Recent Results on P-wave Charmonium Decays from BESIII

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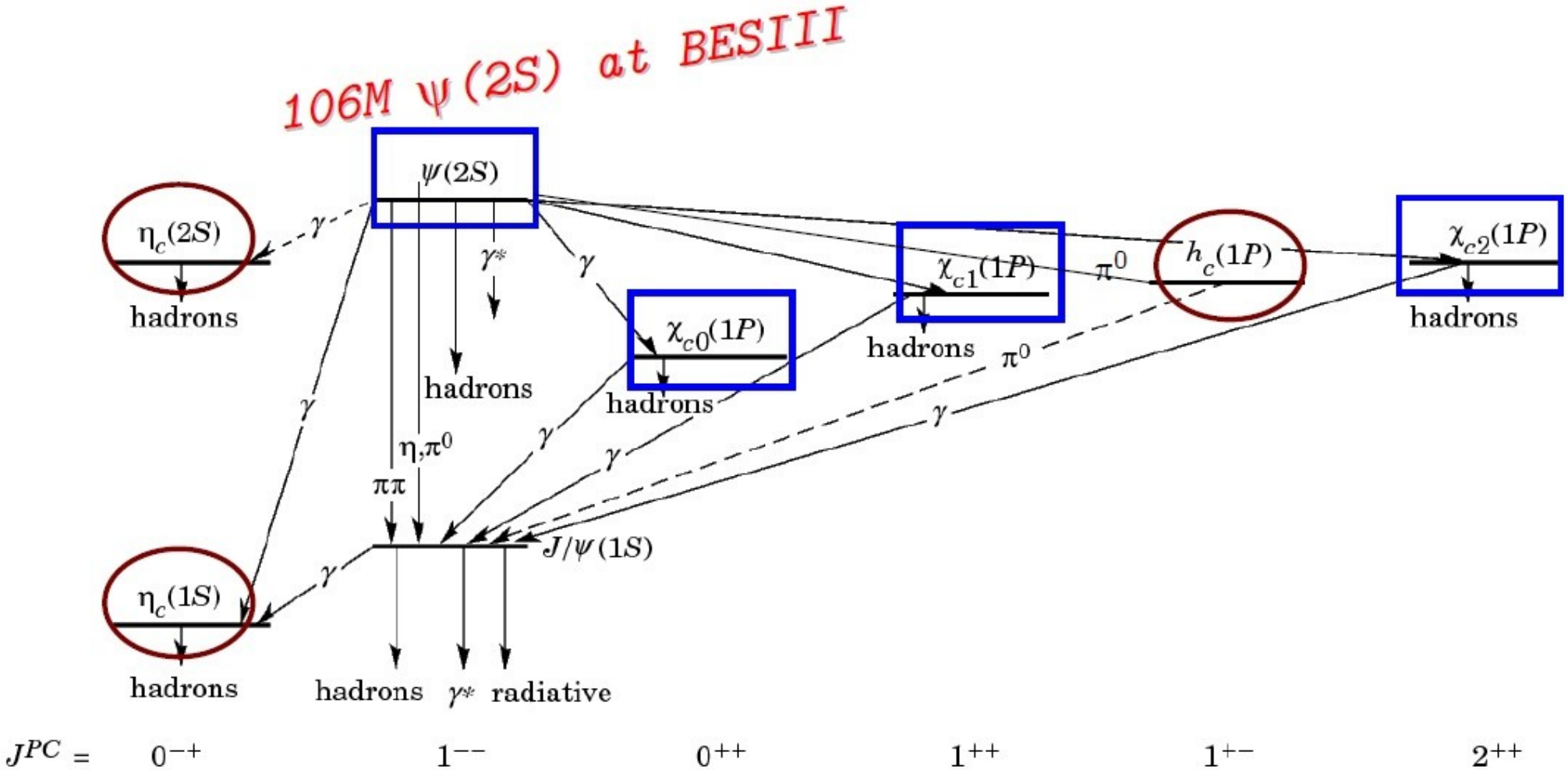
For the BESIII Collaboration

OUTLINE

- Introduction
- $\chi_{cJ} \to p\bar{p}K^+K^-$ Phys. Rev. D 83, 112009 (2011)
- $\chi_{cJ} \to VV$ PRL 107, 092001 (2011)
- $\chi_{cJ} \to \gamma V$ Phys. Rev. D83, 112005 (2011)

Charmonium spectrum below open charm threshold



$\chi_{cJ} \to p\bar{p}K^+K^-$

* Study of $\chi_{cJ} \to B\bar{B}$ is a good test of color octet mechanism in χ_{cJ} decays

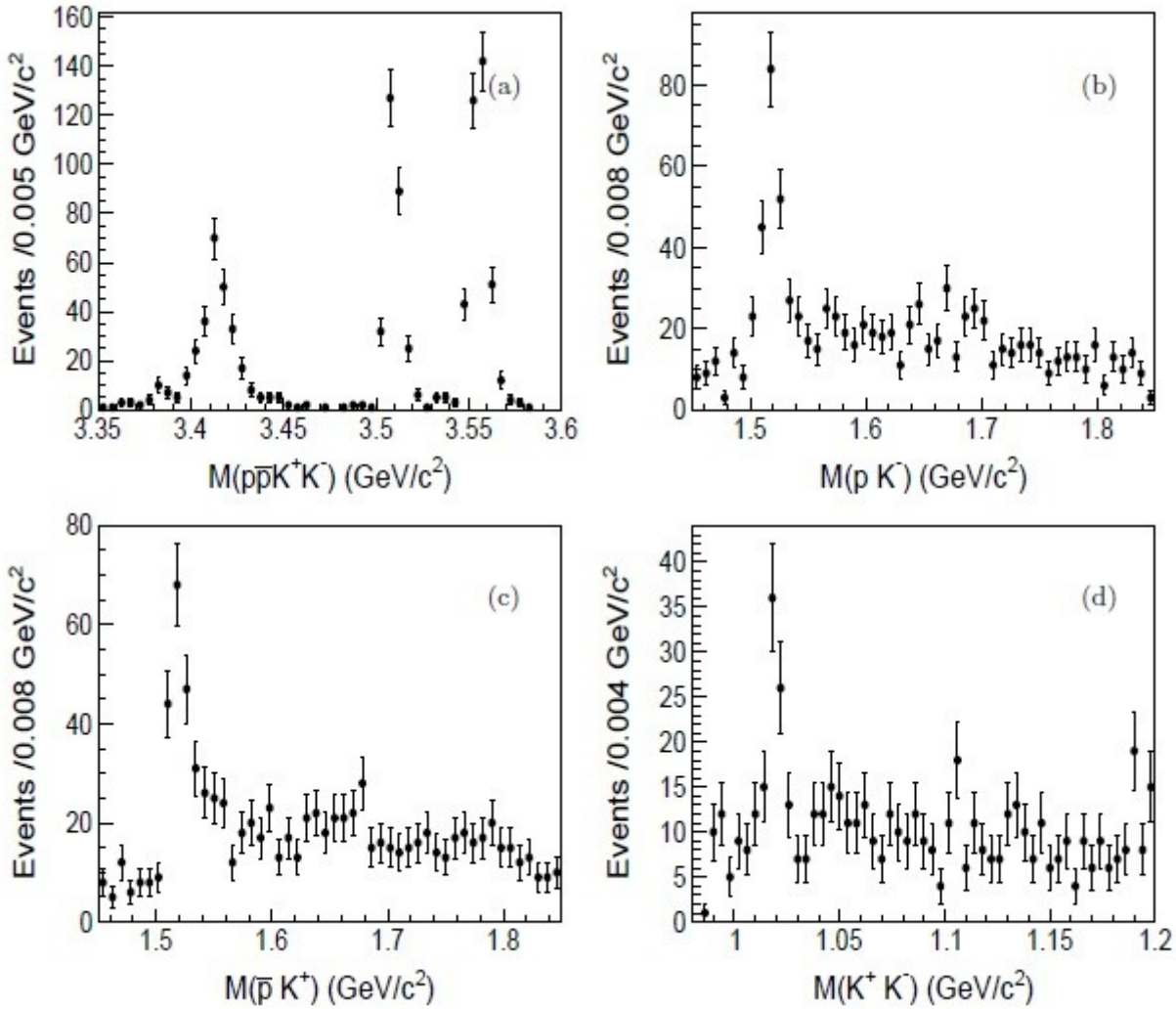
* $\chi_{cJ} \to p\bar{p}$: theory consistent with experiment

* $\chi_{cJ} \to \Lambda\bar{\Lambda}$: BR from experiment larger

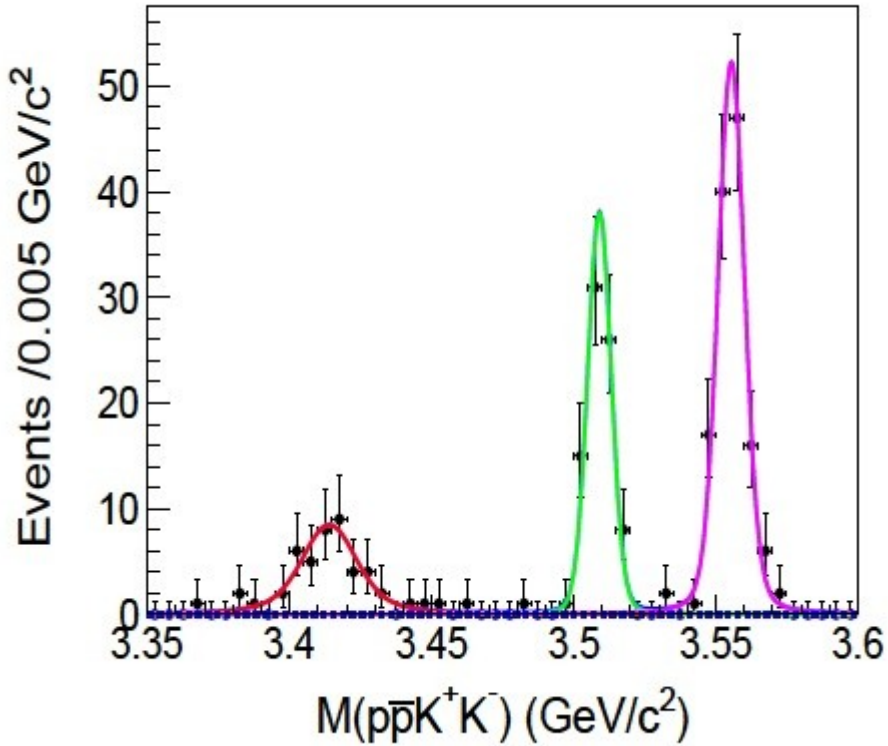
* χ_{cJ} decays into excited baryon pair not measured yet

process	theory	experiment
$\mathcal{B}(\chi_{c0} \to p\,\bar{p})$	–	22.4 ± 2.7
$\mathcal{B}(\chi_{c1} \to p\,\bar{p})$	6.4	7.2 ± 1.3
$\mathcal{B}(\chi_{c2} \to p\,\bar{p})$	7.7	6.8 ± 0.7
$\mathcal{B}(\chi_{c0} \to \Lambda\,\bar{\Lambda})$	–	47 ± 16
$\mathcal{B}(\chi_{c1} \to \Lambda\,\bar{\Lambda})$	3.8	26 ± 12
$\mathcal{B}(\chi_{c2} \to \Lambda\,\bar{\Lambda})$	3.5	34 ± 17

$\chi_{cJ} \to \Lambda\bar{p}K^+K^-$

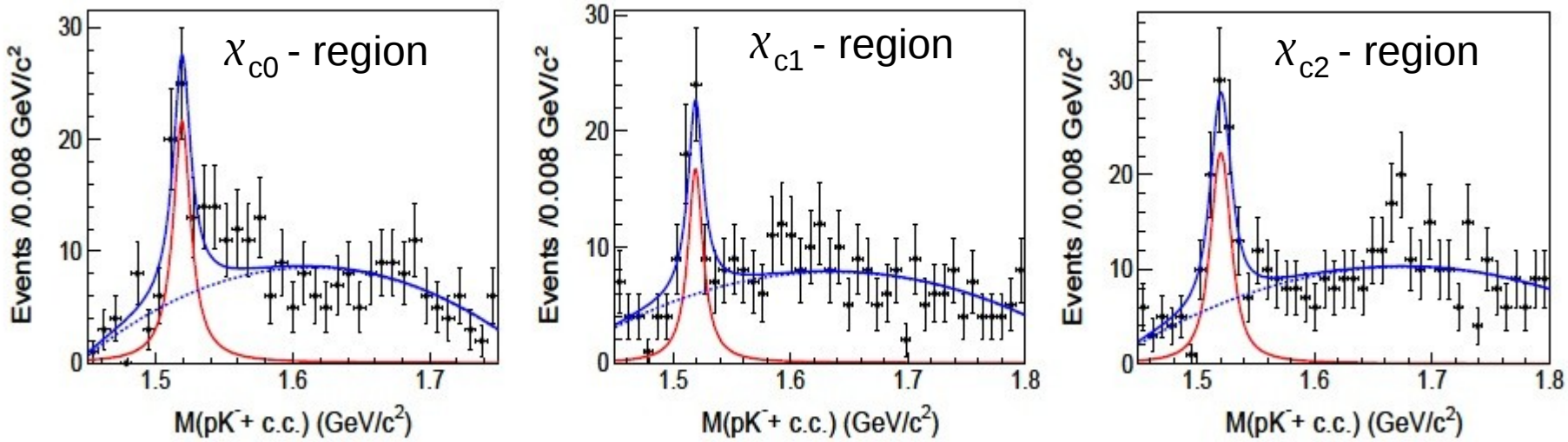


$\chi_{cJ} \to p\bar{p}K^+K^-$



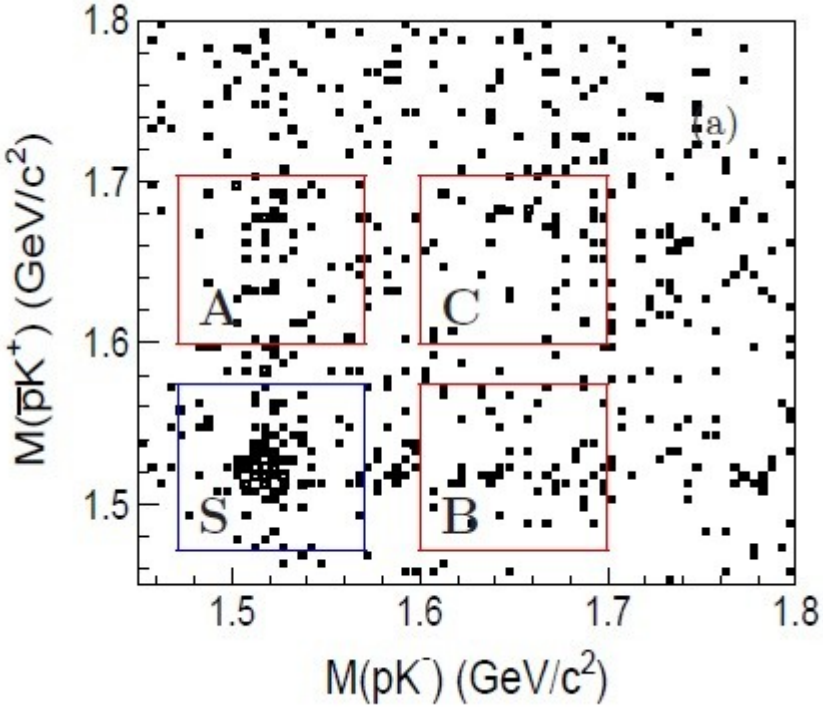
	χ_{c0}	χ_{c1}	χ_{c2}
N_{obs}	48.2 ± 7.7	81.5 ± 9.2	131 ± 12
$\varepsilon(\%)$	3.8 ± 0.1	6.2 ± 0.1	6.8 ± 0.1
$\mathcal{B}(\chi_{cJ} \to p\bar{p}K^+K^-)$ (10^{-4})	1.24 ± 0.20	1.35 ± 0.15	2.08 ± 0.19

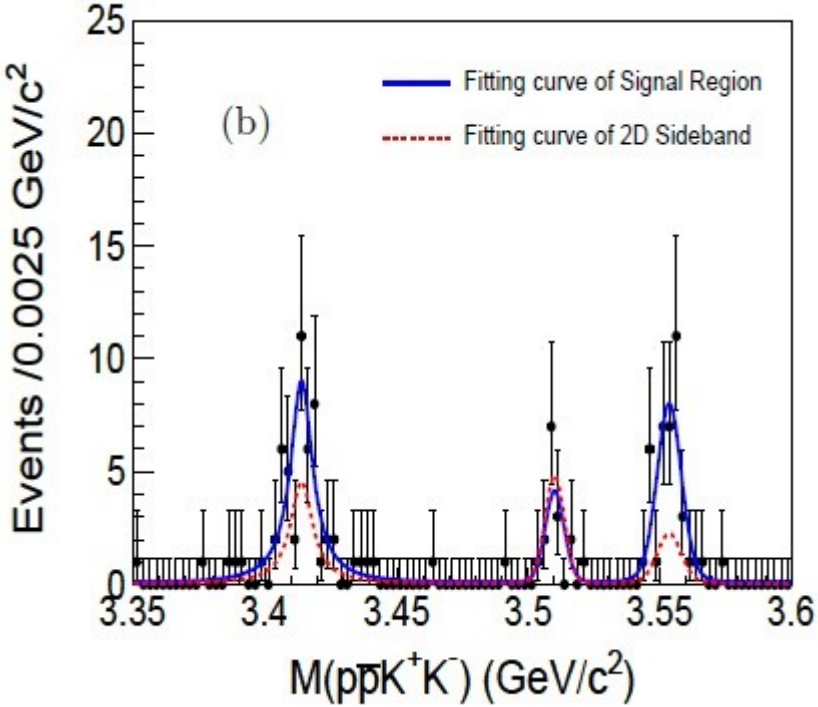
$\chi_{cJ} \to \bar{p}K^{+}\Lambda(1520)$



	χ_{c0}	χ_{c1}	χ_{c2}
N_{obs}	62 ± 12	48 ± 10	79 ± 13
$\varepsilon(\%)$	9.0 ± 0.1	12.1 ± 0.1	12.4 ± 0.1
$\mathcal{B}(\Lambda(1520) \to pK^{-})(\%)$	22.5	22.5	22.5
$\mathcal{B}(\chi_{cJ} \to \bar{p}K^{+}\Lambda(1520) + c.c.)\ (10^{-4})$	3.00 ± 0.58	1.81 ± 0.38	3.06 ± 0.50

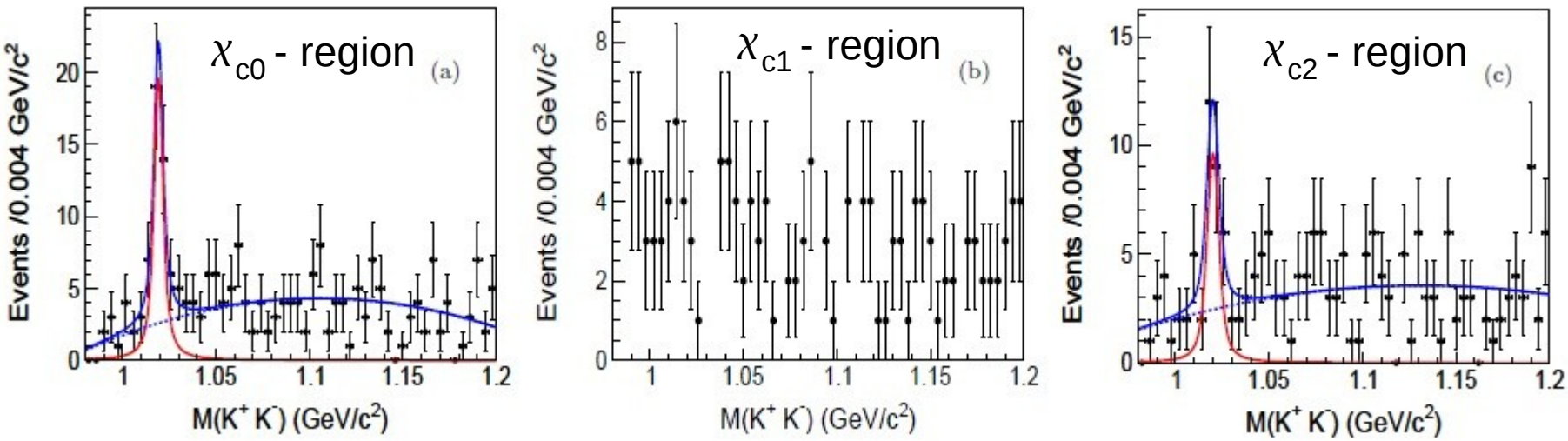
$\chi_{cJ} \to \Lambda(1520)\,\bar{\Lambda}(1520)$





	χ_{c0}	χ_{c1}	χ_{c2}
N_{obs}	28.1 ± 9.8	< 6.9	28.9 ± 7.4
$\varepsilon(\%)$	17.1 ± 0.1	16.3 ± 0.1	12.2 ± 0.1
$\mathcal{B}(\Lambda(1520) \to pK)(\%)$	22.5	22.5	22.5
$\mathcal{B}(\chi_{cJ} \to \Lambda(1520)\bar{\Lambda}(1520))$ (10^{-4})	3.18 ± 1.11	< 0.86	5.05 ± 1.29

$\chi_{cJ} \to p\bar{p}\phi$



	χ_{c0}	χ_{c1}	χ_{c2}
N_{obs}	42.4 ± 8.2	< 13.3	24.4 ± 6.8
$\varepsilon(\%)$	13.9 ± 0.1	17.7 ± 0.1	17.7 ± 0.1
$\mathcal{B}(\phi \to K^+K^-)(\%)$	48.9	48.9	48.9
$\mathcal{B}(\chi_{cJ} \to p\bar{p}\phi)$ (10^{-5})	6.12 ± 1.18	< 1.58	3.04 ± 0.85

Summary $\chi_{cJ} \to p\bar{p}K^+K^-$

	χ_{c0}	χ_{c1}	χ_{c2}
$\mathcal{B}(\chi_{cJ} \to p\bar{p}K^+K^-)$ (10^{-4})	$1.24 \pm 0.20 \pm 0.18$	$1.35 \pm 0.15 \pm 0.19$	$2.08 \pm 0.19 \pm 0.30$
$\mathcal{B}(\chi_{cJ} \to \bar{p}K^+\Lambda(1520) + c.c.)$ (10^{-4})	$3.00 \pm 0.58 \pm 0.50$	$1.81 \pm 0.38 \pm 0.28$	$3.06 \pm 0.50 \pm 0.54$
$\mathcal{B}(\chi_{cJ} \to \Lambda(1520)\bar{\Lambda}(1520))$ (10^{-4})	$3.18 \pm 1.11 \pm 0.53$	< 1.00	$5.05 \pm 1.29 \pm 0.93$
$\mathcal{B}(\chi_{cJ} \to p\bar{p}\phi)$ (10^{-5})	$6.12 \pm 1.18 \pm 0.86$	< 1.82	$3.04 \pm 0.85 \pm 0.43$

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

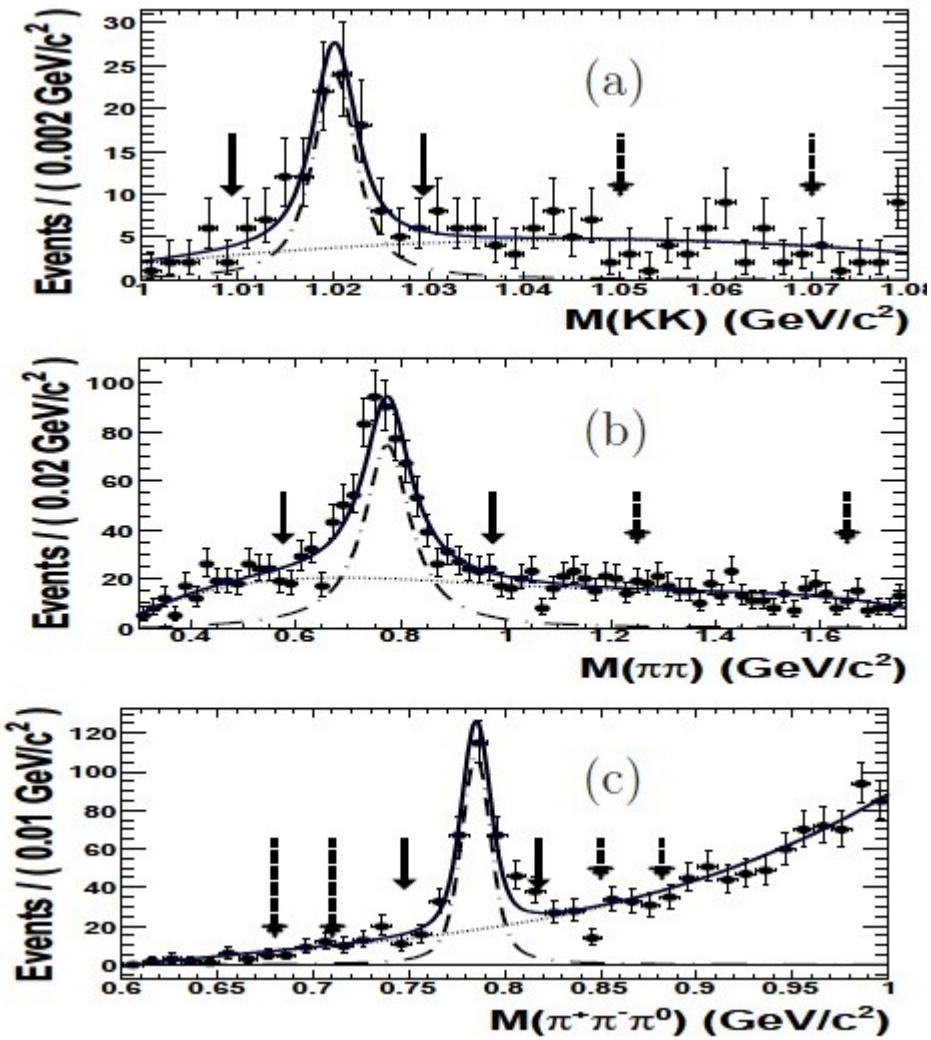
* experimential BR of $\chi_{cJ} \to \gamma V$ not well known
* $\chi_{cJ} \to \gamma V$ (), prediction by pQCD much lower than CLEO's measurement

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

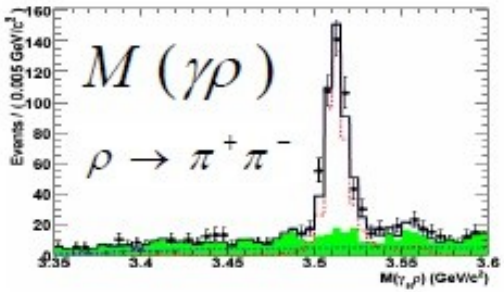
Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7
$\chi_{c2} \to \gamma\omega$	< 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

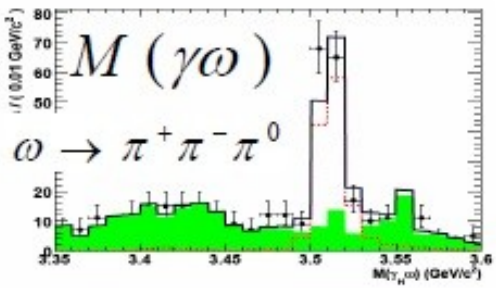
1. PRL 101,151801 (2008), 2. Chin. Phys. Lett. 23, 23776 (2006), 3. hep-ph/0701009

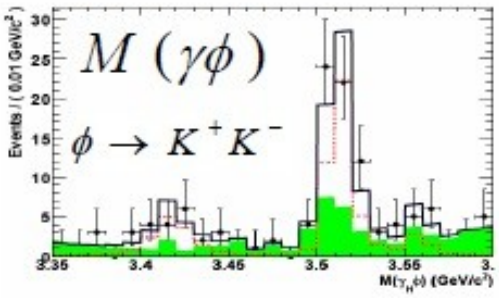
K^+K^-, $\pi^+\pi^-$, $\pi^+\pi^-\pi^0$ mass distribution



Results: $\chi_{cJ} \to \gamma V$







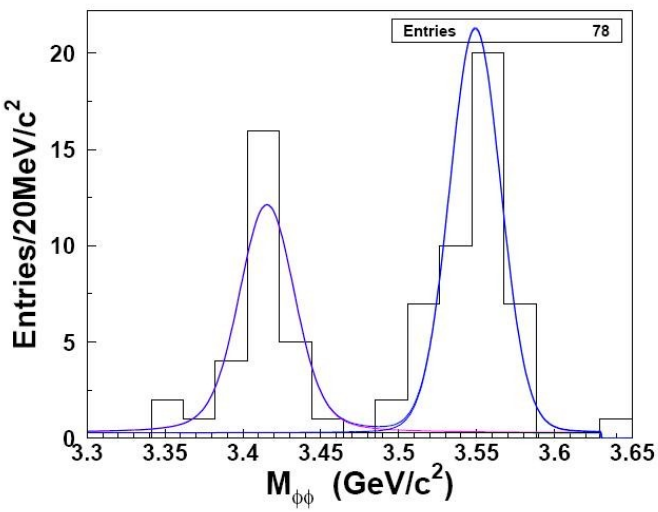
Mode	CLEO[1]	pQCD[2]	QCD[3]	QCD+QED[3]	BESIII
$\chi_{c0} \to \gamma\rho^0$	< 9.6	1.2	3.2	2.0	<10.5
$\chi_{c1} \to \gamma\rho^0$	$243 \pm 19 \pm 22$	14	41	42	228±13±16
$\chi_{c2} \to \gamma\rho^0$	< 50	4.4	13	38	<20.8
$\chi_{c0} \to \gamma\omega$	< 8.8	0.13	0.35	0.22	<12.9
$\chi_{c1} \to \gamma\omega$	$83 \pm 15 \pm 12$	1.6	4.6	4.7	69.7±7.2±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±5.2±2.0
$\chi_{c2} \to \gamma\phi$	< 13	1.1	3.3	6.5	<8.1

First observation

1. PRL 101,151801 (2008), 2. Chin. Phys. Lett. 23, 23776 (2006), 3. hep-ph/0701009

$\chi_{cJ} \rightarrow \Phi\Phi, \Phi\omega, \omega\omega$

- $\Phi\Phi$, $\Phi\omega$ and $\omega\omega$ provide information about OZI rule violation in χ_c decays
- $\Phi\Phi$ and $\omega\omega$ are singly OZI suppressed
- $\chi_{c1} \rightarrow \Phi\Phi$ and $\omega\omega$ only allowed for L=2 (suppressed ?)
- $\Phi\omega$ is doubly OZI suppressed, not measured yet



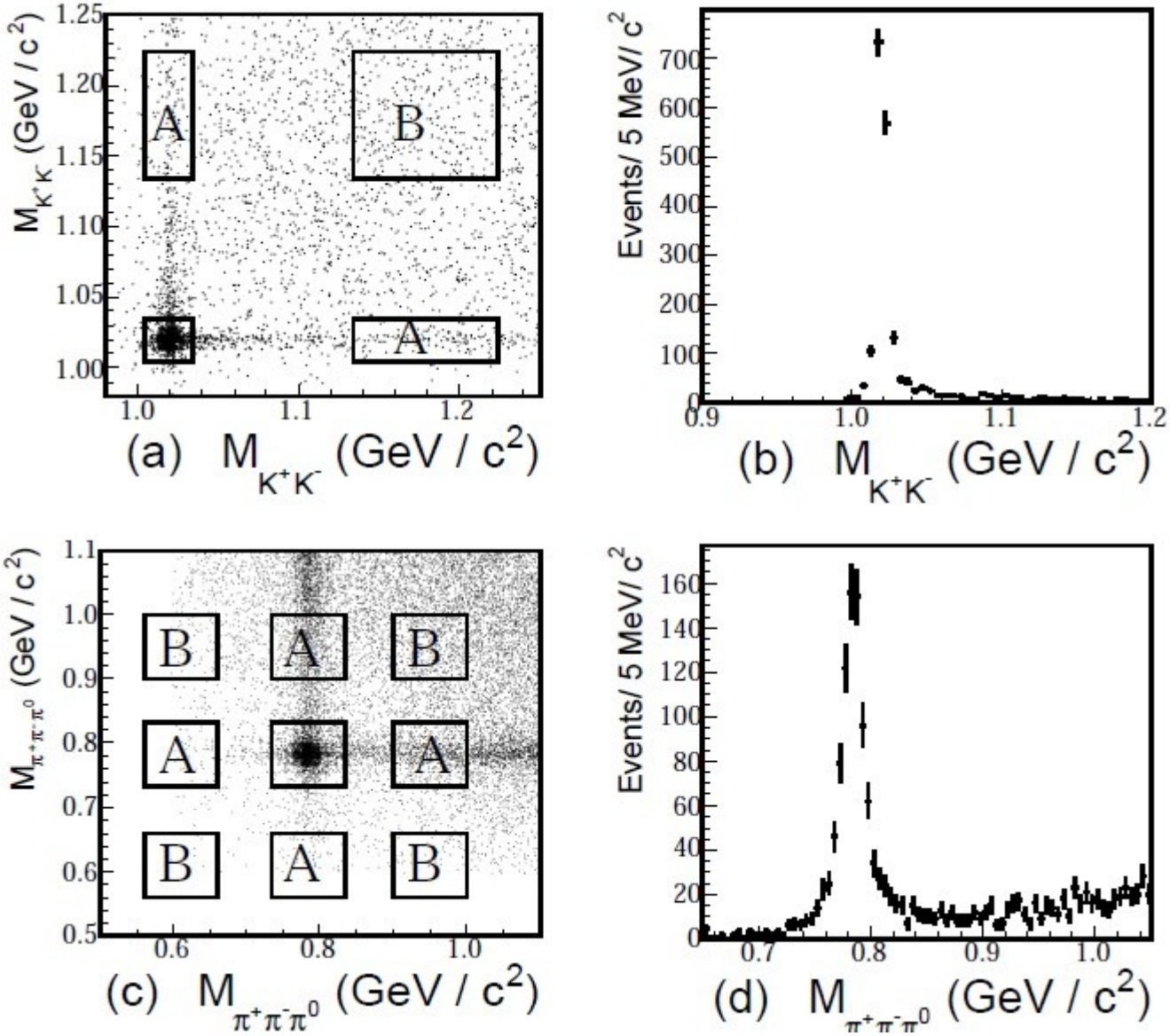
BESII result, PL B642: 192-202, 2006

BR($\chi_{c0} \rightarrow \Phi\Phi$) = (0.94 ± 0.21 ± 0.13) x 10^{-3}

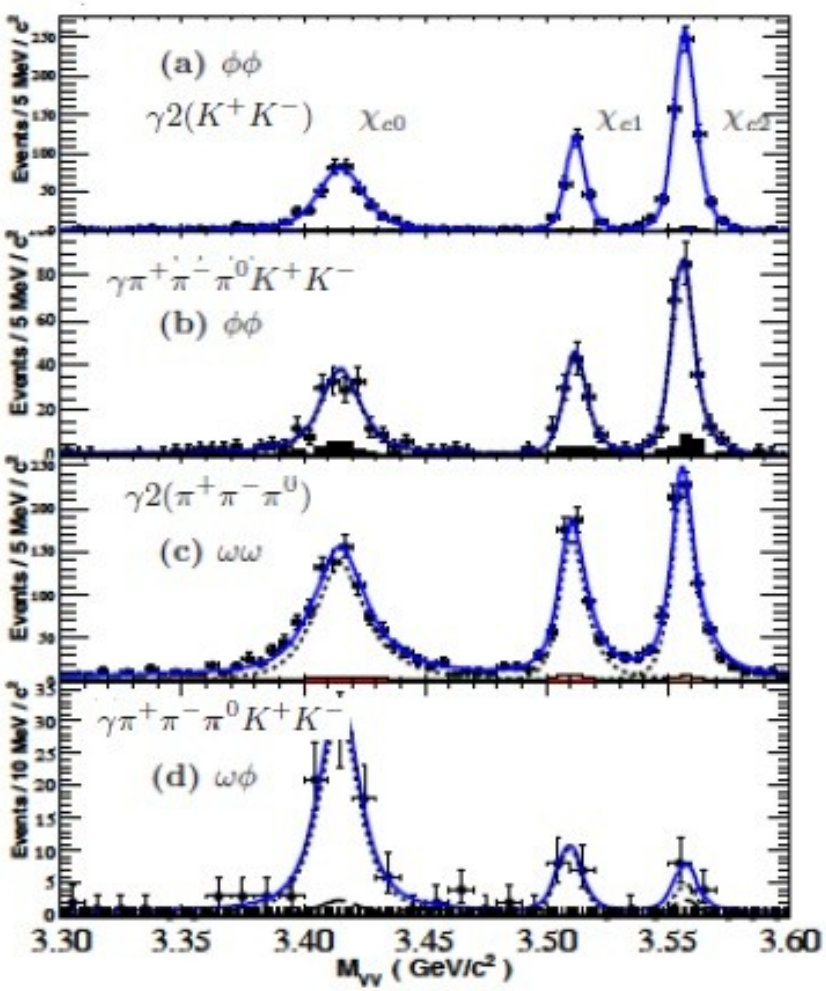
BR($\chi_{c2} \rightarrow \Phi\Phi$) = (1.70 ± 0.30 ± 0.25) x 10^{-3}

No $\chi_{c1} \rightarrow \Phi\Phi$

$\chi_{cJ} \rightarrow \Phi\Phi, \Phi\omega, \omega\omega$



$\chi_{cJ} \to \Phi\Phi, \Phi\omega, \omega\omega$



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

Summary

- $\chi_{cJ} \to p\bar{p}K^+K^-$,$\chi_{cJ} \to VV$, $\chi_{cJ} \to \gamma V$ @ BESIII

- first observation of $\chi_{cJ} \to \Lambda(1520)\,\bar{\Lambda}(1520)$

- first observation of $\chi_{c1} \to \gamma\phi$

- first observation of $\chi_{c1} \to \phi\,\phi$,$\omega\omega$

- first observation of $\chi_{c0,1} \to \phi\,\omega$