Recent results on J/ψ radiative decays from BESIII

Zhang Jingqing

Institute of High Energy Physics

Chinese Academy of Sciences

(On behalf of the BESIII Collaboration)

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Outline

- Introduction

- Selected results on J/ψ radiative decays

  1. Spin-parity determination of the X(1835) in $J/\psi \rightarrow \gamma K_S K_S \eta$

  2. Observation of the X(1840) in $J/\psi \rightarrow \gamma 3(\pi^+ \pi^-)$

  3. Partial wave analysis of $J/\psi \rightarrow \gamma \pi^0 \pi^0$

  4. Partial wave analysis of $J/\psi \rightarrow \gamma \phi \phi$
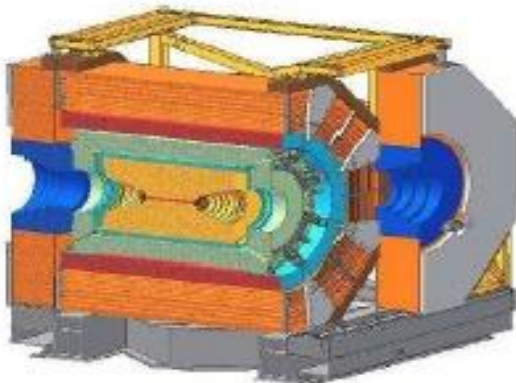
- Summary

BEPCII and BESIII
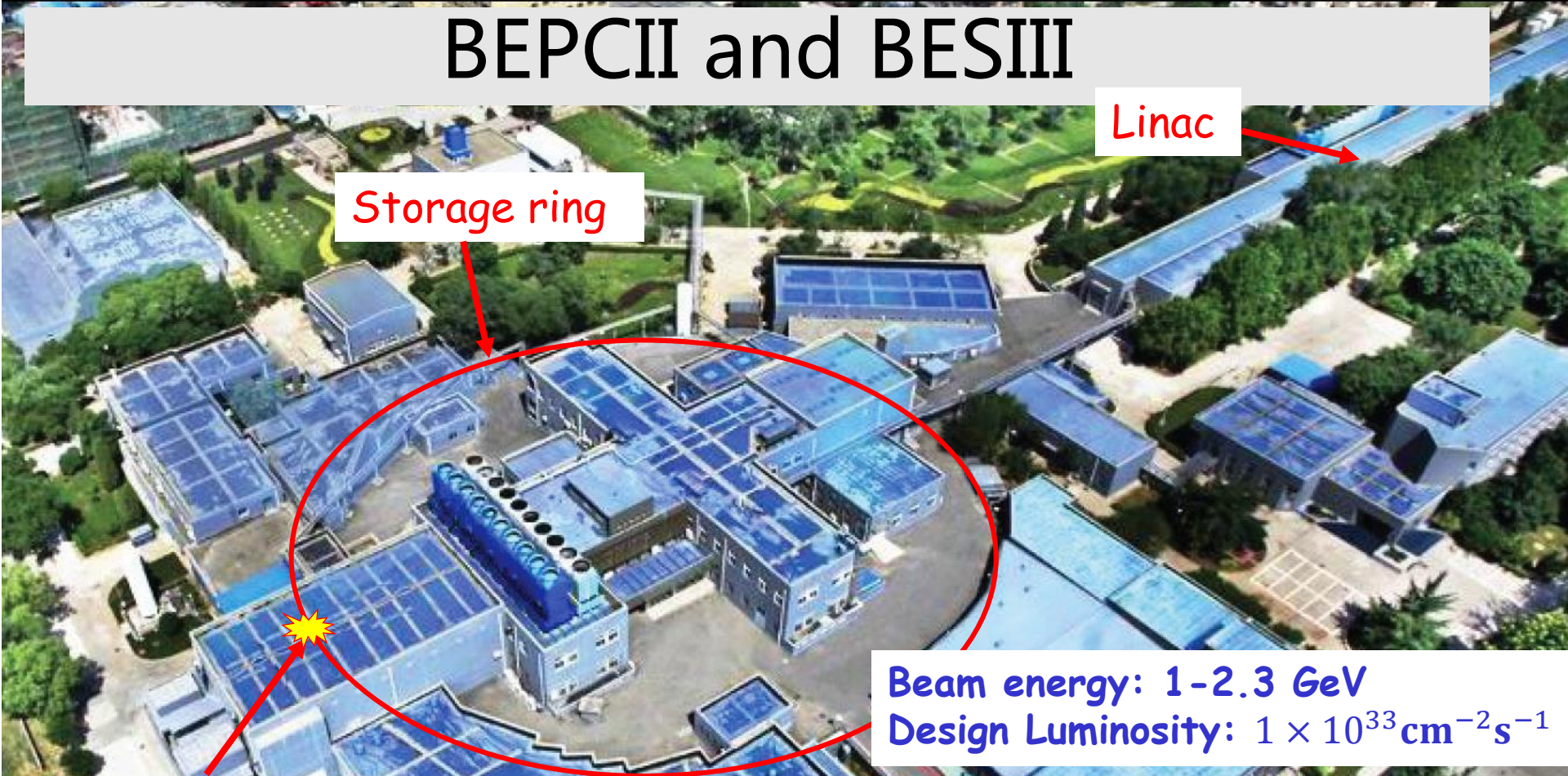
Linac

Storage ring

Beam energy: 1-2.3 GeV
Design Luminosity: $1 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
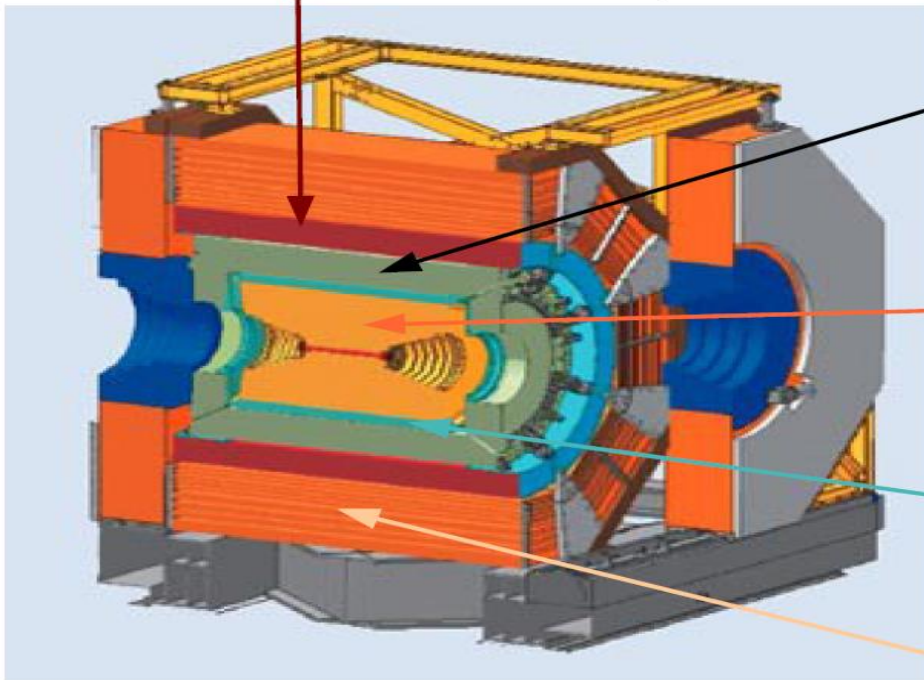
BESIII at BEPCII

BESIII physics program

- Charmonium(-like) physics

- Light hadron spectroscopy

- Charm physics

- τ physics

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The BESIII detector

NIM A614, 345(2010)

Super conducting magnet: 1 T

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

MDC:
- Spatial resolution: $\sigma_{xy} = 120\mu m$
- Momentum resolution: **0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF:
Time resolution: **80ps** (barrel)
                  110ps (endcaps)

Muon ID:
9 layers RPC, 8 for endcaps

BESIII accumulated 1.3 billion J/ψ events in 2009 and 2012: Clean and rich source for light hadrons

J/ψ radiative decays

- J/ψ radiative decays: "gluon-rich" process

- Clean data sample from e^+e^- annihilation

- An ideal environment to study light hadron spectroscopy

- Also search for glueball, hybrid state, multiquark state

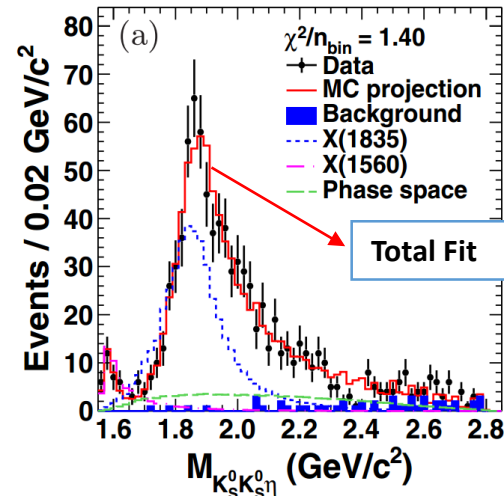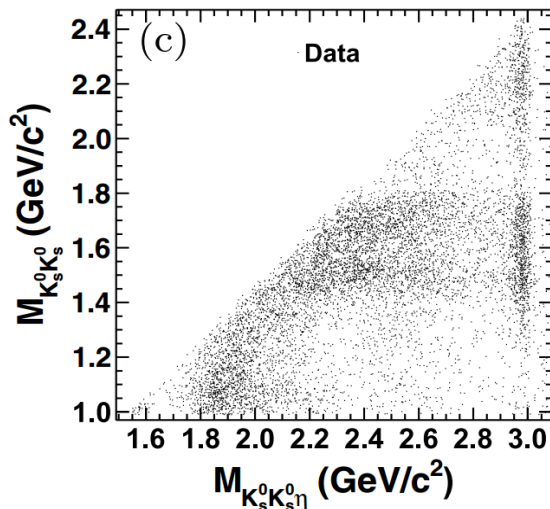# Spin-parity determination of the X(1835)

➤ X(1835) :

- First observed in $J/\psi \to \gamma\eta'\pi\pi$ at BESII in 2005, and confirmed at BESⅢ

- Nature unclear: p$\bar{\text{p}}$ bound state, excited η', glueball

➤ Partial Wave Analysis of $J/\psi \to \gamma K_S K_S \eta$:

- A clean channel ($J/\psi \to K_S K_S \eta$ and $J/\psi \to K_S K_S \eta \pi^0$ are forbidden)

- The X(1835) is observed on $M(K_S K_S \eta)$ in $J/\psi \to \gamma K_S K_S \eta$

- PWA for $M(K_S K_S) < 1.1\ GeV/c^2$

1.3 billion J/ψ events   Phys. Rev. Lett. 115, 091803 (2015)

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Spin-parity determination of the X(1835)

- Two resonant pseudoscalar (0^{-+}) components

- $X(1835) \to K_S K_S \eta$ ($> 12.9\sigma$) dominated by $f_0(980)$ production

$$M = 1844 \pm 9^{+16}_{-25} \text{ MeV}/c^2, \Gamma = 192^{+20+16}_{-17-25} \text{ MeV}$$

✓ Consistent with the X(1835) in $J/\psi \to \gamma\eta'\pi^+\pi^-$

✓ Mass/spin is consistent with those of the X($p\bar{p}$)
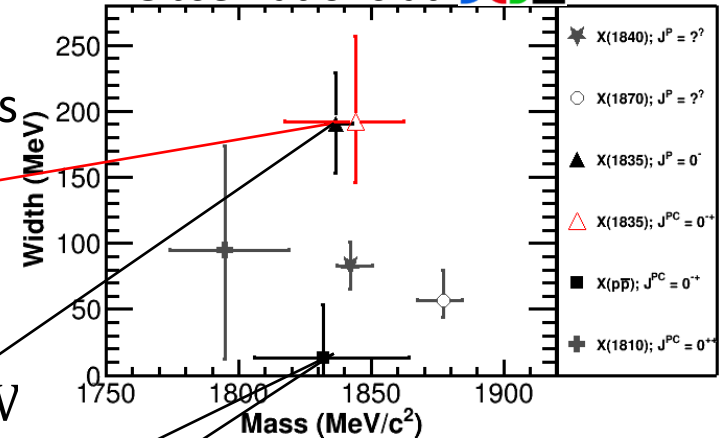
✓ Width is larger than the width of the X($p\bar{p}$)

- $X(1560) \to f_0(980)\eta$ ($> 8.9\sigma$)
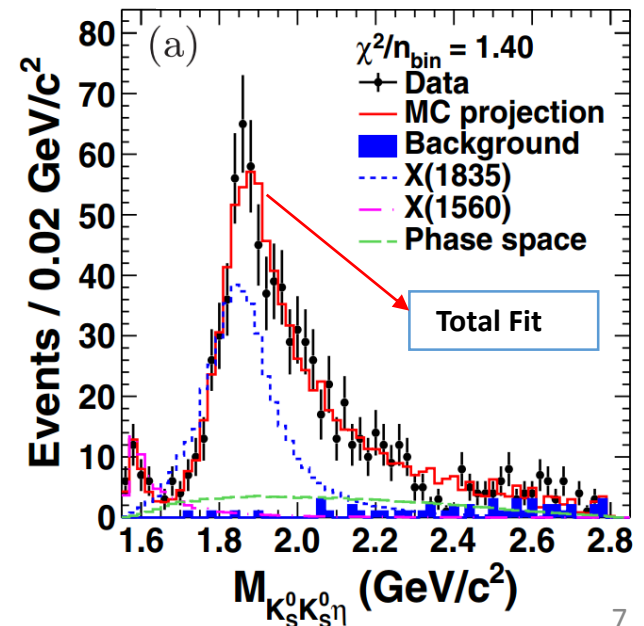
$$M = 1565 \pm 8^{+0}_{-63} \text{ MeV}/c^2$$

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

(Consistent with $\eta(1405)/\eta(1475)$ within 2σ)
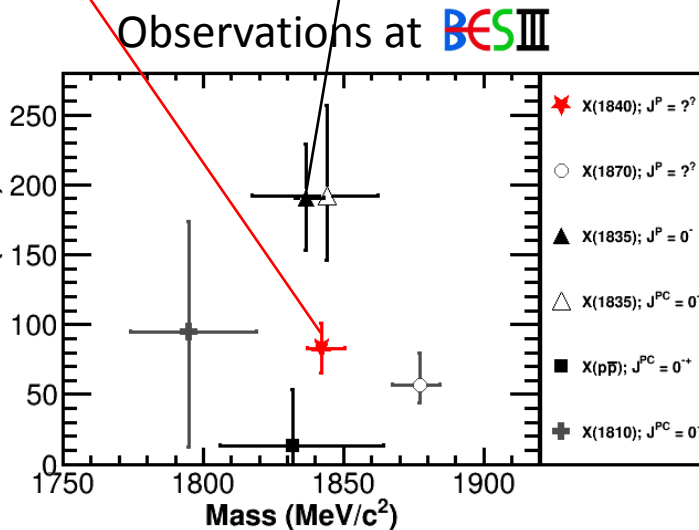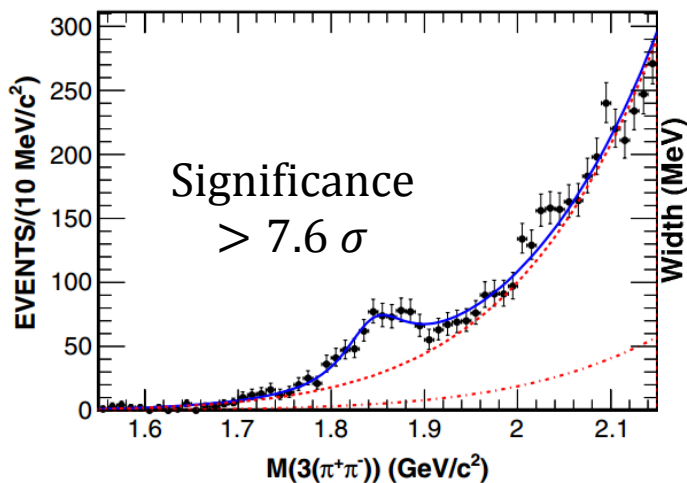

1.3 billion J/ψ events
PRL 115, 091803 (2015)

Observation of the X(1840)

- Clear enhancement at 1.84 GeV/c^2 on $M(3(\pi^+\pi^-))$

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

- $M = 1842.2 \pm 4.2^{+7.1}_{-2.6}$ MeV/c^2, $\Gamma = 83 \pm 14 \pm 11$ MeV

- Mass is consistent with that of the X(1835), but width is much smaller

Observations at BESIII

Significance $> 7.6\,\sigma$

225 million J/ψ events
Phys. ReV. D88, 091502 (2013)

PRD 88, 091502 (2013)
$J/\psi \rightarrow \gamma 3(\pi^+\pi^-)$
PRL 107, 182001 (2011)
$J/\psi \rightarrow \omega\eta\pi^+\pi^-$
PRL 106, 072002 (2011)
$J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$
PRL 115, 091803 (2015)
$J/\psi \rightarrow \gamma K_S K_S \eta$
PRL 108, 112003 (2012)
$J/\psi \rightarrow \gamma p\bar{p}$
PRD 87, 032008 (2013)
$J/\psi \rightarrow \gamma\omega\phi$

Model independent PWA of $J/\psi \to \gamma \pi^0 \pi^0$

- Clean channel (no background from $\rho\pi$, only even^{++} amplitudes)
- $\pi^0\pi^0$ system: only significant 0^{++} and 2^{++} contributions
- Many broad and overlapping resonances (parameterization challenging)
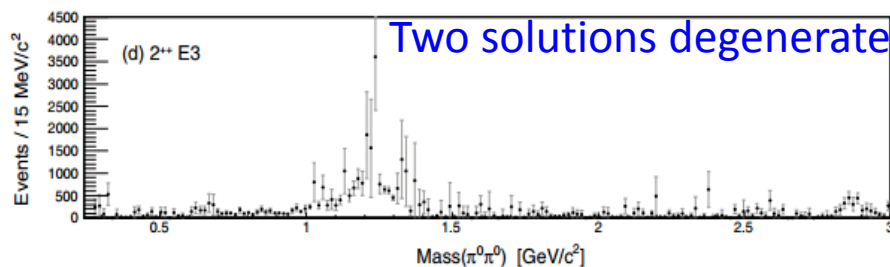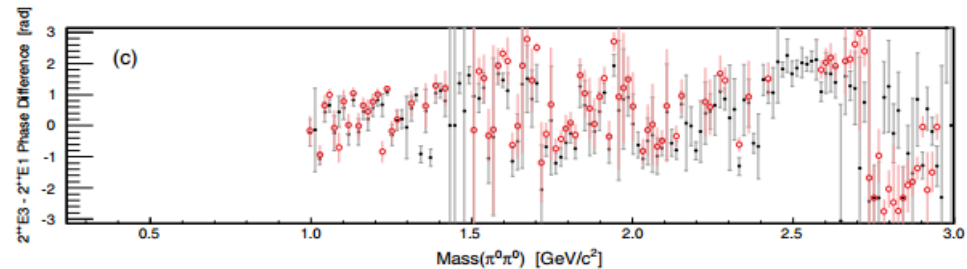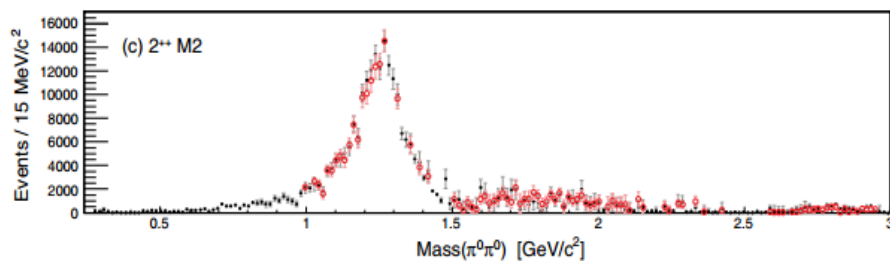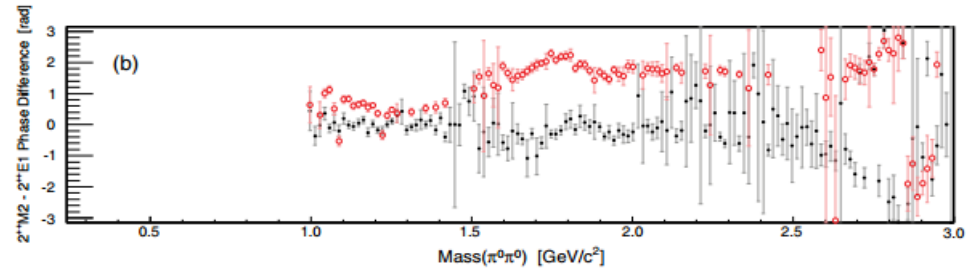- Model independent PWA

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

1.3 billion J/ψ events
Phys. Rev. D 92, 052003 (2015)
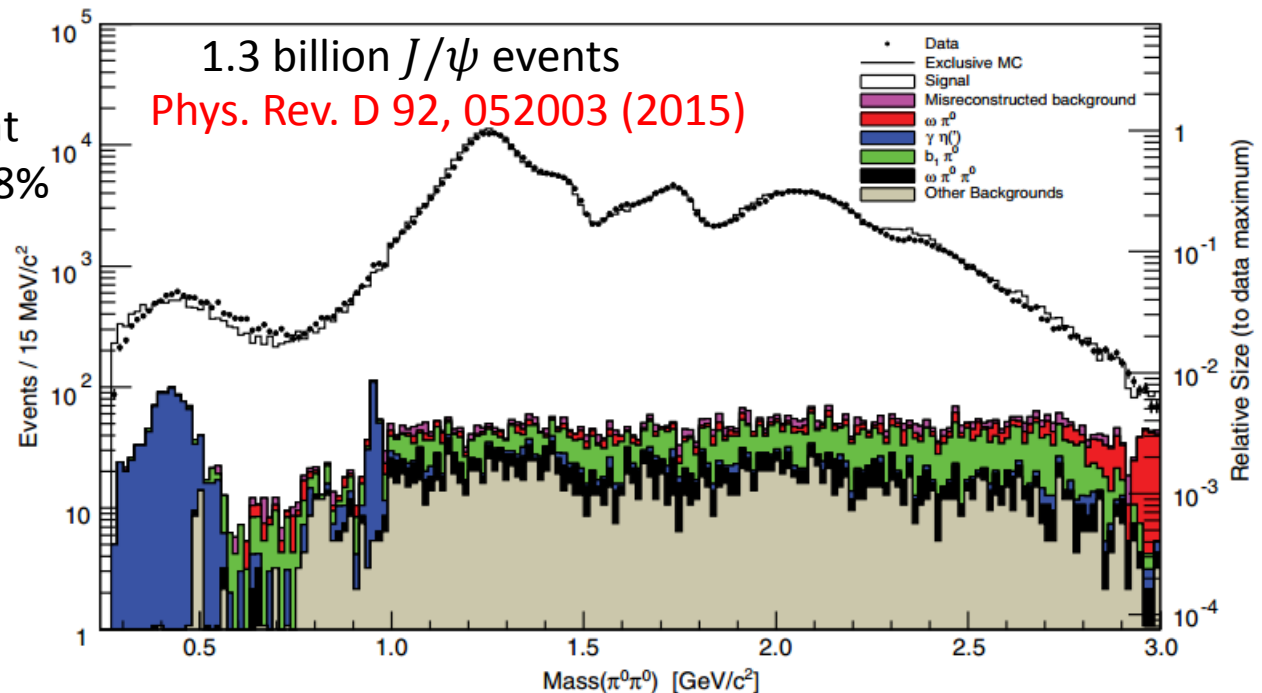
Model independent PWA of $J/\psi \to \gamma\pi^0\pi^0$

Extracted Intensity   1.3 billion J/ψ events

Phys. Rev. D 92, 052003 (2015)   Relative phase

Nominal solution
Ambiguous solution

Two solutions degenerate
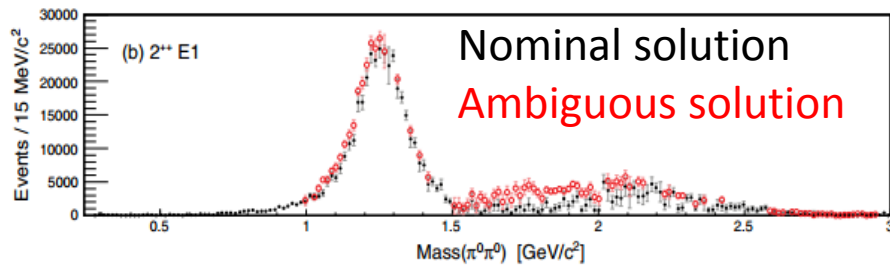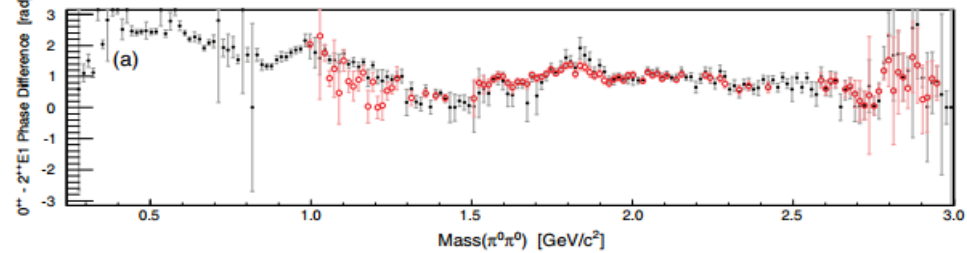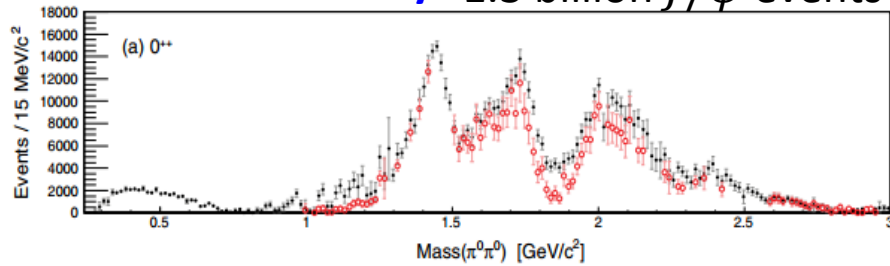
Phys. Rev. D92, 052003 (2015):
- A piecewise function of $M(\pi^0\pi^0)$ to describe the dynamics of the $\pi^0\pi^0$ system
- Significant features of the scalar spectrum near 1.5, 1.7 and 2.2 GeV/c^2
- Ambiguities above the $K\bar{K}$ threshold

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

- Ground-state glueball mass prediction by LQCD
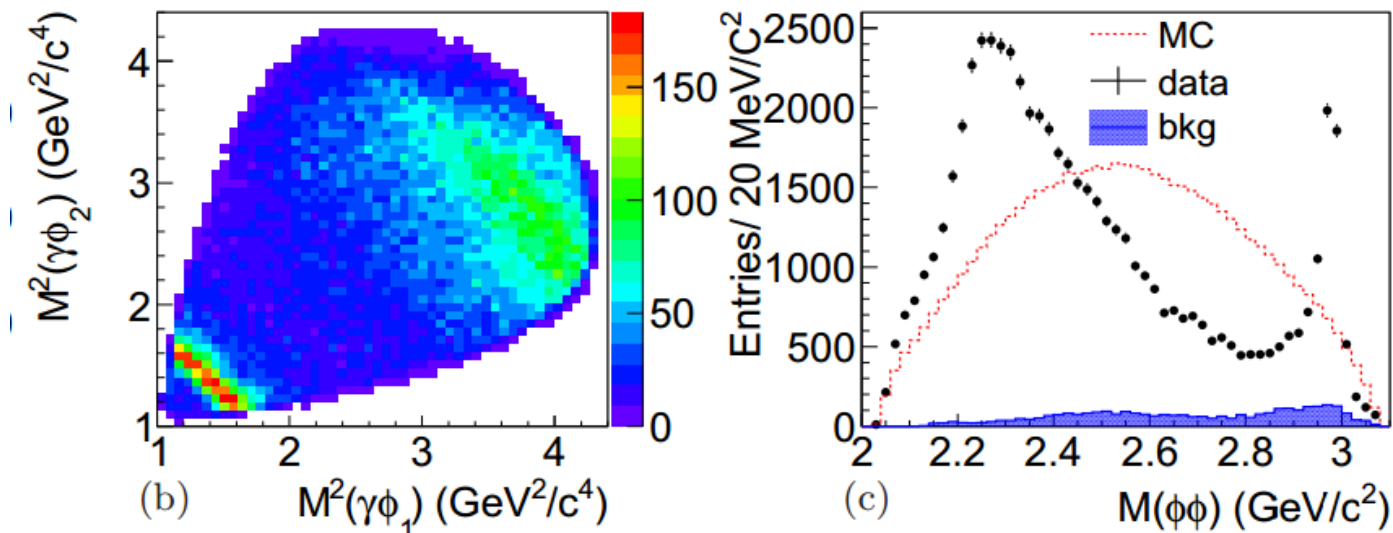
  -- 0^{-+}: 2.3 ~ 2.6 GeV/c^2, 2^{++}: 2.3~2.4 GeV/c^2

- $\phi\phi$ system observations

  -- 0^{-+}: $\eta(2225)$ was observed in $J/\psi \to \gamma\phi\phi$, very little knowledge for those above 2 GeV/c^2

  -- 2^{++}: broad structures around 2.3 GeV/c^2 in $\pi^- N$ reactions and $p\bar{p}$ central collisions

- PWA of $J/\psi \to \gamma\phi\phi$ at BESⅢ (for M($\phi\phi$) < 2.7 GeV/c^2)

1.3 billion J/ψ events;   arXiv:1602.01523

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

1.3 billion J/ψ events;   arXiv:1602.01523

(a)

(f)
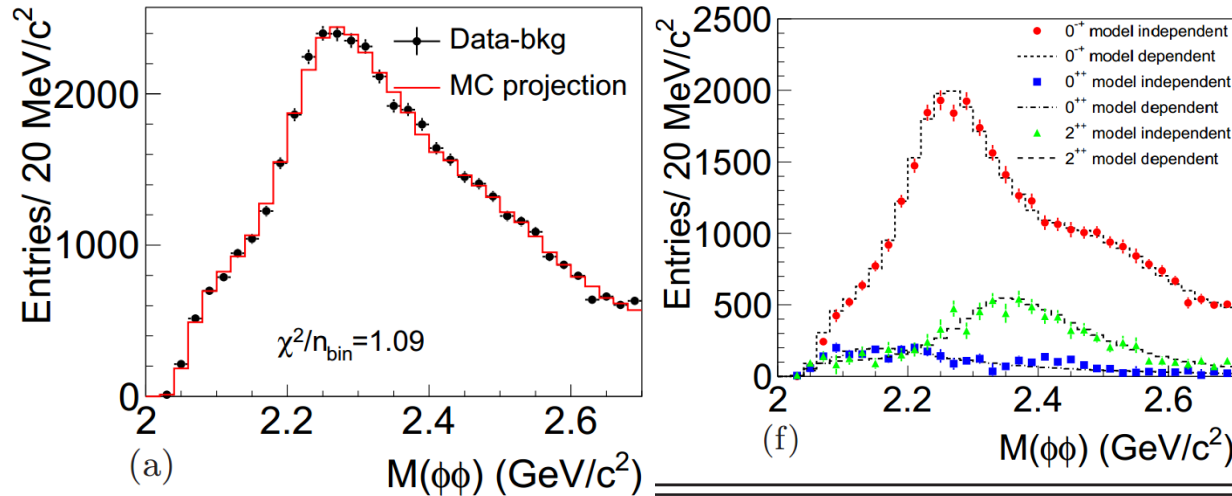
Comparison:
Lines: model dependent fit
Markers: model independent fit

- 0^{-+} dominant

- Also has scalar and tensor components

	Resonance	M(MeV/c^2)	Γ(MeV/c^2)	B.F.($\times 10^{-4}$)	Sig.
0^{-+}	$\eta(2225)$	2216^{+4+21}_{-5-11}	185^{+12+43}_{-14-17}	$(2.40 \pm 0.10^{+2.47}_{-0.18})$	$28\,\sigma$
	$\eta(2100)$	2050^{+30+75}_{-24-26}	$250^{+36+181}_{-30-164}$	$(3.30 \pm 0.09^{+0.18}_{-3.04})$	$22\,\sigma$
	X(2500)	$2470^{+15+101}_{-19-23}$	230^{+64+56}_{-35-33}	$(0.17 \pm 0.02^{+0.02}_{-0.08})$	$8.8\,\sigma$
0^{++}	$f_0(2100)$	2101	224	$(0.43 \pm 0.04^{+0.24}_{-0.03})$	$24\,\sigma$
2^{++}	$f_2(2010)$	2011	202	$(0.35 \pm 0.05^{+0.28}_{-0.15})$	$9.5\,\sigma$
	$f_2(2300)$	2297	149	$(0.44 \pm 0.07^{+0.09}_{-0.15})$	$6.4\,\sigma$
	$f_2(2340)$	2339	319	$(1.91 \pm 0.07^{+0.72}_{-0.73})$	$11\,\sigma$
0^{-+} PHSP				$(2.74 \pm 0.15^{+0.16}_{-1.48})$	$6.8\,\sigma$

Summary

➢ Recent results on J/ψ radiative decays are presented:

1. Spin-parity of the X(1835) is determined to be 0^{-+} in $J/\psi \to \gamma K_S K_S \eta$

2. Observation of the X(1840) in $J/\psi \to \gamma 3(\pi^+\pi^-)$

3. PWA of $J/\psi \to \gamma \pi^0 \pi^0$ is performed:
   0^{++} dominated, also includes 2^{++} components

4. PWA of $J/\psi \to \gamma \phi\phi$ is performed:
   0^{-+} dominated, also includes 0^{++} and 2^{++}

➢ More results are expected to come soon!

Thank you!