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

Charmonium Decays at BESIII

Ping Wang

(for the collaboration of BESIII)

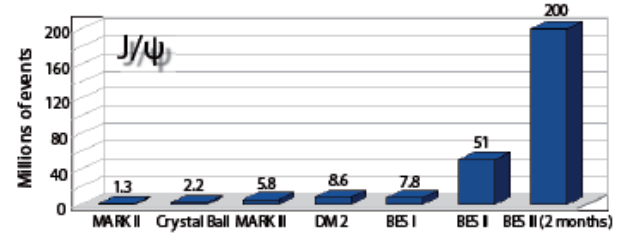
Institute of High Energy Physics, Beijing, China

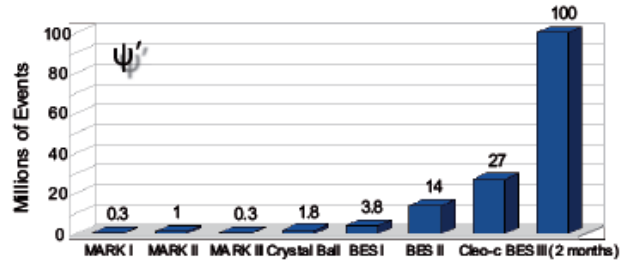
PHIPSI11, Novosibirsk, Sept, 2011

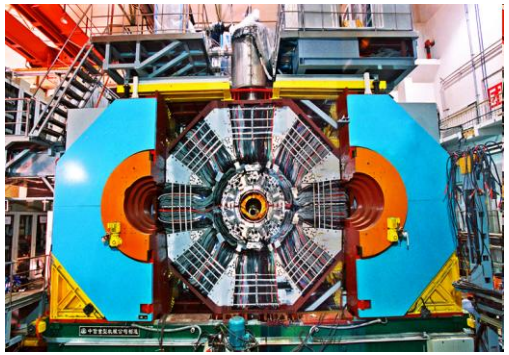
Outline

- Brief introduction of BEPCII & BESIII
- Charmonium decays:
  $\psi' \to \gamma P$, $\chi_{cJ} \to \gamma V$, $\chi_{cJ} \to VV$
- Summary

BEPCII & BESIII







Large luminosity

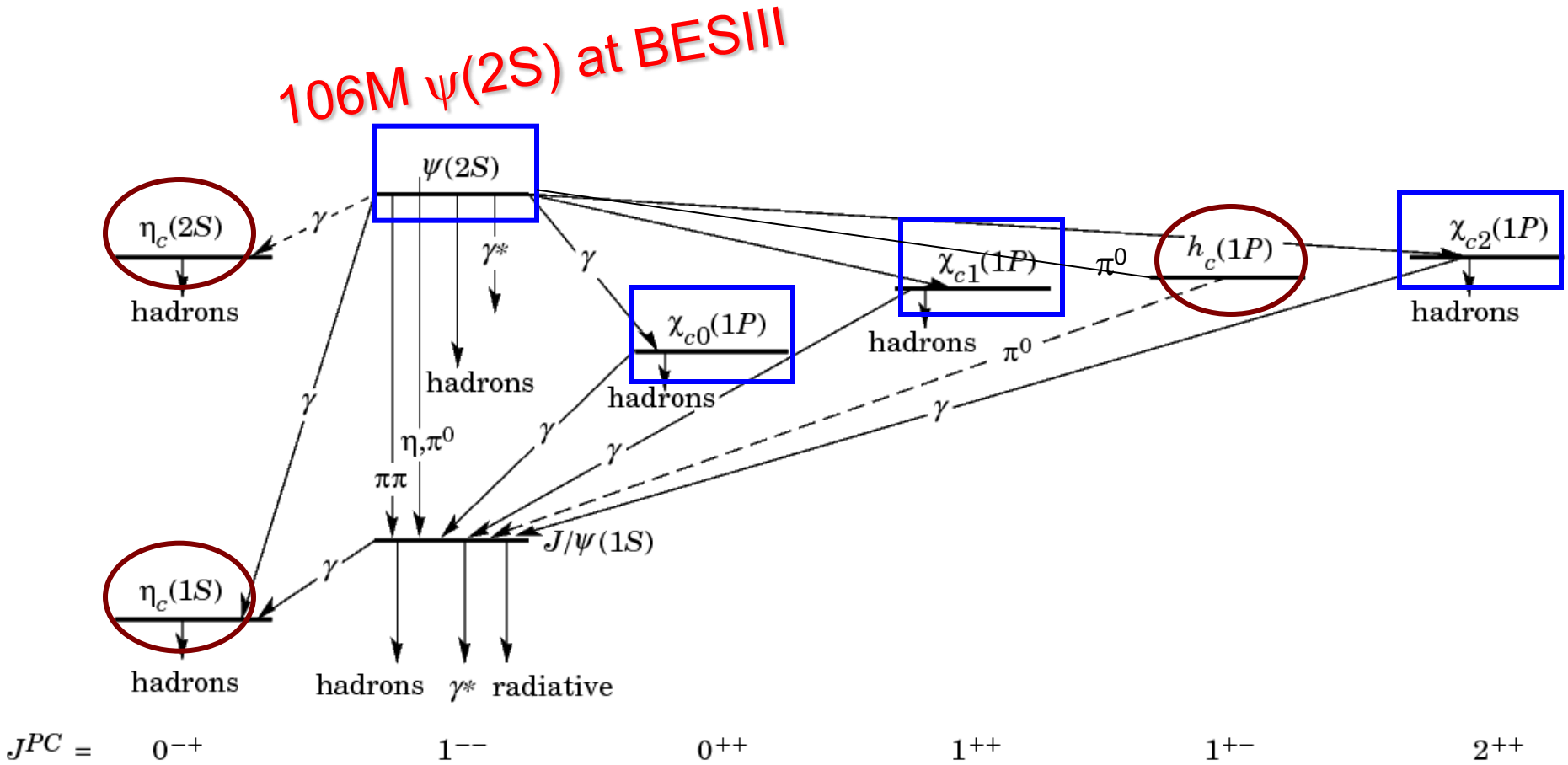
Updated detectors

Charm energy region

BESIII is special!

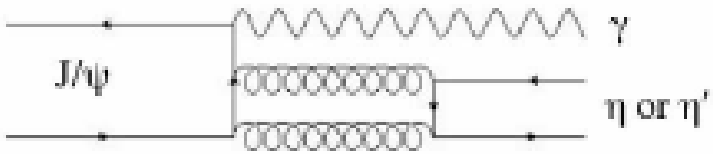
Abundant potential physics with BESIII.

Charmonium spectrum below open charm threshold

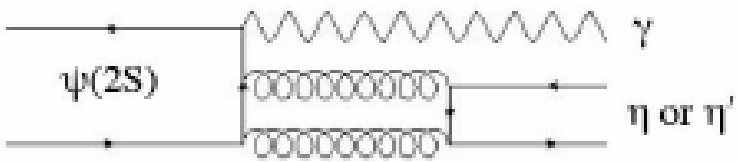


$\psi' \to \gamma\, P(\pi^0, \eta, \eta')$, arise surprises

$V \to \gamma$ P are important tests for various mechanisms:
Vector meson Dominance Model (VDM); Couplings & form factor; Mixing of η-η'(-η_c); FSR by light quarks; 12% rule and "$\rho\ \pi$ puzzle".



VS



theory

$$R_{(c\bar{c})} = \frac{Br((c\bar{c}) \to \gamma\eta)}{Br((c\bar{c}) \to \gamma\eta')}$$

LO-pQCD

$\Downarrow$

$$R_{\psi'} \simeq R_{J/\psi}$$

PRP 112,173 (1984)

experiment

CLEO-c: J/ψ, ψ', ψ'' $\to \gamma$ P

$R_{J/\psi}$ = (21.1 $\pm$ 0.9)%

No Evidence for $\psi' \to \gamma\, \pi^0$ or $\gamma\, \eta$

$Br(\psi' \to \gamma\eta')$=(1.19 $\pm$ 0.09)%

$R_{\psi'}$ < 1.8% at 90% CL

$\Downarrow$

$R_{\psi'} << R_{J/\psi}$

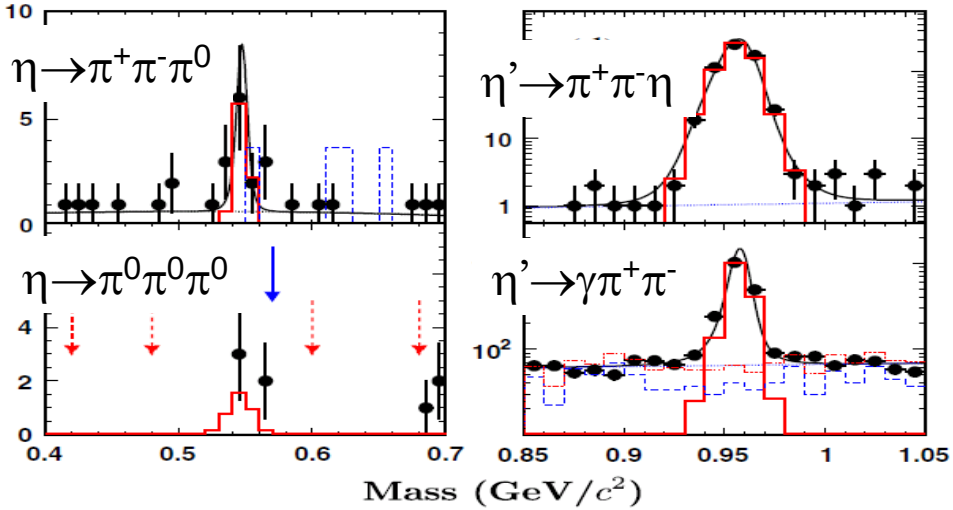
PRD 79, 111101 (2009)

$\psi' \to \gamma P$ at BESIII

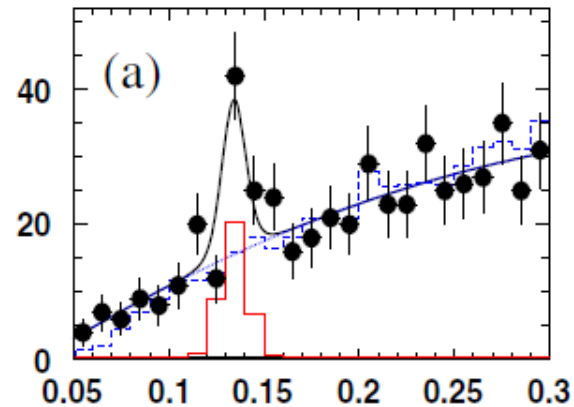
PRL 105, 261801 (2010)

$\psi' \to \gamma\eta$
(First observation)

$\psi' \to \gamma\eta'$



$\psi' \to \gamma\pi^0$
(First observation)

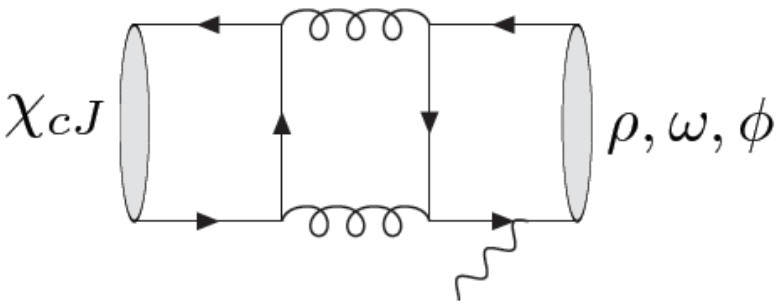


$R_{\psi'} = 1.10 \pm 0.38 \pm 0.07\%$ << $R_{J/\psi}$

Mode	$B(\psi')$ [x10^{-6}]	$B(J/\psi)$ [x10^{-4}]	Q (%)
$\gamma\pi^0$	1.58±0.42	0.35±0.03	4.5 ± 1.3
$\gamma\eta$	1.38±0.49	11.04±0.34	0.13 ± 0.04
$\gamma\eta'$	126±9	52.8±1.5	2.4 ± 0.2

Possible interpretation: Q. Zhao, Phys. Lett. B697, 52 (2011)

$\chi_{cJ} \to \gamma\, V(\rho,\omega,\phi)$, prediction by pQCD much lower than experiment



- Information of C-even state
- Two gluon coupling
- Possible glue-ball or hybrid states
- Hadronization

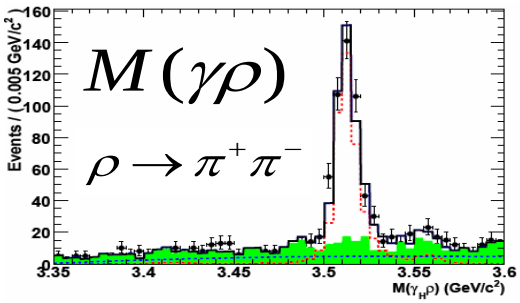
Br. are in unit of 10^{-6}.

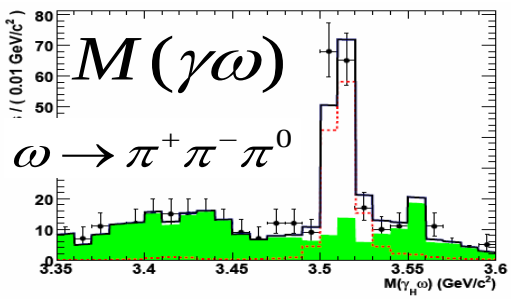
Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7
$\chi_{c2} \to \gamma\omega$	< 7.0	0.5	1.5	4.2
$\chi_{c0} \to \gamma\phi$	< 6.4	0.46	1.3	0.03
$\chi_{c1} \to \gamma\phi$	< 26	3.6	11	11
$\chi_{c2} \to \gamma\phi$	< 13	1.1	3.3	6.5

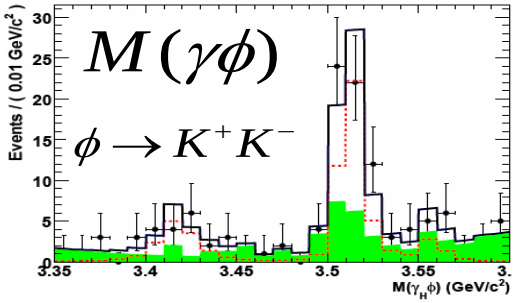
1. PRL 101,151801 (2008). 2. Chin. Phys. Lett. 23, 2376 (2006). 3. hep-ph/0701009

$\chi_{cJ} \to \gamma\, V(\rho,\omega,\phi)$ results at BESIII

Phys. Rev. D 83, 112005 (2011)







Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]	BESIII
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0	**<10.5**
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42	**$228 \pm 13 \pm 16$**
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38	**<20.8**
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22	**<12.9**
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7	**$69.7 \pm 7.2 \pm 5.6$**
$\chi_{c2} \to \gamma\omega$	< 7.0	0.5	1.5	4.2	**<6.1**
$\chi_{c0} \to \gamma\phi$	< 6.4	0.46	1.3	0.03	**<16.2**
$\chi_{c1} \to \gamma\phi$	< 26	3.6	11	11	**$25.8 \pm 5.2 \pm 2.0$**
$\chi_{c2} \to \gamma\phi$	< 13	1.1	3.3	6.5	**<8.1**

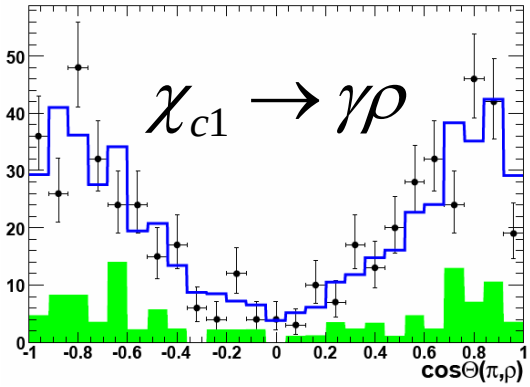
First observation

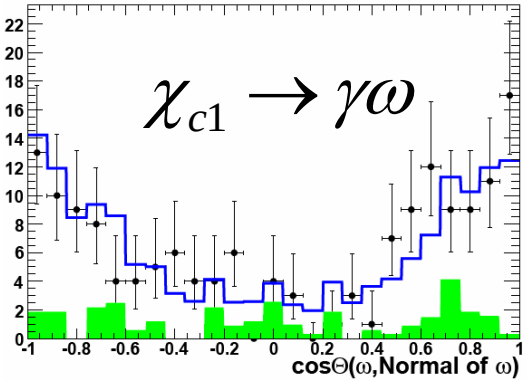
An non-pQCD explanation "hadronic loop connection",
D.Y Chen et al. arXiv:1005.0066v2[hep-ph] EPJC70, 177-182 (2010)

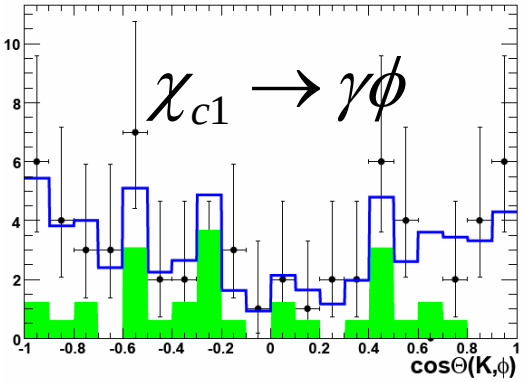
Polarization of $\chi_{c1} \to \gamma\, V(\rho,\omega,\phi)$

L: Longitudinal polarization, T: Transverse polarization, θ: Helicity angle

$$\frac{d\Gamma}{\Gamma d\cos\theta} \propto (1-f_T)\cos^2\theta + \frac{1}{2} f_T \sin^2\theta \qquad f_T = \frac{|A_T|^2}{|A_T|^2 + |A_L|^2}$$







$f_T = 0.158 \pm 0.034^{+0.015}_{-0.014}$ $\qquad$ $f_T = 0.247^{+0.090}_{-0.087}{}^{+0.044}_{-0.026}$ $\qquad$ $f_T = 0.29^{+0.13}_{-0.12}{}^{+0.10}_{-0.09}$

Longitudinal polarization dominates

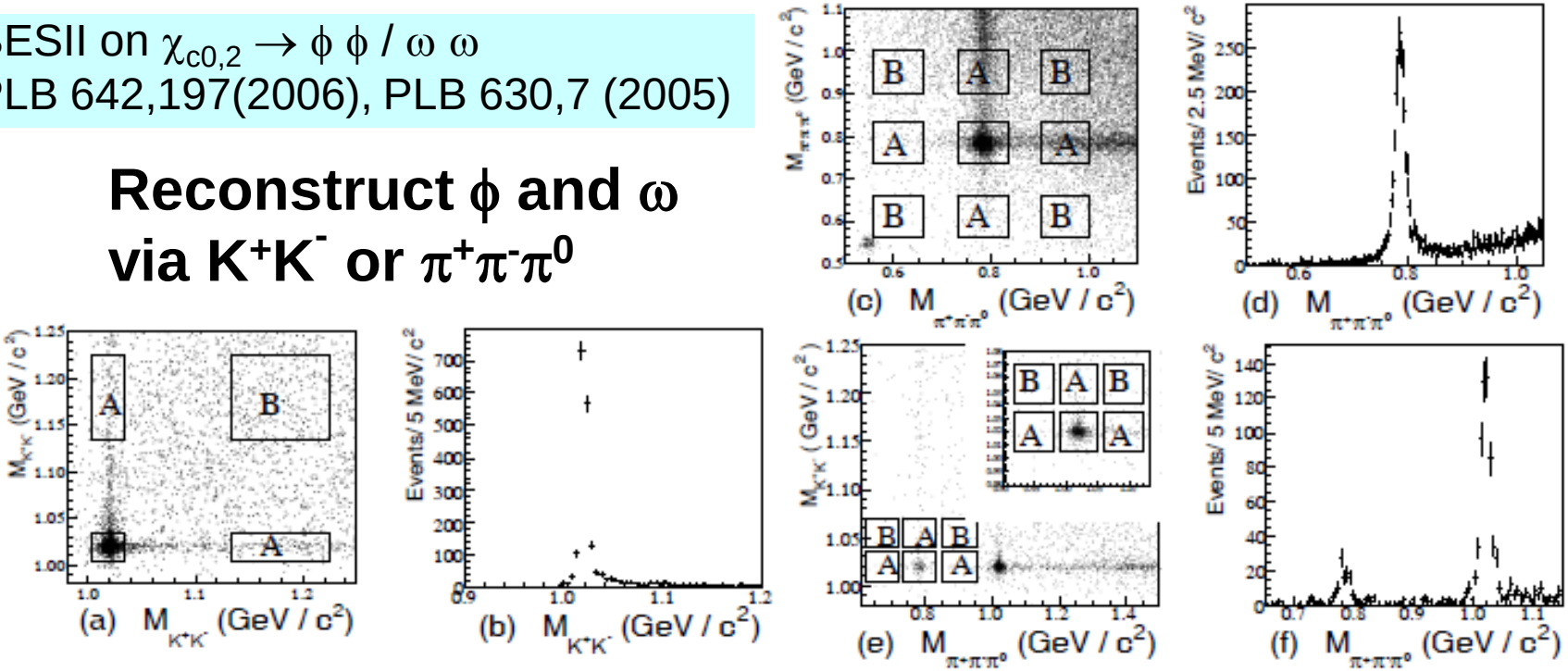
D.V. Amelin et al. (VES Collaboration), Z. Phys. C 66, **71** (1995)
C.N. Yang, Phys. Rev. **77**, 242 (1950)

$\chi_c \rightarrow VV(V=\omega, \phi)$, suppressed decays

- $\chi_{cJ} \rightarrow \phi\,\phi$ and $\chi_{cJ} \rightarrow \omega\,\omega$ are Singly OZI suppressed
- $\chi_{c1} \rightarrow \phi\phi$ and $\chi_{c1} \rightarrow \omega\omega$ is suppressed by helicity selection rule.
- $\chi_{cJ} \rightarrow \phi\omega$ is doubly OZI suppressed, not measured yet

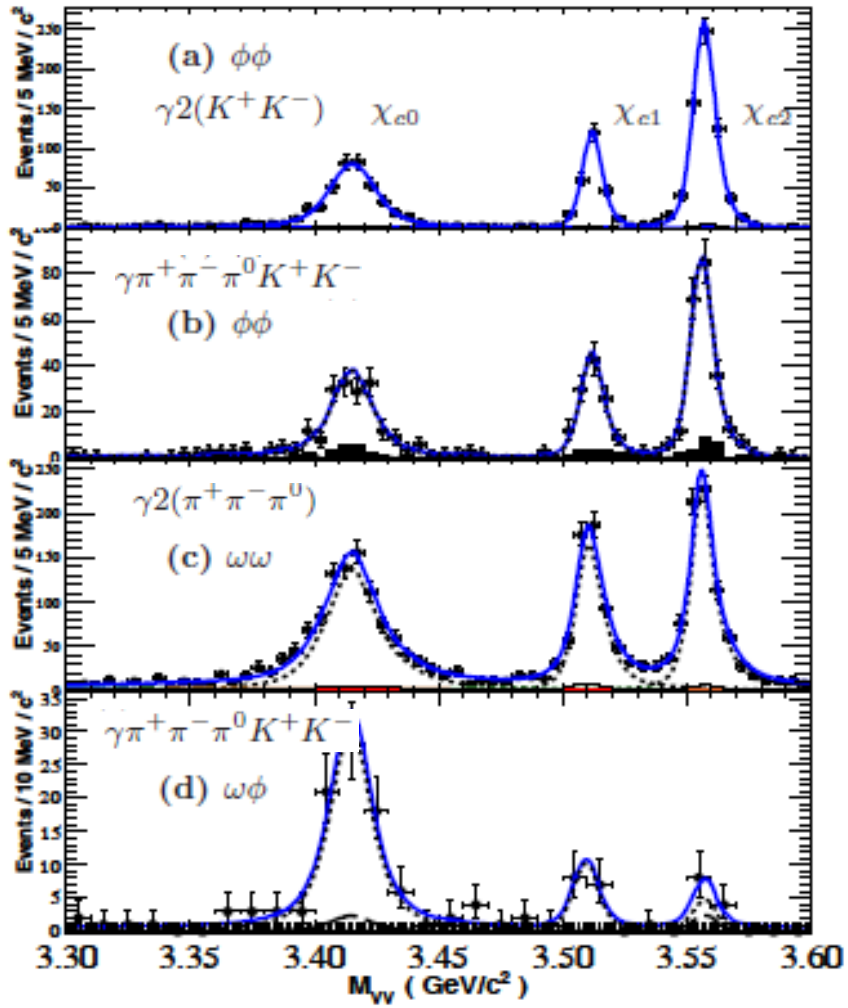
BESII on $\chi_{c0,2} \rightarrow \phi\,\phi$ / $\omega\,\omega$
PLB 642,197(2006), PLB 630,7 (2005)

Reconstruct ϕ and ω via K^+K^- or $\pi^+\pi^-\pi^0$



$\chi_c \rightarrow VV$ at BESIII

Accepted by PRL



Mode	$N_{\rm net}$	ϵ (%)	$\mathcal{B}(\times 10^{-4})$
$\chi_{c0} \to \phi\phi$	433 ± 23	22.4	$7.8 \pm 0.4 \pm 0.8$
$\chi_{c1} \to \phi\phi$	254 ± 17	26.4	$4.1 \pm 0.3 \pm 0.4$
$\chi_{c2} \to \phi\phi$	630 ± 26	26.1	$10.7 \pm 0.4 \pm 1.1$
$\to 2(K^+K^-)$			
$\chi_{c0} \to \phi\phi$	179 ± 16	1.9	$9.2 \pm 0.7 \pm 1.0$
$\chi_{c1} \to \phi\phi$	112 ± 12	2.3	$5.0 \pm 0.5 \pm 0.6$
$\chi_{c2} \to \phi\phi$	219 ± 16	2.2	$10.7 \pm 0.7 \pm 1.2$
$\to K^+K^-\pi^+\pi^-\pi^0$			
Combined:			
$\chi_{c0} \to \phi\phi$	—	—	$8.0 \pm 0.3 \pm 0.8$
$\chi_{c1} \to \phi\phi$	—	—	$4.4 \pm 0.3 \pm 0.5$
$\chi_{c2} \to \phi\phi$	—	—	$10.7 \pm 0.3 \pm 1.2$
$\chi_{c0} \to \omega\omega$	991 ± 38	13.1	$9.5 \pm 0.3 \pm 1.1$
$\chi_{c1} \to \omega\omega$	597 ± 29	13.2	$6.0 \pm 0.3 \pm 0.7$
$\chi_{c2} \to \omega\omega$	762 ± 31	11.9	$8.9 \pm 0.3 \pm 1.1$
$\to 2(\pi^+\pi^-\pi^0)$			
$\chi_{c0} \to \omega\phi$	76 ± 11	14.7	$1.2 \pm 0.1 \pm 0.2$
$\chi_{c1} \to \omega\phi$	15 ± 4	16.2	$0.22 \pm 0.06 \pm 0.02$
$\chi_{c2} \to \omega\phi$	< 13	15.7	< 0.2
$\to K^+K^-\pi^+\pi^-\pi^0$			

First observation

Evidence

Large distance effect: X. H. Liu, et al, PRD **81,** 014017 (2010)
D.Y. Chen, et al, PRD **81,** 074006 (2010)

summary

- With very high luminosity, BEPCII/BESIII is the best instrument to study the physics at τ-charm region.
- BESIII has obtained good measurements on decays of $\psi' \to \gamma$ P, $\chi_{cJ} \to \gamma$ V and $\chi_{cJ} \to$ VV.
- With the accumulated 106M ψ' sample, these results are precision measurements or first observation.
- More exciting/interesting results are coming.

Thanks!