Motivation
The production rates of $b$ and $\bar{b}$ hadrons is not expected to be equal in $pp$ collisions. Anti-quarks (quarks) produced in the hard scattering can combine with the valence quarks of the colliding protons to form mesons (baryons), whereas the opposite is not possible.

For this reason, one expects a slight excess in the production of $B^+ - B^0$ and $A_0^+$ with respect to $B^- - B^0$ and $A_0^0$ hadrons. This effect is referred to as production asymmetry ($A_p$).

The knowledge of these quantities is of fundamental importance to perform CP violation measurements. Indeed, observed asymmetries must be corrected for production effects to obtain the CP asymmetries in the decays.

The results of this analysis supersede the ones obtained from the LHCb Collaboration in Ref. [1].

Measuring $A_p(B^+$ and $A_p(B^0$)
The time-dependent decay rate asymmetry is:

\[
A(t) = \frac{\mathcal{B}(t \to f) - \mathcal{B}(t \to f)}{\mathcal{B}(t \to f) + \mathcal{B}(t \to f)} = A_{CP} + A_P \cos(\Delta m_d t) + A_P \cos(\Delta m_s t/2)
\]

where $B(t)$ stands for $B^0(t)$ or $B^0(t)$.

Oscillatory term whose amplitude is the production asymmetry

Final state detection asymmetry

Integrated results
The production asymmetries integrated in the ranges $0 < p_T < 30$ GeV/c and $2.1 < y < 4.5$ for $B^0$ and $B^+$ mesons and $2 < p_T < 30$ GeV/c and $2.1 < y < 4.5$ for $B^0$ and $A_0^+$ hadrons are found to be:

\[
A_p(B^+)_{\Delta S=7\,\text{TeV}} = -0.0023 \pm 0.0024 \,\text{(stat)} \pm 0.0037 \,\text{(syst)}
\]

\[
A_p(B^0)_{\Delta S=8\,\text{TeV}} = -0.0074 \pm 0.0015 \,\text{(stat)} \pm 0.0032 \,\text{(syst)}
\]

\[
A_p(B^0)_{\Delta S=7\,\text{TeV}} = +0.0044 \pm 0.0088 \,\text{(stat)} \pm 0.0011 \,\text{(syst)}
\]

\[
A_p(B^0)_{\Delta S=8\,\text{TeV}} = -0.0034 \pm 0.0161 \,\text{(stat)} \pm 0.0076 \,\text{(syst)}
\]

Data sample and strategy
The data sample used corresponds to an integrated luminosity of 1.0 fb$^{-1}$ collected at a centre of mass energy of 7 TeV and 2.0 fb$^{-1}$ collected at a centre of mass energy of 8 TeV by the LHCb experiment.

The $B^+ - B^0$ and $B^0$ production asymmetries are measured using $B^+ \to J/\psi K^+, B^0 \to J/\psi K^0(K^-\pi^+)$ and $B^0 \to D_s^+(K^-\pi^-\pi^+) \pi^+$ decays. Then $A_p(A^0_S)$ can be measured by means of the relation:

\[
A_p(A^0_S) = \frac{\int_{y_1}^{y_2} f_y A_p(B^+) + \int_{y_1}^{y_2} f_y A_p(B^0) + \int_{y_1}^{y_2} f_y A_p(B^0)}{\int_{y_1}^{y_2} f_y}
\]

where the $f_y$ represent the quarks hadronisation fractions.

To account for the dependence of the production asymmetries on the kinematics each data sample is divided into bins of $(p_T, y)$, performing the measurement for each bin.

Measuring $A_p(B^+)$
The $B^+$ production asymmetry can be expressed as:

\[
A_p(B^+) = A_{RAW}(B^+) - A_{CP}(B^+ \to J/\psi K^+)
\]

where:

- $A_{RAW} = \frac{N(B^+) - N(B^0)}{N(B^+) + N(B^0)}$ obtained performing binned maximum likelihood fits to the invariant mass spectra.

- $A_{CP}(B^+ \to J/\psi K^+)$ is the kaon detection asymmetry due to the different interaction cross-section of charged kaons in the matter. This is measured using charm control samples.

- $A_{CP}(B^+ \to J/\psi K^+) = (0.09 \pm 0.27 \pm 0.07) \times 10^{-2}$ obtained from Ref. [2].

Dependence on kinematics

No striking evidence of a dependence of the production asymmetries on $p_T$ or $y$ is found within the current experimental precision.

References