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RECENT RESULTS FROM BES II $\psi(2S)$ DATA

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Recent results on charmonia decays at BES II are reported, including the measurements of $\psi(2S) \to$ Vector-Pseudoscalar, $\psi(2S) \to$ Vector-Tensor and $\psi(2S) \to K_S^0 K_L^0$ for a test of the pQCD "12% rule" between $\psi(2S)$ and J/ψ decays; the first observations of $\chi_{c0} \to f_0(980) f_0(980)$, $\chi_{cJ} \to K^*(892)^0 \bar{K}^*(892)^0$; and a study of the pentaquark state in $\psi(2S)$ and J/ψ decays.

Keywords: charmonium; pQCD; χ_c decays.

1. Introduction

The Beijing Spectrometer (BES) is a general purpose solenoidal detector at the Beijing Electron Positron Collider (BEPC) storage ring at a center-of-mass energies corresponding to $M_{\psi(2S)}$ and $M_{J/\psi}$. BES (BES I) is described in detail in Ref. 1, and the upgraded BES detector (BES II) is described in Ref. 2.

2. $\psi(2S) \to$ Vector-Pseudoscalar (preliminary)

Using $(14 \pm 0.6) \times 10^6$ $\psi(2S)$ events collected with the BES II detector, we investigate ten Vector-Pseudoscalar (VP) decay channels $\psi(2S) \to (\rho, \omega, \phi)(\pi, \eta, \eta')$ and $K^*(892)\bar{K} + c.c.$ to test the perturbative QCD (pQCD) "12% rule".[3,4,5,6]

The $\psi(2S) \to K^*(892)\bar{K} + c.c.$ decays are studied with $K_S^0 K^+ \pi^- + c.c.$ final state.[3] The Dalitz plot of the candidate events is shown in Fig. 1(a). Fig. 1(b) shows the invariant mass of $K^\pm \pi^\mp$ with an additional cut $m_{K_S^0 \pi^\pm} > 1.0$ GeV to remove the influence from $K^{*\pm} K^\mp$, and Fig. 1(c) shows the invariant mass of $K_S^0 \pi^\pm$ for $K_S^0 K^\pm \pi^\mp$ candidate events with an additional cut $m_{K^\pm \pi^\mp} > 1.0$ GeV to remove the influence from $K^{*0}\bar{K}^0 + c.c.$. Clear $K^{*+}K^- + c.c.$ and $K^{*0}\bar{K}^0 + c.c.$ signals are observed in the plots. The fit of the invariant mass spectra for $K^\pm \pi^\mp$ and $K_S^0 \pi^\mp$,

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as shown in Fig. 1(b) and (c), yields (65.6 ± 9.0) $K^{*0}\bar{K}^0 + c.c.$ and (9.6 ± 4.2) $K^{*+}K^- + c.c.$ events. Their statistical significance are 11σ and 3.5σ, respectively. The branching fractions are listed in Table 1, compared with the corresponding branching fractions of J/ψ decays,[7] $\psi(2S)$ deacys are suppressed relative to the 12% rule expection. A large isospin violation is observed between the charged mode and neutral mode of $\psi(2S) \to K^*\bar{K} + c.c.$ decays, this is understandable since the electromagnetic decay amplitudes are different in these two channels.

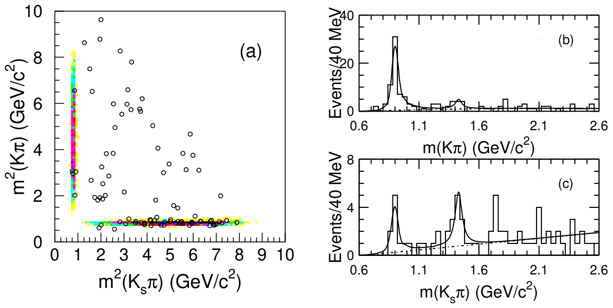

Fig. 1. (a) Dalitz plot, (b) $K^\pm\pi^\mp$ invariant mass, and (c) $K^0_S\pi^\pm$ invariant mass for $K^0_S K^\pm\pi^\mp$ candidate events after the selection. The circles are data, and the shadow regions are simulated $\psi(2S) \to K^*\bar{K} + c.c.$ events (the horizontal band for $K^{*0}\bar{K}^0 + c.c.$ and the vertical band for $K^{*+}K^- + c.c.$). The curves in (b) and (c) show the best fit described in the text.

Table 1. Branching fractions for $\psi(2S) \to K^*(892)\overline{K} + c.c.$. Results for corresponding J/ψ branching fractions are also given as well as the ratios $Q_h = \frac{\mathcal{B}(\psi(2S)}{\mathcal{B}(J/\psi)}$.

Channels	$\mathcal{B}(\psi(2S))$ $(\times 10^{-5})$	$\mathcal{B}(J/\psi)$ $(\times 10^{-4})$	Q_h (%)
$K^*(892)^+K^- + c.c.$	$2.9 \pm 1.3 \pm 0.4$	50 ± 4	0.58 ± 0.25
$K^*(892)^0\overline{K}^0 + c.c.$	$15.0 \pm 2.1 \pm 1.9$	42 ± 4	3.6 ± 0.8

In the study of the $\rho\pi$ puzzle, $\psi(2S) \to \rho\pi$ is one of the key decay modes and is of great interest to both theorists and experimentalists. For the $\psi(2S)$ sample, 250 events are obtained with about 13% non-π^0 background, while for the continuum sample, 11 events are obtained with about 42% non-π^0 background.[4] The selected events are fitted in the helicity amplitude formalism with an unbinned maximum likelihood method using MINUIT. The fit results are shown in Fig. 2; the fit describes the data reasonably well. The fit yields $(28 \pm 3)\%$ $\rho(770)\pi$ in all $\pi^+\pi^-\pi^0$

events. By comparing the likelihood difference with and without the $\rho(770)\pi$ in the fit, the significance of $\rho(770)\pi$ is determined to be 7.8σ. The significance of $\rho(2150)\pi$ is larger than 10σ. We obtain the branching fractions of $\psi(2S) \to \pi^+\pi^-\pi^0$, $\rho(770)\pi$ and $\rho(2150)\pi$ as

$$\mathcal{B}(\pi^+\pi^-\pi^0) = (18.1 \pm 1.8 \pm 1.9) \times 10^{-5},$$
$$\mathcal{B}(\rho(770)\pi \to \pi^+\pi^-\pi^0) = (5.1 \pm 0.7 \pm 0.8) \times 10^{-5},$$
$$\mathcal{B}(\rho(2150)\pi \to \pi^+\pi^-\pi^0) = (19.4 \pm 2.5^{+11.2}_{-2.1}) \times 10^{-5},$$

where the first errors are statistical and the second systematic. Comparing with the corresponding J/ψ decay branching fractions,[7] it is found that both $\pi^+\pi^-\pi^0$ and $\rho(770)\pi$ are highly suppressed compared with the "12% rule", while for $\rho(2150)\pi$, there is no measurement in J/ψ decays.

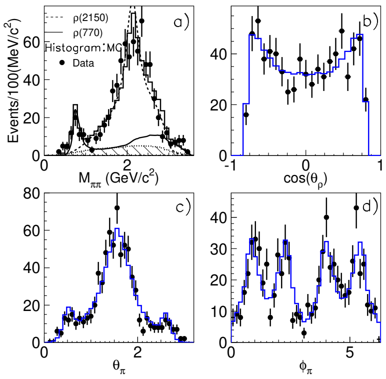

Fig. 2. Comparison between data (dots with error bars) and the final fit (solid histograms) for (a) two pion invariant mass, with a solid line for the $\rho(770)\pi$, a dashed line for the $\rho(2150)\pi$, and a hatched histogram for background; (b) the ρ polar angle in the $\psi(2S)$ rest frame; and (c) and (d) for the polar and azimuthal angles of the designated π in ρ helicity frame.

The other measurements of $\psi(2S) \to$ VP decay modes $\phi\pi^0, \phi\eta, \phi\eta', \omega\eta, \omega\eta'$ and $\omega\pi^0, \rho\eta, \rho\eta'$ can be found in Refs. 5, 6.

3. $\psi(2S) \to$ Vector-Tensor

Four Vector-Tensor decay channels $\psi(2S) \to \omega f_2(1270) \to \pi^+\pi^-\pi^+\pi^-\pi^0$, $\rho a_2(1320) \to \pi^+\pi^-\pi^+\pi^-\pi^0$, $K^*(892)^0\bar{K}_2^*(1430)^0 + c.c. \to \pi^+\pi^-K^+K^-$ and $\phi f_2'(1525) \to K^+K^-K^+K^-$ are also investigated to test the pQCD "12% rule".[8] The statistical significance for all four channels are larger than 3σ; those for $\omega f_2(1270)$ and $K^*(892)^0\bar{K}^*(1430)^0 + c.c.$ are larger than 5σ. All four VT decay modes are suppressed by a factor of 3 to 5 compared with the pQCD expectation.

4. Observation of $\psi(2S) \to K_S^0 K_L^0$

The branching fraction of $\psi(2S) \to K_S^0 K_L^0$ is measured to be $\mathcal{B}(\psi(2S) \to K_S^0 K_L^0) = (5.24 \pm 0.47 \pm 0.48) \times 10^{-5}$.[9] A similar analysis of the J/ψ data sample yields an improved measurement of the $J/\psi \to K_S^0 K_L^0$ branching fraction:[10] $\mathcal{B}(J/\psi \to K_S^0 K_L^0) = (1.82 \pm 0.04 \pm 0.13) \times 10^{-4}$. Using above measurements, one gets $Q_h = \frac{\mathcal{B}(\psi(2S) \to K_S^0 K_L^0)}{\mathcal{B}(J/\psi \to K_S^0 K_L^0)} = (28.8 \pm 3.7)\%$. This result indicates that $\psi(2S)$ decay is enhanced by more than 4σ relative to the "12% rule" expected from pQCD.

In conclusion, we present the measurements of ten $\psi(2S) \to$ VP decay modes, four VT modes and $\psi(2S) \to K_S^0 K_L^0$, while for most channles where the deviations from the "12% rule" are observed, $\psi(2S)$ decays are suppressed. This may shed light on the understanding of the $\psi(2S)$ decay dynamics.

5. Pentaquark search, $\chi_{c0} \to f_0(980) f_0(980)$ and $\chi_{cJ} \to K^*(892)^0 \bar{K}^*(892)^0$

The results of the first observations of $\chi_{c0} \to f_0(980) f_0(980)$, $\chi_{cJ} \to K^*(892)^0 \bar{K}^*(892)^0$; and a study of the pentaquark state in $\psi(2S)$ and J/ψ decays are also reported, and the analysis details are described in Refs. 11, 12, 13.

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