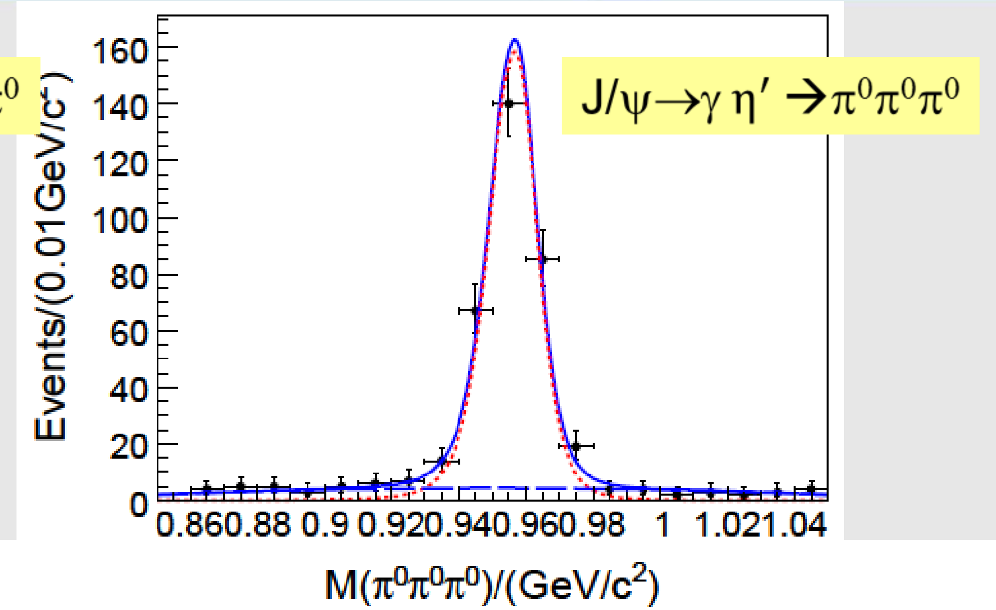
Process	$\mathcal{B}^{\mathrm{UP}}$	$\mathcal{B}^{\mathrm{UP}}_{\mathrm{PDG}}$
$\eta \to \pi^+\pi^-$	3.9×10^{-4}	1.3×10^{-5}
$\eta' \to \pi^+\pi^-$	5.5×10^{-5}	2.9×10^{-3}
$\eta \to \pi^0\pi^0$	6.9×10^{-4}	3.5×10^{-4}
$\eta' \to \pi^0\pi^0$	4.5×10^{-4}	9×10^{-4}

@90% C.L.

BF measurement of η′→π+π−π^0, π^{0}π^{0}π^0

PRL 108, 182001 (2012)





$Br(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15 \pm 0.39) \times 10^{-3}$ **PDG12:** $(3.6^{+1.1}_{-0.9}) \times 10^{-3}$

$Br(\eta' \to \pi^0\pi^0\pi^0) = (3.56 \pm 0.22 \pm 0.34) \times 10^{-3}$ **PDG12:** $(1.68 \pm 0.22) \times 10^{-3}$

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 :

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

Search for $\eta/\eta' \to$ invisible in $J/\psi \to \phi\eta/\eta'$

- offer a window for physics beyond the standard model
- observation of the invisible final states (may) provides information of light dark matter
- easy to tag with $J/\psi \to \phi\eta/\eta'$: two body decays; ϕ's width is quite narrow

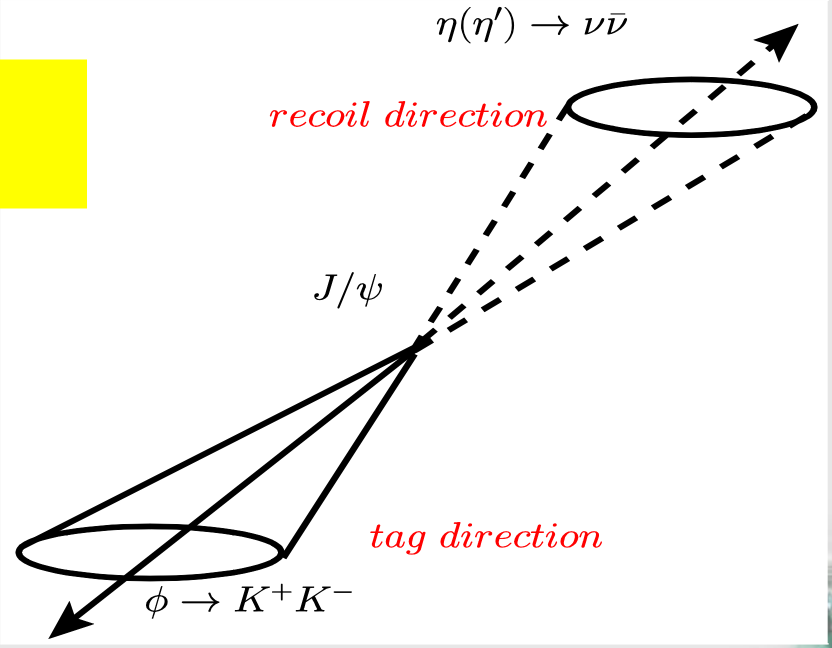
Reconstructing $\phi \to K^+K^-$ and looking at recoiling mass of ϕ

Theoretical predictions:

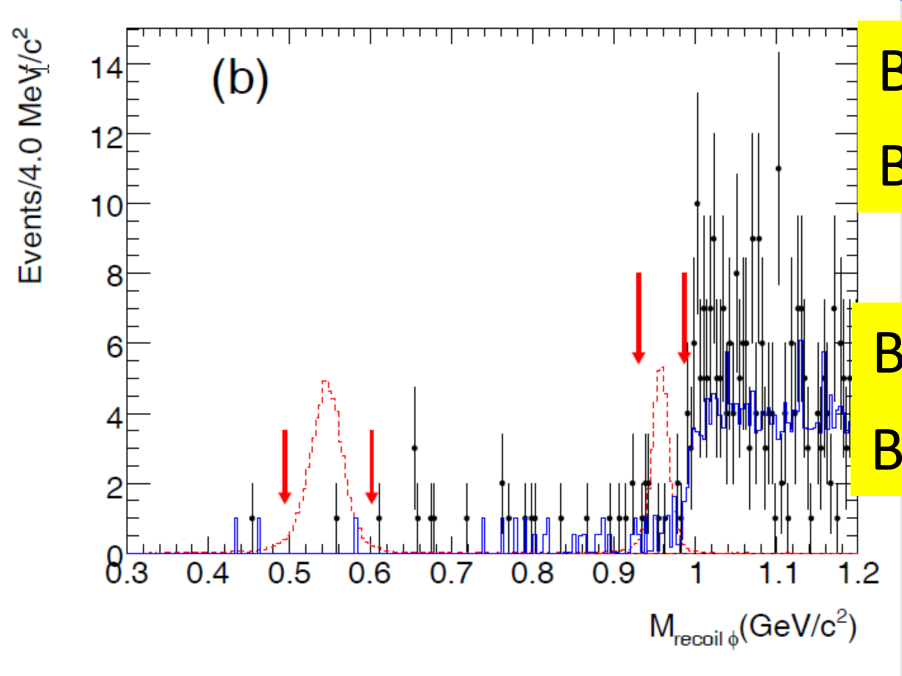
B. McElrath PRD 72, 103508(2005)

$B(\eta \to \chi\chi) \sim 7.4 \times 10^{-5}$

$B(\eta' \to \chi\chi) \sim 8.1 \times 10^{-7}$



Search for $\eta/\eta' \to$ invisible in $J/\psi \to \phi\eta/\eta'$ (arXiv: 1209.2469)



$B(\eta' \to \text{invisible})/B(\eta' \to \gamma\gamma) < 2.39 \times 10^{-2}$

$B(\eta \to \text{invisible})/B(\eta \to \gamma\gamma) < 2.58 \times 10^{-4}$

$B(\eta' \to \text{invisible}) < 5.21 \times 10^{-4}$ @ 90% C.L.

$B(\eta \to \text{invisible}) < 1.01 \times 10^{-4}$ @ 90% C.L.

$BR(\eta \to \chi\chi) \sim 7.4 \times 10^{-5}$

$BR(\eta' \to \chi\chi) \sim 8.1 \times 10^{-7}$

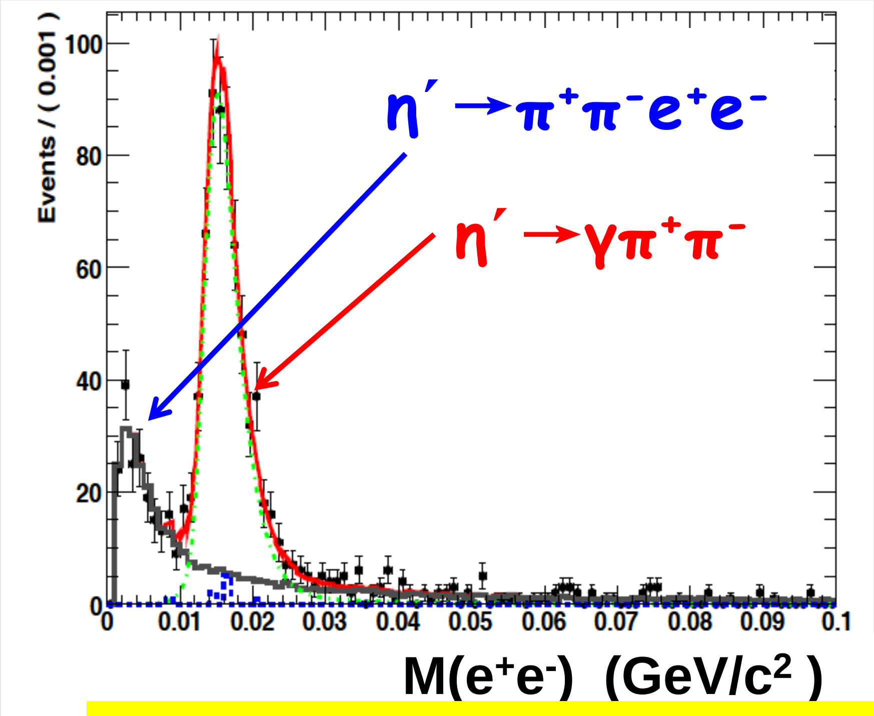
Theory:
B. McElrath PRD 72, 103508(2005)

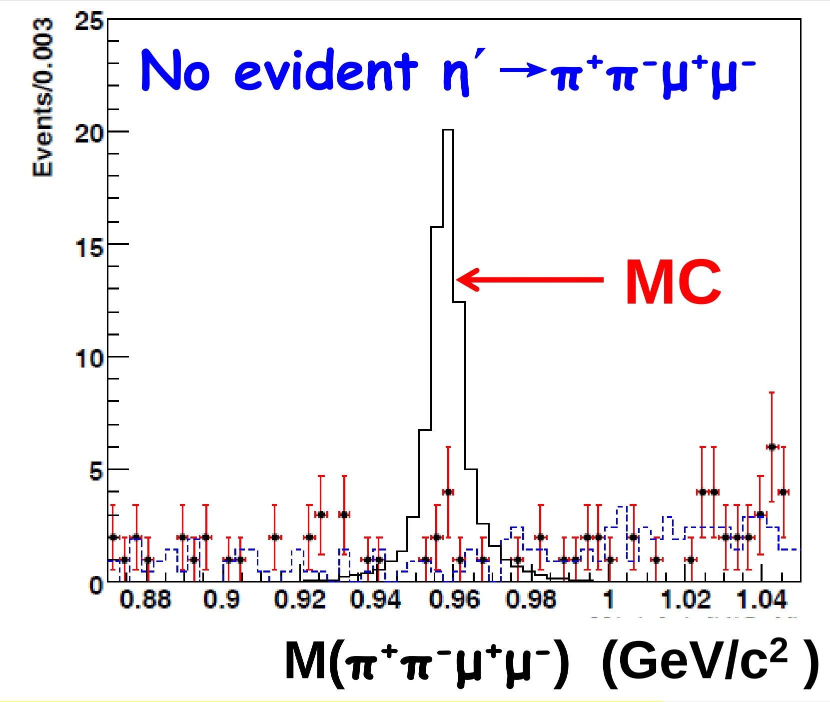
$B(\eta' \to \text{invisible}) < 1.4 \times 10^{-3}$ @ 90% C.L.

$B(\eta \to \text{invisible}) < 6.0 \times 10^{-4}$ @ 90% C.L.

BESII results: PRL 97, 202002 (2006)

BF measurement of $\eta' \to \pi^+\pi^-e^+e^-, \pi^+\pi^-\mu^+\mu^-$ (Preliminary results)





$B(\eta' \to \pi^+\pi^-e^+e^-) = (2.13 \pm 0.13(stat)) \times 10^{-3}$

$B(\eta' \to \pi^+\pi^-\mu^+\mu^-) < 2.65 \times 10^{-5}$ @90%C.L.

Decay	Effective meson theory PRC 61,0305206(2000)	Chiral Unitary EPJA33,95(2007)
$B(\eta' \to \pi^+\pi^-e^+e^-)$	1.8×10^{-3}	$(2.13^{+0.19}_{-0.32}) \times 10^{-3}$
$B(\eta' \to \pi^+\pi^-\mu^+\mu^-)$	2.0×10^{-5}	$(1.57^{+0.96}_{-0.75}) \times 10^{-5}$

Summary

- Huge data samples collected for charmonium decays at BESIII. A lot of results have been obtained,
  - ✓ Confirmation 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 $J/\psi\to\omega\pi\pi\eta$
  - ✓ ……
  - ✓ η and η' physics
- We expect rich physics results in the coming years from BESIII !

Thanks !