arXiv:1303.4219v1 [hep-ex] 18 Mar 2013

LHCb Results on Semileptonic B/B_s/Λ_b Decays

Concezio Bozzi
Istituto Nazionale di Fisica Nucleare
Sezione di Ferrara
I-44122 Ferrara, ITALY

on behalf of the LHCb Collaboration

Proceedings of CKM 2012, the 7th International Workshop on the CKM Unitarity Triangle, University of Cincinnati, USA, 28 September - 2 October 2012

1 Introduction

The LHCb experiment at the LHC has been taking pp collision data in 2011 and 2012 at $\sqrt{s}$ =7 and 8 TeV respectively, integrating a luminosity in excess of 3 fb^{-1}. The large (several hundred microbarns) production cross sections and efficient trigger strategies allow to collect unprecedentedly large data sets for charm and beauty decays. As an example, about 1.2 million $\overline{\mathrm{B}}^0 \to \mathrm{D}^{*+}\mu^-\overline{\nu}_\mu$ decays [1] have been reconstructed in 1 fb^{-1}. In the vast physics program which can be exploited with these large datasets, semileptonic decays play an important role.

2 Semileptonic B Decays at LHCb

Semileptonic B decays were firstly studied in LHCb in order to determine the $b\bar{b}$ production cross section [1], the performance of flavour tagging algorithms [2], and the various b-hadron production fractions at the LHC [3]. More recently, semileptonic decays of B_s mesons were used to test CP violation in neutral meson mixing, resulting in the most precise measurement of the semileptonic asymmetry in the B_s sector [4]. Besides these studies, LHCb can contribute to the understanding of currently open issues in semileptonic decays of B, B_s and Λ_b hadrons, including the composition of the inclusive semileptonic widths in terms of exclusive decays, measurements of form factors and determinations of CKM parameters $|V_{ub}|$ and $|V_{cb}|$.

Semileptonic B decays give an experimentally clean signature, due to a charm hadron and a muon originating from a common vertex. A requirement on the impact

[1] charge-conjugation is always implied, unless specified otherwise

parameter of the charmed hadron with respect to the primary vertex to be significantly different from zero suppresses copious background of charm produced promptly in the pp collision. The b hadron species are determined from the reconstructed charm hadron, *i.e.* samples with D^0, D^+, D_s^+, Λ_c^+ in the final states are originating mainly from B^-, B^0, B_s^0 and Λ_b^0 decays, respectively. *Cross-feeds* due to *e.g.* $\overline{B}_s^0 \to (D_s^{**} \to DK)X\mu^-\nu$ or $\overline{B}^{0,+} \to (D_sK)X\mu^-\nu$ (and similar baryonic decays), can be estimated by reconstructing final states with a D^0 and a charged kaon or proton, by using other available measurements and assuming *e.g.* isospin conservation. The production fractions of B_s^0 and Λ_b, f_s and f_{Λ_b}, are measured relative to the sum of the production fractions of B^0 and B^+ mesons, $f_u + f_d$. Therefore, the most abundant B^+–B^0 cross-feed, due to $\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu$ decays followed by $D^{*+} \to D^0\pi^+$, is avoided. Relative production fractions are determined in intervals of pseudorapidity (η) and transverse momentum (p_T) of the charm-muon pair, using a data sample of 3 pb^{-1} [3]. Table 1 shows the obtained signal and background yields. The results are:

$$\begin{aligned}
\frac{f_s}{f_u + f_d} &= 0.134 \pm 0.004^{+0.011}_{-0.010} \\
\frac{f_{\Lambda_b}}{f_u + f_d}(p_T) &= (0.404 \pm 0.017 \pm 0.027 \pm 0.105) \times \\
&\quad \times [1 - (0.031 \pm 0.004 \pm 0.003) p_T(\mathrm{GeV})]
\end{aligned}$$

where units are given with $c = 1$, the first and second uncertainties are respectively of statistical and systematical origin and the third one is due to the limited knowledge of the $\Lambda_c \to pK\pi$ branching fraction. The latter dominates the measurement of the Λ_b production fraction, whereas systematic uncertainties due to the modeling of B_s semileptonic decays and D^+, D_s branching fractions dominate the measurement of the B_s production fraction. No dependence on p_T is observed in B_s production fraction, which is found to be in agreement with previous determinations at LEP and about one standard deviation lower than the Tevatron measurement. For Λ_b, the production fraction is not flat over p_T, in agreement with similar results from the Tevatron in the same p_T region. A somewhat smaller fraction had been measured by the LEP experiments, on a harder p_T spectrum. A detailed discussion and interpretation of these results is given in Ref. [5].

As a by-product of these measurements, the D^0K final state was searched for P-wave D_s mesons, giving the first observation of the semileptonic decay $\overline{B}_s \to D_{s2}^{*+} X\mu\overline{\nu}$ and the most precise measurement of the $\overline{B}_s \to D_{s1}^+ X\mu\overline{\nu}$ decay.

3 Future Prospects

Measurements of the CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$ in exclusive semileptonic decays imply the reconstruction, in the b hadron rest frame, of observables such as the squared invariant mass of the lepton pair (q^2). This difficult task at hadron colliders can be accomplished by exploiting the separation between primary and secondary vertices at LHCb. Therefore, the B flight direction vector can be determined and the neutrino momentum can be measured with a two-fold ambiguity. The resulting q^2 resolution (with a core of about 0.4 GeV^2) [6] is similar to that observed at the B factories. The distributions of q^2 and $m(\mathrm{D}_s + \mu)$ in a sample of $\overline{\mathrm{B}}_s \to \mathrm{D}_s^+ X \mu \overline{\nu}$ decays is shown in Figure 1, where the different contributions, also shown, can be statistically separated [3]. Similar results have been obtained on a sample with Λ_c baryons in the final state (see Figure 2). The ultimate goals of these studies will be the determination of form factors, $|V_{cb}|$ and $|V_{ub}|$ in exclusive B_s and Λ_b decays.

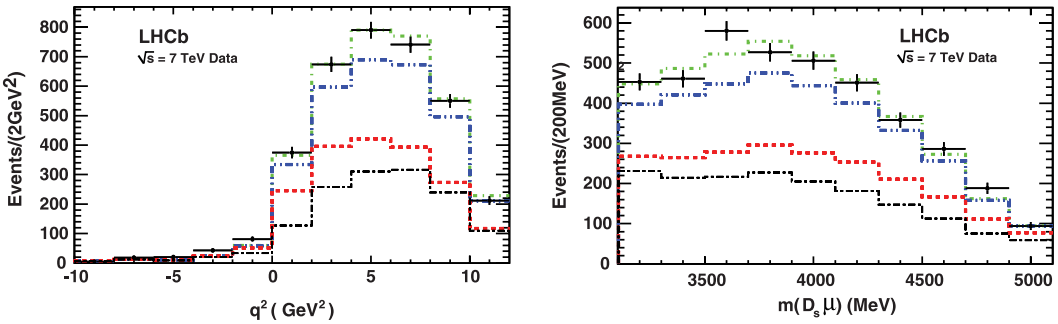

Figure 1: Projections of a two-dimensional fit to the q^2 and $m(D_s + \mu)$ distributions of semileptonic decays including a D_s^+ meson. The different components are stacked: the background is represented by a black dot-dashed line, D_s^+ by a red dashed line, D^{*+} by a blue dash-double dotted line and P-wave D mesons by a green dash-dotted line.

Final state	Signal	Background sources:		
		Prompt charm	Combinatorial	Λ_c reflections
$\mathrm{D}^0\mu\nu X$	27666± 167	695±43	1492±30	
$\mathrm{D}^+\mu\nu X$	9257± 110	362±34	1150±22	
$\mathrm{D}_s\mu\nu X$	2192± 64	63±16	985±145	387±132
$\Lambda_c\mu\nu X$	3028± 112	43±17	589±27	

Table 1: Signal and background yields for the final states analyzed in the measurement of b-hadron production fractions.

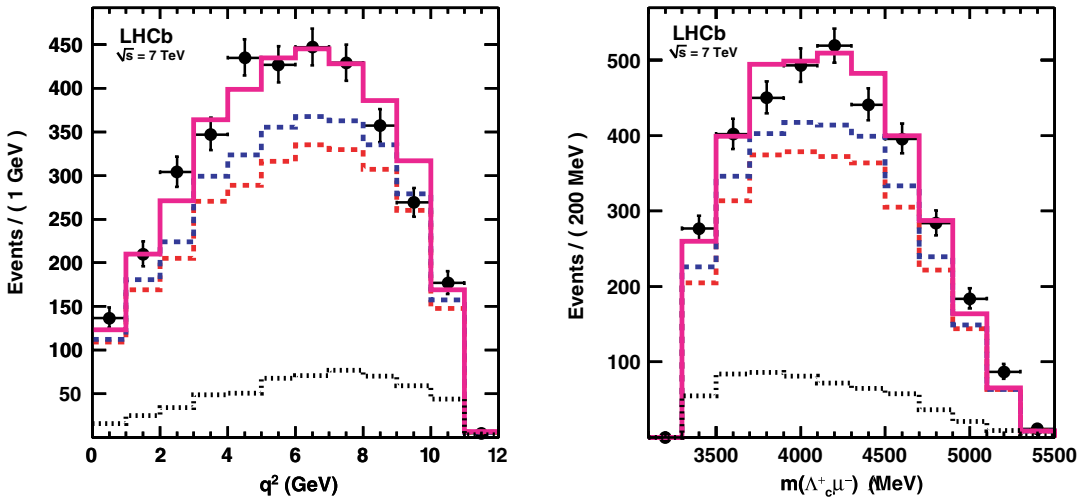

Figure 2: Projections of a two-dimensional fit to the q^2 and $m(\Lambda_c + \mu)$ distributions of semileptonic decays including a Λ_c baryon. The different components are stacked: the dotted line represents the combinatoric background, the bigger dashed line (red) represents the $\Lambda_c^+\mu^-\overline{\nu}$ component, the smaller dashed line (blue) the $\Lambda_c(2595)^+$, and the solid line represents the $\Lambda_c(2625)^+$ component.

LHCb has also good potential to measure $\overline{\mathrm{B}} \to D^{(*)}\tau^-\overline{\nu}$ decays, which recently received great attention after Babar measured branching fractions which exclude the Standard Model expectations at the 3.4 sigma level [7]. However, the neutrino reconstruction method outlined above is much more difficult to apply in purely leptonic tau decays, due to the presence of two additional neutrinos. Therefore, three-prong decays such as $\tau^\pm \to \pi^+\pi^-\pi^\pm\nu_\tau$ have been exploited. In this case, the neutrino reconstruction procedure can be applied and the tau momentum can be determined with a two-fold ambiguity, which becomes four-fold on the B meson momentum. Moreover, care must be taken in order to avoid non-physical solutions due to the finite momentum and vertex resolutions. A recent measurement of $\mathrm{B}_{(s)} \to \mathrm{D}_{(s)}\pi\pi\pi$ decays [8] indicates that similar decays with high track multiplicity can be reconstructed in LHCb, with low combinatorial background.

The long standing puzzle of the composition of the inclusive semileptonic rate in terms of the exclusive decays can also be investigated, by reconstructing decays in P-wave charm mesons as well as in radial excitations. An investigation of three-body decays of these particles, already in progress in hadronic B decays [8], will also help in normalizing their corresponding semileptonic B branching fractions, which are typically computed by assuming that P-wave charm mesons decay in two-body final states only.

4 Conclusions

In conclusion, semileptonic $B/B_s/\Lambda_b$ decays are an important part of the LHCb physics program. They have been succesfully used to measure the $b\overline{b}$ cross section and b hadron production fractions at the LHC, and to establish the most accurate limit on CP violation in the mixing of B_s mesons. Studies of B_s and Λ_b decays have been performed, which will eventually lead to novel determinations of the $|V_{cb}|$ and $|V_{ub}|$ CKM matrix elements, which can help to clarify the existing tension between measurements with inclusive and exclusive semileptonic B decays. A measurement of $\overline{B} \to D^{(*)}\tau^-\overline{\nu}$ decays seems also feasible at LHCb, although neutrino reconstruction will be challenging. Precise measurements of semileptonic decays in higher D meson excitations will allow to reduce systematic errors on other measurements, and possibly solve long-standing puzzles in semileptonic B decays.

References

[1] R. Aaij *et al.* (LHCb Collaboration), Phys. Lett. **B694**, 209 (2010).

[2] R. Aaij *et al.* (LHCb Collaboration), Eur. Phys. J. **C72**, 2022 (2012).

[3] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. **D85**, 032008 (2012).

[4] R. Aaij *et al.* (LHCb Collaboration), LHCb-CONF-2012-022 (CERN-LHCb-CONF-2012-022); see also X. Zhou, talk at this workshop.

[5] Y. Amhis et al. (The Heavy Flavour Averaging Group), arXiv:1207.1158.

[6] P. Urquijo, proceedings of CKM2010 (arXiv:1102.1160v1).

[7] J.P. Lees *et al.* (Babar Collaboration), Phys. Rev. Lett. **109**, 101802 (2012)

[8] R. Aaij *et al.* (LHCb Collaboration), Phys. Rev. **D84**, 092001 (2011)