Measurement of $B^0$, $B_s^0$, $B^+$ and $\Lambda_b^0$ production asymmetries in 7 and 8 TeV $pp$ collisions at LHCb

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Summary. — The $B^0$, $B_s^0$, $B^+$ and $\Lambda_b^0$ hadron production asymmetries are measured using a data sample corresponding to an integrated luminosity of 3.0 fb$^{-1}$, collected by the LHCb experiment in proton-proton collisions at centre-of-mass energies of 7 and 8 TeV. The measurements are performed as a function of transverse momentum and rapidity of the $b$ hadrons within the LHCb detector acceptance. The overall production asymmetries, integrated over transverse momentum and rapidity, are also determined.

1. – Introduction

The production rates of $b$ and $\bar{b}$ quarks in $pp$ collisions are not expected to be equal. This phenomenon, commonly referred to as production asymmetry, is due to the fact that $\bar{b}$ ($b$) quarks produced in the hard scattering might combine with the spectators quarks from the $pp$ collision in order to form a meson (baryon), whereas the opposite is not possible. Models describing these production effects predict values of the asymmetries up to a few percent and an enhancement at high rapidities and small transverse momenta [1, 2]. The knowledge of these asymmetries plays a key role in CP violation measurements, since one needs to correct for production effects in order to obtain the physical asymmetries. The $b$ hadrons production asymmetries are defined as

\[ A_P(x) = \frac{\sigma(x) - \sigma(\bar{x})}{\sigma(x) + \sigma(\bar{x})}, \quad x \in \{B^0, B_s^0, B^+, \Lambda_b^0\}, \]

where $\sigma$ denotes the inclusive production cross-section in a certain region of phase space.

2. – Analysis

The $B_s^0$ and $B^0$ production asymmetries are measured using $B_s^0 \rightarrow D^- (K^+ K^- \pi^0) \pi^+$ and $B^0 \rightarrow J/\psi (\mu^+ \mu^-) K^{*0} (K^+ \pi^-)$ decays. Two-dimensional simultaneous invariant

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mass and decay time fits in \((p_T, y)\) bins of the \(B\) mesons are performed in order to measure the quantity

\[
A(t) = A_{\text{CP}}(f) + A_D(f) + \omega(t)A_P,
\]

where \(\omega(t) \equiv [\cos(\Delta m_{H(\phi)}t)]/[\cosh(\Delta \Gamma_{H(\phi)}t/2)]\). \(A_{\text{CP}}(f)\) is the physical asymmetry and \(A_D(f)\) is the detection asymmetry of the final state \(f\). The production asymmetry is then measured as the amplitude of the oscillating term \(\omega(t)\).

The \(B^+\) production asymmetry is measured by means of \(B^+ \rightarrow J/\psi(\mu^+\mu^-)K^+\) decays. Invariant mass fits in \((p_T, y)\) bins of the \(B^+\) meson are performed to measure the raw asymmetry, \(A_{\text{raw}}(B^+)\). \(A_P(B^+)\) can be measured as

\[
A_P(B^+) = A_{\text{raw}}(B^+) - A_{\text{CP}}(B^+ \rightarrow J/\psi K^+) - A_D(K^-),
\]

where \(A_{\text{CP}}(B^+ \rightarrow J/\psi K^+)\) is taken as an external input [3] and \(A_D(K^-)\) is measured by means of \(D^+ \rightarrow K^-\pi^+\pi^+\) and \(D^+ \rightarrow K_0^{*}\pi^+\) decays.

Finally, the \(\Lambda_b^0\) production asymmetry is obtained exploiting the fact that \(b\) and \(\bar{b}\) quarks are produced in pairs through the relation

\[
A_P(\Lambda_b^0) = -\left[ f_u \frac{f_u}{f_{\Lambda_b^0}} A_P(B^+) + f_d \frac{f_d}{f_{\Lambda_b^0}} A_P(B^0) + f_s \frac{f_s}{f_{\Lambda_b^0}} A_P(B_s^0) \right],
\]

where \(f_u\), \(f_d\), \(f_s\) and \(f_{\Lambda_b^0}\) are the \(B^+, B^0, B_s^0\) and \(\Lambda_b^0\) hadronization fractions, where the \(B_s^+\) and \(\Xi_b\) contributions have been considered as systematic uncertainties.

3. – Results and conclusions

The \(b\) hadrons production asymmetries within the LHCb acceptance are found to be

\[
\begin{align*}
A_P(B_s^0)_{7\text{ TeV}} &= (+0.44 \pm 0.88 \pm 0.11)\%, & A_P(B^0)_{8\text{ TeV}} &= (+1.40 \pm 0.55 \pm 0.10)\%, \\
A_P(B_s^0)_{7\text{ TeV}} &= (+0.65 \pm 2.88 \pm 0.59)\%, & A_P(B^0)_{8\text{ TeV}} &= (+1.98 \pm 1.90 \pm 0.59)\%, \\
A_P(B^+)_{7\text{ TeV}} &= (+0.23 \pm 0.24 \pm 0.37)\%, & A_P(B^+)_{8\text{ TeV}} &= (+0.74 \pm 0.15 \pm 0.32)\%, \\
A_P(\Lambda_b^0)_{7\text{ TeV}} &= (+0.11 \pm 2.53 \pm 1.08)\%, & A_P(\Lambda_b^0)_{8\text{ TeV}} &= (+3.44 \pm 1.61 \pm 0.76)\%,
\end{align*}
\]

where the first error is statistical and the second is systematic. All the results are found to be compatible with zero and no evidence of a dependence of the production asymmetries on the \(b\) hadrons \(p_T\) or \(y\) is observed. The production asymmetries are also measured in bins of \(p_T\) and \(y\) of the \(b\) hadrons, as reported in ref. [4].

REFERENCES