The Measurement of χ_{cJ} Decays at BESIII

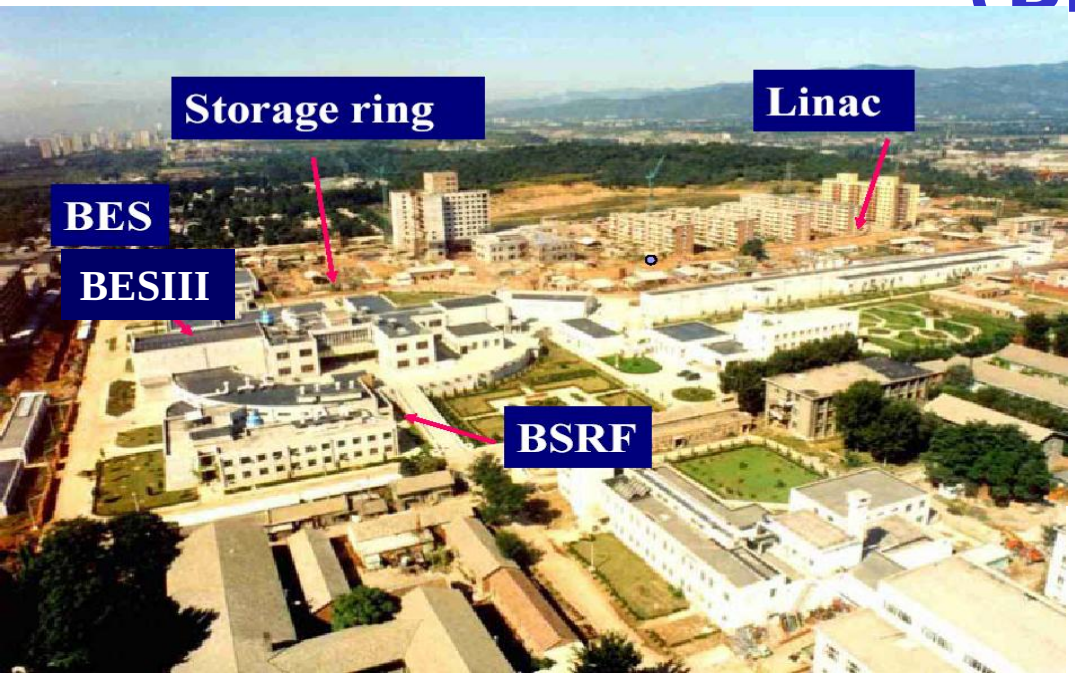
Guofa XU

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

For BESIII Collaboration

MENU2010, College of William and Mary

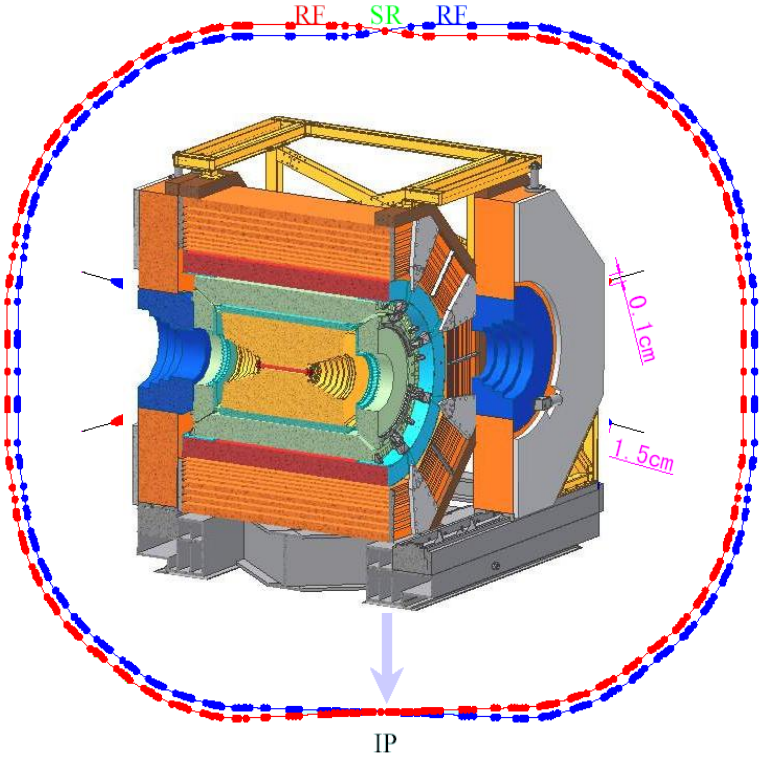
Beijing Electron Positron Collider II (BEPCII) @ IHEP



Beijing Spectrometer

BESI: 1989 - 1998
BESII: 1999 - 2004
- **L ~ 5×10^{30}cm^{-2}s^{-1} @ J/ψ**
- **E_{beam} ~ 1- 2.5GeV**

BESIII: 2008 –
- **Physics run from March 2009,**
- **~106M ψ(2S), ~226M J/ψ**



BEPCII

- **Beam energy:**
  - **1.0-2.3 GeV**
- **Luminosity:**
  - **1×10^{33} cm^{-2}s^{-1}**
- **Optimum energy:**
  - **1.89 GeV**
- **Energy spread:**
  - **5.16×10^{-4}**
- **No. of bunches:**
  - **93**
- **Bunch length:**
  - **1.5 cm**
- **Total current:**
  - **0.91 A**

BESIII performance

Subdetectors			design	measurement
MDC	Momentum resolution (1 GeV)		0.5-0.7%	0.58 %
	dE/dx resolution		6-8%	6.0% (hadron) 5.3% (Bhabha)
EMC	Energy resolution (1 GeV)		2.5-3%	2.5 %
	Spatial resolution		5-7 mm	6.0 mm
TOF	Time resolution	Barrel	80-90 ps	80 ps (Bhabha)
		Endcap	100-110 ps	100 ps (dimuon)
μ counter	$\delta_{R\Phi}$=1.4 cm~1.7 cm			< 1.7 cm

Outline

- Introduction of BEPCII & BESIII
- Inclusive photon spectrum
- Measurements of exclusive χ_{cJ} decays
  - $\chi_{c0,2} \to \pi^0\pi^0, \eta\eta$
  - $\chi_{cJ} \to 4\pi^0$ (KsKs)
  - $\chi_{cJ} \to \phi\phi$, $\omega\omega$, $\phi\omega$
  - $\chi_{cJ} \to \gamma V$ (ϕ, ρ, ω)
- Summary

Milestones of BESIII

April 30, 2008: BESIII moved

July 20, 2008: First e^+e^- collision event

April 14, 2009: ~106M $\psi(2S)$ events collected ($\times$4 CLEOc)

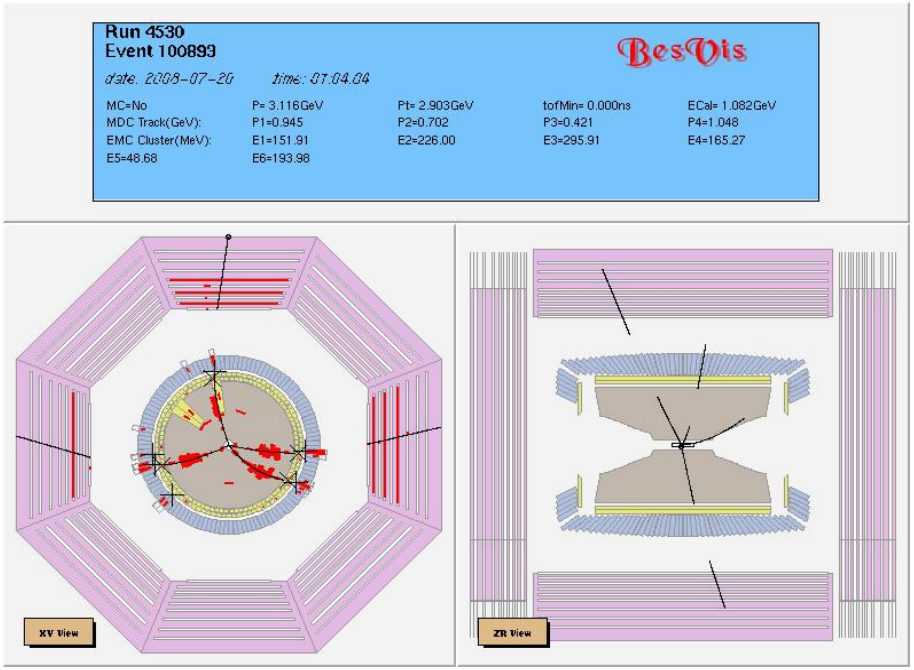
May 30, 2009: 42 pb^{-1} at continuum(3.65 GeV) collected

July 28, 2009: ~226M J/ψ events collected ($\times$4 BESII)

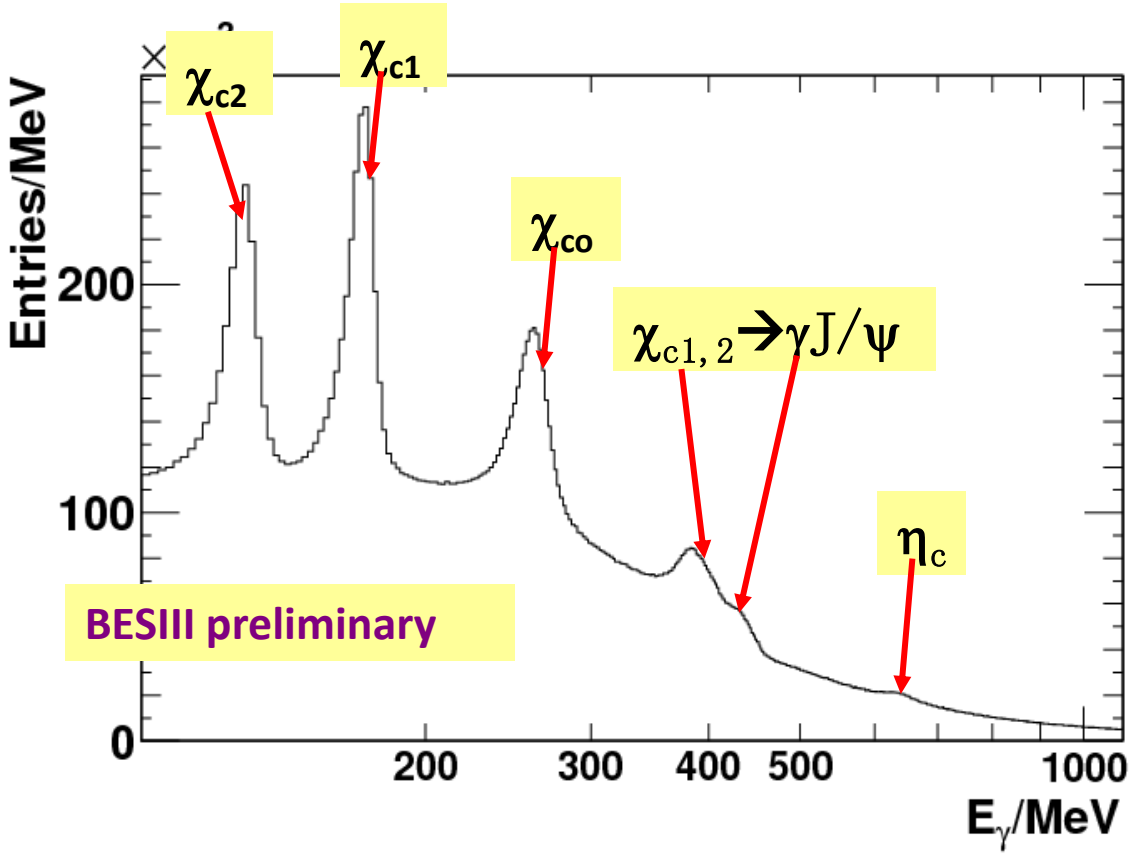
Peak Lumi. @ May 2009: $3.2\times10^{32}cm^{-2}s^{-1}$

→ $\times$5 CESRc @ ψ''

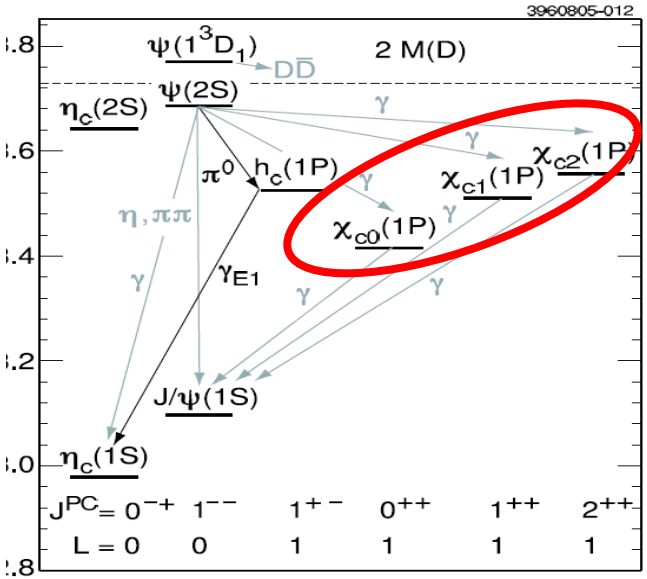
→ $\times$30 BEPCI



Inclusive Photon Spectrum



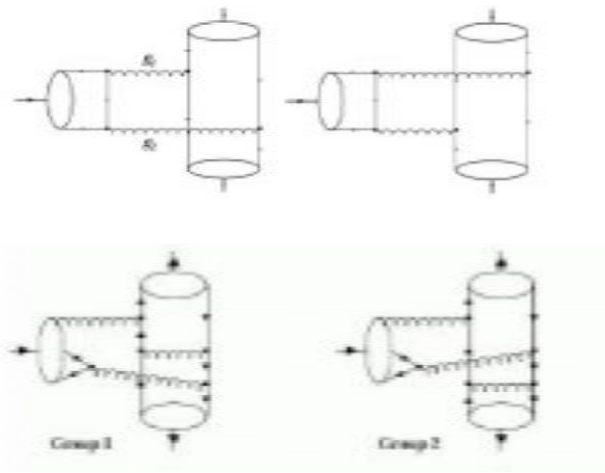
PRD 72(2005)092004



- **Clear inclusive photon spectrum**
- **Excellent photon resolution**

χ_{cJ} Decays

- **Test of color singlet/octet models in χ_{cJ} decays**



- **Probe single/double OZI suppressed decay of charmonium states**

Exclusive decays of χ_{cJ} are a good laboratory to test the color-octet mechanism in P-wave charmonium decays.

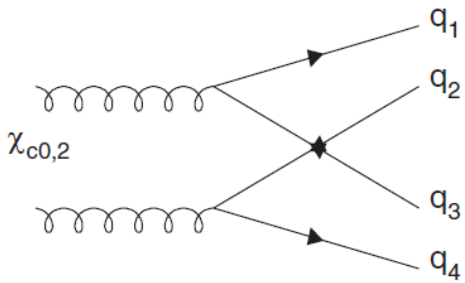
[1] G.T. Bodwin et al., Phys Rev. Lett. D51, 1125 (1995)
[2] H.-W. Huang and K.-T. Chao, Phys. Rev. D54, 6850 (1996)
[3] J.Bolz et al., Eur.Phys.J.C2:705-719 (1998)

decay width	theory[3]	PDG08
$\Gamma[\chi_{c0} \to \pi^0 \pi^0]$ / keV	23.5	25 ± 2
$\Gamma[\chi_{c2} \to \pi^0 \pi^0]$ / keV	1.93	1.4 ± 0.2
$\Gamma[\chi_{c0} \to \eta\eta]$ / keV	32.7	25 ± 4
$\Gamma[\chi_{c2} \to \eta\eta]$ / keV	2.66	

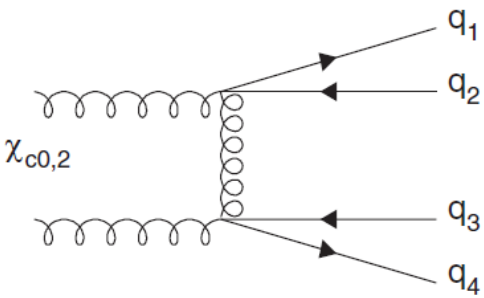
$\chi_{c0,2} \rightarrow \pi^0\pi^0$, $\eta\eta$

•BRs of $\eta\eta$,$\eta'\eta$,$\eta'\eta'$ determine the relative strength of SOZI and DOZI contributions

SOZI



DOZI

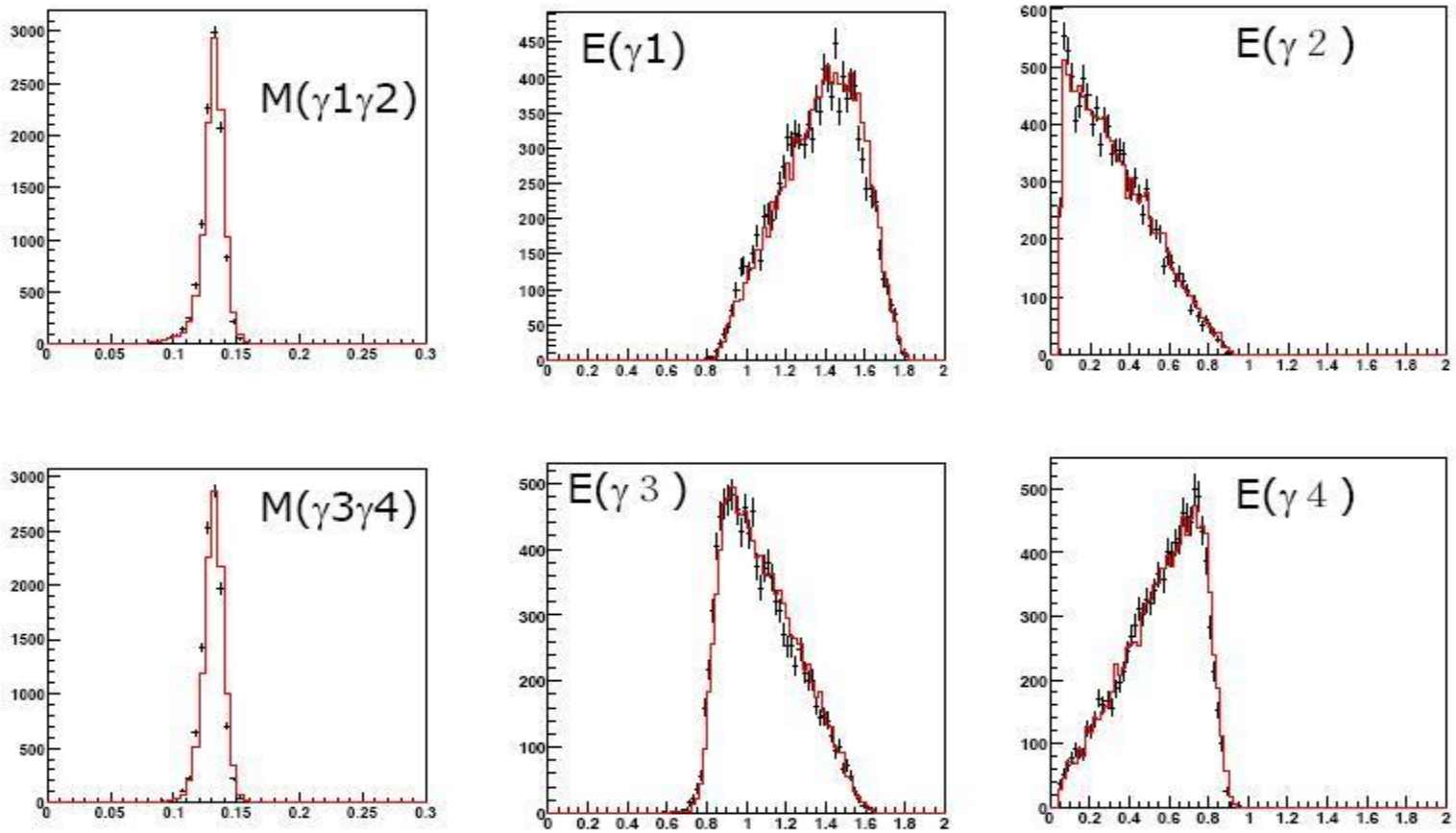


Zhao PRD 72, 074001 (2005)

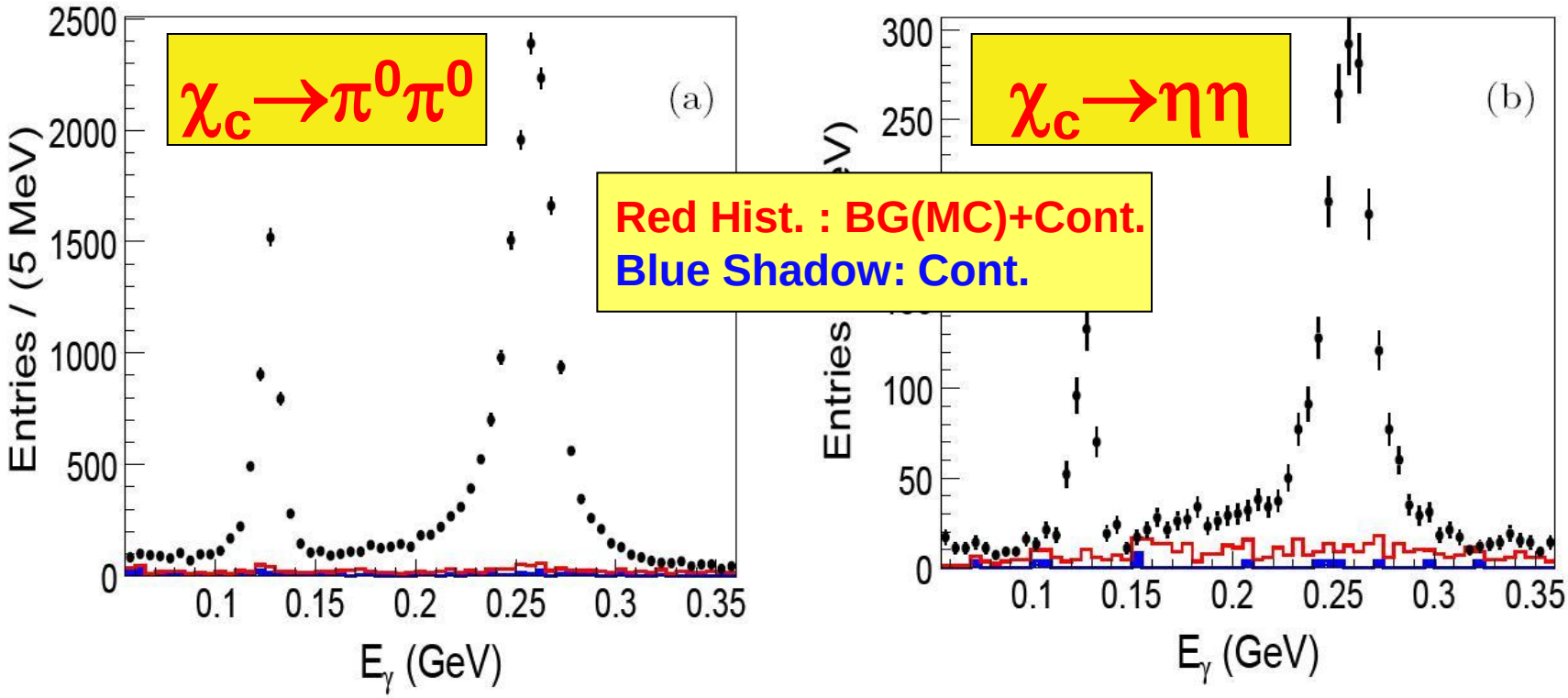
•Radiative decay of charmonium to $\pi^0\pi^0$, $\eta\eta$ are interesting channels for glueball searches

Study of $\chi_{c0,2} \rightarrow \pi^0\pi^0$,$\eta\eta$ ($\eta \rightarrow \gamma\gamma$, $\pi^0 \rightarrow \gamma\gamma$)

DATA/MC comparisons
(π^0's are unambiguously reconstructed)



Study of $\chi_{c0,2} \rightarrow \pi^0\pi^0$,$\eta\eta$ ($\eta \rightarrow \gamma\gamma$, $\pi^0 \rightarrow \gamma\gamma$)

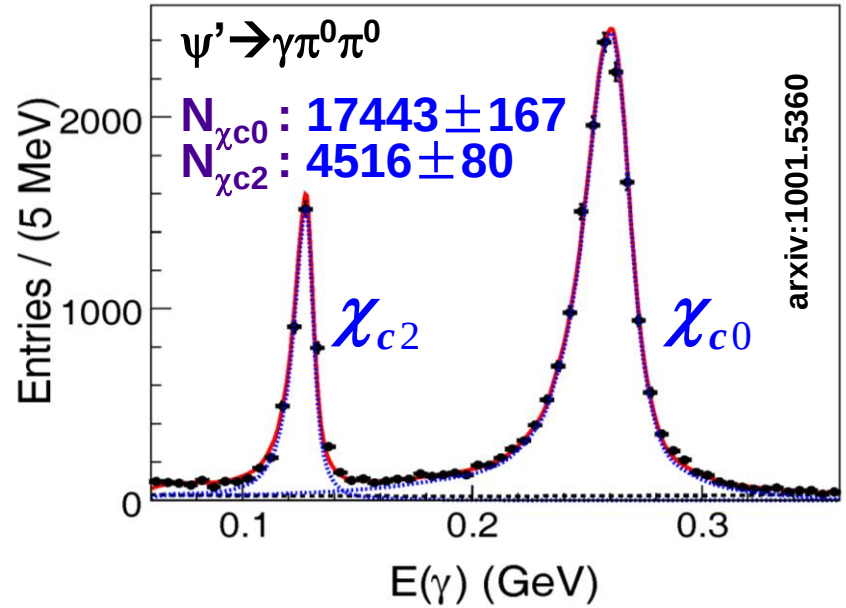


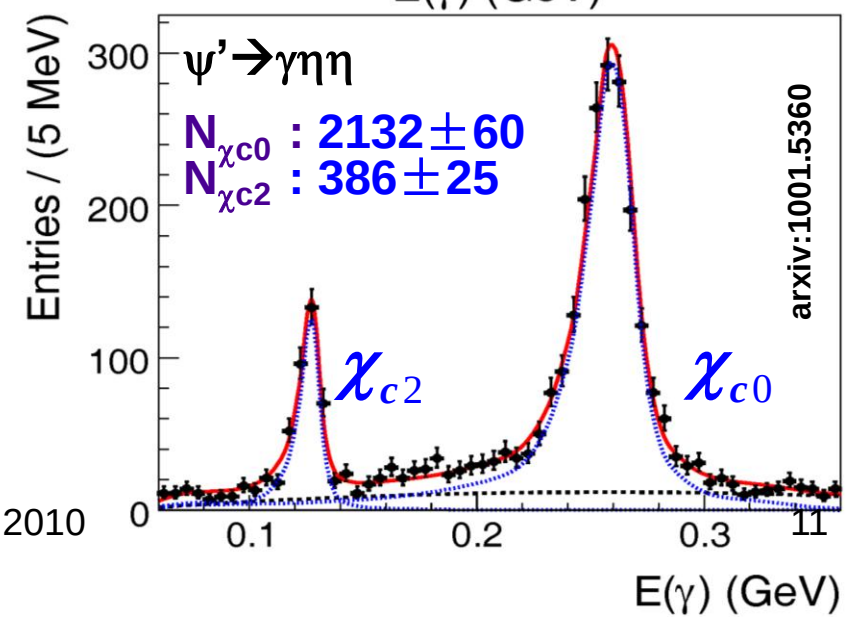
For $\chi_c \rightarrow \pi^0\pi^0$:100M inclusive MC have been used to estimate backgrounds. BG is small

For $\chi_c \rightarrow \eta\eta$: 100M inclusive MC have been used. BG mainly from $\psi' \rightarrow \pi^0\pi^0 J/\psi$; $\psi' \rightarrow \eta J/\psi$; $\chi_c \rightarrow \gamma J/\psi$.

Study of $\chi_{c0,2} \rightarrow \pi^0\pi^0$,$\eta\eta$ ($\eta \rightarrow \gamma\gamma$, $\pi^0 \rightarrow \gamma\gamma$)

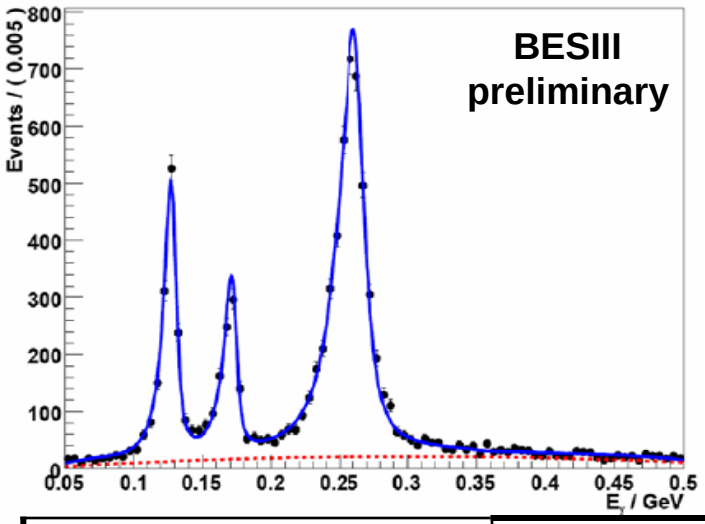
Mode		χ_{c0}	χ_{c2}
$\pi^0\pi^0$	BESIII	$3.23 \pm 0.03 \pm 0.23 \pm 0.14$	$0.88 \pm 0.02 \pm 0.06 \pm 0.04$
	CLEOc [2]	$2.94 \pm 0.07 \pm 0.32 \pm 0.15$	$0.68 \pm 0.03 \pm 0.07 \pm 0.04$
	PDG [10]	2.43 ± 0.20	0.71 ± 0.08
$\eta\eta$	BESIII	$3.44 \pm 0.10 \pm 0.24 \pm 0.13$	$0.65 \pm 0.04 \pm 0.05 \pm 0.03$
	CLEOc [2]	$3.18 \pm 0.13 \pm 0.31 \pm 0.16$	$0.51 \pm 0.05 \pm 0.05 \pm 0.03$
	PDG [10]	2.4 ± 0.4	< 0.5





BES Collab. PRD 81, 052005 (2010)

$\chi_{cJ} \to 4\pi^0$ from $\psi' \to \gamma\chi_{cJ}$ decays



Excluding $K_S \to \pi^0\pi^0$

$Br(\chi_{co} \to 4\pi^0) = (3.42 \pm 0.07 \pm 0.45) \times 10^{-3}$

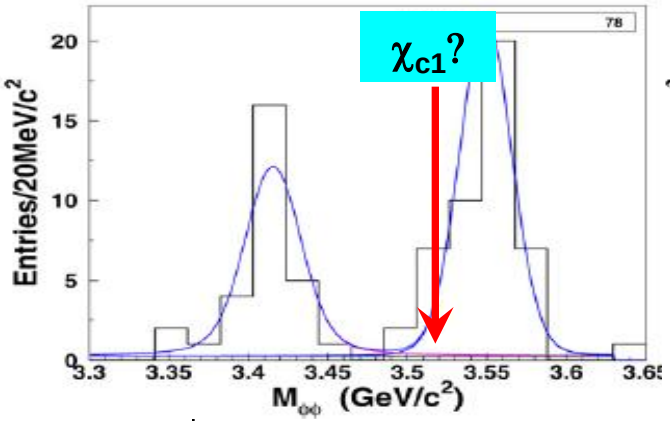
$Br(\chi_{c1} \to 4\pi^0) = (0.60 \pm 0.03 \pm 0.09) \times 10^{-3}$

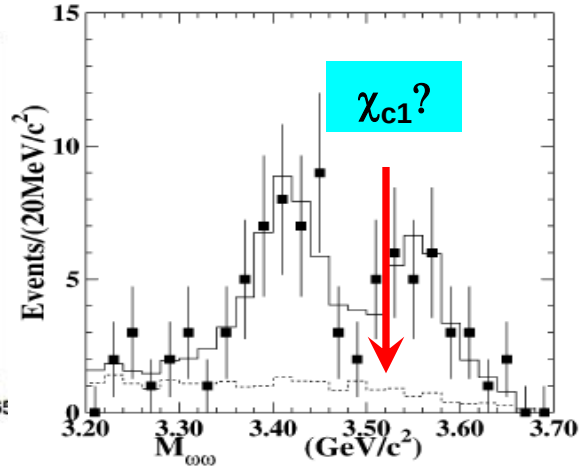
$Br(\chi_{c2} \to 4\pi^0) = (1.13 \pm 0.04 \pm 0.15) \times 10^{-3}$

BESIII	**$Br(\chi_{c0} \to K_S K_S) = (4.1 \pm 0.4_{stat}) \times 10^{-3}$**
PDG	$Br(\chi_{c0} \to K_S K_S) = (2.82 \pm 0.28) \times 10^{-3}$
CLEO-c	$Br(\chi_{c0} \to K_S K_S) = (3.49 \pm 0.08 \pm 0.17) \times 10^{-3}$
BESIII	**$Br(\chi_{c2} \to K_S K_S) = (0.6 \pm 0.2_{stat}) \times 10^{-3}$**
PDG	$Br(\chi_{c2} \to K_S K_S) = (0.68 \pm 0.11) \times 10^{-3}$
CLEO-c	$Br(\chi_{c2} \to K_S K_S) = (0.53 \pm 0.03 \pm 0.03) \times 10^{-3}$

Study of $\chi_{cJ} \rightarrow VV$

- **Puzzles for $\chi_{c0} \rightarrow V\,V$: no helicity suppress**



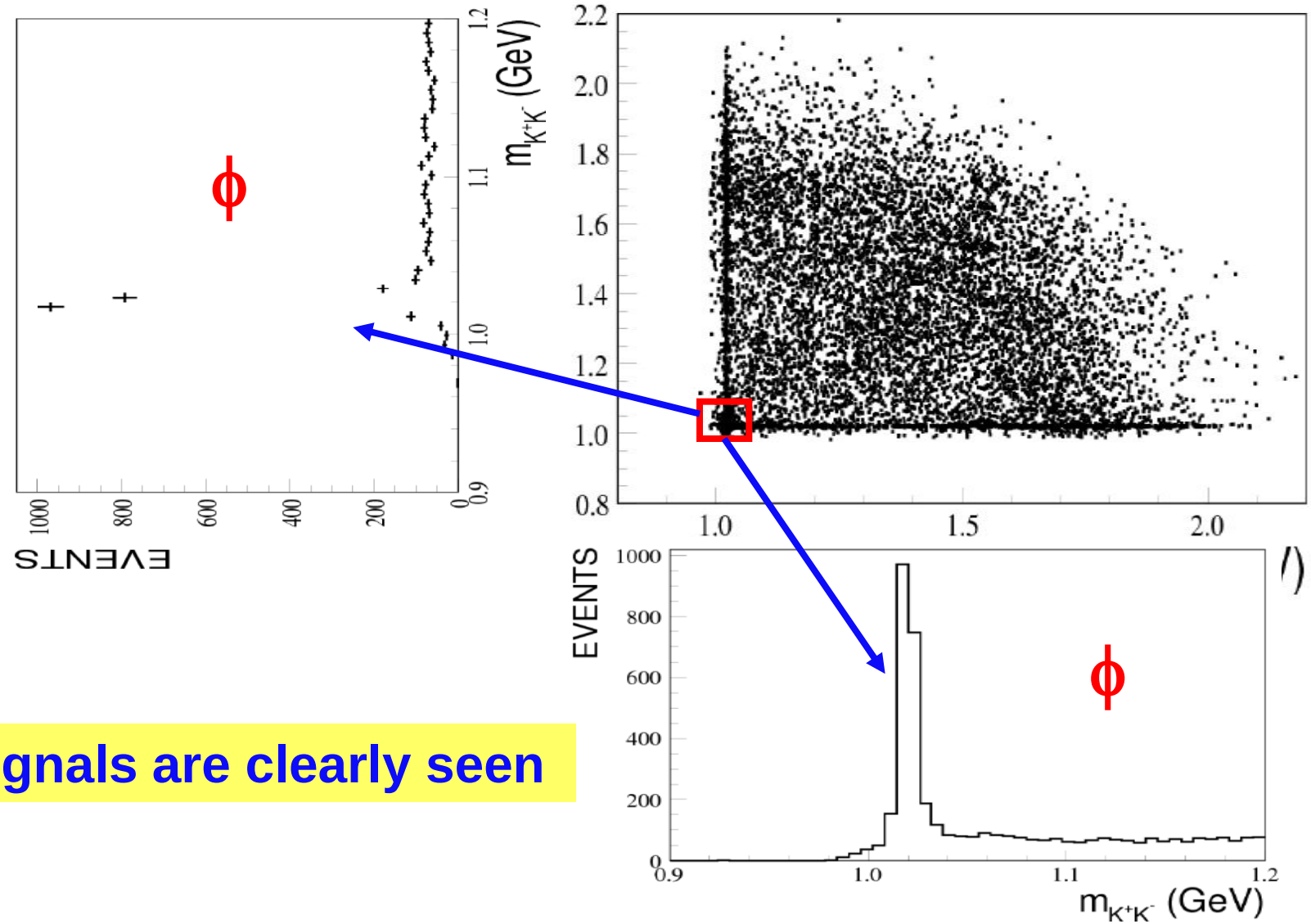


BESII Results (BR(10^{-3}))		
	χ_{c0}	χ_{c2}
$\phi\phi$	0.94±0.21±0.13	1.7±0.3±0.25
$\omega\omega$	2.29±0.58±0.41	1.77±0.47±0.36

PLB 642,197(2006)
PLB 630,7 (2005)

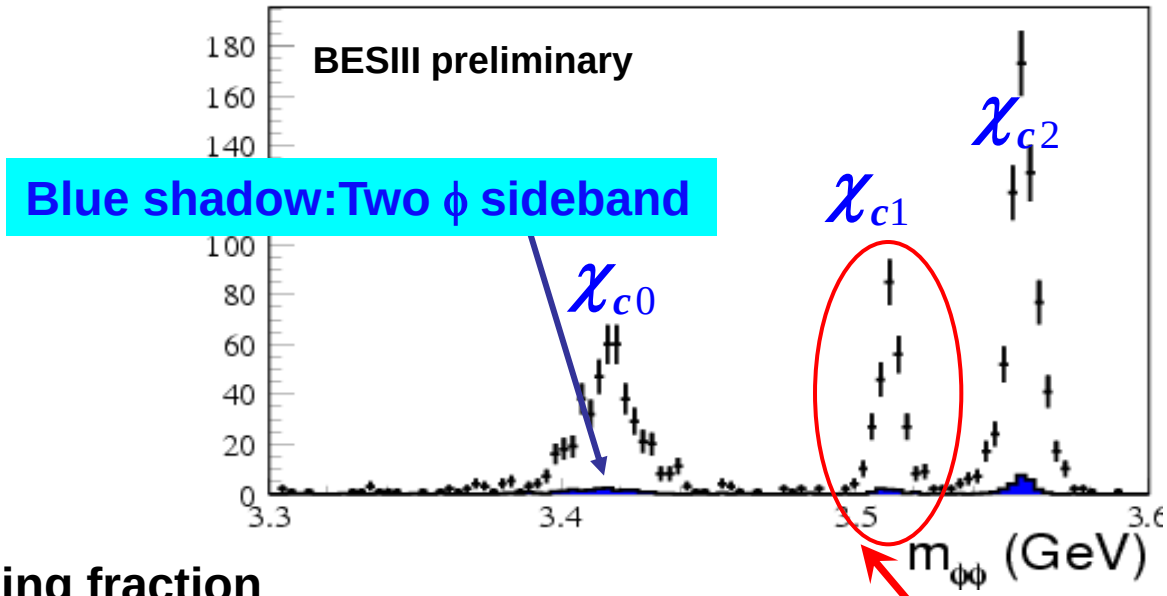
- **$\chi_{cJ} \rightarrow \phi\phi/\omega\omega$ single OZI suppressed**
- **$\chi_{cJ} \rightarrow \phi\omega$ double OZI suppressed**

Study of $\chi_{cJ} \rightarrow \phi(KK)\phi(KK)$



φφ signals are clearly seen

Study of $\chi_{cJ} \rightarrow \phi(KK)\phi(KK)$

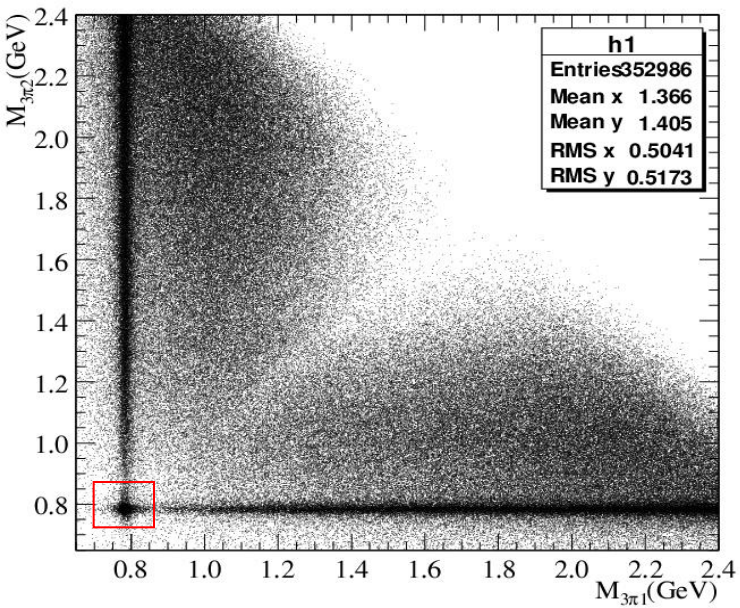


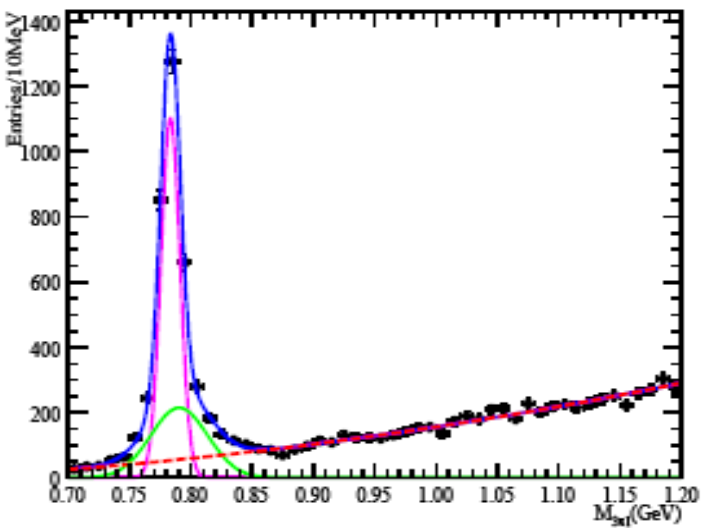
Branching fraction

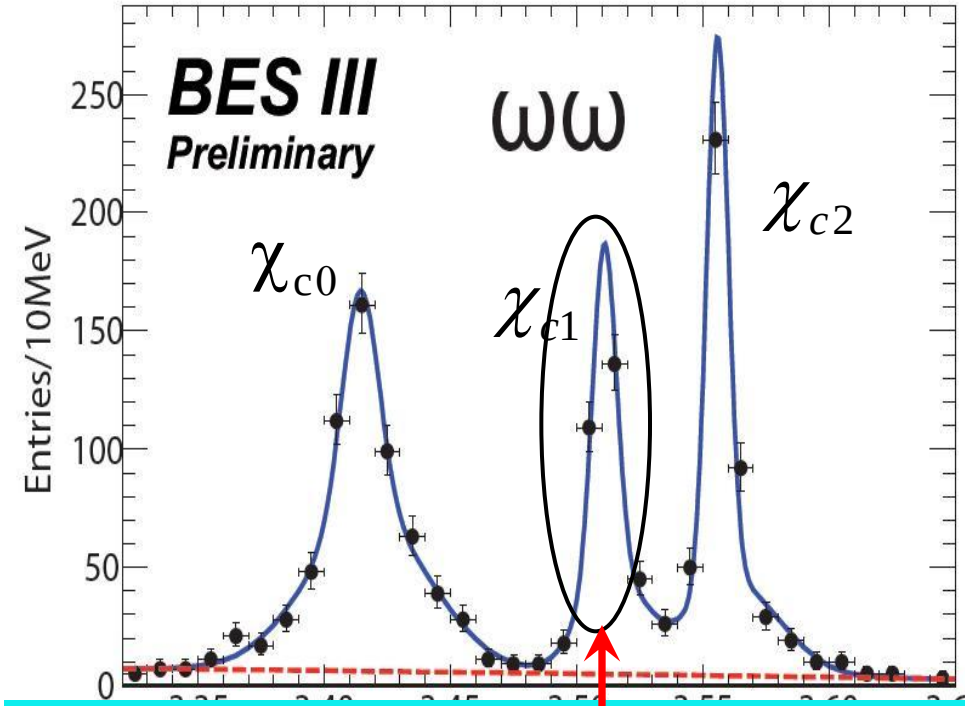
channel	$(\times 10^{-4})$	PDG$(\times 10^{-4})$
$\chi_{c0} \rightarrow \phi\phi$	8.0 ± 0.4	9.3 ± 2.0
$\chi_{c1} \rightarrow \phi\phi$	4.2 ± 0.3	$- - -$
$\chi_{c2} \rightarrow \phi\phi$	11.3 ± 0.4	15.4 ± 3.0

The first measurement of $\chi_{c1} \rightarrow \phi\phi$

Study of $\chi_{cJ} \rightarrow \omega(\pi^+\pi^-\pi^0)\omega(\pi^+\pi^-\pi^0)$





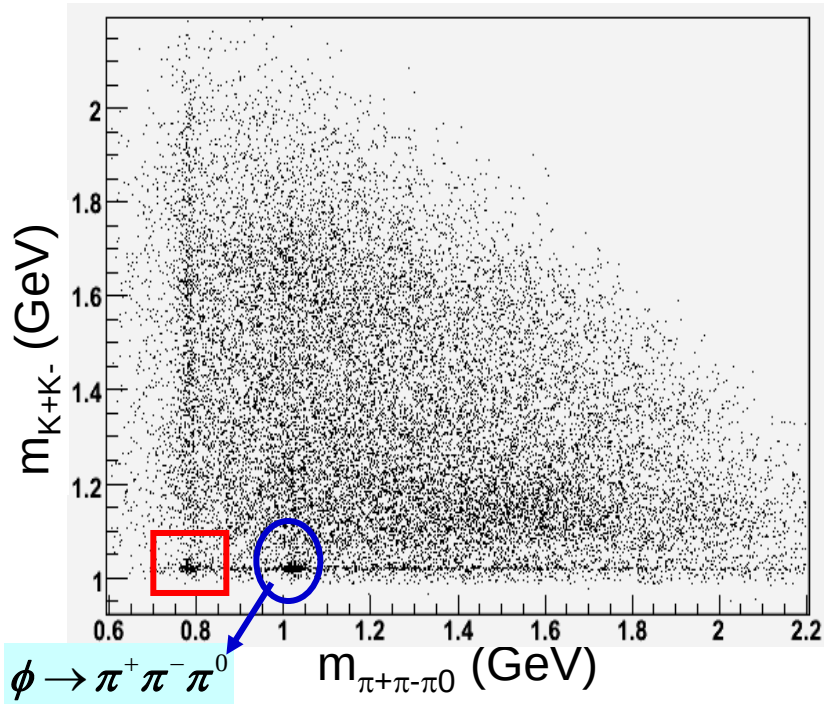


The first measurement of $\chi_{c1} \rightarrow \omega\omega$

- $\omega\omega$ signals are clearly observed
- backgrounds and non-resonance contributions are studied with two-ω sidebands and continuum data, very low.

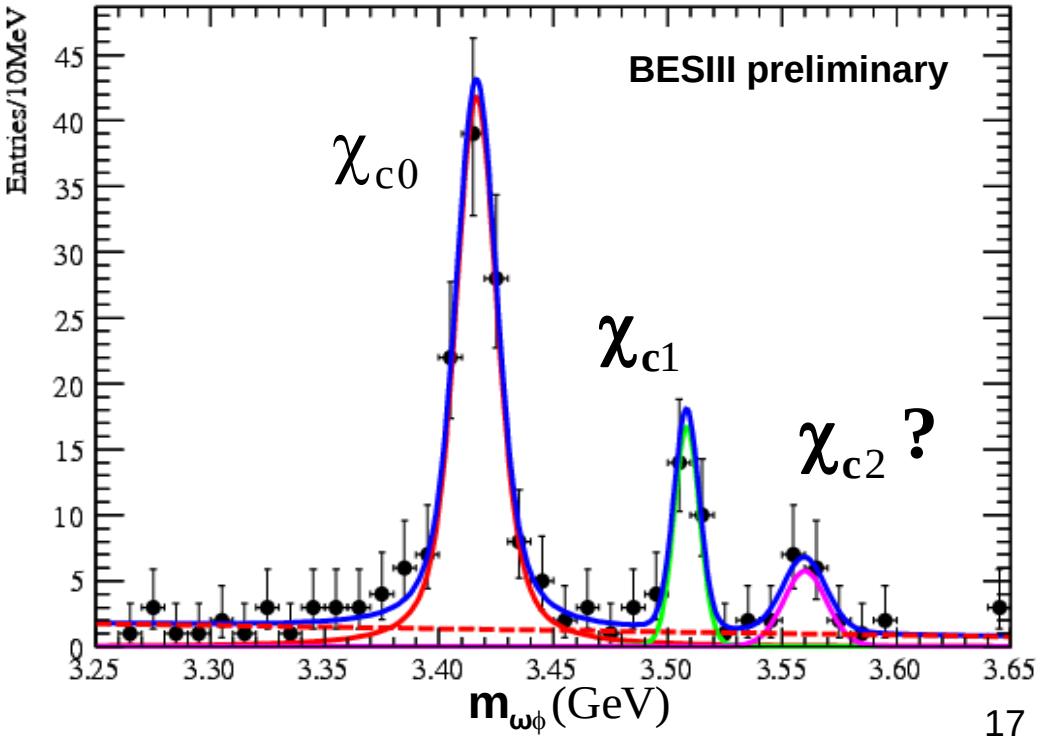
First observation of $\chi_{cJ} \rightarrow \omega\phi$

m_{KK} versus $m_{\pi+\pi-\pi0}$ for Data



- $\omega\phi$ signals are clearly observed
- backgrounds and contributions from non-resonances are studied with ω & ϕ sidebands, and continuum data.

- $\chi_{c1} \rightarrow \phi\omega$ double OZI suppressed
- Double OZI suppressed decay is first observed!



$\chi_{cJ} \rightarrow \gamma V$

- **The radiative decays of P-wave charmonium (χ_{cJ}) to light-quark vector states(ρ, ω, and ϕ) provide an independent, complementary, $c\bar{c}$-annihilation decay**
- **CLEO-c observed χ_{c1} in $\gamma\rho$ and $\gamma\omega$ decay modes, but not in $\gamma\phi$ decay mode**

PRL 101 , 151801 (2008)

- **pQCD, QCD, and QCD+QED predications are one order of magnitude lower than CLEO-c results**

Chin. Phys. Lett. 23, 2376 (2006)

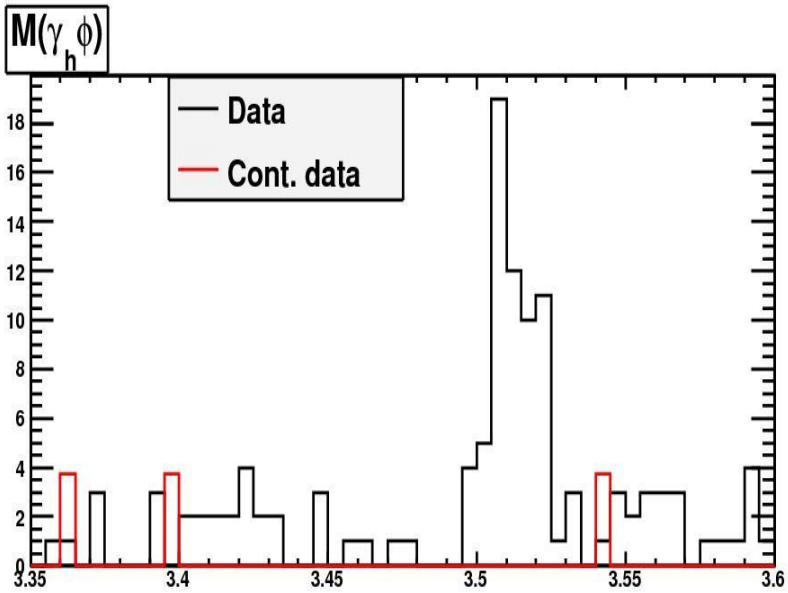
- **New theoretical paper including hadronic loop contributions gives consistent results with CLEO-c**

arXiv:1005.0066v2[hep-ph]

$\chi_{cJ} \rightarrow \gamma\phi(KK)$

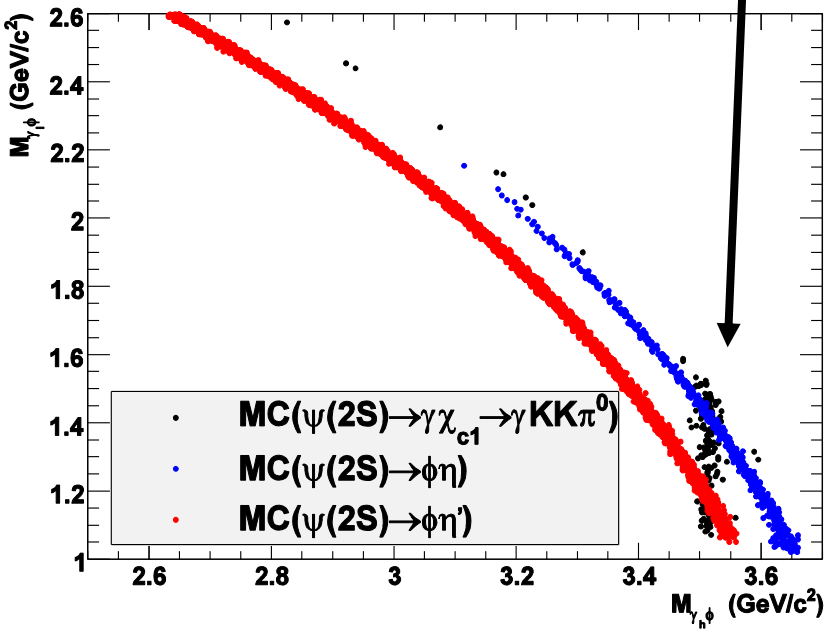
Background Check

- ✓ **Continuum data at 3.65 GeV (42.6 pb^{-1})**
- ✓ **100M $\psi(3686)$ Inclusive decay sample(MC)**
- ✓ **Exclusive MC**
- ✓ **ϕ side-band**

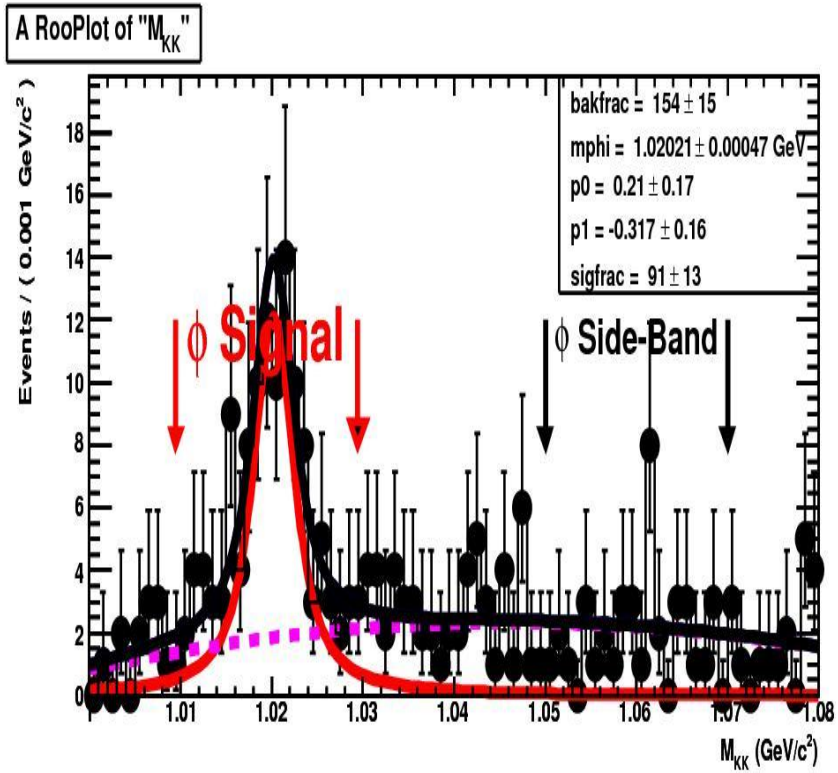


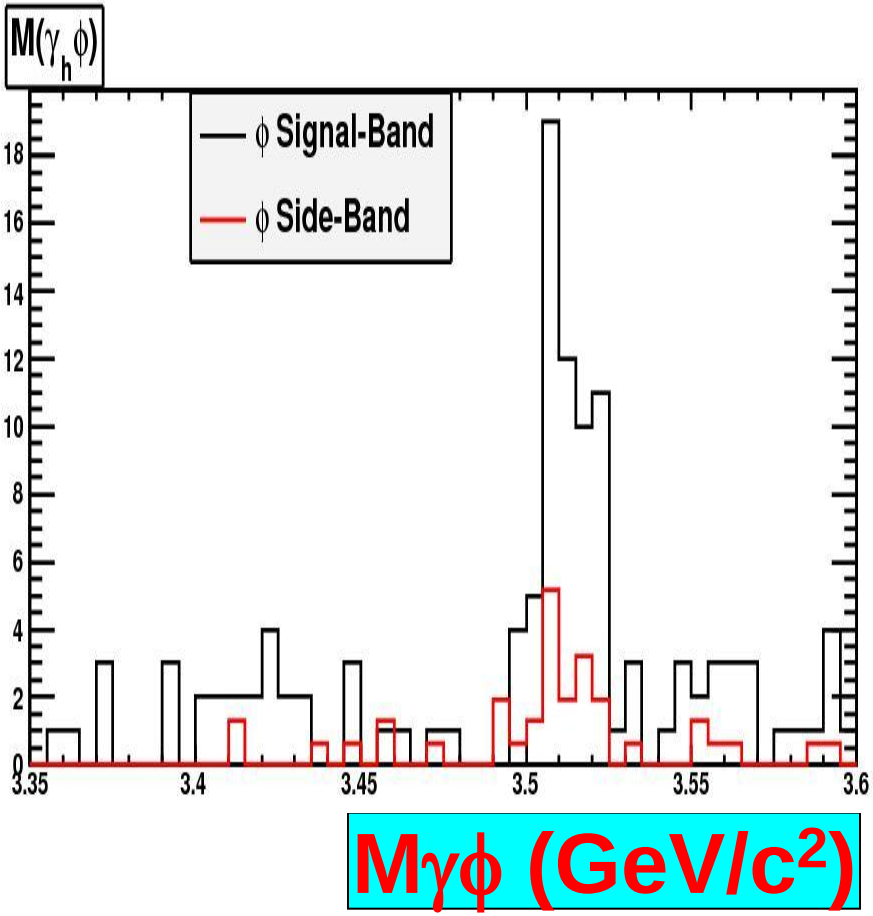
$M\gamma\phi$ (GeV/c^2)

$\psi' \rightarrow \gamma\chi_{c1} \rightarrow \gamma KK\pi^0$

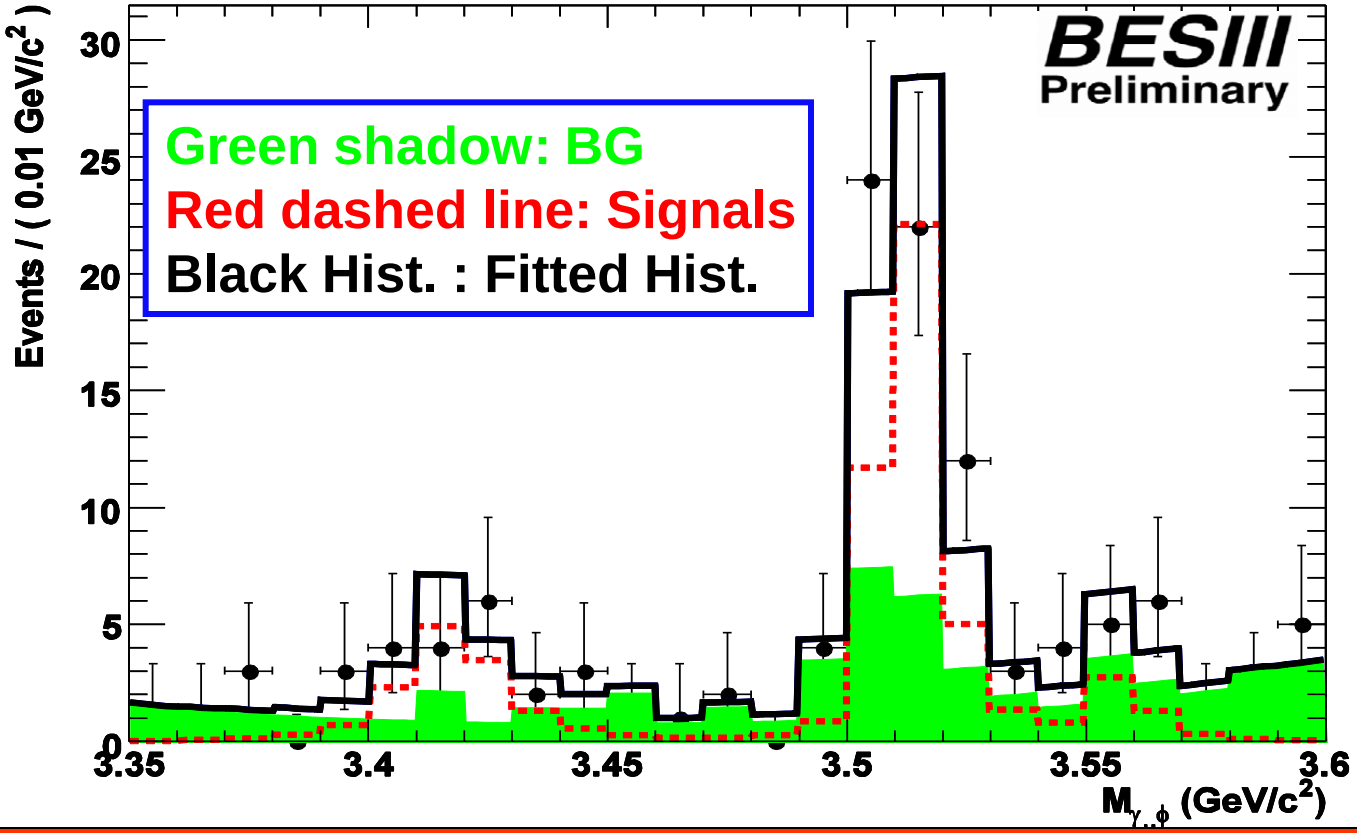


$\chi_{cJ} \rightarrow \gamma\phi(KK)$





$\chi_{cJ} \rightarrow \gamma\phi(KK)$



BG: ϕ side-band + 2nd order poly.

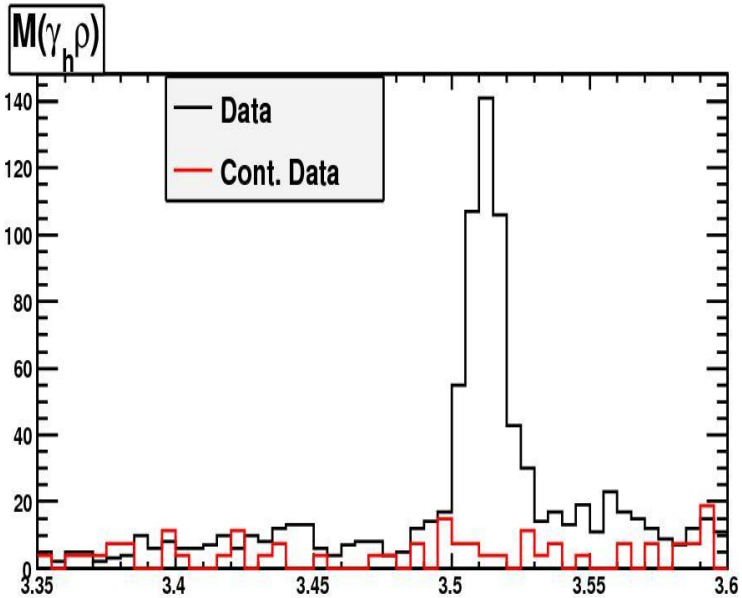
$\chi_{cJ} \rightarrow \gamma\rho(\pi\pi)$

Background Check

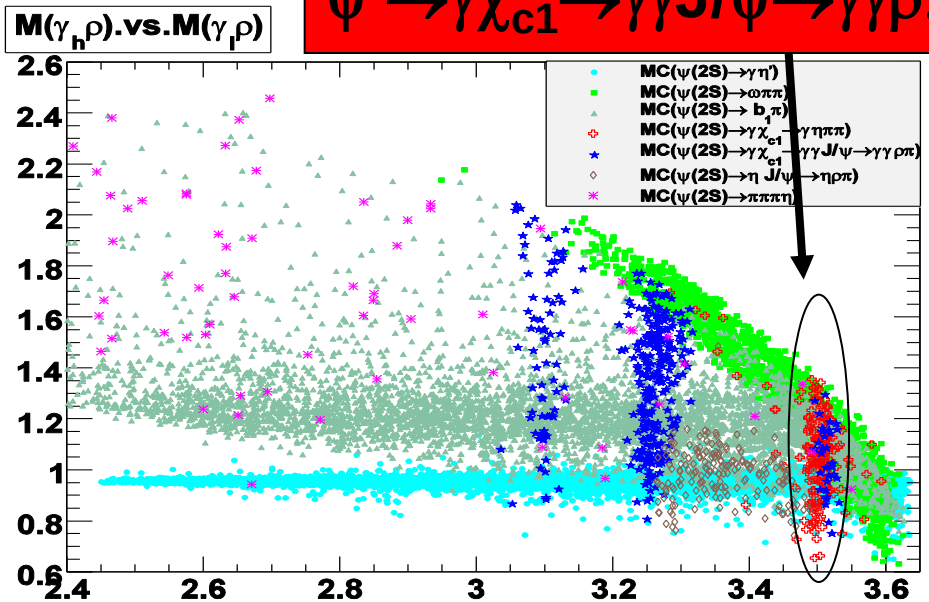
- ✓ Continuum data at 3.65 GeV (42.6 pb^{-1})
- ✓ 100M ψ(3686) Inclusive decay sample(MC)
- ✓ Exclusive MC
- ✓ ρ side-band

$\psi' \rightarrow \gamma\chi_{c1} \rightarrow \gamma\eta\pi\pi$

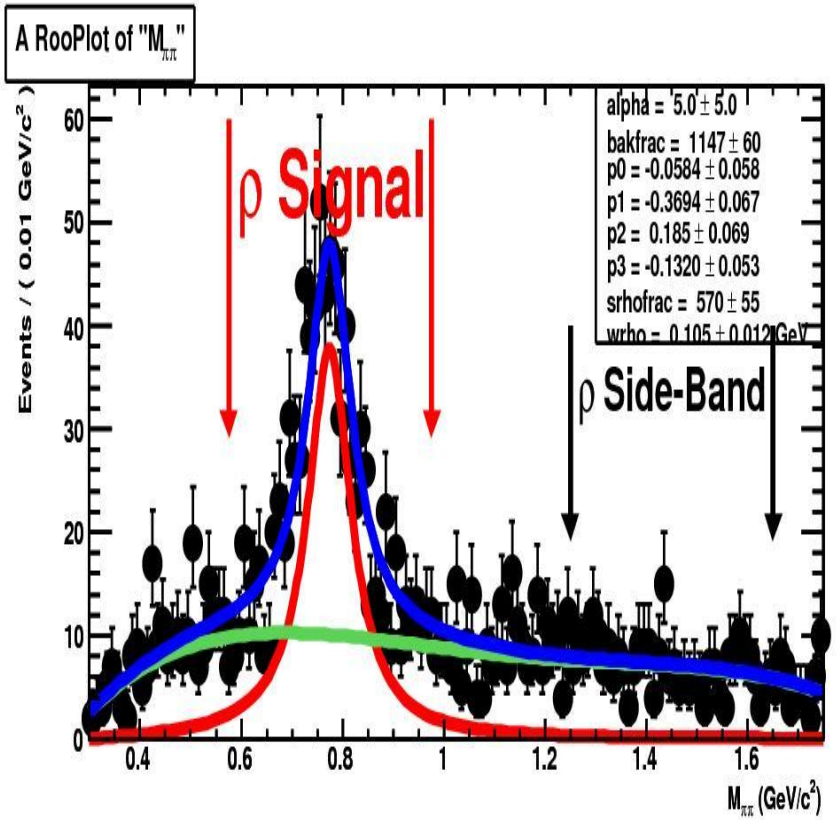
$\psi' \rightarrow \gamma\chi_{c1} \rightarrow \gamma\gamma J/\psi \rightarrow \gamma\gamma\rho\pi$

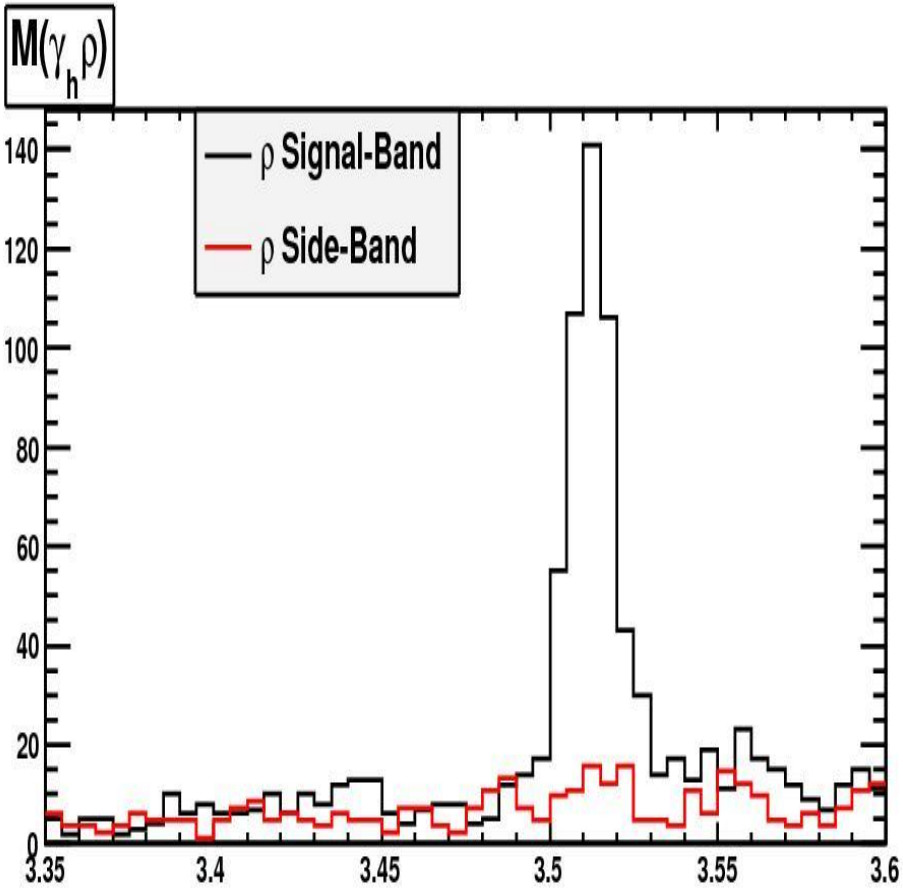


$M\gamma\rho$ (GeV/c^2)



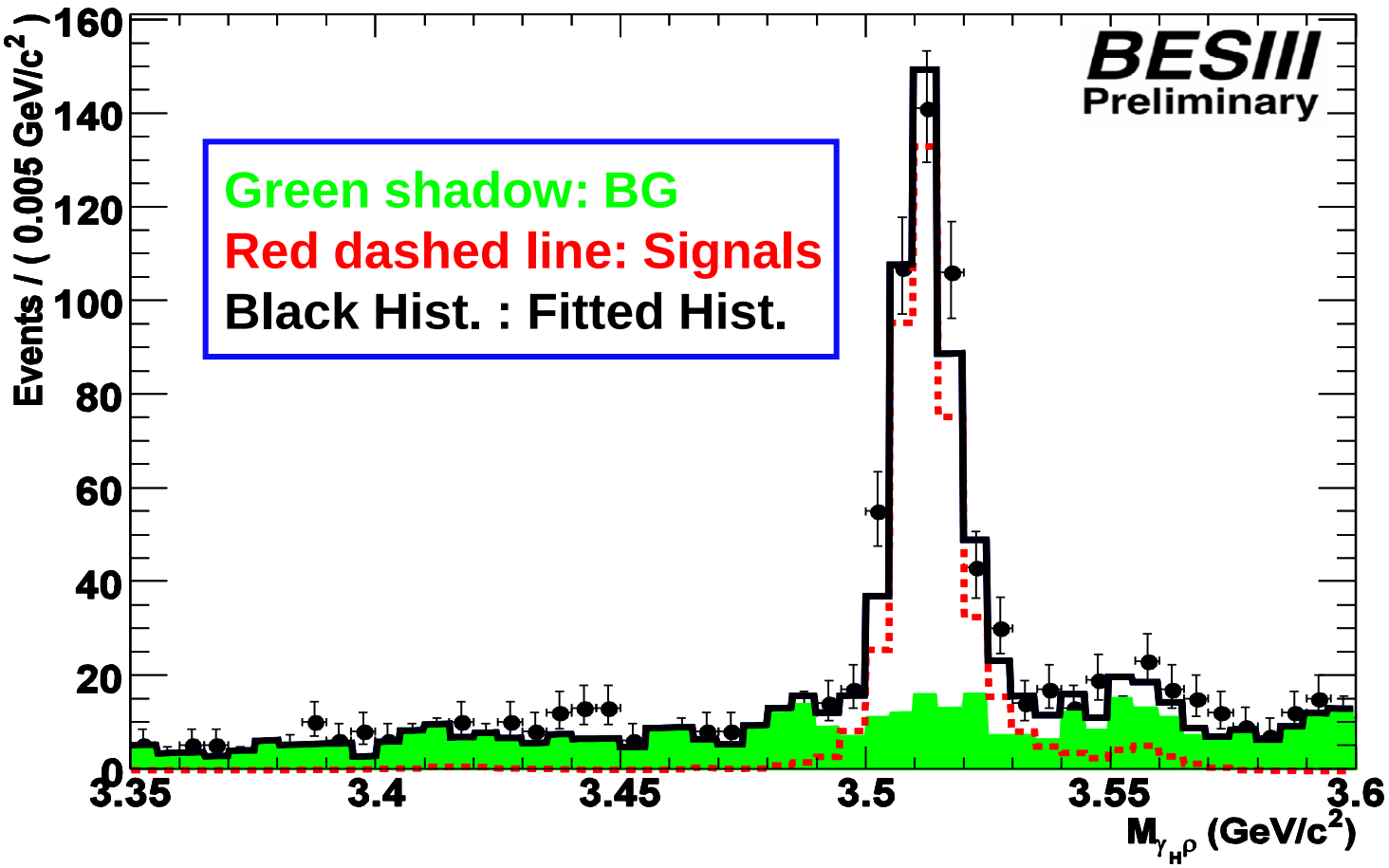
$\chi_{cJ} \rightarrow \gamma\rho(\pi\pi)$





$M\gamma\rho$ (GeV/c^2)

$\chi_{cJ} \rightarrow \gamma\rho(\pi\pi)$



BG: ρ side-band + 2nd order poly.

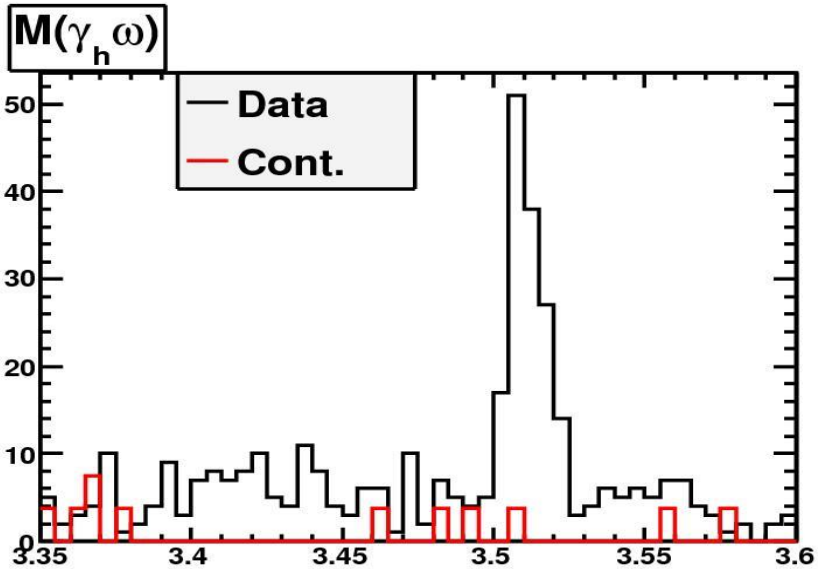
$\chi_{cJ} \to \gamma\omega(\pi\pi\pi^0)$

Background Check

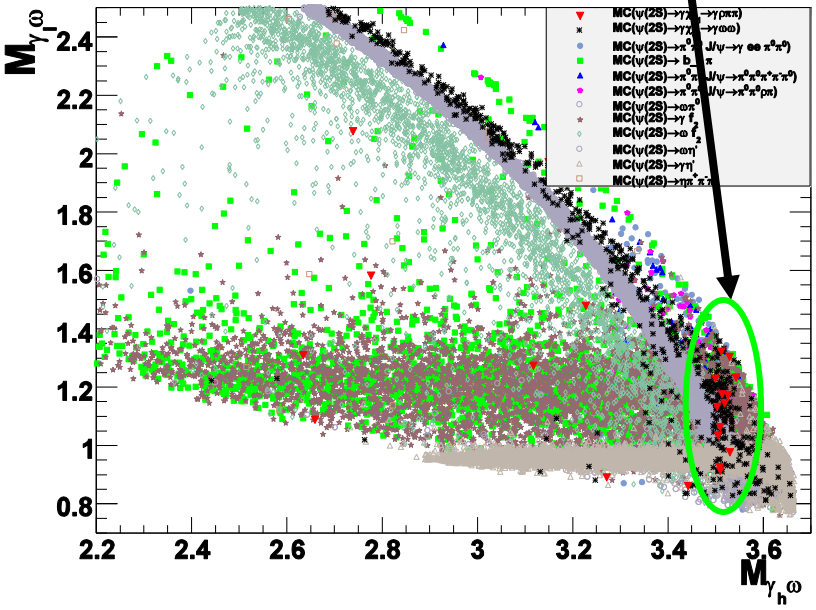
- ✓ Continuum data at 3.65 GeV (42.6 pb^{-1})
- ✓ 100M ψ(3686) Inclusive decay sample(MC)
- ✓ Exclusive MC
- ✓ ω side-band

$\psi' \to \gamma\chi_{c1} \to \gamma\omega\omega$

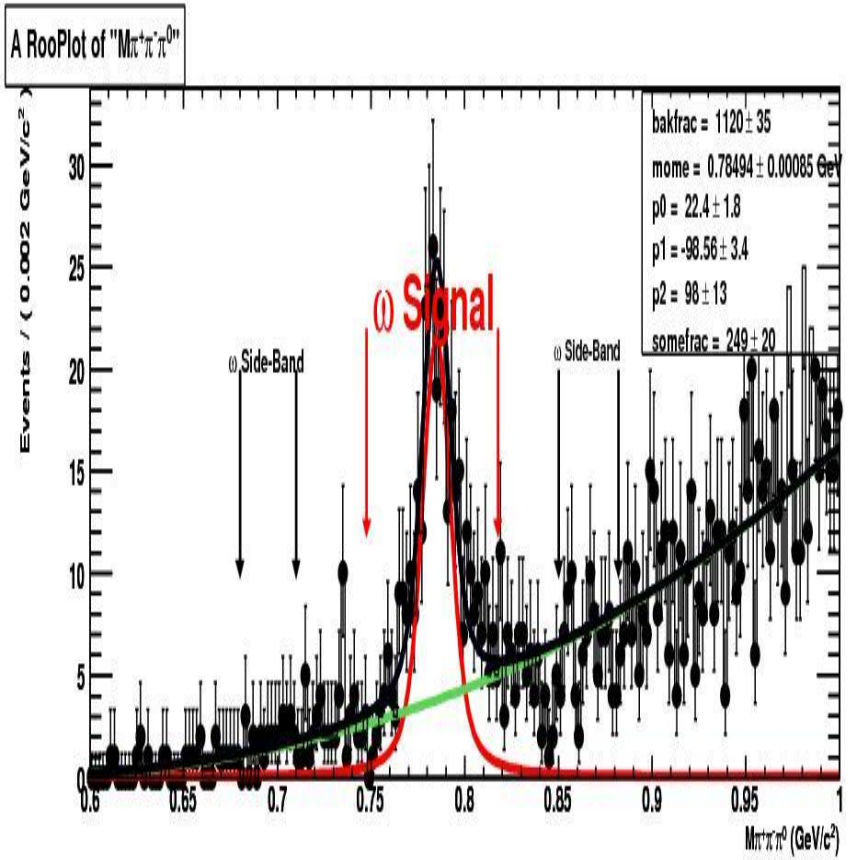
$\psi' \to \gamma\chi_{c1} \to \gamma\rho\pi\pi$

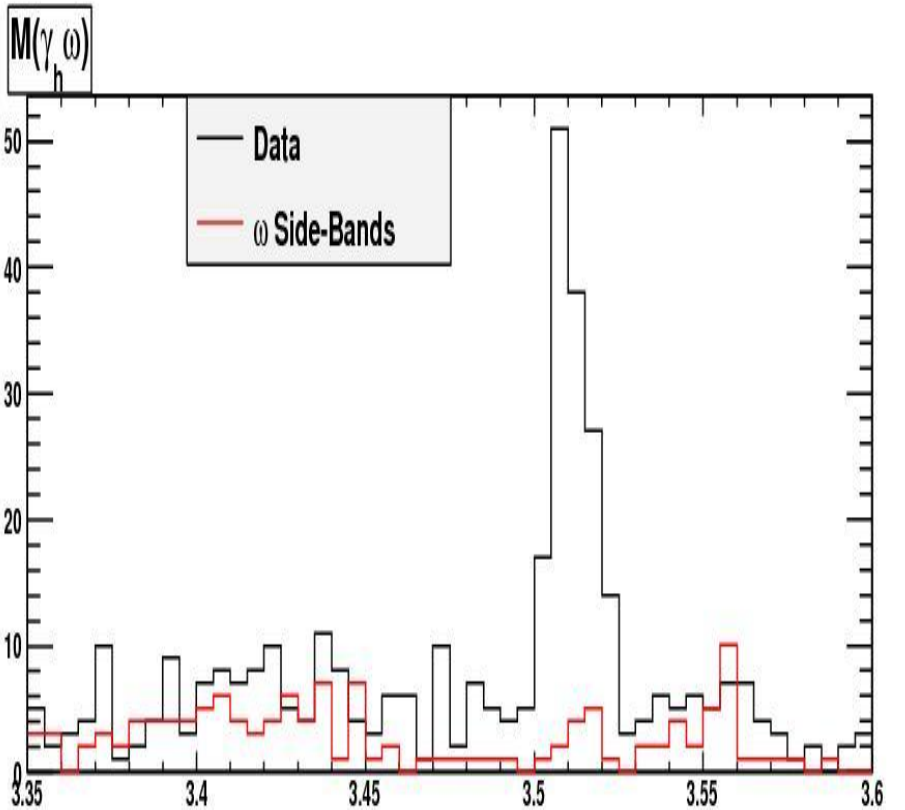


$M\gamma\omega$ (GeV/c^2)



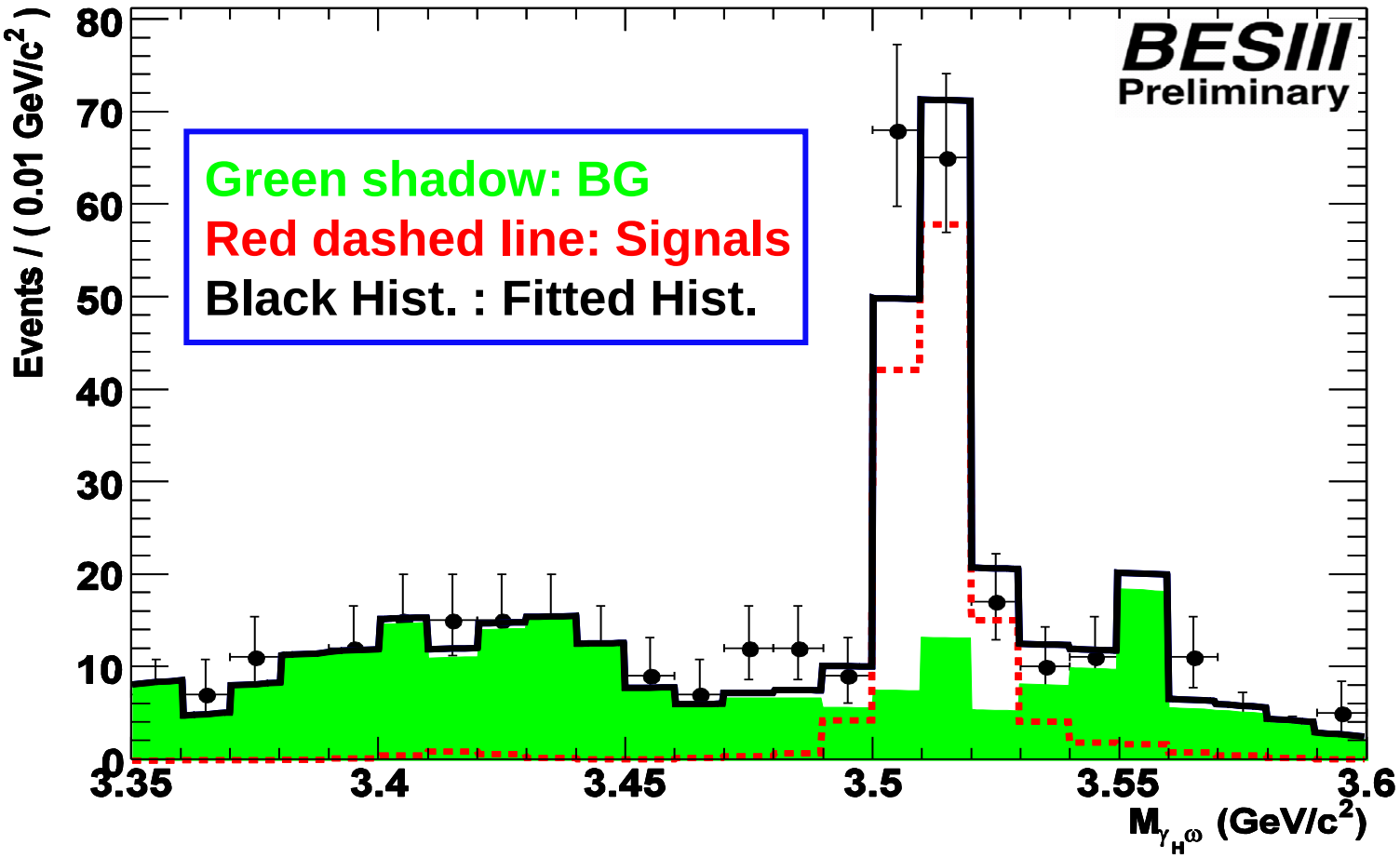
$\chi_{cJ} \rightarrow \gamma\omega(\pi\pi\pi^0)$





$M_{\gamma\omega}$ (GeV/c²)

$\chi_{cJ} \rightarrow \gamma\omega(\pi\pi\pi^0)$



BG: ω side-bands + 2nd order poly.

	Events	Br(10^{-6})	U.L. (90%CL) (10^{-6}) *	Stat.Sig.	CLEO-c	pQCD
$\chi_{c0}\to\gamma\phi$	15.0±6.6	9.4±4.2	14.8	2.9σ	6.4	0.46
$\chi_{c1}\to\gamma\phi$	42.6±8.6	27.3±5.5		6.4σ	26	3.6
$\chi_{c2}\to\gamma\phi$	4.6±4.9		7.8		13	1.1
$\chi_{c0}\to\gamma\rho$	6±12		9.5		9.6	1.2
$\chi_{c1}\to\gamma\rho$	432±25	241±14		>>10σ	243±19±22	14
$\chi_{c2}\to\gamma\rho$	13±11		19.7		50	4.4
$\chi_{c0}\to\gamma\omega$	5±11		11.7		8.8	0.13
$\chi_{c1}\to\gamma\omega$	136±14	73.5±7.6		>>10σ	83±15±12	1.6
$\chi_{c2}\to\gamma\omega$	1±6		5.8			0.5

***Only the statistical error has been considered**

Summary

- BF measurements on $\chi_{cJ} \rightarrow \pi^0\pi^0/\eta\eta$ are Published.
- Preliminary results on $\chi_{cJ} \rightarrow VV$ including first observations of $\chi_{c1} \rightarrow \phi\phi/\omega\omega$ and $\chi_{cJ} \rightarrow \phi\omega$
- Preliminary results of $\chi_{cJ} \rightarrow 4\pi^0$ ($K_S K_S$)
- Preliminary results of $\chi_{cJ} \rightarrow \gamma V$
- More exciting results from BESIII are coming soon

Thanks

谢谢