Charmonium Results From BESIII

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(For the BESIII collabration)

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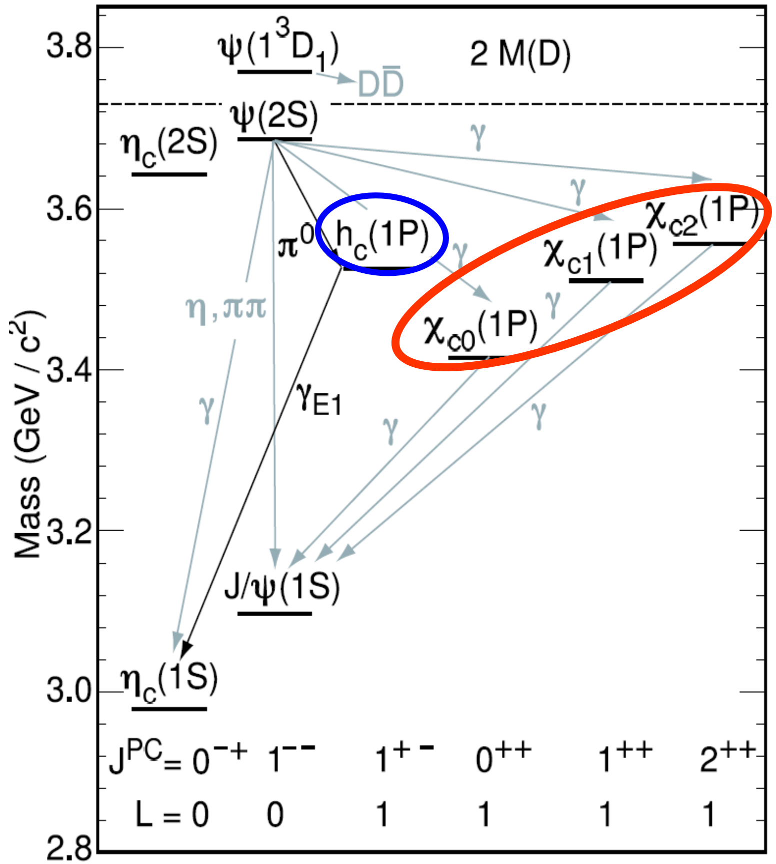
Outline

- Introduction
- $\chi_{c0,2} \rightarrow \pi^0\pi^0,\ \eta\eta$
- $\chi_{cJ} \rightarrow VV$
- h_c
- Summary

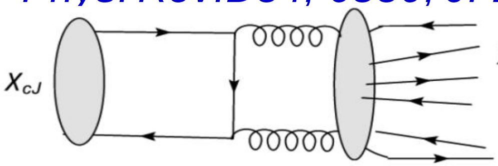


χ_{cJ} *decays*

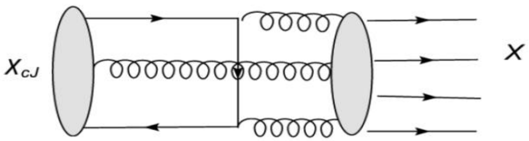
- Most hadronic decays of χ_{cJ} are not known.
- A good laboratory to study QCD
  - Color octet mechanism in χ_{cJ} decays
  - Study singly and doubly OZI suppressed decays
- Study of light hardrons produced in χ_{cJ} decays
- The e^+e^- BEPCII machine provides clean sample via $\psi' \to \gamma\chi_{cJ}$

$\chi_{cJ} \rightarrow \pi^0\pi^0, \eta\eta$

- Radiative decays of charmonium to $\pi^0\pi^0$, $\eta\eta$ are interesting channels for glueball searches.
- Exclusive decays of χ_{cJ} provide a good lab to test the color octet mechanism in P-wave charmonium decays.
  - *G.T. Bodwin et al., Phys Rev. Lett. D51, 1125 ; H.-W. Huang and K.-T. Chao, Phys. Rev.D54, 6850; J. Bolz et. al., Eur.Phys.J. C 2:705-719(1998)*



Leading-order QCD



Color octect theory

- BFs of $\eta\eta$, $\eta\eta'$, $\eta'\eta'$ determine the relative strength of Singly-OZI and Doubly-OZI contributions.
  - *Zhao PRD 72, 074001 (2005)*

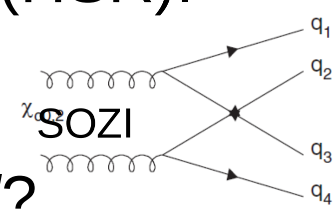
$\chi_{cJ} \rightarrow VV$ (V: ω, ϕ)

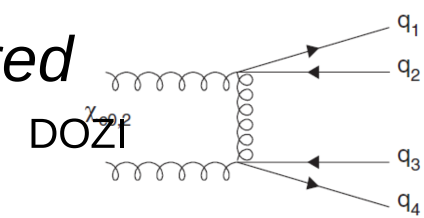
- Results from BESII

$\times 10^{-3}$	$\phi\phi$	$\omega\omega$	$\omega\phi$
χ_{c0}	**0.94±0.21 ±0.13**	**2.29±0.58 ±0.41**	**DOZI (Thy 0.45)**
χ_{c2}	**1.70±0.30 ±0.25**	**1.77±0.47±0.36**	**DOZI (Thy 0.24)**
χ_{c1}	-- **HSR**	-- **HSR**	-- **DOZI HSR**

Ref: PLB630:7, 2005. PLB642:197,2006. PRD72,074001.Q.Zhao

- $\chi_{c1} \rightarrow VV$, suppressed by Helicity Selection Rule (HSR).
- $\chi_{cJ} \rightarrow \phi\phi/\omega\omega$, singly OZI suppressed.
- $\chi_{c1} \rightarrow \phi\phi/\omega\omega$, only allowed for L=2. *Suppressed?*
- $\chi_{cJ} \rightarrow \phi\omega$, doubly-OZI suppressed. *Not measured*



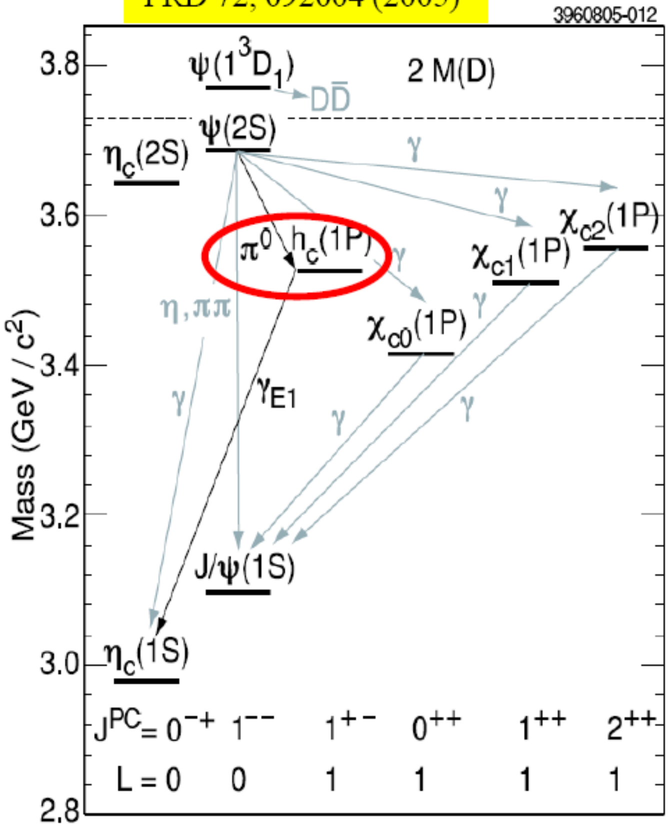


h_c ($^1P_1$)

- Spin singlet P wave (L=1, S=0)
- $M(h_c)$ is important to learn about hyperfine (spin-spin) interaction of P wave states.
- Mass and product BF from CLEOc

$M(h_c)_{AVG} = 3525.20 \pm 0.18 \pm 0.12$ MeV/c^2
$(B_1 \times B_2)_{AVG} = (4.16 \pm 0.30 \pm 0.37) \times 10^{-4}$

PRD 72, 092004 (2005)



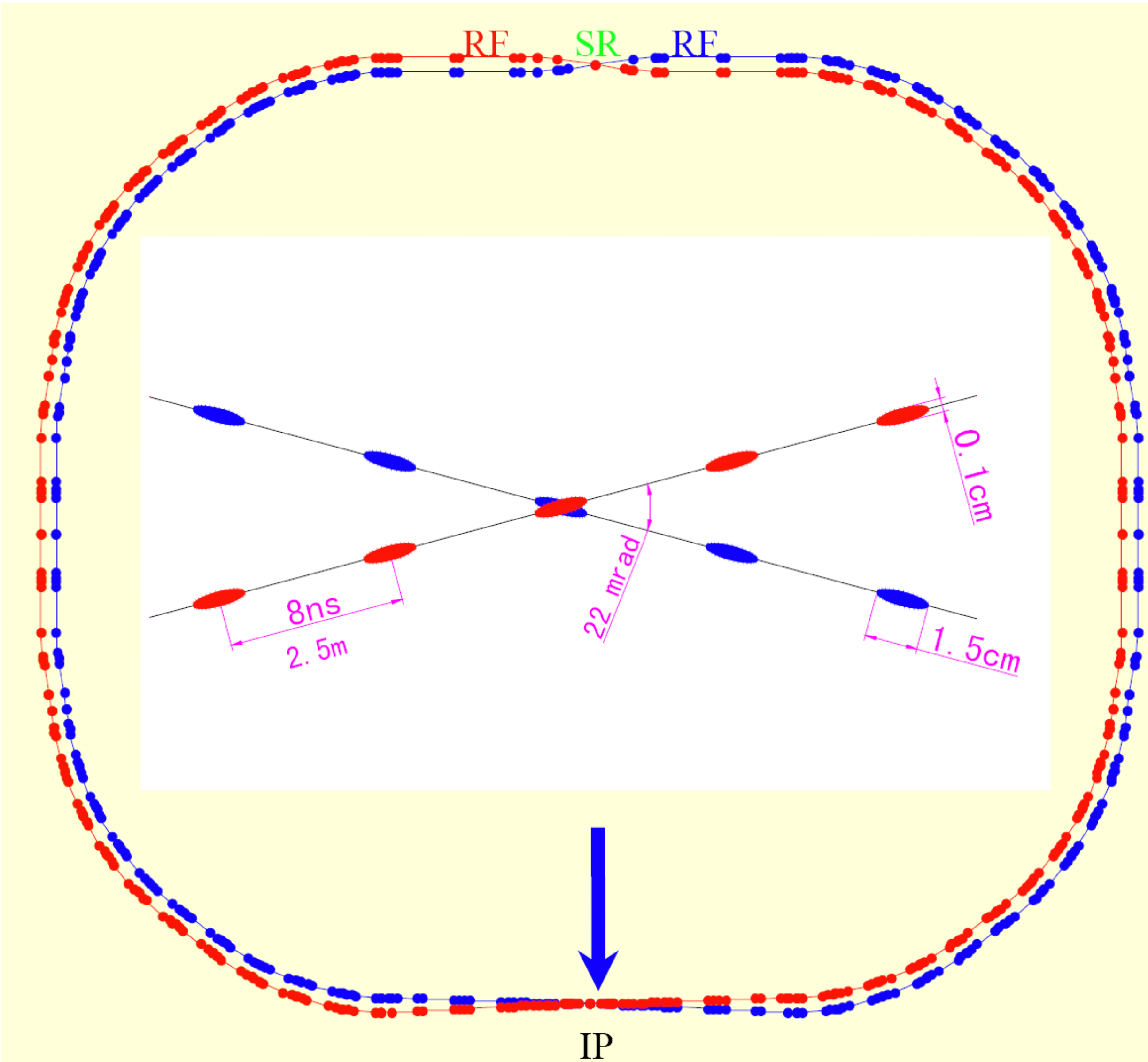
$\Delta M_{hf}(1P) = \langle M(^3P_J)\rangle - M(^1P_1) = 0.08 \pm 0.08 \pm 0.12$ MeV/c^2

$\langle M(^3P_J)\rangle$: the spin weighted centroid of 3PJ states, to represent $M(^3P_J)$.

Consistent with lowest order expectation of 0.

Ref: PRL,101,182003 (2008) CLEOc

BEPCII Storage ring: Large angle, double-ring



Beam energy:
1.0-2.3 GeV

Luminosity:
$3\sim10\times10^{32}$ $cm^{-2}s^{-1}$

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

SR mode:
0.25A @ 2.5 GeV

BESIII Detector

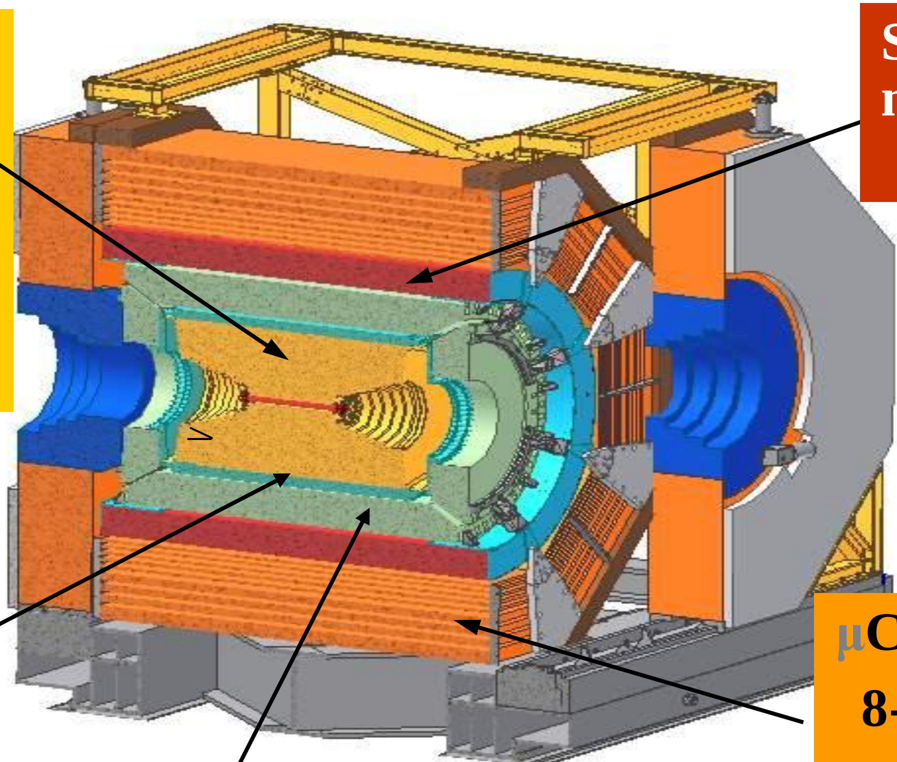
Main Drift Chamber (MDC)

$\sigma(p_T)/p_T = 0.32\% \oplus 0.37\%$ (1 GeV)

$\sigma_{dE/dx} = 5.3\%$

Super-conducting magnet

1.0 tesla



Time Of Flight (TOF)

σ_T = 80ps Barrel

100ps endcap

μCounter

8- 9 layers

$\delta R\Phi$=1.4 cm~1.7 cm

EMC： $\Delta E/\sqrt{E} = 2.5\ \%$ @ 1 GeV

$\sigma_{z,\phi} = 0.6\ \text{cm}/\sqrt{E}$

BESIII Data-taking

- July 18, 2008: First e^+e^- collision event in BESIII
- Peak luminosity achieved

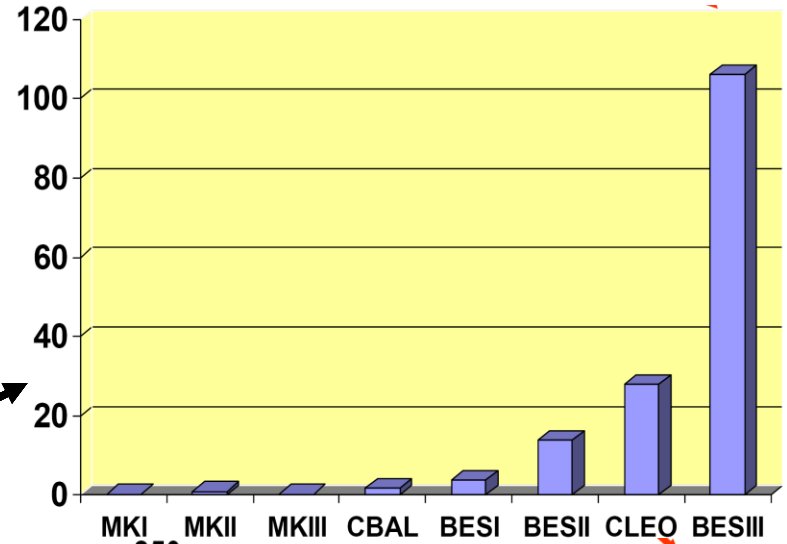
  0.32×10^{33} $cm^{-2}s^{-1}$

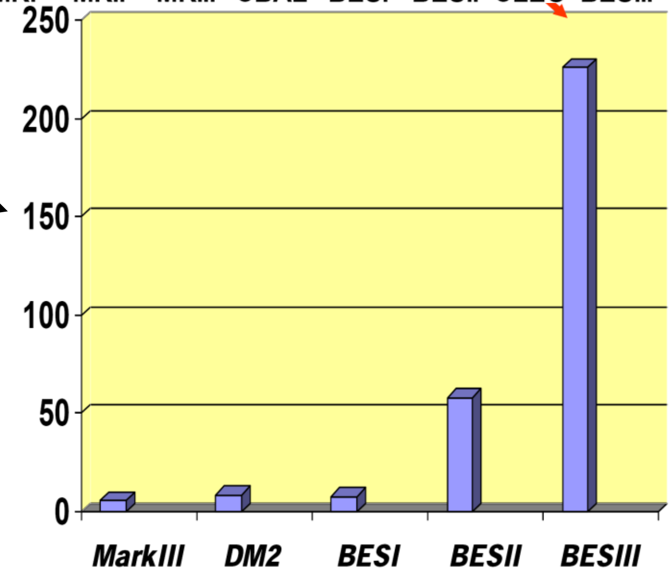
- Data samples (2009):

  106M ψ' events (150pb^{-1})

  220M J/ψ events (65pb^{-1})

  $\psi(3770) \sim 0.9$ fb^{-1}

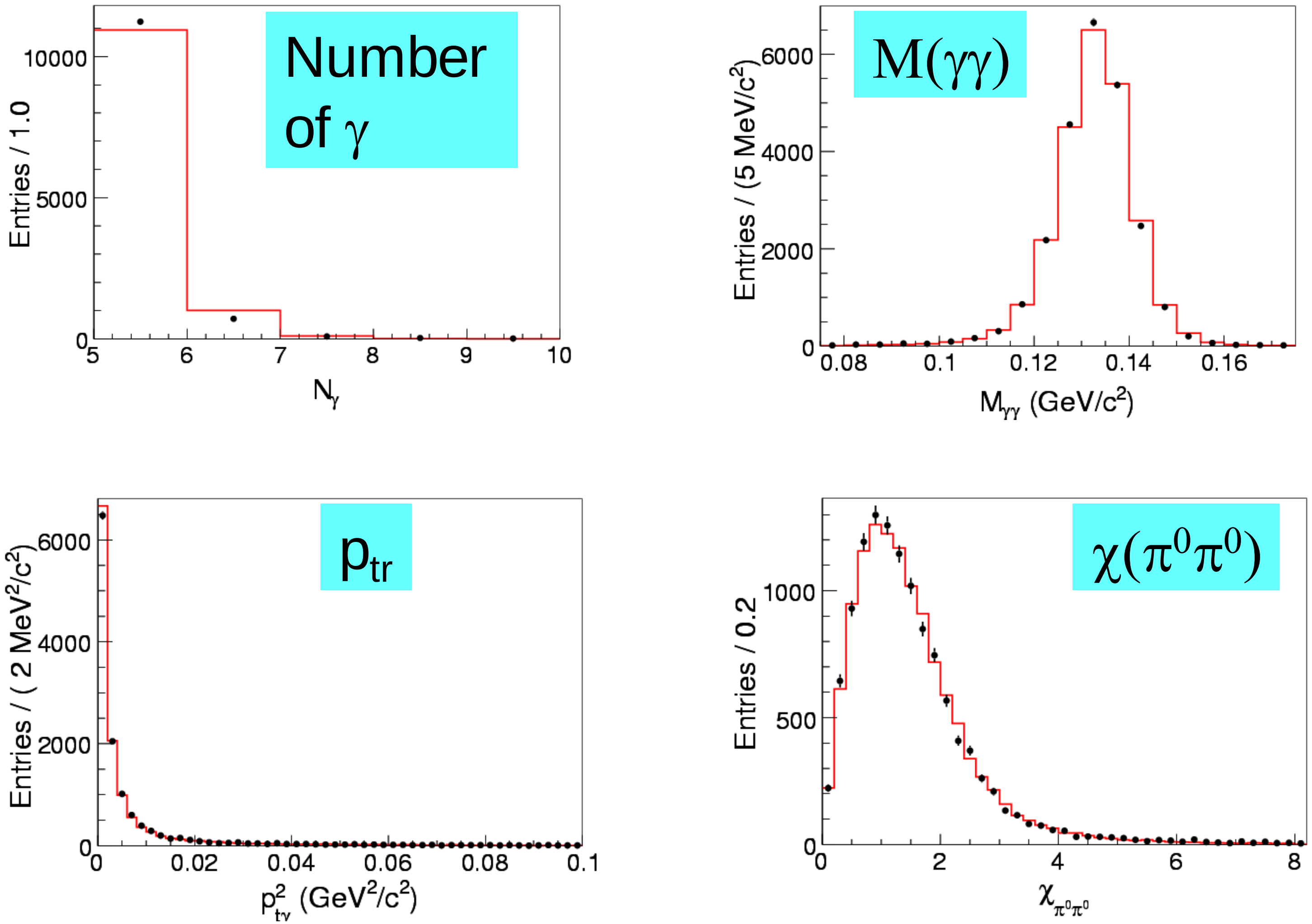




Results presented are based on 106M ψ'

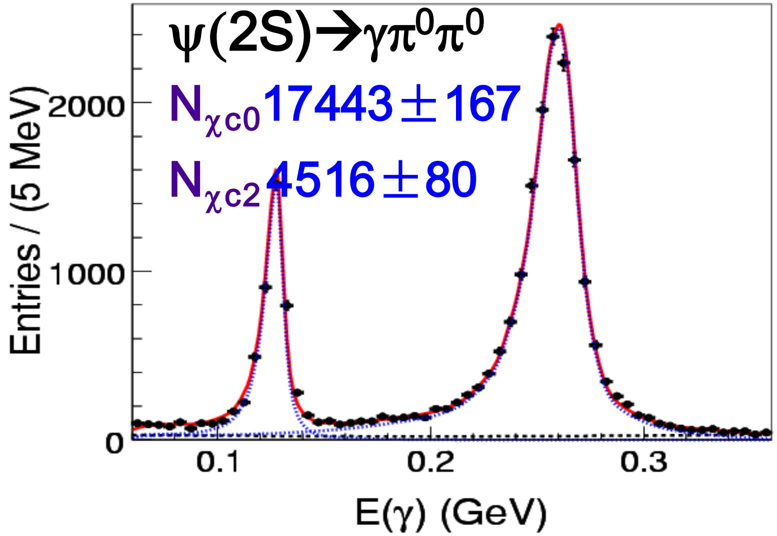
$\chi_{c0,2} \to \pi^0\pi^0, \eta\eta$

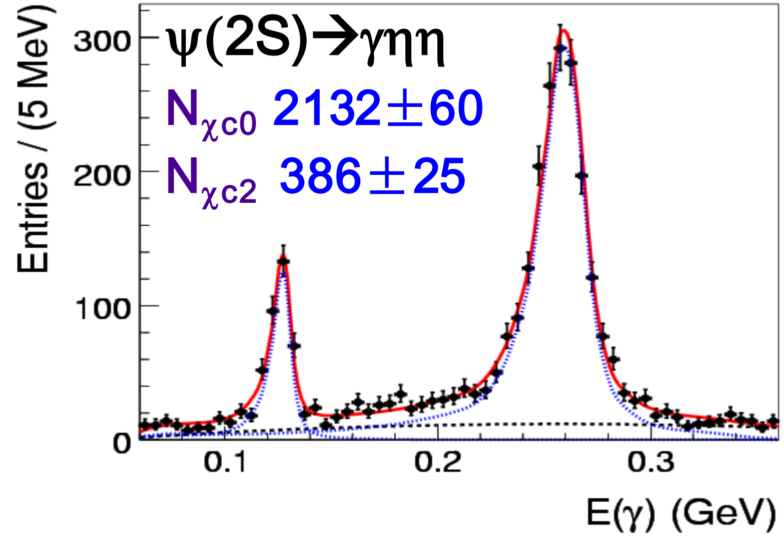
$\chi_{c0,2} \to \pi^0\pi^0, \eta\eta \quad (\eta/\pi^0 \to \gamma\gamma)$



<u>Good agreement of data & MC</u>

$\psi' \to \gamma \chi_{cJ}$, $\chi_{cJ} \to \pi^0\pi^0, \eta\eta$





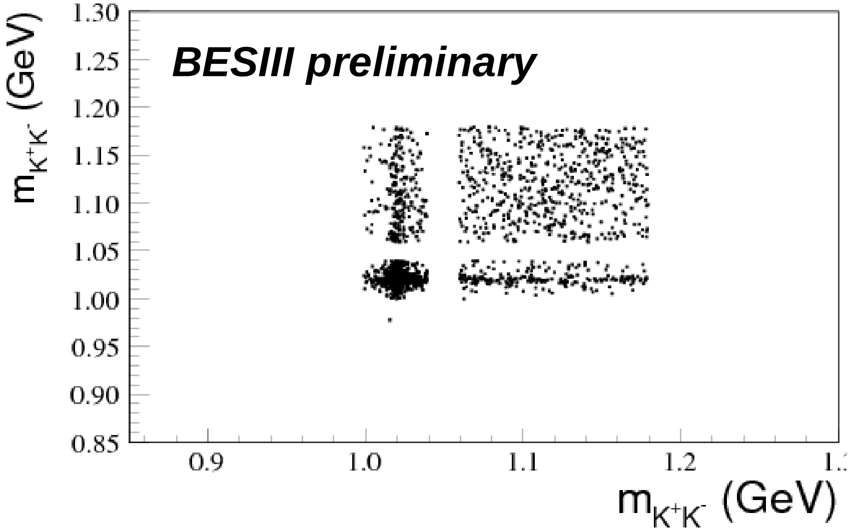
BR (10^{-3})		χ_{c0}	χ_{c2}
$\pi^0\pi^0$	BESIII	3.23±0.03±0.23±0.14	0.88±0.02±0.06±0.04
	CLEO-c	2.94±0.07±0.32±0.15	0.68±0.03±0.07±0.04
	PDG08	2. 43±0.20	0.71±0.08
$\eta\eta$	BESIII	3.44±0.10±0.24±0.13	0.65±0.04±0.05±0.03
	CLEO-c	3.18±0.13±0.31±0.16	0.51±0.05±0.05±0.03
	PDG08	2.4±0.4	<0.5

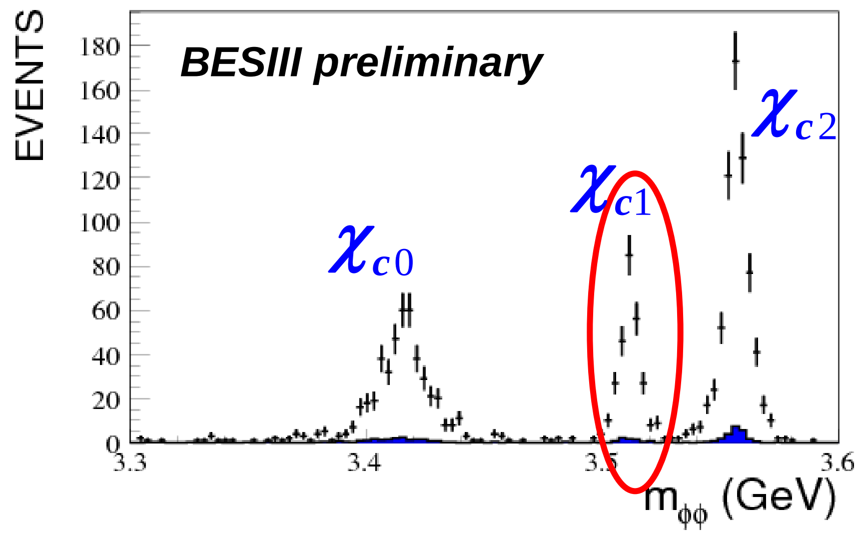
Note: the third error are due to the branching fractions of $\psi' \to \gamma \chi_{cJ}$

Ref: PRD81, 052005 (BESIII); PRD79,072007 (CLEO)

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

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



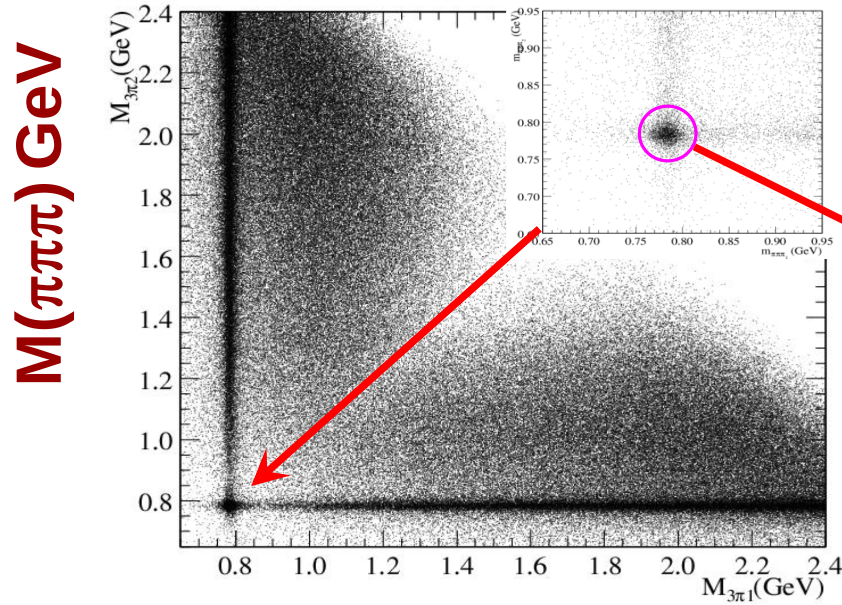


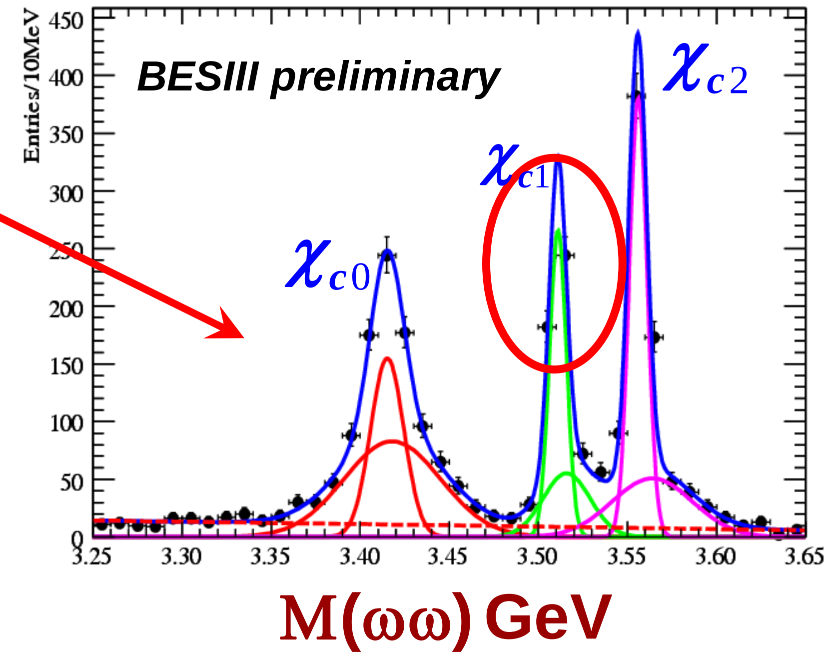
channel	$(\times 10^{-4})$	PDG$(\times 10^{-4})$
$\chi_{c0} \rightarrow \phi\phi$	8.0 ± 0.4	9.3 ± 2.0
$\chi_{c1} \rightarrow \phi\phi$	4.2 ± 0.3	$---$
$\chi_{c2} \rightarrow \phi\phi$	11.3 ± 0.4	15.4 ± 3.0

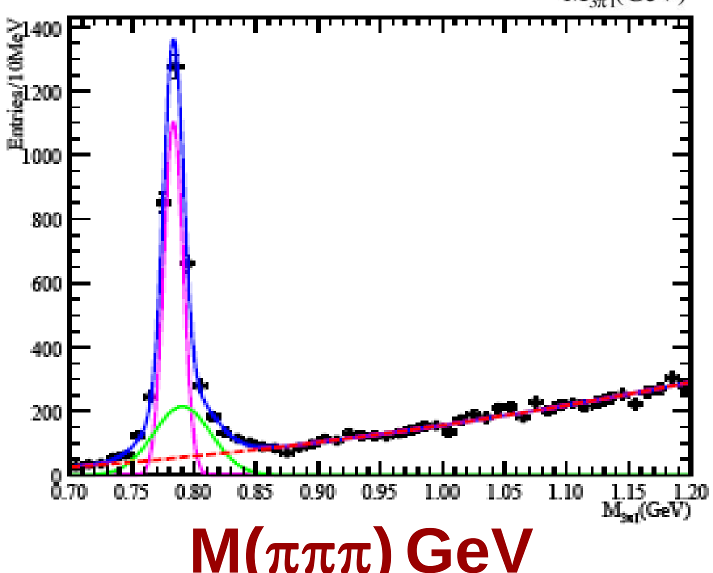
Errors statistical only

- First observation $\chi_{c1} \rightarrow \phi\phi$
- Contribution from non-resonance estimated from ϕ sideband (as blue)

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

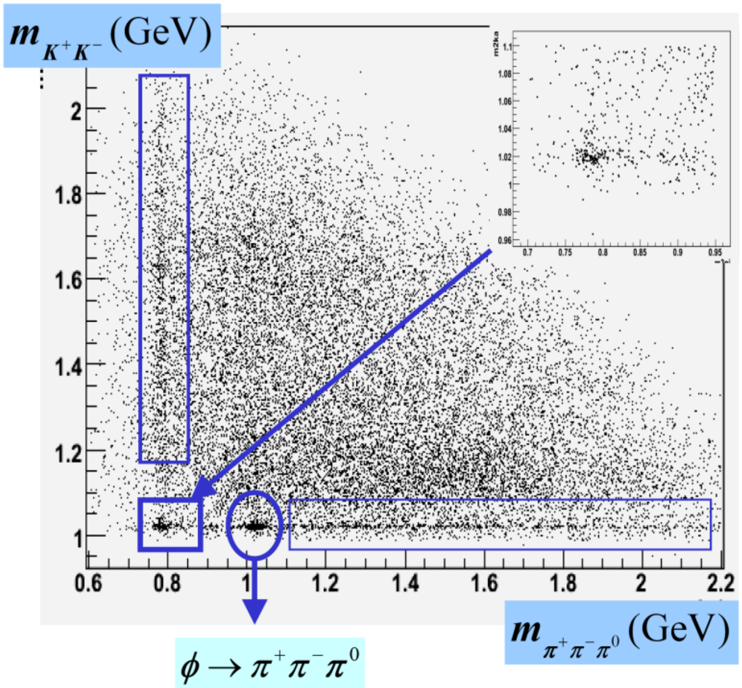




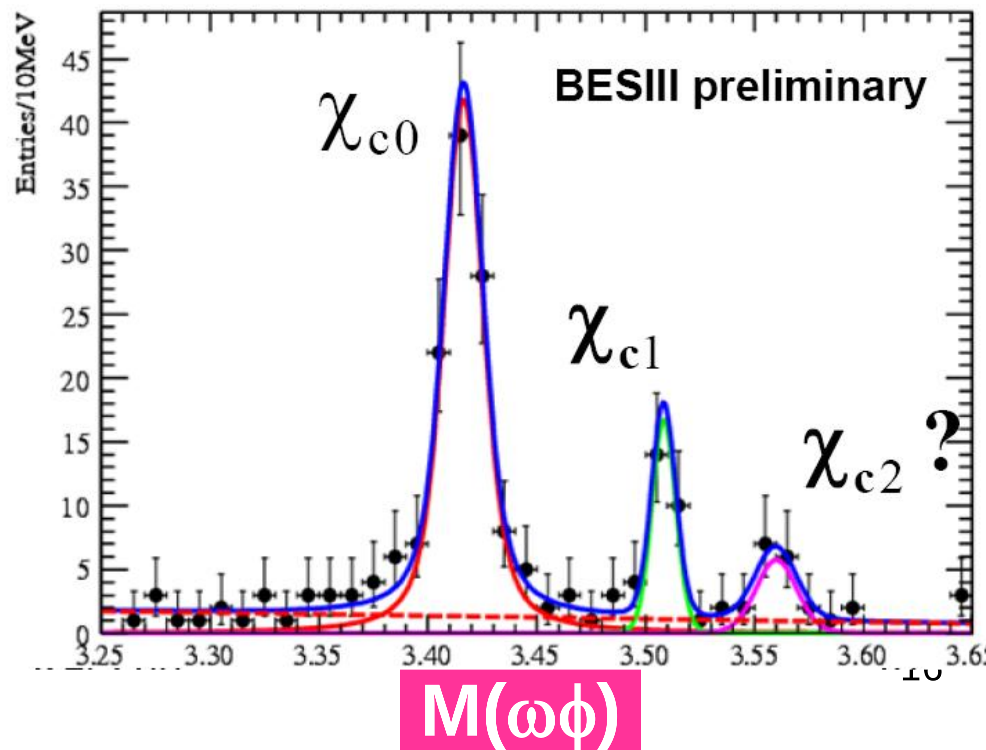


- $\chi_{c1} \rightarrow \omega\omega$ first observation
- Non-resonance & other backgrounds are investigated from ω sideband.

Study of $\chi_{cJ} \to \omega\phi$



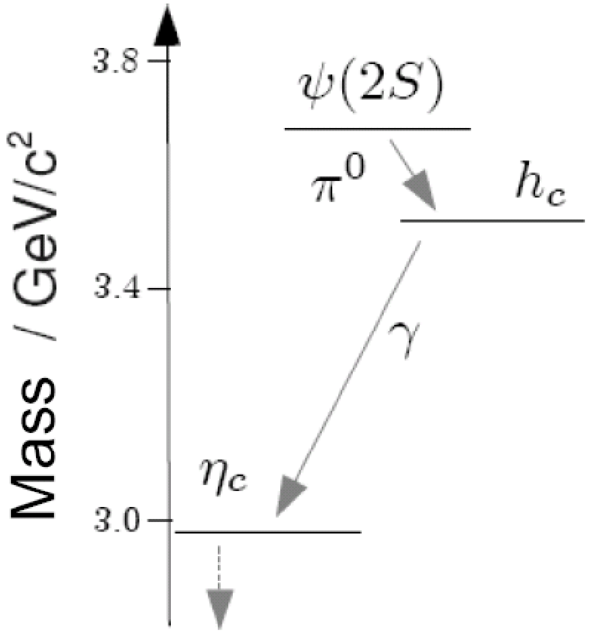
- *Clear $\omega\phi$ signals are seen*
- *Background studied from sideband & 100M MC.*



- <u>$\chi_{cJ} \to \phi\omega$ *doubly OZI suppressed.*</u>
- <u>*This is observed for the first time.*</u>

Observation of h_c:

$\psi' \rightarrow \pi^0 h_c$, $h_c \rightarrow \gamma \eta_c$ / anything

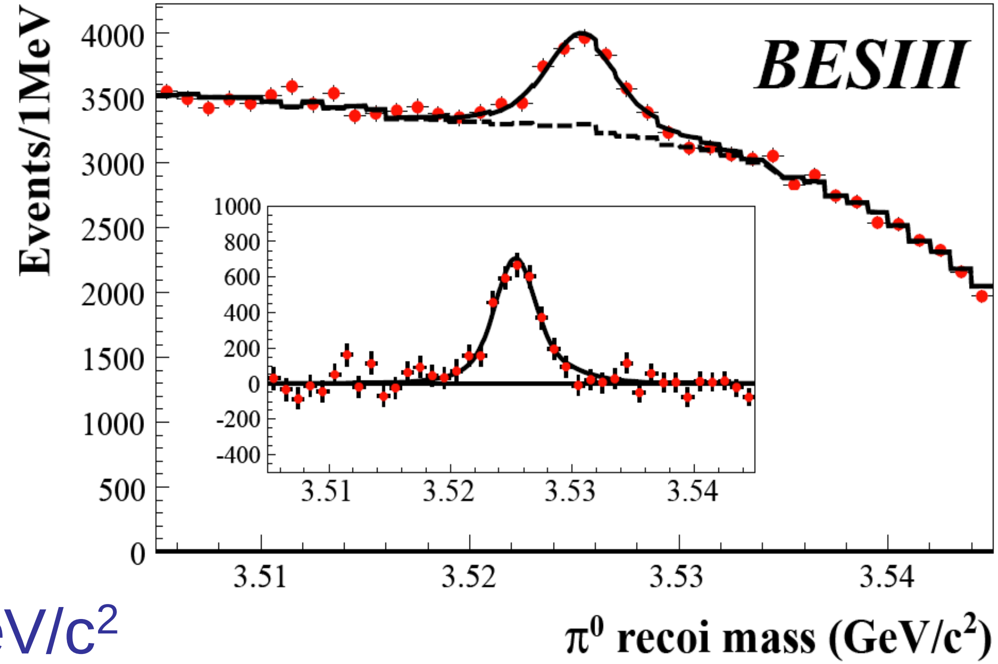


h_c: E1-γ tagged inclusive analysis

- Select inclusive π^0 ($\psi' \rightarrow \pi^0 h_c$)
- Use E1-photon γ to tag $h_c \rightarrow \gamma \eta_c$
- Double-Gauss $\otimes$ BW

  + E1-γ sideband

Ref: PRL 104, 132002



Results:

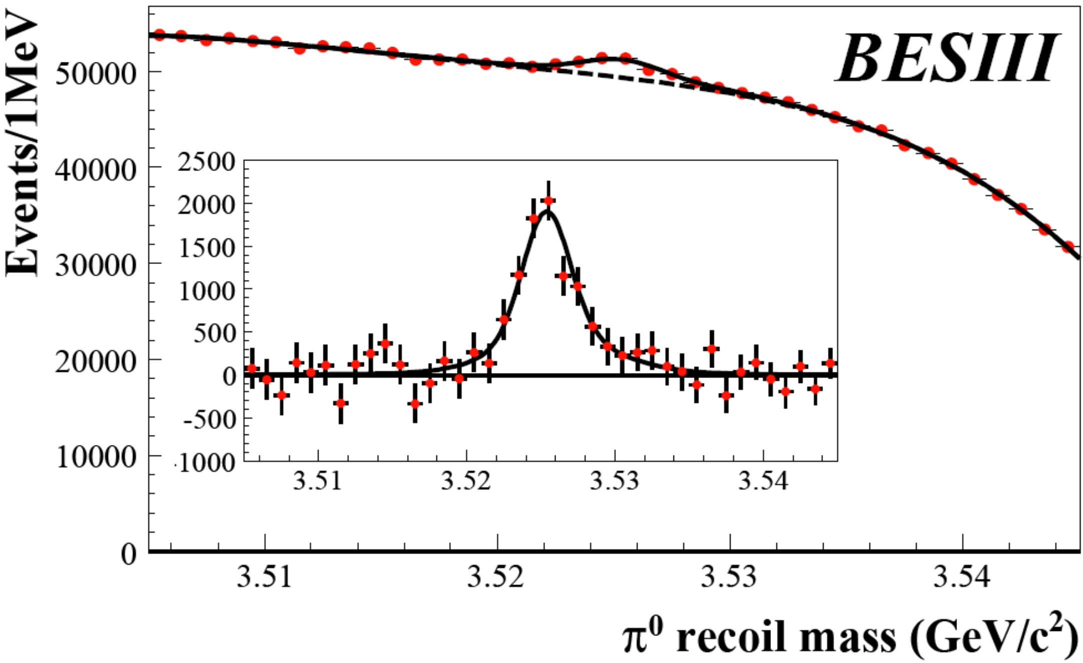
- $Br(\psi' \rightarrow \pi^0 h_c) \times Br(h_c \rightarrow \gamma \eta_c)$

  $= (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$
- $M = 3525.40 \pm 0.13 \pm 0.18$ MeV/c^2
- $\Gamma = 0.73 \pm 0.45 \pm 0.28$ MeV (<1.44 MeV 90%C.L.)

h_c: inclusive analysis

- *Select inclusive π^0 ($\psi' \to \pi^0 h_c$)*
- *D-Gauss $\otimes$ BW (for signal) + 4th Poly. (for bkg)*
- *Fit: mass and width fixed as tagged measurement*

Combining with tagged results, we first measured:
Br($\psi' \to \pi^0 h_c$)
$= (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$
Br($h_c \to \gamma \eta_c$)
$= (54.3 \pm 6.7 \pm 5.2)\%$



Ref: PRL 104, 132002

Summary of h_c

Ref: BESIII, PRL 104, 132002 (2010)

	BESIII	CLEOc
$Br(\psi' \to \pi^0 h_c) \times Br(h_c \to \gamma\eta_c)$ [10^{-4}]	$4.58 \pm 0.40 \pm 0.50$	$4.19 \pm 0.32 \pm 0.45$
M [MeV/c^2]	$3525.40 \pm 0.13 \pm 0.18$	$3525.80 \pm 0.23 \pm 0.15$
Γ [MeV]	$0.73 \pm 0.45 \pm 0.28$ <1.44 @ 90%CL	1.1 (NRQCD) Kuang 0.51 (PQCD) Kuang
$\Delta M_{hf}(1P)$ [MeV/c^2]	$0.10 \pm 0.13 \pm 0.18$	$0.08 \pm 0.18 \pm 0.12$

Ref: CLEOc PRL 101, 182003 (2008)

	BESIII	theoretical prediction
$Br(\psi' \to \pi^0 h_c)$ [$\times 10^{-4}$]	$8.4 \pm 1.3 \pm 1.0$	4 - 13
$Br(h_c \to \gamma\eta_c)$	$54.3 \pm 6.7 \pm 5.2$	41 (NRQCD) Kuang 88 (PQCD) Kuang 38 Godfrey, Rosner

Ref: Theory, PRD65, 094024 (2002) & PRD 66, 014012 (2002).

Summary

- We measured the transition rates of $\psi' \to \pi^0 h_c$, $h_c \to \gamma\eta_c$ for the first time; improved the mass and width measurements of h_c.
- Observed $\chi_{cJ} \to \phi\phi$, $\omega\omega$, $\omega\phi$;

  $\chi_{c1} \to \phi\phi$, $\omega\omega$ and $\chi_{cJ} \to \omega\phi$ are first observations.
- Improved measurements of the branching fractions of χ_{cJ} decays into two neutral pseudoscalar meson pairs, i.e. $\chi_{c0,2} \to \pi^0\pi^0$, $\chi_{c0,2} \to \eta\eta$.
- More BESIII results are coming. Stay tuned.

Backup slides

$\chi_{c0,2} \to \pi^0\pi^0$, $\eta\eta$, $\eta/\pi^0 \to \gamma\gamma$ selection

- **No charged tracks**
- **Photon:**

  $E_\gamma > 50$ MeV, timing

- **π^0, η**
  - $-0.06 < M(\gamma\gamma) - m_{\pi 0} < 0.04$; $-0.09 < M(\gamma\gamma) - m_\eta < 0.06$ GeV/c^2
  - Decay angle $\cos\theta < 0.95$;
- **Events**
  - Have two π^0/η with a minimum χ

$$\chi = \sqrt{P_1^2(\eta/\pi_1^0) + P_2^2(\eta/\pi_2^0)},$$

where $P(\eta/\pi^0) = (M(\gamma\gamma) - m_{\eta/\pi^0})/\sigma_{\eta/\pi^0}$.

$$\sigma_{\pi^0} = 7MeV/c^2, \sigma_\eta = 12MeV/c^2.$$

Decay angle is the polar angle of γ in π^0 / η rest frame

$\chi_{cJ} \rightarrow V\ V$ Event selection

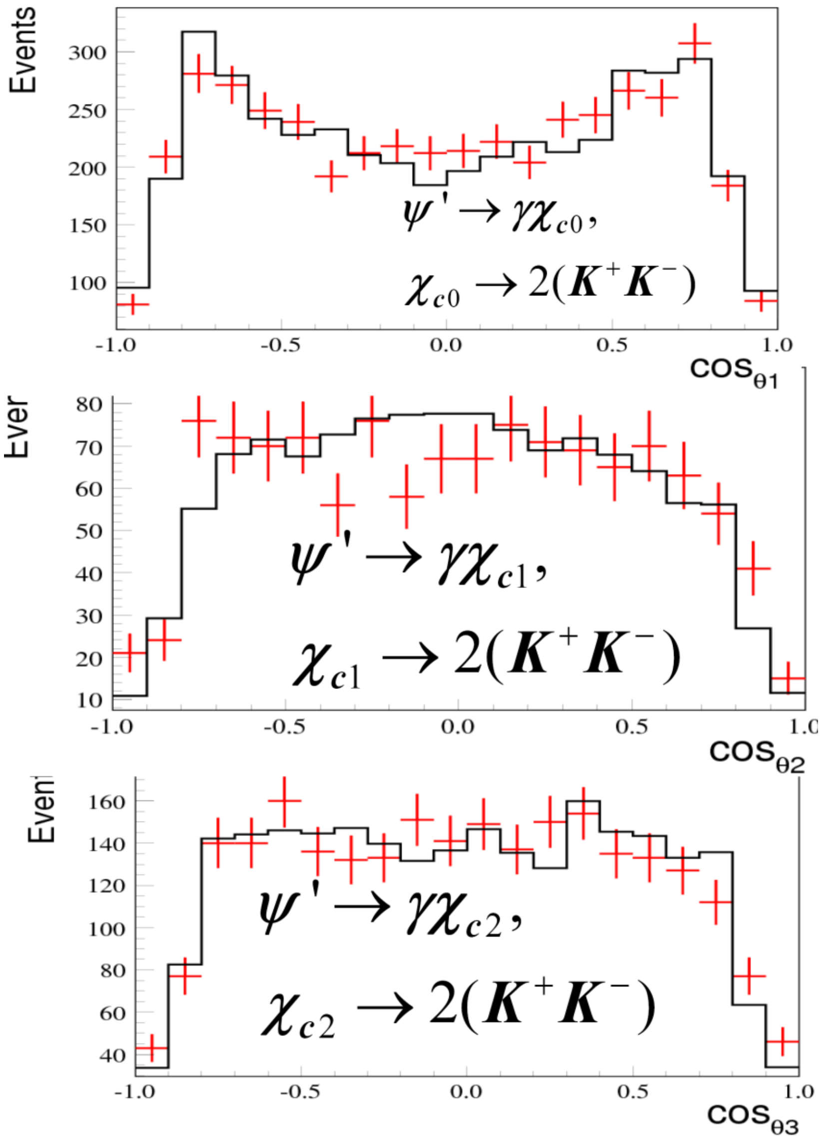
- Photons
  - $|\cos\theta|<0.93$; $E_\gamma>25$MeV
- Charged tracks
  - $|V_z|<5$cm, $|V_r|<0.5$cm, $|\cos\theta|<0.8$

- Events
  - $N_{charged} = 4$; $\Sigma Q=0$; $N\gamma>N_{should}$
  - Selection best γ by minimizing 4C χ^2 .
  - ϕ: $|M_{KK} - m_\phi| < 0.015$ GeV; ω: $|M_{\pi\pi\pi 0} - m_\omega| < 0.050$ GeV
  - $\chi^2 < 60$

$\psi' \to \gamma \chi_{cJ}$, $\chi_{cJ} \to \pi^0\pi^0, \eta\eta$ Systematics

- The systematic uncertainties from
  - γ detection (1% per γ)
  - π^0 (η) reconstruction (1% per π^0)
  - Selection cuts
  - Signal/bkg shape, fit range
  - Trigger (0.1%)
  - Number of ψ' (4%)

E1 photon angular distribution



- MC: E1 transition assumed in $\psi(2S) \to \gamma\chi_{cJ}$

$$dN/d\cos\theta_\gamma \propto (1+\alpha\cos^2\theta_\gamma)$$

$$\alpha = 1 \quad (\chi_{c0})$$
$$-1/3 \quad (\chi_{c1})$$
$$1/13 \quad (\chi_{c2})$$