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Recent results of charmonium decays from BESIII

Rong-Gang PING[*†]
Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China
E-mail: pingrg@ihep.ac.cn

Using $(106 \pm 4) \times 10^6$ ψ' decays collected at BESIII/BEPCII, some interesting results are obtained. The branching fractions of $\chi_{cJ} \to \pi^0\pi^0,\ \eta\eta,\ 4\pi^0$ are measured, and the precisions are improved. The decays of $\chi_{c1} \to \phi\phi,\ \omega\omega\ ,\omega\phi$ are observed for the first time, the precision of branching fractions for $\chi_{c0}, \chi_{c2} \to \phi\phi,\ \omega\omega$ are improved.

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[*]Speaker.
[†]Represent the BES Collaboration.

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1. Introduction

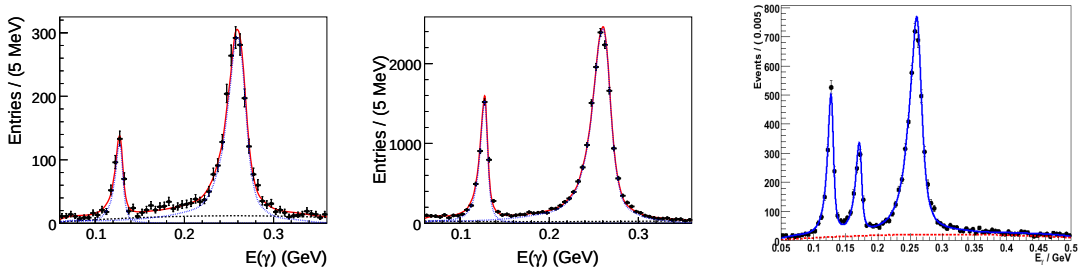
The analyses reported in this talk were performed based on $\psi^{'}$ events collected with BESIII detector at the upgraded BEPC (BEPCII) in the year of 2009. The total number of decays is $(106\pm4)\times10^6$ [1].

2. $\chi_{cJ}\to\pi^0\pi^0,\eta\eta$, and $4\pi^0$

χ_{cJ} decays into pseudoscalar meson pairs (PP) have been extensively studied in the framework of perturbative quantum chromodynamics (pQCD). It turns out that the measured decay widths of $\chi_{cJ}\to PP$ can not explained theoretically. Recently, the color-octet decay mechanism is proposed, whose contributions to the decay widths of χ_{cJ} $(J=0,2)\to\pi^0\pi^0$, $\eta\eta$ are predicted [2].

Using 106×10^6 $\psi^{'}$ decays collected with the BESIII detector, the decays $\chi_{cJ}\to\pi^0\pi^0$, $\eta\eta$ $(J=0,2)$ are studied via the decay $\psi^{'}\to5\gamma$ [1]. The two π^0/ηs are reconstructed with four photons selected by requiring the $\sqrt{P_1^2(\pi^0/\eta)+P_2^2(\pi^0/\eta)}$ having a minimum value in all possible photon's combinations, where $P_i(\pi^0/\eta)=(M_{\gamma\gamma}-M_{\pi^0/\eta})/\sigma_{\gamma\gamma}$, and $\sigma_{\gamma\gamma}$ is the mass resolution for two photons. Figures 1(a) and 1(b) show the invariant mass distributions of $m_{\pi^0\pi^0}$ and $m_{\eta\eta}$, respectively. The signals of χ_{c0} and χ_{c2} are clearly observed. The χ_{c1} decays into two pseudoscalar pairs are suppressed due to the spin-parity conservation. The branching fractions are measured to be $Br(\chi_{c0}\to\pi^0\pi^0)=(3.23\pm0.03\pm0.23\pm0.14)\times10^{-3}$, $Br(\chi_{c2}\to\pi^0\pi^0)=(8.8\pm0.2\pm0.6\pm0.4)\times10^{-4}$, $Br(\chi_{c0}\to\eta\eta)=(3.44\pm0.10\pm0.24\pm0.20)\times10^{-3}$ and $Br(\chi_{c2}\to\pi^0\pi^0)=(6.5\pm0.4\pm0.5\pm0.3)\times10^{-4}$, where the uncertainties are statistical, systematic in this measurement, and systematic due to the branching fractions of $\psi^{'}\to\gamma\chi_{cJ}$.

The decays of $\chi_{cJ}\to4\pi^0$ are studied with the final state $\psi^{'}\to9\gamma$, where the candidates of $4\pi^0$ are reconstructed with eight photons by requiring the χ^2 combination [$\chi^2=\sum_i P_i^2(\pi^0)$] to have a minimum value. Figure 1(c) shows the distribution of $m_{4\pi^0}$, in which the decays $\chi_{cJ}\to K_SK_S\to4\pi^0$ are removed. The branching fractions are measured to be $Br(\chi_{cJ}\to4\pi^0)=(3.42\pm0.07\pm0.45,\ 0.60\pm0.03\pm0.09,\ 1.13\pm0.04\pm0.15)\times10^{-3}$ for $J=(0,\ 1,2)$ respectively. The results provide information on the decay mechanism of χ_{cJ} states into pseudoscalars.

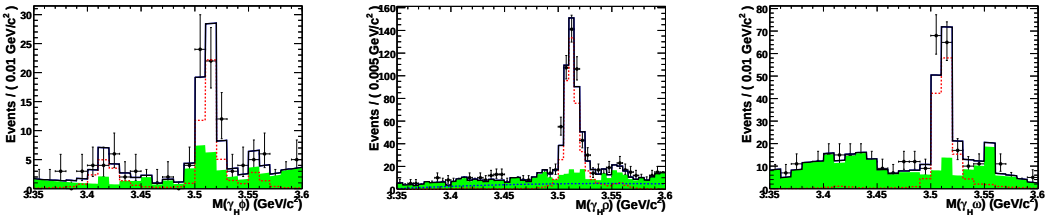


(a) The radiative photon energy spectrum of selected $\chi_{cJ}\to\pi^0\pi^0$.

(b) The radiative photon energy spectrum of selected $\chi_{cJ}\to\eta\eta$.

(c) The radiative photon energy spectrum of selected $\chi_{cJ}\to4\pi^0$.

Figure 1: The radiative photon energy spectrum of selected $\chi_{cJ}\to\pi^0\pi^0$, $\eta\eta$ and $4\pi^0$, where the points with error bars are data, and the solid curves are the fitted results, the dashed curves are the fitted backgrounds.



(a) The mass spectrum of $\gamma\phi$. (b) The mass spectrum of $\gamma\rho$. (c) The mass spectrum of $\gamma\omega$.

Figure 2: The invariant mass distribution of $m_{\gamma V}$, $V = \phi$, ρ, ω. Dots with error bars are data; histograms are the fitted results; dash histograms are signals; shaded histograms are backgrounds estimated with the vector sidebands.

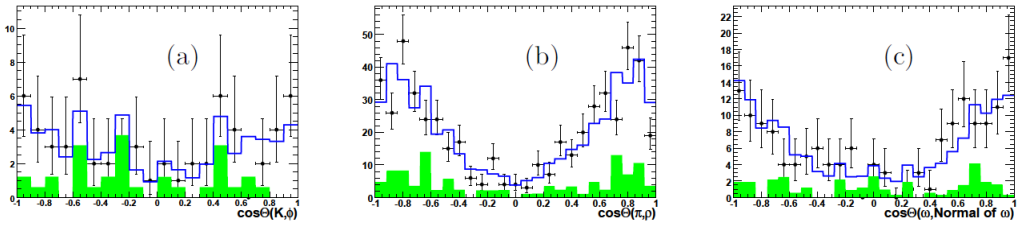


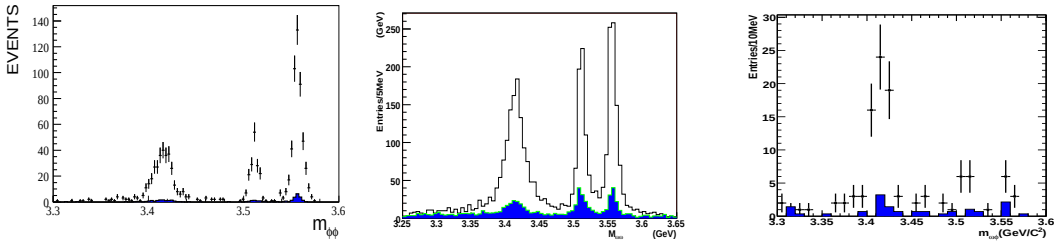
Figure 3: The distributions of $\cos\Theta$ for $(a):\ \chi_{c1}\to\gamma\phi$, $(b):\chi_{c1}\to\gamma\rho$ and $(c):\chi_{c1}\to\gamma\omega$ (c). The points with error bars are data, and shaded histograms are backgrounds, and solid line histograms are the fitted results.

3. $\chi_{cJ}\to\gamma V$ ($V=\phi,\rho,\omega$)

Decays of $\chi_{cJ}\to\gamma V$ ($V=\phi,\rho,\omega$) provide an additionally ideal place to study the χ_{cJ} decay mechanisms. The branching fractions of $\chi_{cJ}\to\gamma V$ are extensively studied in the framework of QCD[3], pQCD[4] and QCD+QED [4] pictures. However, the previously experimental results [5] are an order of magnitude higher than these theoretical predictions.

The candidates of vector meson ($V=\phi$, ρ, ω) are reconstructed with the decay $\phi\to K^+K^-$, $\rho^0\to\pi^+\pi^-$ and $\omega\to\pi^+\pi^-\pi^0$. Then candidates of χ_{cJ} signals are reconstructed by looking at the mass spectrum of vector meson and energic photon as shown in Fig. 2. The $\chi_{c1}\to\gamma\phi$, $\gamma\rho$ and $\gamma\omega$ are significantly observed. Their branching fractions are measured to be $Br(\chi_{c1}\to\gamma V)=(27.3\pm5.5,\ 241\pm14,\ 73.5\pm7.6)\times10^{-6}$ for $V=\phi$, ρ and ω, respectively. Where the errors are only statistical. The decay $\chi_{c1}\to\gamma\phi$ is observed for the first time. Decays of $\chi_{c0},\chi_{c2}\to\gamma V$ are not observed. The upper limits at the 90% C.L. are set as $Br(\chi_{c0}\to\gamma V)<(14.8,\ 9.5,\ 11.7)\times10^{-6}$ and $Br(\chi_{c2}\to\gamma V)<(7.8,\ 19.7,\ 5.8)\times10^{-6}$ for $V=(\phi,\ \rho,\ \omega)$, respectively.

Polarizations of vector meson produced from χ_{c1} decays are measured. Figure 3 shows the helicity angular distributions $\cos\Theta$ for ϕ, ρ and ω meson, respectively. Where Θ is defined as the angle between the vector meson flight direction in the χ_{cJ} rest frame and either the π/K^+ direction in the ρ^0/ϕ rest frame or the normal to the ω decay plane in the ω rest frame. The longitudinal (transverse) polarization exhibits a $\cos^2\Theta$ ($\sin^2\Theta$) dependence. Helicity distributions in Fig. 3 indicate that the longitudinal polarization dominates the vector meson production from χ_{c1} decays.



(a) The mass spectrum of $m_{\phi\phi}$. (b) The mass spectrum of $m_{\omega\omega}$. (c) The mass spectrum of $m_{\omega\phi}$.

Figure 4: In plots, dots with error bars or histograms are data; shaded histograms are backgrounds estimated with the vector meson sidebands.

4. Observation of $\chi_{cJ} \to \phi\phi,\ \omega\omega$, and $\omega\phi$

χ_{cJ} decays into vector meson pairs serves as laboratory to test the color-octet decay mechanism [6]. The branching fractions still remain to be a puzzle to understand within QCD theory. The previous measurements show that the χ_{cJ} $(J = 0,2)$ have larger branching fractions to decay into these final states [7, 8]. Especially, for the decays of $\chi_{c1} \to \omega\omega, \phi\phi$, they are expected to be highly suppressed due to helicity selection rule [9]. For the $\chi_{cJ} \to \omega\phi$, they are the doubly OZI suppressed decays, and they are still not observed in experiment. The large $\psi^{'}$ data sample at BESIII offers opportunity to search for these suppressed decays.

Figure 4(a) shows the mass spectrum of $\phi\phi$ reconstructed via the decay $\psi^{'} \to \gamma 2(K^+K^-)$. In the scatter plot of the mass K^+K^- versus other two kaon, the $\phi\phi$ signals are clearly seen. After requiring the two K^+K^- pairs in the ϕ mass region, the χ_{cJ} $(J = 0,\ 1,\ 2)$ signals are clearly seen in the distribution of invariant mass of $\phi\phi$. The contribution from nonresonance decays of $\chi_{cJ} \to 2(K^+K^-)$ and $\chi_{cJ} \to \phi K^+K^-$ can be estimated with the ϕ sidebands as shown in Fig. 4(a) (shaded histogram). The branching fractions are measured to be $Br(\chi_{cJ} \to \phi\phi) = (0.8 \pm 0.04,\ 0.42 \pm 0.03,\ 1.15 \pm 0.04) \times 10^{-3}$ for $J = (0,\ 1,\ 2)$, respectively. Where the errors are only statistical.

Figure 4(b) shows the mass spectrum of $\omega\omega$ reconstructed via the decay $\psi^{'} \to 5\gamma 2(\pi^+\pi^-)$. Where the two π^0 candidates are reconstructed with the four photons with the masses closest to the two π^0 masses, i.e. $\sqrt{(M^{(1)}_{\gamma\gamma} - M_{\pi^0})^2 + (M^{(2)}_{\gamma\gamma} - M_{\pi^0})^2}$, then an ω is reconstructed with a combination of $\pi^+\pi^-\pi^0$ selected by minimizing $|M_{\pi^+\pi^-\pi^0} - M_\omega|$. The other combination of $\pi^+\pi^-\pi^0$ is regarded as a candidate of an ω signal. After requiring the both ωs falling into the ω mass window $|M_{\pi^+\pi^-\pi^0} - M_\omega| < 0.04$ GeV, the χ_{cJ} $(J = 0,1,2)$ signals are clearly observed at the mass spectrum $\omega\omega$. The backgrounds from $\psi^{'} \to \pi^+\pi^- J/\psi \to 5\gamma 2(\pi^+\pi^-)$ are rejected by requiring $|M^{recoil}_{\pi^+\pi^-} - M_{J/\psi}| > 0.008$ GeV, and the nonresonance contribution is estimated via the sidebands of ω mass windows.

Figure 4(c) shows the mass spectrum of $\omega\phi$ reconstructed via the decay $\psi^{'} \to 3\gamma K^+K^-\pi^+\pi^-$, where a ϕ is reconstructed with the decay $\phi \to K^+K^-$, while ω is reconstructed with the decay $\omega \to \pi^+\pi^-\pi^0$, where the π^0 is reconstructed with two photons in the three selected photons by minimizing the $\sqrt{(M_{\gamma\gamma} - M_{\pi^0})^2 - (M_{\gamma\gamma\pi^+\pi^-} - M_\omega)^2}$. After requiring the mass widows $|M_{\pi^+\pi^-\pi^0} - M_\omega| < 0.04$ GeV and $|M_{K^+K^-} - M_\phi| < 0.015$ GeV, the χ_{cJ} $(J = 0,\ 1,\ 2)$ signals are observed at the mass spectrum of $\omega\phi$. The non-ϕ/ω's contribution are studied with the ϕ/ω sidebands.

5. Summary

Using $(106 \pm 4) \times 10^6$ ψ' decays collected at BESIII/BEPCII, we have obtained many interesting results. The branching fractions of $\chi_{cJ} \to \pi^0\pi^0,\ \eta\eta,\ 6\pi^0$ are measured. The decays of $\chi_{c1} \to \phi\phi,\ \omega\omega,\ \omega\phi$ are observed for the first time.

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