Light hadron spectroscopy at BESIII

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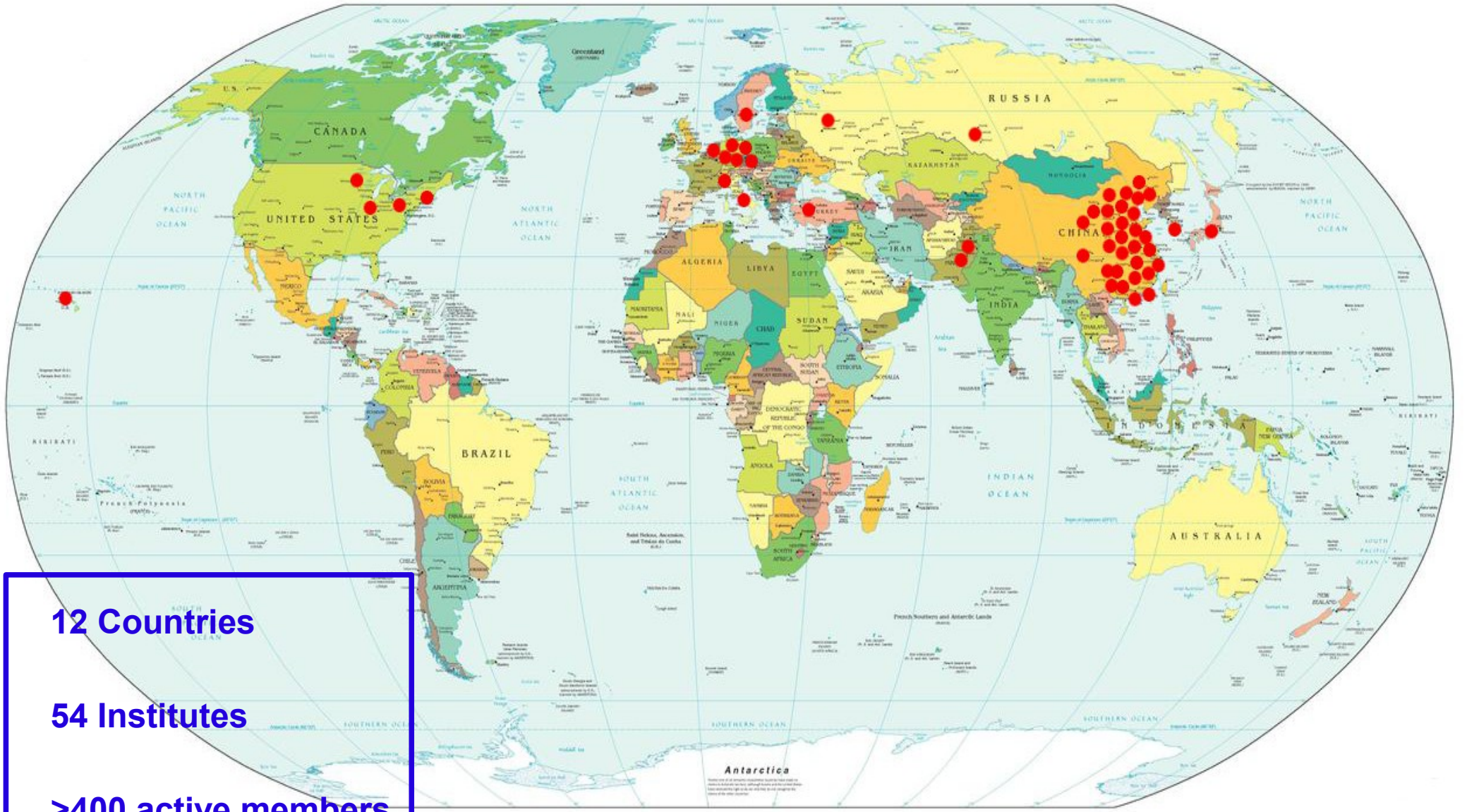
on behalf of BES-III Collaboration

The BES-III Collaboration



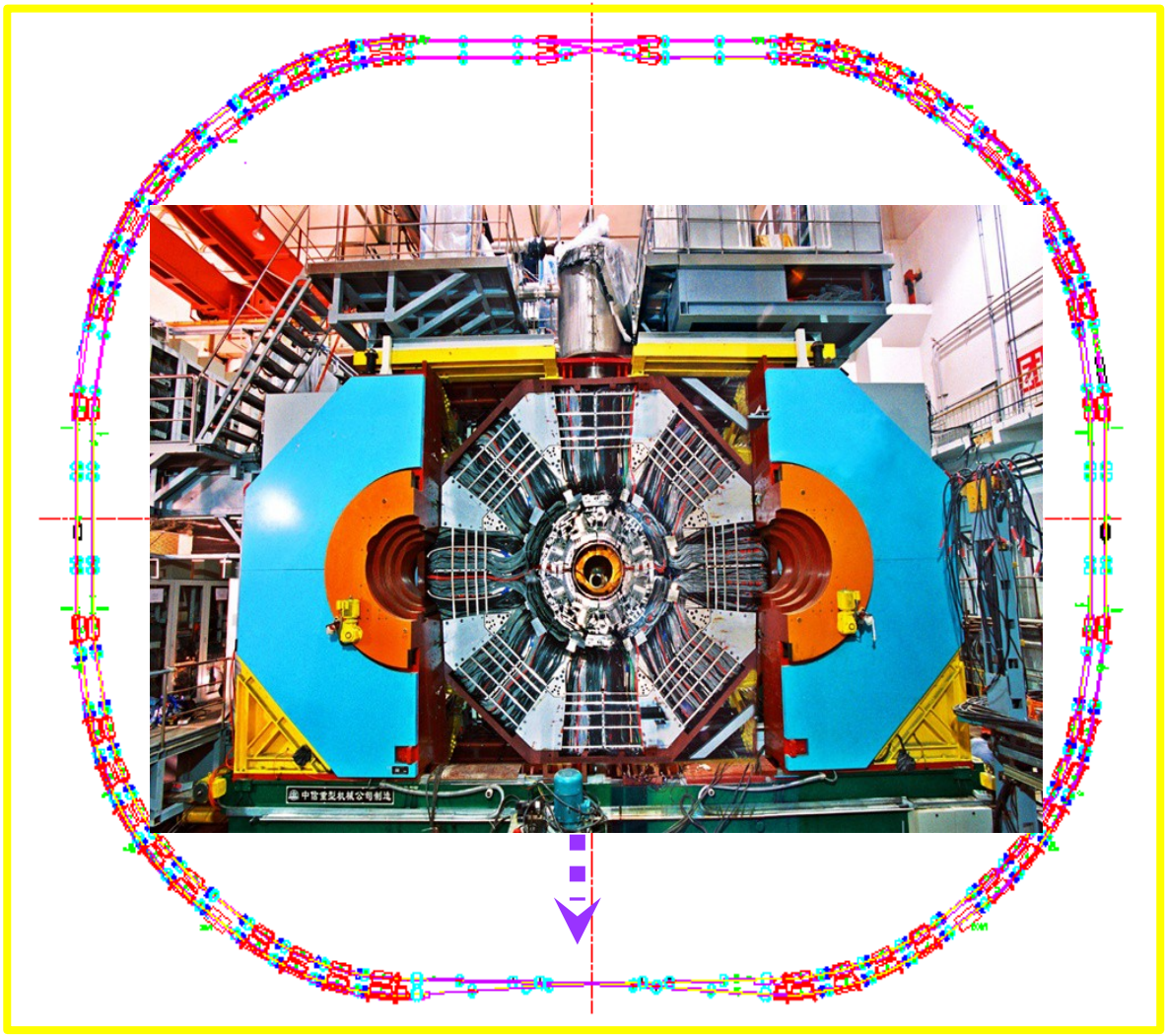
12 Countries

54 Institutes

>400 active members

The BES-III experiment

China, Germany, Italy, Japan, JINR, Korea, Netherlands, Pakistan, Russia, Sweden, Turkey, USA



Site:
IHEP CAS, Beijing, China

BEPC-II beam energy:
1.0-2.3 GeV

Design luminosity
$1 \times 10^{33}/cm^2/s$ @ψ(3770)

Achieved luminosity:
$0.65 \times 10^{33}/cm^2/s$

Project timeline:

2004 – Start of BEPC upgrade

2006 - The detector installation

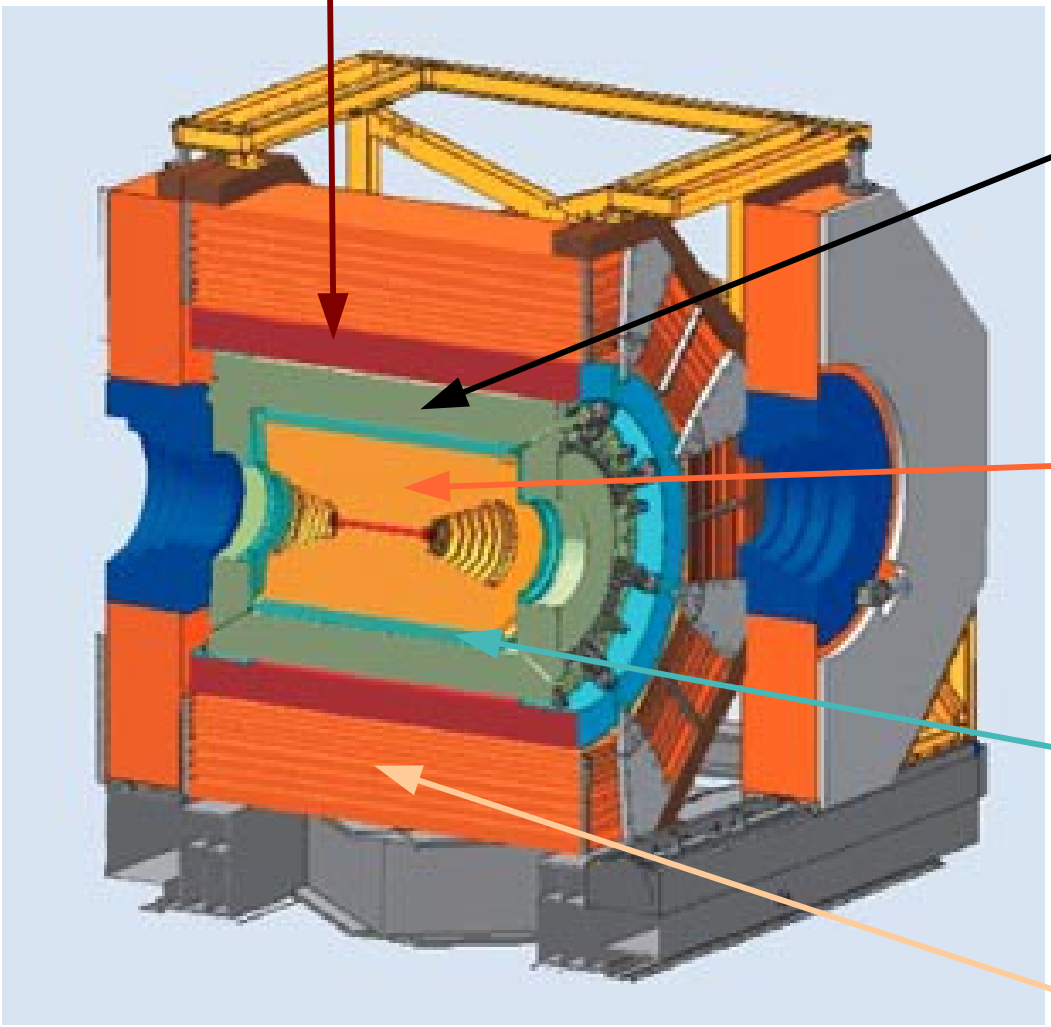
2007 - BEPCII/BESIII commissioning

2009 – Start of physics data taking

The BES-III detector

NIM A614, 345(2010)

Super conducting magnet: 1 T



EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

MDC:
- Spatial resolution: **σ_{xy}= 120μm**
- Momentum resolution:**0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF (double layer scitiliator):
Time resolution: **90 ps**

Muon ID:
9 layers RPC (8 for endcaps) in the flux-return yoke

Data samples after 5 years of data taking

J/ψ	1.3 x10^9 events	world largest sample
ψ'	0.6 x10^9 events	world largest sample
ψ(3770)	~2.9 fb^{-1}	world data sample X 3
$D_s\bar{D}_s$ @ 4.01 GeV	~0.5 fb^{-1}	unique data
Y (4260)	~2.2 fb^{-1}	unique data
Y (4360)	~0.6 fb^{-1}	unique data
τ mass scan	24 pb^{-1}	
3850 MeV - 4590 MeV	**0.8 f**b^{-1}	unique data
4100 MeV - 4400 MeV	**0.5** fb^{-1}	unique data
4420 MeV	**1** fb^{-1}	unique data
4600 MeV	**0.5** fb^{-1}	unique data

About 70 papers based on these data !

Data samples after 5 years of data taking

Samples of 0.225×10^9 J/ψ and 0.106×10^9 ψ' events were used in analyses presented further

ψ(3770)	~2.9 fb^{-1}	world data sample X 3
$D_s\bar{D}_s$ @ 4.01 GeV	~0.5 fb^{-1}	unique data
Y (4260)	~2.2 fb^{-1}	unique data
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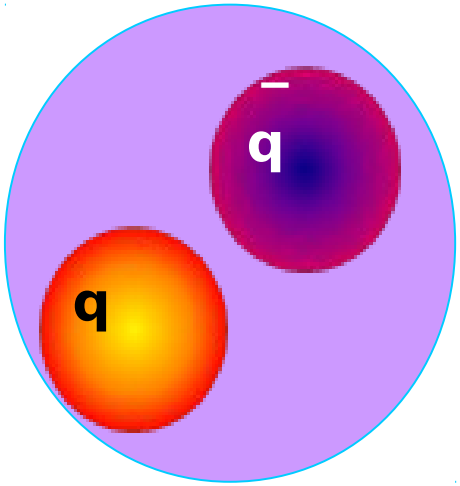
4420 MeV	**1** fb^{-1}	unique data
4600 MeV	**0.5** fb^{-1}	unique data

About 70 papers based on these data !

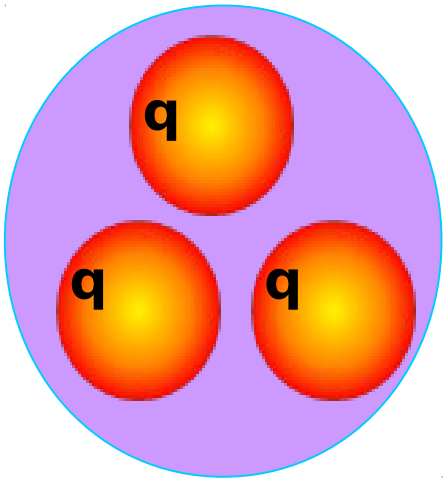
Light hadron spectroscopy

Conventional hadrons:

Mesons



Baryons



QCD predicts more, "exotic" states: hybrids (qqg), glueballs (ggg), multiquarks (qqqq, qqqqq), …

Light hadrons at BES-III

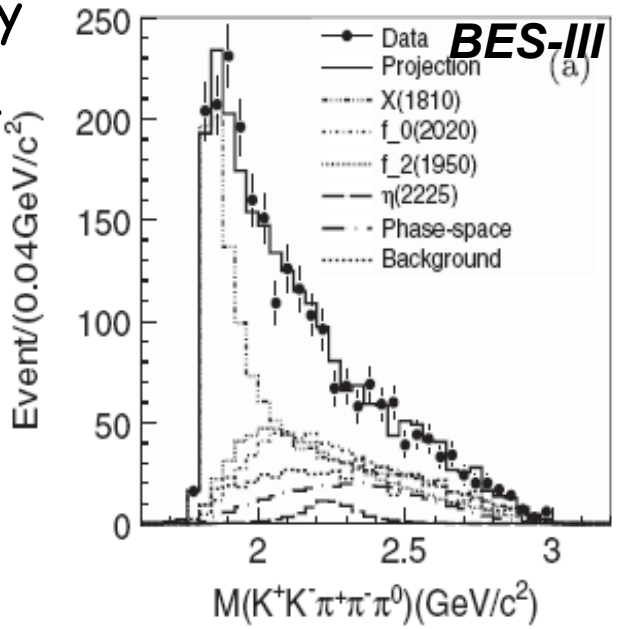
- Light meson spectroscopy
  - $J/\Psi \to \gamma\omega\phi$ PRD87 (2013) 032008
  - $J/\Psi \to \gamma 3(\pi^+\pi^-)$ PRD88 (2013) 091502(R)
  - PWA of $J/\Psi \to \gamma\eta\eta$ PRD87 (2013) 092009
- Baryon spectroscopy
  - PWA of $\Psi' \to \pi^0 p\bar{p}$ PRL110 (2013) 022001
  - PWA of $\Psi' \to n\bar{p}p$ PRD88 (2013) 032010
- η and η' physics
  - Search for weak η and η' decays PRD87 (2013) 032006
  - Search for invisible η and η' decays PRD87 (2013) 012009
  - $\eta' \to \pi^+ \pi^- l^+ l^-$ PRD87 (2013) 092011
  - Observation of $\eta' \to \pi^+ \pi^- \pi^+ \pi^-$ and $\eta' \to \pi^+ \pi^- \pi^0 \pi^0$ PRL 112 (2014) 251801
- $J/\Psi \to p\bar{p}\, a_0(980)$ arXiv:1408.3938v1

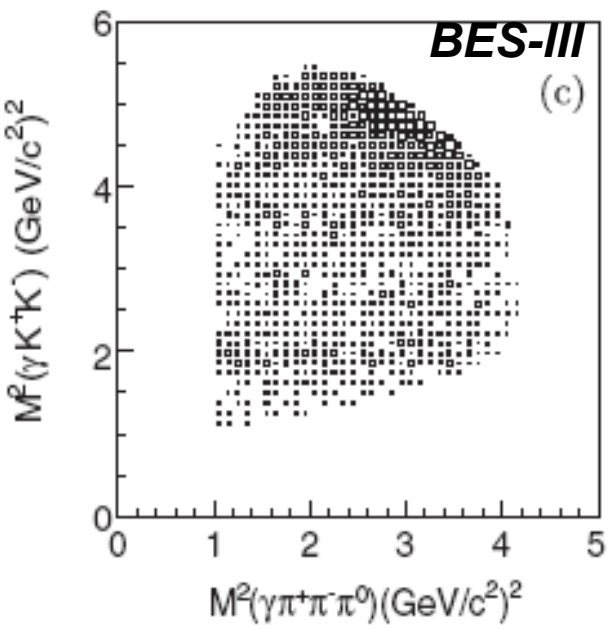
Light meson spectroscopy

$J/\psi \rightarrow \gamma\omega\phi$

PRD87 (2013) 032008

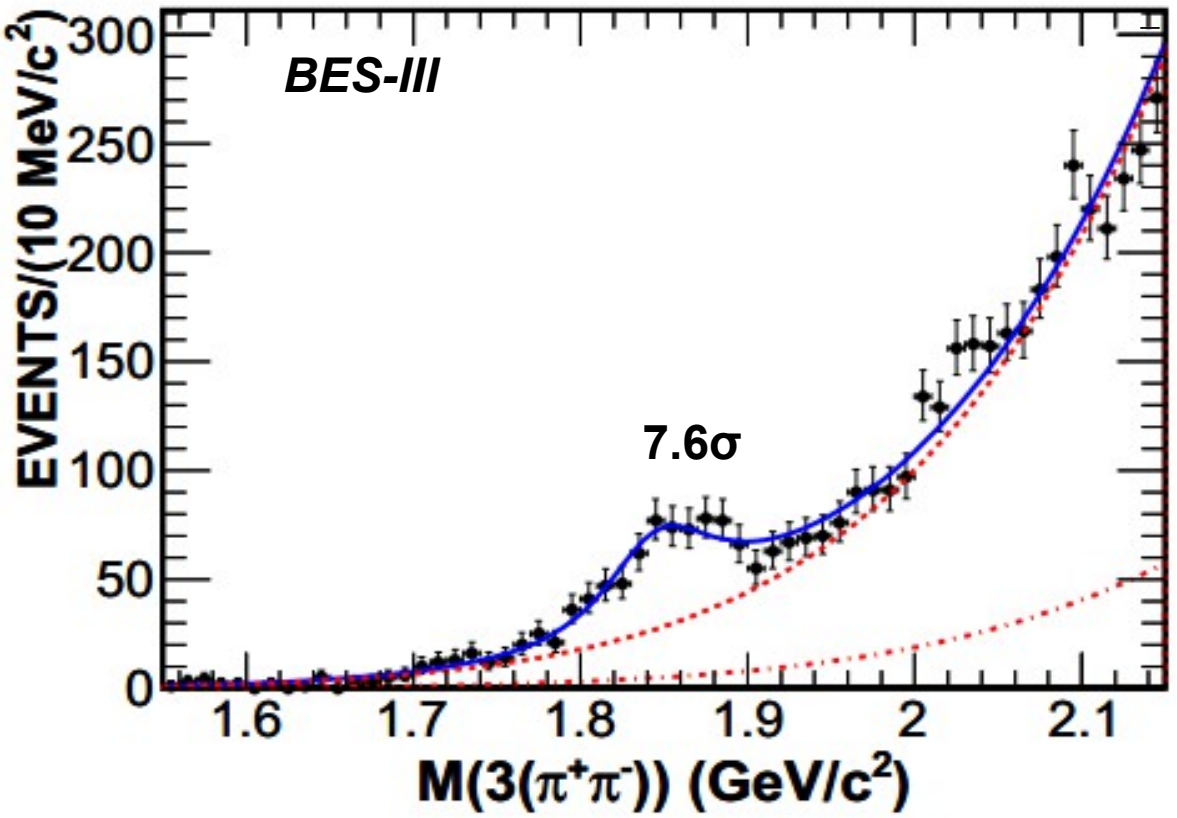
- Double OZI suppressed decay
- Near-threshold enhancement in the $\omega\phi$ mass spectrum (X(1810)) was reported by BES-II
- Not found by BELLE in $B^{\pm} \rightarrow K^{\pm}\omega\phi$





Resonance	J^{PC}	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	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	20.4σ
$f_0(2020)$	0^{++}	1992	442	715 ± 45	100	2	13.9σ
$\eta(2225)$	0^{-+}	2226	185	70 ± 30	23	2	6.4σ
Coherent nonresonant component	0^{-+}	...	...	319 ± 24	45	2	9.1σ

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



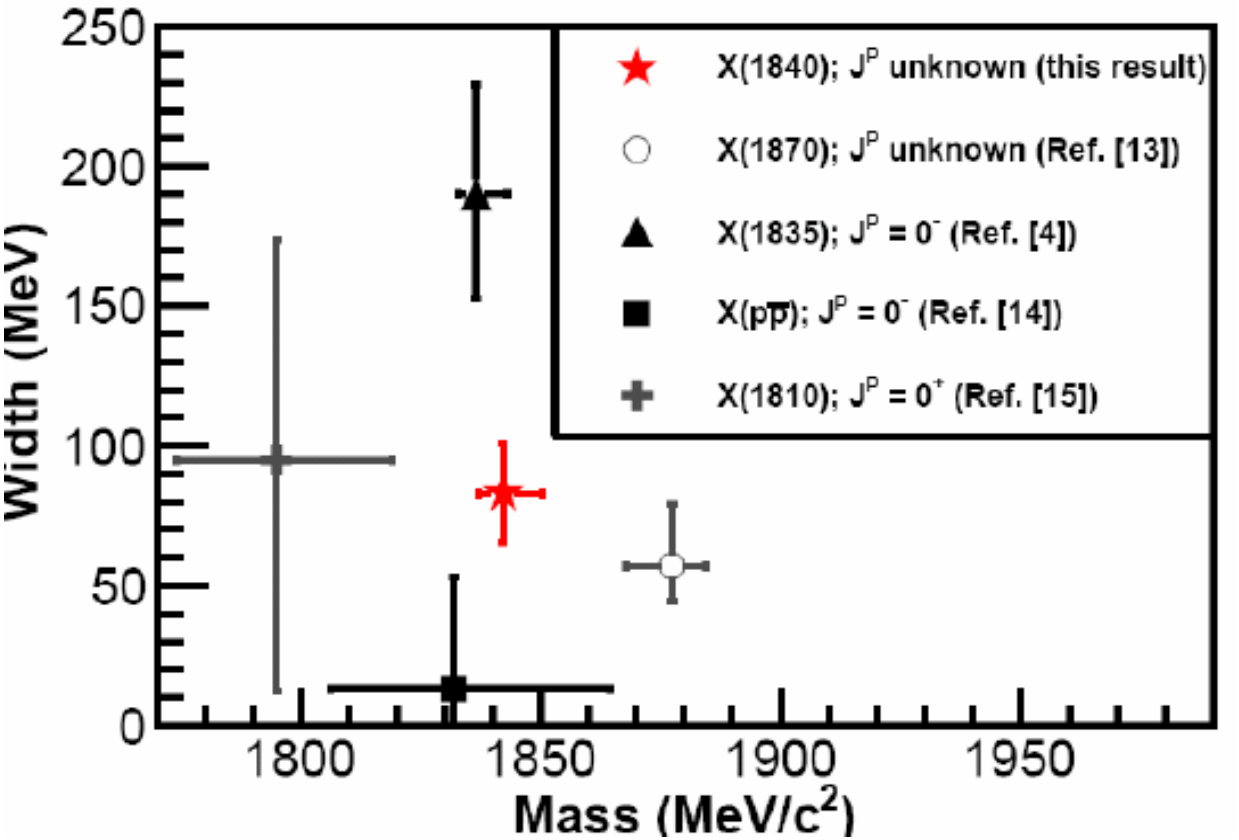
PRD88 (2013) 091502(R)

- A structure is observed in $3(\pi^+\pi^-)$ mass spectrum

$$M=1842.2\pm4.2^{+7.1}_{-2.6}\ \mathrm{MeV}/c^2 \quad \Gamma=83\pm14\pm11\ \mathrm{MeV}/c^2$$

- Mass is consistent with X(1835) from $J/\psi \to \gamma\pi^+\pi^-\eta'$ confirmed recently by BES-III and CLEO-c, but the width is much smaller

X-zoo at BES-III

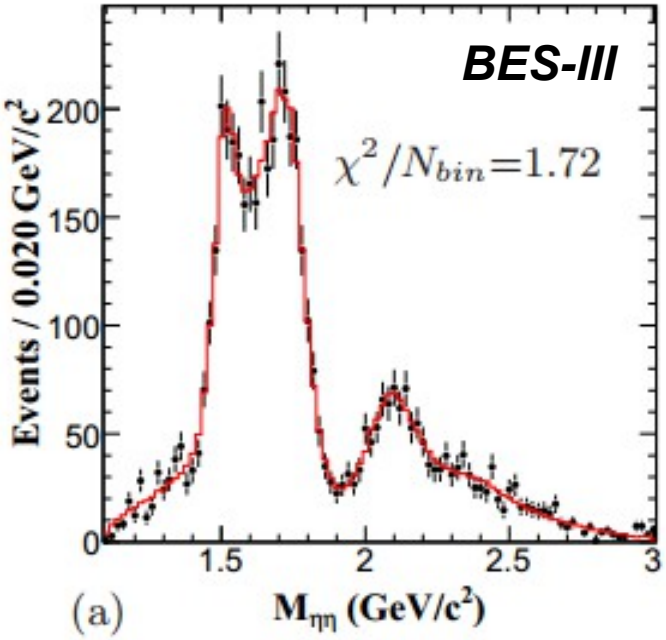


★	γ3(ππ) X(1840)	PRD 88, 091502
○	ωηππ X(1870)	PRL107, 182001
▲	γη'ππ X(1835)	PRL106, 072002
■	γppbar X(ppbar)	PRL108, 112003
+	γωψ X(1810)	PRD 87, 032008

Same data sample (225M J/Ψ)

PWA of $J/\psi \to \gamma\eta\eta$

PRD87 (2013) 092009

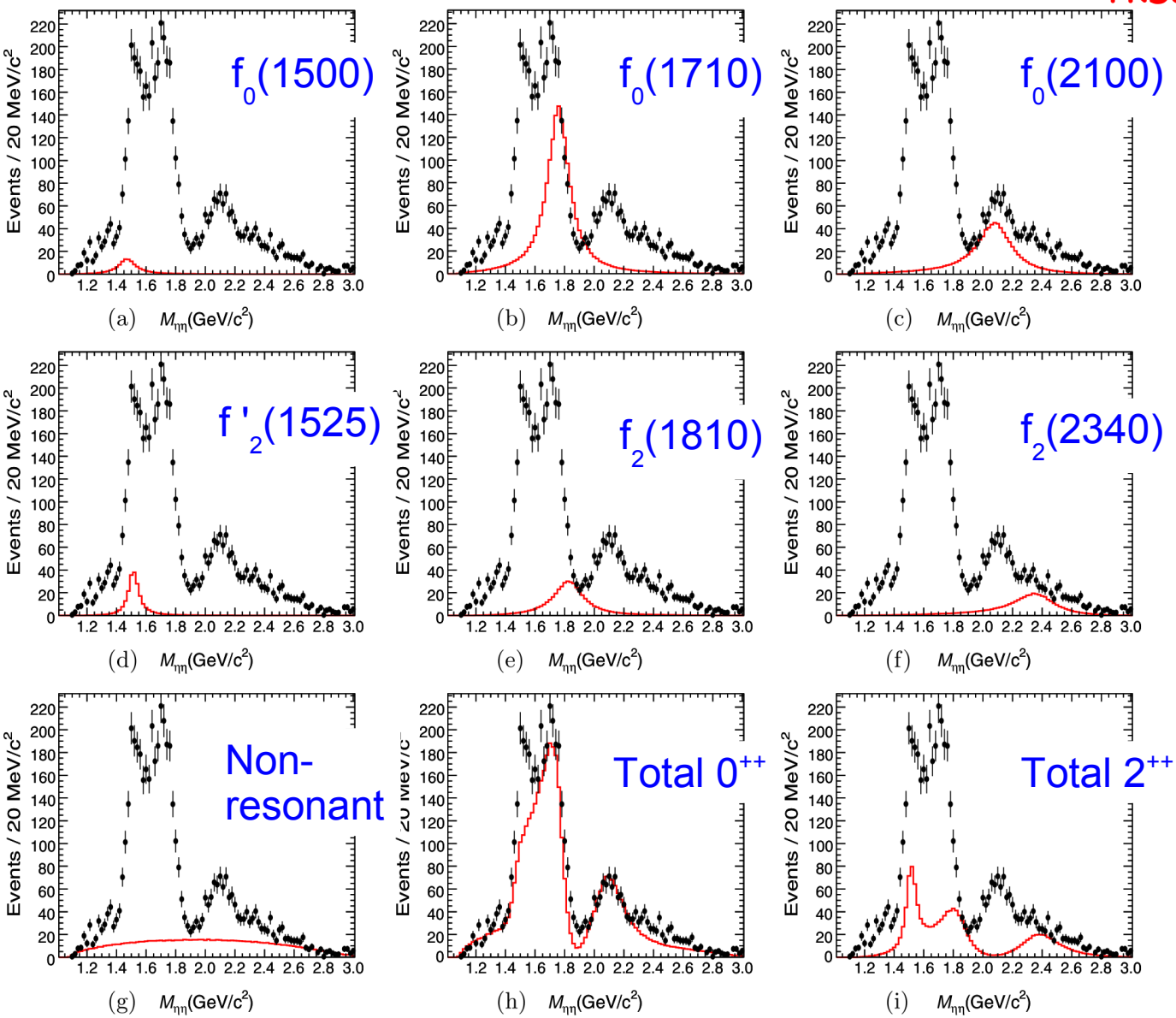


- No clear evidence of $f_0(1370)$ and $f_0(1790)$
- Fit cannot distinguish between $f_2(1810)$, $f_2(1910)$ and $f_2(1950)$
- Large non-resonant contribution ($B=1.47^{+0.01}_{-0.02}\times 10^{-4}$)
- Combined PWA of several channels ($\gamma\eta\eta$, $\gamma\pi\pi$, γKK, ...) may help to shed light on the meson spectrum and possibly to search for glueballs

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}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40})\times 10^{-5}$	8.2σ
$f_0(1710)$	$1759 \pm 6^{+14}_{-25}$	$172 \pm 10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74})\times 10^{-4}$	25.0σ
$f_0(2100)$	$2081 \pm 13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28})\times 10^{-4}$	13.9σ
$f_2'(1525)$	$1513 \pm 5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30})\times 10^{-5}$	11.0σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35})\times 10^{-5}$	6.4σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07})\times 10^{-5}$	7.6σ

PWA of $J/\psi \to \gamma\eta\eta$

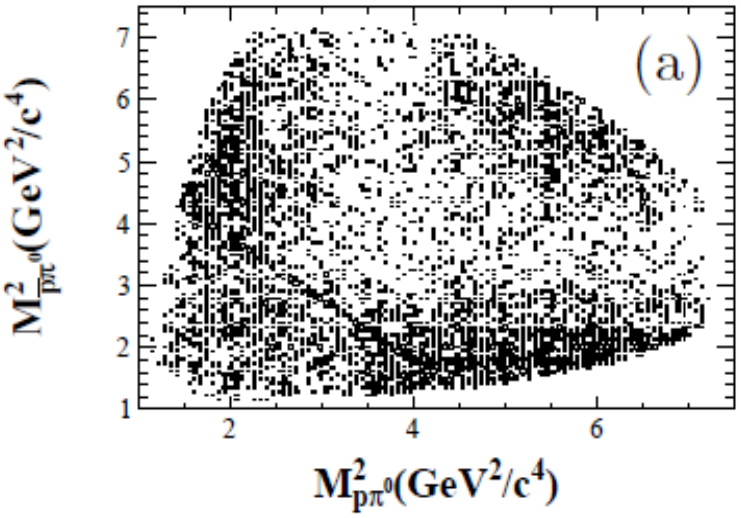
PRD87 (2013) 092009

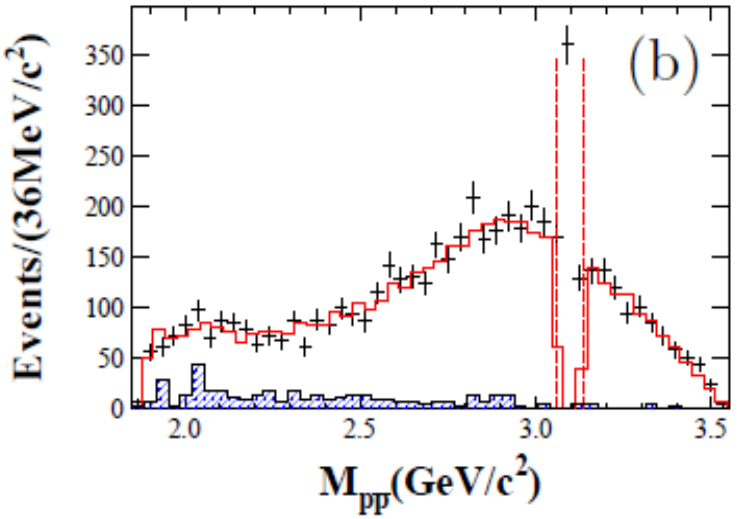


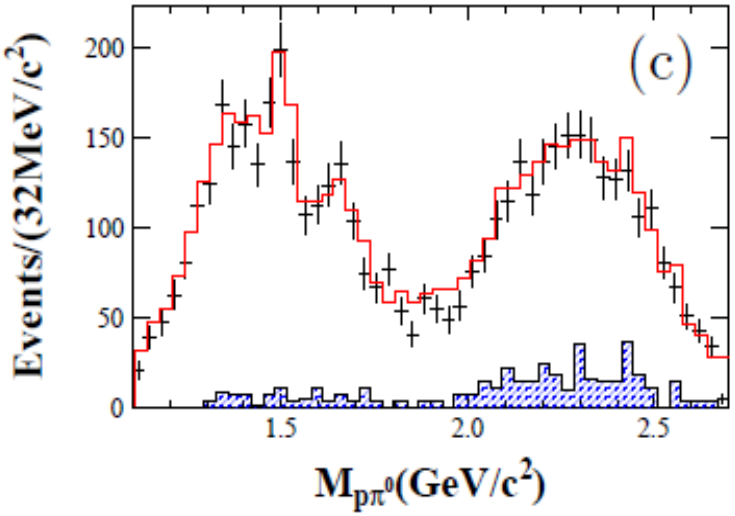
Baryon spectroscopy

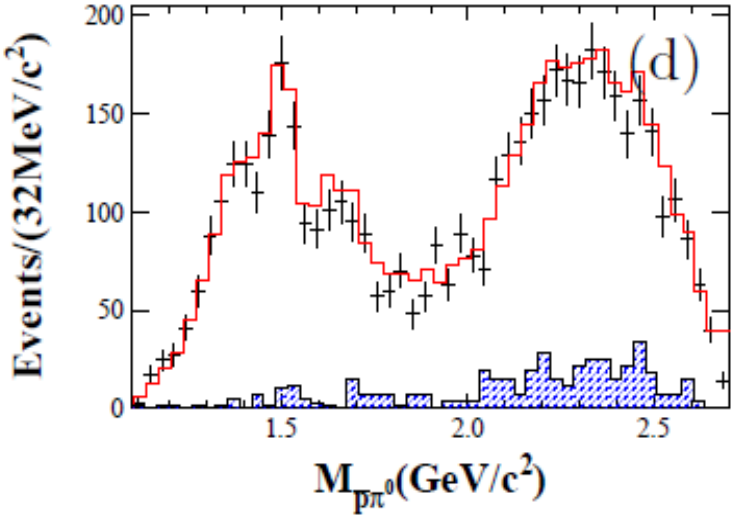
PWA of $\psi' \to \pi^0 p\bar{p}$

PRL110 (2013) 022001



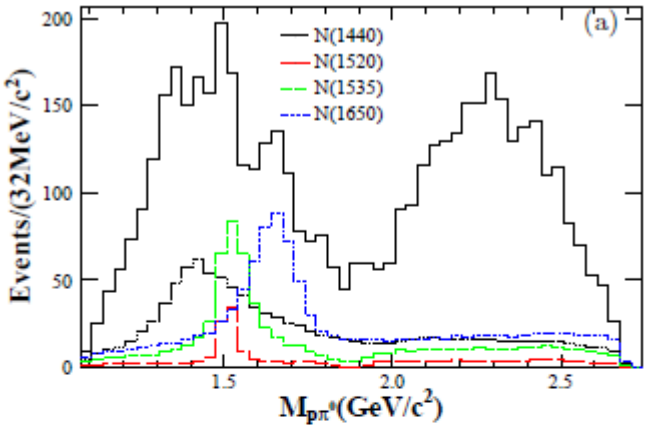


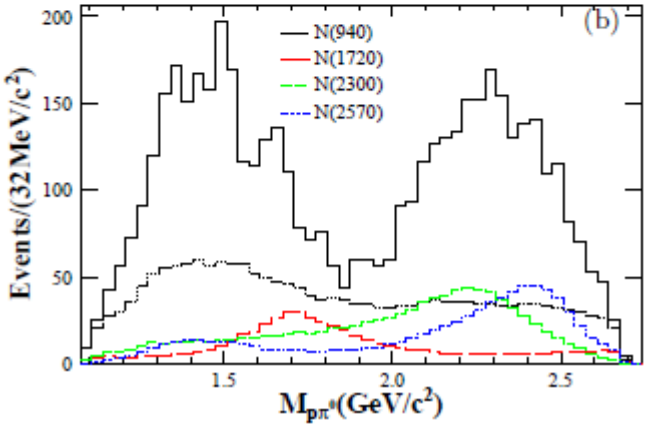




PWA of $\psi' \to \pi^0 p\bar{p}$

PRL110 (2013) 022001



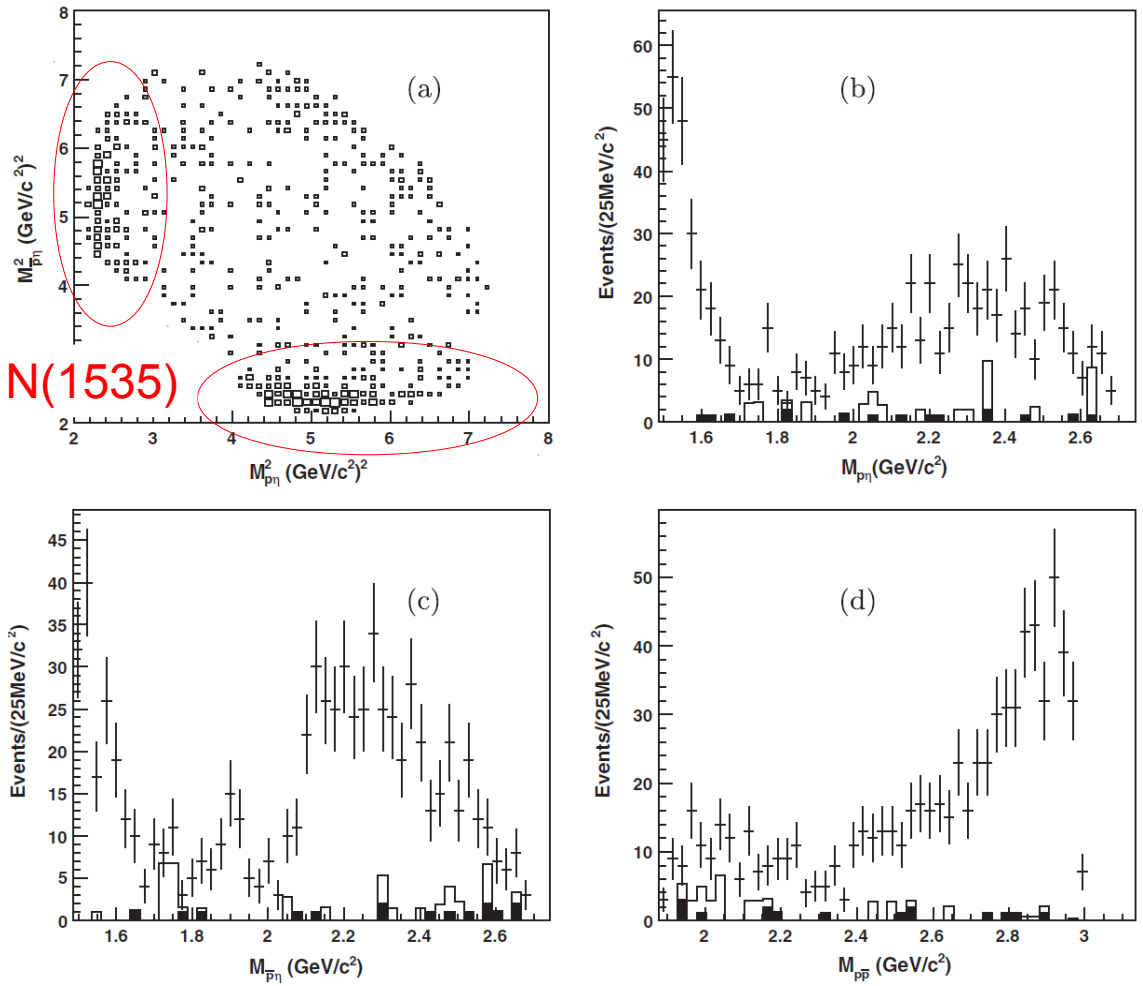


Resonance	M(MeV/c^2)	Γ(MeV/c^2)	ΔS	ΔN_{dof}	Sig.
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	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 N* baryons were found:
- N(2300) $1/2^+$
- N(2570) $5/2^-$
- No clear evidence for N(1885) and N(2065)

PWA of $\psi' \to \eta p\bar{p}$

PRD88 (2013) 032010



N(1535)

$M = 1524 \pm 5\ ^{+10}_{-4}$ MeV/c^2

$\Gamma = 130^{+27}_{-24}\ ^{+57}_{-10}$ MeV/c^2

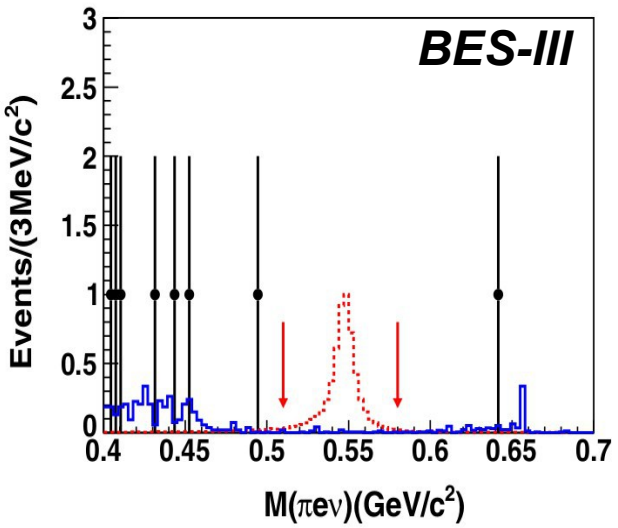
No significant $p\bar{p}$ resonance is observed

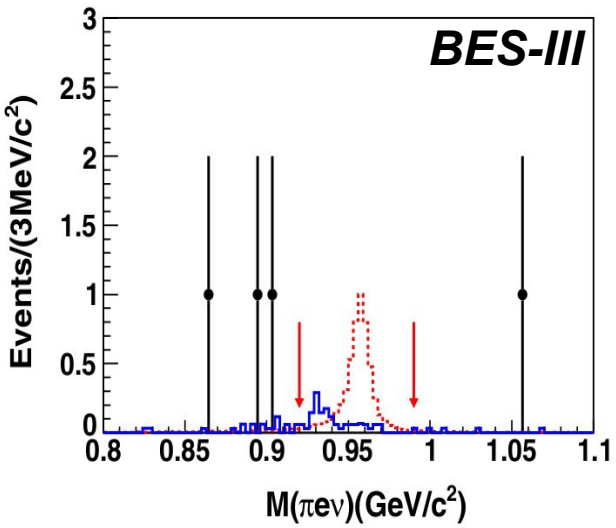
η and η' physics

Search for weak η and η' decays

- Theoretical expectations — PRD87 (2013) 032006
  - SM: $B(\eta\to\pi^-e^+\nu + c.c.) \sim \mathbf{2\times10^{-13}}$ (Z.Phys. C68 (1995) 91)
  - New type (S or V) interactions: $\sim \mathbf{10^{-8} - 10^{-9}}$ (Prog. Part. Nucl. Phys.46 (2001) 413)
- Tagging of η / η' with $J/\Psi\to\phi\eta/\eta'$
  - two-body decay, narrow φ resonance
  - normalization to $\eta\to\gamma\gamma$ cancels systematics
- Results:

$B(\eta\to\pi^-e^+\nu + c.c.) < 1.7\cdot 10^{-4}$ (90% CL)
$B(\eta'\to\pi^-e^+\nu + c.c.) < 2.2\cdot 10^{-4}$ (90% CL)





Search for invisible η and η' decays

- Theoretical expectations
  - SM: η / η' → νν is helicity suppressed
  - Light dark matter η / η' → χχ (PRD72 (2005) 103508)

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

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

- Experimental upper limit from BES-II (PRL97 (2006) 202002)

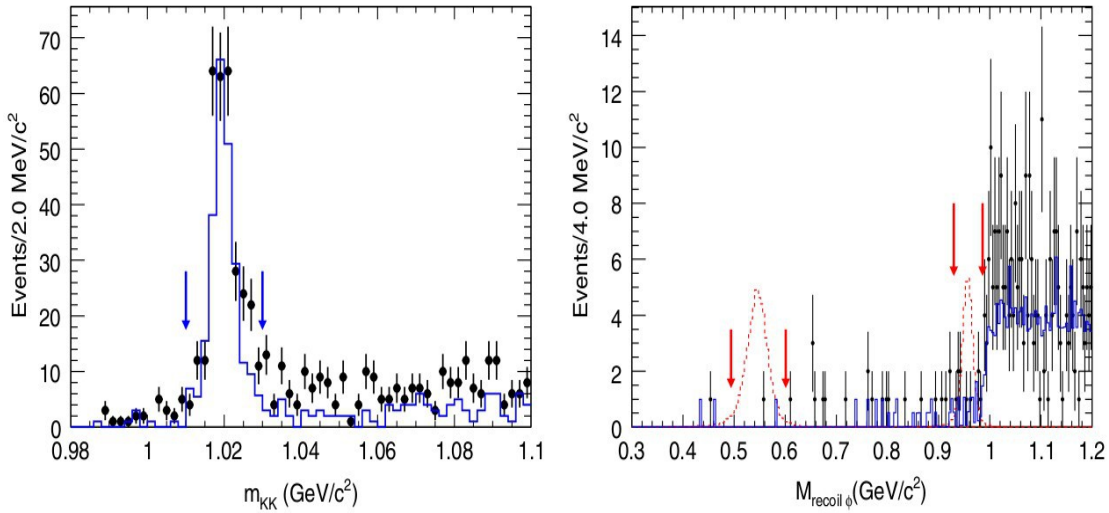
$B(\eta \to \text{invisible}) < 6.0 \cdot 10^{-4}$ 90% CL

$B(\eta' \to \text{invisible}) < 1.4 \cdot 10^{-3}$ 90% CL

- Tagging of η / η' with $J/\Psi \to \phi\eta/\eta'$

PRD87 (2013) 012009

BES-III result

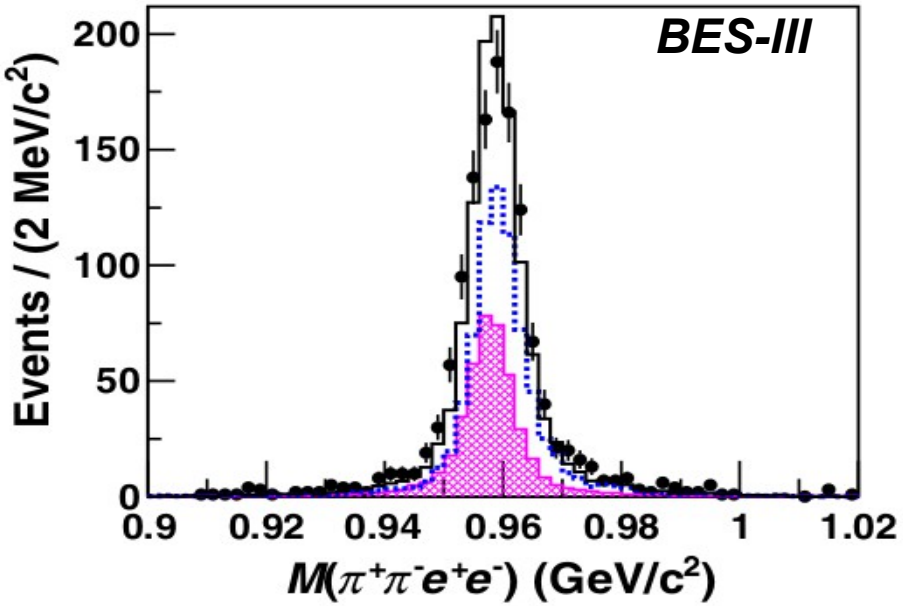


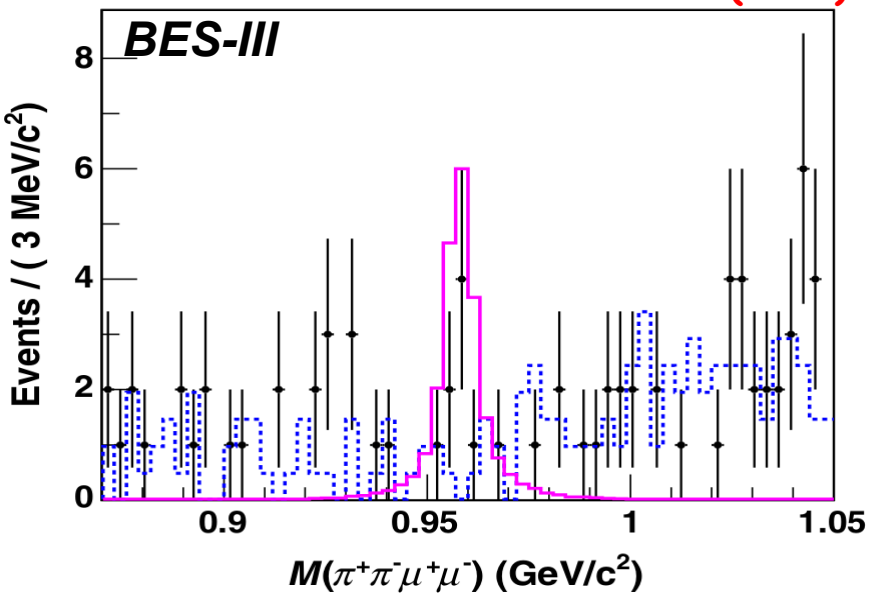
$B(\eta \to \text{invisible}) / B(\eta \to \gamma\gamma) < 2.6 \cdot 10^{-4}$ 90% CL
$B(\eta' \to \text{invisible}) / B(\eta' \to \gamma\gamma) < 2.4 \cdot 10^{-2}$ 90% CL

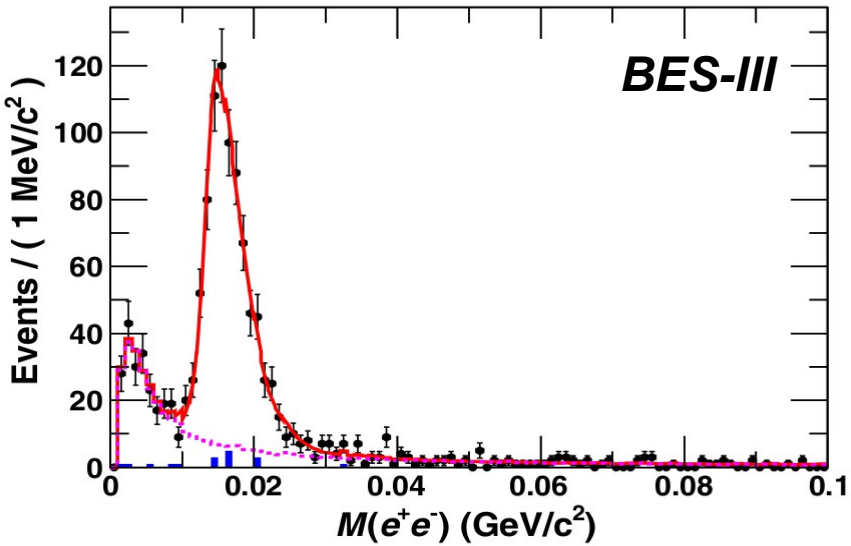
$B(\eta \to \text{invisible}) < 1.0 \cdot 10^{-4}$ 90% CL
$B(\eta' \to \text{invisible}) < 5.3 \cdot 10^{-4}$ 90% CL

Measurement of $\eta' \to \pi^+ \pi^- l^+ l^-$

PRD87 (2013) 092011







$B(\eta' \to \pi^+ \pi^- e^+ e^-) = (2.11 \pm 0.12 \pm 0.14) \times 10^{-3}$

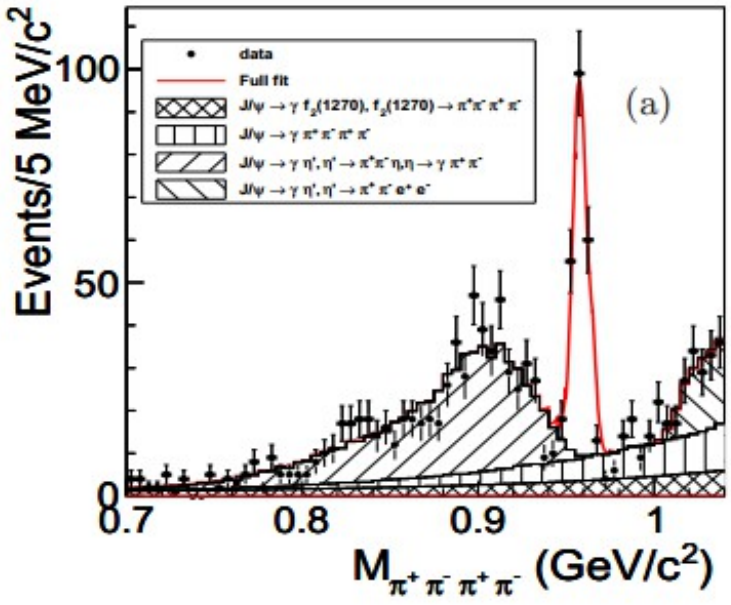
$B(\eta' \to \pi^+ \pi^- \mu^+ \mu^-) < 2.9 \times 10^{-5}$ 90% CL

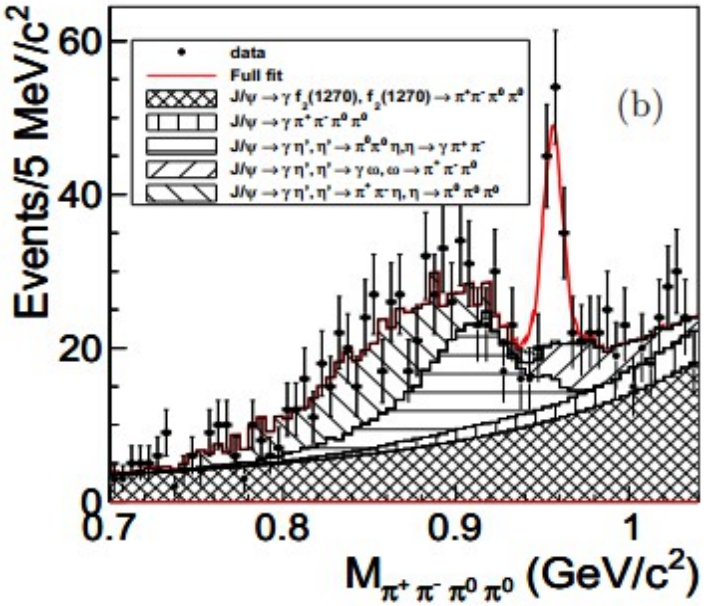
Observation of $\eta' \to \pi^+ \pi^- \pi^+ \pi^-$ and $\eta' \to \pi^+ \pi^- \pi^0 \pi^0$

PRL 112 (2014) 251801

First observation!

Full sample of 1.3×10^9 J/ψ was used





Mode	Yield	ε (%)	$B(J/\Psi \to \gamma\eta')B(\eta' \to \pi^+ \pi^- \pi^{+(0)} \pi^{-(0)})$
$\eta' \to \pi^+\pi^-\pi^+\pi^-$	199 ± 16	34.5	$(4.40 \pm 0.35 \pm 0.30) \times 10^{-7}$
$\eta' \to \pi^+\pi^-\pi^0\pi^0$	84 ± 16	7.0	$(9.38 \pm 1.79 \pm 0.89) \times 10^{-7}$

Results are consistent with the theoretical predictions based on a combination of ChPT and VMD, but not with the broken-$SU_6 \times O_3$ quark model

$J/\psi \to p\bar{p}\, a_0(980)$

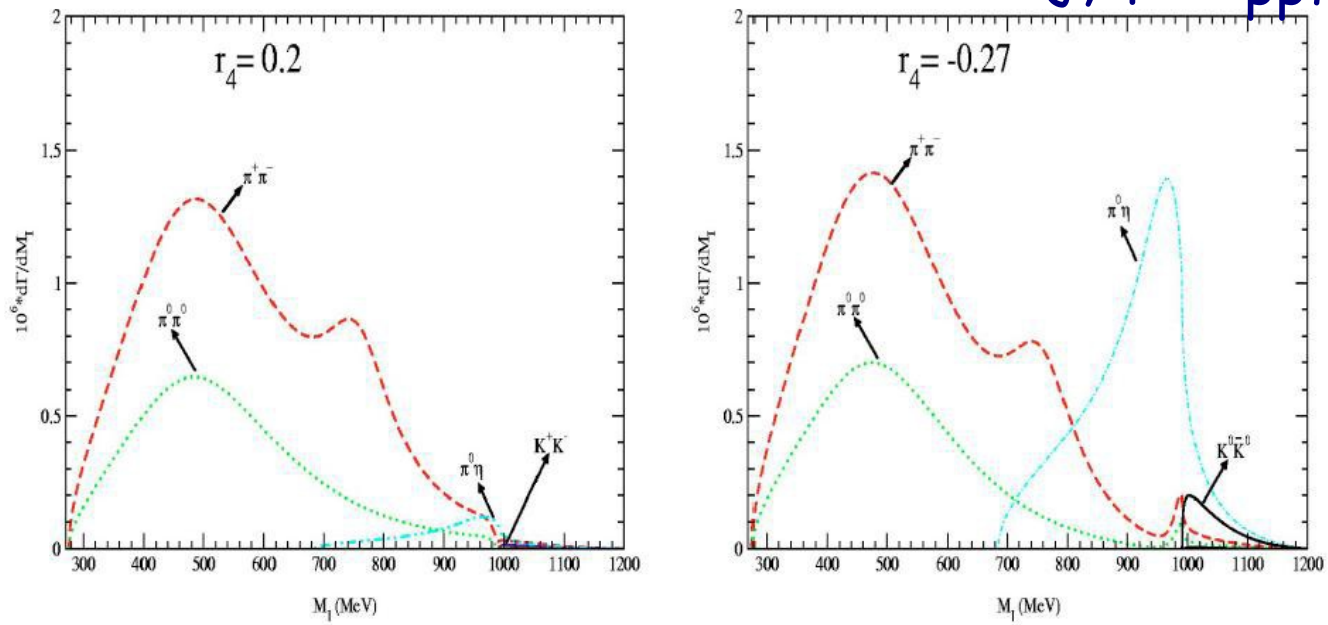
$J/\Psi \to p\bar{p}\, a_0(980)$

arXiv:1408.3938v1

- The nature of $a_0(980)$ and $a_0(980)/f_0(980)$ puzzle is a long-standing problem of physics
- The measurement of $J/\Psi \to p\bar{p}\, a_0(980)$ is an additional constraint to any model describing $a_0(980)$ formation and decay
- χPT provides a description of $J/\Psi \to N\bar{N}MM$ process, yet to be tested experimentally.

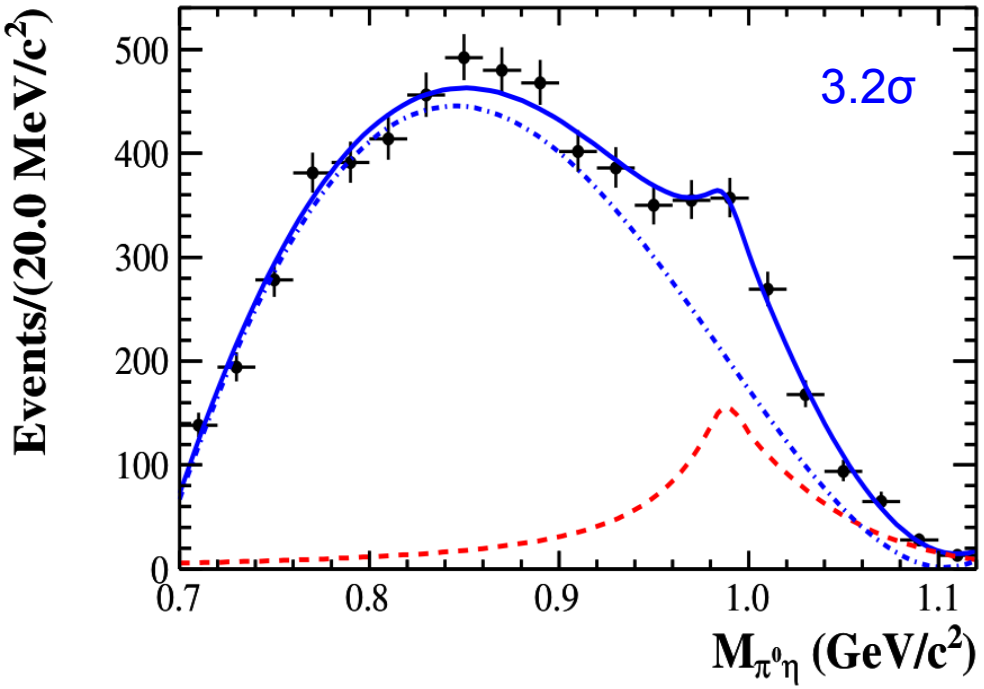
PHYSICAL REVIEW C **69**, 015201 (2004)

$J/\Psi \to p\bar{p}\pi^0\eta$



$J/\Psi \to p\bar{p}\, a_0(980)$

arXiv:1408.3938v1



$J/\Psi \to p\bar{p}\, a_0(980)$, $a_0(980) \to \pi^0\eta$ is observed for the first time

- $Br(J/\psi \to p\bar{p}a_0(980) \to p\bar{p}\pi^0\eta) = (6.8 \pm 1.2 \pm 1.5) \times 10^{-5}$
- Interference with intermediate N* states is not taken into account
- Comparison with $Br(J/\Psi \to p\bar{p}\pi^+\pi^-)$ from the PDG shows preference to r_4=0.2 in ChPT

Summary

- The BES-III experiment continues to take data. It will remain the world leading project in the τ-charm domain for the next 6-8 years.
- Largest samples of J/Ψ and Ψ' provide an excellent source of light hadrons, complementary to hadron scattering and photoproduction experiments
- Many interesting results have been obtained recently, looking forward to theoretical insights: X-zoo, new N* states, new experimental constraints on ChPT and BSM theories. More physics results are coming.
- For many analyses statistics ceases to be a limiting factor. Results getting more affected by systematics and model uncertainties.