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b-hadrons lifetime measurements using exclusive $b \to J/\Psi(\mu^+\mu^-)\ X$ decays at LHCb

F. Dordei

Heidelberg University, Physikalisches Institut - Heidelberg, Germany

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Summary. — In this proceedings are reported precision measurements of different b-hadrons lifetimes in the exclusive decays $B^+ \to J/\psi K^+$, $B^0 \to J/\psi K^{*0}$, $B^0 \to J/\psi K_s^0$, $B_s^0 \to J/\psi\phi$, and $\Lambda_b^0 \to J/\psi\Lambda$, using $1\,\text{fb}^{-1}$ of data collected in 2011 with the LHCb detector at a centre-of-mass energy of 7 TeV.

PACS 14.40.Nd – Bottom mesons ($|B| > 0$).
PACS 14.20.Mr – Bottom baryons ($|B| > 0$).
PACS 12.39.Hg – Heavy quark effective theory.

1. – Introduction

Precision measurements of b-flavoured hadron lifetimes are an important test of the theoretical approach to determine b-hadron observables, known as Heavy Quark Expansion (HQE) [1]. This model is based on the operator product expansion in inverse powers of the heavy b-quark mass; it is used, for example, to extract $|V_{ub}|$ and $|V_{cb}|$ from measurements of inclusive semileptonic B meson decays. In the free quark model the lifetimes of all b-hadrons are equal, because the decay width is determined by the b quark lifetime. Different corrections alter the lifetime at approximately 10% level. In the case of the ratio of lifetimes of the Λ_b^0 to the B^0, differences of only a few percent are expected. However, different LEP measurements indicated that the corrections were significantly bigger [2], suggesting a small value of the ratio. Recent measurements have shown indications that a higher value is possible [3], although the uncertainties are still large.

The B_s^0 meson lifetime is measured using a single exponential to model the proper time distribution, *i.e.*, ignoring the non-zero decay-width difference between mass eigenstates ($\Delta\Gamma_s$) of the B_s^0 system. Measurements of the effective lifetimes in B_s^0-meson decays allow to probe the width difference $\Delta\Gamma_s$ and the CP-violating phase ϕ_s of $B_s^0 - \overline{B}_s^0$ mixing box-diagram [4], with the advantage that only an untagged analysis is needed.

Finally, the precision reached in these lifetime measurements demonstrates the excellent understanding of the LHCb detector and of the reconstruction system.

2. – Lifetime determination

The exclusive b-hadrons lifetimes presented here have been measured through the decay channels $B^+ \to J/\psi K^+$, $B^0 \to J/\psi K^{*0}$, $B^0 \to J/\psi K_s^0$, $B_s^0 \to J/\psi\phi$ and $\Lambda_b^0 \to$

TABLE I. – *Results of the b-hadrons lifetime measurements. First uncertainty is statistical and the second systematic. The value is blinded.*

Channel	$\tau \pm \sigma_{\text{stat}} \pm \sigma_{\text{sys}}$ [ps]
$B^+ \to J/\Psi\, K^+$	1.xxx ± 0.004 ± 0.004
$B^0 \to J/\Psi\, K^{*0}$	1.xxx ± 0.006 ± 0.004
$B^0 \to J/\Psi\, K^0_s$	1.xxx ± 0.012 ± 0.008
$B^0_s \to J/\Psi\, \phi$	1.xxx ± 0.012 ± 0.005
$\Lambda^0_b \to J/\Psi\, \Lambda$	1.xxx ± 0.024 ± 0.008

$J/\psi\Lambda$ (charge conjugate modes are implied throughout), using $1.0\,\text{fb}^{-1}$ of data collected in pp collisions at $\sqrt{s} = 7\,\text{TeV}$ with the LHCb detector [5]. At LHCb, b-hadrons are produced with an average momentum of around 100 GeV/c and have decay vertices displaced from the primary interaction vertex (around 1-2 cm), whereas combinatorial background candidates are produced by the random combination of tracks, which tend to originate from the primary vertex. So conventional selections exploit these features to select b-hadrons by requiring that their decay products are energetic and significantly displaced from the primary interaction point. However, this introduces a time-dependent acceptance which needs to be taken into account in the analysis and, making use of a limited unbiased sample, a data driven correction has been developed for it. Moreover, there are also implicit biases ($\sim 20\,\text{fs}$), for example due to geometrical and reconstruction acceptances. Experimentally it is challenging to correct for these biases. In this analysis we have established in great details the origin of this decay time acceptance. The main contribution is due to a drop in the reconstruction efficiency at large decay time in the Vertex Locator for tracks with large impact parameter relative to the z-beam axis. We developed a data-driven method to derive this inefficiency and to re-weight each event in order to compensate for this effect. Further biases are instead reduced significantly, *e.g.*, implementing a new method to reconstruct the primary vertex. All these methods have been validated on large statistics samples of fully simulated events for each channel. Making use of a 2-dimensional unbinned maximum likelihood fit in the mass and in the decay time distribution of the b-hadron it is possible to determine the B^+, B^0 and Λ^0_b lifetime and the B^0_s effective lifetime.

The b-hadrons lifetime measurements are listed in table I, where first uncertainty is statistical and the second systematic, while the value is still blinded. All the measurements are the most precise measurements to date and are still statistically limited.

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