EPJ Web of Conferences **81**, 04012 (2014)
DOI: 10.1051/epjconf/20148104012

Meson spectroscopy at LHCb

Tomasz Szumlak[1,a]

[1] *AGH - University of Science and Technology, Faculty of Physics and Applied Computer Science, al. Mickiewicza 30 30-059, Krakow Poland*

Abstract. The 7 and 8 TeV proton-proton collision data collected by the LHCb experiment during 2011 and 2012 provide a rich sample of heavy flavour production and decays in which the studies of hadron properties can be performed. We present a summary of the recent experimental results from LHCb including studies of D_J mesons, B^{**}. We also report a search for the doubly charmed baryon Ξ_{cc}.

1 Introduction

The LHCb detector [1] is dedicated for studying heavy-flavour physics at the Large Hadron Collider (LHC), at CERN. Since, the $b\bar{b}$ pairs are predominantly produced in the same forward or backward direction at LHC energies, the LHCb detector is built as a single arm forward spectrometer with an unique pseudo-rapidity acceptance range of $2 < \eta < 5$. The LHCb experiment has collected data corresponding approximately to 1 fb^{-1} of data at $\sqrt{s} = 7$ TeV during the period 2010 - 2011, and more than 2 fb^{-1} of proton-proton collisions at $\sqrt{s} = 8$ TeV in 2012.

The LHC experiments in general, and LHCb in particular, are very well suited to perform detailed study of the production of the heavy-flavoured hadrons, which in turn, constitute fundamental tests of quantum chromodynamics. These studies also provide excellent opportunity to probe latest theoretical predictions based on fixed-order and next-to-leading logarithm techniques [2]. The LHCb Collaboration performed both inclusive and exclusive production studies of the c- (D^0, D^+, D_s^0, Λ_s^0) and b-hadrons (B^0, B^+, B_s^0, B^*, Λ_b^0). Excellent tracking capabilities of the LHCb detector allow also to disentangle prompt (i.e., hadrons produced directly at the proton-proton collision or through the decay of havier states) and non-prompt contributions (i.e., these comming from long-lived hadrons). The most vital variables used for this process are the impact parameter or the pseudo-proper time, defined as follow $t_z = \frac{(z_B - z_{PV})M_B}{p_z}$, where z_B, z_{PV}, M_B and p_z are the position along the beam axis of the B candidate decay vertex, the primary vertex position, the reconstructed mass of the candidate and finally its momentum component along the z-axis.

2 Studies of excited B_s^0 mesons

One of the most important and successful theoretical tools for calculating beauty and charm mesons properties is the Heavy Quark Effective Theory (HQET), which describes states with one heavy and

[a] e-mail: Tomasz.Szumlak@agh.edu.pl

one light quark. The great advantages of the HQET is its sensitivity to New Physics effects (such as large CP violation in charm meson decays) and its predictive power for calculating properties of excited B and B_s^0 mesons. In turn the LHCb spectrometer is able to perform very precise measurement that can be used as very sensitive tests of this theory.

The LHCb Collaboration performed a search for orbitally excited B_s^0 mesons in the mass spectrum of B^+K^- pairs using 1 fb^{-1} of proton-proton collision data [3]. The charged beauty mesons were selected using the following decay modes: $B^+ \to J/\psi(\mu^+\mu^-)K^+$, $B^+ \to \overline{D^0}(K^+\pi^-)\pi^+$, $B^+ \to \overline{D^0}(K^+\pi^-\pi^+\pi^-)\pi^+$ and finally $B^+ \to \overline{D^0}(K^+\pi^-)\pi^+\pi^-\pi^+$. The offline selection of the B mesons is based on cuts that suppress the majority of the combinatorial background. In case of the semileptonic decay (listed as the first one above) the main requirements imposed on the B^+ candidate are related to its transverse momentum, that must be at least 2 GeV/c, as well as its decay time that must be greater than 0.3 ps. For the remaining hadronic decay modes the selection is based on topological trigger that must use exclusively tracks from which the mother B candidate is formed. Additional variables used in the selection algorithm were related to the B meson transverse momentum, its detachement from the primary vertex and impact parameter χ^2, which is defined as the difference between the χ^2 of the primary vertex reconstructed with and without the regarded track.

This selection procedure allows to obtain clear signals above respective backgrounds for all listed decay channels. In order to improve the purity of the selected events a dedicated optimisation of the boosted decision tree classifiers (for each decay channel) is performed. The mass spectra of selected B^+ candidates are subsequently fitted with double Gaussian and a second order polynomial for the signal and background respectively. For the used data sample the selection gave about one milion B^+ mesons candidates that were, in turn, combined with all tracks of opposite charge identified as kaons. Figure 1 presents the mass difference for the selected candidates for all four decay channels. The mass difference is defined as $Q = m(B^+K^-) - m(B^+) - m(K^-)$. The narrow peaks at 10 and 67 MeV/c^2 are identified as the $B_{s1} \to B^{*+}K^-$ and $B_{s2}^* \to B^+K^-$ signals, which were observed previously. In addition a much smaller peak is visible at around 20 MeV/c^2, which was classified as previously unobserved $B_{s2}^* \to B^{*+}K^-$ decay mode. Also, a dedicated analysis was performed to measure this new decay's branching fraction relative to the decay of $B_{s2}^* \to B^+K^-$, which yielded $\frac{Br(B_{s2}^* \to B^{*+}K^-)}{Br(B_{s2}^* \to B^+K^-)} = (9.3 \pm 1.3 \pm 1.2)\%$.

2.1 Search for excited D_J mesons

Spectroscopy of charmed mesons also provides important tests of the quark model. This is of great importance since only very few predicted states are well established so far. Many of the expected states have never been observed or need confirmation. In this paper a search for D_J mesons decaying to the following final states: $D^0\pi^+$, $D^+\pi^-$ and $D^{*+}\pi^-$ is discussed [4]. Excellent performance of the LHCb experiment allows to perform both fit to the invariant mass of D_J mesons candidates and angular analysis of the $D_J \to D^{*+}\pi^-$. This in turn allows to separate natural and unnatural parity states [1]. Spin-parity components are separated using the angle between the π^+ comming from the D^{*+} and the π^-, which is determined in the D_J rest frame.

The searches performed by the LHCb Collaboration found seven high-mass resonances. For the $D^{*+}\pi^-$ final state two natural parity states: $D_J^*(2650)^0$ and $D_J^*(2760)^0$, and three unnatural parity ones: $D_J(2580)^0$, $D_J^*(2740)^0$ and $D_J^*(3000)^0$ have been observed. Additionally their masses and widths have been measured. The $D_J^*(2760)^0$ meson is observed for $D^0\pi^+$ and $D^+\pi-$ final states. No compelling

[1] We use the following definitions - the states with $P = (-1)^J$, i.e., spin-parity $J^P = 0^+, 1^-, 2^+, ...$ are called natural and are labelled as D^*. In turn, states with $J^P = 0^-, 1^+, 2^-, ...$ are called unnatural

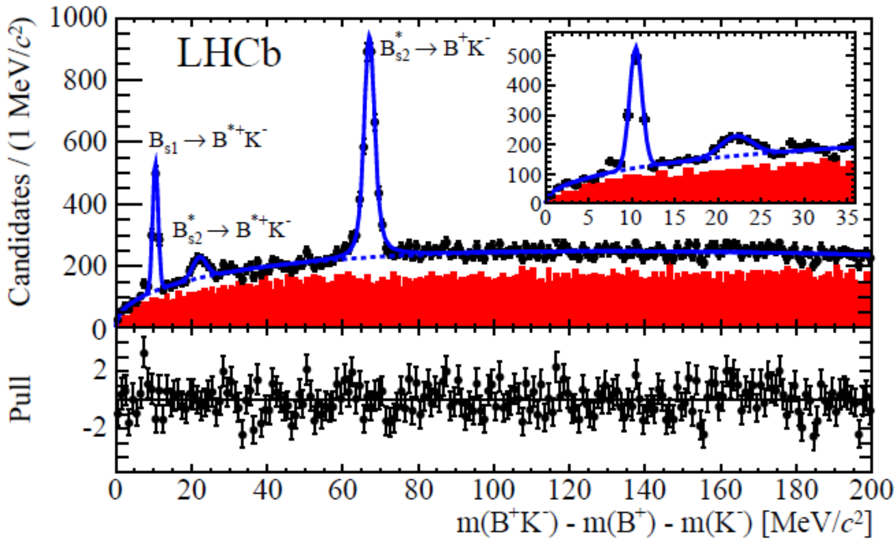

Figure 1. Mass difference distribution defined as $m(B^+K^-)-m(B^+)-m(K^-)$. The three visible peaks are identified as (left) $B_{s1} \to B^{*+}K^-$, (middle) $B^*_{s2} \to B^{*+}K^-$, and (right) $B^*_{s2} \to B^+K^-$. The total fit function is shown as solid blue line. The inset shows an expanded view of the $B_{s1}/B^*_{s2} \to B^{*+}K^-$ signals. The bottom plot shows the fit pulls. Figure reproduced from [3].

evidence has been found to confirm the $D^*_J(2650)^0$ observation for these final states. Both $D^*_J(3000)^0$ and $D^*_J(3000)^+$ structures are visible for $D^0\pi^+$ and $D^+\pi-$ final states.

2.2 Search for doubly charmed baryon Ξ^+_{cc}

According to the quark model three baryon states with charm quantum number $C = 2$ are expected: one isodoublet Ξ_{cc} and one isosinglet Ω_{cc}. So far, an unconfirmed observation of the Ξ^+_{cc} baryon decaying to $\Lambda^+_c K^-\pi+$ and pD^+K- final states has been made by the SELEX experiment [5]. The mass and upper limit for the lifetime were measured to be 3519 ± 2 MeV/c^2 and 33 fs respectively. Theoretical predictions for the Ξ^+_{cc} lifetime are between 100 fs and 250 fs. Subsequent searches performed by the FOCUS, BaBar and Belle experiments have not provide any evidence in favour.

The LHCb experiment performed search for the $\Xi^+_{cc} \to \Lambda^+_c K^-\pi^+$. The state was searched for in mass range from 3300 MeV/c^2 to 3800 MeV/c^2 and for lifetimes between 100 fs and 400 fs (as predicted by the theory). No signal has been found [6]. Upper limits on: $R = \frac{\sigma(\Xi^+_{cc})\times Br(\Xi^+_{cc}\to\Lambda^+_c K^-\pi^+)}{\sigma(\Lambda^+_c)}$ have been determined instead for various mass and lifetime hypotheses.

Acknowledgements

This research was supported in part by PL-Grid Infrastructure.

References

[1] The LHCb Collaboration, JINST **3**, (2008)

[2] M. Cacciari, S. Frixione, N. Houdeau, M. L. Mangano, P. Nason and G. Ridolfi, JHEP **10**, (2012)
[3] The LHCb Collaboration, Phys. Rev. Lett. **110**, (2013)
[4] The LHCb Collaboration, J. High Energy Phys. **09**, (2013)
[5] M. Mattson et al., Phys. Rev. Lett. **89**, (2002)
[6] The LHCb Collaboration, J. High Energy Phys. **090** 1312, (2013)