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WHAT ARE THE D_{sJ} AND $X(3872)$ PARTICLES?

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We report measurements of B decay modes involving the newly discovered D_{sJ} and $X(3872)$ particles. Possible spin-parity and quark content assignments of these new states are discussed. The results are based on a large data sample recorded by the Belle detector at the KEKB e^+e^- collider.

Keywords: Spectroscopy; charmonium; B-factory.

1. The $D^*_{sJ}(2317)$ and $D_{sJ}(2460)$ production in B decays

Two narrow resonances denoted as $D^*_{sJ}(2317)^+$ and $D_{sJ}(2460)^+$ have been observed recently in e^+e^- continuum interactions. The quantum numbers have been classified tentatively as $J^P = 0^+$ for $D^*_{sJ}(2317)^+$ and $J^P = 1^+$ for $D_{sJ}(2460)^+$. However, the measured masses are significantly lower than the values predicted within potential models for 0^+ and 1^+ states [1]. There has been a significant effort to explain the surprising D_{sJ} masses [1], and some authors have discussed the possibility of four-quark content in the D_{sJ} states. To clarify behaviours of the D_{sJ} states the Belle collaboration looked for the B decays to two-body final states involving a combination of a D^+_{sJ} meson and a D, D^*, kaon or pion.

1.1. $B \to \bar{D}^{(*)} D_{sJ}$ decays

With a data sample of 253 fb^{-1} collected with the Belle detector, the $B \to \bar{D} D_{sJ}$ decay modes are measured with improved accuracy (Belle previously published the observation of these decays with 140 fb^{-1} of data [2]) and new decay modes $B \to \bar{D}^* D_{sJ}$ are observed. These processes are described by conventional tree diagrams, similar to the $B \to \bar{D}^{(*)} D_s$ decays with a pseudoscalar D_s meson. D_{sJ} candidates are reconstructed in the modes $D_s^{(*)}\pi^0$, $D_s^{(*)}\gamma$ and $D_s^{(*)}\pi^+\pi^-$.

The results of the combined data fit (assuming isospin invariance) are listed in Table 1. From these measurements we obtain the branching fraction ratio: $\mathcal{B}(D_{sJ}(2460)^+ \to D_s^+\gamma)/\mathcal{B}(D_{sJ}(2460)^+ \to D_s^{*+}\pi^0) = 0.43 \pm 0.08 \pm 0.04$.

Table 1. Branching fractions and signal significances for the combined fit assuming isospin invariance.

Decay channel	$\mathcal{B}$, 10^{-4}	Significance
$B \to \bar{D} D^*_{sJ}(2317)$ $[D_s\pi^0]$	$10.1 \pm 1.5 \pm 3.0$	9.5σ
$B \to \bar{D} D^*_{sJ}(2317)$ $[D^*_s\gamma]$	$4.0^{+1.5}_{-1.4}(< 8.4)$	3.5σ
$B \to \bar{D} D_{sJ}(2460)$ $[D^*_s\pi^0]$	$14.8^{+2.8}_{-2.5} \pm 4.4$	8.6σ
$B \to \bar{D} D_{sJ}(2460)$ $[D_s\gamma]$	$6.4 \pm 0.8 \pm 1.9$	11σ
$B \to \bar{D} D_{sJ}(2460)$ $[D^*_s\gamma]$	$2.6^{+1.1}_{-1.0}(< 5.7)$	3.0σ
$B \to \bar{D} D_{sJ}(2460)$ $[D_s\pi^+\pi^-]$	$1.0^{+0.5}_{-0.4}(< 2.3)$	2.6σ
$B \to \bar{D} D_{sJ}(2460)$ $[D_s\pi^0]$	$0.2^{+0.7}_{-0.5}(< 1.7)$	-
$B \to \bar{D}^* D^*_{sJ}(2317)$ $[D_s\pi^0]$	$3.1^{+2.1}_{-1.7}(< 8.5)$	2.0σ
$B \to \bar{D}^* D_{sJ}(2460)$ $[D^*_s\pi^0]$	$28.7^{+7.4}_{-6.4} \pm 8.6$	6.9σ
$B \to \bar{D}^* D_{sJ}(2460)$ $[D_s\gamma]$	$12.7^{+2.2}_{-2.0} \pm 3.8$	10σ

The efficiency-corrected helicity angle [2] distributions are consistent with expectations for the $J = 0$ hypothesis for $D^*_{sJ}(2317) \to D_s\pi^0$ decay (Fig. 1, left) and with expectations for the $J = 1$ hypothesis for $D_{sJ}(2460) \to D_s\gamma$ decay (Fig. 1, right).

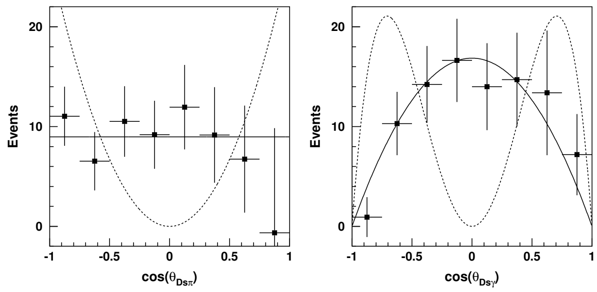

Fig. 1. The efficiency-corrected $\cos\theta_{\rm hel}$ distributions for $D_{sJ}(2317) \to D_s\pi^0$ (left) and $D_{sJ}(2460) \to D_s\gamma$ (right) decays. Solid and dashed curves are predictions: for the $J = 0$ and $J = 1$ hypotheses of $D^*_{sJ}(2317)$; $J = 1$ and $J = 2$ hypotheses of $D_{sJ}(2460)$, respectively.

1.2. $\bar{B}^0 \to D^+_{sJ}K^-$ and $\bar{B}^0 \to D^-_{sJ}\pi^+$ decays

The decays $\bar{B}^0 \to D^+_{sJ}K^-$ and $\bar{B}^0 \to D^-_{sJ}\pi^+$ are studied by the Belle collaboration for the first time with 140 fb^{-1} of data. The $\Delta M(D_{sJ}) \equiv M(D^+_s\pi^0(/\gamma)) - M(D^+_s)$ distribution for the various $D^+_{sJ}K^-$ and $D^-_{sJ}\pi^+$ combinations are shown in Fig. 2. A clear $\bar{B}^0 \to D^*_{sJ}(2317)^+K^-$ signal is observed; no significant signals are observed in the remaining modes. The branching fractions, upper limits and significances for these decay channels are listed in Table 2.

Taking into account approximate values of D_{sJ} decay branching fractions ($\mathcal{B}(D^*_{sJ}(2317)^+ \to D^+_s\pi^0) \sim 100\%$, $\mathcal{B}(D_{sJ}(2460)^+ \to D^+_s\gamma) \sim 30\%$) we conclude that $\mathcal{B}(\bar{B}^0 \to D^*_{sJ}(2317)^+K^-)$ is of the same order of magnitude as $\mathcal{B}(\bar{B}^0 \to D^+_sK^-)$ but at least a factor of two larger than $\mathcal{B}(\bar{B}^0 \to D_{sJ}(2460)^+K^-)$.

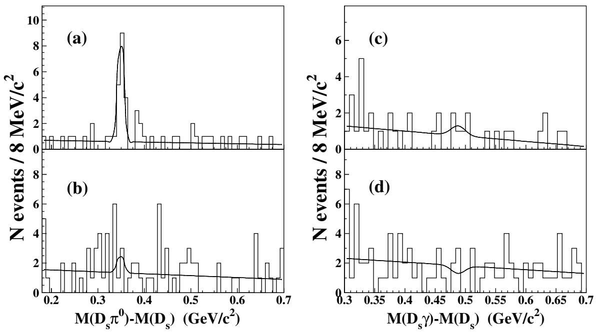

Fig. 2. $\Delta M(D_{sJ})$ distributions for $\bar{B}^0$ decays to (a) $D^*_{sJ}(2317)^+K^-$, (b) $D^*_{sJ}(2317)^-\pi^+$, (c) $D_{sJ}(2460)^+K^-$ and (d) $D_{sJ}(2460)^-\pi^+$.

Table 2. Branching fractions and signal significances for the B decays to $D^+_{sJ}K^-$ and $D^-_{sJ}\pi^+$ final states.

Decay channel	$\mathcal{B}$, 10^{-5}	Significance
$\bar{B}^0 \to D^*_{sJ}(2317)^+K^-$ $[D_s\pi^0]$	$5.3^{+1.5}_{-1.3} \pm 0.7 \pm 1.4$	6.8σ
$\bar{B}^0 \to D^*_{sJ}(2317)^-\pi^+$ $[D_s\pi^0]$	< 2.5 (90% C.L.)	-
$\bar{B}^0 \to D_{sJ}(2460)^+K^-$ $[D_s\gamma]$	< 0.94 (90% C.L.)	-
$\bar{B}^0 \to D_{sJ}(2460)^-\pi^+$ $[D_s\gamma]$	< 0.40 (90% C.L.)	-

2. B decays to the final states with $X(3872)$

Recently the narrow $X(3872)$ resonance, decaying to the $J/\Psi\pi^+\pi^-$ final state, has been observed by the Belle collaboration in the $B^+ \to K^+\pi^+\pi^-J/\Psi$ decays [3]. New decay modes of $X(3872)$ are searched for by Belle using similar techniques.

With 140 fb^{-1} of data the following upper limits are set at the 90% C.L. : $\Gamma(X \to \gamma\chi_{c1})/\Gamma(X \to \pi^+\pi^-J/\Psi) < 0.89$, $\Gamma(X \to \gamma\chi_{c2})/\Gamma(X \to \pi^+\pi^-J/\Psi) < 1.1$, $\Gamma(X \to \gamma J/\Psi)/\Gamma(X \to \pi^+\pi^-J/\Psi) < 0.40$. Evidence is found for the decay $X(3872) \to \omega J/\Psi$ in 253 fb^{-1} of data; the corresponding branching fraction ratio is $\Gamma(X \to \omega J/\Psi)/\Gamma(X \to \pi^+\pi^-J/\Psi) = 0.8 \pm 0.3 \pm 0.1$. These results are in conflict with expectations for conventional charmonium states and provide support for the $D\bar{D}^*$ molecular state interpretation for $X(3872)$.

References

1. See P. Colangelo, F. De Fazio and R. Ferrandes, BARI-TH/04-486, hep-ph/0407137 and references therein.
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3. Belle Collaboration, S.-K. Choi, S. L. Olsen *et al.*, Phys. Rev. Lett. **91**, 262001 (2003).