Conference Paper

Recent charmonium results at BESIII

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Abstract

Based on the world's largest J/ψ and $\psi(3686)$ data sample at on-threshold production accumulated with BESIII detector, the recent results for charmonium decays are presented. These results selected in this proceeding are the study of J/ψ and $\psi(3686)$ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$, improved measurements of $\psi(3686) \rightarrow \gamma\chi_{cJ}$, observation of $h_c \rightarrow \gamma\eta'$ and evidence of $h_c \rightarrow \gamma\eta$, $\psi(3686)$ Dalitz decay to χ_{cJ} and χ_{cJ} Dalitz decay to J/ψ.

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1. Introduction

The charmonium spectroscopy is of great importance to understand the quantum chromo-dynamic (QCD) theory in perturbative and non-perturbative calculation. The charmonium states below the $D\bar{D}$ threshold are well measured, and all these measured states are in good agreement with the theoretical predications of relativistic potential model [1]. However, it is still desirable to investigate the decay properties of these charmonium states. With the high statistics collected for J/ψ and $\psi(3686)$ decays, the first observations or more precise results could be achieved. In this proceeding, the study of J/ψ and $\psi(3686)$ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$, improved measurements of $\psi(3686) \rightarrow \gamma\chi_{cJ}$, observation of $h_c \rightarrow \gamma\eta'$ and evidence of $h_c \rightarrow \gamma\eta$, and $\psi(3686)$ Dalitz decay to χ_{cJ} and χ_{cJ} Dalitz decay to J/ψ are presented.

The BESIII experiment is operated at the Beijing electron positron collider II (BEPCII) with a peak luminosity of 1.0×10^{33} cm^{-2}s^{-1} at a center-of-mass energy of 3773 MeV. The BESIII experiment aims to study the multiple-purpose physics in the $\tau - c$ region based the world's largest charmonium data sample at on-threshold production. A detailed description of the detector can be found in Ref. [2].

2. The study of J/ψ and $\psi(3686)$ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$ [3]

The study of J/ψ and $\psi(3686)$ (denoted as ψ) decays plays an important role in the test of perturbative QCD (pQCD) calculation. Since the discovery of $\rho\pi$ puzzle which violates the 12% rule, more decay channels are required to further investigate the rule and give information for the development of the future theories.

In this analysis, the branching fractions (BFs) of ψ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$ are measured with the improved precision based on 1.3 billion J/ψ and 448 million $\psi(3686)$ decays. Both baryon and anti-baryon are tagged by their subsequent decay products. The left panel of Fig. 1 shows the distributions of invariant masses of $p\pi^-$ ($M_{p\pi^-}$) and $p\pi^-\gamma$ ($M_{p\pi^-\gamma}$) for the ψ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$, respectively. The production yields are extracted from the fits to these distributions. The polar angle distributions of baryons in the ψ reference frame can be interpreted as $1 + \alpha\cos^2\theta$, and they are measured in the right panel of Fig. 1. The fitted α values and the measured BFs are listed in Table. 1. Note that the α value for $J/\psi \to \Sigma^0\bar{\Sigma}^0$ decay is negative, which is contradictory with the existing theories. The possible explanation for this negative value could be the re-scattering effect [4] of baryon and anti-baryon in the final states. The 12% rule is observed to be violated since the ratios $\frac{\mathscr{B}(\psi(3686)\to\Lambda\bar{\Lambda})}{\mathscr{B}(J/\psi\to\Lambda\bar{\Lambda})}$ and $\frac{\mathscr{B}(\psi(3686)\to\Sigma^0\bar{\Sigma}^0)}{\mathscr{B}(J/\psi\to\Sigma^0\bar{\Sigma}^0)}$ are calculated to be $(20.43 \pm 0.11 \pm 0.58)\%$ and $(20.96 \pm 0.27 \pm 0.92)\%$, respectively.

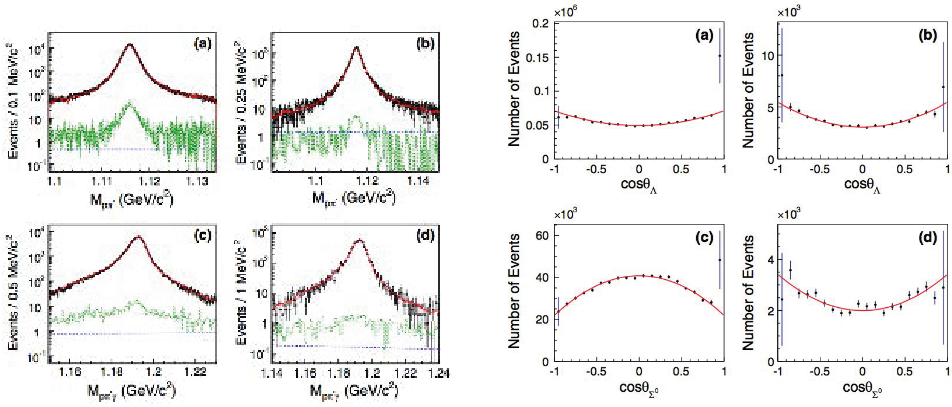

Figure 1: Left panel: Fit results to the $M_{p\pi^-}$ distributions for the decays (a) $J/\psi \to \Lambda\bar{\Lambda}$ and (b) $\psi(3686) \to \Lambda\bar{\Lambda}$, and the $M_{p\pi^-\gamma}$ distributions for the decays (c) $J/\psi \to \Sigma^0\bar{\Sigma}^0$ and (d) $\psi(3686) \to \Sigma^0\bar{\Sigma}^0$. Right panel: Fit results to the efficiency corrected distributions of polar angle of the baryons for the corresponding decays.

Table 1: The fitted α values and the measured BFs for ψ decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$, respectively.

Decay channel	α	BF (10^{-4})
$J/\psi \to \Lambda\bar{\Lambda}$	$0.469 \pm 0.026 \pm 0.008$	$19.43 \pm 0.03 \pm 0.33$
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	$-0.449 \pm 0.020 \pm 0.008$	$11.64 \pm 0.04 \pm 0.23$
$\psi(3686) \to \Lambda\bar{\Lambda}$	$0.82 \pm 0.08 \pm 0.02$	$3.97 \pm 0.02 \pm 0.12$
$\psi(3686) \to \Sigma^0\bar{\Sigma}^0$	$0.71 \pm 0.11 \pm 0.04$	$2.44 \pm 0.03 \pm 0.11$

;

3. Improved measurements of $\psi(3686) \to \gamma\chi_{cJ}$ [5]

The electro-magnetic (EM) decay $\psi(3686) \to \gamma\chi_{cJ}$ is an important decay mode since the decay is very sensitive to the inner structure of the $\psi(3686)$ charmonium state. Based on the data set of 106 M $\psi(3686)$ decays collected in the year 2009, the precision on the BF of decay $\psi(3686) \to \gamma\chi_{cJ}$ is improved. This improvement is quite necessary in the determination of BFs of χ_{cJ} decays.

In this analysis, the inclusive decays of $\psi(3686) \to \gamma X$ where X represents all the possible final states are used to determine the BF of the decay $\psi(3686) \to \gamma\chi_{cJ}$. To constrain the signal shape, a clear γ spectrum from $\psi(3686) \to \gamma\chi_{cJ}$, χ_{cJ} decays to two or four charged particles is used. Figure 2 shows the reconstructed γ spectrum for the inclusive and exclusive $\psi(3686)$ decays, respectively. Simultaneous fit is used to extract the BF of the decay $\psi(3686) \to \gamma\chi_{cJ}$. The five peaks from left to right in the left panel of Fig. 2 correspond to the decay $\psi(3686) \to \gamma\chi_{c2}$, $\gamma\chi_{c1}$, $\gamma\chi_{c0}$, and χ_{c1} and χ_{c2} to $\gamma J/\psi$. The BFs of $\psi(3686) \to \gamma\chi_{c0,1,2}$ are determined to be $(9.389 \pm 0.014 \pm 0.332)$%, $(9.905 \pm 0.011 \pm 0.353)$% and $(9.621 \pm 0.013 \pm 0.272)$%, respectively.

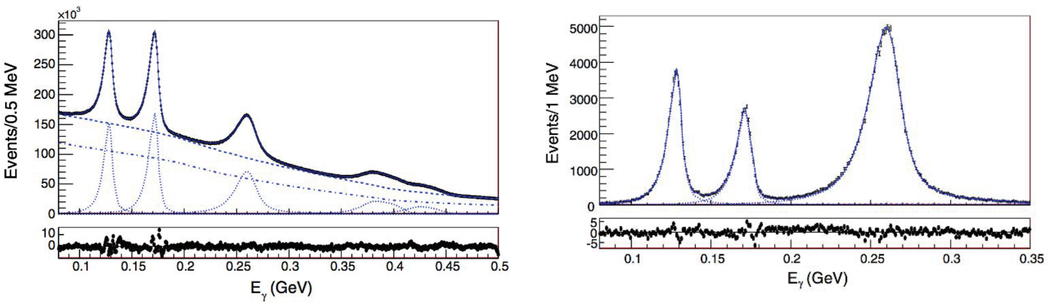

Figure 2: The reconstructed γ spectrum for the inclusive (left) and exclusive (right) $\psi(3686)$ decays, respectively.

4. Observation of $h_c \to \gamma\eta'$ and evidence of $h_c \to \gamma\eta$ [6]

The knowledge on the h_c decay is quite limited since only two decay modes are observed before this study, the radiative decay $h_c \to \gamma\eta_c$ with a BF of about 50% and the hadronic decay $h_c \to 2(\pi^+\pi^-)\pi^0$ with a BF of about 2%. Search for more decay modes are desirable to understand the properties of the h_c particle.

Based on the data sample of 448 M $\psi(3868)$ decays, we present the first observation and the evidence for the radiative decay of $h_c \to \gamma\eta'$ and $h_c \to \gamma\eta$, respectively. The particle η' in the decay channel $h_c \to \gamma\eta'$ is reconstructed from the decay $\eta' \to \pi^+\pi^-\eta$, $\eta \to \gamma\gamma$ and $\eta' \to \gamma\pi^+\pi^-$, while the particle η in the decay channel $h_c \to \gamma\eta$ is reconstructed from the decay $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$. Figure 3 shows the distributions

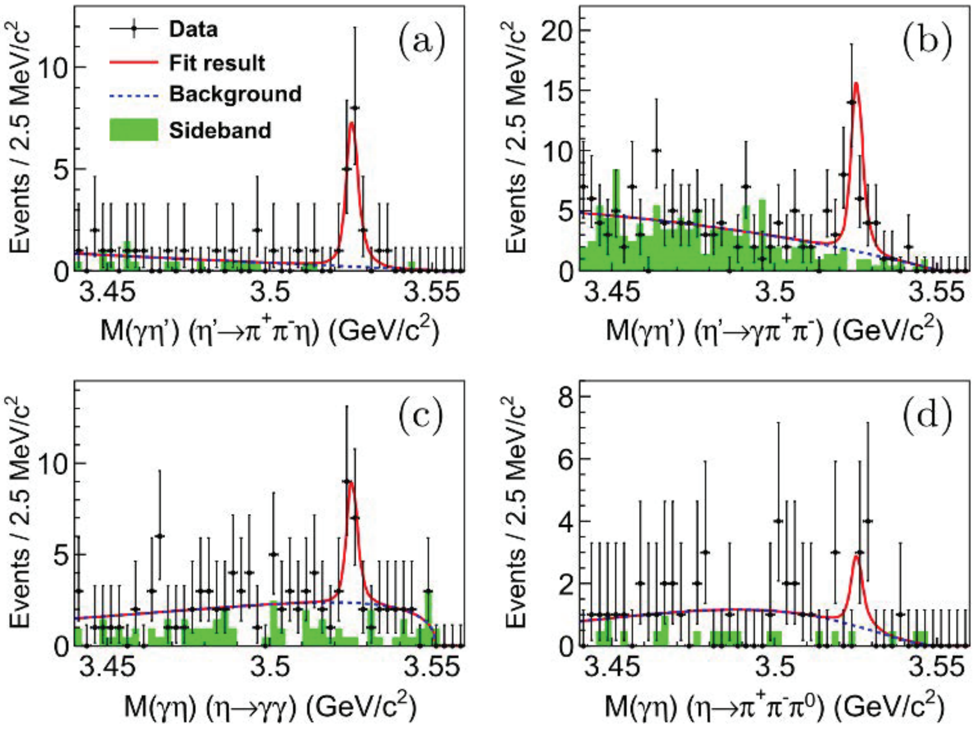

Figure 3: The distributions of $M(\gamma\eta')$ and $M(\gamma\eta)$, respectively.

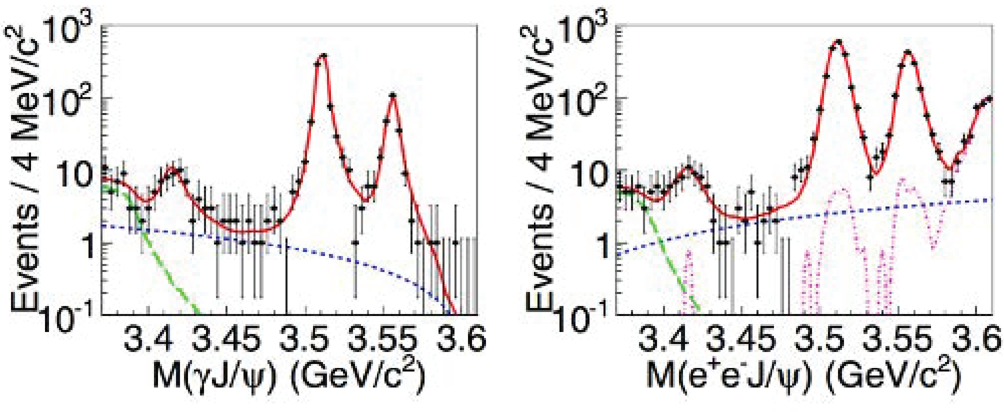

Figure 4: The distributions of $M(\gamma J/\psi)$ and $M(e^+e^- J/\psi)$, respectively.

of invariant masses of $\gamma\eta'$ ($M(\gamma\eta')$) and $\gamma\eta$ ($M(\gamma\eta)$), respectively. Production yields of the decay $h_c \to \gamma\eta'$ and $h_c \to \gamma\eta$ are extracted from the fits to these mass distributions. The BFs of the decay $h_c \to \gamma\eta'$ and $h_c \to \gamma\eta$ are calculated to be $(1.52 \pm 0.27 \pm 0.29) \times 10^{-3}$ and $(4.7 \pm 1.5 \pm 1.4) \times 10^{-4}$ with a statistical significance of 8.4σ and 4.0σ, respectively. With these two values, the ratio between the BF of $h_c \to \gamma\eta$ and $h_c \to \gamma\eta'$ is calculated to be $(30.7 \pm 11.3 \pm 8.7)$%, from where the $\eta - \eta'$ mixing angle can be extracted to test the SU(3) flavor symmetry.

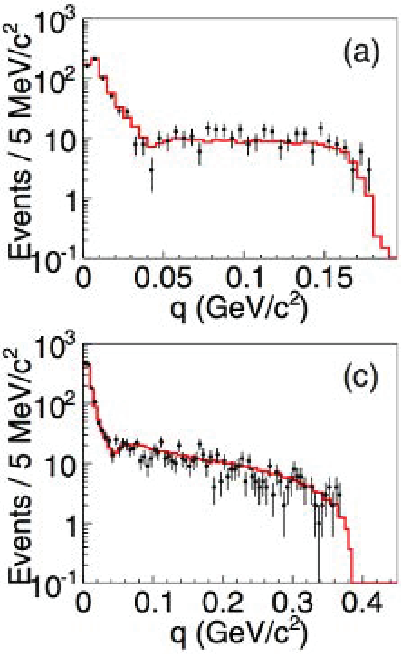

Figure 5: The comparison of q^2 between the data and Monte Carlo (MC) simulation.

5. $\psi(3686)$ Dalitz decay to χ_{cJ} and χ_{cJ} Dalitz decay to J/ψ [7]

The investigation of EM Dalitz transition plays an essential role in the understanding of the internal structure of hadrons and the interaction between the photons and hadrons. Such transition has not been observed in the charmonium decays before this analysis. The Dalitz decay of $\psi(3686) \to e^+e^-\chi_{cJ}$ and $\chi_{cJ} \to e^+e^-J/\psi$ can have access to the EM transition form factor (TFF) of these charmonium states by studying the square of invariance mass of e^+e^- pair (q^2) dependence.

Based on the data sample of 448 M $\psi(3868)$ decays, we present the first observation of the Dalitz decay of $\psi(3686) \to e^+e^-\chi_{cJ}$ and $\chi_{cJ} \to e^+e^-J/\psi$, where the χ_{cJ} in the former and latter decay channel is reconstructed by $\chi_{cJ} \to \gamma J/\psi$ and $\chi_{cJ} \to e^+e^-J/\psi$, $J/\psi \to l^+l^-$, respectively. Figure 4 shows the distributions of invariant masses of $\gamma J/\psi$ ($M(\gamma J/\psi)$) and e^+e^-J/ψ ($M(e^+e^-J/\psi)$), respectively. The BFs are measured to be $\mathscr{B}(\psi(3686) \to e^+e^-\chi_{c0,1,2} = (11.7 \pm 2.5 \pm 1.0) \times 10^{-4}$, $(8.6 \pm 0.3 \pm 0.6) \times 10^{-4}$, $(6.9 \pm 0.5 \pm 0.6) \times 10^{-4}$ and $\mathscr{B}(\chi_{c0,1,2} \to e^+e^-J/\psi = (1.51 \pm 0.30 \pm 0.13) \times 10^{-4}$, $(3.73 \pm 0.09 \pm 0.25) \times 10^{-3}$, $(2.48 \pm 0.08 \pm 0.16) \times 10^{-3}$, respectively. Figure 5 shows the consistency of q^2 distribution between the data and Monte Carlo (MC) simulation, where MC simulated sample is generated according to the model based on the assumption of a point-like meson described in Ref. [8].

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