

Light Meson Spectroscopy At BES III

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(on behalf of the BES III Collaboration)

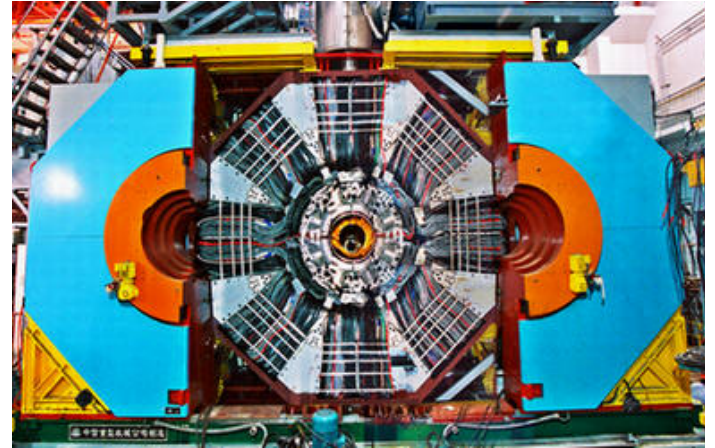
EuNPC 2015
Aug. 31- Sep. 4, 2015
Groningen, The Netherlands

DFG

BES III

Physics Program

- Light Hadron Spectroscopy
 - Understand QCD in the non-perturbative regime
 - Understand origin of the hadron mass
 - Search for exotic hadrons, e.g. glueballs, hybrids, tetraquarks
- Charmonium Physics
 - X, Y, and Z states
 - Decays and transitions
- Open Charm Physics
 - D meson decays
 - $D\bar{D}$ mixing
 - CP violation in the charm sector
- And many further topics
 - e.g. tau and two-photon physics



Further BESIII presentations at this conference

Hadron Structure II (Mon.)

X. Wang, Baryon spectroscopy at BESIII

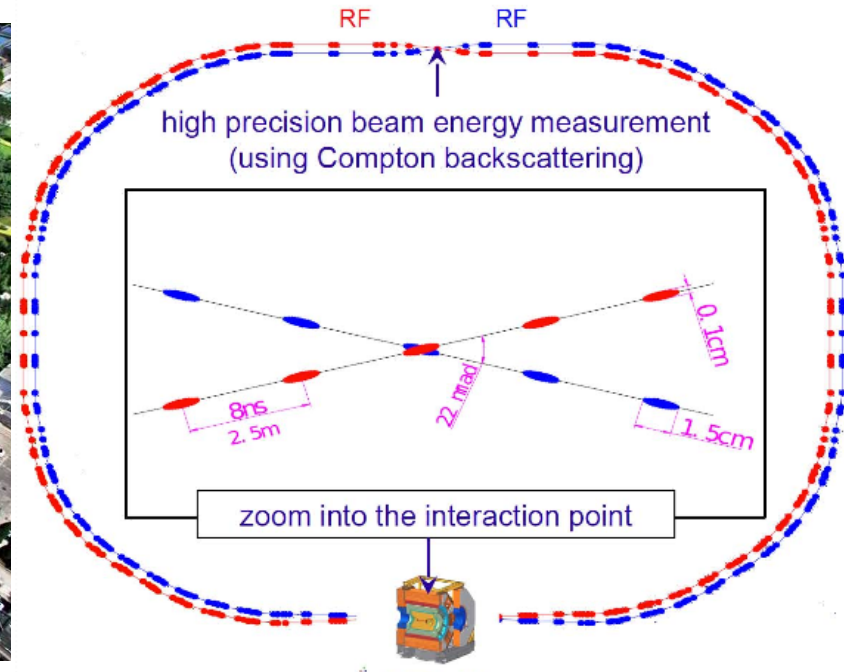
L. Liu , XYZ spectroscopy at BESIII

Hadron Structure III (Tue.)

R. Ping, Studies of Charmonium at BESIII

Z. Haddadi, Radiative transition studies with BESIII

BES III at BEPC II



Symmetric electron-positron collider BEPC II

- Energy range: $\sqrt{s} = 2.0\text{-}4.6$ GeV
- Design luminosity: $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ (at $\psi(3770)$)
- Energy spread: $\sim 5 \times 10^{-4}$
- Operating since March 2008
- Achieved luminosity: $0.7 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

The BES III Detector

RPC Muon Detector

8 layers (end caps), 9 layers (barrel)

$$\delta R_\phi = 1.4 - 1.7 \text{ mm}$$

Electromagnetic

CsI(Tl) Calorimeter

$$\sigma_E/E < 2.5\%/\sqrt{E}$$

$$\sigma_{z,\phi} = 0.5 - 0.7 \text{ cm}/\sqrt{E}$$

Time of Flight System

$$\sigma_t = 80 \text{ ps} \quad (\text{barrel})$$

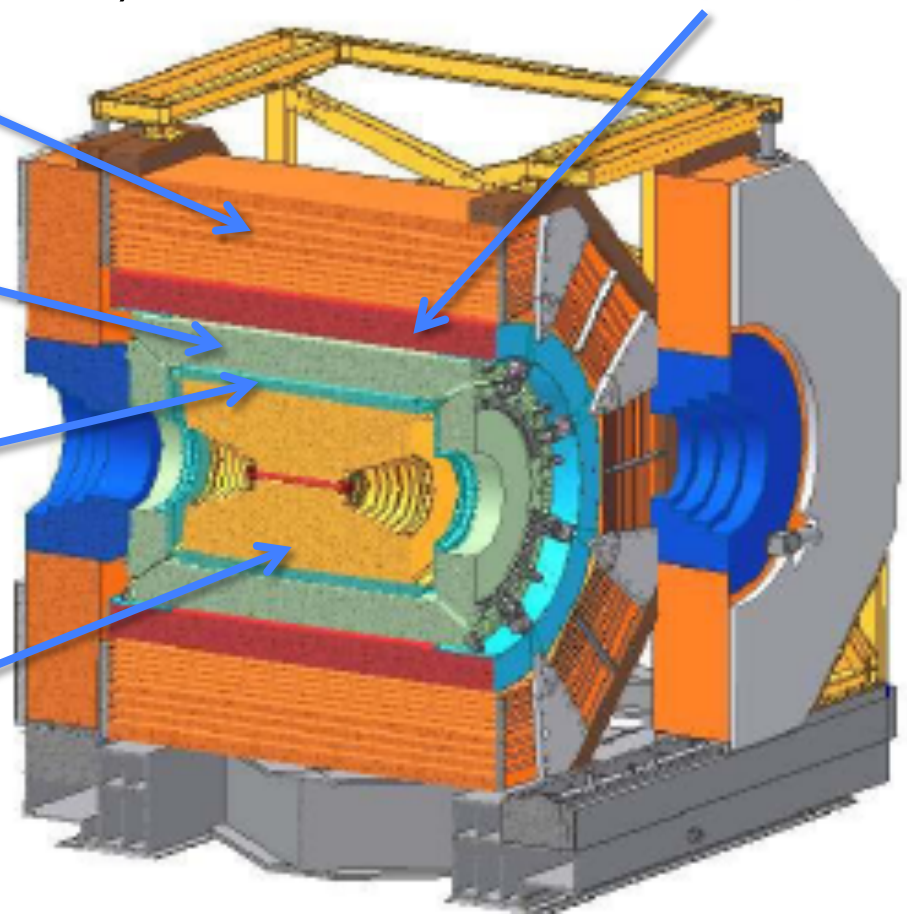
$$\sigma_t = 110 \text{ ps} \quad (\text{end caps})$$

Drift Chamber

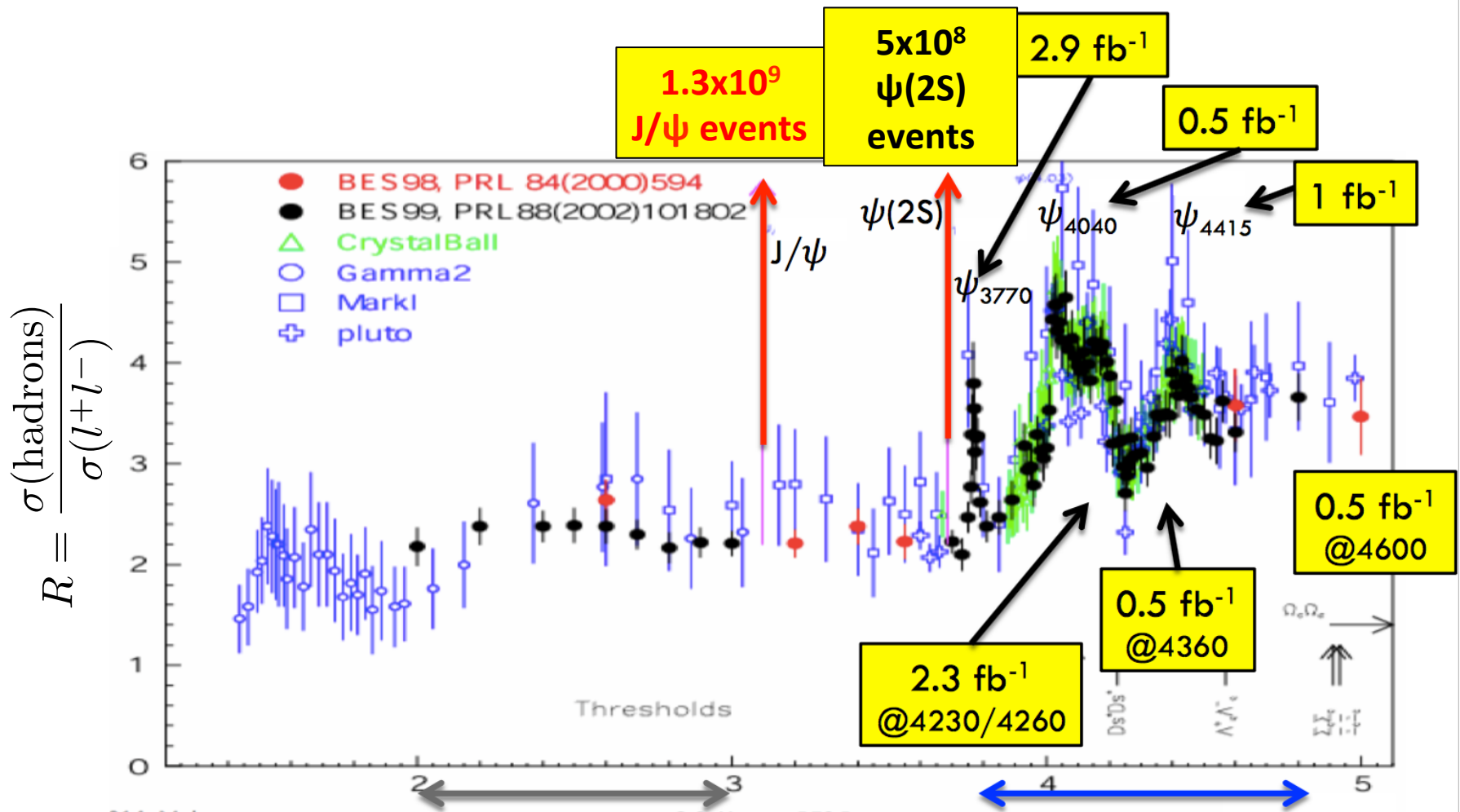
$$\sigma(dE/dx) = 6\%$$

$$\sigma_{p_t}/p_t = 0.5\%$$

Superconducting Solenoid (1 T)



Data Samples



R scan: 2-3 GeV, 19 points, ~0.5 fb⁻¹; 3.85-4.59 GeV, 104 points, ~0.8 fb⁻¹

plus 24/pb at τ mass threshold and
0.5/fb in the region 4100-4400 MeV

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

BESIII, Phys. Rev. Lett. 106, 072002 (2011)

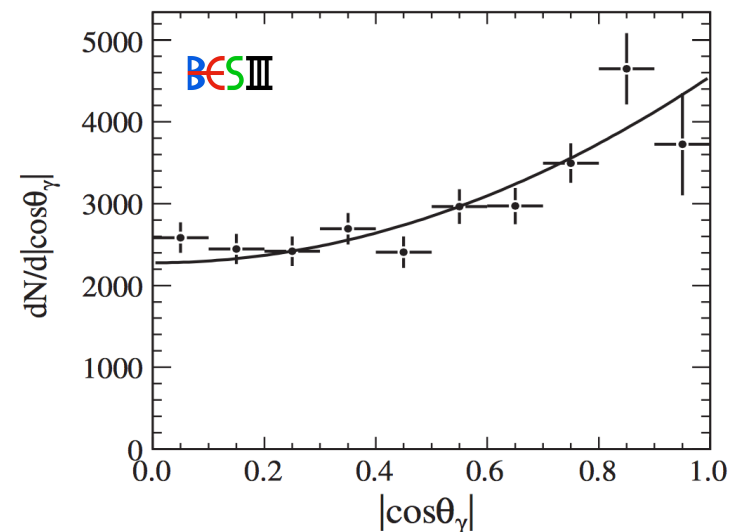
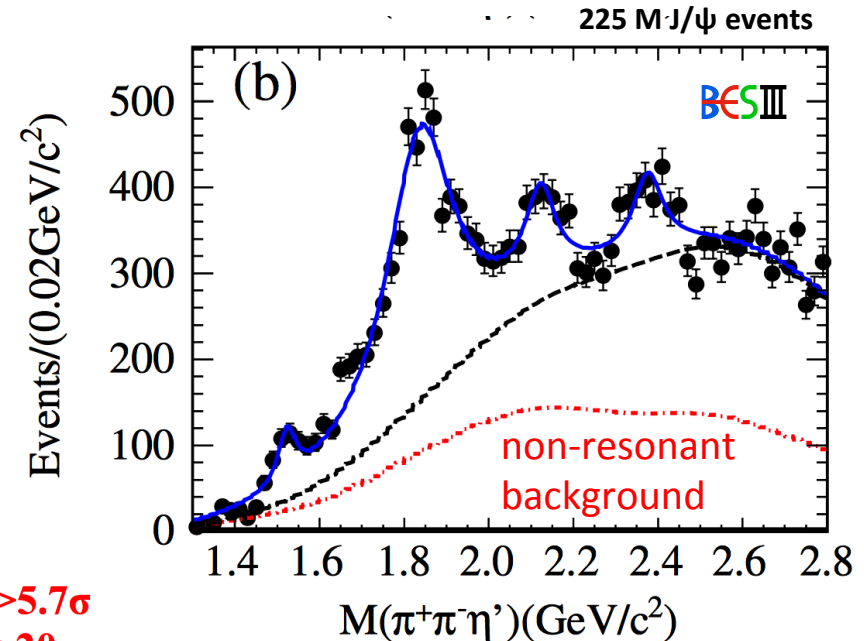
- X(1835) previously observed at BES and BESII
- Nature unclear, interpretations include glueball, $\bar{p}p$ bound state, excited η meson
- Confirmed at BESIII with two additional structures above 2 GeV/c²

Resonance	$M(\text{MeV}/c^2)$	$\Gamma(\text{MeV}/c^2)$
$f_1(1510)$	1522.7 ± 5.0	48 ± 11
X(1835)	1836.5 ± 3.0	190.1 ± 9.0
X(2120)	2122.4 ± 6.7	83 ± 16
X(2370)	2376.3 ± 8.7	83 ± 17

>5.7σ
>20σ
>7.2σ
>6.4σ

- X(1835) angular distribution consistent with pseudoscalar, but other spin-parity assignments not excluded

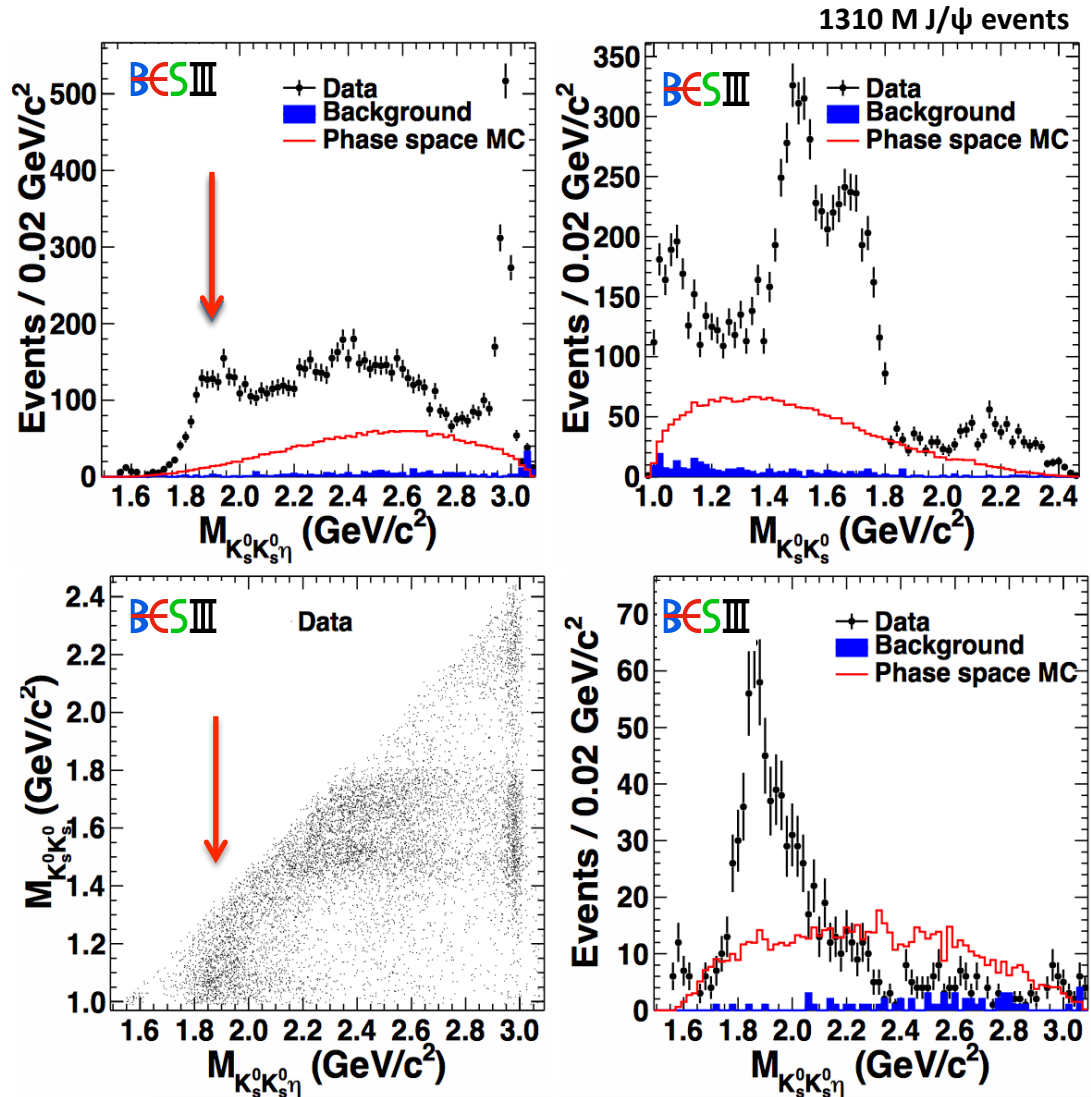
→ Systematic studies of X(1835) ongoing at BESIII (new decay modes, production mechanisms, PWA)



X(1835) in $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$

BESIII, Phys. Rev. Lett. 115, 091803 (2015)

- Structure in invariant $K_S K_S \eta$ mass at $\sim 1.85 \text{ GeV}/c^2$
- Strong correlation with enhancement at $K_S K_S$ mass threshold (interpreted as $f_0(980)$)
- Structure in $K_S K_S \eta$ is enhanced for $m(K_S K_S) < 1.1 \text{ GeV}/c^2$



X(1835) in $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta$

BESIII, Phys. Rev. Lett. 115, 091803 (2015)

- Partial wave analysis for $m(K_S K_S) < 1.1 \text{ GeV}/c^2$ and $m(K_S K_S \eta) < 2.8 \text{ GeV}/c^2$
- Two resonant pseudoscalar components (Breit-Wigner parameterization) required in best fit hypothesis

$$X(1835) \rightarrow f_0(980)\eta \quad (>12.9\sigma)$$

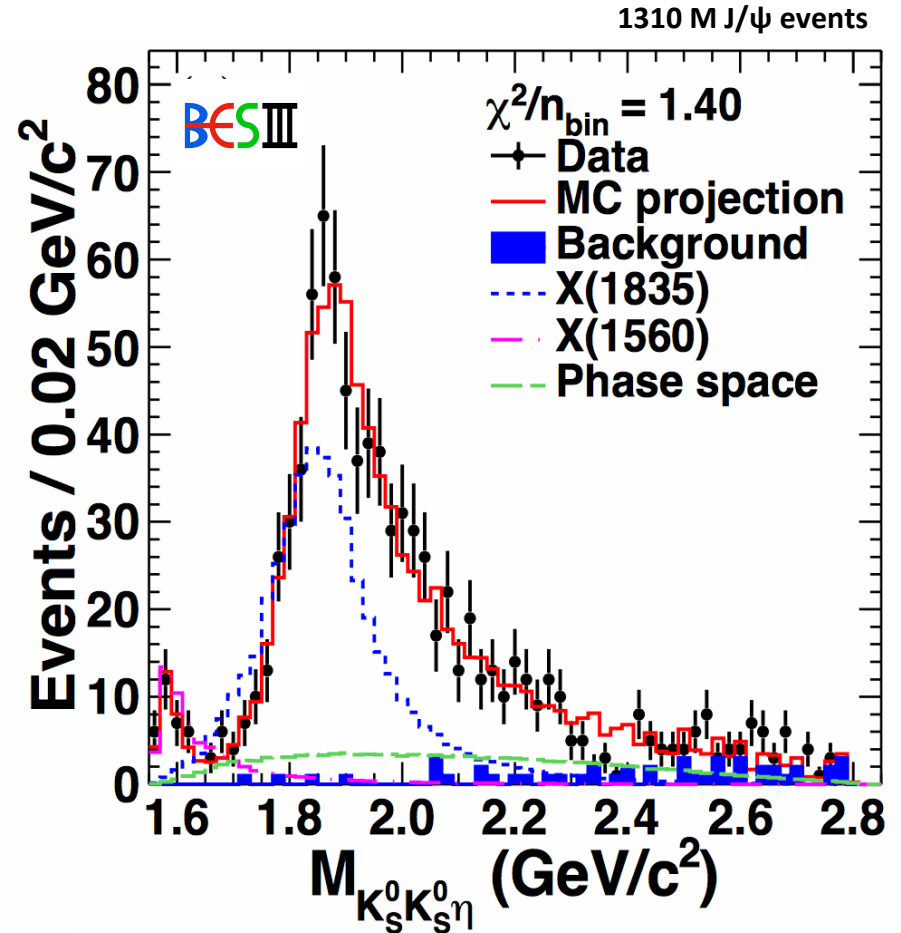
$$m = 1844 \pm 19_{-25}^{+16} \text{ MeV}/c^2$$

$$\Gamma = 192_{-17-43}^{+20+62} \text{ MeV}$$

$$X(1560) \rightarrow f_0(980)\eta \quad (>8.9\sigma)$$

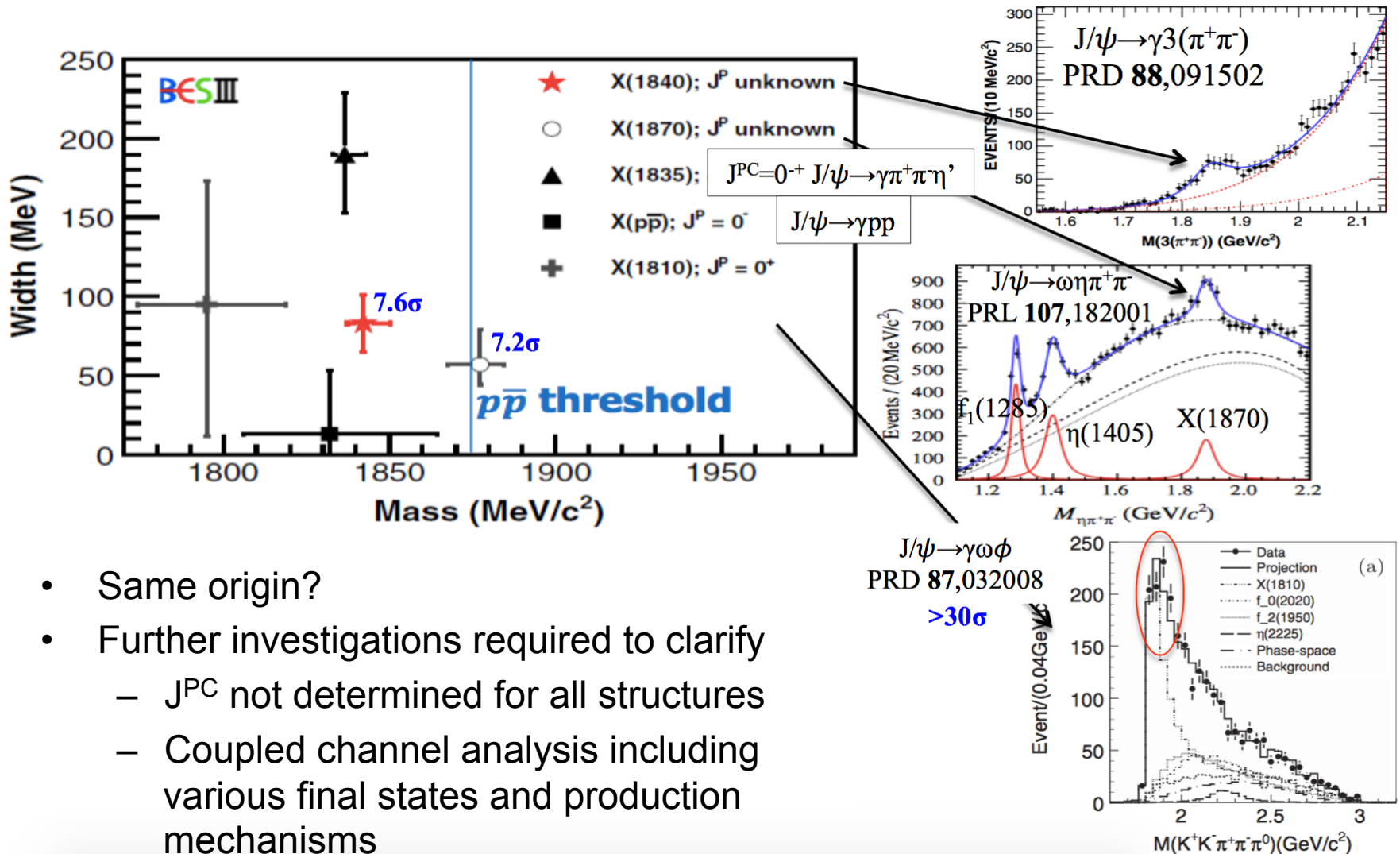
$$m = 1565 \pm 8_{-63}^{+0} \text{ MeV}/c^2$$

$$\Gamma = 45_{-13-28}^{+14+21} \text{ MeV}$$



Values consistent with those of $\eta(1405)$ / $\eta(1475)$ at $\sim 2\sigma$
 $\rightarrow$ needs further investigation

Further Observations At $p\bar{p}$ Threshold



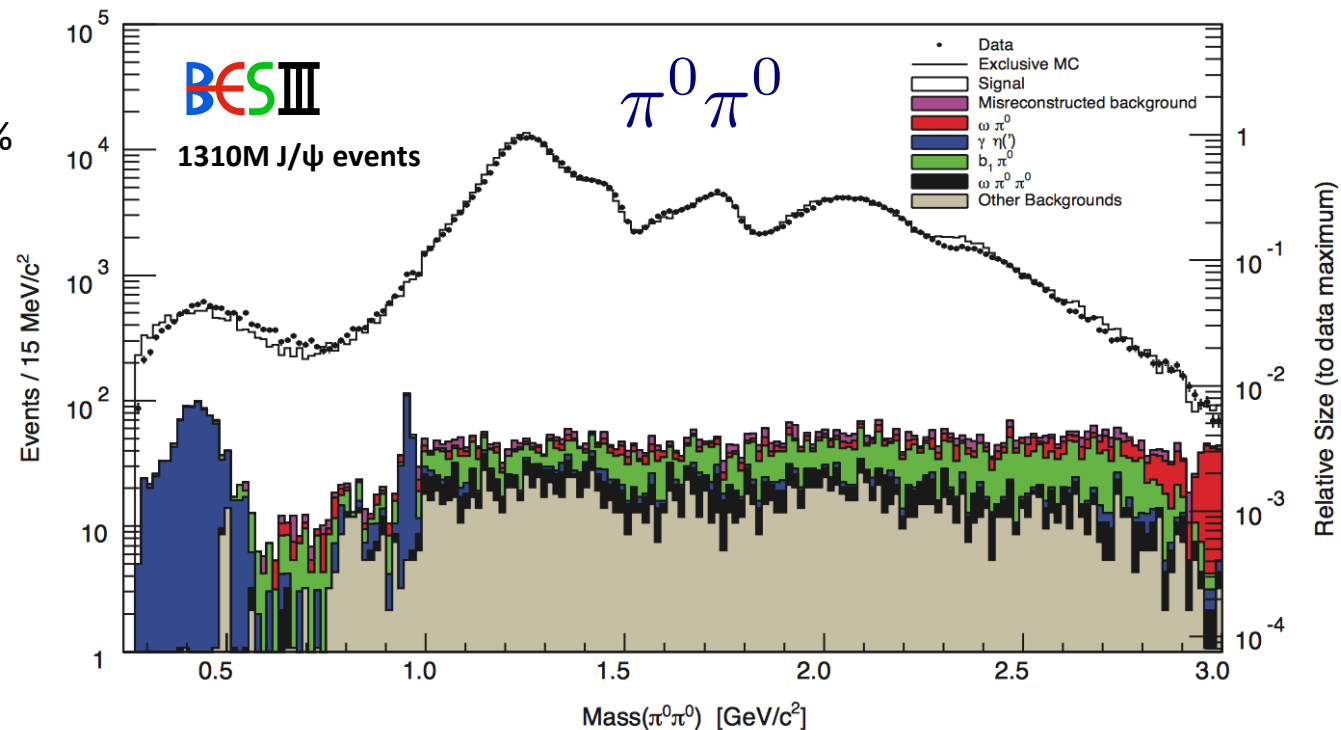
- Same origin?
- Further investigations required to clarify
 - J^{PC} not determined for all structures
 - Coupled channel analysis including various final states and production mechanisms

Model Independent PWA of $J/\psi \rightarrow \gamma \pi^0 \pi^0$

- Radiative J/ψ decays into two pseudoscalar mesons
 - Search for scalar and tensor glueballs (predicted at ~ 1.5 to ~ 2 GeV/c^2)
- $\pi^0 \pi^0$ system: only significant 0^{++} and 2^{++} contributions
 - Many broad and overlapping resonances, many open channels
→ complex structure, parameterization challenging
 - Model Independent Partial Wave Analysis

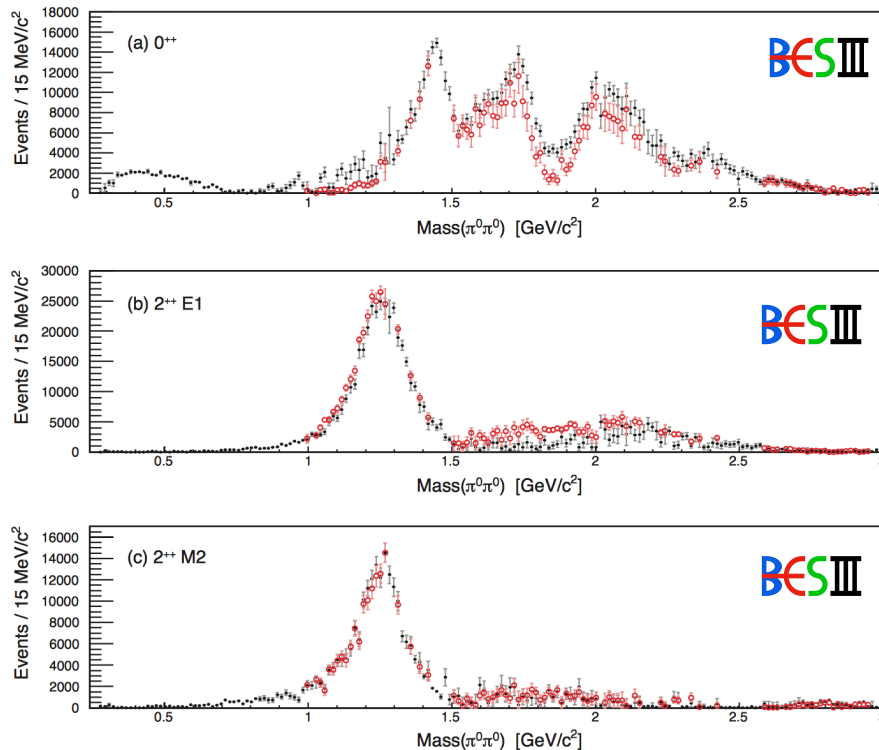
arXiv:1506.00546
accepted by Phys. Rev. D

>440k reconstructed events
at a background level of 1.8%

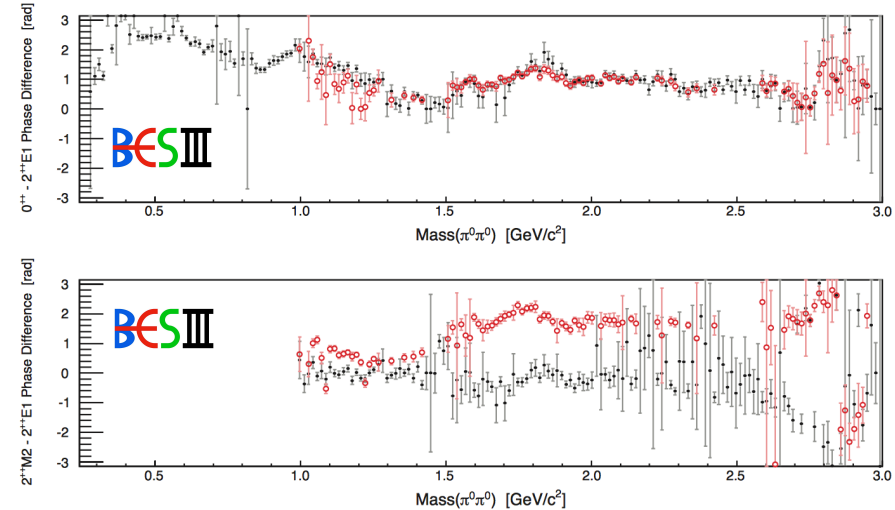


Model Independent PWA of $J/\psi \rightarrow \gamma \pi^0 \pi^0$

Extracted Intensity



Relative Phase wrt/ 2^{++} E1 amplitude



nominal solution
ambiguous solution

Ambiguities may be resolved in a model-dependent fit enforcing continuity between neighboring mass intervals

arXiv:1506.00546
accepted by Phys. Rev. D

Model independent approach is under investigation for other systems (e.g. $\eta\eta$, KK)
→ improve our understanding of the nature of the observed resonances

Conclusions and Outlook

- BESIII is successfully operating since 2008
 - World's largest data sample at the J/ψ resonance recorded
 - Clean and rich source for light hadrons
- Systematic studies to understand $X(1835)$ and other structures observed near $p\bar{p}$ threshold
 - Nature unclear: $p\bar{p}$ bound state, glueball, excited η meson?
- Sophisticated model-independent analysis of $J/\psi \rightarrow \gamma\pi^0\pi^0$
 - Improve our understanding of the rich structure in $\pi\pi$
 - Future: Include information from other channels (e.g. KK and $\eta\eta$) to understand nature of observed resonances ($\rightarrow$ glueballs)

Exciting times in light hadron spectroscopy with many important results and still more to come!

The BES III Collaboration

