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Charmed B decays at Belle

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Abstract. Recent results of B decays to charmed mesons and charmonium states from Belle collaboration are reviewed. The contributions of two-body $B \to D^{**}\pi$ decays with narrow (j_q=3/2) and broad (j_q=1/2) D^{**} have been determined. We report the first observation of the decay $B^+ \to \psi(3770)K^+$ ($\psi(3770) \to D^0\bar{D}^0$ and D^+D^-). Also we report the observation of the $D_{sJ}(2317)$ and $D_{sJ}(2457)$ in B decays.

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1 Introduction

Precice measurement of B decays to charmed mesons, charmonium states, and charmed meson pairs provide information on quark dynamics and nice testing grounds of several models describing heavy quark physics, such as heavy quark effective theory (HQET), factorization hypothesis and QCD sum rule. Here we report results on charmed meson production in $D\pi\pi$, $D^*\pi\pi$ decays with 60.4fb^{-1}, on $B \to D\bar{D}K$ decays and production of $\psi(3770)$ with 88fb^{-1}, and briefly on D_{sJ} production in exclusive B decays.

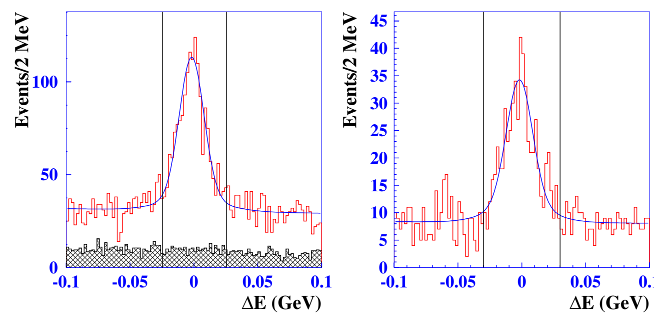

Fig. 1. ΔE distribution for $B^- \to D^+\pi^-\pi^-$ (*left*) and $B^- \to D^{*+}\pi^-\pi^-$ events (*right*). The hatched histogram (*left*) shows the D mass sideband

2 Charmed mesons in $B \to D^{(*)}\pi\pi$ decays

To describe D meson excited states, heavy quark limit is a good approximation and j_q (total angular moment of light quark) is a good quantum number. The ratio of the B meson decay branchiong fractions to two $j_q = 3/2$ states,

$$R = \mathcal{B}(B^- \to D_2^{*0}\pi^-)/\mathcal{B}(B^- \to D_1^0\pi^-) \qquad (1)$$

is calculated in HQET and factorization hypothesis. Neubert gives a value around 0.35 [1] but CLEO gives much larger value as 1.8 [2]. Also QCD sum rule predicts dominance of narrow $j_q = 3/2$ states [3], but this is questioned by semi-leptnic decays and this has to be examined by the data.

$B^- \to D^+\pi^-\pi^-$ and $D^{*+}\pi^-\pi^-$ decays are studied with the data sample of 60.4fb^{-1}. The D^+ and D^{*+} are reconstructed in the $D^+ \to K^-\pi^+\pi^+$ and $D^{*+} \to D^0\pi^+$ modes, and D^0 is reconstructed in $K^-\pi^+$ and $K^-\pi^+\pi^+\pi^-$ decay modes. ΔE distribution for these decay processes are shown in Fig. 1. The fit gives 1100 events for the $D^+\pi^-\pi^-$ final state and 560 events for the $D^{*+}\pi^-\pi^-$ final state. Correcting the detection efficiencies, the decay branching fractions are measured to be $\mathcal{B}(B^- \to D^+\pi^-\pi^-) = (1.02 \pm 0.04 \pm 0.15) \times 10^{-3}$ and $\mathcal{B}(B^- \to D^{*+}\pi^-\pi^-) = (1.25 \pm 0.08 \pm 0.22) \times 10^{-3}$, which are consistent with CLEO upper limit [4] and world average [5].

Looking for D^* production, we take two $D\pi$ masses ($D\pi$ maximal and minimal) to describe the decay kinematics. In $D\pi$ minimal mass distribution, we can see clear D-wave contribution around 2.5 GeV, and likelihood also requires broad S-wave contribution (Fig. 2(left)). Best fit gives masses and widths for D_2^* and D_0^* as follows; $M(D_2^{*0}) = (2461.6 \pm 2.1 \pm 0.5 \pm 3.3)\mathrm{MeV}/c^2$, $\Gamma(D_2^{*0}) = (45.6 \pm 4.4 \pm 6.5 \pm 1.6)\mathrm{MeV}/c^2$ and $M(D_0^{*0}) = (2308 \pm 17 \pm 15 \pm 28)\mathrm{MeV}/c^2$, $\Gamma(D_0^{*0}) = (276 \pm 21 \pm 18 \pm 60)\mathrm{MeV}/c^2$. Resulting branching fraction producs are given by

$$\begin{aligned}\mathcal{B}(B^- \to D_2^{*0}\pi^-) \times \mathcal{B}(D_2^{*0} \to D^+\pi^-) \\ = (3.4 \pm 0.3 \pm 0.6 \pm 0.4) \times 10^{-4}, \\ \mathcal{B}(B^- \to D_0^{*0}\pi^-) \times \mathcal{B}(D_0^{*0} \to D^+\pi^-) \\ = (6.1 \pm 0.6 \pm 0.9 \pm 1.6) \times 10^{-4}.\end{aligned}$$

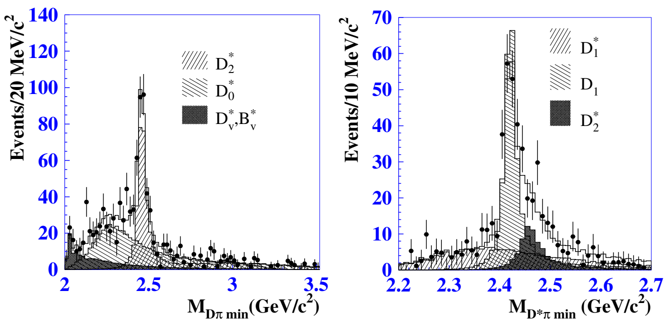

Fig. 2. The minimal $D\pi$ mass distribution of $B^- \to D^+\pi^-\pi^-$ candidates (*left*), and $D^*\pi$ mass distribution of $B^- \to D^{*+}\pi^-\pi^-$ candidates (*right*)

Similar analysis is done for $D^{*+}\pi^-\pi^-$ decay. The $D^{*+}\pi^-$ mass distribution shows narrow structure around 2.4 GeV, which is interpreted as D_1 (Fig. 2(right)). But this is not enough for this region and multi-dimensional fit also requires broad D_1' and narrow D_2^*. Resonance parameters for D_1 and D_1' are defined by fit as follows; $M(D_1^0) = (2421.4\pm1.5\pm0.4\pm0.8)\mathrm{MeV}/c^2$, $\Gamma(D_1^0) = (23.7\pm2.7\pm0.2\pm 4.0)\mathrm{MeV}/c^2$, and $M(D_1'^0) = (2427\pm26\pm20\pm15)\mathrm{MeV}/c^2$, $\Gamma(D_1'^0) = (384^{+107}_{-75}\pm24\pm70)\mathrm{MeV}/c^2$. One is narrow and one is broad. Parameters for D_2^* are fixed to the values defined in the $D^+\pi^-\pi^-$ analysis.@ The results of branching fraction products are;

$$\begin{aligned}&\mathcal{B}(B^- \to D_1^0\pi^-) \times \mathcal{B}(D_1^0 \to D^{*+}\pi^-)\\ &\quad = (6.8 \pm 0.7 \pm 1.3 \pm 0.3) \times 10^{-4},\\ &\mathcal{B}(B^- \to D_2^{*0}\pi^-) \times \mathcal{B}(D_2^{*0} \to D^{*+}\pi^-)\\ &\quad = (1.8 \pm 0.3 \pm 0.3 \pm 0.2) \times 10^{-4},\\ &\mathcal{B}(B^- \to D_1'^0\pi^-) \times \mathcal{B}(D_1'^0 \to D^{*+}\pi^-)\\ &\quad = (5.0 \pm 0.4 \pm 1.0 \pm 0.4) \times 10^{-4}.\end{aligned}$$

Note that the contribution of broad component D_1' is found to be fairly large.

If we assume that the D_2^{*0} and D_1^0 decays are saturated by $D^+\pi^-$ and $D^{*+}\pi^-$ final states, the ratio (1) is given as

$$\begin{aligned}R &= \frac{\mathcal{B}(B^- \to D_2^{*0}\pi^-)}{\mathcal{B}(B^- \to D_1^0\pi^-)}\\ &= \frac{\mathcal{B}(B^- \to D_2^{*0}\pi^-) \times \mathcal{B}(D_2^{*0} \to D^{*+}\pi^- + D^+\pi^-)}{\mathcal{B}(B^- \to D_1^0\pi^-) \times \mathcal{B}(D_1^0 \to D^{*+}\pi^-)}\\ &= 0.77 \pm 0.15\end{aligned}$$

This can be compared with the calculation by Neubert [1] and CLEO result [2]. Large amount of broad component are known to exist in D^* states. This is inconsistent with the QCD sum rule expectation, which prefers dominance of narrow states. Or, this could be explained with possible contribution of color suppressed amplitudes.

3 $B \to D\bar{D}K$ decays and $\psi(3770)$

This decay is due to $b \to c\bar{c}s$ process, and precise measurement is important to understand thegcharm counting problem". Special interest is that this will be the dominant decay mode of D-state charmonium $\psi(3770)$, which is just above the open charm threshold. For this state, mixing with S-wave states is suggested from its leptonic width, and this leads to the decay rate comparable with $\psi(2s)$ and possible decay modes other than $D\bar{D}$ [6]. Also non-relativistic QCD with color octet model predicts large branching fraction of $B \to \psi(3770)$ [7]. So, the measurement of the B decay rates to $\psi(3770)$ ($1D$ state) and $\psi(2s)$ provides information on S-D mixing and/or color octet mechanism.

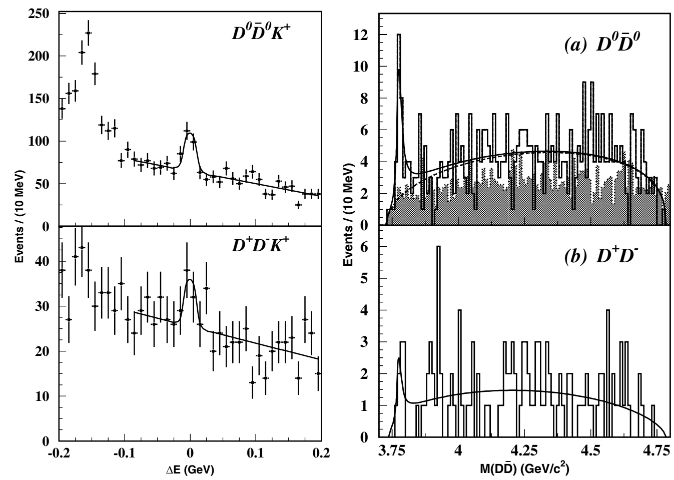

Fig. 3. The ΔE distributions for the $B^+ \to D^0\bar{D}^0K^+$ and $B^+ \to D^+D^-K^+$ candidates (*left*), and $D^0\bar{D}^0$ and D^+D^- mass distribution from the B-signal region (*right*)

Charged and neutral D mesons are reconstructed in the decay modes; $D^+ \to K^-\pi^+\pi^+$, $K^-K^+\pi^+$, and $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0$. After making mass and vertex constrained fit, continuum was suppressed by requiring $R_2 < 0.5$ and $|\cos\theta_{thr.}| < 0.8$. With the cut of $5.272 < M_{bc} < 5.288\mathrm{GeV}/c^2$, ΔE for $B^+ \to D^0\bar{D}^0K^+$ and $D^+D^-K^+$ show nice peak as seen in Fig. 3(left). From the fit, we got 100 events for $D^0\bar{D}^0K^+$ with 5.5 σ, and also found 20 events for $D^+D^-K^+$ with 2.7 σ. We define the branching fraction for $B^+ \to D^0\bar{D}^0K^+$ and upper limit for $B^+ \to D^+D^-K^+$ as

$$\begin{aligned}&\mathcal{B}(B^+ \to D^0\bar{D}^0K^+) = (1.17 \pm 0.21 \pm 0.25) \times 10^{-3}\\ &\mathcal{B}(B^+ \to D^+D^-K^+) < 0.79 \times 10^{-3}\ \text{@90\%C.L.}\end{aligned}$$

In the $D\bar{D}$ mass spectrum, we can see clear signal in $D^0\bar{D}^0$, which is interpreted as $\psi(3770)$ (Fig. 3(right)). The signal is fitted by relativistic Breit-Wigner with floated mass and fixed width of 23.6 MeV. The mass given by the fit is $3778.4 \pm 3.0 \pm 0.8$ MeV, and we count 34 events with the significance of 5.9 σ. This is the first observation of $B^+ \to \psi(3770)K^+$. Less prominent signal is seen in D^+D^-. We count 8 events with 2.5 σ assuming the same mass and width. The branching fraction products are given as;

$$\begin{aligned}&\mathcal{B}(B^+ \to \psi(3770)K^+) \times \mathcal{B}(\psi(3770) \to D^0\bar{D}^0)\\ &\quad = (0.34 \pm 0.08 \pm 0.08) \times 10^{-3},\end{aligned}$$

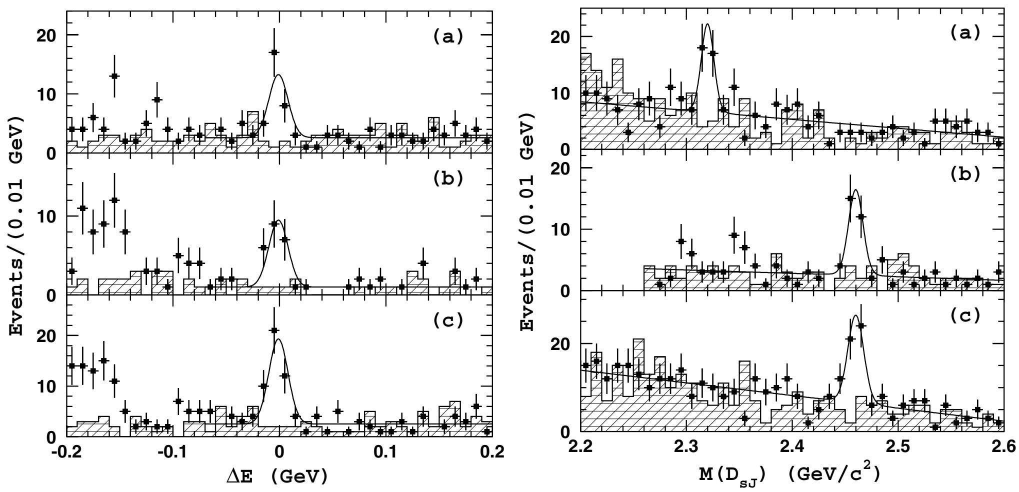

Fig. 4. ΔE (*left*) and $M(D_{sJ})$ (*right*) distributios for the $B \to \bar{D}D_{sJ}$ candidates: **a** $D_{sJ}(2317) \to D_s\pi^0$, **b** $D_{sJ}(2457) \to D_s^*\pi^0$ and **c** $D_{sJ}(2457) \to D_s\gamma$

$$\mathcal{B}(B^+ \to \psi(3770)K^+) \times \mathcal{B}(\psi(3770) \to D^+D^-) = (0.14 \pm 0.08 \pm 0.03) \times 10^{-3}.$$

The helicity angle distribution is checked to be consistent with the expectation of $P \to VP$ and subsequent $V \to PP$ decay. In summary, assuming that $D^0\bar{D}^0$ and D^+D^- saturate the decay of $\psi(3770)$, $B^+ \to \psi(3770)K^+$ branching fraction is defined as

$$\mathcal{B}(B^+ \to \psi(3770)K^+) = (0.48 \pm 0.11 \pm 0.12) \times 10^{-3}$$

and this is very close to the value $\mathcal{B}(B^+ \to \psi(2s)K^+) = (0.66 \pm 0.06) \times 10^{-3}$[5]. This implies large S-D mixing in the ψ states.

4 D_{sJ} production in exclusive B decays

BaBar and CLEO observed production of new resonances in inclusive $D_s\gamma$ and $D_s^*\gamma$ states, which are interpreted as D_{sJ} [8][9]. Dominant exclusive production process in B decay is $B \to \bar{D}D_{sJ}$.

Search is done in the processes of $B \to \bar{D}D_s\pi^0$, $\bar{D}D_s^*\pi^0$, $\bar{D}D_s\gamma$ and $\bar{D}D_s^*\gamma$. D_s^+ is reconstructed in $\phi\pi^+$, $K^{*0}K^+$ and $K_s^0K^+$ modes, D_s^* is in $D_s\gamma$ mode, and D mesons are reconstructed in $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0$ and $D^+ \to K^-\pi^+\pi^+$ decays. @ Figure 4 shows ΔE of $B \to \bar{D}D_{sJ}$ processes (left) and effective mass for D_{sJ} candidates (right). Clear signals of $D_{sJ}(2317)$ is observed in $D_s\pi^0$. Also $D_{sJ}(2457)$ is observed in $D_s^*\pi^0$ and $D_s\gamma$ final states. Statistical significance observed here are more than 6 σ. The mass values defined in the fit for $D_{sJ}(2317)$ and $D_{sJ}(2457)$ are $(2319.8 \pm 2.1 \pm 2.0)\mathrm{MeV}/c^2$ and $(2459.2 \pm 1.6 \pm 2.0)\mathrm{MeV}/c^2$, respectively.

These are the first observation of D_{sJ} in exclusive B decays, and branching fraction product are given as follows;

$$\mathcal{B}(B \to \bar{D}D_{sJ}(2317)) \times \mathcal{B}(D_{sJ}(2317) \to D_s\pi^0) = (8.5^{+2.1}_{-1.9} \pm 2.6) \times 10^{-4},$$

$$\mathcal{B}(B \to \bar{D}D_{sJ}(2457)) \times \mathcal{B}(D_{sJ}(2457) \to D_s^*\pi^0) = (17.8^{+4.5}_{-3.9} \pm 5.3) \times 10^{-4},$$

$$\mathcal{B}(B \to \bar{D}D_{sJ}(2457)) \times \mathcal{B}(D_{sJ}(2457) \to D_s\gamma) = (6.7^{+1.3}_{-1.2} \pm 2.0) \times 10^{-4}.$$

Also we set 90% C.L. for other less prominent channels. It should be noted that the branching fraction is almost the same order as $\bar{D}D_s^{(*)}$.

5 Summary

We have measured branching fraction of $B \to D^{(*)}\pi\pi$ decays, and observed all the P-wave states of charmed mesons. Ratio of the branching fraction to narrow tensor/vector mesons gives comparable value by HQET. Also shown that the broad component exists, which contradicts with the consequence of QCD sum rule. The $D\bar{D}K$ processes are studied and branching fractions are measured. We made the first observation of $\psi(3770)$ in B decays, and the results imply large S-D mixing in ψ's. D_{sJ} resonances are observed in exclusive $B \to \bar{D}D_{sJ}$ processes.

References

1. M. Neubert, Phys. Letters B418 (1998) 173
2. J. Grounberg et al. (CLEO collabvoration), CLEO CONF 96-25 (1996)
3. A. Le Yaouanc et al., Phys. Lett. B **520** (2001) 25
4. M.S. Alan et al. (CLEO collaboration), Phys. Rev. D **50** (1994) 43
5. K. Hagiwara et al. (PDG group), Phys. Rev. D **66** (2002) 010001
6. J.L. Rosner, Phys. Rev. D **64** (2001) 094002
7. Feng Yuan et al., Phys. Rev. D **56** (1997) 329
8. B. Aubert et al., Phys. Rev. Lett. **90** (2003) 242001
9. D. Besson et al., hep/ex-0305017