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Measurements of b-quark production at 7 TeV with the CMS experiment

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In this article are presented measurements in the beauty sector performed by the CMS experiment in proton-proton collisions at $\sqrt{s}$ = 7 TeV. The total and differential cross sections versus transverse momentum and rapidity for B_d^0, B_s^0, and B^+ mesons are measured, together with the inclusive cross section for $b-\overline{b}$ production, based on fitting the impact parameter of the dimuons coming from the decay of the $b-\overline{b}$ pair. Also, angular correlations between beauty and anti-beauty hadrons, probing for the first time the small angular separation region are determined. Results are compared with predictions based on perturbative QCD calculations at leading and next-to-leading order.

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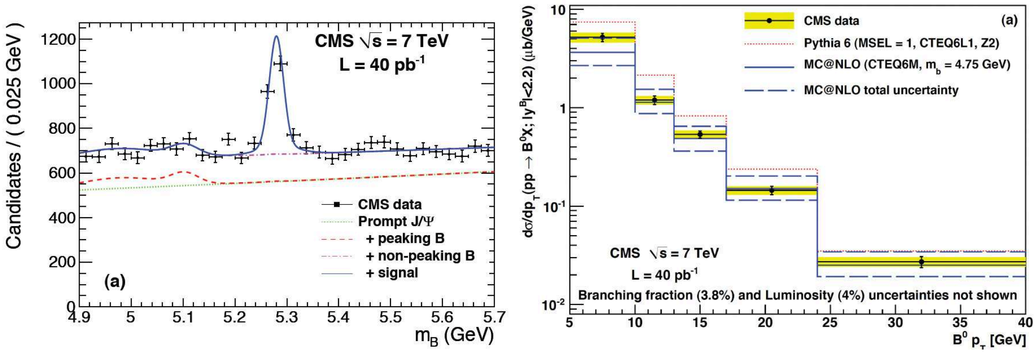

Figure 1: Invariant mass peak and differential cross section ($p_T(B^0_d) > 5$ GeV/c, $|y(B^0_d)| < 2.2$).

1. Differential production cross section in bins of p_T of the B^0_d, B^0_s, B^+ mesons

In this section are presented measurements of the differential production cross section as a function of p_T for B^0_d, B^0_s, and B^+ mesons. All three measurements have the following features in common: J/Ψ candidates are built from muon pairs, which are then combined with 1 (2) tracks from the same vertex to form B^+ (B^0_s) candidates or with 2 tracks from a new vertex consistent with K^0_s mass for B^0_d candidates. A kinematic fit with mass and vertex constraints is then performed. The signal yields are extracted from an unbinned 2-dimensional likelihood fit in variables of B mass and $c\tau$ with shape parameters determined from data as far as possible [1], [2], [3]. Figures 1 and 2 show the invariant mass peaks and the differential cross sections as a function of the B-meson p_T (the B^+ is shown elsewhere [3]). The total cross section for $p_T(B^0_d) > 5$ GeV/c, $|y(B^0_d)| < 2.2$ has been measured to be $\sigma(pp \to B^0_d X) = 33.2 \pm 2.5(stat) \pm 3.5(syst)\mu$b while the MC@NLO prediction is equal to $25^{+9.6}_{-6.2}\mu$b. For 8 GeV/c < $p_T(B^0_s)$ < 50 GeV/c, $|y(B^0_s)| < 2.4$ the total cross section has been measured to be $\sigma(pp \to B^0_s X) \cdot BR(B^0_s \to J/\Psi\phi) = 6.9 \pm 0.6(stat) \pm 0.6(syst)$nb which must be compared to the MC@NLO prediction of $4.6^{+1.9}_{-1.7}$nb. Finally, the total cross section for $p_T(B^+) > 5$ GeV/c, $|y(B^+)| < 2.4$ has been measured to be $\sigma(pp \to B^+ X) = 28.1 \pm 2.4(stat) \pm 2.0(syst) \pm 3.1(lumi)\mu$b, while the MC@NLO prediction is $19.1^{+6.5}_{-1.4}\mu$b. All three MC@NLO predictions are in good agreement with data.

2. Measurement of $\sigma(pp \to b\bar{b}X \to \mu\mu Y)$

The signal fraction is extracted from a template fit to the dimuon impact parameter distribution (d_{xy}). The following classes of muon events have been considered in Monte Carlo: (**B**) $b \to \mu$ (sequential $b \to c \to \mu$ are considered part of the signal); (**C**) $c \to \mu$; (**P**) prompt muons (from primary vertex or hadron punch-through); (**D**) decays in flight ($\pi \to \mu$, $K \to \mu$). The dimuon templates (**BB**, **CC**, etc. . . and combinations) are obtained from single muon ones. The d_{xy} distributions for **B**, **C** and **D** are extracted from simulation while the one for **P** is extracted from Υ(1S) decays in data. The d_{xy} distribution in data is built by taking d_{xy} for the two selected muons in random order. The sources of systematic uncertainties are: template shape - 5.1% (due to detector resolution, b, c hadrons fractions and lifetimes, decays in flight sample); fit method - 4.7% (due

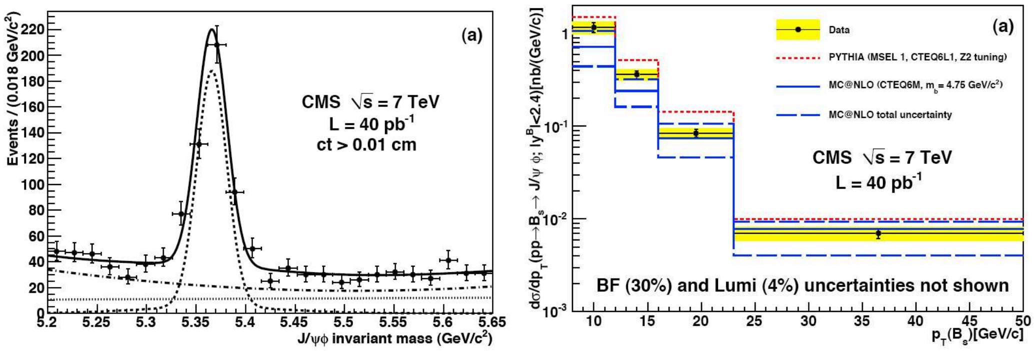

Figure 2: Invariant mass peak and differential cross section (8 GeV/c < $p_T(B_s^0)$ < 50 GeV/c, $|y(B_s^0)| < 2.4$).

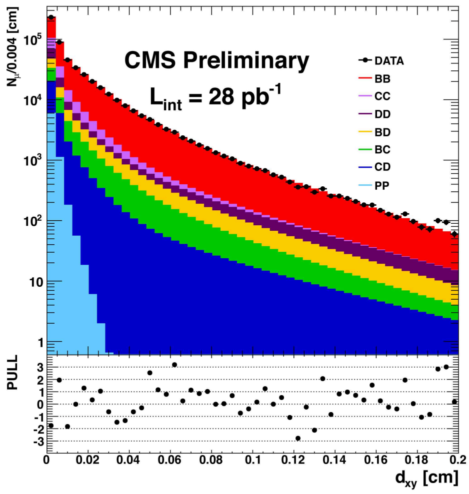

Figure 3: Fit projection superimposed to data. The BB fraction in red is 65.1%±0.3.

to fit constraints - the fraction of mixed events **BC**, **BD** ,**CD** are constrained using simulation); efficiency and normalization - 8.3% (due to statistical uncertainty of the Tag&Probe method); luminosity - 11.4%. The total cross section for $p_T^\mu > 4$ GeV/c, $|\eta^\mu| < 2.1$ has been measured to be $\sigma(pp \to b\bar{b}X \to \mu\mu Y) = 26.18 \pm 0.14(stat) \pm 2.82(syst) \pm 1.05(lumi)$nb while the MC@NLO prediction is equal to $19.95 \pm 0.46(stat)^{+4.68}_{-4.33}(syst)$nb, consistent with data [4]. Figure 3 shows the projection of the result of the fit to the data.

3. $b - \bar{b}$ angular correlations based on secondary vertex reconstruction

The $b\bar{b}$-pair production cross section has been measured as a function of the opening angle for different event scales, characterized by the leading jet transverse momentum. The method is based on an iterative inclusive secondary vertex finder which has the unique capability to detect $b\bar{b}$-pairs even at small opening angles, in which case the decay products of the b-hadrons tend to be merged into a single jet. The variables used for the characterization of the angular correlations between the two hadrons are the difference in azimuthal angles ($\Delta\phi$) and the combination of the difference

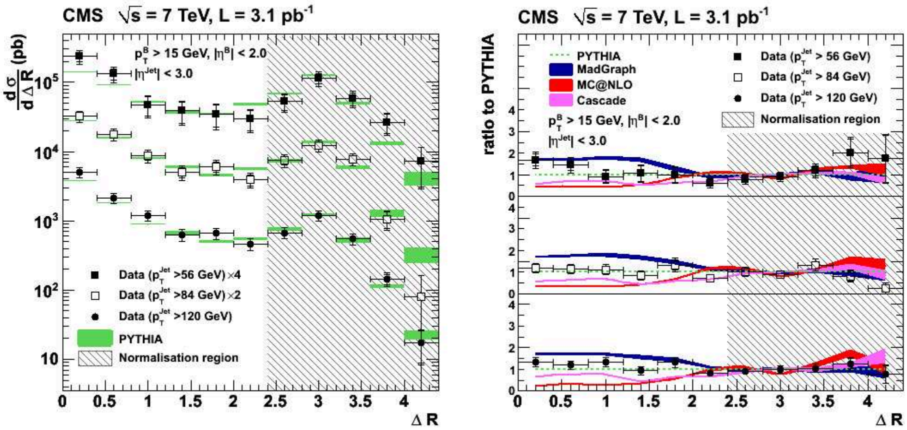

Figure 4: Differential (left) and ratio (right) $b\bar{b}$ production cross section as a function of ΔR for the three leading jet p_T regions (b-hadron kinematic region: $p_T > 15$ GeV/c, $|\eta| < 2$; the regions with $\Delta R < 0.8$ and $\Delta R > 2.4$ are used for comparison or normalization of the simulation).

in pseudorapidities and difference in azimuthal angles $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ (see Fig. 4). The measurements show a substantial enhancement of the $b\bar{b}$ production cross section at small angular separation. Data lie between MADGRAPH and PYTHIA predictions but neither MC@NLO nor CASCADE calculations describe the shape of the ΔR distribution well, especially at small values [5].

4. Conclusions

Measurements of total and differential cross sections for B^0_d, B^0_s, and B^+ have been presented. All MC@NLO predictions are in good agreement with the measurements. The inclusive b-hadron production cross sections have been measured with the decay $pp \to b\bar{b}X \to \mu\mu Y$, finding reasonable agreement with simulations. Instead the $b - \bar{b}$ angular correlation based on secondary vertices shows discrepancies with simulations at small angular aperture where the gluon splitting process is not well described.

References

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