Results on hadronic $\psi(2S)$ decays into VP and VT final states

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Results from the BES/BEPC experiment are presented based on 3.6 million $\psi(2S)$ decays. $\rho\pi/K^*\bar{K}$ puzzle persists with new upper limits. Measurements on the branching fractions for the decays into ωf_2, $a_2\rho$ and $K^{*0}\bar{K}_2^{*0}$ + *c.c.* reveal new suppression in Vector-Tensor mode.

One of the outstanding puzzles in charmonium physics is the great disparity in branching fractions for decays to $\rho\pi$ and $K^{*+}K^- + c.c.$ between two $^3S_1$ $c\bar{c}$ bound states, J/ψ and $\psi(2S)$. As has been revealed by MARK II [1], these dominant hadronic channels for J/ψ decays are not seen in $\psi(2S)$ decays; the limits at 90% confidence level on the ratio of $\psi(2S)$ to J/ψ decay rates are more than an order of magnitude below the theoretically expected value of about 15%. This so called *15% rule*, though established originally for inclusive hadronic decays on the basis of perturbative QCD with apparent approximations, appears to exist for most measurements of J/ψ and $\psi(2S)$ exclusive decay channels. The anomaly in decays J/ψ and $\psi(2S) \to \rho\pi$ and $K^*\bar{K}$ has stimulated a number of theoretical attempts to explain it, but none of them seems convincing. It is thus expected that main advance in understanding the problem will come from getting a large statistics $\psi(2S)$ sample to measure the pattern of hadronic $\psi(2S)$ decays relative to the J/ψ. We present here recent results on studies of the two-body decays of the $\psi(2S)$ into vector-pseudoscalar (VP) and vector-tensor (VT) meson pairs based on a sample of 3.6×10^6 produced $\psi(2S)$ events collected with the BES detector at the Beijing Electron Positron Collider BEPC.

The BES detector, a solenoidal magnetic spectrometer optimized for BEPC physics, has been described in detail elsewhere [2]. Branching fractions from the $\psi(2S)$ to the final states $\rho\pi$, $K^{*+}K^- + c.c.$, $K^{*0}\bar{K}^0 + c.c.$, $K^{*0}\bar{K}_2^{*0} + c.c.$, ωf_2 and $a_2\rho$ have been measured. The results are given in Table I. We have also analyzed several other $\psi(2S)$ decays and obtained preliminary results on their branching fractions. As example of decay mode observing the *15%* rule, the decay $\psi(2S) \to \phi f_0$ is included in the table for comparison. On each result the first error is statistical and the second systematic. The upper limit is given at the 90% confidence level. The comparison between observed and predicted $\psi(2S)$ decay rates by PQCD is shown in Fig.1, where the measured

$B(\psi(2S) \rightarrow f)$ normalized to the expected $0.15 \cdot B(J/\psi \rightarrow f)$ is plotted for various hadronic final states. The results show the following.

Table 1: Branching fractions of $\psi(2S)$ decays

Decay Mode	Final state	Events	Efficiency(%)	$Br(\times 10^{-5})$
$\rho\pi$	$\pi^+\pi^-\pi^0$	< 10.6	10.1	< 2.9
$K^+\bar{K}^*(892)^- + c.c.$	$K^+K^-\pi^0$	< 4.3	5.85	< 6.1
$K^+\bar{K}^*(892)^- + c.c.$	$K^0_s K^\pm\pi^\mp$	< 3.89	10.6	< 3.2
$K^0\bar{K}^*(892)^0 + c.c.$	$K^0_s K^\pm\pi^\mp$	14 ± 4	14.4	$8.4 \pm 2.4 \pm 1.6$
$K^*(892)^0\bar{K}^*_2(1430)^0 + c.c.$	$\pi^+\pi^-K^+K^-$	< 25.2	17.7	< 1.8
$a_2\rho$	$2(\pi^+\pi^-)\pi^0$	28.4 ± 13.7	5.49	$31 \pm 15 \pm 11$
$\omega f_2(1270)$	$2(\pi^+\pi^-)\pi^0$	< 13.4	5.31	< 15
$\phi f_0(980)$	$\pi^+\pi^-K^+K^-$	16.6 ± 5.2	23.4	$77 \pm 24 \pm 15$

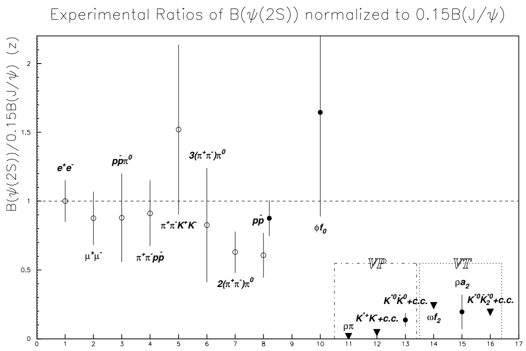

Fig.1: $B(\psi(2S) \rightarrow f)$ normalized to $0.15 \cdot B(J/\psi \rightarrow f)$: BES measurements in black dots and triangles (upper limits at 90% C.L.), PDG data in cycle.

(1) Our analysis confirm the MARK II measurements: the suppression of $\psi(2S)$ to $\rho\pi$ and $K^{*+}K^- + c.c.$ compared with the prediction of PQCD persists at much higher levels of sensitivity provided by the BES data sample; the branching fractions of $\psi(2S) \rightarrow \rho\pi$ and $\psi(2S) \rightarrow K^{*+}K^- + c.c.$ are found to be lower by more than a factor of 60 and 20, respectively, than the *15% rule* expectation.

(2) The BES upper limit for $\psi(2S) \rightarrow \rho\pi$ is well below either of the predicted values given by Chaichian-Tornqvist [3] and Pinsky models [4]. The another intriguing possible explanation by Brodsky et al. [5] is also disfavored by a recent test performed based on an energy scan at BEPC [6]. It seems that none of the existing models is able to explain the $\rho\pi$ puzzle satisfactorily.

(3) It is seen from our measurements that $\frac{B(\psi(2S)\to K^{*0}\bar{K}^0+c.c.)}{B(\psi(2S)\to K^{*+}K^-+c.c.)} > 1$, whereas $\frac{B(J/\psi\to K^{*0}\bar{K}^0+c.c.)}{B(J/\psi\to K^{*+}K^-+c.c.)} < 1\,(\approx 0.8\pm 0.1)$ using the data in Ref. [7]. These apparent isospin-violating effects may be understood by a phenomenological model described in Ref. [8]. In the case of the J/ψ, the predicted decay amplitudes for J/ψ decays to neutral and charged $K^*\bar{K}$ states should be less than 1 due to the different quark content of the neutral $(d\bar{s})$ and charged $(u\bar{s})$ states. In the $\psi(2S)$ case, assuming that the contribution of the strong process is much less than the electromagnetic amplitude, one expects $B(\psi(2S)\to K^{*+}K^-+c.c.) \approx \frac{1}{4}B(\psi(2S)\to K^{*0}\bar{K}^0+c.c.) \sim 2.1\times 10^{-5}$ using our value of $B(\psi(2S)\to K^{*0}\bar{K}^0+c.c.)$. If all the four $K^{*\pm}$ candidate events observed in our analysis (see Table I) are from direct decay, we obtain the branching fraction, instead of an upper limit, of $B(\psi(2S)\to K^{*+}K^-+c.c.) = (2.0\pm 1.0\pm 0.6)\times 10^{-5}$, in good agreement with the predicted value.

(4) Our measurements on the branching fractions for the decays into ωf_2, $K^{*0}\bar{K}_2^{*0}+c.c.$ and $a_2\rho$ reveal newly observed suppressions in VT decay modes. It is noted that these VT decays are allowed by the PQCD theorem that the total hadron helicity is conserved in high-momentum transfer exclusive processes, whereas the VP decays, $\rho\pi$ and $K^*\bar{K}$, are forbidden by the hadron helicity conservation theorem [9]. Thus this finding of new suppression poses an additional challenge to theoretical understanding in charmonium physics.

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