Results from Charmonium Decays

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Recent results from BES and CLEOc experiments on charmonium decays using J/ψ, ψ' and ψ'' data samples collected in e^+e^- annihilation are reviewed, including the measurement of the relative phase between strong and electromagnetic decays of ψ', the study of the "$\rho\pi$ puzzle" in J/ψ and ψ' decays, and the search for the non-$D\bar{D}$ decays of ψ''. The decays of χ_{cJ} produced in ψ' radiative transition are also reviewed. These new results shed light on the understanding of QCD.

1. Introduction

BESII [1] running at BEPC and CLEOc [2] running at CESR are the two detectors operating in the τ-charm energy region. Both experiments have collected large data samples of charmonium decays including 58 M J/ψ events, 14 M ψ' events, and 33 pb^{-1} data around ψ'' peak at BESII, and 4 M ψ' events, and 281 pb^{-1} ψ'' events at CLEOc. To study the continuum background in the charmonium decays, special data samples at the center of mass energy lower than the ψ' mass were taken both at BESII ($\sqrt{s} = 3.650$ GeV) and at CLEOc ($\sqrt{s} = 3.671$ GeV), the luminosities are 6.4 pb^{-1} and 21 pb^{-1} respectively. These data samples are used for the study of the hadron spectroscopy, the D decay properties and the CKM matrix, as well as the charmonium decay dynamics.

In this paper, we focus on the the extensive study of the "$\rho\pi$ puzzle" in J/ψ and ψ' decays, the relative phase between strong and electromagnetic amplitudes of ψ' decays, and the non-$D\bar{D}$ decays of ψ''. The study of χ_{cJ} decays are also reviewed.

It should be noted that performance of the CLEOc detector is much better than the BESII detector, especially in the photon detection, this makes the 4 M ψ' events data sample at CLEOc produces results with similar precision as from 14 M ψ' events from BESII.

2. Relative Phase in ψ' Decays

It has been determined that for many two-body exclusive J/ψ decays, like vector pseudoscalar (VP), vector vector (VV), and pseudoscalar pseudoscalar (PP) meson decays and nucleon anti-nucleon (N$\overline{\text{N}}$) decays, the relative phases between the three-gluon and the one-photon annihilation amplitudes are near 90° [3–8]. For ψ' decays, the available information about the phase is much more limited because there are fewer experimental measurements. It has been argued that the relative phases in ψ' decays should be similar to those in J/ψ decays [3, 9], but the analysis of ψ' to VP decays in Ref. [3] indicates this phase is likely to be around 180°. Another analysis of this mode though shows the relative phase observed in J/ψ decays could also fit these decays [10], but it could not rule out the 180° possibility due to the big uncertainties in the experimental data.

BES measured the branching fraction of $\psi' \to K^0_S K^0_L$ [11] to be $(5.24 \pm 0.47 \pm 0.48) \times 10^{-5}$, together with the known branching fractions of $\psi' \to \pi^+\pi^-$ and $\psi' \to K^+K^-$, two possible solutions of the phase are found, which is either $-(82 \pm 29)°$ or $+(121 \pm 27)°$, following the procedure developed in Ref. [12]. Benefits from the good detector performance, CLEO measures all three pseudoscalar meson pair decay modes [13]. The branching fraction of $\psi' \to K^0_S K^0_L$ is $(5.8 \pm 0.8 \pm 0.4) \times 10^{-5}$, that of $\psi' \to K^+K^-$ is $(6.3 \pm 0.6 \pm 0.3) \times 10^{-5}$; the signal of $\psi' \to \pi^+\pi^-$ is not significant, and the upper limit of the branching fraction is determined to be 2.1×10^{-5} at 90% C.L. CLEO measures the relative phase to be $(95 \pm 15)°$, assuming there is no interference between continuum amplitude and the resonance decay amplitudes, which is questionable since the two components of the resonance decays has a relative phase around 90°, as measured by both BESII and CLEOc experiments. Following the same procedure developed in Ref. [12], CLEO measurements also result in two solutions for the phase, one at around −80 degrees, while another at around +120 degrees, in good agreement with the BES result. The error is large due to the small statistics of the data samples, and there is no way to determine which solution is the physical one.

3. "$\rho\pi$ Puzzle" in J/ψ and ψ' Decay

From perturbative QCD (pQCD), it is expected that both J/ψ and ψ' decaying into light hadrons are dominated by the annihilation of $c\bar{c}$ into three gluons or one virtual photon, with a width proportional to the square of the wave function at the origin [14]. This yields the pQCD "12% rule",

$$Q_h = \frac{\mathcal{B}_{\psi' \to h}}{\mathcal{B}_{J/\psi \to h}} = \frac{\mathcal{B}_{\psi' \to e^+e^-}}{\mathcal{B}_{J/\psi \to e^+e^-}} \approx 12\%. \qquad (1)$$

A large violation of this rule was first observed in decays to $\rho\pi$ and $K^{*+}K^- + c.c.$ by Mark II [15], known as *the ρπ puzzle*, where only the upper limits on the branching fractions were reported in ψ' decays. Since then, many two-body decay modes of the ψ' have been measured by the BES collaboration and recently by the CLEO collaboration; some decays obey the rule while others violate it [11, 13, 16–18].

3.1. $\psi \to \rho\pi$: Current Status

The $\rho\pi$ mode of the vector charmonia decays is essential for this study, since this is the first puzzling channel found in J/ψ and ψ' decays. The new measurements, together with the old information, show us a new picture of the charmonium decay dynamics.

3.1.1. $J/\psi \to \pi^+\pi^-\pi^0$

BESII measured the $J/\psi \to \pi^+\pi^-\pi^0$ branching fraction using its J/ψ and $\psi' \to J/\psi\pi^+\pi^-$ data samples [19], and BABAR measured the same branching fraction using J/ψ events produced by initial state radiative (ISR) events at $\sqrt{s} = 10.58$ GeV [20]. Together with the measurement from Mark-II [15], we get a weighted average of $\mathcal{B}(J/\psi \to \pi^+\pi^-\pi^0) = (2.00 \pm 0.09)\%$.

To extract the $J/\psi \to \rho\pi$ branching fraction, partial wave analysis (PWA) is needed to consider the possible contribution from the excited ρ states, the only available information on the fraction of $\rho\pi$ in $J/\psi \to \pi^+\pi^-\pi^0$ was got from Mark-III. Using the information given in Ref. [21], we estimate $\frac{\mathcal{B}(J/\psi\to\rho\pi)}{\mathcal{B}(J/\psi\to\pi^+\pi^-\pi^0)} = 1.17(1 \pm 10\%)$, with the error from an educated guess based on the information in the paper since we have no access to the covariant matrix from the fit showed in the paper. From this number and $\mathcal{B}(J/\psi \to \pi^+\pi^-\pi^0)$ got above, we estimate $\mathcal{B}(J/\psi \to \rho\pi) = (2.34 \pm 0.26)\%$. This is substantially larger than the world average listed by PDG [22], which is $(1.27 \pm 0.09)\%$.

3.1.2. $\psi' \to \pi^+\pi^-\pi^0$

$\psi' \to \rho\pi$ was studied both at BESII [17] and CLEOc [18]. After selecting two charged pions and two photons, clear π^0 signals are observed in the two photon invariant mass spectra, the numbers of signals are found to be 229 and 196 from BESII and CLEOc respectively, and the branching fraction of $\psi' \to \pi^+\pi^-\pi^0$ is measured to be $(18.1 \pm 1.8 \pm 1.9) \times 10^{-5}$ and $(18.8^{+1.6}_{-1.5} \pm 1.9) \times 10^{-5}$ at BESII and CLEOc respectively. The two experiments give results in good agreement with each other.

To extract the branching fraction of $\psi' \to \rho\pi$, however, BESII uses a PWA including the high mass ρ states and the interference between them, while CLEOc counts the number of events by applying a ρ mass cut. The branching fraction from BESII is $(5.1 \pm 0.7 \pm 1.1) \times 10^{-5}$, while that from CLEOc is $(2.4^{+0.8}_{-0.7} \pm 0.2) \times 10^{-5}$, the difference is large. Although a big difference exists between the BESII and CLEOc results, it does mean that the $\psi' \to \rho\pi$ signal exists, rather than the signal is completely missing as has been guessed before. If we take a weighted average neglecting the difference between the two measurements, we get $\mathcal{B}(\psi' \to \rho\pi) = (3.1 \pm 0.7) \times 10^{-5}$.

Comparing $\mathcal{B}(\psi' \to \rho\pi)$ with $\mathcal{B}(J/\psi \to \rho\pi)$, one gets

$$Q_{\rho\pi} = \frac{\mathcal{B}(\psi' \to \rho\pi)}{\mathcal{B}(J/\psi \to \rho\pi)} = (0.13 \pm 0.03)\%.$$

The suppression compared to the 12% rule is obvious.

3.2. Other Studies

There are many more new measurements on ψ' decays for the extensive study of the 12% rule [11, 13, 16, 18, 23], among which the VP modes are measured as first priority. The ratios of the branching fractions are suppressed for almost all these VP modes compared with the 12% rule; while the PP modes, $K^0_S K^0_L$ and K^+K^-, are enhanced compared with the 12% rule. The multi-hadron modes and the baryon-antibaryon modes are either suppressed, or enhanced, or normal, which are very hard to be categorized simply. The various models, developed for interpreting specific mode can hardly find solution for all these newly observed modes.

One observation is that many of the attempts to interpret the $\rho\pi$ puzzle are based on the potential models for the charmonium which were developed more than 20 years ago, as the B-factories discovered many new charmonium states [24] which are hard to be explained in the potential models, it may indicate even the properties of J/ψ and ψ' are not as expected from the potential models. The further understanding of the other high mass charmonium states may shed light on the understanding of the low lying ones.

4. Non-$D\bar{D}$ Decays of ψ''

Since ψ'' is above the $D\bar{D}$ threshold, it decays predominantly into charmed mesons, however, since the old measurements may indicate big contribution of ψ'' charmless decays [22], and large fraction of charmless decays of ψ'' is expected if ψ'' is a mixture of S- and D-wave charmonium states and the mixing is responsible for the 12% rule violation in J/ψ and ψ' decays [25], both BESII and CLEOc experiments tried to search for the non-$D\bar{D}$ decays of ψ'' in both exclusive modes and inclusive measurement.

4.1. Exclusive Decays

It has been pointed out that the continuum amplitude plays an important role in measuring ψ'' decays into light hadrons [25]. In fact, there are two issues which need to be clarified in ψ'' decays, that is whether ψ'' decays into light hadrons really exist, and if it exists, how large is it. The searches for the non-$D\bar{D}$ decays are performed by comparing the cross sections on and off the ψ'' resonance peak.

4.1.1. $\psi'' \to \pi^+\pi^-\pi^0$

By comparing the cross sections of $e^+e^- \to \pi^+\pi^-\pi^0$ at the ψ'' resonance peak ($\sqrt{s} = 3.773$ GeV) and at a continuum energy point ($\sqrt{s} = 3.650$ GeV at BESII and 3.671 GeV at CLEOc) below the ψ' peak, both BESII and CLEOc found that $\sigma(e^+e^- \to \pi^+\pi^-\pi^0)$ at continuum is larger than that at ψ'' resonance peak. The average of the two experiments [26, 27] are

$$\sigma(e^+e^- \to \pi^+\pi^-\pi^0)_{\rm on} = 7.5 \pm 1.2 \text{ pb},$$

$$\sigma(e^+e^- \to \pi^+\pi^-\pi^0)_{\rm off} = 13.7 \pm 2.6 \text{ pb}.$$

The difference, after considering the form factor variation between 3.650 and 3.773 GeV, is still significant, and it indicates that there is an amplitude from ψ'' decays which interferes destructively with the continuum amplitude, and makes the cross section at the ψ'' peak smaller than the pure contribution of continuum process.

For the $\rho\pi$ mode, BESII can only give upper limit of its cross section due to the limited statistics of the data sample, the upper limit at 90% C. L. is found to be 6.0 pb [26] at the ψ'' peak, which is in consistent with the measurement from CLEOc using a much larger data sample: $\sigma(e^+e^- \to \rho\pi)_{\rm on} = 4.4 \pm 0.6$ pb [27]; while the cross section at the continuum is $8.0^{+1.7}_{-1.4} \pm 0.9$ pb measured by CLEOc.

To extract the information on the $\psi'' \to \rho\pi$ branching fraction, BESII developed a method based on the measured cross sections at ψ'' resonance peak and at the continuum [26]. By neglecting the electromagnetic decay amplitude of ψ'', there are two amplitudes which contribute to the cross section at the ψ'' peak, the strong decay amplitude of ψ'' and the continuum amplitude. Taking the continuum amplitude as a real number, the ψ'' strong decay amplitude is described as one real number for the magnitude, and one phase between ψ'' strong and electromagnetic decays to describe the relative phase between the two amplitudes. Since only two measurements are available (at ψ'' peak and at continuum), one can only extract ψ'' decay branching fraction as a function of the relative phase. BESII measurement on the upper limit of the $e^+e^- \to \rho\pi$ cross section at ψ'' peak, together with the CLEOc measurement of the continuum cross section restrict the physics region of the branching fraction and the relative phase as shown in Fig. 1. From the Figure, we see that the branching fraction of $\psi'' \to \rho\pi$ is restricted within 6×10^{-6} and 2.4×10^{-3}, and the phase is between -150° and -20°, at 90% C.L.

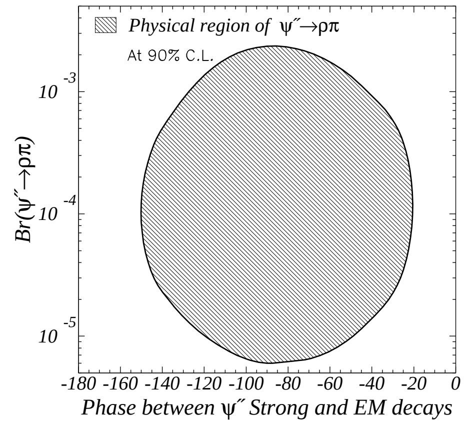

Figure 1: Physics region on $\mathcal{B}(\psi'' \to \rho\pi)$ and the relative phase (ϕ) between ψ'' strong and electromagnetic decays from BESII.

The observation of the $e^+e^- \to \rho\pi$ signal at ψ'' peak and the measurement of the cross section [27] at CLEOc further make the physical region in the branching ratio and relative phase plane smaller: the CLEOc measurement gives a similar outer bound of the physical region as BES gives, while also indicates the central part of the physical region in Fig. 1 is not allowed by physics. By using a toy Monte Carlo to simulate the CLEOc selection criteria and the interference between the resonance and continuum amplitudes, we found that the $\psi'' \to \rho\pi$ branching fraction could be either $(2.1 \pm 0.3) \times 10^{-3}$ or $(2.4^{+3.4}_{-2.0}) \times 10^{-5}$ from the CLEOc measurements, if the relative phase between ψ'' strong and electromagnetic decay amplitudes is -90° as observed in J/ψ and ψ' decays [10].

4.1.2. Other Exclusive Modes

The ψ'' decays into light hadrons were searched for in various ψ'' decay modes, including two-bady and multi-hadron modes [27–29]. However, only the comparison between the cross sections at continuum and those at ψ'' resonance peak are given, instead of giving the ψ'' decay branching fractions. In current circumstances, it is still not clear whether the ψ'' decays into light hadrons with large branching fractions, since, as has been shown in the $\rho\pi$ case, there could be two solutions for the branching fraction, and the two values could be very different.

As the luminosity at the ψ'' peak is large enough, current study is limited by the low statistics at the continuum: at CLEOc, the luminosity at continuum is more than an order of magnitude smaller than that at peak, this prevents from a high precision comparison between the cross sections at the two energy points.

One conclusion we can draw from the existing data is that the measurements do not contradict with the assumption that the relative phase between ψ'' strong and electromagnetic decay amplitudes is around $-90°$, and the ψ'' decays into light hadrons could be large.

4.2. Inclusive Measurements

The inclusive non-$D\bar{D}$ decays of ψ'' is searched for by measuring the $D\bar{D}$ cross section and the total hadronic cross section above the *uds* continuum contribution at the ψ'' resonance peak.

BES and CLEO measure the $D\bar{D}$ cross section [30, 31] using both single tag and double tag methods, the results are shown in Fig. 2. Good agreement between BES and CLEO on the D^+D^- and $D^0\bar{D}^0$, as well as the total $D\bar{D}$ cross sections are found. The weighted average of the two experiments is $(6.32^{+0.18}_{-0.12})$ nb for the total $D\bar{D}$ cross section.

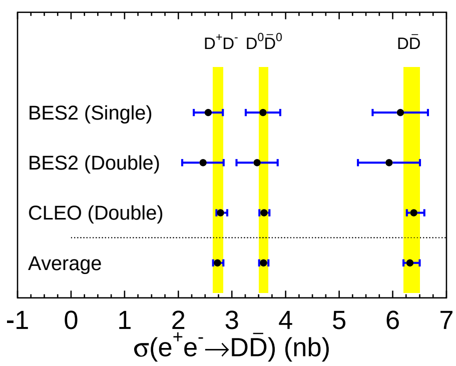

Figure 2: Measurements of the $D\bar{D}$ cross section from BES and CLEOc, and the weighted average of the measurements.

The total hadronic cross section of ψ'' decay is obtained by comparing the cross sections at the ψ'' peak and the data points below the resonance peak. The contributions of the radiative tails of J/ψ and ψ' are also subtracted. By comparing this cross section and the $D\bar{D}$ cross section, BES found a non-$D\bar{D}$ decay branching fraction of $(14.0 \pm 1.7 \pm 6.0)\%$ [29], while CLEO measured the non-$D\bar{D}$ cross section of $(-0.01 \pm 0.08^{+0.41}_{-0.30})$ nb [32], which corresponds to an upper limit of the non-$D\bar{D}$ decay branching fraction of 11% at 90% C. L.

Although the BES and CLEO measurements are not in contradiction considering the large uncertainties, the big difference between the two central values calls for a better understanding of the procedure from which the total inclusive cross section is obtained. An obvious difference between the two measurements is how to consider the interference between the resonance and the continuum amplitudes.

5. χ_{cJ} Decays

Since each χ_{cJ} $(J = 0, 1, 2)$ is produced about 10% of the ψ' decays, they are studied at BES to understand the P-wave charmonium decay dynamics, as well as the light hadron spectroscopy.

5.1. $\chi_{cJ} \to VV$

Two modes, $\omega\omega$ [33] and $\phi\phi$, were measured recently, while the former is the first observation, the latter improves the precision. The results are summarized in Table I, together with the measurement of $\chi_{cJ} \to K^*(892)\bar{K}^*(892)$ [34]. These results are used to predict the decay branching fractions of χ_{cJ} to other vector meson pairs, like $\rho\rho$ and $\omega\phi$ [35], large double OZI suppressed amplitude is expected.

Table I Branching fractions of $\chi_{cJ} \to$ VV (in 10^{-3}), the results on $\phi\phi$ are BES preliminary.

Decay mode	χ_{c0}	χ_{c2}
$\omega\omega$	$2.29 \pm 0.58 \pm 0.41$	$1.77 \pm 0.47 \pm 0.36$
$\phi\phi$	$0.94 \pm 0.21 \pm 0.14$	$1.48 \pm 0.26 \pm 0.23$
$K^*(892)\bar{K}^*(892)$	$1.78 \pm 0.34 \pm 0.34$	$4.86 \pm 0.56 \pm 0.88$

5.2. $\chi_{cJ} \to \Xi^-\bar{\Xi}^+$

The importance of the Color Octet Mechanism (COM) for χ_{cJ} decays has been pointed out for many years [36], and theoretical predictions of two-body exclusive decays have been made based on it. Recently, new experimental results on χ_{cJ} exclusive decays have been reported [37, 38]. COM predictions for many χ_{cJ} decays into meson pairs are in agreement with experimental values, while predictions for some decays into baryon pairs, for example, the branching fractions of $\chi_{cJ} \to \Lambda\bar{\Lambda}$, disagree with measured values. For further testing of the COM in the decays of the P-wave charmonia, measurements of other baryon pair decays of χ_{cJ}, such as $\chi_{cJ} \to \Xi^-\bar{\Xi}^+$ is desired.

The measurement of $\chi_{c0} \to \Xi^-\bar{\Xi}^+$ is helpful for understanding the Helicity Selection Rule (HSR) [39], which prohibits χ_{c0} decays into baryon antibaryon $(B\bar{B})$ pairs. However, the measured branching ratios for χ_{c0} decays into $p\bar{p}$ and $\Lambda\bar{\Lambda}$ do not vanish, demonstrating a strong violation of HSR in charmonium decays. Measurements of χ_{c0} decays into other baryon anti-baryon pairs would provide additional tests of the HSR.

The measured branching fractions or upper limits are summarized in Table II [40], along with some theoretical predictions. Theoretically, the quark creation model (QCM) predicts $B(\chi_{c0} \to \Xi^-\bar{\Xi}^+) =$

$(2.3 \pm 0.7) \times 10^{-4}$, which is consistent with the experimental value within 1σ. For χ_{c1} and χ_{c2} decays into $\Xi^-\bar{\Xi}^+$, the measured upper limits cover both the COM and QCM predictions. Within 1.8σ the branching fraction of $\chi_{c0} \to \Xi^-\bar{\Xi}^+$ does not vanish. For further testing of the violation of the HSR in this decay, higher accuracy measurements are required.

Table II The comparison of the branching fractions or upper limits for $\chi_{cJ} \to \Xi^-\bar{\Xi}^+$ between experimental values and theoretical predictions. The COM predictions are from Ref. [41], and the quark creation model (QCM) predictions are from Ref. [42]. The numbers are in unit of 10^{-4}, the upper limits are at 90% C. L.

Channel	Branching Fraction	COM	QCM
χ_{c0}	$5.3 \pm 2.7 \pm 0.9$	–	2.3 ± 0.7
	or < 10.3		
χ_{c1}	< 3.4	0.24	–
χ_{c2}	< 3.7	0.34	0.48 ± 0.21

5.3. $\chi_{cJ} \to PPP$

χ_{c0} decays into three pseudoscalars is forbidden by the spin-parity conservation, while χ_{c2} decays is suppressed due to high orbital angular momentum. BES tries to measure the branching fractions of χ_{c1} decays into $K^0_S K^+\pi^- + c.c.$ and $\eta\pi^+\pi^-$. Significant signals are observed and the branching fractions are measured as

$$\mathcal{B}(\chi_{c1} \to K^0_S K^+\pi^- + c.c.) = (4.1 \pm 0.3 \pm 0.7) \times 10^{-3},$$

$$\mathcal{B}(\chi_{c1} \to \eta\pi^+\pi^-) = (6.1 \pm 0.8 \pm 1.0) \times 10^{-3}.$$

The $K^0_S K^+\pi^- + c.c.$ events are mainly produced via $K^*(892)$ intermediate state, and the $\eta\pi^+\pi^-$ events via $f_2(1270)\eta$ or $a_0(980)\pi$. Except $\chi_{c1} \to K^0_S K^+\pi^- + c.c.$, all other modes are first observations. $\chi_{c2} \to K^0_S K^+\pi^- + c.c.$ is also observed for the first time with a branching fraction of $(0.8 \pm 0.3 \pm 0.2) \times 10^{-3}$. These results from BESII experiment are preliminary.

5.4. $\chi_{c0} \to SS$

Partial wave analysis of $\chi_{c0} \to \pi^+\pi^- K^+K^-$ is performed [43] using χ_{c0} produced in ψ' decays at BESII to study the pair production of scalars. In 14 M produced ψ' events, 1371 $\psi' \to \gamma\chi_{c0}$, $\chi_{c0} \to \pi^+\pi^- K^+K^-$ candidates are selected with around 3% background contamination.

Besides $(\pi\pi)(KK)$ and $(K\pi)(K\pi)$ modes which are used to study the scalars, $(K\pi\pi)K$ mode which leads to a measurement of $K_1(1270)K$ and $K_1(1400)K$ decay processes is also included in the fit. The PWA results are summarized in Table III. From these results, we notice that scalar resonances have larger decay fractions compared to those of tensors, and such decays provide a relatively clean laboratory to study the properties of scalars, such as $f_0(980)$, $f_0(1370)$, $f_0(1710)$, and so forth. The upper limits of the pair production of the scalar mesons which are less significant are determined at the 90% C.L. to be at 10^{-4} level.

Table III Summary of the $\chi_{c0} \to \pi^+\pi^- K^+K^-$ results, where X represents the intermediate decay modes, and s.s. indicates signal significance.

Decay mode (X)	$\mathcal{B}[\chi_{c0} \to X \to \pi^+\pi^- K^+K^-]$ (10^{-4})	s.s.
$f_0(980)f_0(980)$	$3.46 \pm 1.08^{+1.93}_{-1.57}$	5.3σ
$f_0(980)f_0(2200)$	$8.42 \pm 1.42^{+1.65}_{-2.29}$	7.1σ
$f_0(1370)f_0(1710)$	$7.12 \pm 1.85^{+3.28}_{-1.68}$	6.5σ
$K^*(892)^0\bar{K}^*(892)^0$	$8.09 \pm 1.69^{+2.29}_{-1.99}$	7.1σ
$K^*_0(1430)\bar{K}^*_0(1430)$	$10.44 \pm 2.37^{+3.05}_{-1.90}$	7.2σ
$K^*_0(1430)\bar{K}^*_2(1430) + c.c.$	$8.49 \pm 1.66^{+1.32}_{-1.99}$	8.7σ
$K_1(1270)^+K^- + c.c.$,		
$K_1(1270) \to K\rho(770)$	$9.32 \pm 1.83^{+1.81}_{-1.64}$	8.6σ
$K_1(1400)^+K^- + c.c.$,		
$K_1(1400) \to K^*(892)\pi$	< 11.9 (90% C.L.)	2.7σ

The above results supply important information on the understanding of the natures of the scalar states [35], as well as the decay dynamics of χ_{cJ} decays into pair of scalar particles.

6. Summary

There are many new results in charmonium decays from BESII and CLEOc experiments. The decay properties of the vector charmonium states have been studied for more than three decades, but they are still far from being understood, one extreme example is the "$\rho\pi$ puzzle" in J/ψ and ψ' decays. Further studies of all these are expected from the BESIII at BEPCII which will start its data taking in late 2007.

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