

# Charm and charmonium-like spectroscopy in $B$ decays in Belle

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## Abstract

We report measurements of the branching fractions for the decays  $B \rightarrow D_{s1}(2536)^+ \bar{D}^{(*)}$ , where  $\bar{D}^{(*)}$  is  $\bar{D}^0$ ,  $D^-$  or  $D^{*-}$ , and study of  $B \rightarrow X(3872)K$  with  $X(3872)$  decaying to  $D^{*0} \bar{D}^0$  using a sample of 657 million  $B\bar{B}$  pairs recorded at the  $\Upsilon(4S)$  resonance with the Belle detector at the KEKB asymmetric-energy  $e^+e^-$  collider.

*Key words:* Charm, charmonium, exotic mesons, XYZ mesons  
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## 1. Introduction

Recent discoveries of a number of new states, such as  $D_{s0}^*(2317)$ ,  $D_{s1}(2460)$ ,  $X(3872)$ ,  $Z(4430)$  and etc., show that our understanding of charm and charmonium spectroscopy might be incomplete. Quark Parton Model can not explain all of these states as  $c\bar{s}$  or  $\bar{c}\bar{c}$  mesons. Some of them could be *exotic* hadrons including tetraquark mesons ( $q\bar{q}q\bar{q}$ ) or molecule states. Study of the properties of these particles is important for the understanding of their structures.

The results presented in this article are based on a  $605\text{fb}^{-1}$  data sample, corresponding to  $657 \times 10^6 B\bar{B}$  pairs, collected at the  $\Upsilon(4S)$  resonance with the Belle detector [1] at the KEKB asymmetric-energy  $e^+e^-$  collider [2].

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## 2. Study of the decays $B \rightarrow D_{s1}(2536)^+ \bar{D}^{(*)}$

The  $D_{s1}(2536)^+$  meson is reconstructed in its main decay modes:  $D^{*0}(D^0\pi^0)K^+$ ,  $D^{*0}(D^0\gamma)K^+$  and  $D^{*+}K_S$ . The combinations of  $D_{s1}(2536)^+$  and the second charm  $D^{(*)}$  meson, which can be either  $\bar{D}^0$ ,  $D^-$  or  $D^{*-}$ , with opposite flavor are considered as  $B$  candidates. Inclusion of charge conjugate modes is implied throughout the paper.

The nine distributions corresponding to three  $B$  decay modes times three  $D_{s1}(2536)^+$  decay modes are fitted simultaneously to obtain the branching fractions for each of the  $B$  decay modes (Fig. 1). Statistically significant results are obtained for each of the decay modes.

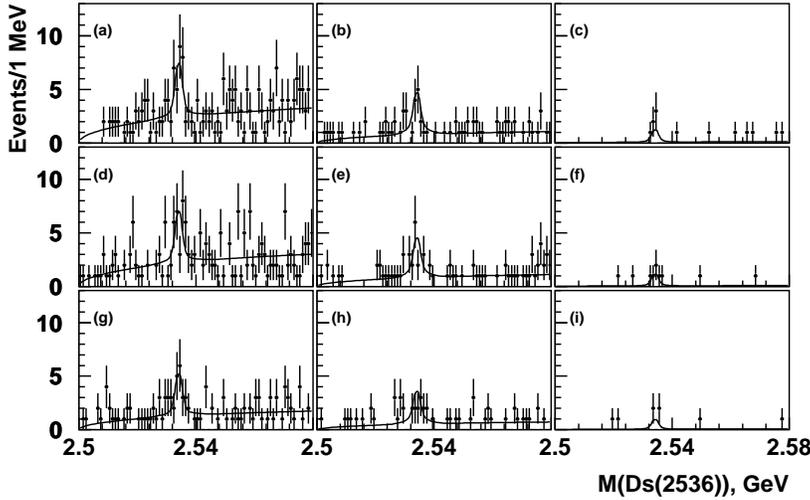


Fig. 1.  $D_{s1}^+(2536)$  mass distributions for the  $B$  decays to a), b), c)  $D_{s1}^+(2536)\bar{D}^0$ , d), e), f)  $D_{s1}^+(2536)D^-$  and g), h), i)  $D_{s1}^+(2536)D^{*-}$ , followed by  $D_{s1}^+(2536)$  decays to a), d), g)  $D_{s1}^+(2536) \rightarrow D^{*0}(D^0\gamma)K^+$ , b), e), h)  $D_{s1}^+(2536) \rightarrow D^{*0}(D^0\pi^0)K^+$  and c), f), i)  $D_{s1}^+(2536) \rightarrow D^{*+}(D^0\pi^+)K_S$ . Points with error bars show the data, lines represent the fit result.

$B$ decay mode	$N$	$\mathcal{B} \times 10^4$	$\mathcal{S}$
$D_{s1}(2536)(D^*K)\bar{D}^0$	$42.7 \pm 8.6$	$3.99 \pm 0.84 \pm 0.57$	$7.0\sigma$
$D_{s1}(2536)(D^*K)D^-$	$40.4 \pm 8.7$	$2.76 \pm 0.63 \pm 0.35$	$6.9\sigma$
$D_{s1}(2536)(D^*K)D^{*-}$	$33.4 \pm 7.6$	$5.03 \pm 1.21 \pm 0.68$	$6.3\sigma$

Table 1

Summary of the results for  $B \rightarrow D_{s1}(2536)^+ \bar{D}^{(*)}$  decay modes.

## 3. Study of the decay $B \rightarrow X(3872)(D^{*0}\bar{D}^0)K$

The study described in this paper is a search for the  $X(3872) \rightarrow D^{*0}\bar{D}^0$  decay mode, followed either by  $D^{*0} \rightarrow D^0\gamma$  or  $D^{*0} \rightarrow D^0\pi^0$ , in charged and neutral  $B \rightarrow X(3872)K$  decays. We use the notation  $D^{*0}\bar{D}^0$  to indicate both  $D^{*0}\bar{D}^0$  and  $\bar{D}^{*0}D^0$ .

The  $M(D^*D)$  mass distribution is described by a relativistic Breit-Wigner function convoluted with the mass-dependent Gaussian resolution for the signal and a square root function for the background. This fit gives  $50.1^{+14.8}_{-11.1}$  events with a statistical significance of  $8.8\sigma$  (Fig. 2). The branching fraction, averaged over charged and neutral  $B$  mesons, is

$$\mathcal{B}(B \rightarrow X(3872)K) \times \mathcal{B}(X(3872) \rightarrow D^{*0}\bar{D}^0) = (0.80 \pm 0.20 \pm 0.11) \times 10^{-4},$$

where  $\mathcal{B}(X(3872) \rightarrow D^{*0}\bar{D}^0)$  stands for  $\mathcal{B}(X(3872) \rightarrow D^{*0}\bar{D}^0) + \mathcal{B}(X(3872) \rightarrow \bar{D}^{*0}D^0)$ .

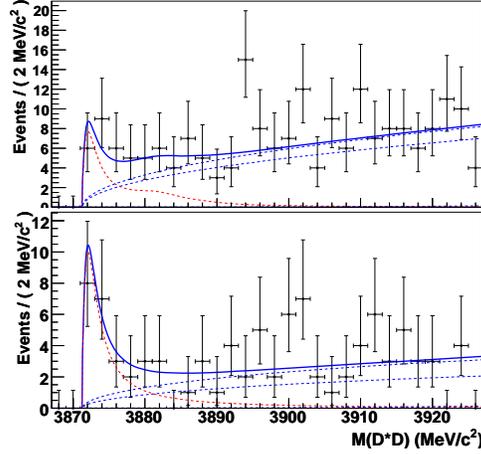


Fig. 2. Distribution of  $M(D^*D)$  mass for  $D^{*0} \rightarrow D^0\gamma$  (top) and  $D^{*0} \rightarrow D^0\pi^0$  (bottom). The points with error bars are data, the dotted curve is the signal, the dashed curves represent the backgrounds.

#### 4. Conclusion

In the summary we report the measurement of the branching fractions for the decays  $B \rightarrow D_{s1}(2536)^+\bar{D}^{(*)}$ , where  $\bar{D}^{(*)}$  is  $\bar{D}^0$ ,  $D^-$  or  $D^{*-}$ . From the simultaneous fit of all  $D_{s1}(2536)^+$  channels we have measured  $\mathcal{B}(B^+ \rightarrow D_{s1}(2536)^+\bar{D}^0) = (3.99 \pm 0.84 \pm 0.57) \times 10^{-4}$ ,  $\mathcal{B}(B^0 \rightarrow D_{s1}(2536)^+D^-) = (2.76 \pm 0.63 \pm 0.35) \times 10^{-4}$ ,  $\mathcal{B}(B^0 \rightarrow D_{s1}(2536)^+D^{*-}) = (5.03 \pm 1.21 \pm 0.68) \times 10^{-4}$  with the statistical significances  $7.0\sigma$ ,  $6.9\sigma$  and  $6.3\sigma$ , respectively.

We find a near-threshold enhancement in the  $D^{*0}\bar{D}^0$  invariant mass spectrum at  $3872.9^{+0.6+0.3}_{-0.4-0.4}$  MeV/ $c^2$  in  $B \rightarrow D^{*0}\bar{D}^0K$  decays. The significance of this enhancement is  $8.8\sigma$ . The measured branching fraction of the decay is  $\mathcal{B}(B \rightarrow X(3872)K) \times \mathcal{B}(X(3872) \rightarrow D^{*0}\bar{D}^0) = (0.80 \pm 0.20 \pm 0.11) \times 10^{-4}$ .

#### References

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