B-HADRON PRODUCTION ASYMMETRIES AT LHCb

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Using a data sample corresponding to an integrated lumunosity of 1.0 fb^{-1}, collected by LHCb in pp collisions at a centre-of-mass energy of 7 TeV, the B^0 and B_s^0 production asymmetries, $A_{\mathrm{P}}(B^0)$ and $A_{\mathrm{P}}(B_s^0)$, are determined. These quantities are measured by means of an untagged time-dependent analysis of $B^0 \to J/\psi K^{*0}$, $B^0 \to D^-\pi^+$ and $B_s^0 \to D_s^-\pi^+$ decays. The production asymmetries are measured as a function of the trasverse momentum and pseudorapidity of the B^0 and B_s^0 mesons. Finally, the total production asymmetries integrated over p_{T} and η in the range $4 < p_{\mathrm{T}} < 30$ GeV/c and $2.5 < \eta < 4.5$ are determined and they are found to be $A_{\mathrm{P}}(B^0) = (-0.35 \pm 0.76 \pm 0.28)\%$ and $A_{\mathrm{P}}(B_s^0) = (1.09 \pm 2.61 \pm 0.61)\%$, where the first uncertainties are statistical and the second systematic.

1 Introduction

The production of b and $\bar{b}$ hadrons in pp collisions at the LHC are not expected to be equal. This is due to the fact that the $\bar{b}$ quarks produced in the pp interaction might combine with the valence quark of the collinding protons, whereas the same is not true for the b quarks. As a consequence, one could expect a slight excess in the production of B^0 and B^+ mesons over $\bar{B}^0$ and B^- mesons, which has to be compensated by an opposite asymmetry in the other b meson and baryon species. Some theoretical prediction also foresee an enhancement of this effect in the forward region, where the $b\bar{b}$ pair is closer to the valence quarks of the colliding protons. Finally, there could also be other effects kicking in at high transverse momenta of the b mesons [1,2,3].

The determination of the impact of this phenomenon, referred to as production asymmetry, is of fundamental importance for *CP* violation measurements. In fact, one must disentangle the *CP* asymmetry from other spurious effects that could potentially mimic the effect of *CP* violation. The production asymmetry for B^0 and B_s^0 mesons is defined as:

$$A_{\mathrm{P}}(B^0_{(s)}) = \frac{\sigma(\bar{B}^0_{(s)}) - \sigma(B^0_{(s)})}{\sigma(\bar{B}^0_{(s)}) + \sigma(B^0_{(s)})} \quad (1)$$

where σ stands for the production cross-section.

The production asymmetries of B^0 and B_s^0 mesons are determined by means of an untagged time-dependent analysis of the $B^0 \to J/\psi K^{*0}$, $B^0 \to D^-\pi^+$ and $B_s^0 \to D_s^-\pi^+$ decays. The production asymmetries are firstly determined in bins of p_{T} and η of the B^0 and B_s^0 mesons, in order to investigate whether there is a dependence on such quantities. Finally, the overall production asymmetries are obtained integrating over p_{T} and η in the range $4 < p_{\mathrm{T}} < 30$ GeV/c and $2.5 < \eta < 4.5$.

The analysis presented is performed using the data collected by LHCb during 2011 at a centre-of-mass energy of 7 TeV, corresponding to an integrated luminosity of 1 fb^{-1}.

2 Fit model

Each signal and background contribution to the invariant mass and decay time spectra of every mode is modelled with appropriate probability density functions (PDFs). In the following section the fit employed model is described.

2.1 Mass model

The signal component for each mode is obtained convolving a double Gaussian function with a function parameterizing the final state radiation. The resulting PDF for the B meson mass is given by:

$$g(m) = A\,[\Theta(\mu - m)(\mu - m)]^{s} \otimes G(m), \tag{2}$$

where A is a normalization factor, Θ is the Heaviside function, $G(m)$ is the sum of two Gaussian functions with different widths and zero mean, μ is the B meson mass, and s is a parameter governing the amount of final state radiation and it is determined using fully simulated events. The combinatorial background is modelled using an exponential function. In the case of $B^0 \to D^-\pi^+$ and $B_s^0 \to D_s^-\pi^+$ decays there is also a background due to partially reconstructed decays where a γ or a π^0 are missed. This contribution is modelled by means of a kernel estimation technique [4] based on invariant mass distributions obtained from fully simulated events.

2.2 Decay time

The time dependent decay rate of a neutral $B^0_{(s)}$ or $\bar{B}^0_{(s)}$ meson to a flavour specific f or $\bar{f}$ final state is given by the PDF:

$$\begin{aligned} h(t,\psi) = \quad K \quad & (1 - \psi A_{CP})(1 - \psi A_f) \\ & \left\{ e^{-\Gamma t}\left[\Lambda_+ \cosh\left(\frac{\Delta\Gamma t}{2}\right) + \psi\Lambda_- \cos(\Delta m t)\right]\right\} \otimes R(t)\epsilon(t) \end{aligned} \tag{3}$$

where K is a normalization factor, $\epsilon(t)$ is the acceptance as a function of the decay time, $R(t)$ is the decay time resolution function, $\Delta m \equiv m_{\rm H} - m_{\rm L}$ and $\Delta\Gamma \equiv \Gamma_{\rm L} - \Gamma_{\rm H}$ are the mass and decay-width differences. The subscripts H and L denote the heavy and light eigenstates respectively. The A_{CP} and A_f quantities are the final state physical and detection asymmetry, respectively. The observables of the PDF are the decay time t and the tag of the final state ψ, that takes the values $\psi = 1(-1)$ for the final state $f(\bar{f})$. The terms Λ_+ and Λ_- are defined as:

$$\Lambda_\pm \equiv (1 - A_{\rm P})\left|\frac{q}{p}\right|^{1-\psi} \pm (1 + A_{\rm P})\left|\frac{q}{p}\right|^{-1-\psi}, \tag{4}$$

where p and q are complex parameters entering the definition of the mass eigenstates and $A_{\rm P}$ is the production asymmetry.

The combinatorial and partially reconstructed backgrounds are parameterized in an empirical way by studying the low and high invariant mass sidebands from data. As for the invariant mass spectra case, the partially reconstructed components are present only in $B^0 \to D^-\pi^+$ and $B_s^0 \to D_s^-\pi^+$ decays.

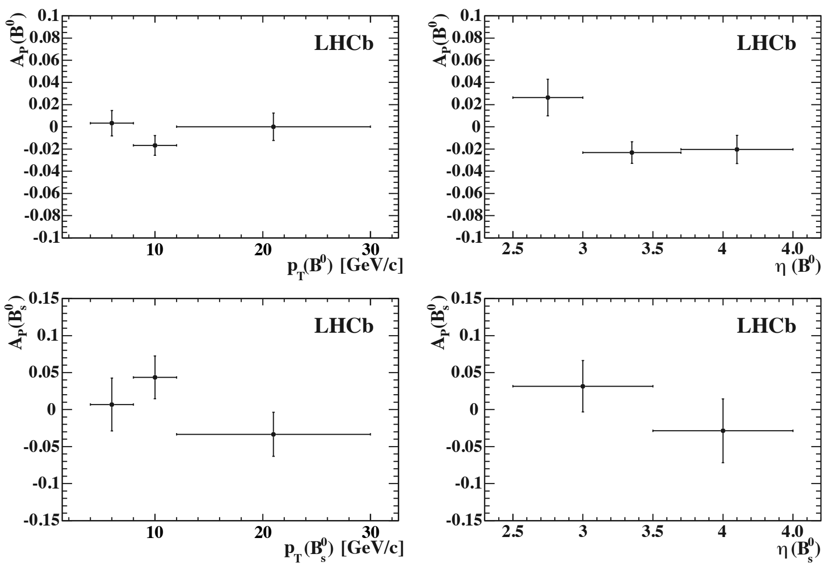

Figure 1 – Production asymmetries of (top) B^0 and (bottom) B^0_s mesons as a function of (left) transverse momentum and (right) pseudorapidity. The error bars include both statistical and systematic errors. No evidence of a dependency on such quantities is found.

3 Determination of the production asymmetries

The production asymmetries for each decay mode are determined by means of simultaneous invariant mass and decay time fits to the relative spectra. A global fit to the total sample of selected events is performed for each of the three decay modes. Furthermore, in order to investigate whether the production asymmetries show a dependence on the transverse momentum and pseudorapidity of the B^0 and B^0_s, the fit is repeated in different (p_{T}, η) bins.

4 Results

The integrated value of A_{P} is given by:

$$A_{\mathrm{P}} = \sum_i \omega_i A_{\mathrm{P},i} \qquad (5)$$

where $\omega_i = f_i / \sum_i f_i$. The quantity f_i is the fraction of B mesons produced in the i-th kinematic bin. The values of the ω_i are obtained using simulated events. The values of $A_{\mathrm{P}}(B^0)$ are determined separately for $B^0 \to J/\psi K^{*0}$ and $B^0 \to D^-\pi^+$ modes and then averaged.

The overall production asymmetries of B^0 and B^0_s mesons in the ranges $4 < p_{\mathrm{T}} < 30$ GeV/c and $2.5 < \eta < 4.5$ are found to be:

$$\begin{aligned} A_{\mathrm{P}}(B^0) &= (-0.35 \pm 0.76 \pm 0.28)\% \\ A_{\mathrm{P}}(B^0_s) &= (\ \ 1.09 \pm 2.61 \pm 0.66)\% \end{aligned}$$

where the first uncertainties are statistical and the second systematics. Finally, the dependences of $A_{\mathrm{P}}(B^0)$ and $A_{\mathrm{P}}(B^0_s)$ on p_{T} and η are shown in Fig. 1. The numerical values are reported in Tables 1 and 2.

No clear evidence of dependency of the production asymmetries on p_{T} and η is observed.

Table 1: Value of the production asymmetry $A_{\mathrm{P}}(B^0)$ in bins p_{T} and η from $B^0 \to J/\psi K^{*0}$ and $B^0 \to D^-\pi^+$ decays. The first uncertainty is statistical and the second systematic.

Variable	Bin	$A_{\mathrm{P}}(B^0)$
p_{T} (GeV/c)	$(4, 7)$	$0.0033 \pm 0.0111 \pm 0.0028$
	$(7, 12)$	$-0.0167 \pm 0.0084 \pm 0.0028$
	$(12, 30)$	$0.0001 \pm 0.0130 \pm 0.0029$
η	$(2.5, 3.0)$	$0.0264 \pm 0.0161 \pm 0.0030$
	$(3.0, 3.7)$	$-0.0232 \pm 0.0093 \pm 0.0028$
	$(3.7, 4.5)$	$-0.0203 \pm 0.0125 \pm 0.0021$

Table 2: Value of the production asymmetry $A_{\mathrm{P}}(B_s^0)$ in bins p_{T} and η from $B_s^0 \to D_s^-\pi^+$ decays. The first uncertainty is statistical and the second systematic.

Variable	Bin	$A_{\mathrm{P}}(B_s^0)$
p_{T} (GeV/c)	$(4, 8)$	$0.0069 \pm 0.0351 \pm 0.0067$
	$(8, 12)$	$0.0435 \pm 0.0283 \pm 0.0039$
	$(12, 30)$	$-0.0334 \pm 0.0296 \pm 0.0038$
η	$(2.5, 3.5)$	$0.0315 \pm 0.0342 \pm 0.0060$
	$(3.5, 4.5)$	$-0.0286 \pm 0.0412 \pm 0.0088$

The LHCb Collaboration is continuing its campaign in the b hadron production asymmetries sector and an update of this measurement with the full Run 1 data sample, together with the determination of $A_{\mathrm{P}}(B^+)$ and $A_{\mathrm{P}}(\Lambda_b^0)$, is ongoing.

References

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