Light hadron results at BESIII

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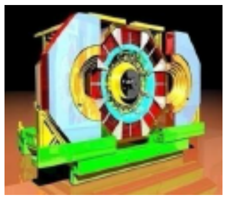
(For BESIII Collaboration)

HFCPV-2012,Qingdao



Outline

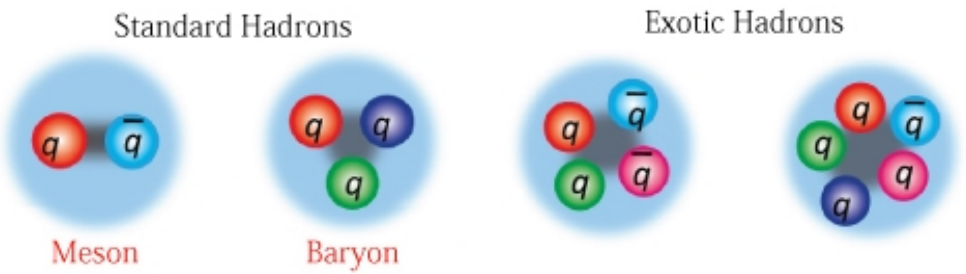
- Introduction
- X(1835) and two new structure in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$
- $p\bar{p}$ threshold enhancement in $J/\psi \rightarrow \gamma p\bar{p}$
- X(1870) in $J/\psi \rightarrow \omega X$, $X \rightarrow a_0(980)\pi \rightarrow \eta\pi\pi$
- $\omega\varphi$ threshold enhancement in $J/\psi \rightarrow \gamma\omega\varphi$
- Preliminary PWA results of $J/\psi \rightarrow \gamma\eta\eta/\ \pi^0\pi^0$
- Observation of two new N* resonances in $\psi' \rightarrow p\bar{p}\pi^0$
- Isospin violate process $J/\psi \rightarrow \gamma\eta(1405) \rightarrow \gamma f_0(980)\pi^0 \rightarrow \gamma\pi\pi\pi^0$
- Summary

Introduction

- Goal of the study of light hadron spectrosopy:

✓ Test theory: non-perturbative QCD(LQCD…)…

✓ Search for exotic states: glueball, multiquarks, molecular states…



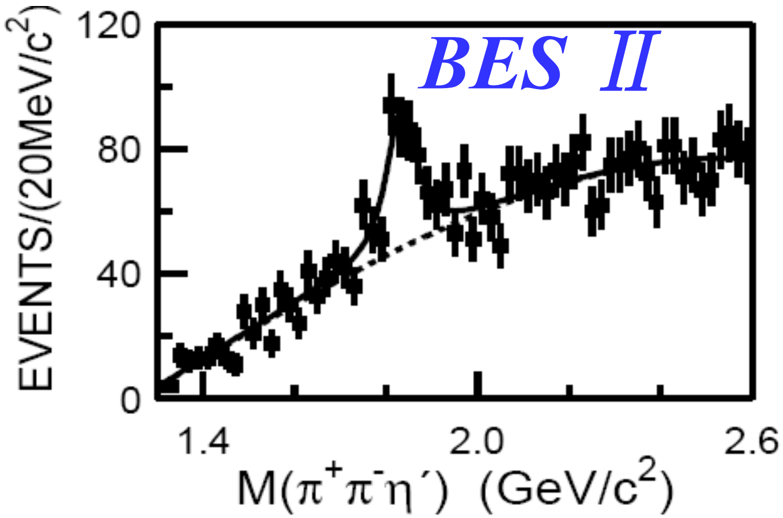
- Data Samples:

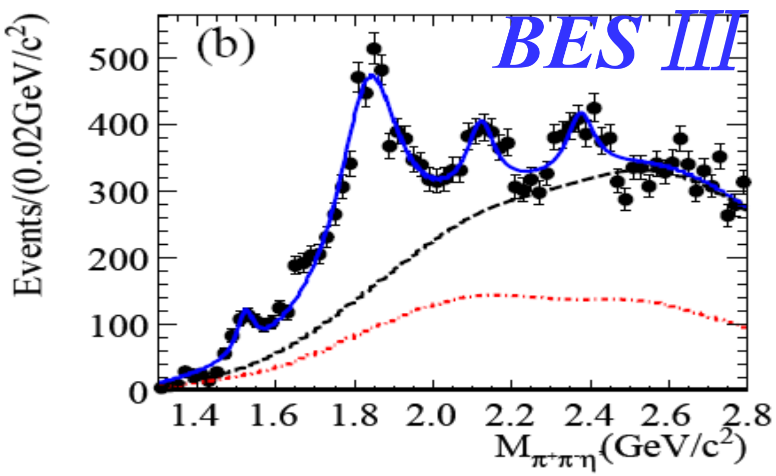
BesII: 58M J/ψ, 14M ψ(2S)

BesIII round one: 225M J/ψ, 106M ψ(2S)

BesIII round two: 1billion J/ψ, 0.4billion ψ(2S)

X(1835) and two new structure in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$





- **BESII, PRL 95,262001(2005)**

$$M = (1833.7 \pm 6.1 \pm 2.7)\mathrm{MeV/c^2}$$
$$\Gamma = (67.7 \pm 20.3 \pm 7.7)\mathrm{MeV/c^2}$$
$$\mathrm{Br}(J/\psi \to \gamma X)\cdot \mathrm{Br}(X \to \eta'\pi^+\pi^-)$$
$$= (2.2 \pm 0.4 \pm 0.4)\times 10^{-4}$$

- **BESIII, PRL 106, 072002(2011)**
- **Conform the existence of X (1835),**
- **Two new states are observed.**

X(1835) and two new structure in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$

- the parameters of the 3 states.
  - $X(1835)$

    $M = 1836.5 \pm 3.0(\text{stat})^{+5.6}_{-2.1}(\text{syst})\ \text{MeV}/c^2$

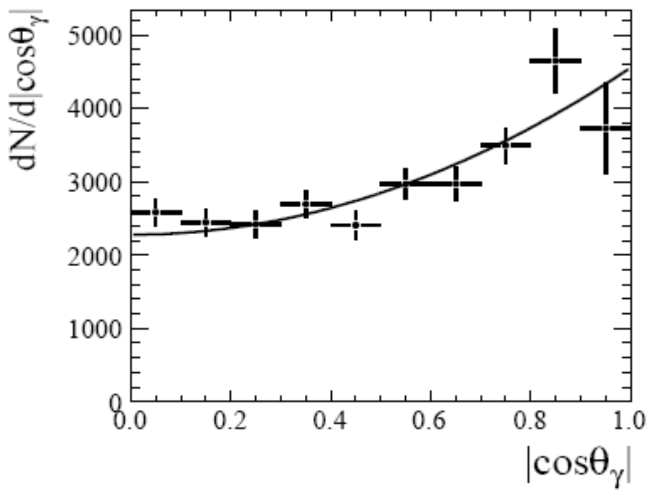
    $\Gamma = 190 \pm 9(\text{stat})^{+38}_{-36}(\text{syst})\ \text{MeV}/c^2$
  - $X(2120)$

    $M = 2122.4 \pm 6.7(\text{stat})^{+4.7}_{-2.7}(\text{syst})\ \text{MeV}/c^2$

    $\Gamma = 83 \pm 16(\text{stat})^{+31}_{-11}(\text{syst})\ \text{MeV}/c^2$
  - $X(2370)$

    $M = 2376.3 \pm 8.7(\text{stat})^{+3.2}_{-4.3}(\text{syst})\ \text{MeV}/c^2$

    $\Gamma = 83 \pm 17(\text{stat})^{+44}_{-6}(\text{syst})\ \text{MeV}/c^2$

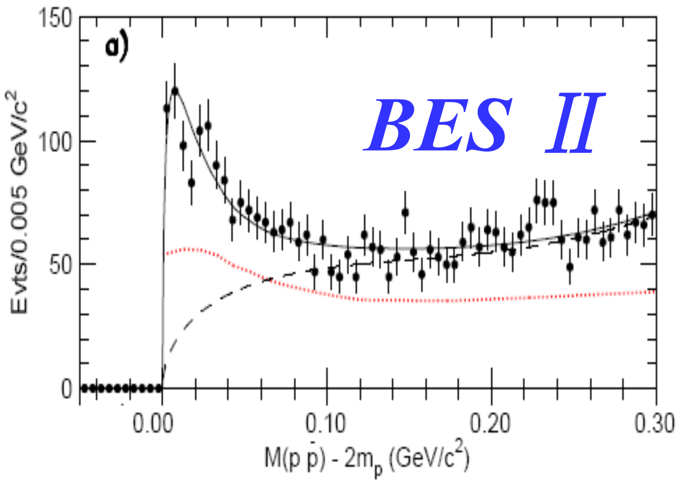


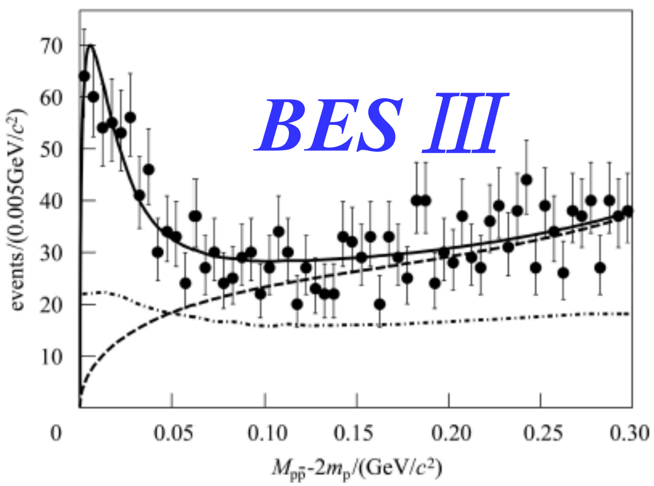
□ The angular distribution X(1835) consistent with 0^{-+}

□Lattice QDC predicted the lowest 0^{-+} glueball to be around 2.3GeV.

□PWA needed to determine the J^{PC} of the 3 structures.

$p\bar{p}$ threshold enhancement in $J/\psi \rightarrow \gamma p\bar{p}$





- **Observed by BESII. PRL91(2003) 022001**

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

$$\Gamma < 30 \mathrm{MeV/c^2} @ 90\% CL.$$

- **Confirmed at BESIII with $\psi' \rightarrow \pi\pi J/\psi$, $J/\psi \rightarrow \gamma pp$**
- **CPC34(2010)421**

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

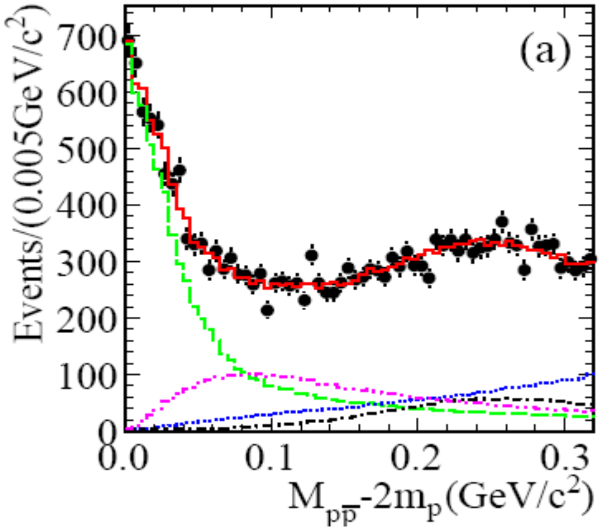
$$\Gamma < 38 \mathrm{MeV/c^2} @ 90\% CL.$$

□ **Not observed in B-meson decay nor $J/\psi \rightarrow \omega pp$**
→ the enhancement isn't pure FSI effect

□ **normal meson/ppbar bound state/multiquark state/glueball?**

PWA of $J/\psi \rightarrow \gamma p\bar{p}$ and $\psi' \rightarrow \gamma p\bar{p}$

$J/\psi \rightarrow \gamma pp$



- **PRL108(2012)112003**
- **PWA with Julich-FSI effects considered.**
- **$J^{PC}=0^{-+}$**

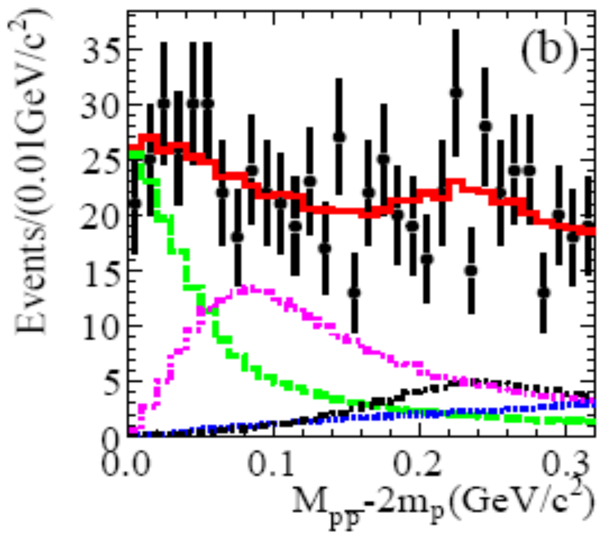
$$M = 1832^{+19}_{-5}\ {}^{+18}_{-17} \pm 19\,\mathrm{MeV/c^2}$$

$$M = 13 \pm 39^{+10}_{-13} \pm 4\,\mathrm{MeV/c^2}$$

$$\mathrm{Br}(J/\psi \rightarrow \gamma X) \cdot \mathrm{Br}(X \rightarrow p\bar{p})$$

$$= (9.0^{+0.4}_{-1.1}\ {}^{+1.5}_{-5.0} \pm 2.3) \times 10^{-5}$$

$\psi' \rightarrow \gamma pp$

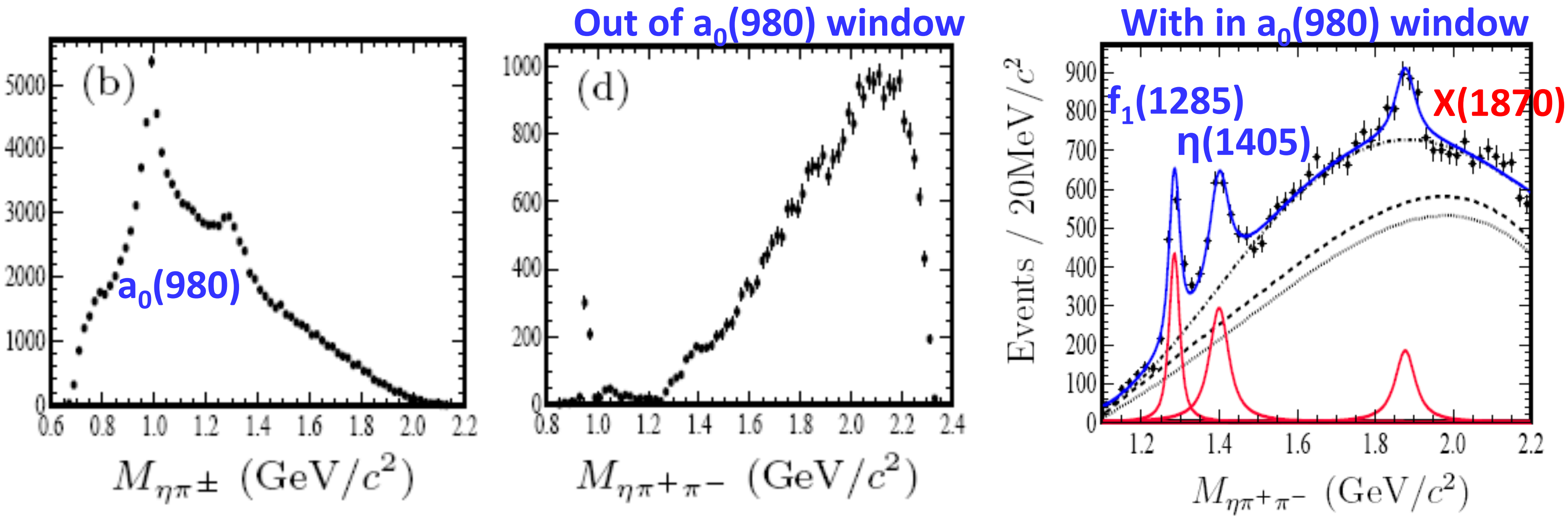


$$R = \frac{Br(\psi(2s) \rightarrow \gamma X)}{Br(J/\psi \rightarrow \gamma X)}$$

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

□ X(pp) and X(1835) observed in $J/\psi \rightarrow \gamma\eta'\pi\pi$ are the same state?

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

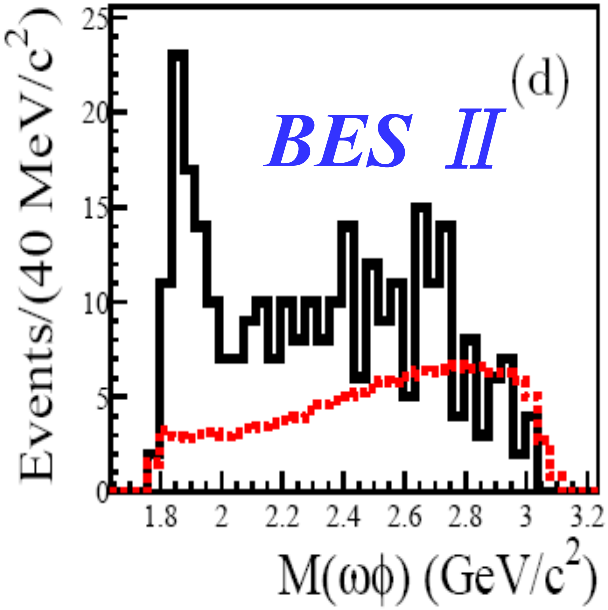


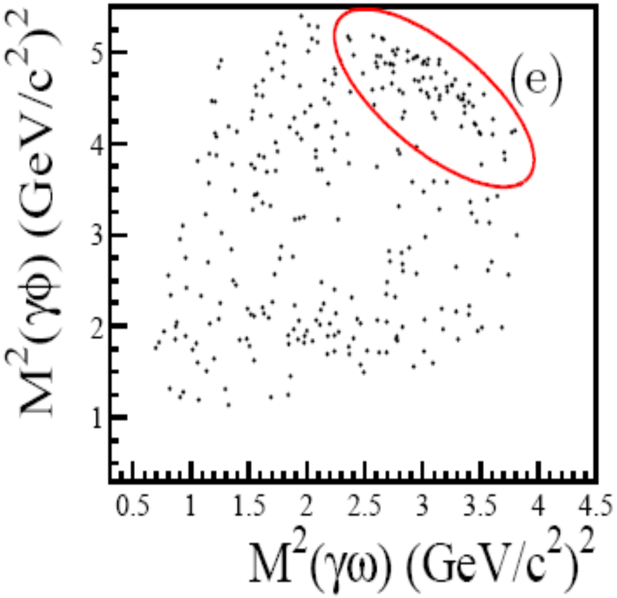
- **PRL 107, 182001(2011)**

Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	$\mathcal{B}$ (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(1870)** **J^{PC}? X(1835)? Need PWA.**

ωφ threshold enhancement in J/ψ→γωφ



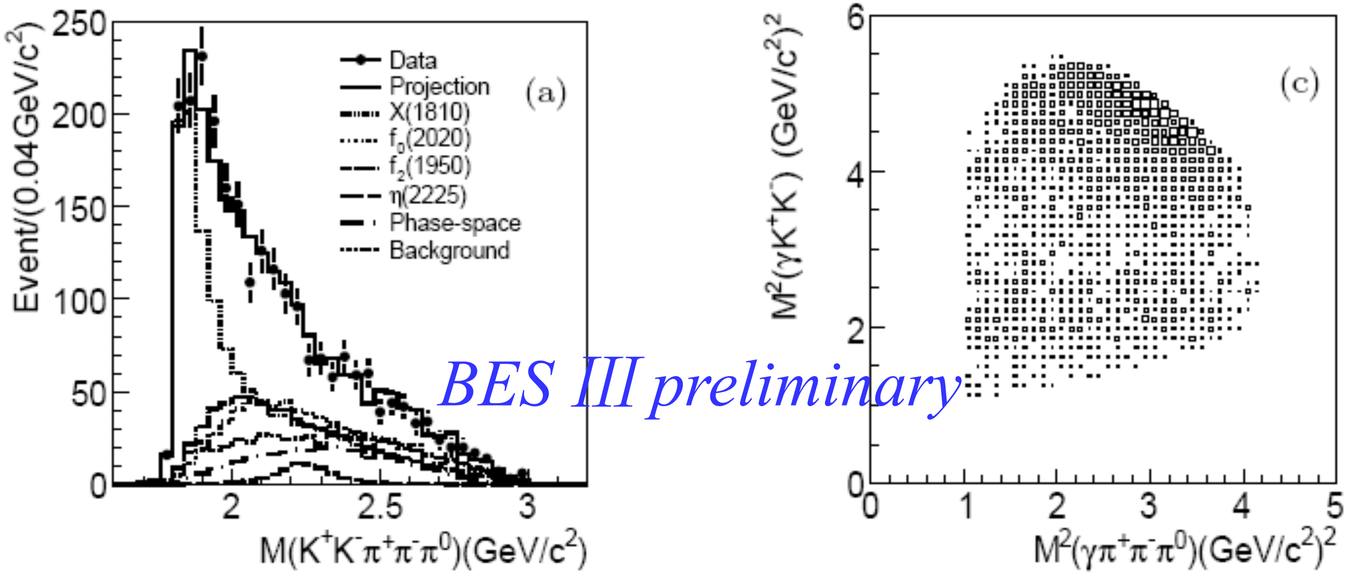


- **First observed in BESII.** **Phys. Rev. Lett. 96(2006)162002**
- **Partial wave analysis with helicity covariant amplitude.**
- **Threshold enhancement: X(1810)**

$\mathbf{J^{PC} = 0^{++}}$, $\quad M = 1812^{+19}_{-26} \pm 18\mathrm{MeV/c^2} \quad \Gamma = 105 \pm 20 \pm 28\mathrm{MeV/c^2}$

$$B(J/\psi \to \gamma X(1810) \cdot B(X(1810) \to \omega\phi) = (2.61 \pm 0.27 \pm 0.65) \times 10^{-4}$$

ωφ threshold enhancement in $J/\psi \rightarrow \gamma\omega\phi$



- **PWA with covariant tensor amplitude**
- **Threshold enhancement: X(1810)**

$J^{PC} = 0^{++}$, $\quad M = 1795 \pm 7^{+23}_{-5}\,\mathrm{MeV/c^2} \qquad \Gamma = 95 \pm 10^{+78}_{-34}\,\mathrm{MeV/c^2}$

$$B(J/\psi \rightarrow \gamma X(1810)\cdot B(X(1810) \rightarrow \omega\phi) = (2.00 \pm 0.08^{+1.38}_{-1.00})\times 10^{-4}$$

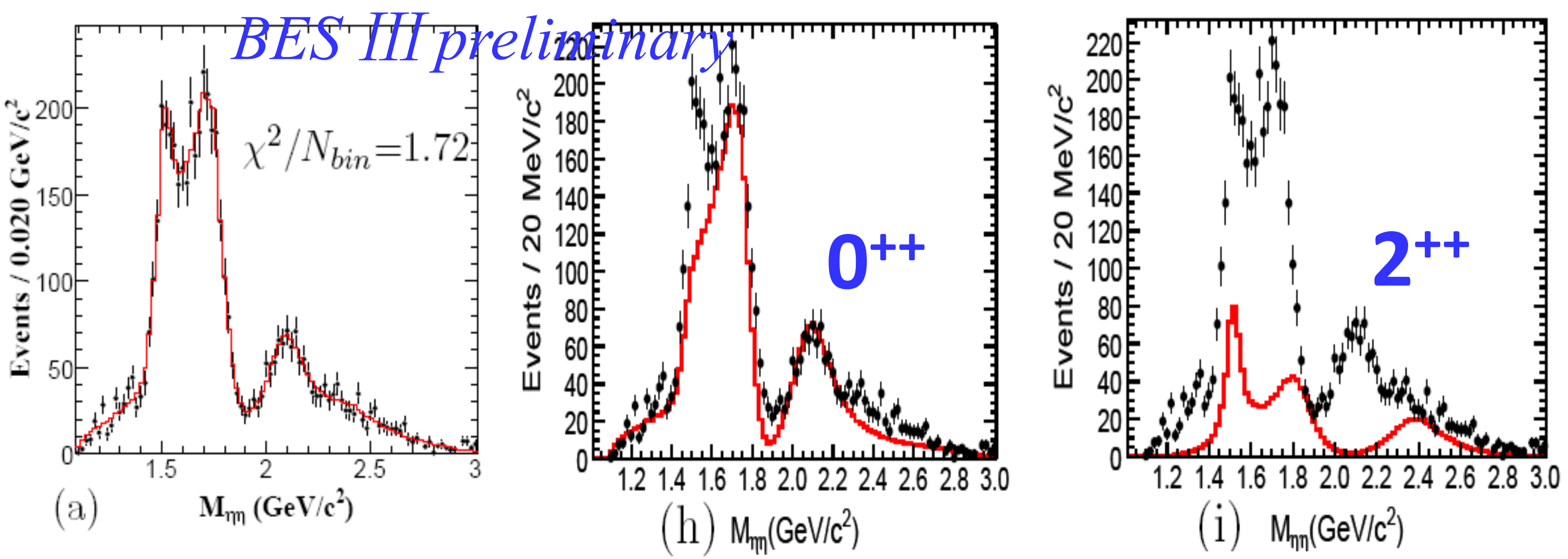
- **DOZI suppressed, the branch fraction is too large.**

Why? X(1810) is exotic states? $f_0(1710)$?

Study of J/ψ→γηη/ $\pi^0\pi^0$

- $\frac{1}{P.S.}\Gamma(G \to \pi\pi : K\overline{K} : \eta\eta : \eta\eta' : \eta'\eta')$ predicted to be 3:4:1:0:1. Glueball is flavor blindness.
- Neutral channels can take advantage of excellent performance of electromagnetic calorimeter of BESIII.
- GPUPWA package is developed to perform PWA of large data samples.

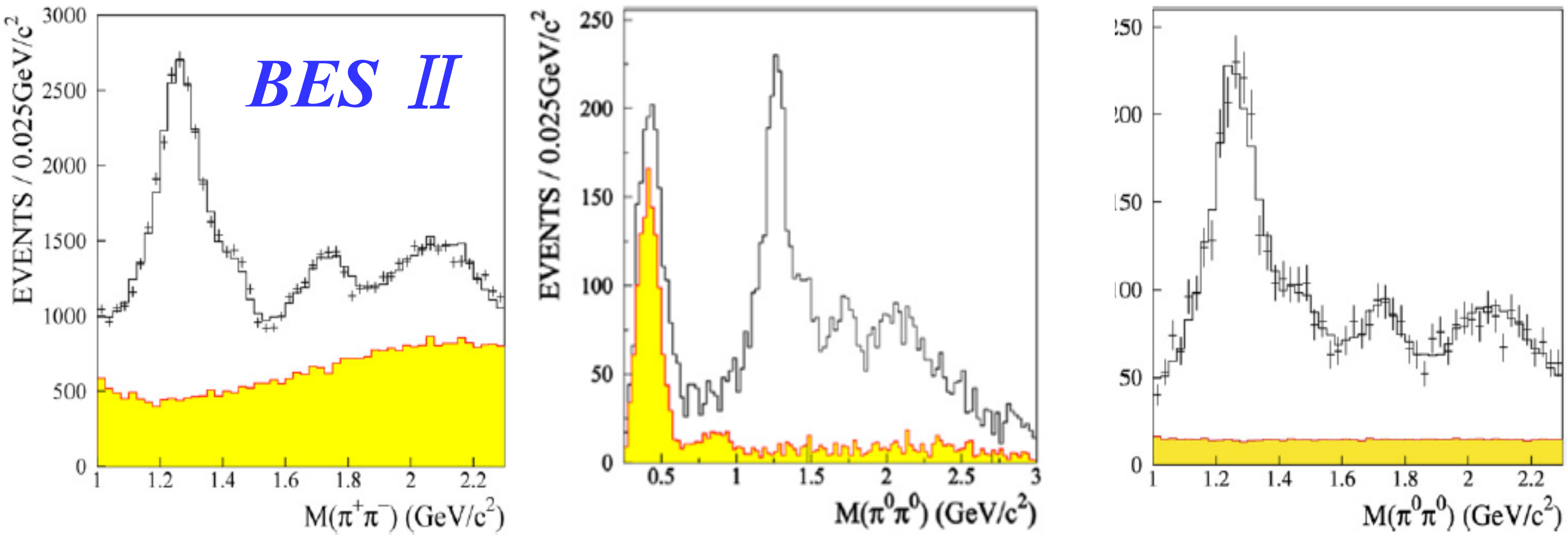
Preliminary PWA results of J/ψ→γηη



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+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.61^{+0.29+0.49}_{-0.32-1.37}) \times 10^{-5}$	8.2 σ
$f_0(1710)$	1759^{+6+15}_{-6-25}	172^{+10+32}_{-10-16}	$(2.35^{+0.07+1.24}_{-0.07-0.74}) \times 10^{-4}$	25.0 σ
$f_0(2100)$	2081^{+13+24}_{-13-36}	273^{+27+70}_{-24-23}	$(9.99^{+0.57+5.64}_{-0.52-2.46}) \times 10^{-5}$	13.9 σ
$f_2'(1525)$	1513^{+5+4}_{-5-10}	75^{+12+14}_{-10-8}	$(3.41^{+0.43+1.37}_{-0.50-1.29}) \times 10^{-5}$	11.0 σ
$f_2(1810)/f_2(1950)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.38^{+0.60+3.41}_{-0.67-2.34}) \times 10^{-5}$	6.4 σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.58^{+0.61+2.36}_{-0.65-2.06}) \times 10^{-5}$	7.6 σ

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

PWA results of $J/\psi \rightarrow \gamma\pi^+\pi^-/\pi^0\pi^0$ at BESII



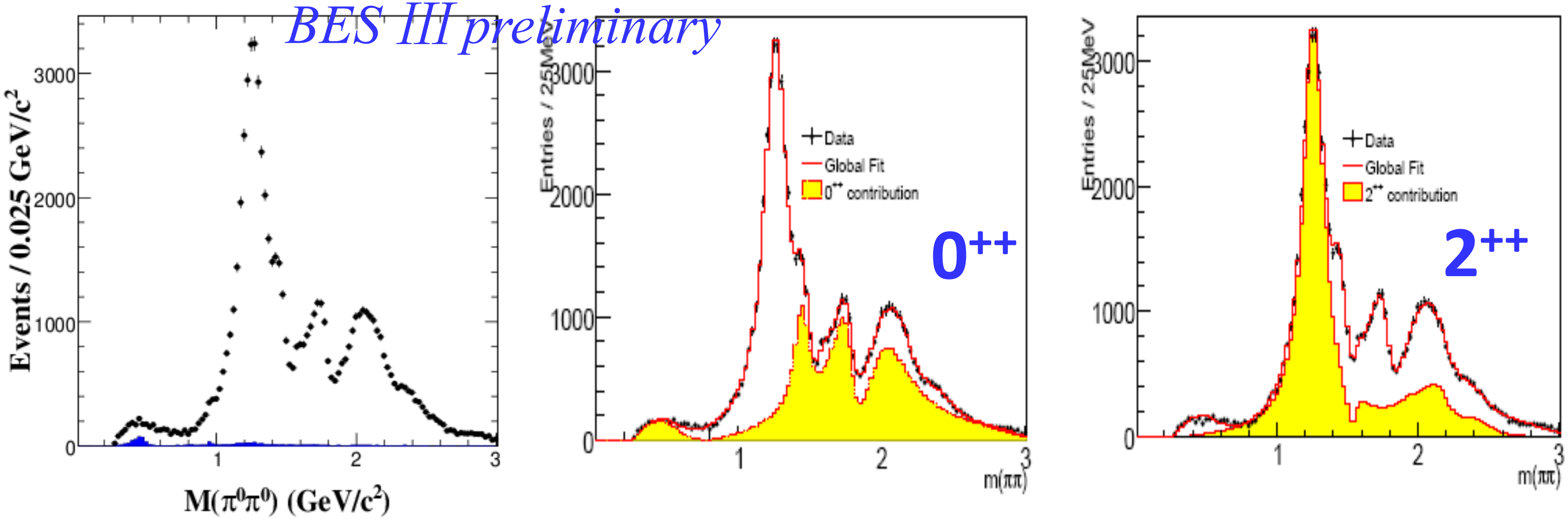
$J/\psi \to \gamma X, X \to \pi^+\pi^-$			
	Mass (MeV/c^2)	Γ (MeV/c^2)	$\mathcal{B}$ ($\times 10^{-4}$)
$f_2(1270)$	$1262^{+1}_{-2} \pm 8$	$175^{+6}_{-4} \pm 10$	$9.14 \pm 0.07 \pm 1.48$
$f_0(1500)$	$1466 \pm 6 \pm 20$	$108^{+14}_{-11} \pm 25$	$0.67 \pm 0.02 \pm 0.30$
$f_0(1710)$	$1765^{+4}_{-3} \pm 13$	$145 \pm 8 \pm 69$	$2.64 \pm 0.04 \pm 0.75$

$J/\psi \to \gamma X, X \to \pi^0\pi^0$			
	Mass (MeV/c^2)	Γ (MeV/c^2)	$\mathcal{B}$ ($\times 10^{-4}$)
$f_2(1270)$	same as charged channel		$4.00 \pm 0.09 \pm 0.58$
$f_0(1500)$	same as charged channel		$0.34 \pm 0.03 \pm 0.15$
$f_0(1710)$	same as charged channel		$1.33 \pm 0.05 \pm 0.88$

- Phys. Lett. B642(2006) 441
- PWA applied in $\pi\pi$ range 1.0-2.3GeV/c^2

- Two scalar mesons f_0(1500) and f_0(1710), were observed.

Preliminary PWA results of $J/\psi \rightarrow \gamma\pi^0\pi^0$

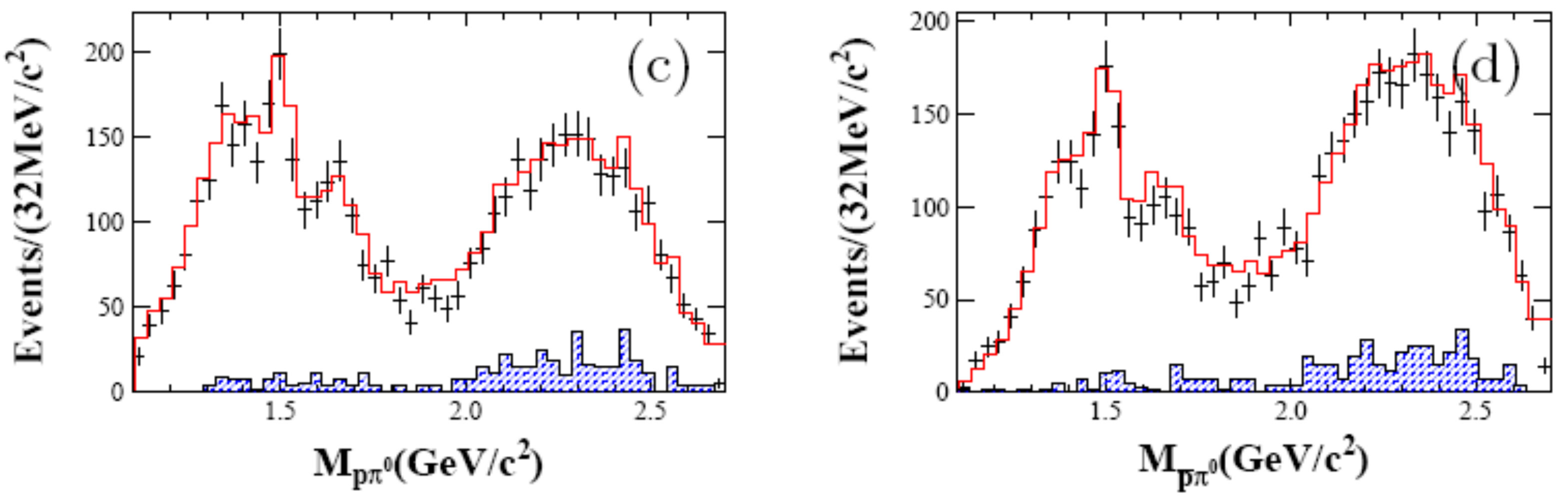


Resonances	Mass(MeV$/c^2$)	Width(MeV$/c^2$)	$Br(J/\psi \to \gamma X \to \gamma\pi^0\pi^0)$	Significance
$f_0(600)$	446(fixed)	578(fixed)	$0.91^{+0.02+0.37}_{-0.02-0.21}\times10^{-4}$	$> 40\sigma$
$f_2(1270)$	1255^{+1+4}_{-1-2}	177^{+2+1}_{-2-7}	$5.77^{+0.03+0.44}_{-0.03-0.36}\times10^{-4}$	$> 40\sigma$
$f_0(1500)$	1445^{+3+9}_{-3-4}	113^{+6+5}_{-6-14}	$0.44^{+0.01+0.06}_{-0.01-0.08}\times10^{-4}$	27.6σ
$f_2'(1525)$	1539^{+5+6}_{-6-9}	72^{+10+30}_{-9-7}	$0.09^{+0.01+0.09}_{-0.01-0.01}\times10^{-4}$	13.5σ
$f_0(1710)$	1765^{+3+4}_{-3-5}	159^{+7+5}_{-7-14}	$1.11^{+0.02+0.13}_{-0.02-0.21}\times10^{-4}$	$> 40\sigma$
$f_2(1950)$	1901^{+22+58}_{-23-20}	313^{+48+76}_{-43-66}	$0.11^{+0.01+0.07}_{-0.01-0.06}\times10^{-4}$	11.4σ
$f_0(2020)$	1971^{+6+25}_{-6-7}	409^{+14+13}_{-13-22}	$5.31^{+0.04+0.45}_{-0.04-0.50}\times10^{-4}$	35.6σ
$f_2(2150)$	2160^{+13+11}_{-13-15}	227^{+22+20}_{-21-38}	$0.32^{+0.02+0.12}_{-0.02-0.10}\times10^{-4}$	14.2σ
$f_2(2340)$	2419^{+13+20}_{-13-19}	286^{+28+22}_{-26-42}	$0.28^{+0.01+0.06}_{-0.01-0.07}\times10^{-4}$	17.8σ

- **Background is much smaller than BESII**
- **$f_0(1500)$ and $f_0(1710)$, were both observed. The result are more precision.**
- **$f_0(600)$ fixed to "The σ pole in $J/\psi \to \omega\pi\pi$" *PLB 598 (2004) 149*.**

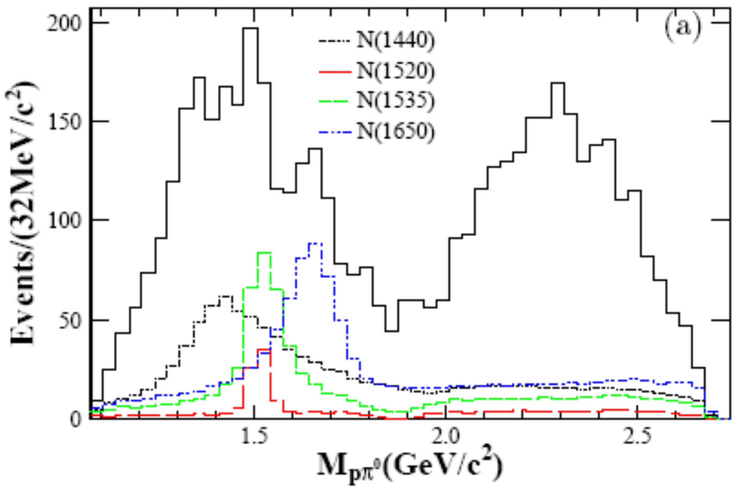
Observation of two new N* resonances in $\psi' \rightarrow p\bar{p}\pi^0$

- **Non-relativistic three-quark models of baryons predicted more excited states than are found experimentally ("missing resonance problem").**
- **Most of the data about baryons on PDG are from πN scattering.**
- **The formula for baryons decay is much more complicated than mesons decay. FDCPWA package is used to generated the formula.**

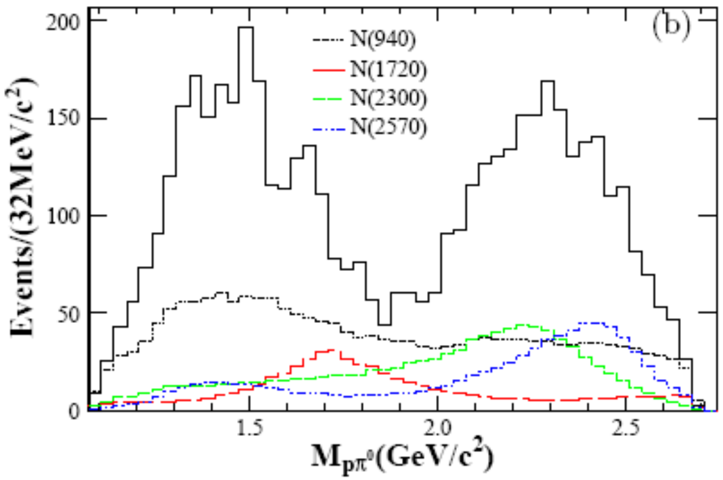


[The global fit result: arXiv:1207.0223]()

Observation of two new N* resonances in $\psi' \rightarrow p\bar{p}\pi^0$



Resonance	N	ϵ(%)	B.F.($\times10^{-5}$)
$N(940)$	$1870^{+90+487}_{-90-327}$	27.5 ± 0.4	$6.42^{+0.20+1.78}_{-0.20-1.28}$
$N(1440)$	$1060^{+90+459}_{-90-227}$	27.9 ± 0.4	$3.58^{+0.25+1.59}_{-0.25-0.84}$
$N(1520)$	190^{+14+64}_{-14-48}	28.0 ± 0.4	$0.64^{+0.05+0.22}_{-0.05-0.17}$
$N(1535)$	$673^{+45+263}_{-45-256}$	25.8 ± 0.4	$2.47^{+0.28+0.99}_{-0.28-0.97}$
$N(1650)$	$1080^{+77+382}_{-77-467}$	27.2 ± 0.4	$3.76^{+0.28+1.37}_{-0.28-1.66}$
$N(1720)$	$510^{+27+50}_{-27-197}$	26.9 ± 0.4	$1.79^{+0.10+0.24}_{-0.10-0.71}$
$N(2300)$	$948^{+68+394}_{-68-213}$	34.2 ± 0.4	$2.62^{+0.28+1.12}_{-0.28-0.64}$
$N(2570)$	$795^{+45+127}_{-45-83}$	35.3 ± 0.4	$2.13^{+0.08+0.40}_{-0.08-0.30}$
Total	4515±93	25.8 ± 0.4	$16.5\pm0.3\pm1.5$



- **Two new N* states are observed, N (2300) and N(2570).**

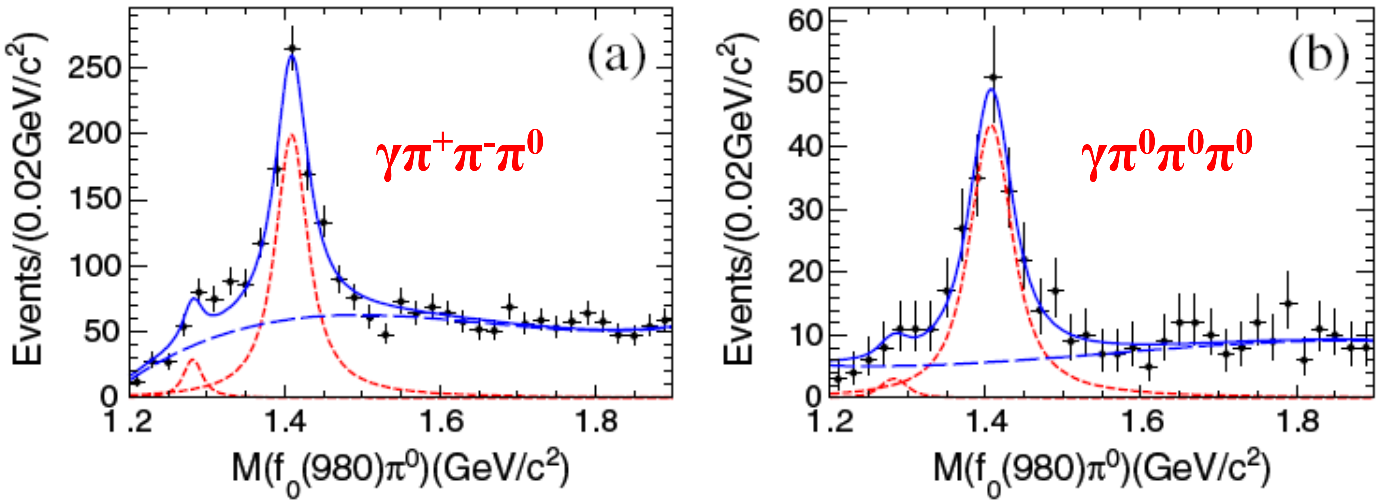
$$M(2300) = 2300^{+40}_{-30}\ {}^{+109}_{-0}\ \mathrm{MeV}/c^2,$$

$$\Gamma(2300) = 340^{+30}_{-30}\ {}^{+110}_{-58}\ \mathrm{MeV}/c^2$$

$$M(2570) = 2570^{+19}_{-10}\ {}^{+34}_{-10}\ \mathrm{MeV}/c^2,$$

$$\Gamma(2570) = 250^{+14}_{-24}\ {}^{+69}_{-21}\ \mathrm{MeV}/c^2$$

Isospin violate process $J/\psi \rightarrow \gamma\eta(1405) \rightarrow \gamma f_0(980)\pi^0 \rightarrow \gamma\pi\pi\pi^0$



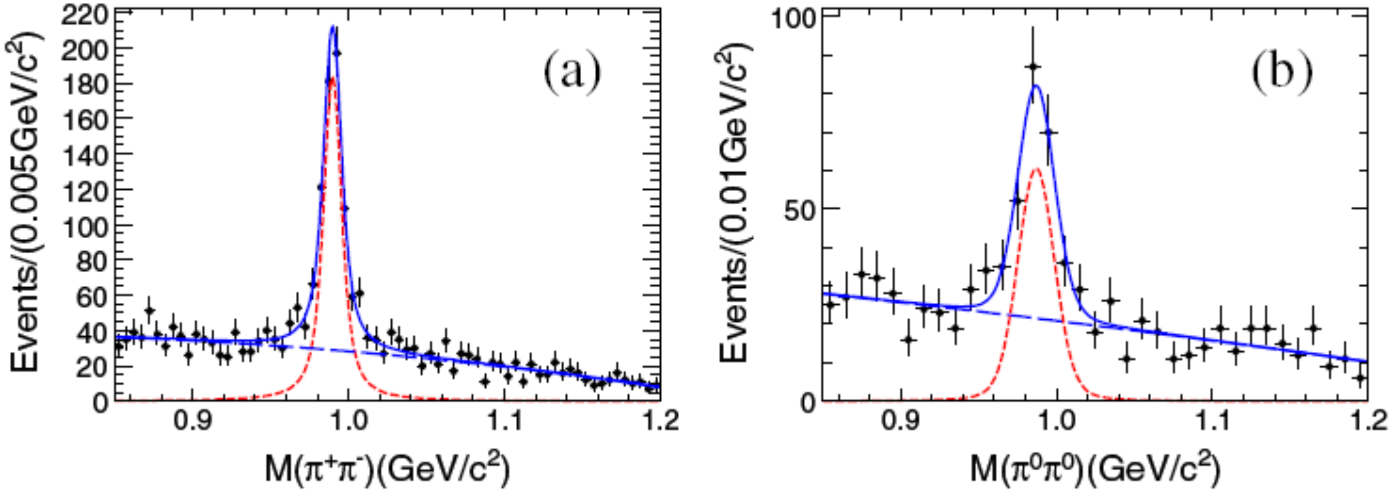
- **PRL 108, 182001 (2012)**
- **$\eta(1405)(0^+(0^{-+})) \rightarrow f_0(980)(0^+(0^{++}))\pi^0(1^-(0^{-+}))$ isospin violate process.**

$$\mathrm{Br}(J/\psi \rightarrow \gamma\eta(1405) \rightarrow \gamma\pi^0 f_0(980) \rightarrow \gamma\pi^0\pi^+\pi^-) = (1.50 \pm 0.11 \pm 0.11)\times 10^{-5}$$

$$\mathrm{Br}(J/\psi \rightarrow \gamma\eta(1405) \rightarrow \gamma\pi^0 f_0(980) \rightarrow \gamma\pi^0\pi^0\pi^0) = (7.10 \pm 0.82 \pm 0.72)\times 10^{-5}$$

- **The branching fraction is surprising large.**

Isospin violate process $J/\psi \rightarrow \gamma\eta(1405) \rightarrow \gamma f_0(980)\pi^0 \rightarrow \gamma\pi\pi\pi^0$



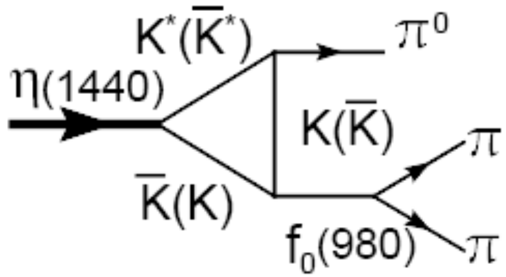
$M = 989.9 \pm 0.4 \mathrm{MeV/c^2}$

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

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

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

- **$f_0(980)$: PDG value Γ=40~100MeV**
- **How to explain the narrow width of $f_0(980)$ and large branch fraction of isospin violated process?**
- **Triangle singularity(TS) mechanism.**
  Phys. Rev.Lett. 108, 081803 (2012).



Summary

- Many interesting states are observed: X(1835)(0^{-+}), X (pp)(0^{-+}), X(1870)(?), X(ωφ)(0^{++})
- Some of them are exotic states candidates.

  lowest scalar glueball(f_0(1500), f_0(1710), x(ωφ)?...)

  lowest pseudo-scalar glueball(X(2370)(?)?, η(1405)?)
- Troubled by the possible mixing between glueball and $q\bar{q}$, it's hard to distinguish an exotic state from normal states.
- PWA is needed to determine the property of these states.