PROCEEDINGS OF SCIENCE

Measurements of heavy flavor properties at CMS

Po-Hsun Chen*†
National Taiwan University
E-mail: pohsun.chen.hep@gmail.com

A new decay channel $B_{s2}(5840)^0 \to B^0 K_s$ has been observed by 6.3σ to 7.0σ. Accompanied with the obserservation, there is also a hint of $B_{s1} \pm B^0 K_s$. Corresponding branching fraction ratio to $B^{()+}K^-$ channel is calculated to be $R_2^{0\pm} = 0.432 \pm 0.077(stat) \pm 0.075(syst.) \pm 0.021(PDG)$ and $R_1^{0\pm} = 0.49 \pm 0.12(stat) \pm 0.07(syst.) \pm 0.02(PDG)$. In the study of $\Lambda_b \to J/\psi\Lambda$ decay, all there decay parameters of interest show consistency with LHCb and ATLAS results. However, the measured parity asymmetry parameter1disagree with the HQET prediction by over 5 standard deviation. Standard lifetime measurement for B^0,B_s,B_c^+,Λ_b matches fine with the world-averaged values. The CMS result for B_c^+ is in favor of the LHCb result to those derived at Tevatron.

ICHEP 2018, XXXIX International Conference on High Energy Physics
4–11 July 2018
Seoul, Korea

*Speaker.
†On behalf of the CMS Collaboration

PoS(ICHEP2018)179

1. Measurements

This letter provides a review of B hadron properties research conducted with the CMS experiment at the Large Hadron Collidor (LHC). All data is collected in proton-proton collision at the center-of-mass energy of 7TeV (5.2 fb^{-1}) and that of 8TeV (19.6 fb^{-1}).

1.1 Studies of P wave excited states of B_s and the observation of $B_{s2}(5840)^0 \to B^0 K_S$ decay

In a B_s^0 bound state, since the bottom quark is heavier than the strange quark, the system is suitable to be described with the heavy quark effective theory (HQET).Several orbitally excited states of B_s^0 meson has seen through $B^{(*)+}K^-$ decay channel. According to HQET, there is no significant difference to replace $B^{(*)+}K^-$ with $B^{(*)0}K_s$. It indeed replaces the $u\bar{u}$ pair with a $d\bar{d}$ pair in the decay. In figure 1, first observation of the $B_{s2}^* \to B^0 K_s$ and the evidence of $B_{s1}^* \to B^* K_s$, in which $B^* \to B^0\gamma$, $B^0 \to J/\psi(\to \mu\mu)K^{*0}(\to K^+\pi^-)$, are presented using the 8TeV data. [1] The significance of the $B_{s2}^* \to B^0 K_s$ decay is calculated to be in the range of 6.3 to 7.0 standard deviation, and it's 3.6 to 3.9 standard deviation for $B_{s1} \to B^{*0}K_s$. The corresponding branching fraction ratios of $B^0 K_s$ channel to $B^{(*)+}(\to J/\psi K^+)K^-$ channel are provided:

$$R_2^{0\pm} = \frac{\mathscr{B}(B_{s2}^* \to B^0 K_s)}{\mathscr{B}(B_{s2}^* \to B^+ K^-)} = 0.432 \pm 0.077(\text{stat}) \pm 0.075(\text{syst.}) \pm 0.021(\text{PDG})$$

$$R_1^{0\pm} = \frac{\mathscr{B}(B_{s1} \to B^{*0} K_s)}{\mathscr{B}(B_{s1} \to B^{*+} K^-)} = 0.49 \pm 0.12(\text{stat}) \pm 0.07(\text{syst.}) \pm 0.02(\text{PDG})$$

in which the branching fraction $\mathscr{B}(B^{*(+)} \to B^{(+)}\gamma)$ is assumed to be 100%.

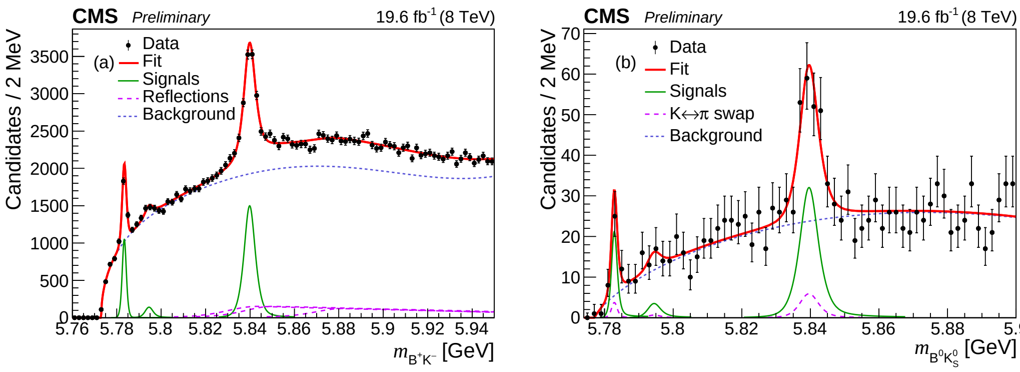

Figure 1: The fitting result to invariant mass spectrum of B^+K^- and B^0K_s, where $m_{BK} = M(BK) - M(B) + M_B^{PDG}$ is used to improve mass resolution. In B^+K^- spectrum, the reflection term comes from the excited B^0 meson decays. While in B^0K_s spectrum, the long-dashed line denotes the swapping of $K^\pm \to \pi^\pm$ in the B^0 reconstruction.

1.2 Λ_b polarization and angular parameters in $\Lambda_b \to J/\psi\Lambda$

The Λ_b decays to $J/\psi\Lambda$ via a $b \to s$ loop, which for long time is treated as a good source of QCD study. For this decay process, assuming uniform detector acceptance over the azimuthal angles, the angular distribution of decay products can be expressed with five parameters [2] and we

Table 1: The measured polarization, parity asymmetry with the corresponding statistical error (former) and systematic error (latter) in comparison with theoretical [4–6] and other experimental results [7, 8]. Remark that notation of α_b used in ATLAS, LHCb, and theoretical papers is equal to $-\alpha_1$. As for α_2, given the reference papers don't provide the value directly, the values are calculated from helicity amplitude provided in common and found to be equivalent to -1.

Parameter	CMS	LHCb	ATLAS	Prediction
P	$0.00 \pm 0.06 \pm 0.06$	$0.06 \pm 0.07 \pm 0.02$	-	$0.1 \sim 0.2$
$-\alpha_1$	$-0.14 \pm 0.14 \pm 0.10$	$0.05 \pm 0.17 \pm 0.07$	$0.30 \pm 0.16 \pm 0.06$	$-0.2 \sim -0.1$ 0.78 (HQET)
α_2	$-1.11 \pm 0.08 \pm 0.11$	-1	-1	-

have most interest in 3 meaningful ones: P, the Λ_b transverse polarization, α_1, the parity asymmetry parameter for the $\Lambda_b \to J/\psi\Lambda$ decay, and α_2, the Λ longitudinal polarization. We performed the angular analysis [3] using both 7 TeV and 8 TeV data. The results is summarized in Table 1. All experimental resuls is in consistency, while the HQET predicted α_1 is disfavored by over 5σ.

1.3 Lifetime of b hadrons in decays with J/ψ

The 8TeV collision data triggered by events with a J/ψ candidate is used, and the result is summarized in Table 2. For B^0 and Λ_b decays, we perform unbinned maximum likelihood fit to the mass spectrum, lifetime ($c\tau$) to extract all the needed information. In the case of B_s, due to the non-negligible contribution from $B^+ \to J/\psi K^+$, extended fit is adopted. We indirectly measure the B_c^+ lifetime on the basis of the precisely known B^+ lifetime from the difference of total decay width.

Table 2: Summary of measured $c\tau$ in comparison with PDG values [9]. Note that the former uncertainty term stands for statistical uncertainty, while the latter stands for systematic uncertainty.

Channel	CMS result	PDG value
$B^0 \to J/\psi K^{*0}$	$453.0 \pm 1.6 \pm 1.8\,\mu$m	$456.0 \pm 1.2\,\mu$m
$B^0 \to J/\psi K_s$	$457.8 \pm 2.7 \pm 2.8\,\mu$m	$456.0 \pm 1.2\,\mu$m
$\Lambda_b \to J/\psi\Lambda$	$442.9 \pm 8.2 \pm 2.8\,\mu$m	$441.0 \pm 3.0\,\mu$m
$B_s^0 \to J/\psi\pi^+\pi^-$	$502.7 \pm 10.2 \pm 3.4\,\mu$m	$497.4 \pm 9.6\,\mu$m
$B_s^0 \to J/\psi\phi(1020)$	$443.9 \pm 2.0 \pm 1.5\,\mu$m	$443.7 \pm 3.6\,\mu$m
$B_c^+ \to J/\psi\pi^+$	$162.3 \pm 7.8 \pm 4.2\,\mu$m	$152.7 \pm 2.7\,\mu$m

As a result, the CMS measurements are all in good match with the world-averaged values. Our measured B_c^+ lifetime, presented in $c\tau$, is in favor of the LHCb result ($153.9 \pm 3.3\,\mu$m) [10] to the Tevatron results($\sim 135\,\mu$m) [11, 12].

2. Conclusion

A new decay channel $B_{s2}^*(5840)^0 \to B^0 K_s$ has been observed by 6.3 to 7.0 standard deviation. Accompanied with the observation, there is also a hint of $B_{s1} \to B^{*0} K_s$. Corresponding branching fraction ratio to $B^{(*)+}K^-$ channel is calculated to be $R_2^{0\pm} = 0.432$ and $R_1^{0\pm} = 0.49$. In the study of

$\Lambda_b \to J/\psi\Lambda$ decay, all the decay parameters of interest show consistency with LHCb and ATLAS results. However, the measured parity asymmetry parameter α_1 disagree with the HQET prediction by over 5 standard deviation. Standard lifetime measurement for B^0, B_s, B_c^+, Λ_b matches fine with the world-averaged values. The CMS result for B_c^+ is in favor of the LHCb result to those derived at Tevatron.

Property study of B hadrons has played a must-have role in understanding QCD. The CMS B physics analysis group has brought numerous results from LHC Run-1 data and foreseen updates with run-II data will lead to deeper insights to the physics picture.

References

[1] CMS Collaboration, "Studies of $\mathrm{B}^*_{s2}(5840)^0$ and $\mathrm{B}_{s1}(5830)^0$ mesons including the observation of the $\mathrm{B}^*_{s2}(5840)^0 \to \mathrm{B}^0\mathrm{K}^0_\mathrm{S}$ decay in proton-proton collisions at $\sqrt{s}$ =8 TeV", *Submitted to: Eur. Phys. J.* (2018) arXiv:1809.03578.

[2] M. Kramer and H. Simma, "Angular correlations in Lambda/b –> Lambda + V: Polarization measurements, HQET and CP violation", *Nucl. Phys. Proc. Suppl.* **50** (1996) 125–129, doi:10.1016/0920-5632(96)00378-7. [,125(1996)].

[3] CMS Collaboration, "Measurement of the Λ_b polarization and angular parameters in $\Lambda_b \to J/\psi\Lambda$ decays from pp collisions at $\sqrt{s} = 7$ and 8 TeV", *Phys. Rev.* **D97** (2018), no. 7, 072010, doi:10.1103/PhysRevD.97.072010, arXiv:1802.04867.

[4] G. Hiller, M. Knecht, F. Legger, and T. Schietinger, "Photon polarization from helicity suppression in radiative decays of polarized Lambda(b) to spin-3/2 baryons", *Phys. Lett.* **B649** (2007) 152–158, doi:10.1016/j.physletb.2007.03.056, arXiv:hep-ph/0702191.

[5] Z. J. Ajaltouni, E. Conte, and O. Leitner, "Lambda(b) decays into Lambda-vector", *Phys. Lett.* **B614** (2005) 165–173, doi:10.1016/j.physletb.2005.04.014, arXiv:hep-ph/0412116.

[6] O. Leitner, Z. J. Ajaltouni, and E. Conte, "An Angular distribution analysis of Lambda(b) decays", *Nucl. Phys.* **A755** (2005) 435–438, doi:10.1016/j.nuclphysa.2005.03.051, arXiv:hep-ph/0412131.

[7] ATLAS Collaboration, "Measurement of the parity-violating asymmetry parameter α_b and the helicity amplitudes for the decay $\Lambda^0_b \to J/\psi + \Lambda^0$ with the ATLAS detector", *Phys. Rev.* **D89** (2014), no. 9, 092009, doi:10.1103/PhysRevD.89.092009, arXiv:1404.1071.

[8] LHCb Collaboration, "Measurements of the $\Lambda^0_b \to J/\psi\Lambda$ decay amplitudes and the Λ^0_b polarisation in pp collisions at $\sqrt{s} = 7$ TeV", *Phys. Lett.* **B724** (2013) 27–35, doi:10.1016/j.physletb.2013.05.041, arXiv:1302.5578.

[9] Particle Data Group Collaboration, "Review of Particle Physics", *Chin. Phys.* **C40** (2016), no. 10, 100001, doi:10.1088/1674-1137/40/10/100001.

[10] LHCb Collaboration, "Measurement of the lifetime of the B_c^+ meson using the $B_c^+ \to J/\psi\pi^+$ decay mode", *Phys. Lett.* **B742** (2015) 29–37, doi:10.1016/j.physletb.2015.01.010, arXiv:1411.6899.

[11] D0 Collaboration, "Measurement of the lifetime of the $B_c^\pm$ meson in the semileptonic decay channel", *Phys. Rev. Lett.* **102** (2009) 092001, doi:10.1103/PhysRevLett.102.092001, arXiv:0805.2614.

[12] CDF Collaboration, "Measurement of the B_c^- meson lifetime in the decay $B_c^- \to J/\psi\,\pi^-$", *Phys. Rev.* **D87** (2013), no. 1, 011101, doi:10.1103/PhysRevD.87.011101, arXiv:1210.2366.