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Charm and beauty reconstruction in ATLAS

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Summary. — The article describes the selection of samples of charm and beauty mesons, exclusively or semi-exclusively reconstructed on data collected in 2010. These samples have been used to calibrate the flavour tagging algorithms (through the selection of pure, or heavily enriched, b-jets samples) and for measurements of direct physical interest (b-hadrons production cross section).

PACS 13.20.-v – Leptonic, semileptonic, and radiative decays of mesons.
PACS 13.25.Hw – Decays of bottom mesons.
PACS 13.25.-k – Hadronic decays of mesons.
PACS 13.25.Ft – Decays of charmed mesons.

1. – Introduction

A precise identification of jets coming from b quark fragmentations (b-tagging) represents an important ingredient for the ATLAS experiment analysis strategies, in particular for the impact that multi b-jet final states could have on LHC physics. After the start of LHC operations, a precise estimate of b-tagging algorithms performances on real data has a great importance. Jets containing charmed mesons correlated to leptons represent an almost pure sample of b-jets, and therefore they are good candidates to evaluate heavy flavour tagging efficiencies. Furthermore, the reconstruction of charmed mesons, correlated with a lepton, is a useful tool to measure beauty hadrons production cross sections at LHC. This is a useful test to check the validity of QCD predictions on heavy quark production at high center-of-mass energy, and also useful in the framework of searches for new physics phenomena for which b quark pairs can be a significant background.

2. – Flavour tagging calibration

The method [1] to evaluate the b-tagging efficiency is based on opposite sign $D^{\star+}\mu^-$ (1) correlations inside jets, where $D^{\star+}$ is fully reconstructed as $D^{\star+} \to \pi^+ D^0(\to K^-\pi^+)$.

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(1) Charge conjugate states are always implied.

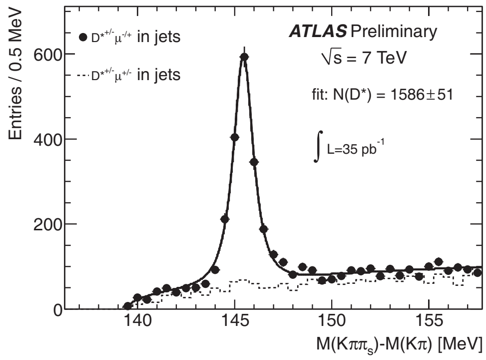

Fig. 1. – ΔM distribution of the opposite- and same-sign $D^{\star+}\mu^-$ combinations reconstructed within a jet.

This sample comes mostly from $b \to D^{\star+}\mu^- X$ processes, and therefore represents an almost pure sample of b-jets. Figure 1 shows the distributions of the $D^{\star+} - D^0$ mass difference (ΔM) for the $D^{\star+}\mu^-$ pairs reconstructed within a jet.

The b-tagging efficiency of any lifetime tagging algorithm can be calculated by comparing the number of fitted $D^{\star+}\mu^-$ candidates before and after requiring the jet to be tagged, obtaining the b-tagging efficiency for jets associated to any type of $D^{\star+}\mu^-$ combinations ($\epsilon_{D^\star\mu}$); to extract the efficiency ϵ_b on jets associated to $D^{\star+}\mu^-$ issued from direct b semileptonic decays, one has to deconvolve the background contribution, which mainly includes $c\bar{c}$ ($c \to D^{\star+}, \bar{c} \to \mu^-$) and other b decays (as $b \to D^{\star+}, \bar{b} \to \mu^-$, or $b \to D^{\star+}\bar{D}, \bar{D} \to \mu^-$):

$$\epsilon_b = \frac{\epsilon_{D^\star\mu}(1 + n_{cc}/n_b + n_{b'}/n_b)}{1 + \alpha n_{b'}/n_b}, \tag{1}$$

where the sample composition n_{cc}/n_b and $n_{b'}/n_b$ and the charm tagging efficiency ϵ_{cc} are taken from Monte Carlo, and $\alpha = \epsilon_{b'}/\epsilon_b$ is assumed equal to 1.

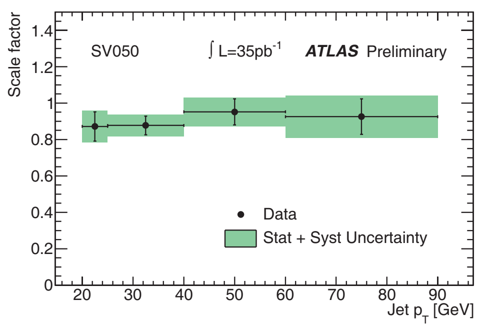

Fig. 2. – Efficiency of the SV0 tagger for a selection at 50% for jets associated to $D^\star\mu$, as a function of the jet transverse momentum.

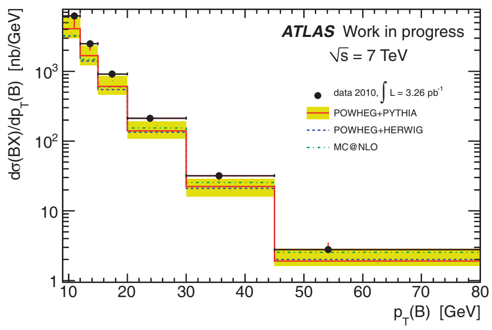

Fig. 3. – b-hadron production cross section as a function of $p_T(B)$.

Systematic uncertainties have been obtained by varying by a conservative amount these different components (50% for α and the sample composition factor, 100% for ϵ_{cc}).

Figure 2 shows the efficiencies, computed in data and Monte Carlo, for the SV0 tagger algorithm (a tagger based on the reconstruction of a secondary decay vertex, [2]) for a selection at 50% efficiency, as a function of the transverse momentum (p_T) of the jets. This method can be applied to any lifetime tagger algorithm, and any efficiency value.

3. – Beauty cross section measurement

The same $D^{\star +}\mu^-$ sample, without the request of jet association, can be used to evaluate the b-hadrons production cross section in pp collisions at $\sqrt{s} = 7\,\text{TeV}$.

This cross section can be expressed as

$$\sigma(pp \to BX) = \frac{f_b N_{D^\star\mu}}{2\alpha\epsilon\mathcal{B}\mathcal{L}}\,, \tag{2}$$

where f_b is the $D^\star\mu$ fraction coming from a direct semileptonic b decay (as in the previous measurement, $c\bar{c}$ and other b are the main background sources), $N_{D^\star\mu}$ is the number of $D^\star\mu$ candidates in the reconstructed sample, α is the decay acceptance correction, ϵ is

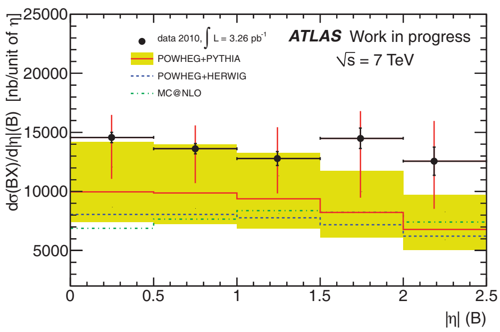

Fig. 4. – b-hadron production cross section as a function of $|\eta(B)|$.

the signal reconstruction efficiency, $\mathcal{B}$ is total branching ratio that takes into account the different cascade decay chains ($\mathcal{B} = \mathcal{B}(b \to D^{\star+}\mu^- X) \times \mathcal{B}(D^{\star+} \to D^0\pi^+) \times \mathcal{B}(D^0 \to K^-\pi^+)$ [3]) and $\mathcal{L}$ is the integrated luminosity of the collected data sample. The factor 2 takes into account that the data sample contains both charge states $D^{\star+}\mu^-$ and $D^{\star-}\mu^+$, while the measurement aims at the b-hadron cross section.

The measured b-hadron integrated production cross section, for $p_T(B) > 9\,\text{GeV}$ and pseudorapidity $|\eta(B)| < 2.5$ turns out to be

$$\sigma(pp \to BX) = 33.1 \pm 0.8(\text{stat})^{+4.3}_{-5.5}(\text{syst}) \pm 2.5(\mathcal{B}) \pm 1.1(\mathcal{L})\,\mu\text{b}\,.$$

Figure 3 and 4 show the differential b hadron cross sections as a function of $p_T(B)$ and $|\eta(B)|$, compared with three NLO theoretical predictions (the shaded band shows the theoretical uncertainty of one of the predictions).

4. – Conclusion

$D^{\star+}\mu^-$ correlations associated to a reconstructed jet have been studied in the 7 TeV collision data collected by the ATLAS experiment. It has been showed how this sample can be used to determine the tagging efficiency on b-jets, which is crucial for the understanding of the b-tagging performance. $D^{\star+}\mu^-$ correlations, without jet association, have been also used for measuring the production cross section of b-hadron in 7 TeV pp collisions. The measured cross section value has been compared with the available next-to-leading order QCD predictions, and has been found to be slightly higher, but still compatible with the theoretical uncertainties of the predictions.

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