Highlights from BESIII

Yaqian Wang

Johannes Gutenberg University
Mainz, Germany

14th International Conference on B-Physics at Hadron Machines
8-12th April, Bologna

BESIII Experiment

BEPC II Storage Ring

Beam energy:
  1.0-2.3 GeV

Design luminosity: 65% achieved
  1×10^{33} cm^{-2}s^{-1}

Optimum energy:
  1.89 GeV

Energy spread:
 5.16 $\times 10^{-4}$

No. of bunches:
  93

Bunch length:
  1.5 cm

Total current:
  0.91 A

Circumference :
  237 m

RF   SR   RF

double ring

8 ns
2.5m

22 mrad

0.1 cm

1.5 cm

IP

The BESIII Detector

Magnet yoke

SC magnet, 1T

RPC

TOF, 90ps

Be beam pipe

MDC, 120 μm

A total weight of 730t, ~40000 readout channels, data rate 6000Hz ~50Mb/s, ~1000 man*year, 30 M$

CsI(Tl) calorimeter, 2.5 %@ 1 GeV
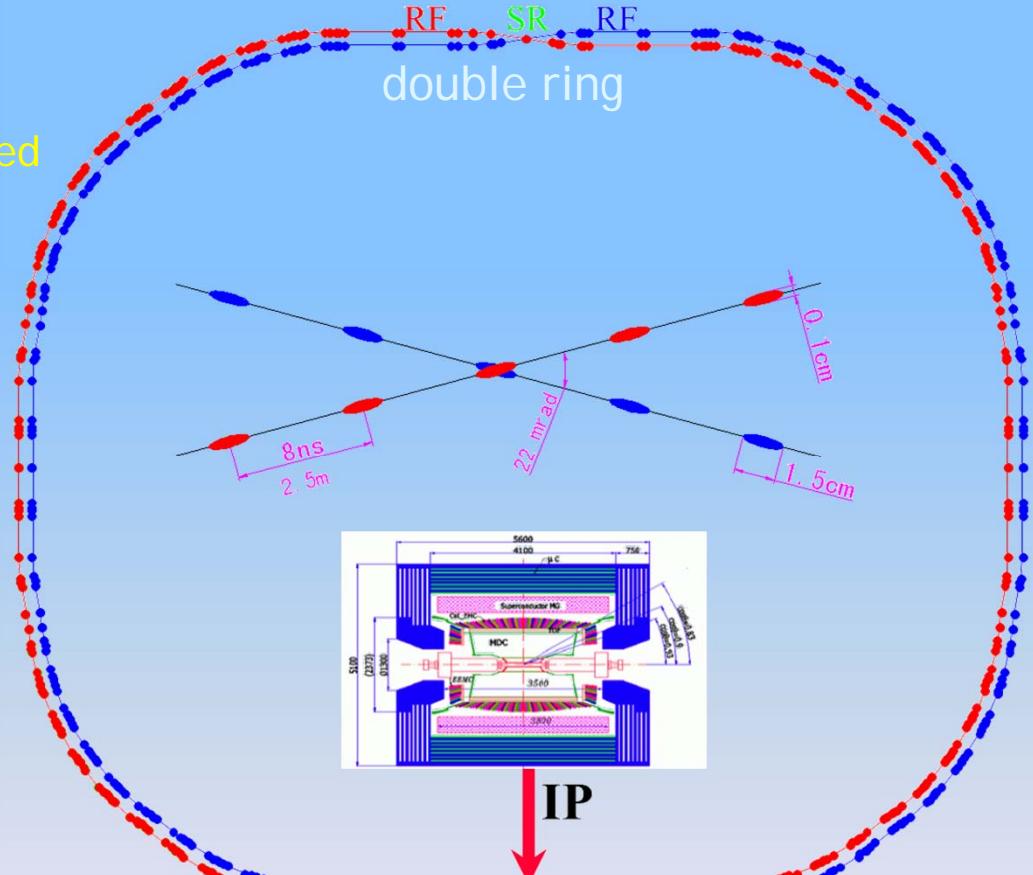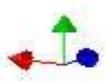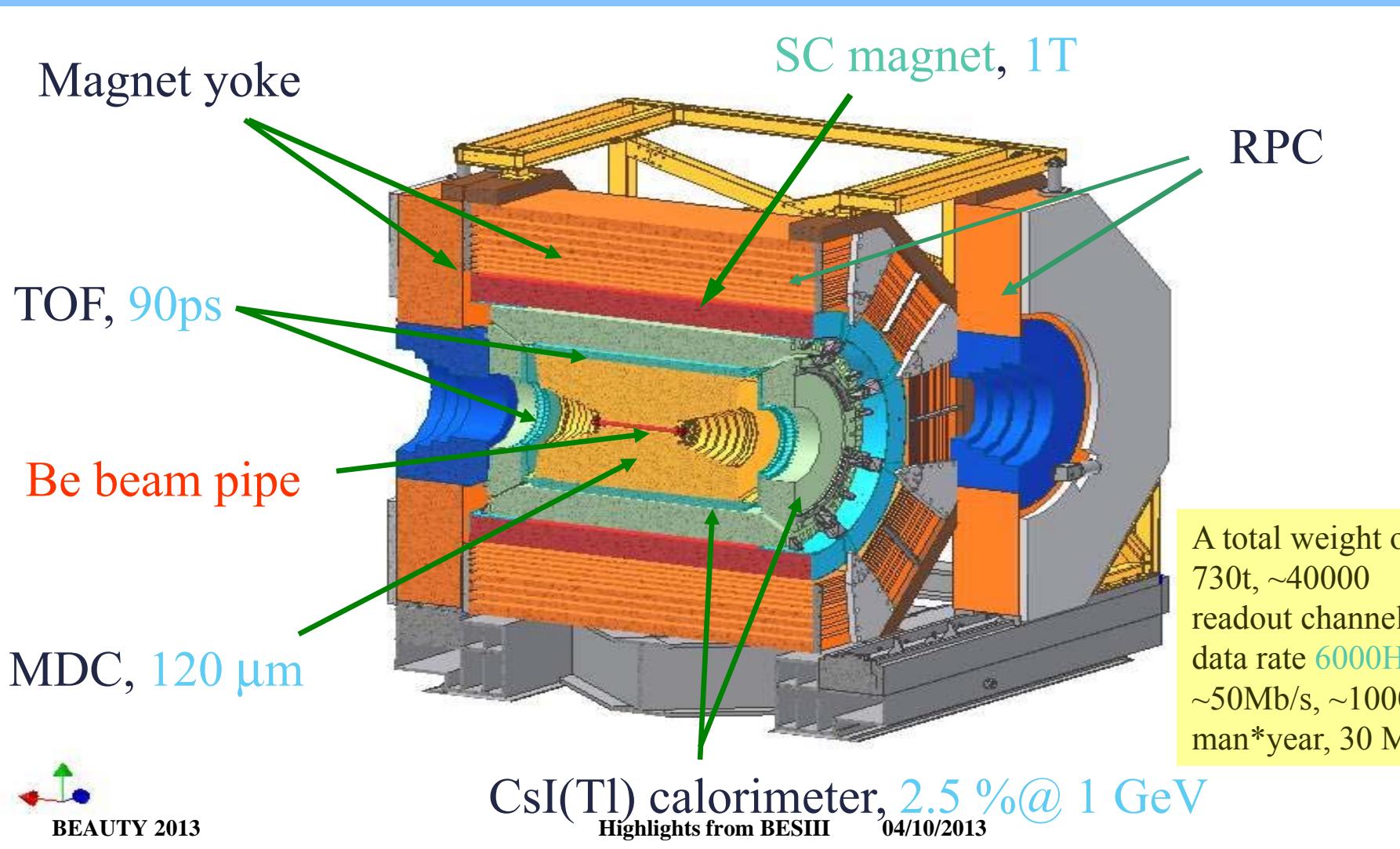
BESIII Collaboration

Political Map of the World, June 1999

Europe (12)

US (6)

Univ. of Hawaii
Univ. of Washington
Carnegie Mellon Univ.
Univ. of Minnesota
 Univ. of Rochester
Univ. of Indiana

Germany: Univ. of Bochum,
Univ. of Giessen, GSI
Johannes Gutenberg Univ.
Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Frascati Lab
Netherland：KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

China(30)

IHEP, CCAST, GUCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ.,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.

~360 members
52 institutions from 11 countries

Data Samples

~500 pb^{-1}

~500 pb^{-1}

~500 pb^{-1}

~2.9 fb^{-1}

106 M +

225 M +

2013

2009

Physics Program @ BESIII

Light hadron physics

- meson & baryon spectroscopy
- multiquark states
- threshold effects
- glueballs & hybrids
- two-photon physics
- p & n form-factors

Charmonium physics:

- precision spectroscopy
- transitions and decays

QCD & τ-physics:

- precision R-measurement
- τ decays

Charm physics:

- semi-leptonic form factors
- f_D & f_{D_s} decay constants.
- CKM matrix: V_{cd}, V_{cs}
- D^0-D^0 mixing and CPV
- strong phases

XYZ meson physics:

- Y(4260)$\rightarrow\pi\pi$J/ψ & other decays
- searches for new states …

Recent Results on Light Hadron Physics

- PWA of $J/\psi \rightarrow \gamma\eta\eta$
- PWA of $J/\psi \rightarrow \gamma\omega\phi$

PWA of J/ψ→γηη

- Search for glueballs, hybrids and multi-quarks

- LQCD: the lowest mass glueball with 0^{++} is in the mass region from 1.5-1.7 GeV

- Difficulty: mixing with $q\bar{q}$ nonet mesons

- Radiative J/ψ decay is a gluon-rich process

- J/ψ radiative decay to two pseudoscalar mesons offers a very clean laboratory to search for **scalar** and **tensor** glueballs

$\chi^2/N_{bin}=1.72$

(a)

Clear peak

f$_2$(1910)?
f$_2$(1950)?

f$_2$(2300)?

~1 order larger than f$_0$(1500)

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}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	$8.2\,\sigma$
$f_0(1710)$	$1759\pm6^{+14}_{-25}$	$172\pm10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	$25.0\,\sigma$
$f_0(2100)$	$2081\pm13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$	$13.9\,\sigma$
$f'_2(1525)$	$1513\pm5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	$11.0\,\sigma$
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	$6.4\,\sigma$
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	$7.6\,\sigma$

PWA of J/ψ→γωφ

- X(1810) was observed in $J/\psi \to \gamma\omega\phi$ by BESII [PRL96,162002]

- PWA: 0^{++} favors ($>30\sigma$)

- doubly OZI suppressed process

- Possible interpretations: a tetraquark state, a hybrid, or a glueball state, a dynamical effect arising from intermediate meson rescattering, or a threshold cusp of an attracting resonance.


PRD 87, 032008 (2013)
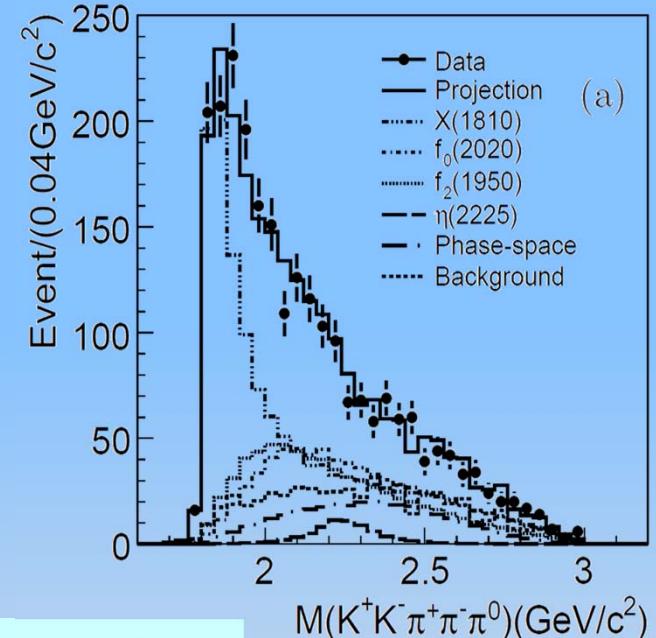
Resonance	J^{PC}	$M(\text{MeV}/c^2)$	$\Gamma(\text{MeV}/c^2)$	Events	$\Delta\mathcal{S}$	Δndf	Significance
X(1810)	0^{++}	1795 ± 7	95 ± 10	1319 ± 52	783	4	$>30\sigma$
$f_2(1950)$	2^{++}	1944	472	665 ± 40	211	2	20.4σ
$f_0(2020)$	0^{++}	1992	442	715 ± 45	100	2	13.9σ
$\eta(2225)$	0^{-+}	2226	185	70 ± 30	23	2	6.4σ
Coherent nonresonant component	0^{-+}	$\cdots$	$\cdots$	319 ± 24	45	2	9.1σ

Charmonium Spectroscopy

- First observation of $\psi' \rightarrow \gamma\eta_c'$
- Properties of h_c

- Mass and width of η_c
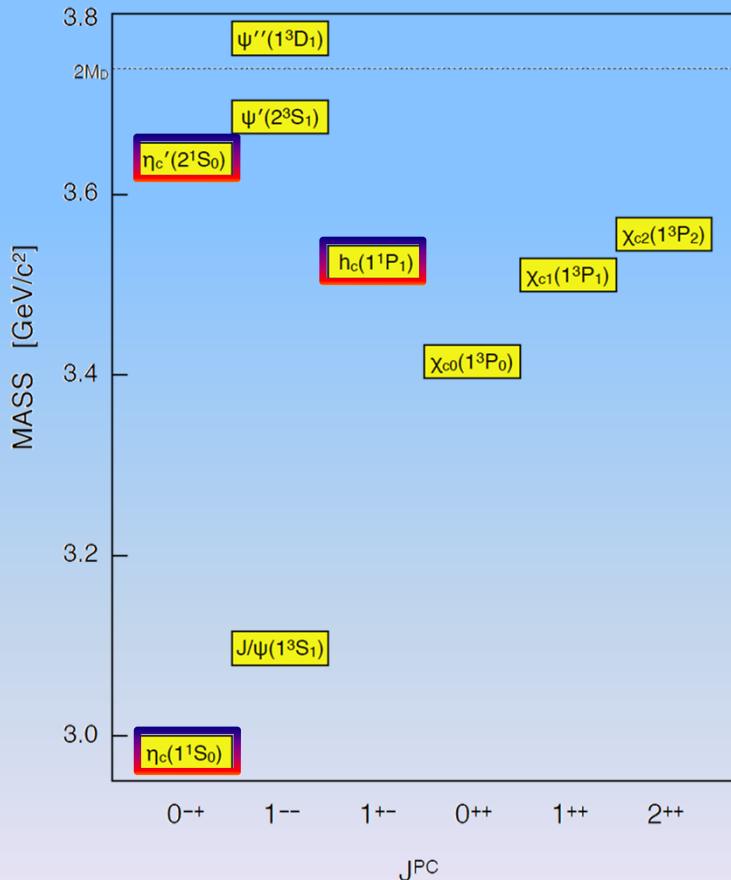
$\eta_c(1S)$

- The S-wave spin-singlet charmonium ground state, found in 1980

- Mass and width measurements:

  -J/ψ radiative transitions: $M \sim 2978.0$ MeV, $\Gamma \sim 10$ MeV

 -$\gamma\gamma$ processes / B$\rightarrow$Kη_c: $M = 2983.1 \pm 1.0$ MeV/, $\Gamma = 31.3 \pm 1.9$ MeV

- $\gamma\gamma$, $p\bar{p}$, B decay

- ψ(1S, 2S)$\rightarrow\gamma\eta_c$

Mass

			χ^2
AUBERT	08AB	BABR	2.4
UEHARA	08	BELL	4.3
ABE	07	BELL	
WU	06	BELL	6.9
WU	06	BELL	0.8
ASNER	04	CLEO	0.4
AUBERT	04D	BABR	2.0
AMBROGIANI	03	E835	2.4
BAI	03	BES	3.7
FANG	03	BELL	0.1
BAI	00F	BES	2.6
BAI	90B	MRK3	4.1
GAISER	86	CBAL	0.6
			30.4

(Confidence Level = 0.0014)

$\eta_c(1S)$ mass (MeV)

C.L.=0.0014

width

			χ^2
AUBERT	08AB	BABR	2.5
UEHARA	08	BELL	0.0
WU	06	BELL	5.7
WU	06	BELL	
ASNER	04	CLEO	0.3
AUBERT	04D	BABR	7.8
AMBROGIANI	03	E835	0.8
BAI	03	BES	1.6
FANG	03	BELL	0.0
BAI	00F	BES	3.3
ARMSTRONG	95F	E760	0.1
BAGLIN	87B	SPEC	7.4
BALTRUSAIT...	86	MRK3	
GAISER	86	CBAL	12.5
			42.0

(Confidence Level < 0.0001)

$\eta_c(1S)$ WIDTH

C.L.<0.0001

ψ' → ɣη_c , η_c → Exclusive Decays

Interference with non-resonant background is significant!!

Relative phase φ values from each mode are consistent within 3σ,

➔ *common phase in the simultaneous fit.*

M: **2984.3 ± 0.6 ± 0.6** MeV/c²

Γ: **32.0 ± 1.2 ± 1.0** MeV

φ: **2.40 ± 0.07 ± 0.08** rad

First Observation of $\psi' \to \gamma \eta_c'$

PRL 109, 042003 (2012)
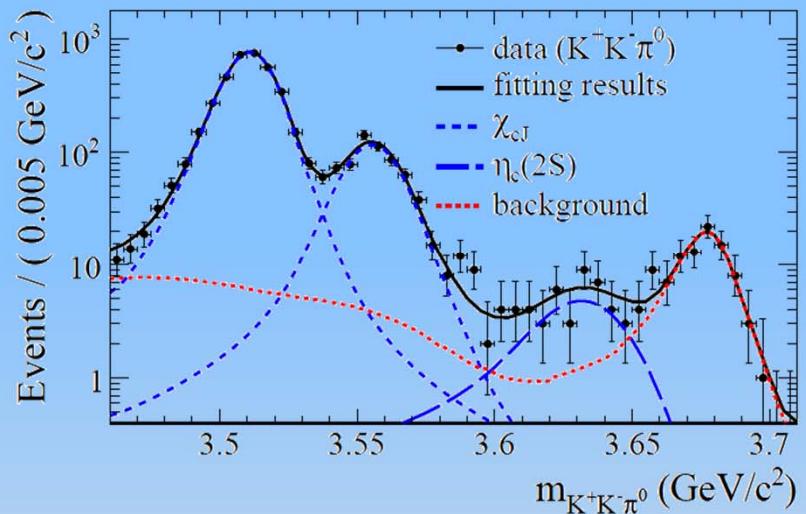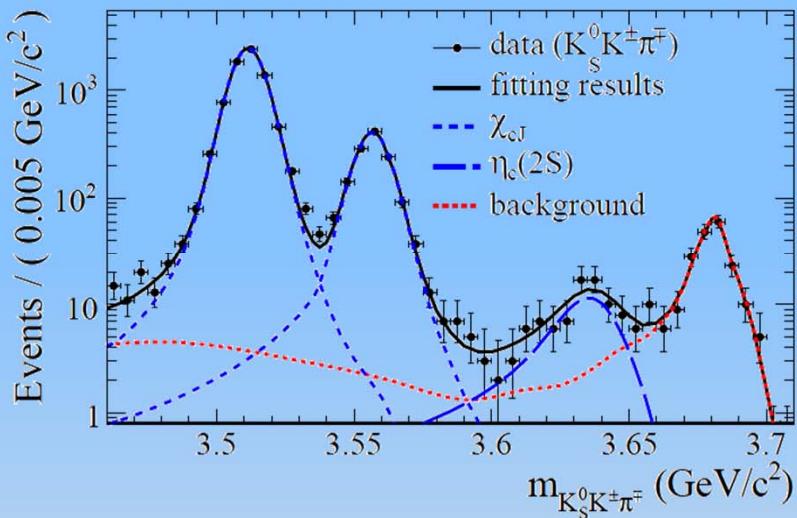
$M(\eta_c') = 3637.6 \pm 2.9 \pm 1.6$ MeV/c^2

$\Gamma(\eta_c') = 16.9 \pm 6.4 \pm 4.8$ MeV

$B(\psi' \to \gamma \eta_c' \to \gamma KK\pi) = (1.30 \pm 0.20 \pm 0.30) \times 10^{-5}$

With $B(\eta_c' \to KK\pi) = (1.9 \pm 0.4 \pm 1.1)\%$ BaBar

$B(\psi' \to \gamma \eta_c') = (6.8 \pm 1.1 \pm 4.5) \times 10^{-4}$

Potential models: $(0.1 \sim 6.2) \times 10^{-4}$

CLEO-c: $< 7.6 \times 10^{-4}$ [PRD 81, 052002 (2010)]

Charm Physics (Preliminary)

- $D^+ \to \mu^+ \, \nu$
- $D^0 \to K^- \, / \, \pi^- \, e^+ \, \nu$

$D \to \mu\nu$ (BESIII: 2.9 fb^{-1})

- Tag side reconstruction:
  - ✓ 9 decay modes
  - ✓ Kinematic variables:
    - ➤ $\Delta E \equiv E_D - E_{beam}$
    - ➤ $M_{bc} \equiv \sqrt{E^2_{beam} - P^2_D}$
  - ✓ (1.57±0.2) M tags found

Beam-constrained mass of tag D
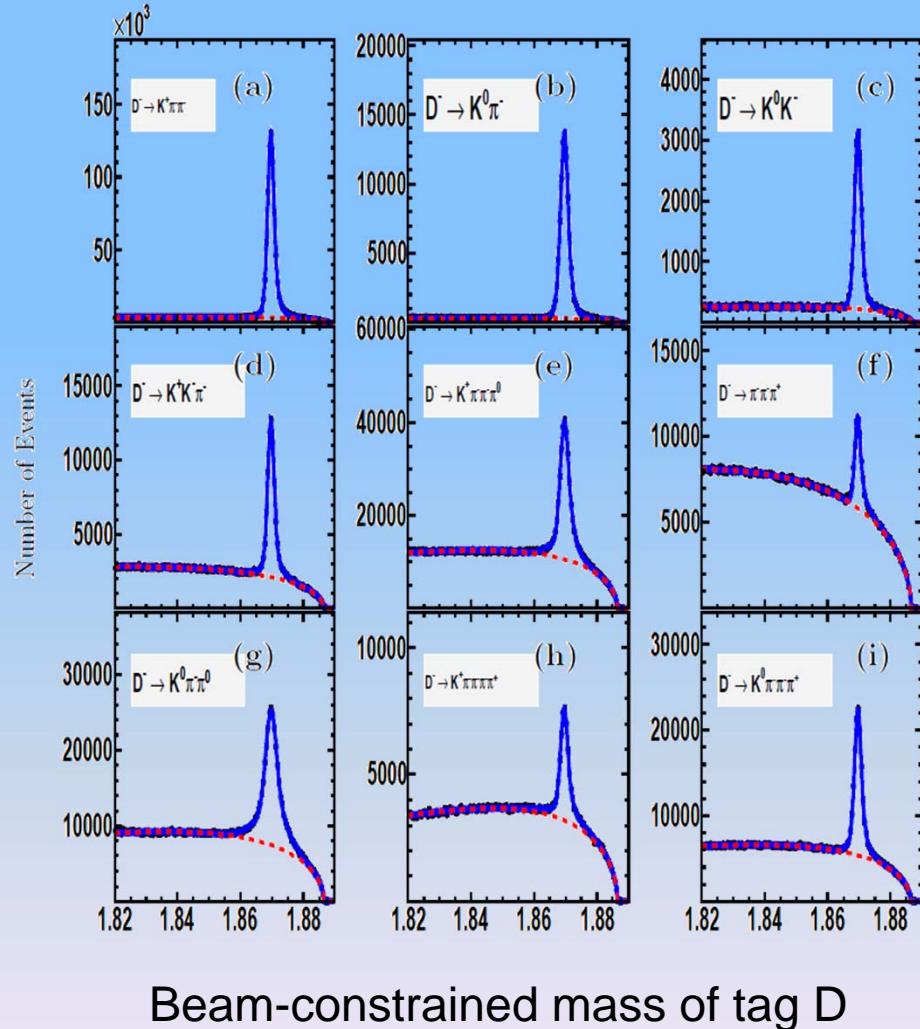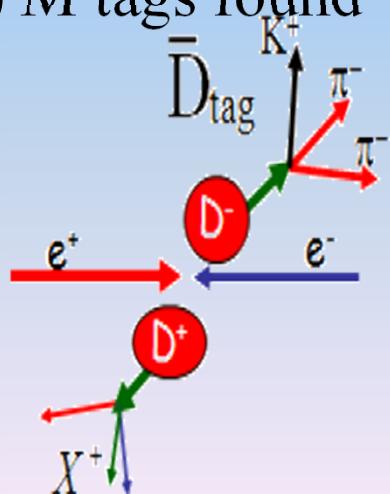
$D \rightarrow \mu\nu$ (BESIII: 2.9 fb^{-1})

- Signal side reconstruction:
  - ✓ One charged track only
  - ✓ Kinematic variable:

$$M_{miss}^2 = \left(E_{Beam} - E_\mu\right)^2 - \left(-\vec{p}_{tag} - \vec{p}_\mu\right)^2 \approx 0$$

- 425 candidates
  BES III preliminary:

  $N(D^+ \rightarrow \mu^+\nu) = 377.3 \pm 20.6$
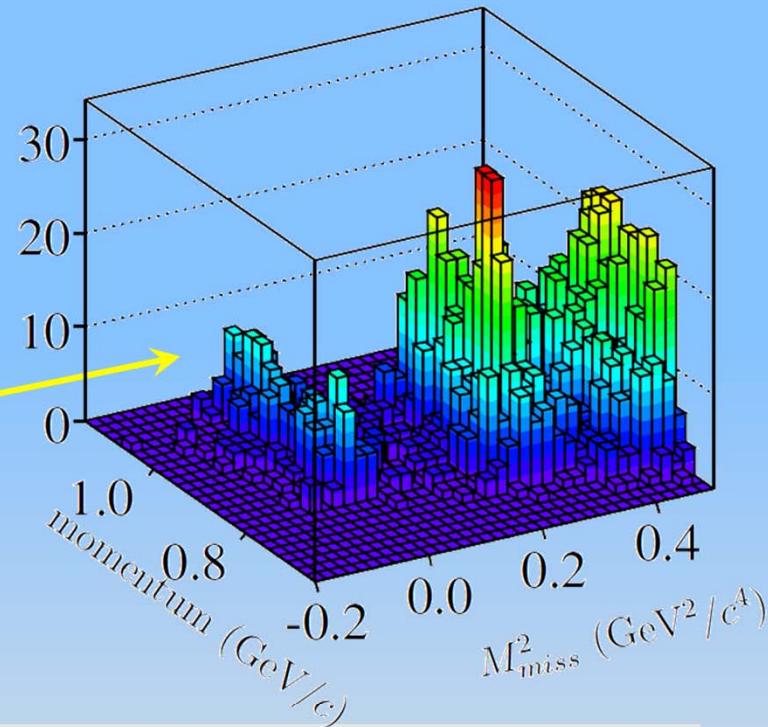
Experiment	$\mathcal{B}(D \rightarrow \mu\nu)$	f_d
BES III (preliminary)	$(3.74 \pm 0.21 \pm 0.06) \times 10^{-4}$	$(203.91 \pm 5.72 \pm 1.97)$ MeV
CLEO-c	$(3.82 \pm 0.32 \pm 0.09) \times 10^{-4}$	$(205.8 \pm 8.5 \pm 2.5)$ MeV
Average	$(3.76 \pm 0.18) \times 10^{-4}$	(204.5 ± 5.0) MeV

The error is still dominated by statistics, more data at threshold is needed.

$D^0 \to K/\pi\, e^+\nu$

- "Partially blind" analysis (0.9 fb^{-1} analyzed so far. Full 2.9 fb^{-1} later for final results)
- Tag side reconstruction:
  - ✓ 4 decay modes
  - ✓ 0.77 M tags found
- Signal side reconstruction:
  - ✓ two oppositely-charged tracks
  - ✓ Kinematic variable: $U = E_{miss} - |\vec{P}_{miss}| \approx 0$
- Systematic uncertainties are preliminary
- Good consistency with CLEO-c, statistical precision is comparable with only 1/3 data analyzed

BESIII Preliminary

$D^0 \to K\, e\, \nu$

$N_{sig} = 18460 +/- 143$

BESIII Preliminary

$D^0 \to \pi\, e\, \nu$

$N_{sig} = 1677 +/- 45$
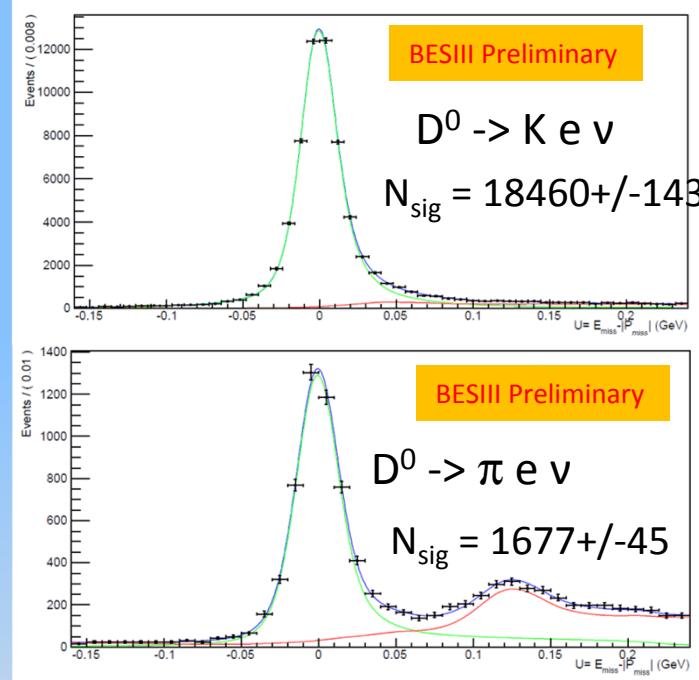
Mode	measured branching fraction(%)	PDG	CLEOc
$\bar{D}^0 \to K^+ e^- \bar{\nu}$	$3.542 \pm 0.030 \pm 0.067$	3.55 ± 0.04	$3.50 \pm 0.03 \pm 0.04$
$\bar{D}^0 \to \pi^+ e^- \bar{\nu}$	$0.288 \pm 0.008 \pm 0.005$	0.289 ± 0.008	$0.288 \pm 0.008 \pm 0.003$

Studies of XYZ at BESIII

- $e^+e^- \rightarrow \eta J/\psi$ @$\sqrt{s}$=4.009 GeV
- $e^+e^- \rightarrow \pi\pi J/\psi$ @$\sqrt{s}$=4.26 GeV

e⁺e⁻→η/π⁰J/ψ@4.01GeV

- First observation: $e^+e^- \to \eta J/\psi$
  (significance $> 10\sigma$)

- Measured Born cross section:
  $(32.1 \pm 2.8 \pm 1.3)$ pb

- Assume $\eta/\pi^0 J/\psi$ from $\psi(4040)$:
  $Br(\psi(4040) \to \eta J/\psi) = (5.2 \pm 0.5 \pm 0.2 \pm 0.5) \times 10^{-3}$
  $Br(\psi(4040) \to \pi^0 J/\psi) < 2.8 \times 10^{-4}$ @90% CL

- Consistent with the theoretical calculation (Q.Wang et al., arXiv:1206.4511)

- Partial width of $\psi(4040) \to \eta J/\psi$: ~400keV (> two times $\psi(4040) \to \pi^+\pi^- J/\psi$)
  - ✓ Similar to the hadronic transition of Y(4S)
    (admixture of a four-quark state in the wave function
    M. B. Voloshin, Mod. Phys. Lett. A 26, 773 (2011))

$e^+e^- \rightarrow \pi^+\pi^- J/\psi$ @ 4.26 GeV
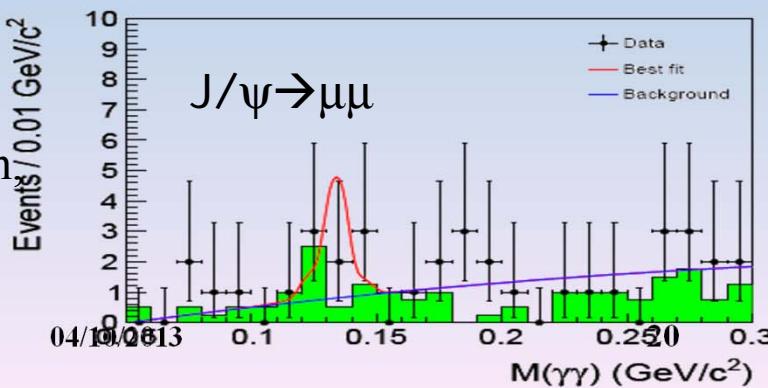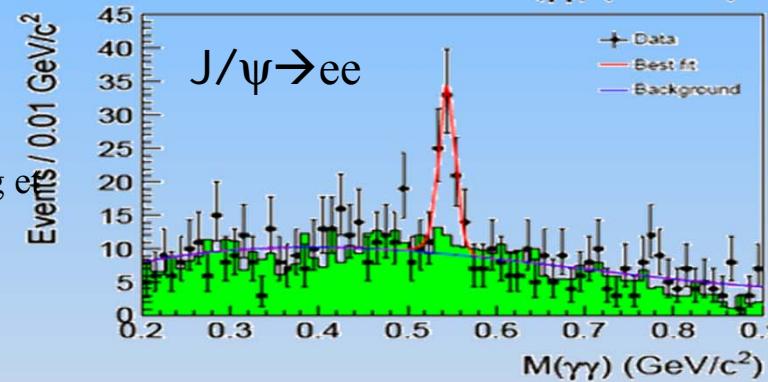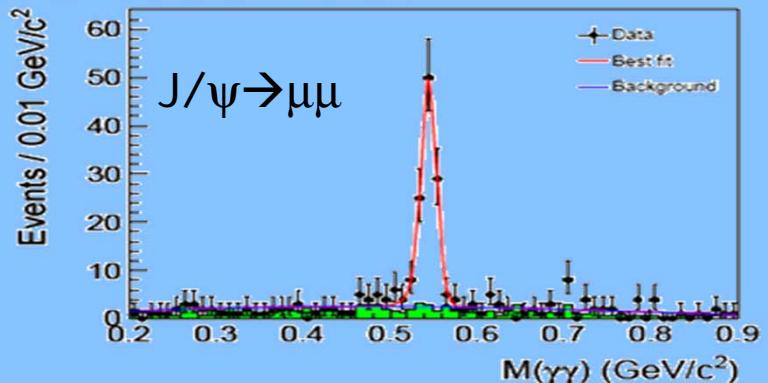
Belle: PRL99, 182004 (2007)

BaBar: PRD86, 051102 (2012)
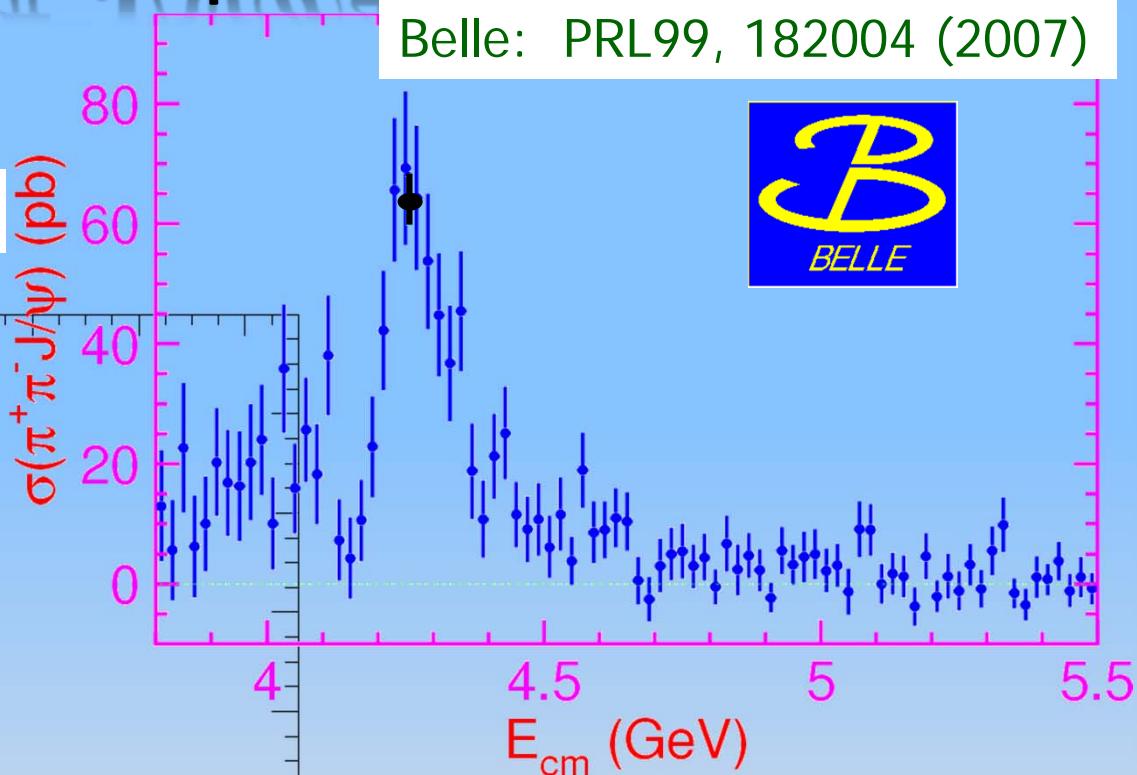
BESIII: $\sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)$
= (62.9±1.9±3.7) pb
Agree with BaBar & Belle!
Best precision!

BESIII: arXiv:1303.5949

# Dalitz Plots & 1D Projections

The $Z_c(3900)$ Signal

Significance>8σ

$\chi^2/\text{ndf}=32.6/37$

Data
Total fit
Background fit
PHSP MC
Sideband

307 ±48 events
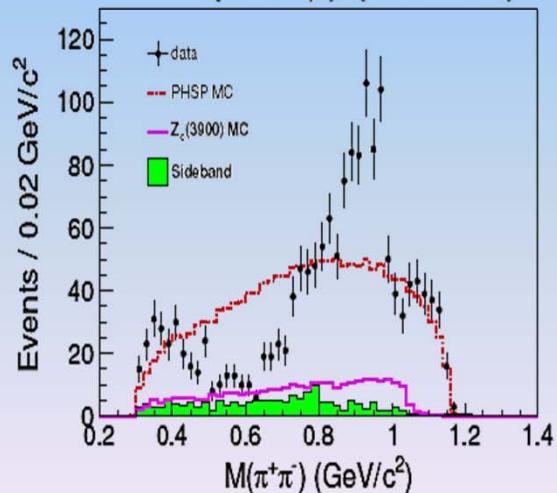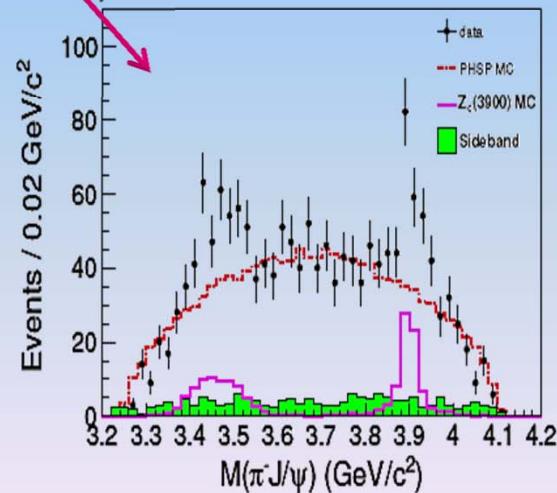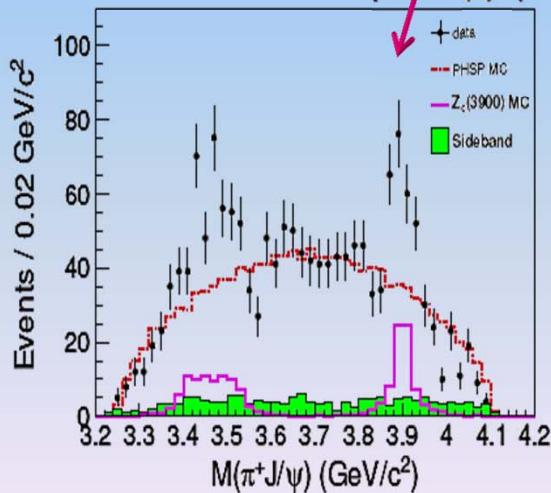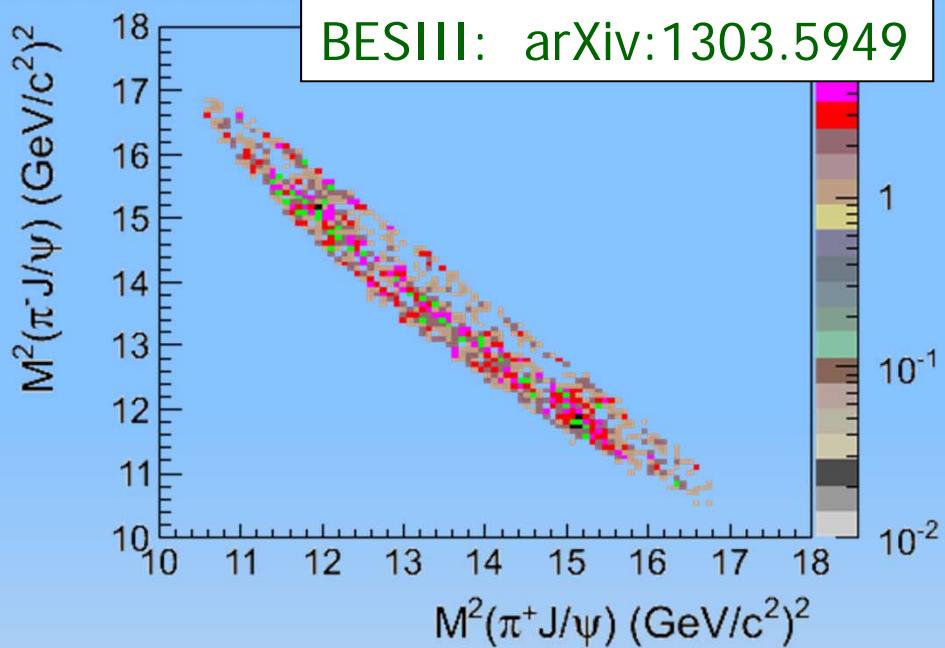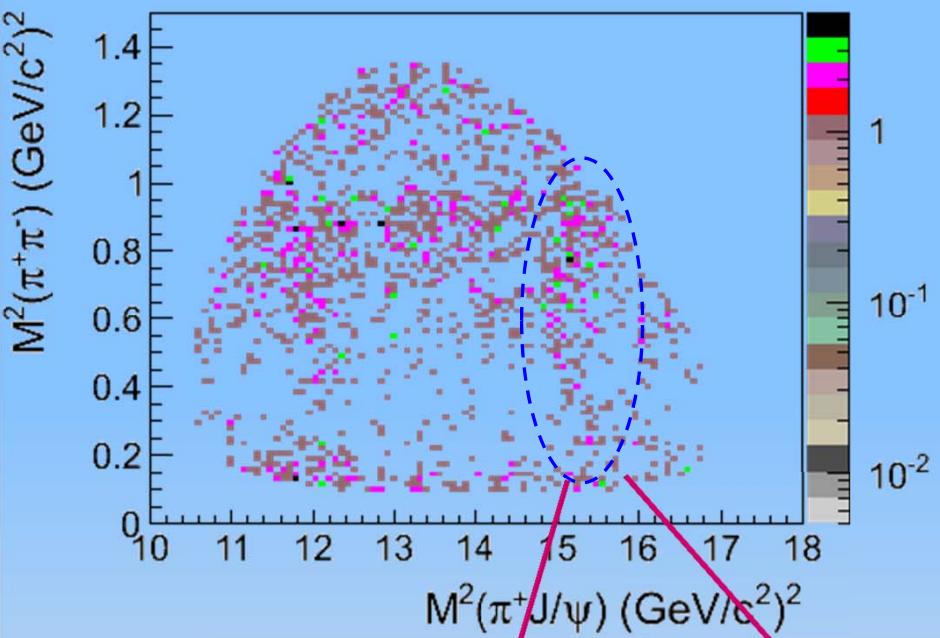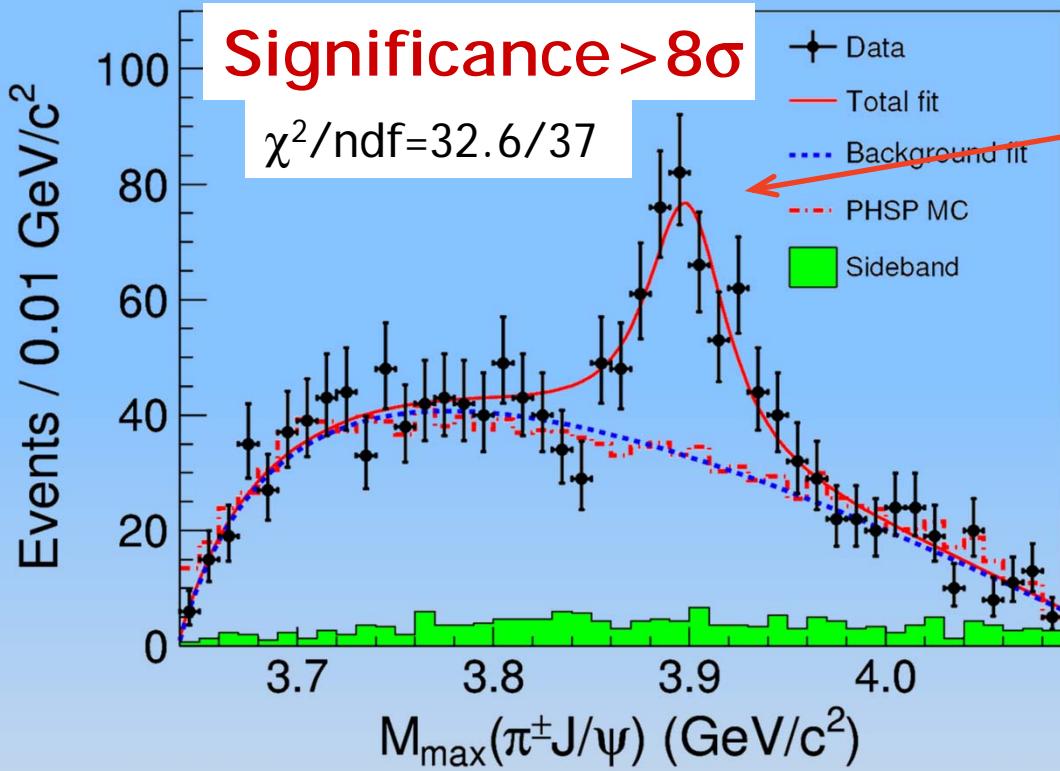
- Couples to $\bar{c}c$
- Has electric charge
- At least 4-quarks
- What is its nature?

(vertical axis) Events / 0.01 GeV/c²

(horizontal axis) $M_{max}(\pi^\pm J/\psi)$ (GeV/c²)
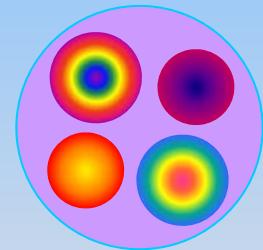
➤ S-wave Breit-Wigner with efficiency correction
➤ Mass = (3899.0±3.6±4.9) MeV
➤ Width = (46±10±20) MeV
➤ Fraction = (21.5±3.3±7.5)%

Summary

● BEPCII and BESIII are operating in good status.

● PWA results about $\psi' \to \gamma\eta\eta$ and $\psi' \to \gamma\omega\phi$ are reported.

● Mass and width of η_c are precisely measured; $\psi' \to \gamma\eta_c$ is first observed.

● With world's largest sample, precision measurements of f_D, $|V_{cs}|$, and $|V_{cd}|$ are in progress.

● Observation of $Z_c(3900)$ in $e^+e^- \to \pi^+\pi^- J/\psi$ @4.26GeV, more precise measurements are underway.

● With excellent detector and machine, interesting programs of physics are expected!

backup

PWA of J/ψ→γηη
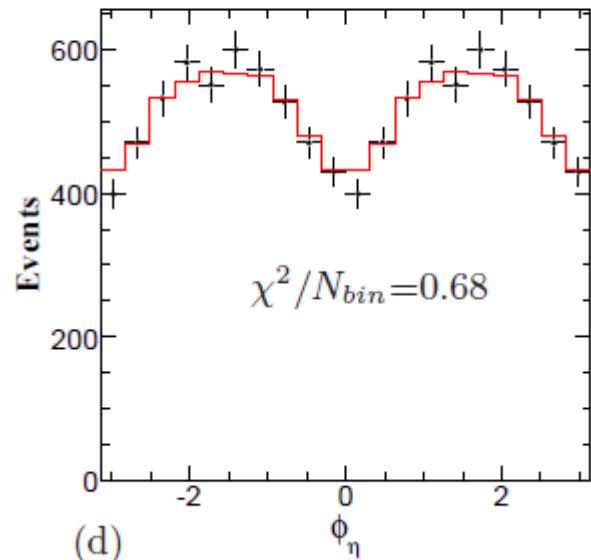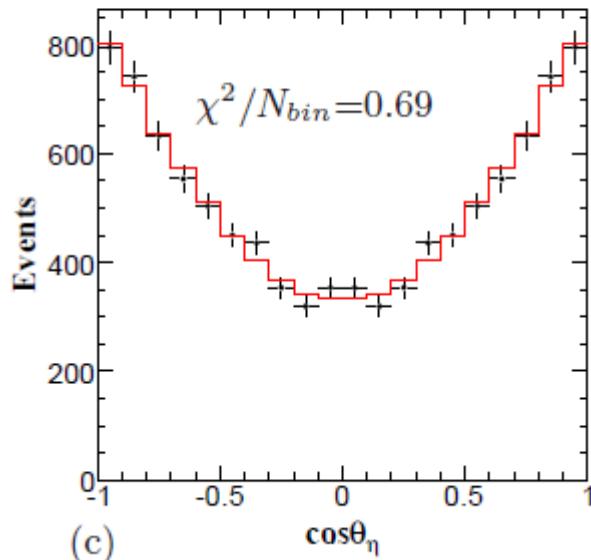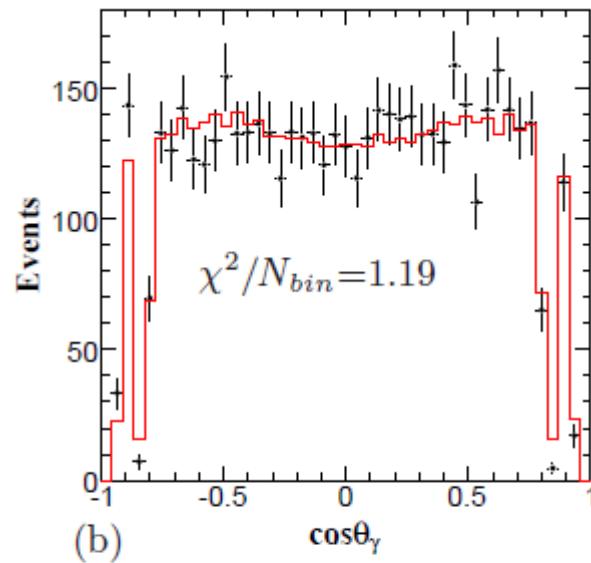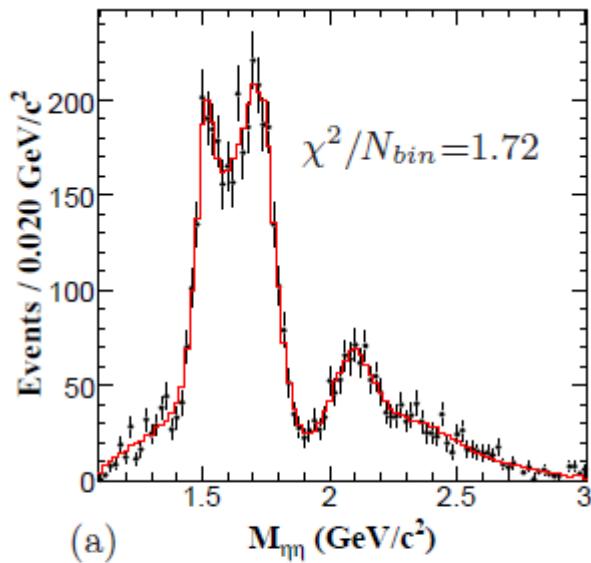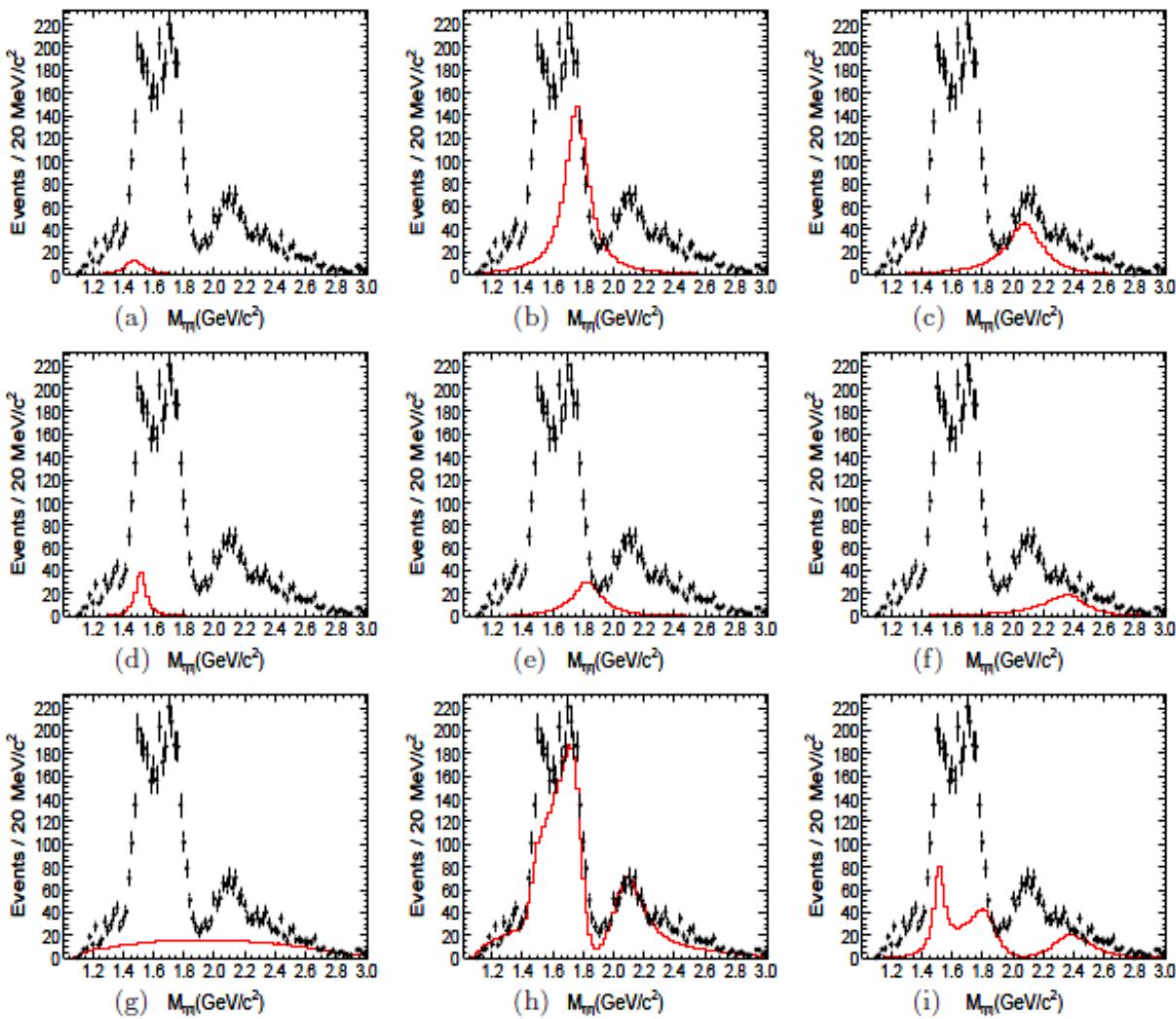
FIG. 3: Contribution of the components. (a) $f_0(1500)$, (b) $f_0(1710)$, (c) $f_0(2100)$, (d) $f_2'(1525)$, (e) $f_2(1810)$, (f) $f_2(2340)$, (g) 0^{++} phase space, (h) total 0^{++} component, and (i) total 2^{++} component. The dots with error bars are data with background subtracted, and the solid histograms are the projection of the PWA.