Progress in light hadron spectroscopy at BESIII

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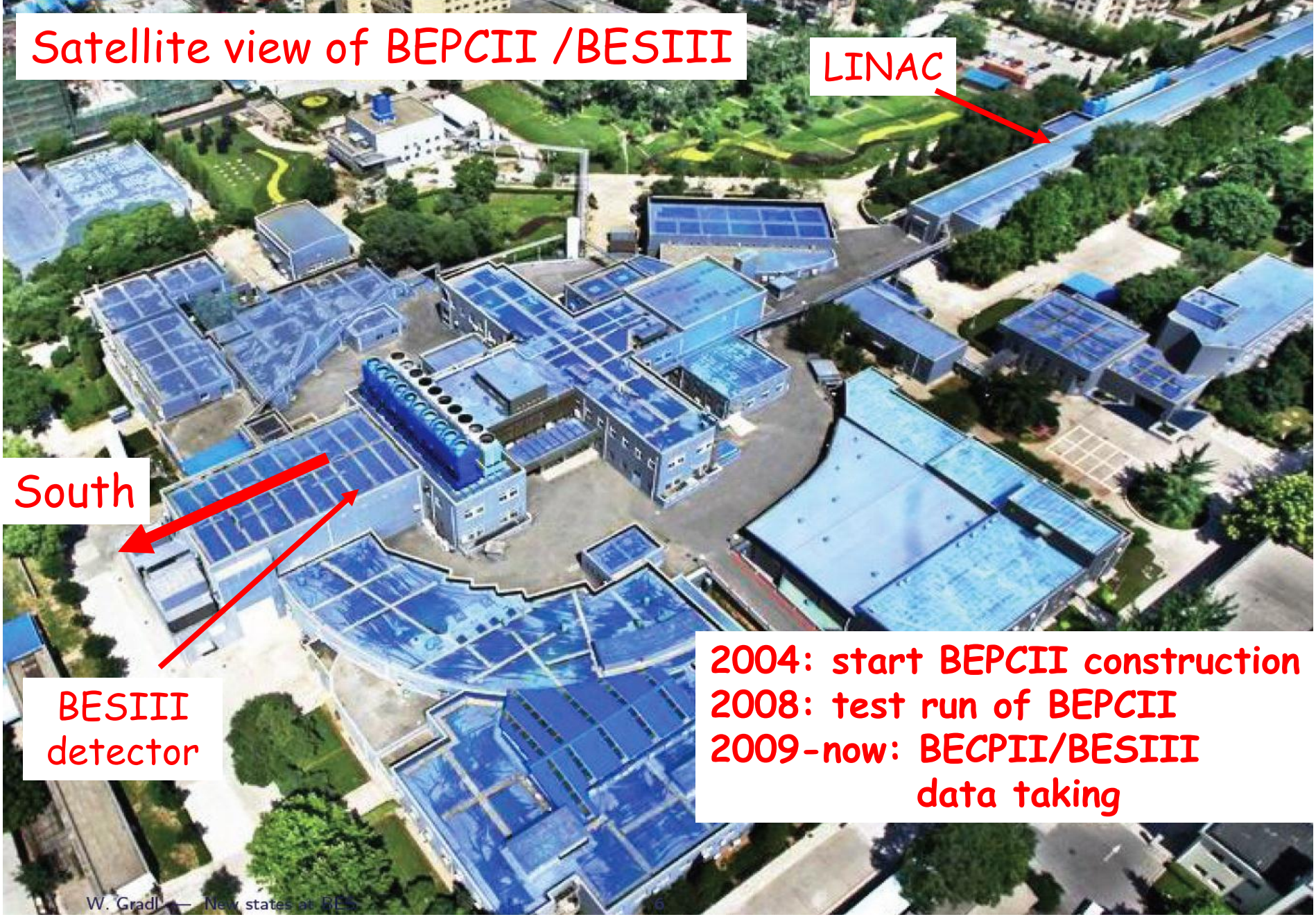
OUTLINE

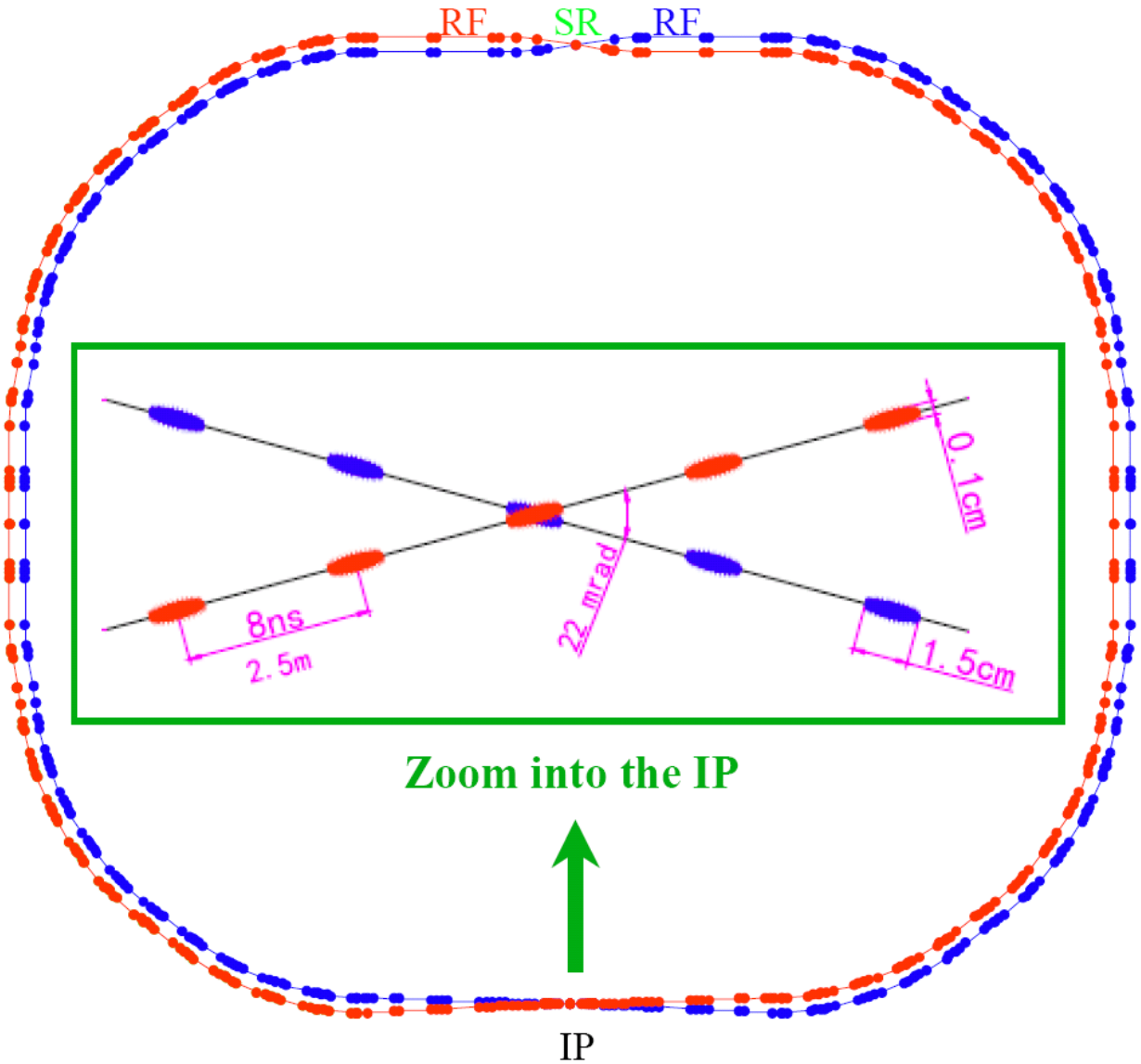
- **Introduction**

- **Latest results on hadron spectroscopy**
  - ✓ $p\bar{p}$ mass threshold enhancement
  - ✓ Confirmation of X(1835) and observation of two new structures
  - ✓ X(1870) in $J/\psi \to \omega X$, $X \to a_0(980)\pi$
  - ✓ $\eta(1405)$ in $J/\psi \to \gamma f_0(980)\pi^0$, $f_0(980) \to \pi\pi$
  - ✓ N* baryon in $\psi' \to \eta p\bar{p}$ decay

- **Summary**


Satellite view of BEPCII /BESIII
LINAC
South
BESIII
detector
2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII
data taking
W. Gradl — New states at BES

BEPCII storage rings



Beam energy:
1.0-2.3 GeV

Design Luminosity:
1×10^{33} $cm^{-2}s^{-1}$

Optimum energy:
1.89 GeV

Energy spread:
5.16×10^{-4}

No. of bunches:
93

Bunch length:
1.5 cm

Total current:
0.91 A

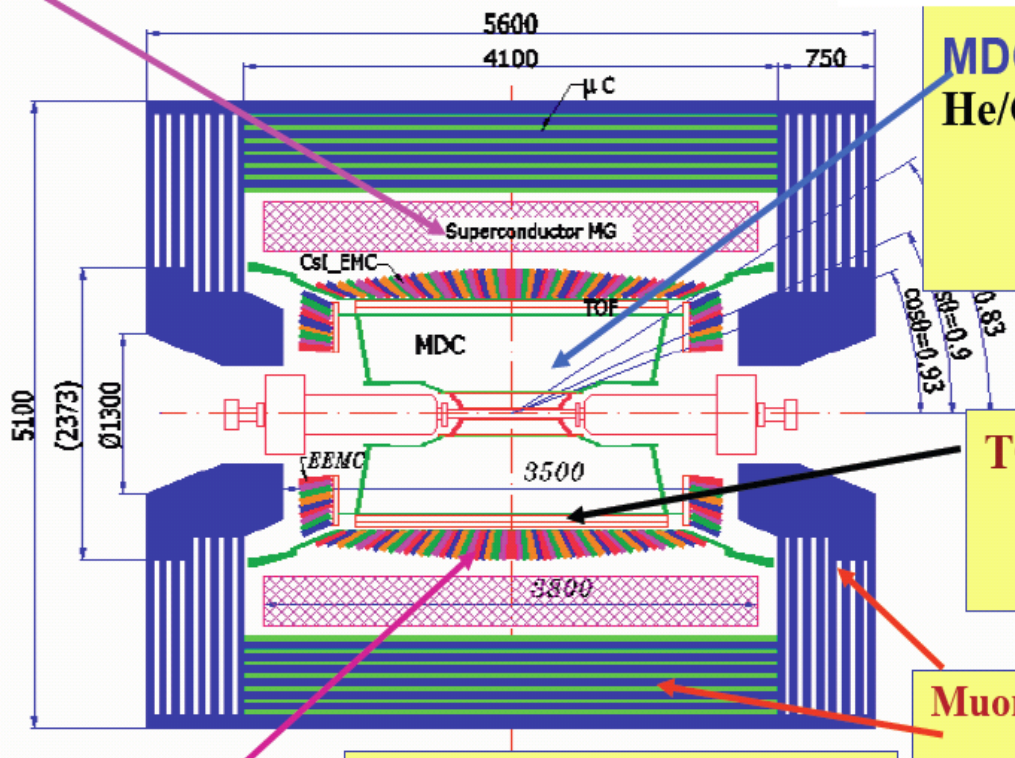
Circumference：
237m

BESIII Detector

BESIII detector: all new !

CsI calorimeter
Precision tracking
Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting



MDC: small cell & Gas:
He/C_3H_8 (60/40), 43 layers
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 100 ps Barrel
110 ps Endcap

Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
$\Delta E/E$ = 2.5% @1 GeV
$\sigma z = 0.6\ cm/\sqrt{E}$

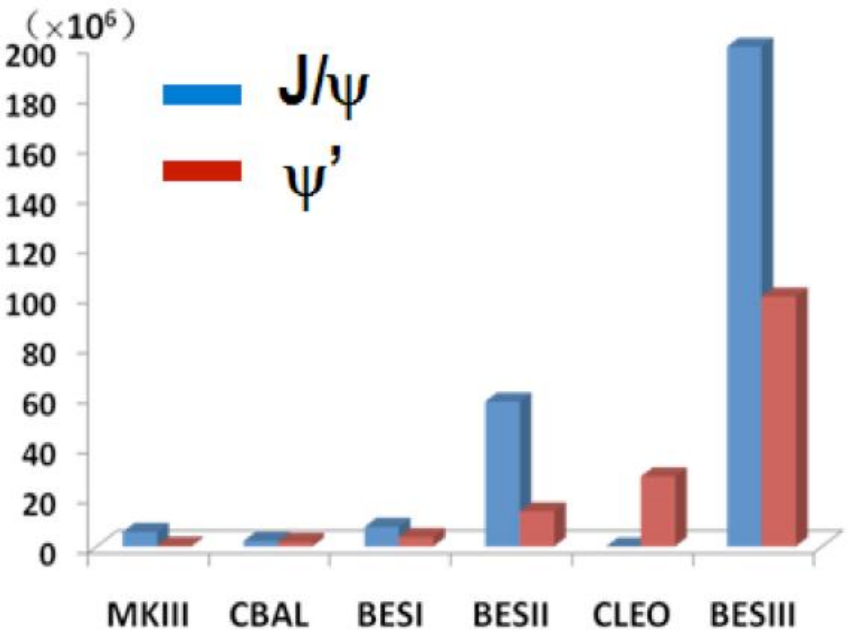
Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

Data samples

- So far BESIII has collected :
  - 2009: 225 Million J/ψ
  - 2009: 106 Million ψ'
  - 2010-11: 2.9 fb^{-1} ψ(3770)

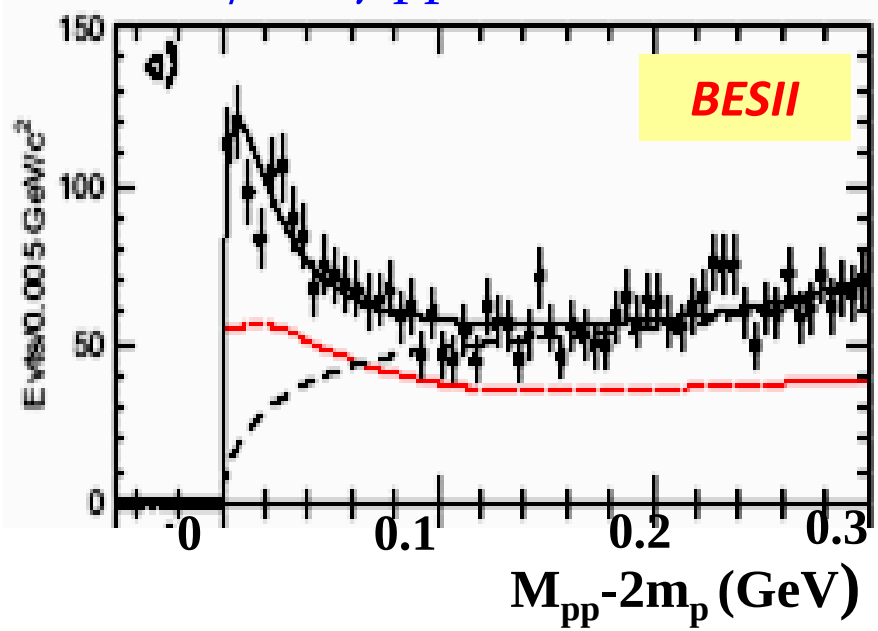
  (3.5 × CLEO-c 0.818fb^{-1})

  - May 2011: 0.5fb^{-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）

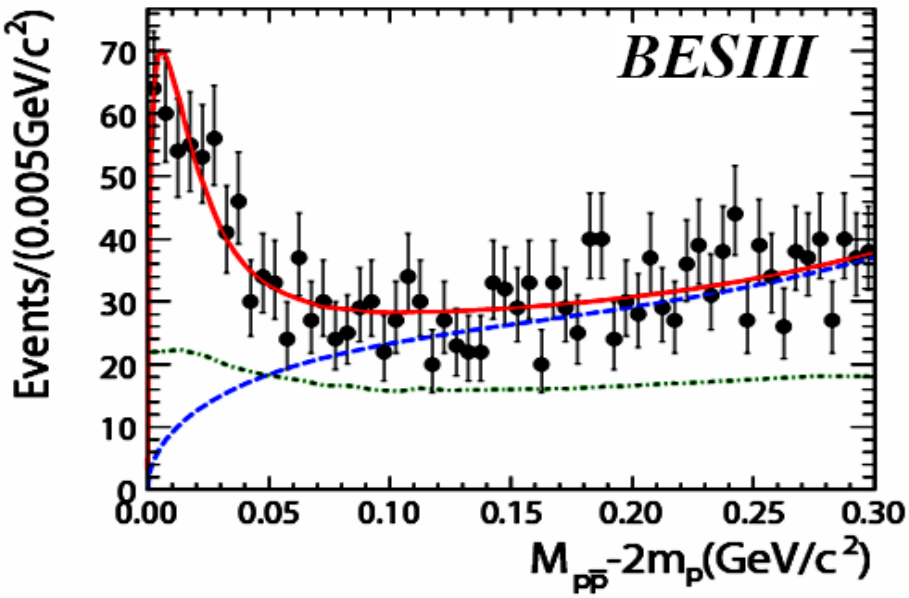


Observation of p $\bar{p}$ mass threshold enhancement at BESII and BESIII

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



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



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

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

PRL 91 (2003) 022001

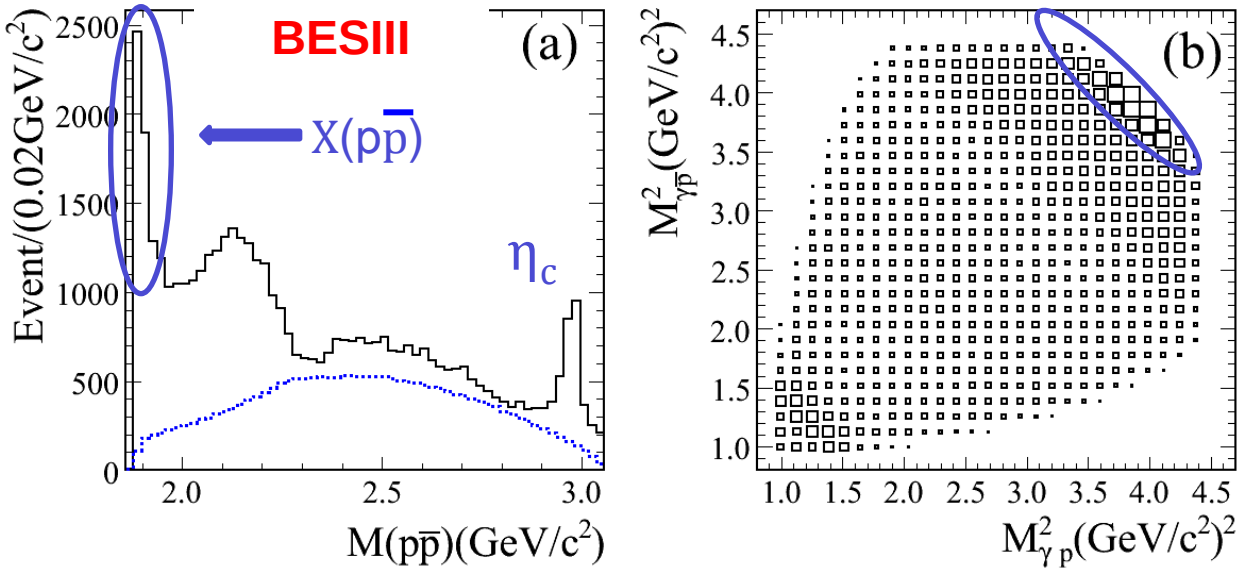
$M = 1861^{+6}_{-13}{}^{+7}_{-26}$ MeV/c^2

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

Chinese Physics C 34, 421 (2010)

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

Preliminary results

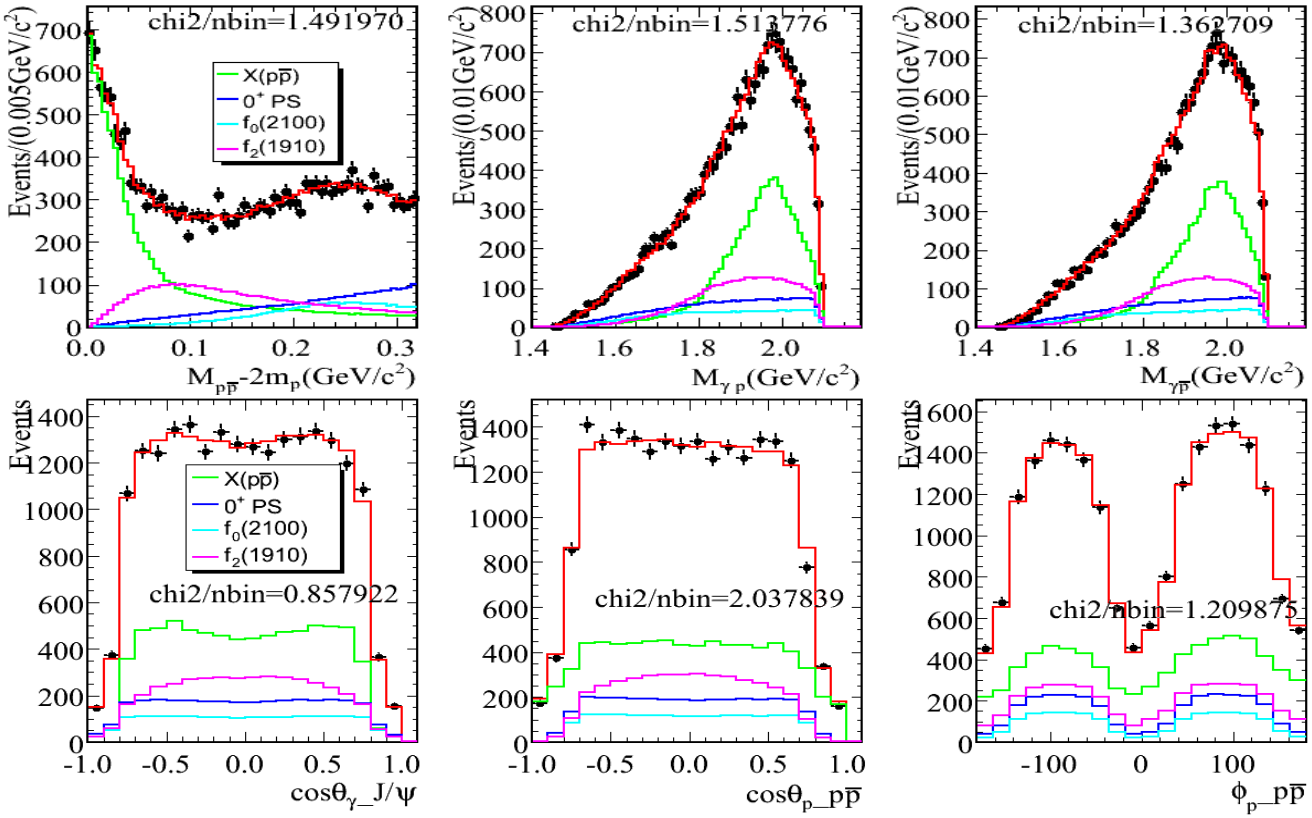


- **Evident narrow ppbar mass threshold enhancement in J/ψ decays.**
- **Partial Wave Analysis (PWA):**
  - Concentrate on dealing with the $p\bar{p}$ mass threshold structure, especially to determine the J^{PC}.
  - Convariant tensor amplitudes (S. Dulat and B. S. Zou, Eur.Phys.J A 26:125, 2005).
 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

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

Component	J^{PC}	M (GeV)	Γ (GeV)	Stat.sig.
$X(p\bar{p})$	0^{-+}	1.832 ± 0.005	0.013 ± 0.020	$\gg 30\sigma$
$f_0(2100)$	0^{++}	2.103	0.209	11.2σ
$f_2(1910)$	2^{++}	1.903	0.196	7.7σ
phase space	0^{++}	–	–	6.3σ

Preliminary results



- 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, and $\Delta 2\ln L=51 \Rightarrow 7.1\sigma$.

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($p\bar{p}$):

Preliminary results

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

$$M = 1832 \pm 5(\text{stat})^{+19}_{-17}(\text{syst}) \pm 19(\text{mod})\ \text{MeV}/c^2$$

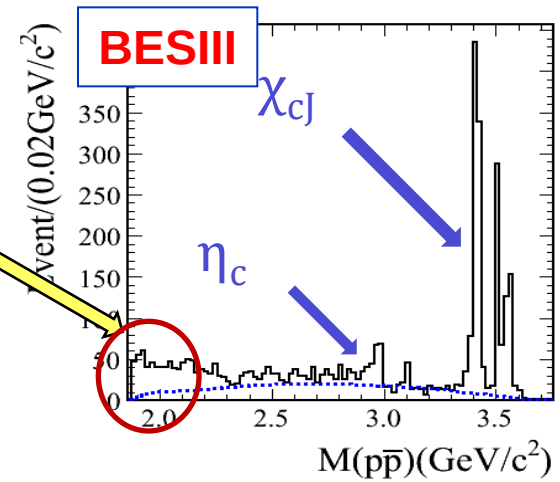
$$\Gamma = 13 \pm 20(\text{stat})^{+11}_{-33}(\text{syst}) \pm 4(\text{mod})\text{MeV}/c^2 \ \text{ or } \ \Gamma < 48\text{MeV}/c^2 \ @90\%\ C.L.$$

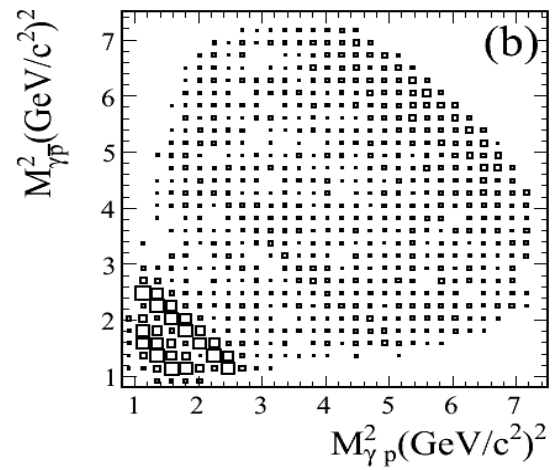
$$B(J/\psi \to \gamma X(p\bar{p}))B(X(p\bar{p}) \to p\bar{p}) = (9.0 \pm 0.7(\text{stat})^{+1.5}_{-5.1}(\text{syst}) \pm 2.3(\text{mod})) \times 10^{-5}$$

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

Preliminary results

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





PWA results:

- Significance of X(p$\bar{p}$) is larger than 6.9σ.
- The production ratio R:

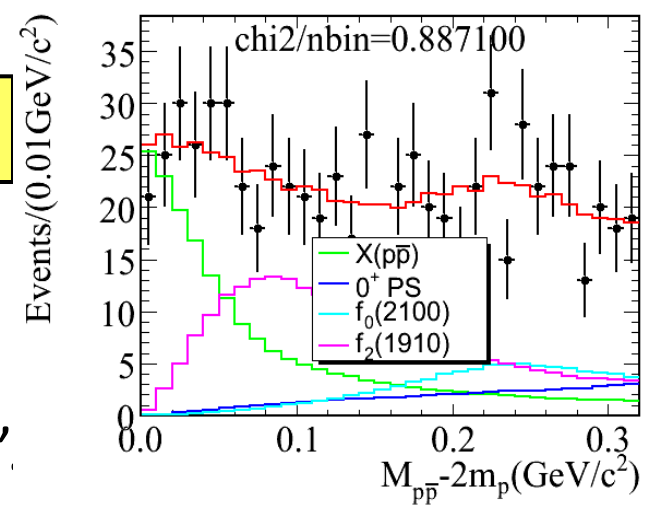
first measurement

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

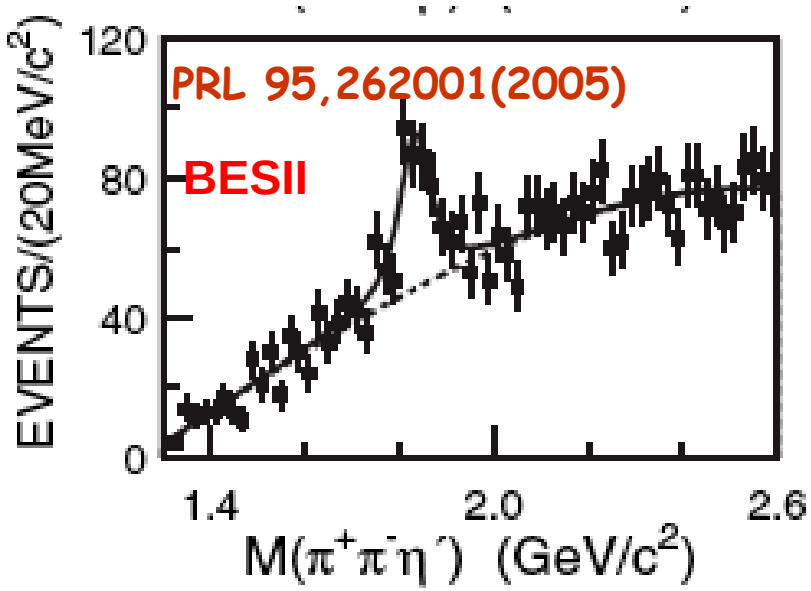
$$= (5.08 \pm 0.56(\text{stat})^{+0.72}_{-3.83}(\text{syst}) \pm 0.12(\text{mod}))\%$$

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

PWA Projection:



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

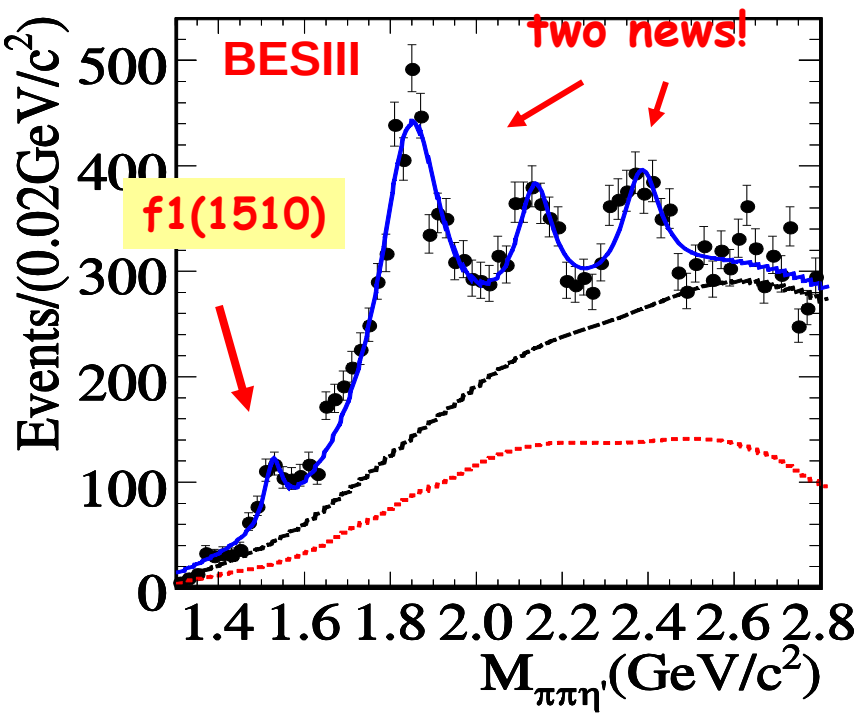


$BESII\ result(\text{Stat. sig.} \sim 7.7\sigma):$

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

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

PRL 106, 072002(2011)



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

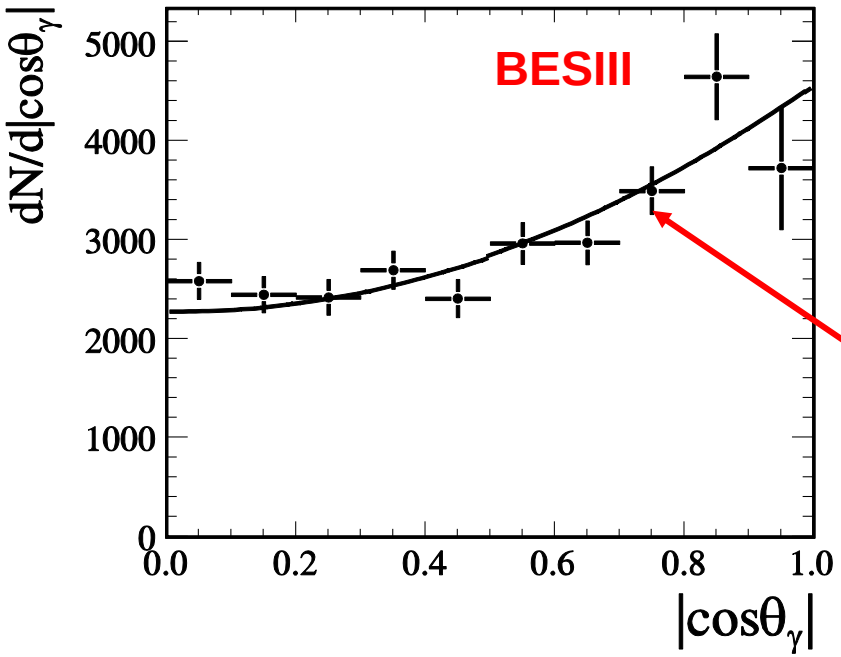
$\eta' \to \eta\pi^+\pi^-$

$\eta' \to \gamma\rho$

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

BESIII fit results:

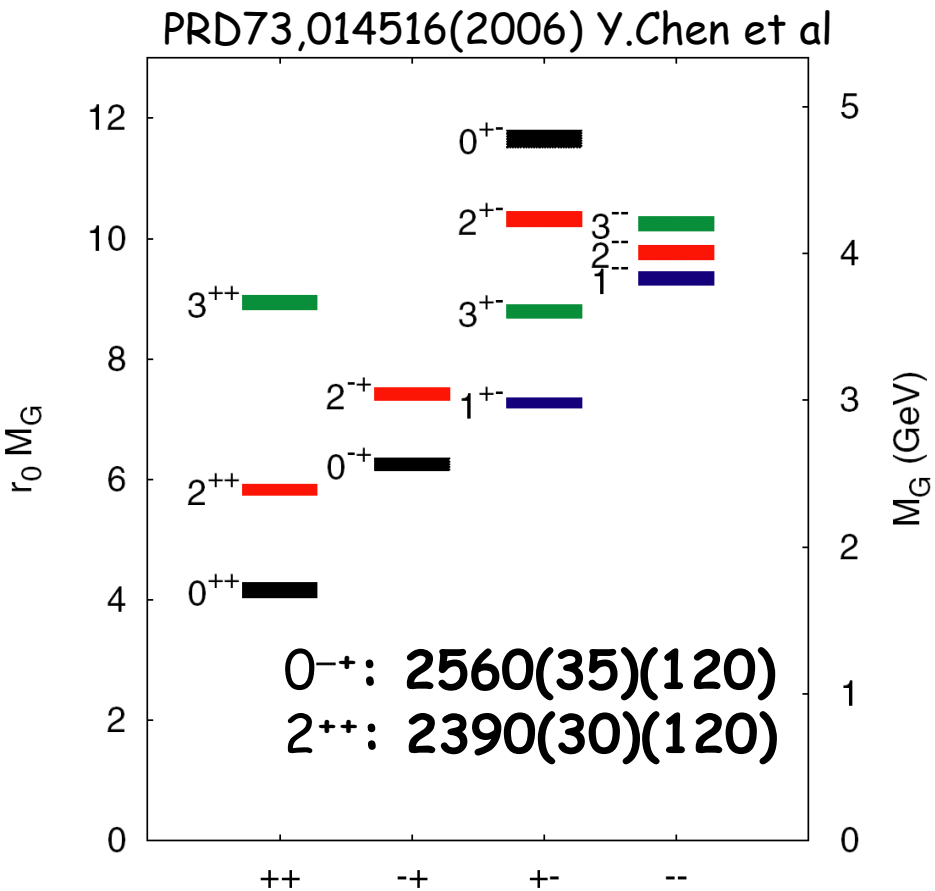
Resonance	M(MeV/c^2)	Γ(MeV/c^2)	Stat.Sig.
X(1835)	$1836.5 \pm 3.0^{+5.6}_{-2.1}$	$190.1 \pm 9.0^{+38}_{-36}$	>20σ
X(2120)	$2122.4 \pm 6.7^{+4.7}_{-2.7}$	$83 \pm 16^{+31}_{-11}$	7.2σ
X(2370)	$2376.3 \pm 8.7^{+3.2}_{-4.3}$	$83 \pm 17^{+44}_{-6}$	6.4σ



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.

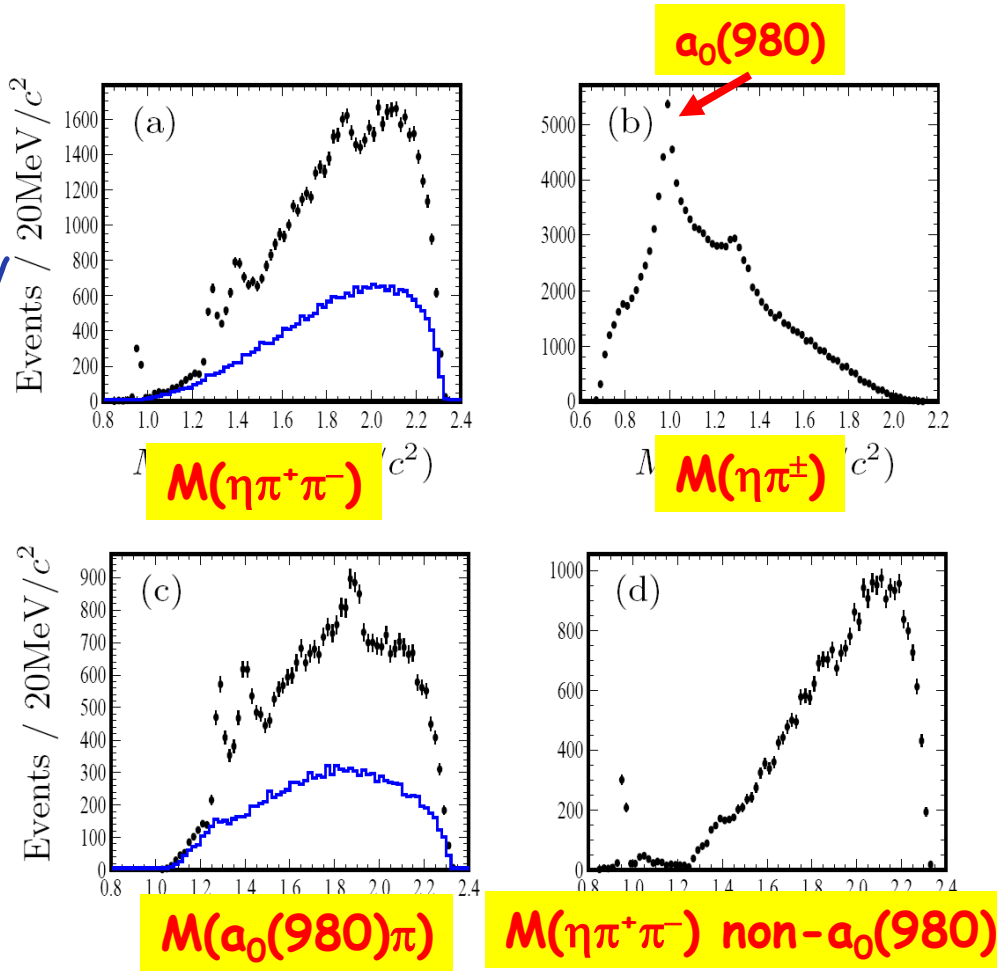
J/ψ-->γππη' decay is a good channel for finding 0^{-+} glueballs.

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

- ✓ 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

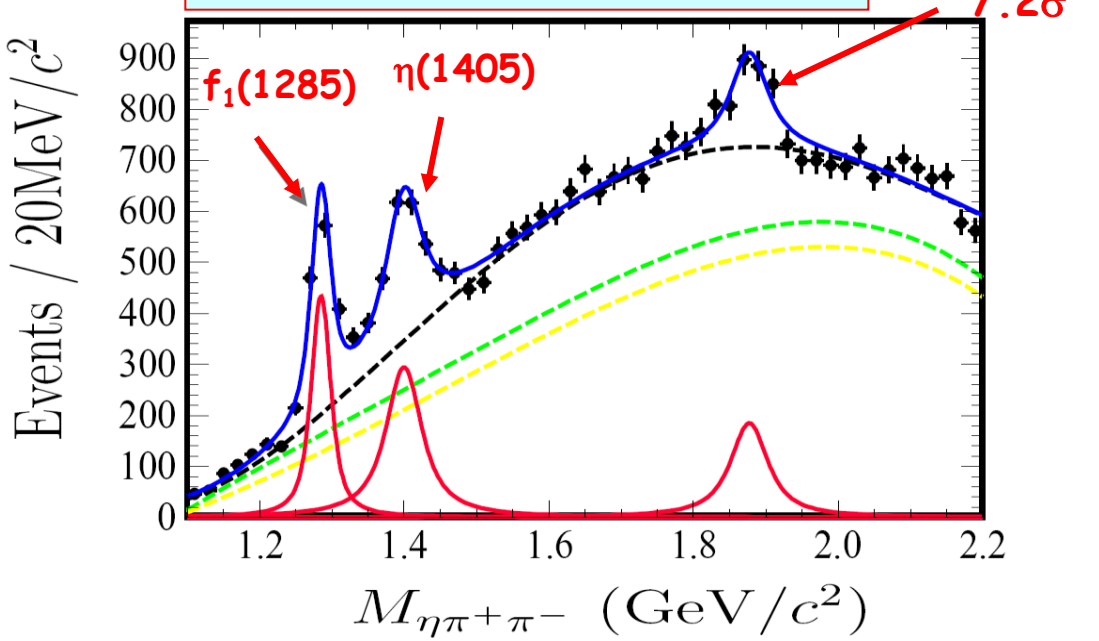


BESIII

arxiv : 1107.1806

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 $\eta\pi^\pm$



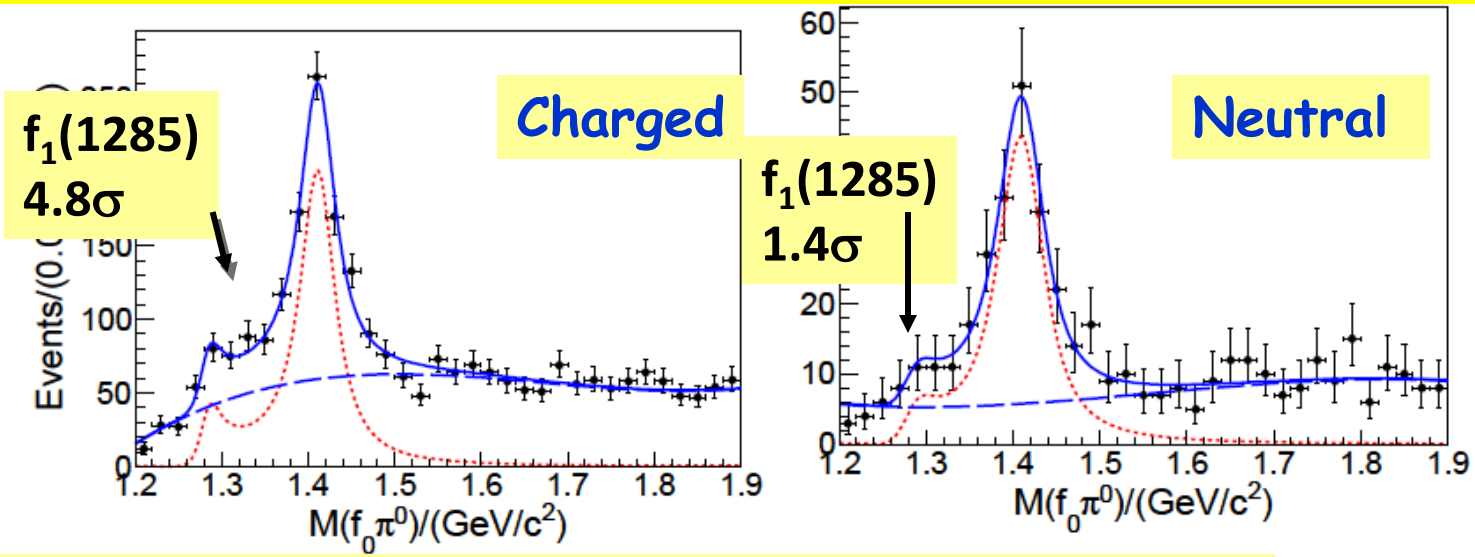
Identification of X(1870): 0^{-+}(?)
It is X(1835)?
Need PWA!

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

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

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 $f_1(1420)$:

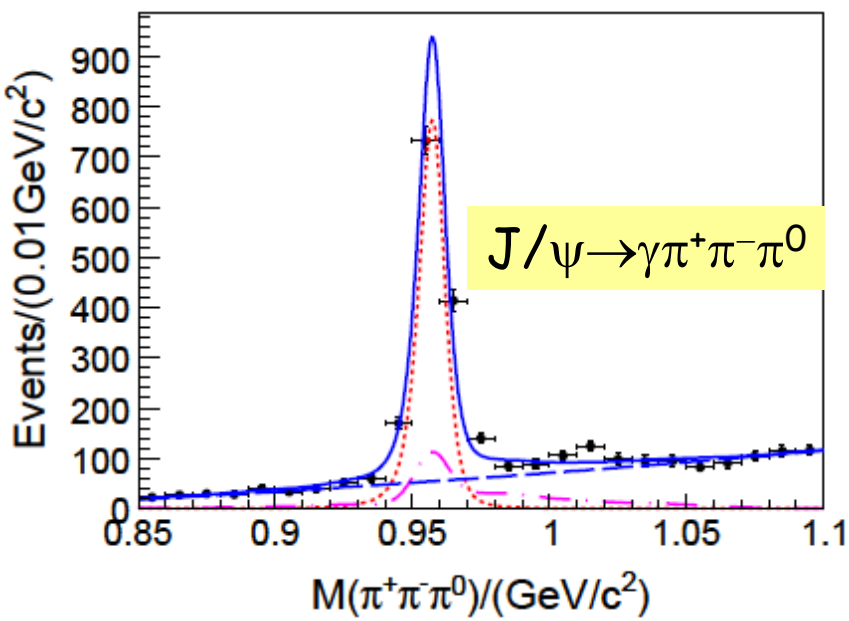
First observation of $\eta(1405) \to f_0(980)\pi^0$ (isospin violated decays) and $J/\psi \to \gamma f_0(980)\pi^0$

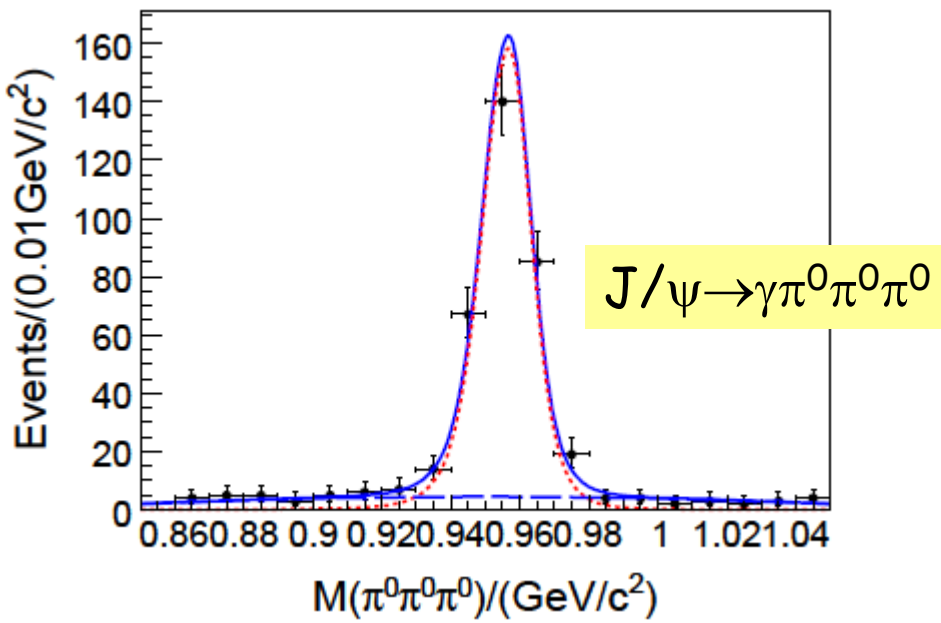
Preliminary results:

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

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

New results on $\eta' \to 3\pi$ in $J/\psi \to \gamma\pi\pi\pi$





Preliminary results:

$$Br(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15(stat.) \pm 0.39(sys.)) \times 10^{-3}$$

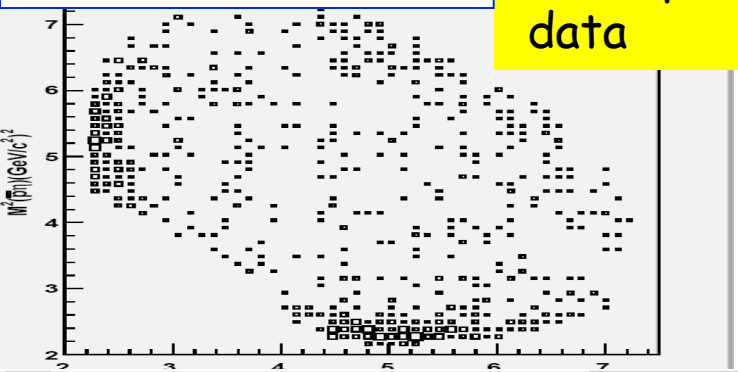
PDG2010: $(3.6^{+1.1}_{-0.9})\times 10^{-3}$ **(2009 CLEO-c)**

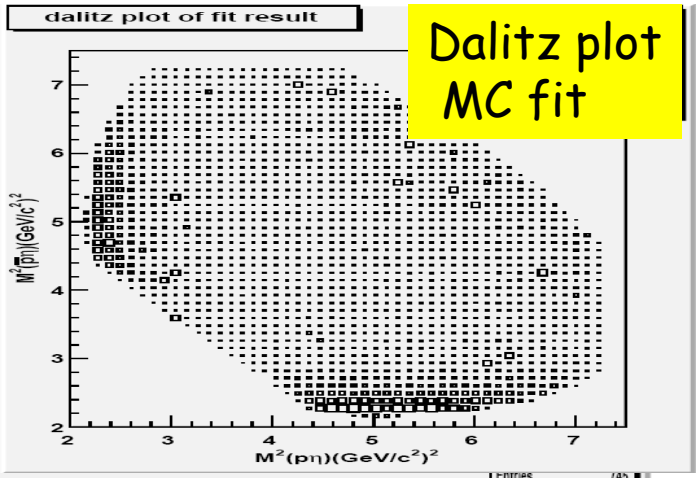
$$Br(\eta' \to 3\pi^0) = (3.56 \pm 0.22(stat.) \pm 0.34(sys.)) \times 10^{-3}$$

PDG2010: $(1.68 \pm 0.22)\times 10^{-3}$ (1984: GAM2)

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

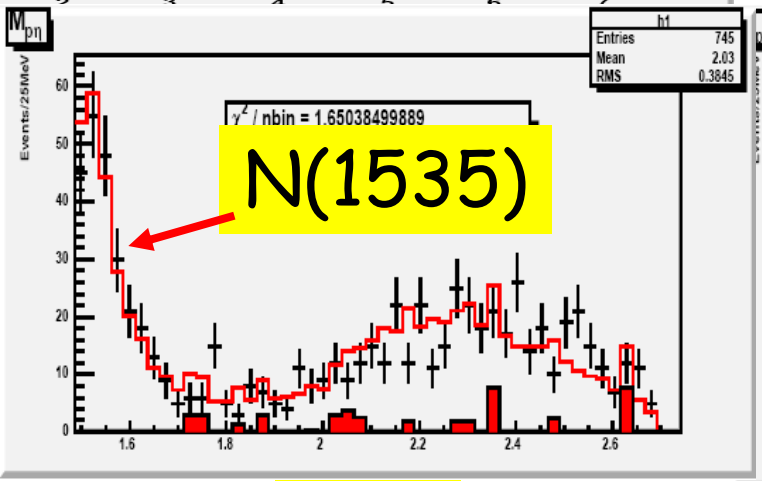
BESIII Preliminary

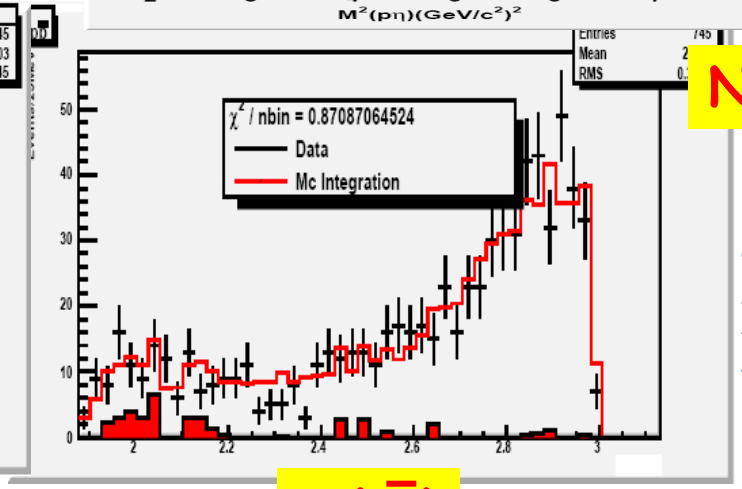




A full PWA is performed.

Background clean!





N(1535) is 1/2⁻

Mass:

$1.524^{+0.005+0.010}_{-0.005-0.004}$ GeV/C²

Width:

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

M(pη) **M(p$\bar{p}$)**

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

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

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

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

Summary and Prospects

- Huge data samples collected for charmonium decays at BESIII. A lot of results have been obtained,
  - ✓ The spin-parity of the $p\bar{p}$ mass threshold enhancement in $J/\psi \to \gamma p\bar{p}$ was first determined as 0^{-+}
  - ✓ Confirmation of X(1835) in $J/\psi \to \gamma\eta'\pi^+\pi^-$ and observation of two new structures X(2120) and X(2370) in $J/\psi \to \gamma\pi\pi\eta'$ decays
  - ✓ Observation of new structure X(1870) in $J/\psi \to \omega\pi\pi\eta$
  - ✓ N* in $\psi' \to \eta p\bar{p}$
- We expect rich physics results in the coming years from BESIII.

many thanks for your attention !