Measurmetns of the B production with the CMS Experiment

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Abstract

We present the measurements of b-quark production in inclusive channels and exclusive decays. The measurements are based on different methods, such as inclusive jet measurements with secondary vertex tagging or selecting a sample of events containing jets and at least one muon. In addition, measurements of B^+, B_0 and B_s meson production cross sections are presented. Finally, a study of the angular correlations between beauty and anti-beauty hadrons is presented, probing for the first time the small angular separation region.

1 Introduction

The presented results were obtained by the CMS Experiment [1] using the data accumulated in the year 2010. The obtained data correspond to an integrated luminosity of 40 pb^{-1}. Measurements of b-quark production are relevant for the following reasons: first, the measurements are performed at a new energy scale, second, the possibility to compare the data to the MC results, possibility to check the next-to-leading order (NLO) QCD predictions and third, the obtaining information about the background for Higgs, SUSY and top physics.

2 Exclusive B-meson production cross-section

The CMS collaboration performed the measurement of exclusive productions of B^+, B^0, and B_s mesons [2, 3, 4] in the following decay modes: $B^+ \to J/\psi(\mu^+\mu^-)K^+$; $B^0 \to J/\psi K^0_S$; $B_s \to J/\psi\phi$. For all three decay channels the analysis strategy is similar. The J/ψ candidate is selected as two oppositely charged muons with an invariant mass within 150 MeV of the nominal J/ψ mass. K_S or ϕ candidates are reconstructed requiring two oppositely charged tracks which originate from a common vertex with an invariant mass within 10 MeV of the world average ϕ mass or within 20 MeV of the world average K_S mass. The B candidates are then selected as a combination of a ϕ or a K_S candidate and the J/ψ candidate. The analysis of the B^+ decay is done with the data sample which corresponds to an integrated luminosity of 5.8 pb^{-1}, while the analysis of B^0 and B_s decay channels correspond to 40 pb^{-1}. The two dimensional unbinned maximum likelihood fits to the invariant masses and the proper decay lengths are performed to extract the exact number of signal and background events. The backgrounds are estimated from the data. The main background contribution comes from prompt- and non-prompt J/ψ decays. The results of the cross section measurements are presented in Fig. 1 with comparison to the MC@NLO [6, 7] predictions.

3 Inclusive B production cross section with muons

This analysis [5] is based on the leptonic decays of B-hadrons. The data sample used for this analysis corresponds to an integrated luminosity of 85 nb^{-1}. The offline selection cuts require a standalone muon with $p_T > 3$ GeV/c, a reconstructed primary vertex with more than three tracks, and at least one muon candidate with $p_T > 6$ GeV/c and pseudorapidity $|\eta| < 2.1$. Jets are reconstructed using the anti-k_T jet algorithm [10]. To extract the fraction of signal events from all the events passing the selection cuts a fit to the observed p_T^{rel} was performed, where $p_T^{rel} = |\vec{p_\mu} \times \vec{p_j}|/|\vec{p_j}|$ and p_j is the

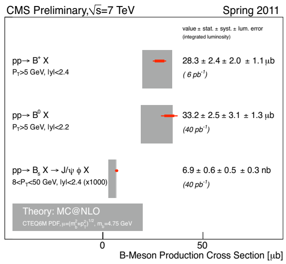

Figure 1: Summary of B meson cross section measurements. The inner error bars of the data points correspond to the statistical uncertainty, the outer error bars correspond to the quadratic sum of statistical and systematic uncertainties. The outermost brackets correspond to the total error, including a luminosity uncertainty.

momentum of the jet and p_μ is the momentum of the muon. The result of a maximum likelihood fit and the estimation from the simulation templates are shown on Fig. 2 (right). The result for the cross-section in the given kinematic region is:

$$\sigma(pp \to b + X \to \mu + X^{'}) = 1.32 \pm 0.01(\text{stat}) \pm 0.3(\text{syst}) \pm 0.15(\text{lumi})\mu\text{b}. \quad (1)$$

The PYTHIA [8] MC generator gives a prediction $\sigma_{PYTHIA} = 1.8$ μb, while the MC@NLO MC generator gives a $\sigma_{MC@NLO} = 0.84^{+0.36}_{-0.19}(\text{scale}) \pm 0.08(\text{m}_\text{b}) \pm 0.04(\text{pdf})$ μb. The differential cross-section as function of the muon transverse momentum and the comparison with the prediction is shown in the Fig.2 (left). The measurement demonstrates reasonable agreement with MC predictions.

4 Inclusive b-jet production cross-section

This measurement [9] is performed using approximately 60 nb^{-1} of collected data. The b-jet production is measured in the kinematic range 18–300 GeV/c and for rapidities $|y| < 2.0$. The jets are reconstructed using the anti-k_T algorithm. The b-jets are tagged using a secondary vertex high-purity tagger (SSVHP [11]). The secondary vertex is fit with at least three charged particle tracks. A selection on the reconstructed 3D decay length significance is applied, corresponding to about 0.1% efficiency to tag light flavor jets and 60% efficiency to tag b-jets at $p_T = 100$ GeV/c.
The differential cross-section of the b-jet production as a function of the b-jet p_T compared to the MC@NLO expectations are shown in the Fig. 3. The measurement shows a reasonable agreement with MC@NLO but significant shape differences in p_T and $|y|$.

5 $B\overline{B}$ angular correlations

In this study [12] $B\overline{B}$ production was measured as a function of the opening angle between between B hadrons for different event scales. To perform the analysis, which requires good angular resolution, a method was introduced based on an iterative inclusive secondary vertex finder that exploits the excellent tracking capabilities of the CMS detector. The data sample used corresponds to an

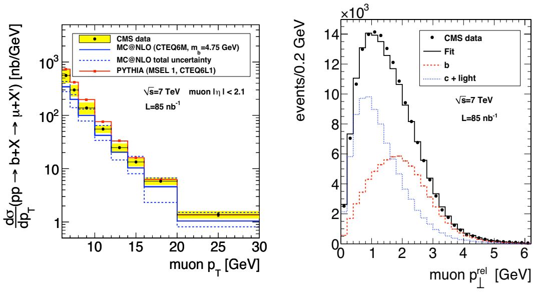

Figure 2: Left: The differential cross-section. The theoretical prediction from MC@NLO and PYTHIA are shown with the lines. The markers represent data points, the band indicates the quadratic sum of statistical and systematic uncertainties. Right: Distribution of the muon p_T^{rel} for b and c+light flavor templates. The black line shows the result of the likelihood fit, the markers show the data points.

integrated luminosity of 3.1 ± 0.3 pb^{-1}. The analysis relies on the single-jet trigger in both the hardware-level (L1) and the high-level (HLT) software components of the CMS trigger system [1]. The visible kinematic range for the measurements is defined at the B hadron level by the requirements $|\eta(B)| < 2.0$ and $p_T(B) > 15$ GeV/c for both B hadrons. The leading jet used to define the minimum energy scale is required to be within $|\eta(jet)| < 3.0$. The differential cross section of $B\overline{B}$ pair production is measured as a function of the angular separation variables (ΔR and $\Delta\phi$) between two reconstructed B-hadrons for three different energy scales. The measured cross-section as a function of ΔR is shown in the Fig. 4 (left). It can be noted that the cross sections at small ΔR values exceed the cross sections observed at large angular separations,where the two B hadrons are emitted in opposite directions.

The measured distributions are compared to the theoretical predictions, based on perturbative QCD calculations. The higher-order processes, such as gluon radiation which splits into $B\overline{B}$ pairs, are anticipated to have a smaller angular separation between the b quarks. The measurement of the $B\overline{B}$ cross -section production ratio as a function of leading jet p_T is shown in the Fig.4 (right) and it can be noted that the production ratio increases with the jet p_T. At the large values of the jet p_T more gluon splitting into $B\overline{B}$ pairs can be expected. This is described by theoretical calculations.

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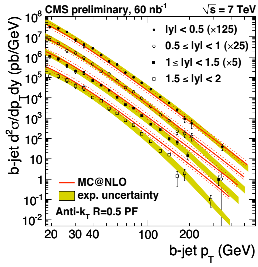

Figure 3: Differential b-jet cross-section. The band indicates the quadratic sum of statistical and systematic uncertainties, not including the luminosity uncertainty. The theoretical prediction from MC@NLO is shown with the lines.

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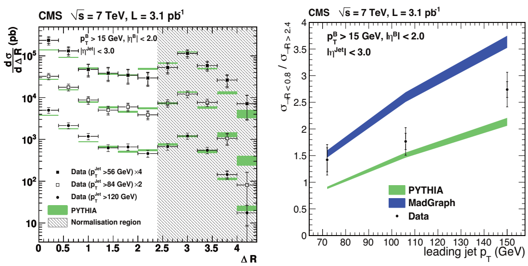

Figure 4: Left: Differential cross-section of $B\overline{B}$ pair production as a function of ΔR. The PYTHIA simulation (shaded) is normalized to the region ΔR as indicated by the shaded normalization regions. Righ: Ratio between $B\overline{B}$ production cross sections in $\Delta R < 0.8$ and $\Delta R > 2.4$. The predictions from PYTHIA and MadGraph [13] MC generators are also shown. For the data points the inner error bars show statistical uncertainty while the outer ones show the systematic uncertainty