The measurements of branching fractions for $\eta_c \to \phi\phi$ and $\omega\phi$ at BESIII

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Outline

- Motivation
- BEPCII & BESIII
- Analysis of $\eta_c \rightarrow \phi\phi$ and $\omega\phi$
- Summary

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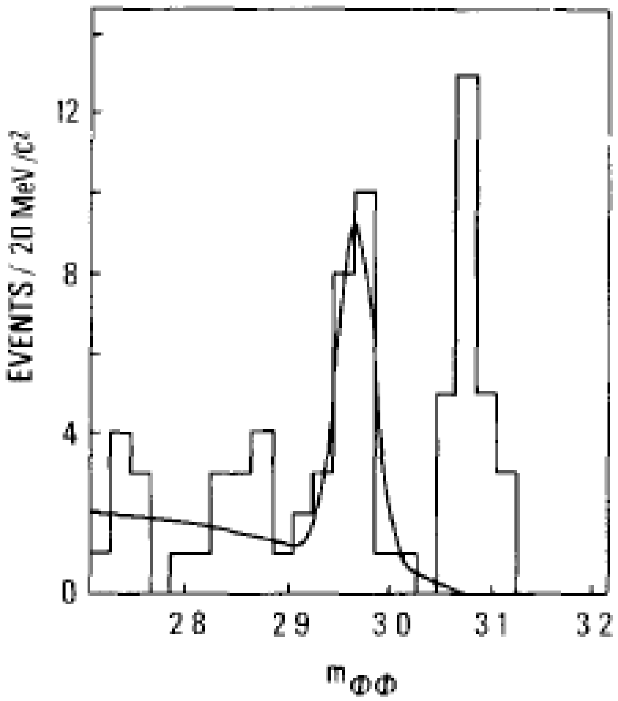
Motivation

- Decays of η_c into vector meson pairs are highly suppressed at leading order in QCD, due to the helicity selection rule (HSR) [1].
- Under HSR, the branching fraction for $\eta_c \to \phi\phi$ was calculated to be $\sim 2\times10^{-7}$[2].
- Improved calculations with next-to-leading order and relativistic corrections in QCD yield varying from 10^{-5}[3] to 10^{-4}[4].
- Some non-perturbative mechanisms have also been phenomenologically investigated[5].

[1] S. J. Brodsky and G. P. Lepage, Phys. Rev. D **24**, 2848(1981).
[2] V. L. Chernyak and A. R. Zhitnitsky, Nucl. Phys. B **201**, 492 (1982); *erratum ibid*. B **214**, 547(E) (1983).
[3] Y. Jia and G. D. Zhao, High Energy Phys. Nucl. Phys. **23**, 765 (1999) (in Chinese).
[4] Peng Sun, Gang Hao and Cong-Feng Qiao, Phys. Lett. B **702**, 49 (2011).
[5] Qian Wang, Xiao-Hai Liu and Qiang Zhao, Phys. Lett. B **711** 364 (2012).

1

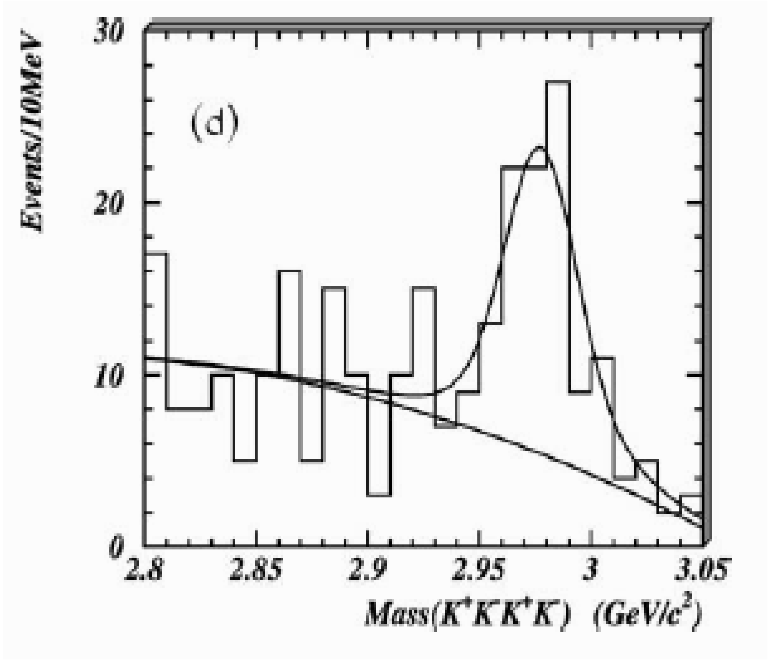
Motivation



DM2 Collaboration, Nucl.Phys.B**350**,1 (1991)

$Br(J/\psi \to \gamma \eta_c) \cdot Br(\eta_c \to \phi\phi) = (3.9 \pm 1.1) \times 10^{-5}$

$Br(\eta_c \to \phi\phi) = (2.3 \pm 0.8) \times 10^{-3}$



BESII Collaboration, PLB**578**, 16 (2004)

$Br(J/\psi \to \gamma \eta_c) \cdot Br(\eta_c \to \phi\phi) = (3.3 \pm 0.8) \times 10^{-5}$

$Br(\eta_c \to \phi\phi) = (1.9 \pm 0.6) \times 10^{-3}$

Both of the two experiments did not observed $\eta_c \to \omega\phi$

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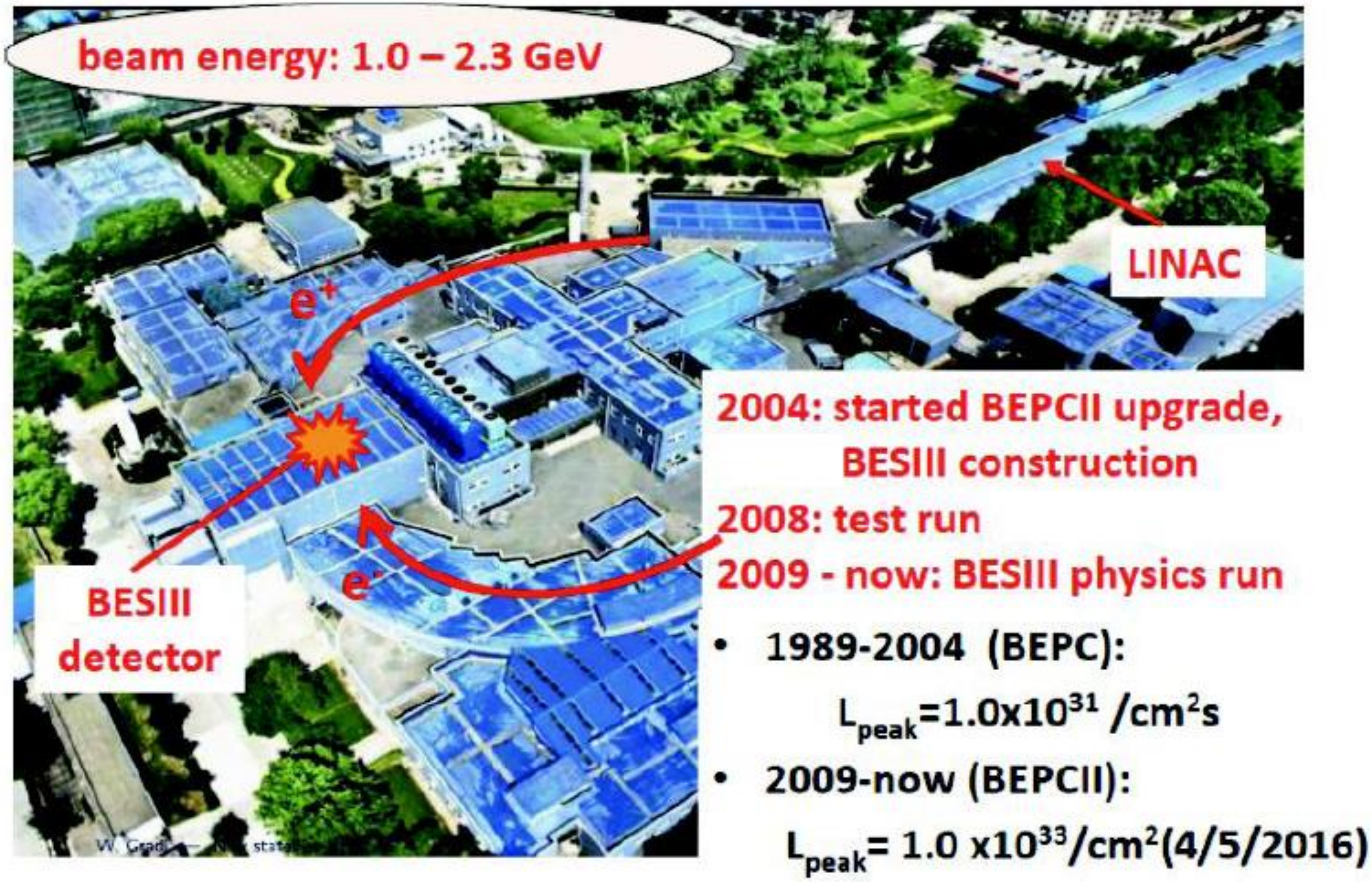
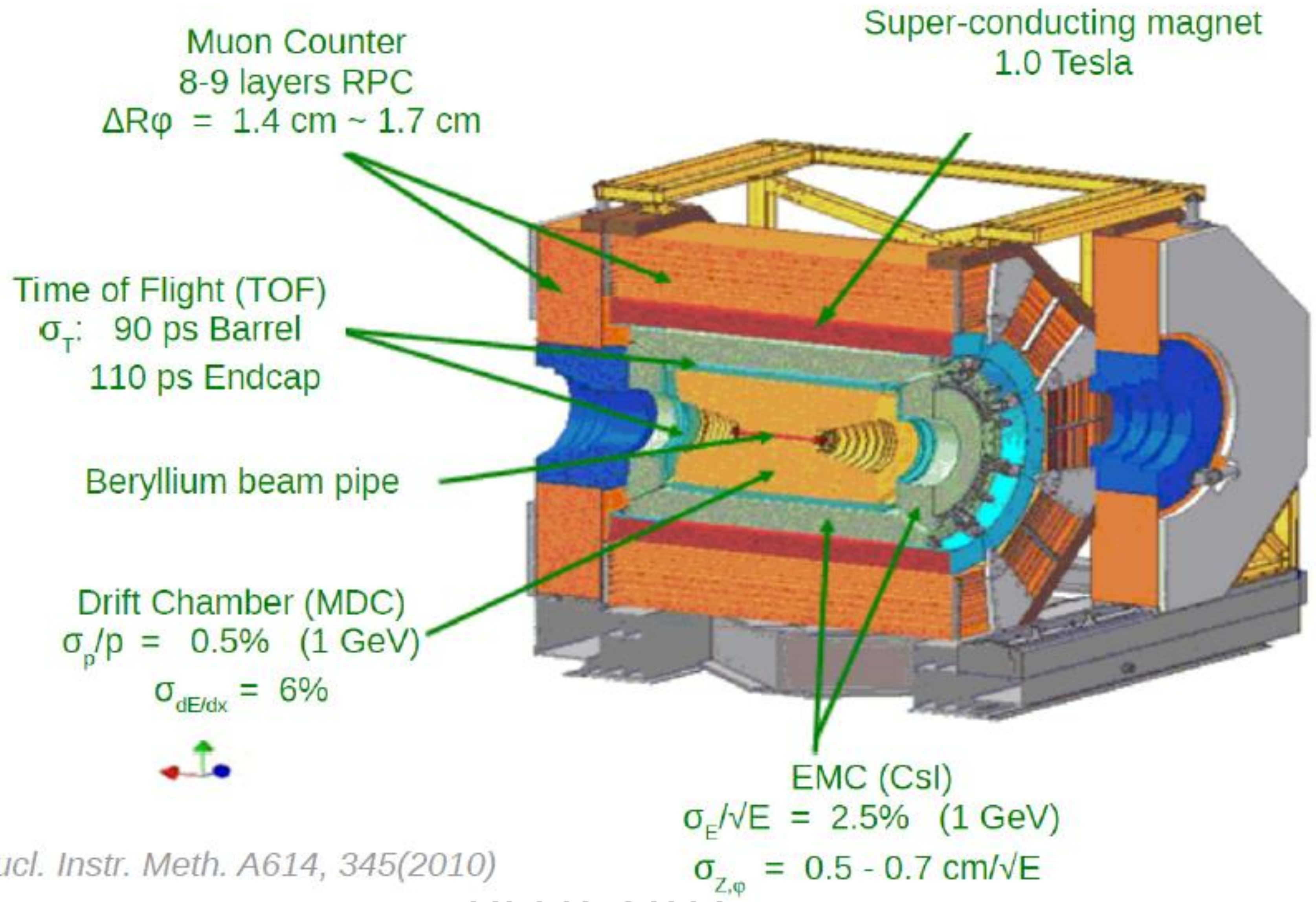
BEPCII&BESIII



2 BEPCII&BESIII



Nucl. Instr. Meth. A614, 345(2010)

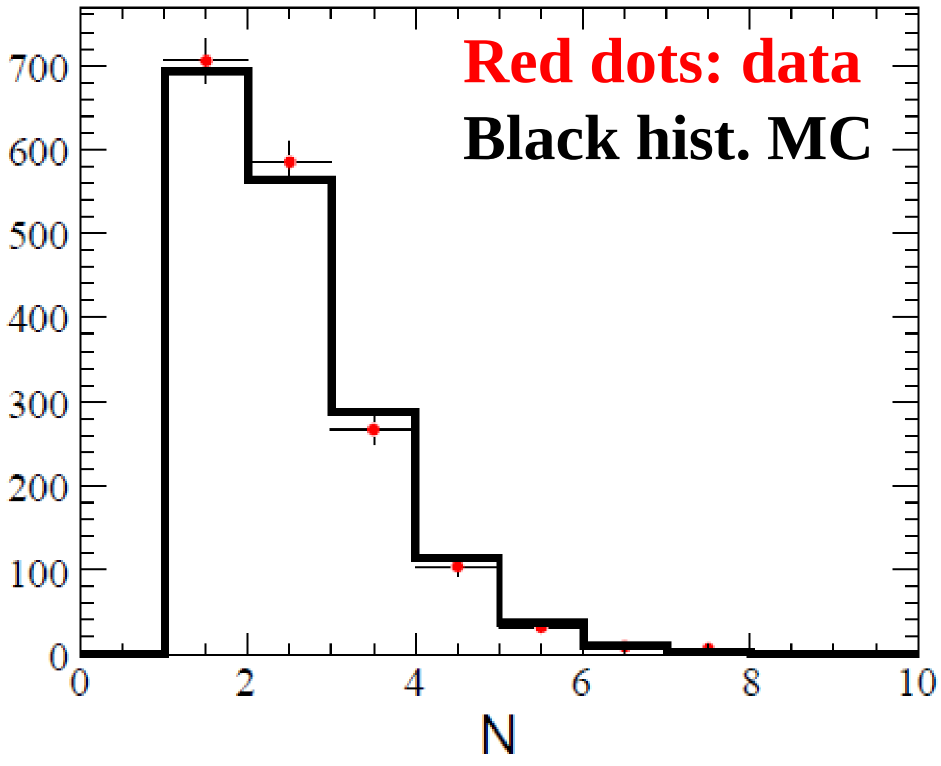
- Data for the analysis: $(223.7 \pm 1.4) \times 10^6$

- Decay chain:

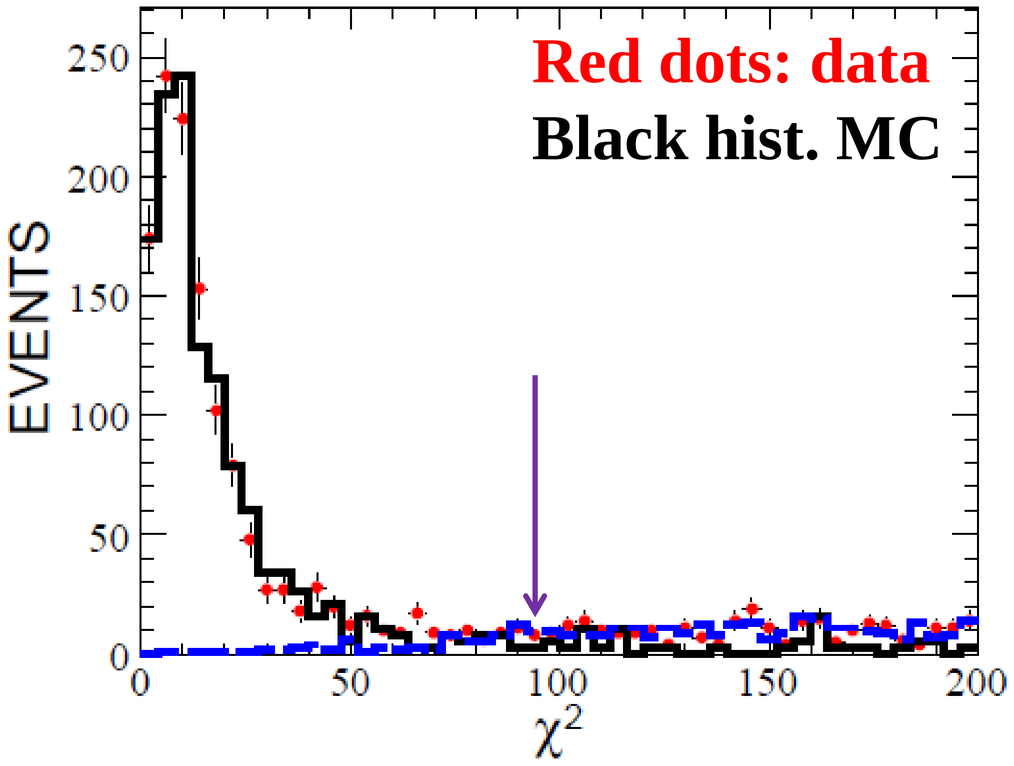
  $J/\psi \to \gamma \eta_c$,

  $\eta_c \to \phi\phi \to K^+K^-K^+K^-$, and $\eta_c \to \omega\phi \to \pi^0\pi^+\pi^-K^+K^-$

$\eta_c \to \phi\phi$

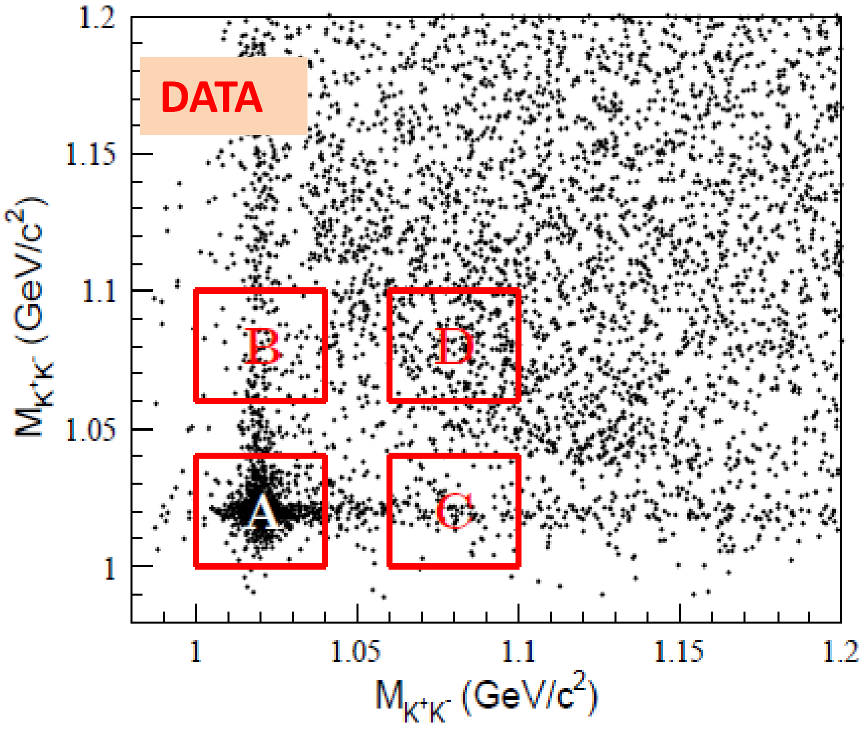


The multiplicity distribution of photons



The χ^2 distribution of kinematic fit

$\eta_c \to \phi\phi$



The signal box A : $|M_{K^+K^-} - M_\phi| \leq 20\text{MeV/c}^2$

Dominant background:
$J/\psi \to \gamma\phi K^+K^-$
$J/\psi \to \gamma K^+K^-K^+K^-$

Peaking background is estimated to be 26 events.

Non-peaking background, such as $J/\psi \to \phi f_1(\pi^0 K^+K^-)$, is estimated to be 75 events.

$\eta_c \to \phi\phi$

The differential cross section is constructed as:

$$\frac{d\sigma}{d\Omega} = \sum_{helicities} \left| A_{\eta c}\left(\lambda_0, \lambda_\gamma, \lambda_1, \lambda_2\right) + \sum_{J^P} A_{NR}^{J^P}\left(\lambda_0, \lambda_\gamma, \lambda_1, \lambda_2\right) \right|^2$$

The likelihood function for observing the *N*-events in data sample:

$$L = \prod_{i=1}^{N} P(x_i)$$

The background contribution to the log-likelihood value is subtracted from that value of data:

$$\ln L = \ln L_{data} - \ln L_{bg}$$

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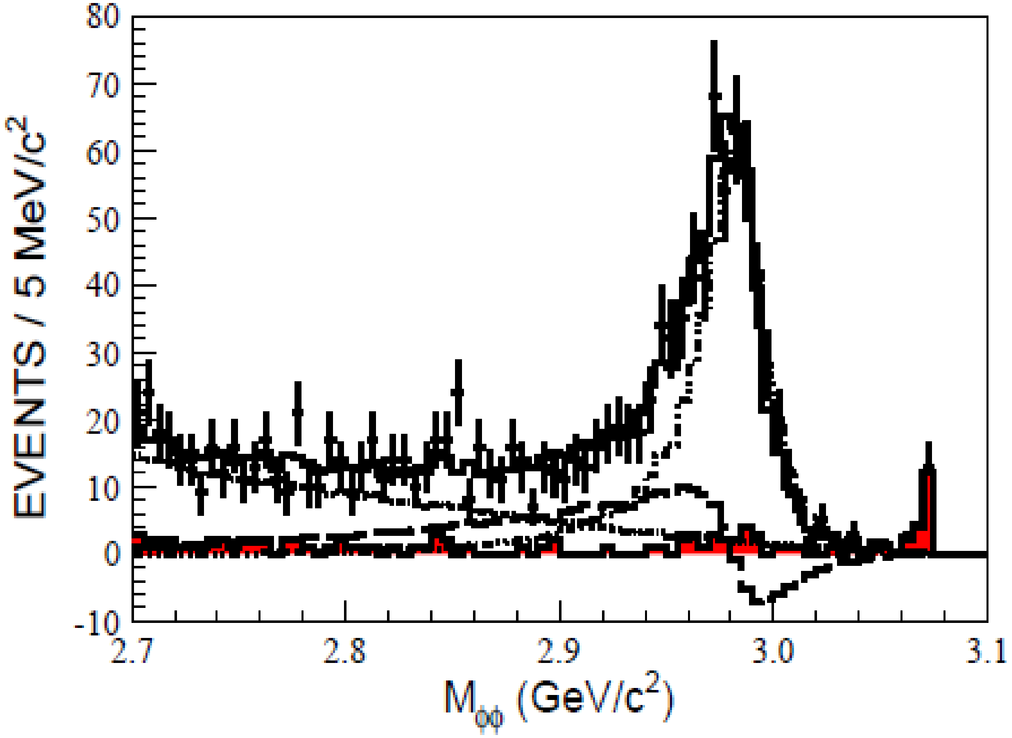
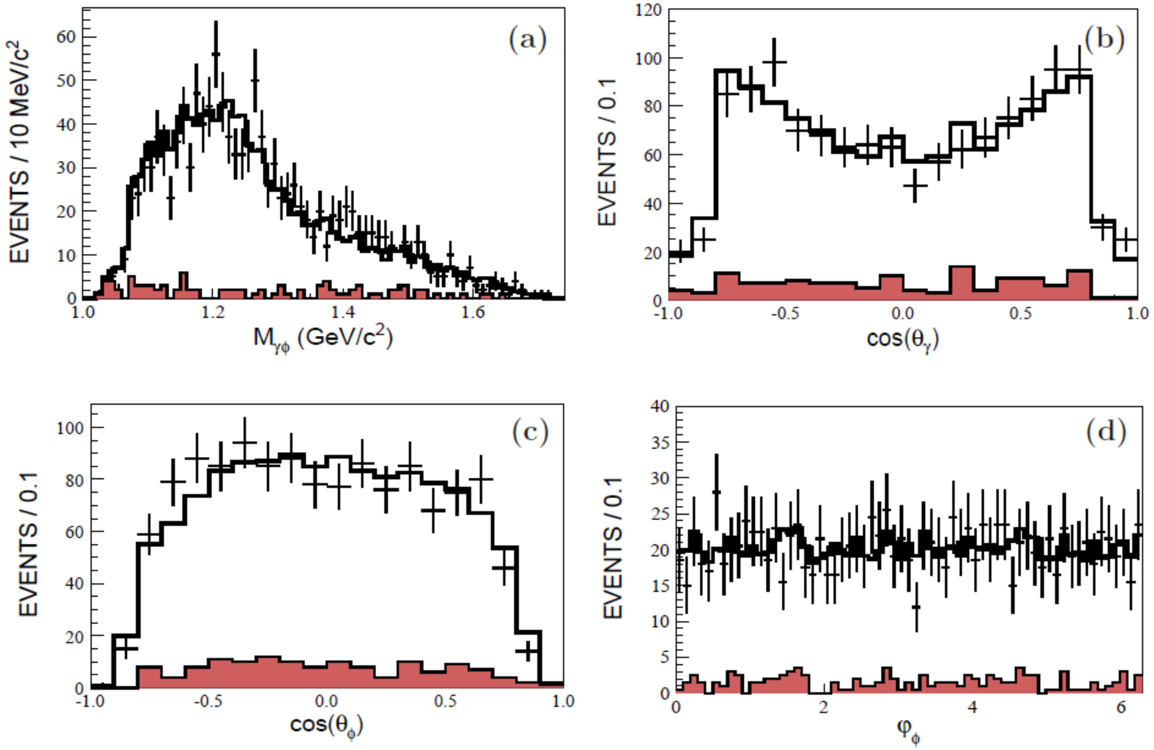
Analysis of $\eta_c \to \phi\phi$ and $\omega\phi$

$\eta_c \to \phi\phi$

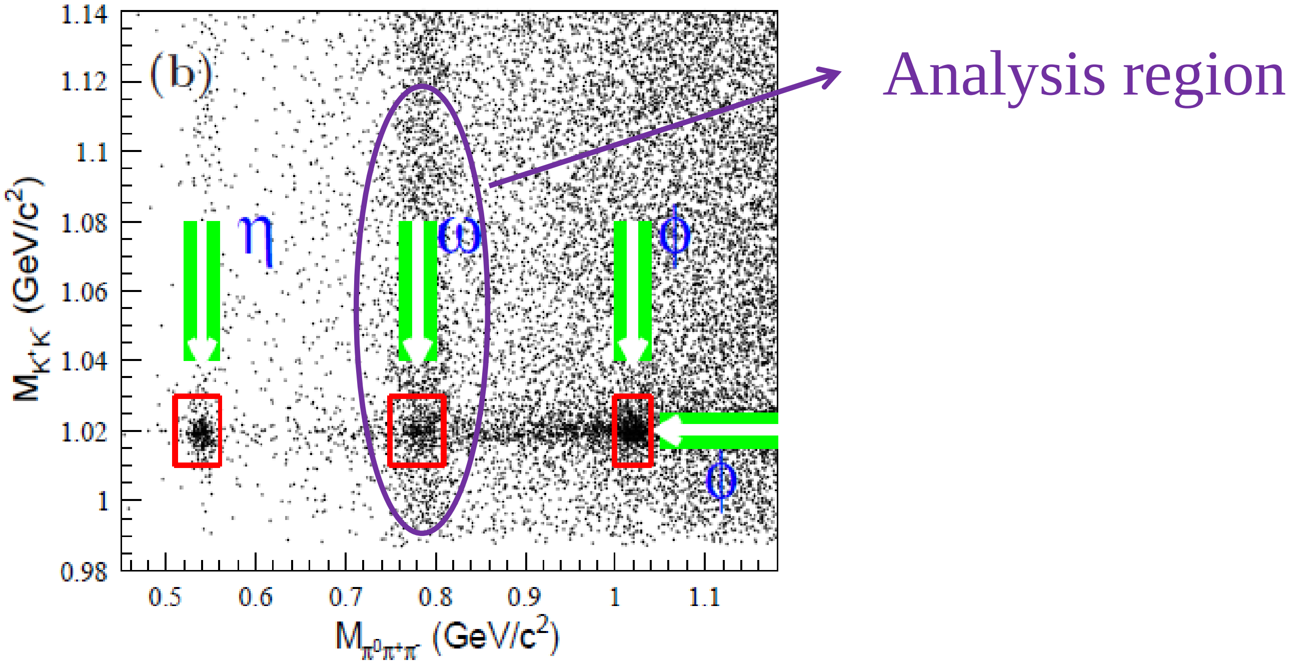




$\chi_g^2/ndf = 1.1$ $N = 549 \pm 65$

$\eta_c \to \omega\phi$

The selections for photons and charged tracks are similar as before. For this channel, there are 3 physical photons and four charged tracks.



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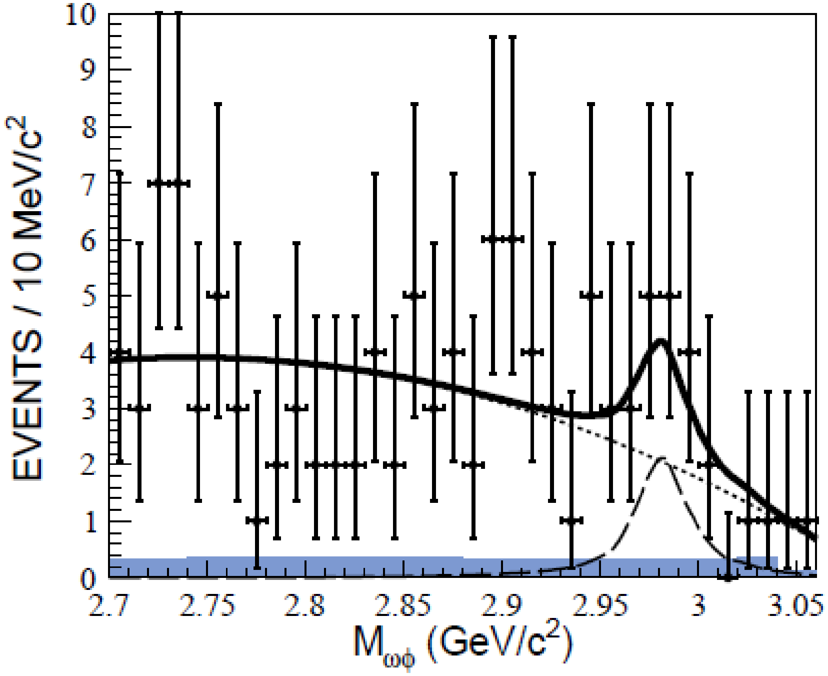
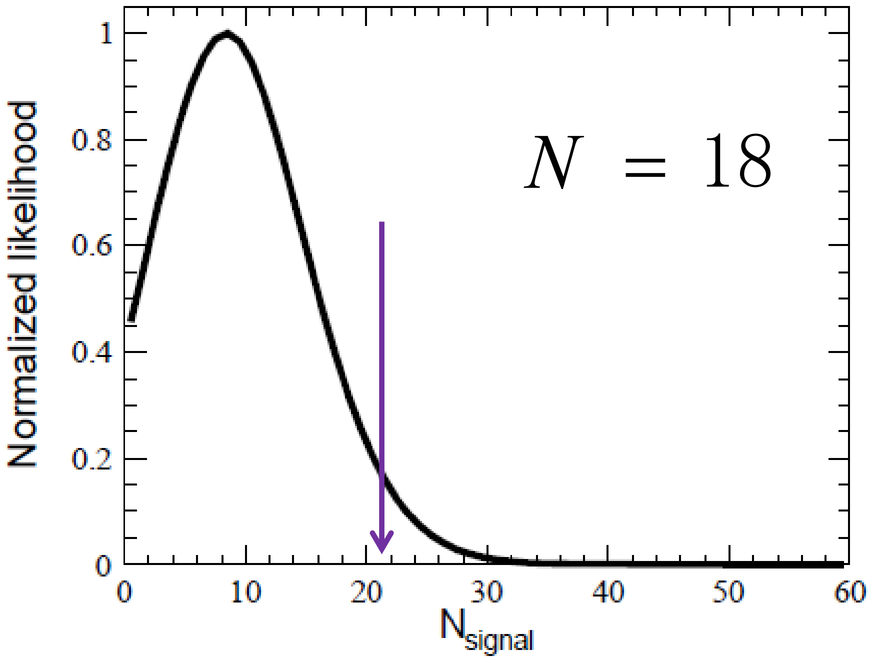
Analysis of $\eta_c \to \phi\phi$ and $\omega\phi$

$\eta_c \to \omega\phi$





No significant η_c signal is observed, the upper limit for the number of signal is calculated at the 90% C.L. by a Bayesian method.

3

Analysis of $\eta_c \to \phi\phi$ and $\omega\phi$

Systematic uncertainties from different sources

sources	$\eta_c \to \phi\phi$	$\eta_c \to \omega\phi$
$N_{J/\psi}$ [1]	0.6	0.6
Photon	1.0	3.0
Tracking [2]	4.0	4.0
PID	—	4.0
$Br(\phi \to K^+K^-)$ [3]	2.0	1.0
$Br(\omega \to \pi^+\pi^-\pi^0)$ [3]	—	0.8
Kinematic fit	6.7	2.4
$M_{K^+K^-}$ mass	0.7	1.1
$M_{\pi^+\pi^-\pi^0}$ mass	—	1.5
Background	0.9	5.6
Fit range	0.7	0.2
η_c Mass and width	1.3	5.6
Amplitude analysis	$^{+7.1}_{-26.1}$	—
Combined	$^{+11.0}_{-27.4}$	10.7
$Br(J/\psi \to \gamma\eta_c)$	23.5	23.5

[1] M. Ablikim *et al.* (BESIII Collaboration), arXiv:1607.00738 [hep-ex].
[2] M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. D **83**, 112005 (2011)
[3] K. A. Olive *et al.* (Particle Data Group), Chin. Phys. C **38**, 090001 (2014)

3

Analysis of $\eta_c \to \phi\phi$ and $\omega\phi$

Calculation of the branching fractions

- $\eta_c \to \phi\phi$

$$Br(J/\psi \to \gamma\eta_c)Br(\eta_c \to \phi\phi) = \frac{N_{sig}}{N_{J/\psi}\varepsilon Br^2(\phi \to K^+K^-)} = \left(4.3 \pm 0.5(sat)^{+0.5}_{-1.2}(syst)\right) \times 10^{-5}$$

$$Br(\eta_c \to \phi\phi) = \left(2.5 \pm 0.3(sat)^{+0.3}_{-0.7}(syst) \pm 0.6(Br)\right) \times 10^{-3}$$

- $\eta_c \to \omega\phi$

$$Br(\eta_c \to \omega\phi) < \frac{N_{up}}{N_{J/\psi}\varepsilon Br(1 - \sigma_{sys})} = 2.5 \times 10^{-4}$$

$$Br = Br(J/\psi \to \gamma\eta_c)Br(\phi \to K^+K^-)Br(\omega \to \pi^+\pi^-\pi^0)$$

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Summary

- The largest data sample of J/ψ and good performance of BESIII allow us to measure the branching fraction of $\eta_c \to \phi\phi$ with higher accuracy.

Experiment	$Br(J/\psi \to \gamma\eta_c)Br(\eta_c \to \phi\phi)(\times 10^{-5})$	$Br(\eta_c \to \phi\phi)\ (\times 10^{-3})$
BESIII	$4.3 \pm 0.5^{+0.5}_{-1.2}$	$2.5 \pm 0.3^{+0.3}_{-0.7} \pm 0.6$
BESII [1]	3.3 ± 0.8	1.9 ± 0.6
DM2 [2]	3.9 ± 1.1	2.3 ± 0.8
Theoretical	prediction	$Br(\eta_c \to \phi\phi)\ (\times 10^{-3})$
	pQCD[3]	$(0.7 \sim 0.8)$
	$^3P_0$ quark model [4]	$(1.9 \sim 2.0)$
	charm meson loop [5]	2.0

[1] M. Ablikim *et al*. (BES Collaboration), Phys. Rev. D**72**, 072005 (2005)
[2] D. Bisello *et al*. (DM2 Collaboration), Nucl. Phys. B **350**, 1 (1991)
[3] Y. Jia and G. D. Zhao, High Energy Phys. Nucl. Phys. **23**, 765 (1999) (in Chinese).
[4] H. Q. Zhou *et al*. Phys. Rev. D **71**, 114002 (2005).
[5] Qian Wang, Xiao-Hai Liu and Qiang Zhao, Phys. Lett. B **711** 364 (2012).

4

Summary

- No significant signal for $\eta_c \to \omega\phi$ is observed. The upper limit at the 90% C.L. on the branching fraction is determined to be

$$Br(\eta_c \to \omega\phi) < 2.5\times10^{-4}$$

which is one order in magnitude more stringent than the previous upper limit[1].

[1] K. A. Olive *et al*. (Particle Data Group), Chin. Phys. C **38**, 090001 (2014)

Thank You!