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RECENT BES RESULTS ON ψ' DECAY

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ABSTRACT

With 14 M ψ' events, many two-body decay channels are studied, which include VP, VT and PP channels. Based on systematical measurements for charmonium decay, 12% rule is tested, the phase between strong and EM amplitudes is studied. In addition, hadronic and radiative transition of charmonia are measured to improve experimental accuracy and test theoretical calculations.

1 Introduction

Charmonium decay continues to present itself as a challenge to our understanding of the strong interaction. Up to 2004, BES collaboration has collected 14 Million (M) ψ' events (luminosity is 19.72 pb^{-1}), 58 M J/ψ events, 27 pb^{-1}

* On behalf of BES collaboration

ψ'' data and 6.4 pb^{-1} data taken at 3.65 GeV for continuum study. With all these samples, studies have made systematically for charmonium decay. Herein the results of ψ' decay is the main content of this report, which contains the following topics: decays of ψ' to Vector Pseudoscalar (VP), Vector Tensor (VT), Pseudoscalar Pseudoscalar (PP) channels, and hadronic and radiative transition of ψ'.

As it is known, both J/ψ and ψ' decays are expected to be dominated by annihilation into three gluons, with widths that are proportional to the square of the $c\bar{c}$ wave function at the origin [1]. This yields the pQCD expectation (so-called "12 % " rule) that

$$Q_h = \frac{\mathcal{B}_{\psi' \to X_h}}{\mathcal{B}_{J/\psi \to X_h}} = \frac{\mathcal{B}_{\psi' \to e^+e^-}}{\mathcal{B}_{J/\psi \to e^+e^-}} = (12.3 \pm 0.7)\% \quad . \tag{1}$$

The observation of deviation from 12 % rule will provide some new clues concerning the dynamics of charmonium decay. Another study relevant to charmonium decay is the relative phase ϕ between strong and electromagnetic (EM) amplitudes. At J/ψ region, the nature of ϕ has been studied in many two-body decay modes: 1^-0^- [2, 3], 0^-0^- [4, 5, 6], 1^-1^- [6] and $N\overline{N}$ [7]; while at ψ' region, only two modes 0^-0^- [8] and 1^-0^- [9] have been discussed phenomenologically, more researches are needed.

Here it is necessary to stress a point. In e^+e^- experiment, the production of ψ' is accompanied by one photon continuum process

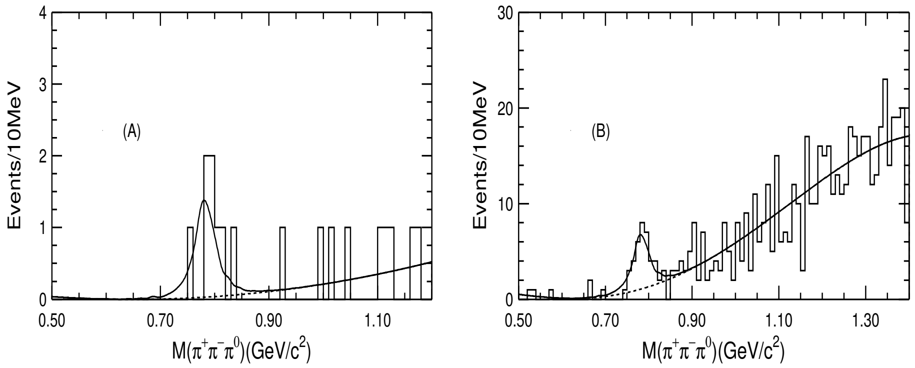
$$e^+e^- \to \gamma^* \to \text{hadrons} \ , \tag{2}$$

in which e^+e^- pair annihilates into a virtual photon without going through the intermediate resonance state. Taking the contribution from this process and its interference effect into consideration, it could determine not only the magnitude but also the sign of ϕ. Furthermore, the continuum contribution and its interference effect will exert obvious influence on the branching ratio measurement, which should be treated carefully in corresponding analyses.

2 Study of ψ' two-body decay

2.1 VP channel

As forementioned the continuum contribution need to be treated carefully, the data at both resonance and continuum are analyzed. Fig. 1 shows the invariant mass distribution of ω, from which the numbers of events are fitted to be 7.4 ± 2.8 at $E_{cm} = 3.65$ GeV and 31.3 ± 7.4 at $E_{cm} = 3.686$ GeV, respectively. The rough estimation based on the present results shows that the continuum contribution is around 70%, which is consistent with 60%, the phenomenological calculation [11]. For $K^*\overline{K}$ channel, $K\pi K_S$ ($K_S \to \pi^+\pi^-$) final state is studied. From the invariant mass distributions of $K\pi$ and $K_S\pi$ at ψ' peak (continuum), the numbers of events are fitted to be 65.6 ± 9.0 (2.5 ± 1.9) and 9.6 ± 4.2 (0) for $K^*\overline{K}^0 + c.c.$ and $K^{*+}\overline{K}^- + c.c.$ respectively. With the luminosities, it is easy to transform the observed numbers of events into the corresponding cross sections. If the parameterization forms in reference [6] are adopted, and observed cross sections are used as inputs, the phase between strong and EM amplitudes can be fitted, at the same time, obtaining the branching ratios, which are 12.7×10^{-5} and 3.1×10^{-5} for $K^*\overline{K}^0 + c.c.$ and $K^{*+}\overline{K}^- + c.c.$, respectively. Comparing with the results listed in Table 1, from which the continuum contribution has not been subtracted, the largest difference is around 18%.



(a) At $E_{cm} = 3.65$ GeV　　(b) At $E_{cm} = 3.686$ GeV

Figure 1: *The invariant mass distribution of ω at (a) continuum and (b) resonance. The dashed line indicates the background while the solid line the synthetic fitting result.*

2.2 VT channel

The measured results for VT channel [10] are listed in Table 1, from which we notice that the Q-value for all VT channel are suppressed by a factor of 3 to 5 compared with the 12 % rule.

2.3 PP channel

For PP channel, the parameterization forms [12]

$$
\begin{array}{rlr}
\pi^+\pi^- : & & E \ , \\
K^+K^- : & \sqrt{3/2}\ M & +\ E \ , \\
K^0_S K^0_L : & \sqrt{3/2}\ M & ,
\end{array}
\tag{3}
$$

are adopted to determine the phase ϕ. So far as e^+e^- experiment is concerned, E must be replaced by $E+E_C$, where E_C denotes the continuum contribution. Fitting together the previous measurements [8] and the recently measured branching ratio for $\psi' \to K^0_S K^0_L$, we determine ϕ to be $(-82\pm29)^\circ$ or $(+121\pm 27)^\circ$. The detailed analyses of $K^0_S K^0_L$ in J/ψ and ψ' decay can be found in references [13] and [14], the final results are summarized in Table 1.

Table 1: *The results of ψ' two-body decay.*

VP channel	$\mathcal{B}_{\psi'}$ (10^{-5}) (from BES)	$\mathcal{B}_{J/\psi}$ (10^{-4}) (from PDG2002)	Q_h
$K^*\overline{K}^0 + c.c.$	$15.0\pm2.1\pm1.7$	42 ± 4	3.6 ± 0.7
$K^{*+}\overline{K}^- + c.c.$	$2.9\pm1.3\pm0.4$	50 ± 4	0.58 ± 0.29
$\omega\pi^0$	< 3.27	4.2 ± 0.6	< 7.8
VT channel	$\mathcal{B}_{\psi'}$ (10^{-4}) (from BES)	$\mathcal{B}_{J/\psi}$ (10^{-3}) (from PDG2002)	Q_h
ωf_2	$2.05\pm0.41\pm0.38$	4.3 ± 0.6	4.8 ± 1.5
ρa_2	$2.55\pm0.73\pm0.47$	10.9 ± 2.2	2.3 ± 1.1
$K^*\overline{K^*_2} + c.c.$	$1.86\pm0.32\pm0.43$	6.7 ± 2.6	2.8 ± 1.3
$\phi f'_2$	$0.44\pm0.12\pm0.11$	1.23 ± 0.21	3.6 ± 1.5
PP channel	$\mathcal{B}_{\psi'}$ (10^{-5}) (from BES)	$\mathcal{B}_{J/\psi}$ (10^{-4}) (from BES)	Q_h
$K^0_S K^0_L$	$5.24\pm0.47\pm0.48$	$1.82\pm0.04\pm0.13$	28.8 ± 3.7

3 12% rule and mixing model

The Q-values for three kinds of two-body decay, VP, VT and PP, are listed in Table 1. It clearly shows that the Q-value is enhanced for some channels while suppressed for others. Indeed, many theoretical efforts are made to settle the problems [15], however, none explains all the existing experimental data naturally. Here we only mention one point: some recent phenomenological studies indicate that S- and D-wave mixing model is a natural and calculable model. It probably give a unified explanation for all 12% rule deviated decays. Using this model, according to the measurement results at J/ψ and ψ', the corresponding decay at ψ'' can be predicted. So the measurement at ψ'' can be used to test the mixing model. One example is given in reference [16], according to which the branching ratio of $\psi'' \to K_S^0 K_L^0$ is estimated to be within a range from $(0.12 \pm 0.07) \times 10^{-5}$ to $(3.8 \pm 1.1) \times 10^{-5}$. With the data at ψ'', BES has detected an upper limit, which does not contradict the current prediction.

4 ψ' hadronic and radiative transition

Motivation for such study is to improve experimental accuracy and test theoretical calculations. Inclusive and exclusive methods are adopted to analyze the following channels extensively:

$$
\begin{array}{cc}
XJ/\psi(J/\psi \to \mu^+\mu^-)\text{ final state} & \gamma\gamma J/\psi(J/\psi \to \ell^+\ell^-)\text{ final state} \\
Anything\ J/\psi & \pi^0 J/\psi \\
\pi^0\pi^0 J/\psi & \eta J/\psi \\
\eta J/\psi & \gamma\chi_{c1}, \chi_{c1} \to \gamma J/\psi \\
\gamma\chi_{c1}, \chi_{c1} \to \gamma J/\psi & \gamma\chi_{c2}, \chi_{c2} \to \gamma J/\psi \\
\gamma\chi_{c2}, \chi_{c2} \to \gamma J/\psi &
\end{array}
\tag{4}
$$

For XJ/ψ final states, μ-pair is used to identify J/ψ particle, the invariant mass distributions of X with and without extra charged-track cases are fitted simultaneously with component shapes determined from Monte Carlo simulation [17]; for $\gamma\gamma J/\psi$ final states, lepton-pair is used to identify J/ψ particle, the various exclusive channels are fitted separately [18]. Based on BES results, some theoretical calculations are tested. Comparisons show that the calculation based on PCAC are smaller than BES measurement, while the Multipole expansion evaluations are consistent with BES present values [18].

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