PROCEEDINGS OF SCIENCE

Search for $B_s^0 \to J/\psi f_0(980)$ and $B_s^0 \to hh$ decays at Belle

Jean Wicht[∗ †]
High Energy Accelerator Research Organization (KEK), Tsukuba (Japan)
E-mail: jwicht@post.kek.jp

We report on searches for the decays $B_s^0 \to J/\psi f_0(980)$ and B_s^0 decaying to K^+K^-, $K_S^0K_S^0$, $K^-\pi^+$, or $\pi^+\pi^-$ final states using 23.6 fb^{-1} of data recorded at the $\Upsilon(5S)$ resonance by the Belle detector at the KEKB accelerator. We measure $\mathscr{B}(B_s^0 \to K^+K^-) = (3.8^{+1.0}_{-0.9} \pm 0.5(\mathrm{syst}) \pm 0.5(f_s)) \times 10^{-5}$ with 5.8 standard deviations. We did not observe any significant signals in the other modes, and we compute 90% upper limits on their branching fractions: $\mathscr{B}(B_s^0 \to J/\psi f_0(980)) < 1.63 \times 10^{-4}$, $\mathscr{B}(B_s^0 \to K^-\pi^+) < 2.6 \times 10^{-5}$, $\mathscr{B}(B_s^0 \to \pi^+\pi^-) < 1.2 \times 10^{-5}$ and $\mathscr{B}(B_s^0 \to K_S^0K_S^0) < 3.3 \times 10^{-5}$.

35th International Conference of High Energy Physics
July 22-28, 2010
Paris, France

∗Speaker.
†On behalf of the Belle Collaboration.

PoS(ICHEP 2010)219

1. Introduction

The Belle detector [1] has recently collected a large sample of e^+e^- collisions ($\sim$ 120 fb^{-1}) produced by the KEKB accelerator [2] at the energy of the $\Upsilon(5S)$ resonance ($E_{\rm CM} \sim 10.58$ GeV). Contrary to the $\Upsilon(4S)$ resonance which sits just above the $B\bar{B}$ threshold ($B = B^+, B^0$), the $\Upsilon(5S)$ resonance lies above the $B_s^0\bar{B}_s^0$ and $B_s^*\bar{B}_s^*$ thresholds. The CLEO collaboration indeed proved that B_s^0 mesons were produced at the $\Upsilon(5S)$ resonance [3] allowing B-factories to compete with hadron colliders for the study of B_s^0 decays and properties. In this report, we search for the decays $B_s^0 \to J/\psi f_0(980)$ and $B_s^0 \to hh$ using about one fifth (23.6 fb^{-1}) of our total integrated luminosity collected at the $\Upsilon(5S)$.

2. Measurement of the number of B_s^0 mesons

The number of $b\bar{b}$ pairs is measured with a continuum subtraction method. We use data collected ~ 60 MeV below the $\Upsilon(4S)$ resonance where $B\bar{B}$ pairs cannot be produced. The $b\bar{b}$ cross-section is computed according to the following formula:

$$\sigma_{b\bar{b}}^{\Upsilon(5S)} = \frac{N_{b\bar{b}}^{\Upsilon(5S)}}{\mathscr{L}_{\Upsilon(5S)}} = \frac{1}{\mathscr{L}_{\Upsilon(5S)}\varepsilon_{\Upsilon(5S)}^{b\bar{b}}}\left(N_{\rm hadr}^{\Upsilon(5S)} - N_{\rm hadr}^{\rm cont.}\frac{\mathscr{L}_{\Upsilon(5S)}}{\mathscr{L}_{\rm cont.}}\frac{E_{\rm cont.}^2}{E_{\Upsilon(5S)}^2}\frac{\varepsilon_{\Upsilon(5S)}^{q\bar{q}}}{\varepsilon_{\rm cont.}^{q\bar{q}}}\right), \tag{2.1}$$

where N are the number of hadronic events counted in data, $\mathscr{L}$ the integrated luminosities, E the center-of-mass (CM) energies and ε the different reconstruction efficiencies. The $b\bar{b}$ reconstruction effiency is very close to 100% while the continuum ($q\bar{q}$, $q = u,d,s,c$) reconstruction efficiencies are $\sim 90\%$. We obtain $\sigma_{b\bar{b}}^{\Upsilon(5S)} = (0.302 \pm 0.015)$ nb which is about four times smaller than at the $\Upsilon(4S)$ resonance where $b\bar{b}$ cross-section is about 1.1 nb.

The fraction of $B_s^0\bar{B}_s^0$ pairs among the $b\bar{b}$ events (f_s) is studied with $D_s^\pm$ mesons. We take advantage of the fact that B_s^0 mesons have a much larger branching fraction to $D_s^\pm$ ($\mathscr{B}(B_s^0 \to D_s^\pm X) = (92 \pm 11)\%$ [3]) than B^+ and B^0 mesons ($\mathscr{B}(B \to D_s^\pm X) = (8.3 \pm 0.8)\%$ [6]). We extract f_s from the following formula:

$$\mathscr{B}(\Upsilon(5S) \to D_s^\pm X)/2 = f_s \times \mathscr{B}(B_s^0 \to D_s^\pm X) + (1 - f_s) \times \mathscr{B}(B \to D_s^\pm X) \tag{2.2}$$

where we measure $\mathscr{B}(\Upsilon(5S) \to D_s^\pm X)$ using continuum subtraction [4]. Taking into account a previous result from CLEO [3], the Particle Data Group computed $f_s = (18.0 \pm 1.3 \pm 3.2)\%$ [6]. The number of B_s^0 mesons in $L_{\rm int} = 23.6$ fb^{-1} can therefore be computed as $N_{B_s^0} = 2 \times L_{\rm int} \times \sigma_{b\bar{b}}^{\Upsilon(5S)} \times f_s = (2.8 \pm 0.4) \times 10^6$. The uncertainty is mainly due to the large uncertainty on $\mathscr{B}(B_s^0 \to D_s^\pm X)$ in the determination of f_s.

B_s^0 mesons can be produced through three $\Upsilon(5S)$ decays: $\Upsilon(5S) \to B_s^*\bar{B}_s^*$, $B_s^*\bar{B}_s^0$ and $B_s^0\bar{B}_s^0$, where the B_s^* mesons decay to B_s^0 by emitting a ~ 50 MeV photon. We measure the different production fractions by fully reconstructing B_s^0 mesons in the high-statistics $B_s^0 \to D_s^-\pi^+$ mode using the well-known B-factory variables $M_{\rm bc} = \sqrt{(E_{\rm CM}/2)^2 - p_{B_s^0}^{\rm CM}}$ and $\Delta E = E_{B_s^0}^{\rm CM} - E_{\rm CM}/2$. Since we do not reconstruct the photon from the B_s^* decay, the three channels peak at different positions in the $M_{\rm bc}$-ΔE plane and are especially well separated in $M_{\rm bc}$. We measure $f_{B_s^*\bar{B}_s^*} = (90.1^{+3.8}_{-4.0} \pm 0.2)\%$ and $f_{B_s^*\bar{B}_s^0} = (7.3^{+3.3}_{-3.0} \pm 0.1)\%$ [5]. B_s^0 decays are therefore mainly searched in $\Upsilon(5S) \to B_s^*\bar{B}_s^*$ decays.

PoS(ICHEP 2010)219

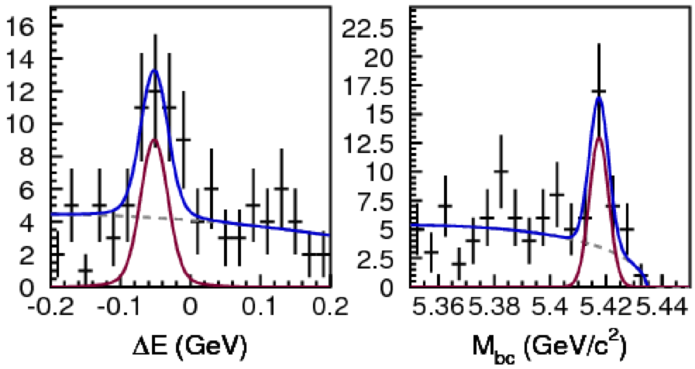

Figure 1: $M_{\rm bc}$ and ΔE distributions of $B_s^0 \to K^+K^-$ candidates together with fit results. The solid red curve shows the signal fit function while the dashed gray curve shows the continuum contribution.

3. Search for $B_s^0 \to hh$

We search for $B_s^0 \to hh$ where hh can be K^+K^-, $K_S^0K_S^0$, $K^-\pi^+$ and $\pi^+\pi^-$ [7]. $B_s^0 \to K^+K^-$ is related to $B^0 \to \pi^+\pi^-$ by $SU(3)$ symmetry. Comparing CP asymmetries can probe the presence of New Physics in the decay [8]. Using the U-spin symmetry, one can measure the CKM angle γ (ϕ_3) [9]. K_S^0 mesons are reconstructed in the $K_S^0 \to \pi^+\pi^-$ decay mode. The dominant background arises from continuum and is suppressed with a likelihood formed from modified Fox-Wolfram moments [10]. $B_s^0 \to K^+K^-$ candidates together with fit results are shown on Fig. 1. We observe 24 ± 6 $B_s^0 \to K^+K^-$ events corresponding to a significance of 5.8σ. We measure $\mathscr{B}(B_s^0 \to K^+K^-) = (3.8^{+1.0}_{-0.9} \pm 0.5(\text{syst}) \pm 0.5(f_s)) \times 10^{-5}$. No significant signal is seen in the three other modes, and we set the following 90% CL upper limits: $\mathscr{B}(B_s^0 \to K^-\pi^+) < 2.6 \times 10^{-5}$, $\mathscr{B}(B_s^0 \to \pi^+\pi^-) < 1.2 \times 10^{-5}$ and $\mathscr{B}(B_s^0 \to K_S^0K_S^0) < 3.3 \times 10^{-5}$. CDF searched for these modes [11, 12]: our measurement of $B_s^0 \to K^+K^-$ is in agreement, our limit on $B_s^0 \to K_S^0K_S^0$ is more stringent but we are not competitive in the two other modes.

4. Search for $B_s^0 \to J/\psi f_0(980)$

β_s, the CP-violating phase in the B_s^0 mixing, can be measured in a time-dependent study of $B_s^0 \to J/\psi f_0(980)$ and $B_s^0 \to J/\psi\phi$ decays [13]. The advantage of $B_s^0 \to J/\psi f_0(980)$ over $B_s^0 \to J/\psi\phi$ is that $B_s^0 \to J/\psi f_0(980)$ is a pure CP-eigenstate due to $f_0(980)$ quantum numbers being $J^P = 0^+$ (ϕ being 1^-). No angular analysis of the decay is therefore required to distinguish the different CP-eigenstates. $B_s^0 \to J/\psi f_0(980)$ branching fraction is however $\sim 2-5$ times smaller than $B_s^0 \to J/\psi\phi$ [14, 15]. In our analysis, J/ψ mesons are reconstructed by combining opposite sign electrons or muons and $f_0(980)$ mesons by combining opposite sign pions. $B_s^0 \to J/\psi f_0(980)$ candidates are selected using ΔE and $M_{\pi\pi}$. Background mainly arises from continuum and B decays including a J/ψ meson ($B \to J/\psi X$). We also consider a possible non-resonant $B_s^0 \to J/\psi\pi^+\pi^-$ contribution that behaves as signal in ΔE but does not peak in $M_{\pi\pi}$. Data together with fit results are shown on Fig 2. No significant signal is seen (6.0 ± 4.4 events corresponding to 1.7σ), and we set the following 90% CL upper limit: $\mathscr{B}(B_s^0 \to J/\psi f_0(980)) \times \mathscr{B}(f_0(980) \to \pi^+\pi^-) < 1.63 \times 10^{-4}$.

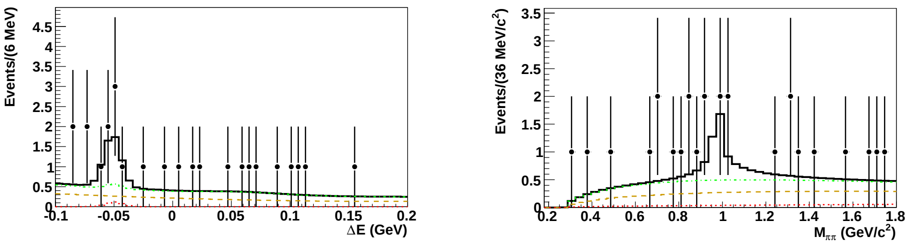

Figure 2: ΔE and $M_{\pi\pi}$ distributions of $B_s^0 \to J/\psi f_0(980)$ candidates together with fit results. The solid black curve shows the total fit function. Other curves show the different background contributions: non-resonant $B_s^0 \to J/\psi\pi^+\pi^-$ in dotted red, $B \to J/\psi X$ background in dashed yellow and sum of all backgrounds (non-resonant $B_s^0 \to J/\psi\pi^+\pi^-$, $B \to J/\psi X$ and continuum) in dashed-dotted green.

5. Summary

We searched for $B_s^0 \to hh$ and $B_s^0 \to J/\psi f_0(980)$ decays in 23.6 fb^{-1} of data collected by the Belle detector at the $\Upsilon(5S)$ resonance. We observed $B_s^0 \to K^+K^-$ decays with 5.8 standard deviations. We did not observe any significant signals in the other modes and improved the upper limit on $\mathscr{B}(B_s^0 \to K_S^0 K_S^0)$. Present and future B-factories can therefore play a role in the study of B_s^0 mesons.

References

[1] A. Abashian et al. (Belle Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A 479 117 (2002).

[2] S. Kurokawa and E. Kikutani, Nucl. Instrum. Methods Phys. Res., Sect. A 499 1 (2003).

[3] M. Artuso et al. (CLEO Collaboration), Phys. Rev. Lett. 95, 261801 (2005).

[4] A. Drutskoy et al. (Belle Collaboration), Phys. Rev. Lett. 98, 052001 (2007).

[5] R. Louvot, J. Wicht, O. Schneider et al. (Belle collaboration), Phys. Rev. Lett. 102, 021801 (2009).

[6] K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010).

[7] C.C. Peng et al. (Belle Collaboration), Phys. Rev. D 82, 072007 (2010).

[8] D. London and J. Matias, Phys. Rev. D 70, 031502 (2004).

[9] R. Fleischer, Phys. Lett. B 459, 306 (1999).

[10] S.H. Lee et al. (Belle Collaboration), Phys. Rev. Lett. 91, 261801 (2003).

[11] A. Abulencia et al. (CDF collaboration), Phys. Rev. Lett. 97, 211802 (2006).

[12] T. Aaltonen et al. (CDF Collaboration), Phys. Rev. Lett. 103, 031801 (2009).

[13] S. Stone and L. Zhang, arXiv:0909.5442v2 [hep-ex] (2009).

[14] S. Stone and L. Zhang, PRD 79, 074024 (2009).

[15] P. Colangelo, F. De Fazio, and W. Wang, Phys. Rev. D 81, 074001 (2010).