LIGHT HADRON SPECTROSCOPY AT BESIII

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- Summary

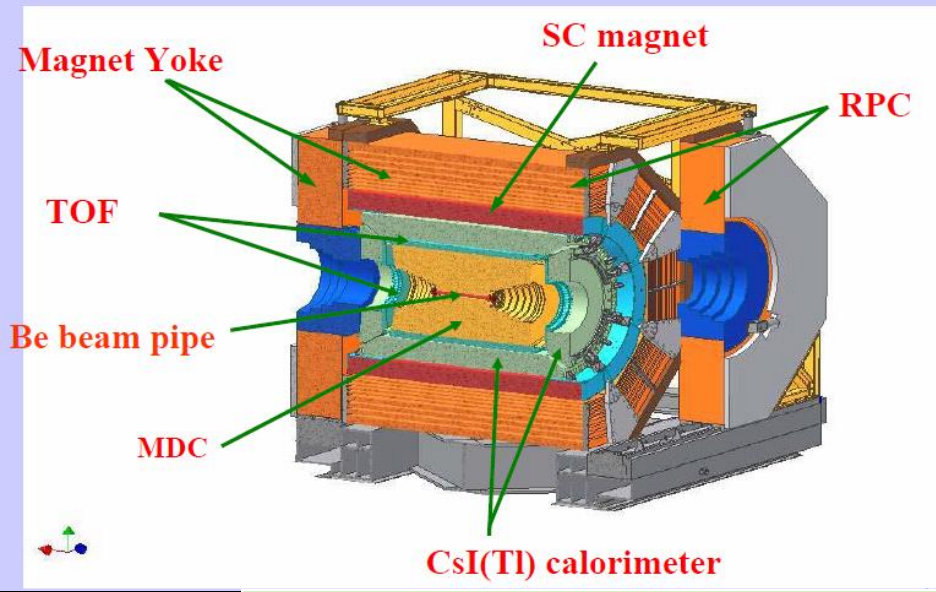
BEPC II

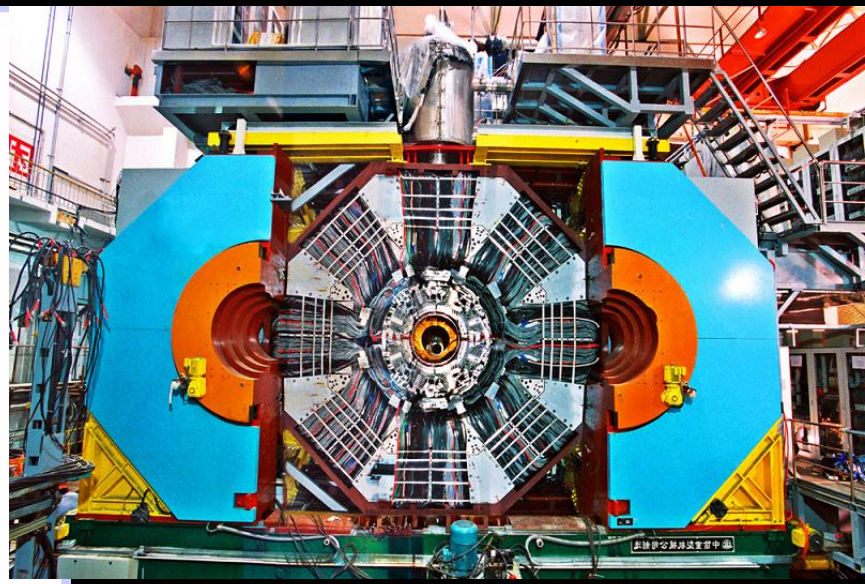
A high luminosity double-ring collider

Beijing Electron Positron Collider (II)

Beam energy:
1.0 – 2.3 GeV
Design Luminosity:
1×10^{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

BESIII Detector





Sub-detectors			Performance
MDC	Momentum resolution		0.5%@1GeV
	dE/dx resolution		6%
EMC	Energy resolution		2.5%@1GeV
	Spatial resolution		6 mm
TOF	Time resolution	Barrel	80 ps (Bhabha)
		Endcap	110 ps (Di-muon)
MUC	9 layers RPC, 8 layers for endcap		

Data Sample

- July 18, 2008:

  First e+e- collision event

- 2009:

  106 M ψ′ events

  (x4 CLEOc)

- 2009:

  ~225 M J/ψ events

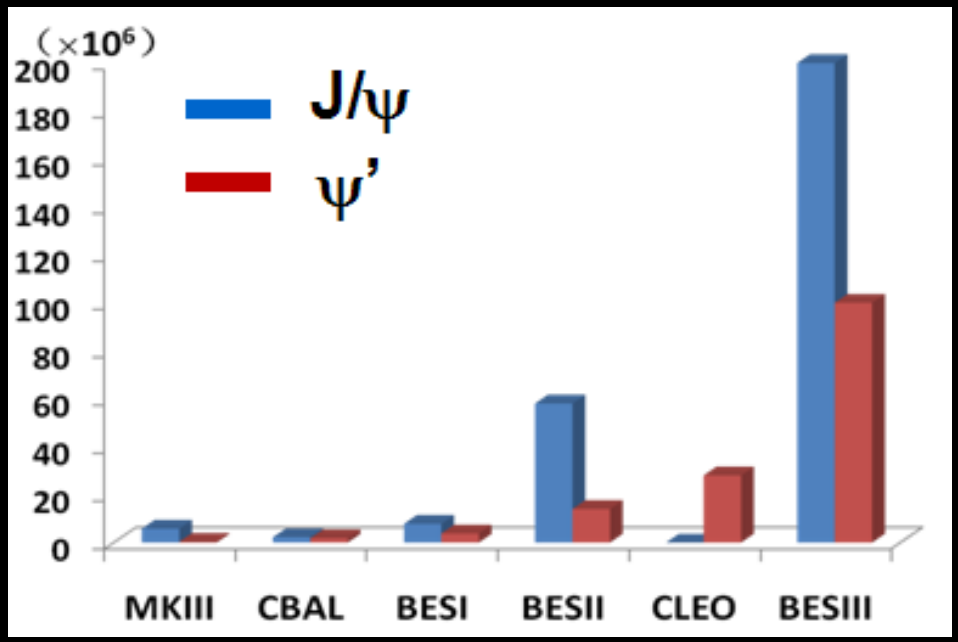
  (x4 BESII)

- 2010-11:

  ~2.9 fb^{-1} at ψ(3770)

- May 2011:

  ~0.5 fb^{-1} at 4010 MeV for D_S and XYZ spectroscopy



Light Hadron Spectroscopy

- Multi-quarks states, glueballs and hybrids have been searched for experimentally for a long time, but none have been established.
- In the past several years, a lot of unexpected experimental evidence for hadron cannot (easily) be explained by the conventional quark model

- Established the light hadron spectroscopy
- Search for non-conventional hadrons

- BESIII advantages:
  - Gluon rich
  - Clean environment
  - Important J^{PC} filter, and isospin filter

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

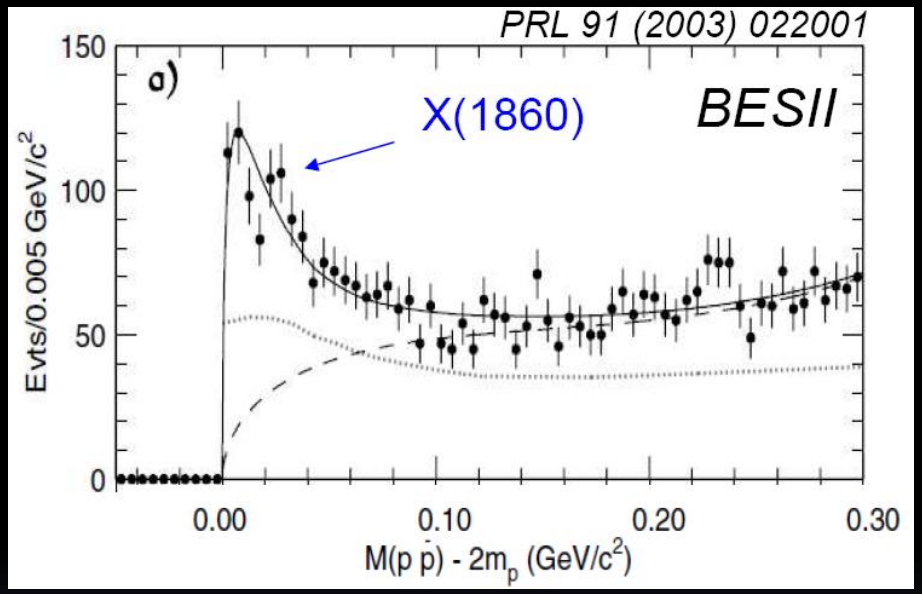
$J/\psi \to \gamma p\bar{p}$

- If fitted with a S-wave resonance

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

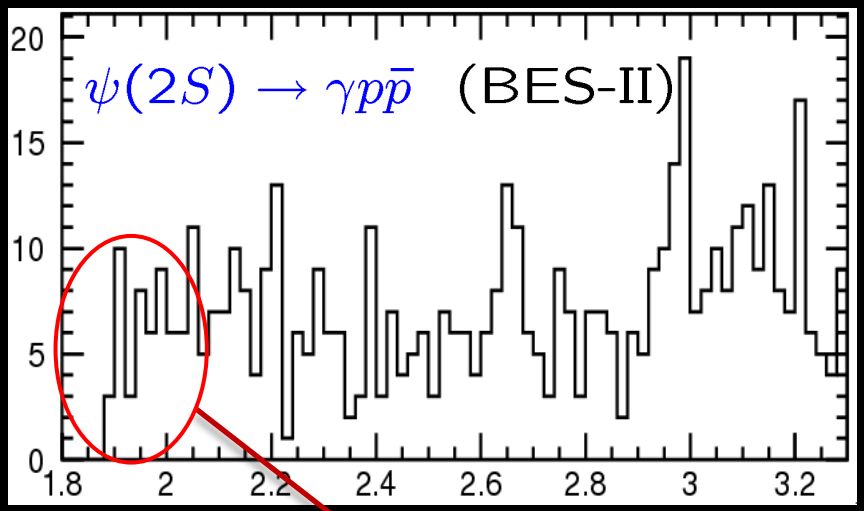
  Γ < 30 MeV (90% CL)

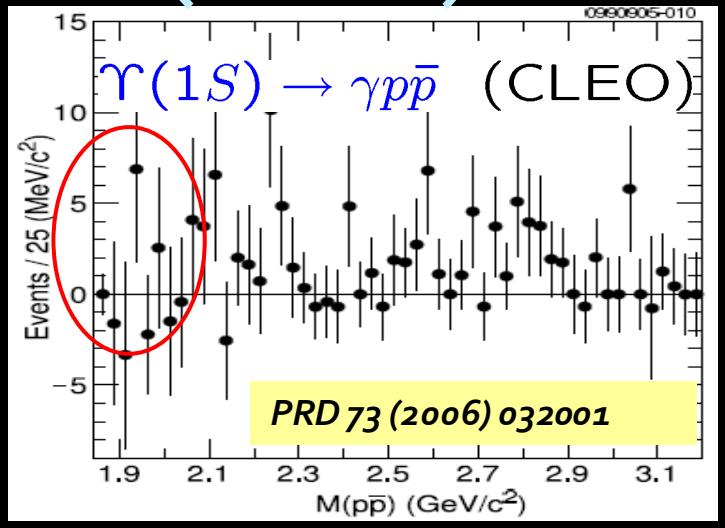
- Theoretical speculation:
  - $\bar{p}p$ bound state?
  - FSI effect?
  - ……



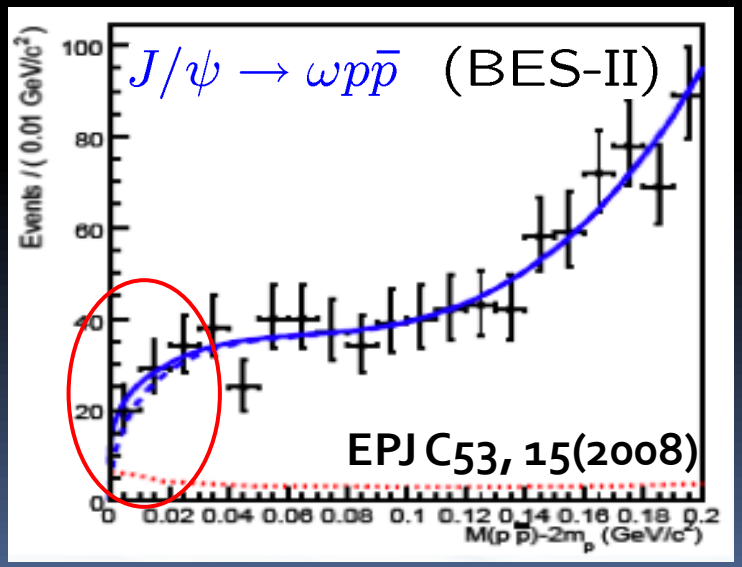
Non-observation of X(1860)

PRL 99 (2007) 011802



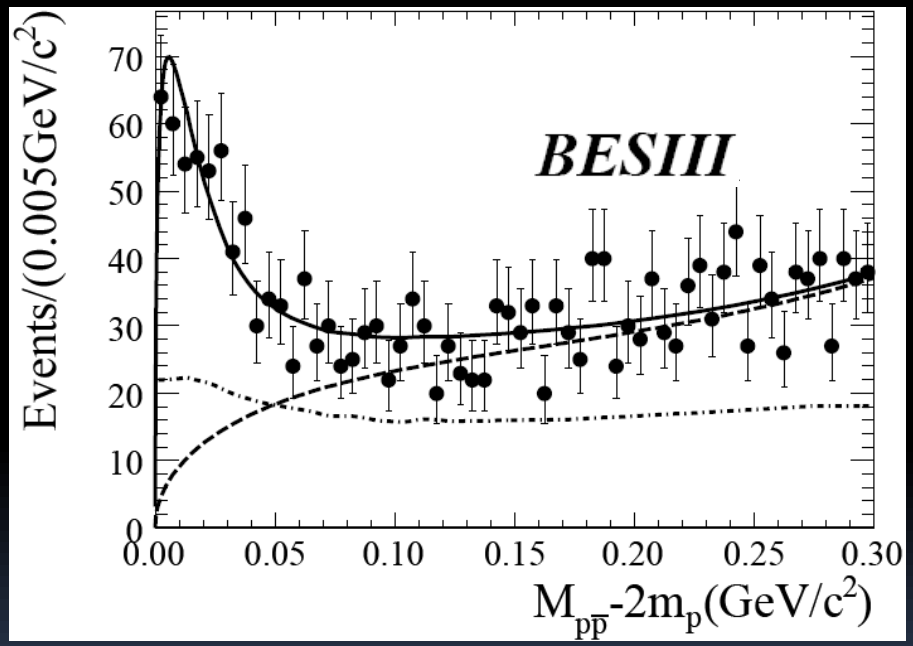


No significant signal of X(1860) found (only 2σ significance)



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

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



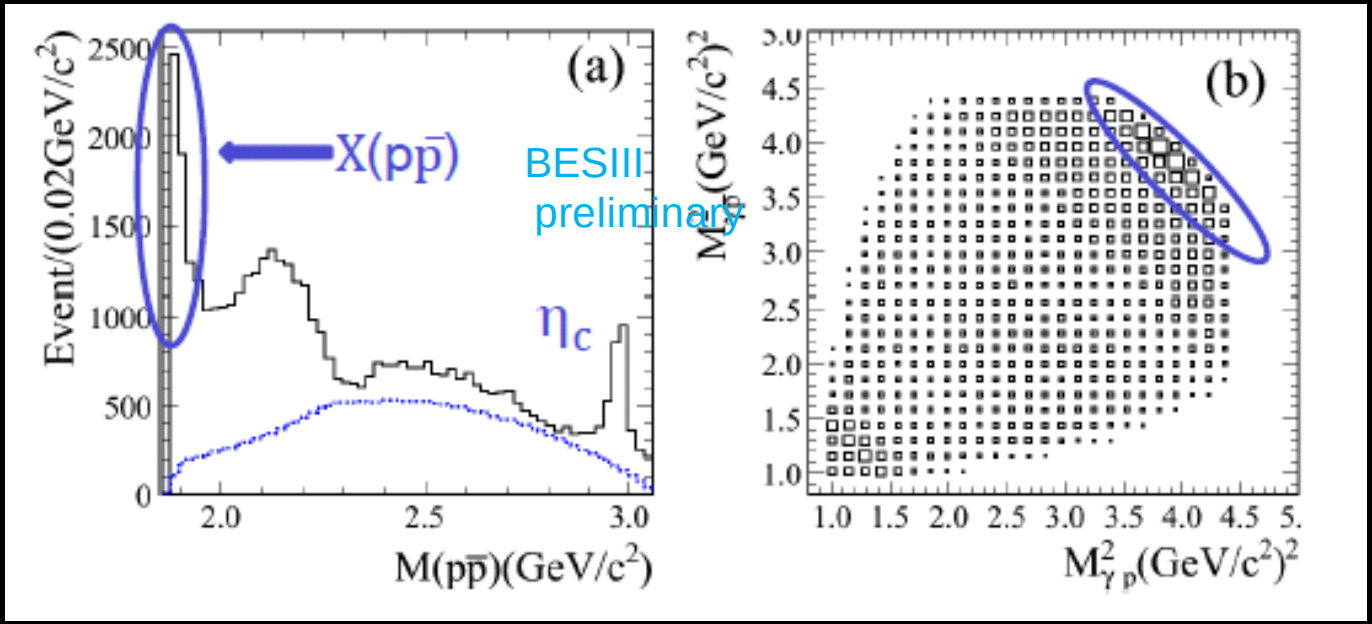
$M=1861\ ^{+6}_{-13}\ ^{+7}_{-26}$ MeV/c^2

$\Gamma < 38$ MeV (90% CL)

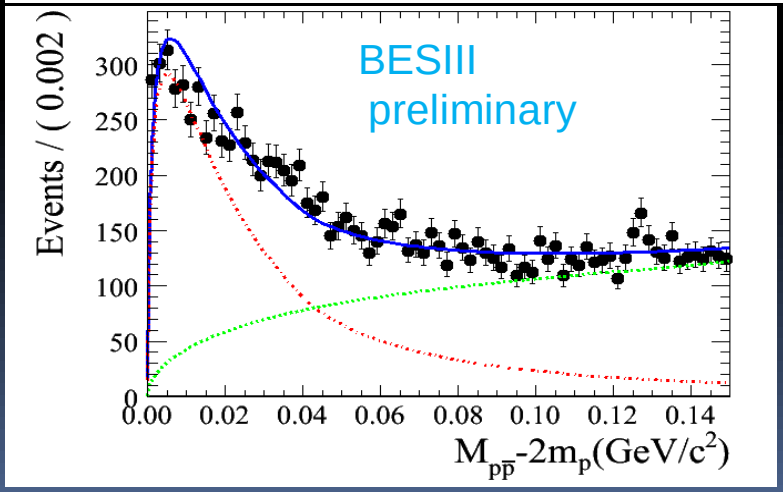
Chinese Physics C 34(2010)421

Consistent observation by BESIII !

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



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



Fit result:

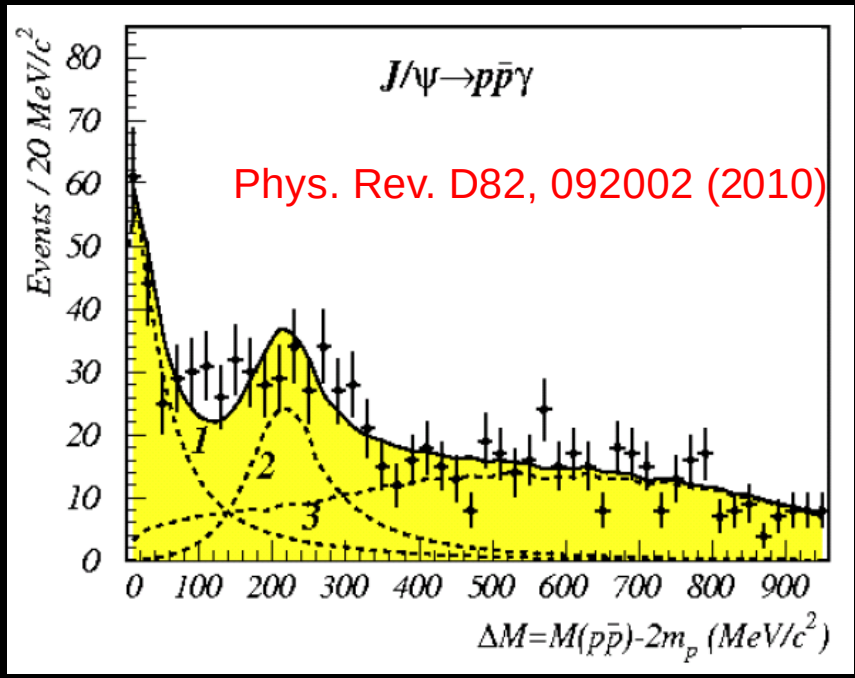
$\text{Mass} = 1861.6 \pm 0.8 MeV/c^2$

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

$\bar{p}p$ threshold enhancement @CLEOc

- CLEO-c does the same fit as that BES, they obtain
  $M(R_{thr})= 1861^{+6}_{-16}$ (MeV/c^2),
  $\Gamma(R_{thr}) = 0^{+32}_{-0}$ (MeV)
  which agree with BESII results.
- CLEO-c fit with three contributions: $R_{thr}+f_0(2100)+PS$
  $M(R_{thr})= 1837^{+10}_{-12}{}^{+9}_{-7}$(MeV/$c^2$),
  $\Gamma(R_{thr}) = 0^{+44}_{-0}$ (MeV)
  CL = 26.1%

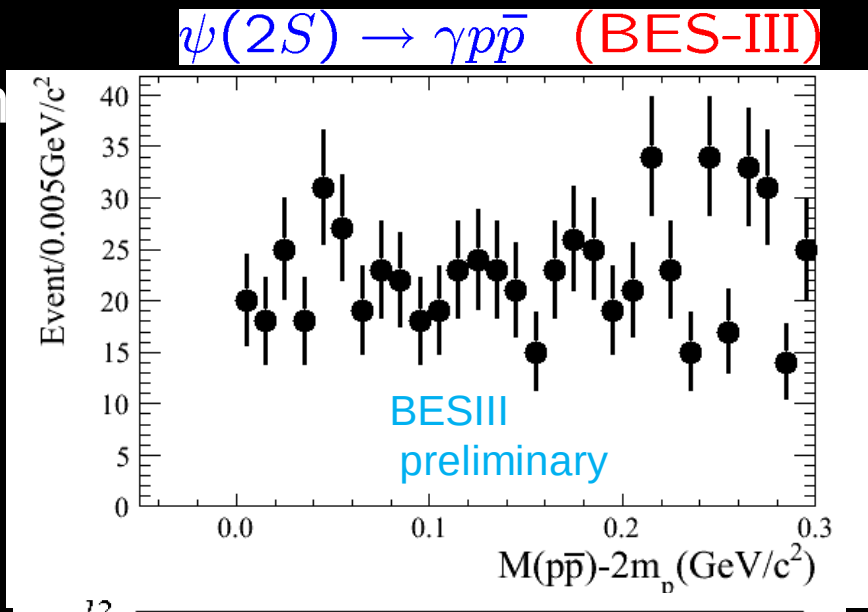
BES considered 2nd and 3rd parts as systematic errors.

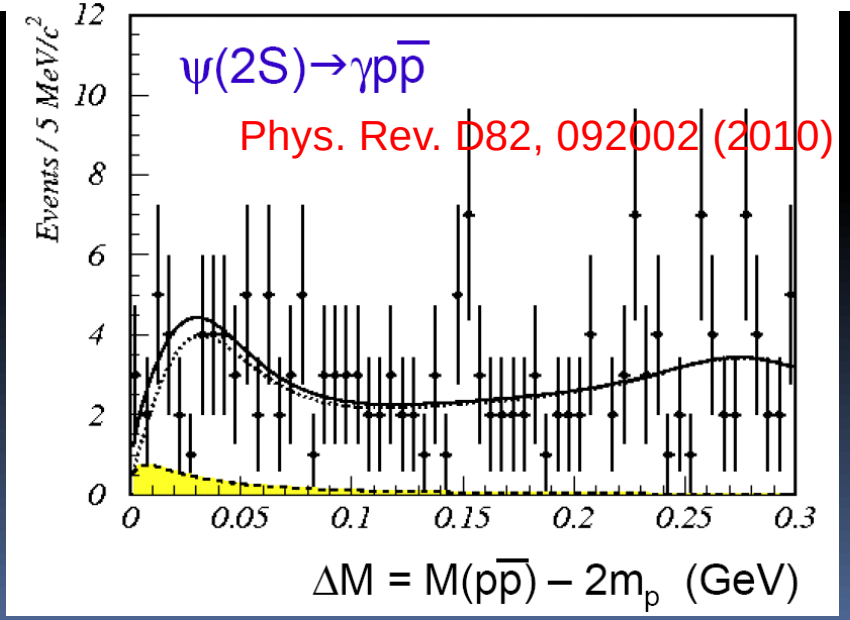


The central value of the mass is close to the resonance mass reported by BES with M(R) = 1833.7 ± 6.1 ± 2.7 MeV/c^2, observed in $J/\psi\to\gamma R$, $R\to\pi^+\pi^-\eta'$ [PRL 95 (2005) 262001]

X(1860) in ψ' decays (preliminary)

- Check also for enhancement in ψ' decays (high statistics)
  confirmation of no observation of enhancement in ψ' channel
  $\Rightarrow$ pure FSI effect unlikely
- B($\psi' \to \gamma$R)xB(R$\to \bar{p}p$)
  - CLEO-c fit assuming
    M=1859MeV/c², Γ=20MeV
    < 1.6 x 10-6 @90% CL
  - BESII result:
    PRL 99(2007)011802
    < 5.4 x 10-6 @90% CL

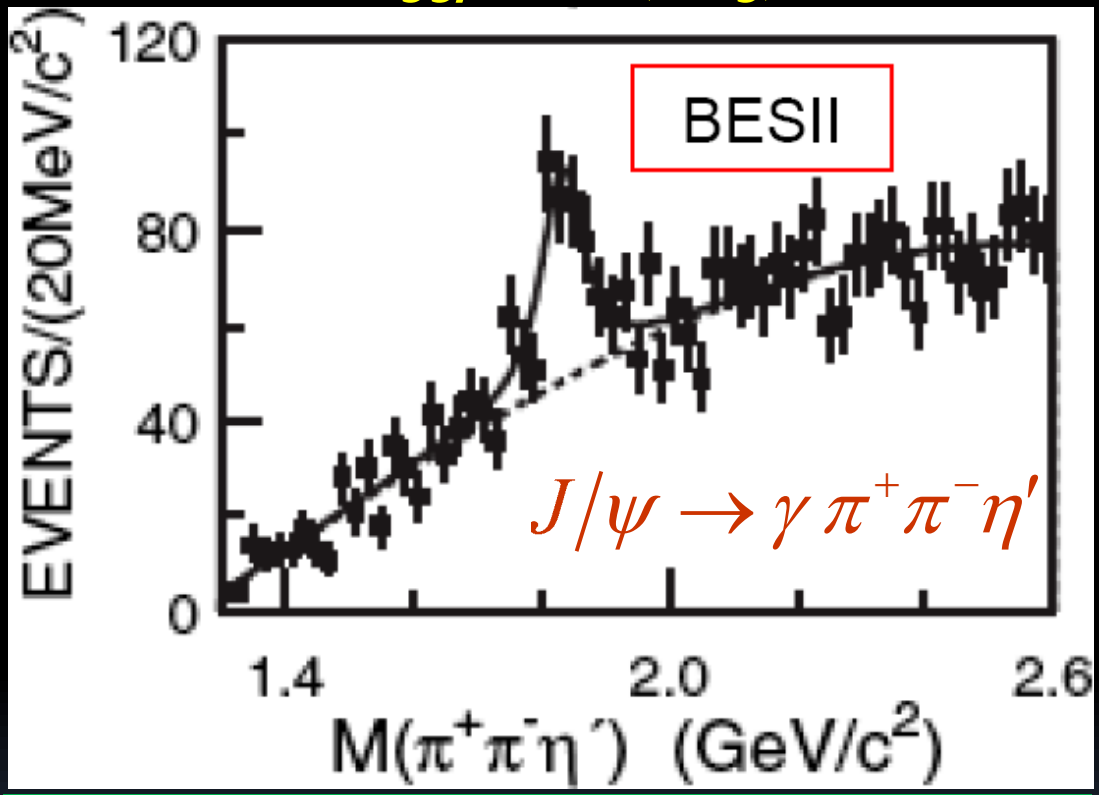




X(1835) at BESII

- 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 pp
  - η' has strong coupling to gluons
- Confirmation of X(1835) is necessary with BESIII ~225M J/ψ data sample

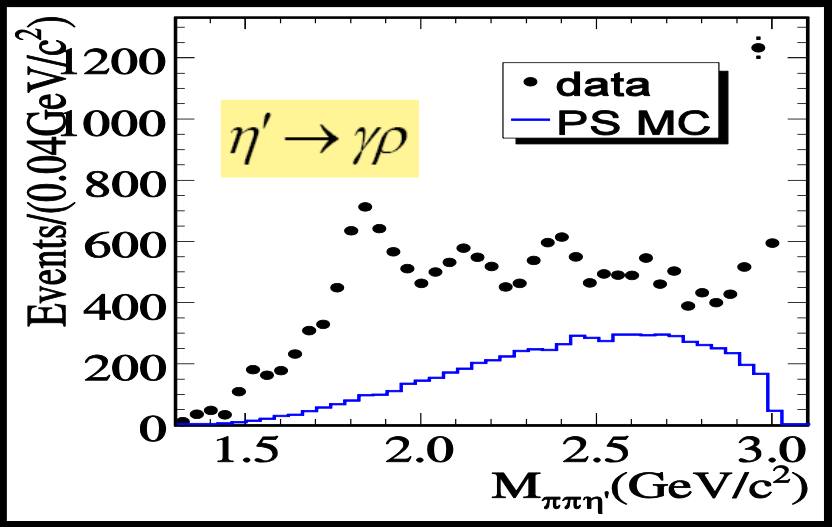
PRL 95,262001(2005)

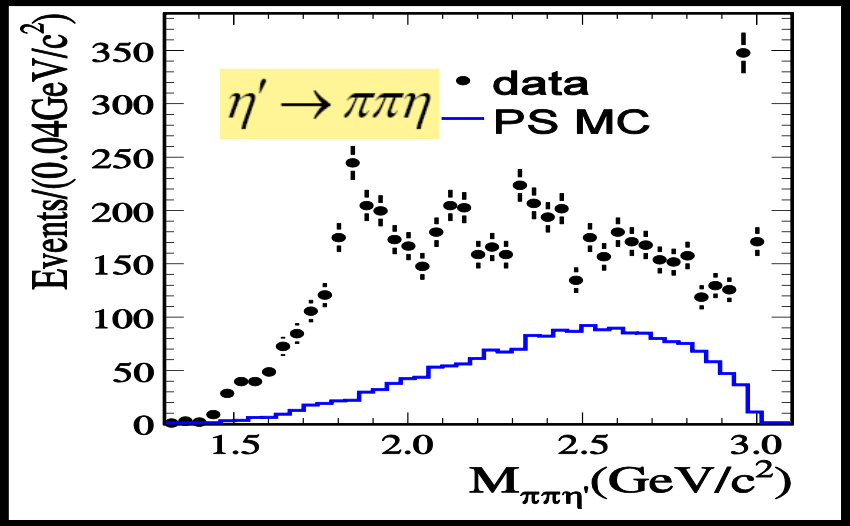


M = 1833.7 ± 6.1 ± 2.7 MeV/c²
Γ = 67.7 ± 20.3 ± 7.7 MeV
B(J/ψ→γX) x B(X→$\pi^+\pi^-\eta'$) = (2.2±0.4±0.4) x 10^{-4}
sig. = 7.7σ

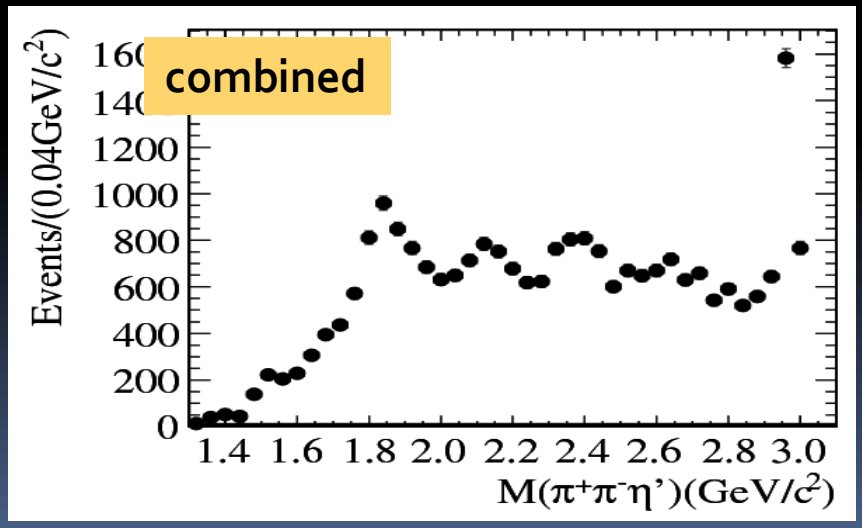
X(1835) at BESIII

PRL 106, 072002 (2011)





X(1835) confirmed by BESIII

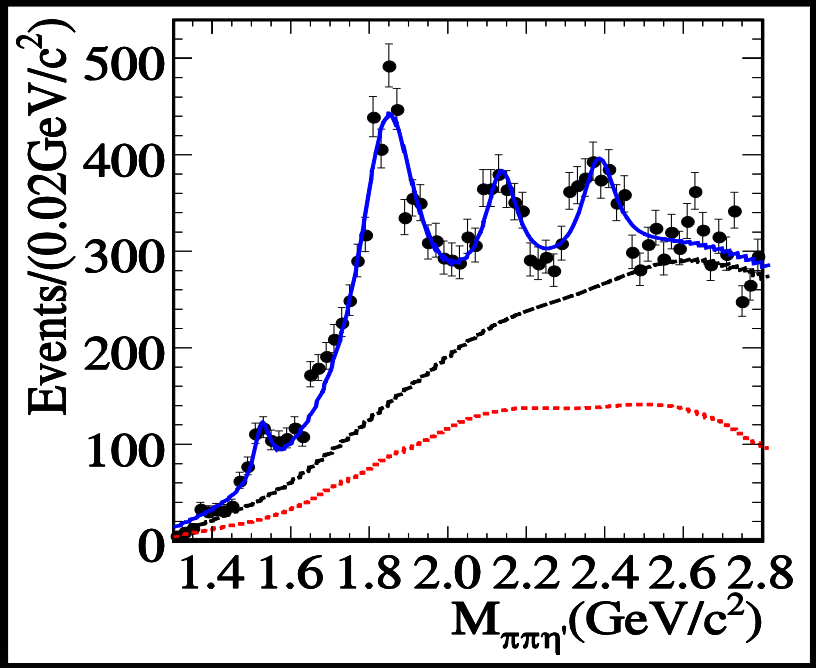


- Two additional structures are observed around 2.1 GeV/c² and 2.3 GeV/c²
- Maybe exist f1(1510)

Fitting results

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

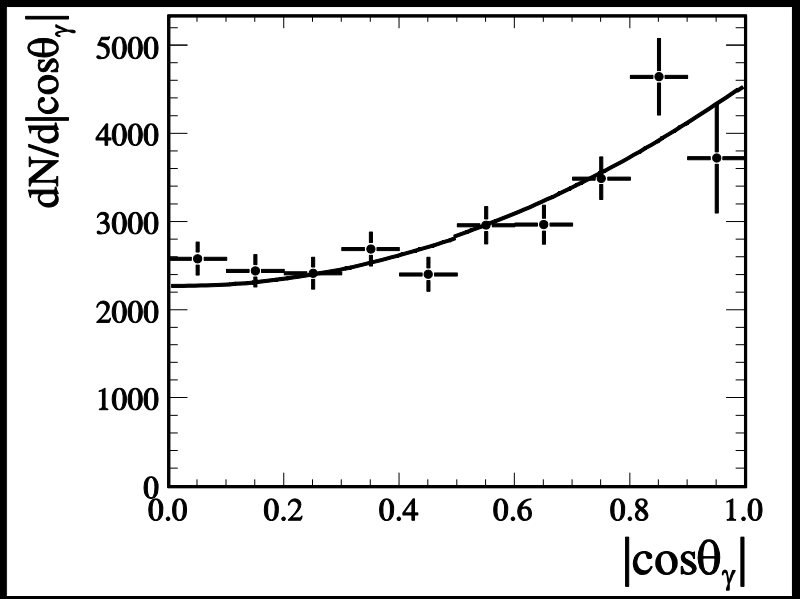
- Fitted with four resonances
- Three bkg components
  - ① η' sideband
  - ② $J/\psi \to \pi^0\pi^+\pi^-\eta'$
  - ③ Phase Space



Resonance	M(MeV/c²)	Γ(MeV)	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

Fitting results

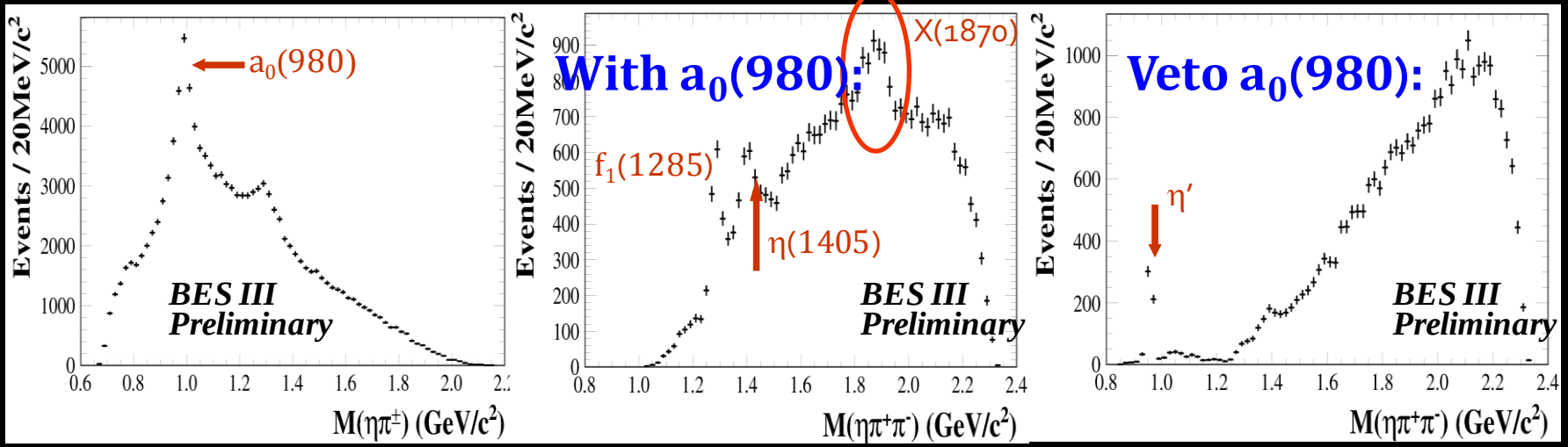
- The angular distribution of the events in X(1835) $\propto$ $1+\cos^2(\Theta)$, which agrees with $J^{PC}=0^{-+}$, but the others are not excluded



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

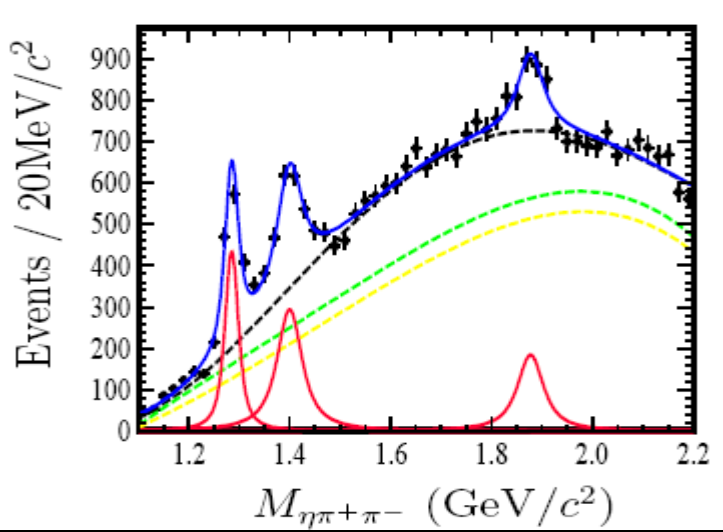
- X(1835) resonance is confirmed at BESIII, but the width is significantly larger than that measured at BESII with one resonance in the fit.
- Two new resonances, X(2120) and X(2370), are observed with significances larger than 7.2σ and 6.4σ respectively.
- PWA is needed not only to determine the spin-parities of above three resonances, but also to make more precise measurements on masses, widths and BRs by considering possible interferences among them.

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



- In addition to the well-known η', $f_1(1285)$ and η(1405), an unknown structure (denoted as X(1870)) around 1.87GeV/c^2 is observed.
- The $f_1(1285)$, η(1405) and X(1870) primarily decay via $a_0(980)\pi^{\pm}$ mode.

Fitting results of $M_{\pi+\pi-\eta}$



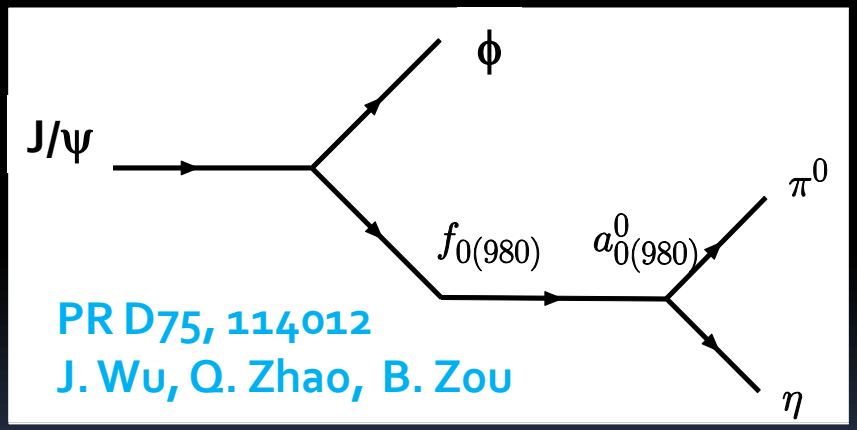
Fitted result of X(1870):

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

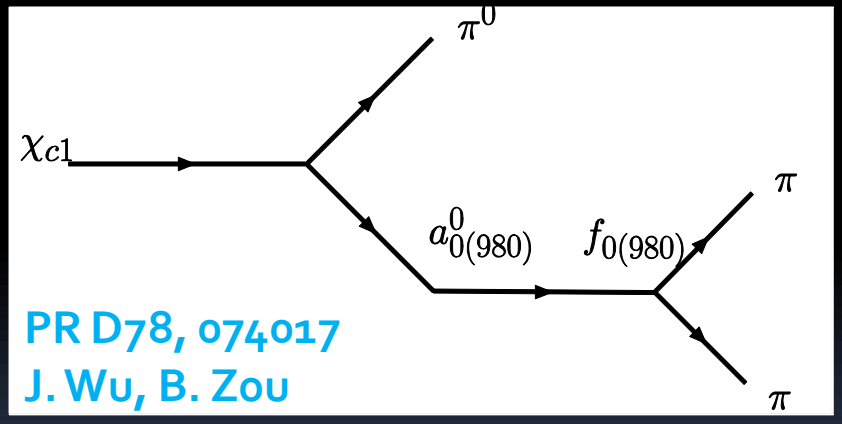
- The fit is performed under the assumption that the interference between the resonances and background can be ignored.
- Current results cannot settle down whether X(1870) is actually $\eta_2(1870)$ (Γ =225 ± 14 MeV/c^2) or a new resonance.

$a_0(980)$ - $f_0(980)$ 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

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

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

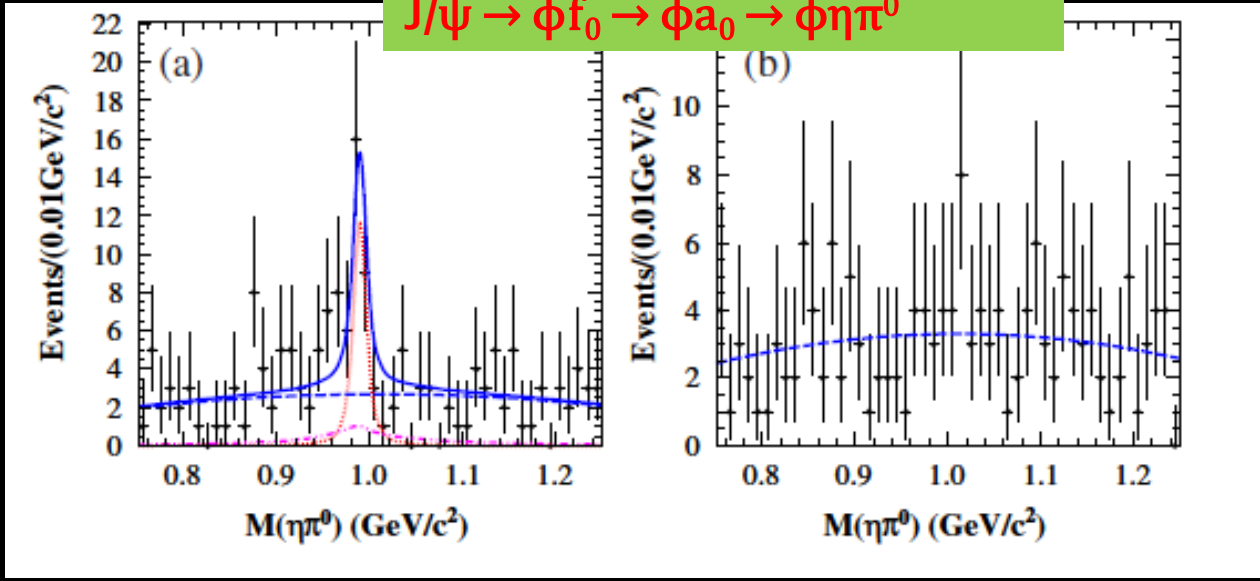
Mixing intensity

$a_0(980)$ – $f_0(980)$ mixing

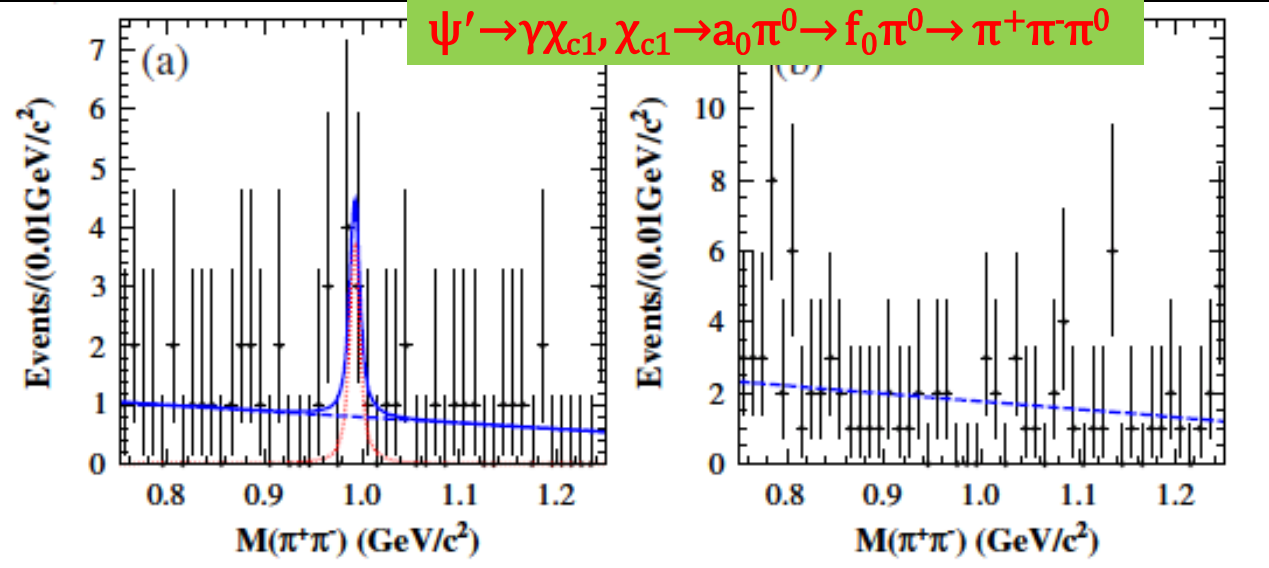
PRD83 032003(2011)

Mixing peaks expected at ~991 MeV/c^2 with 8 MeV width.

$J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0$



$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0$

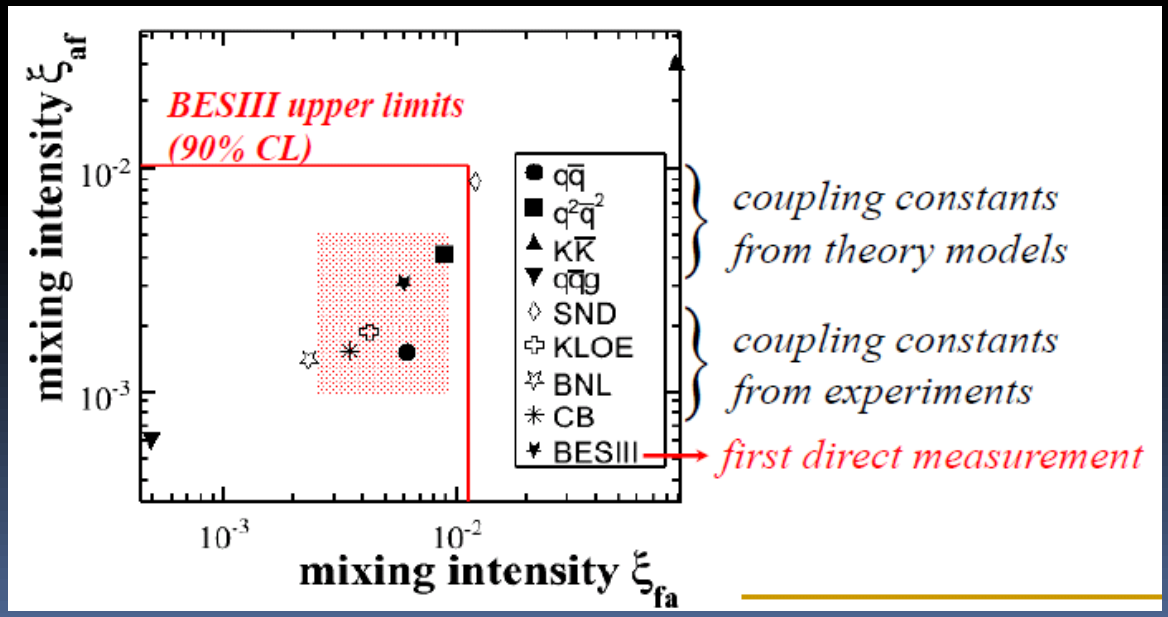


$a_0(980)$ – $f_0(980)$ mixing

- **Mixing intensity**

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

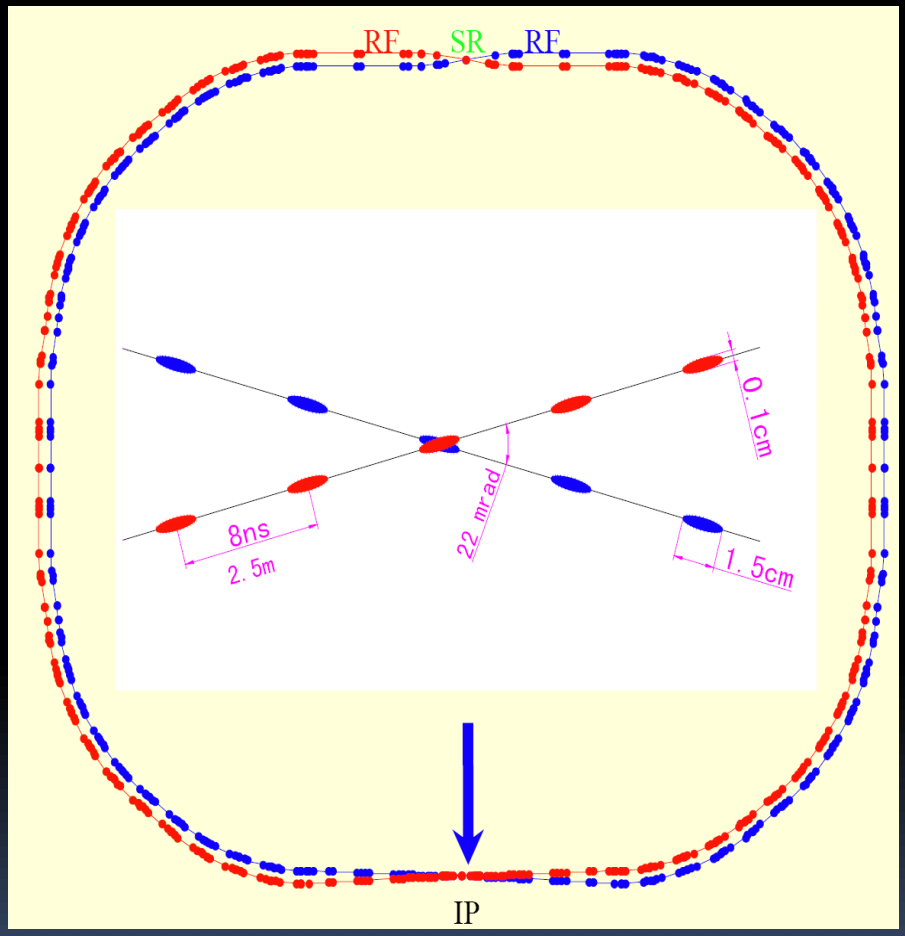
✸ ξ_{af} = (0.31±0.16(stat.)±0.14(sys.)±0.03(para)%
(<1.0% @90% C.L.)



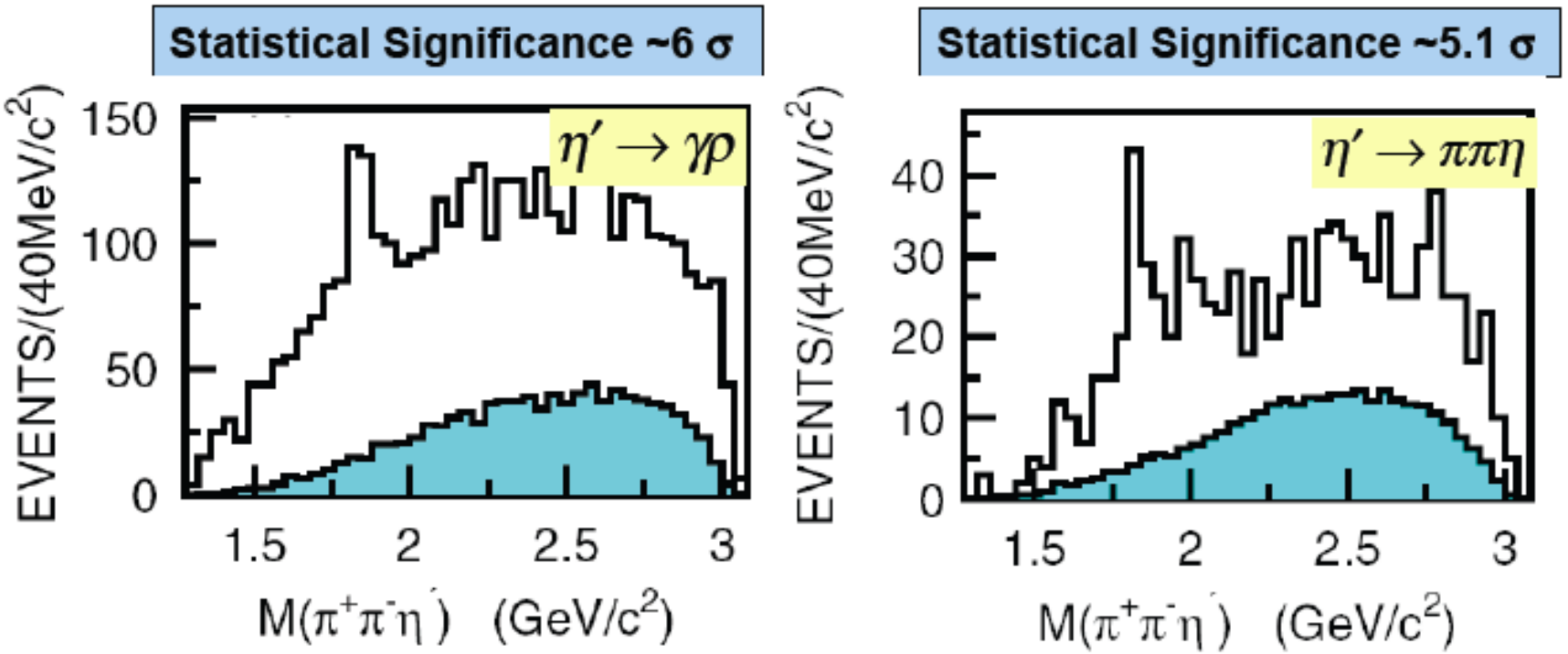
Summary

- $\bar{p}p$ threshold enhancement is confirmed at BESIII
- X(1835) is confirmed at BESIII and two new resonances, X(2120) and X(2370) are observed in the channels of $J/\psi \to \gamma\eta'\pi^+\pi^-$
- A new structure X(1870) is observed in $J/\psi \to \omega\eta\pi^+\pi^-$
- $a_0(980) - f_0(980)$ mixing is measured, the mixing intensities are extracted from experiment, which will help to understand the structure of $a_0(980)$ and $f_0(980)$
- More exciting results are expected

Thank you!


RF
SR
RF
0.1cm
22 mrad
8ns
2.5m
1.5cm
IP

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



PRL 95,262001(2005)