PROCEEDINGS OF SCIENCE

Measurement of the inclusive b production cross section in pp collisions at $\sqrt{s} = 7$ TeV

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This paper presents the measurement of inclusive b production cross section at the central mass energy of 7 TeV in CMS from the PAS BPH-10-007 and PAS BPH-10-009. The measurement are based on two different methods, one of which uses inclusive jets with secondary vertex tagging and the b-jet reconstruction efficiency and the other of which selects a sample of events containing jets and at least one muon whose the transverse momentum with respect to the closest jet axis discriminates b events from the background. At the every beginning of CMS run, 60 nb^{-1} data is used in the b-jet cross section study and jets in the region of $18\,\mathrm{GeV}/c < p_T < 300\,\mathrm{GeV}/c$ and tracker acceptance $|y| < 2.0$ are constructed with the anti-k_T algorithm within cone size $R = 0.5$ using Particle Flow objects. The systematic uncertainty is at 21% and the statistical one is 2%. For the jet with muon cross section is measured with 8.1 nb^{-1}. Events are selected by requiring a good reconstructed muon and the systematic uncertainty is limited to be 20%. At last, both results will compare with the theoretic predictions of Pythia and QCD Monte Carlo predictions at next-to-leading order (NLO).

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1. Introduction

A test of QCD theory is to measure the inclusive b production cross section. This cross section is predicted up to the next-to-leading order (NLO) model in perturbation theory. The Tevatron and HERA experiments have measured the b cross section using b quark decaying into muons and jets[1][2][3][4]. In CMS[5] at LHC, the muons of high quality provide for a clean signal and jets reconstructed using charged tracks only have a good angular resolution and efficiency, even in the low transverse momentum region. However, the theoretical uncertainties are sizeable and measurement of the b hadron production at LHC under a higher energy is another opportunity to test these theoretical models. Here in this proceeding of a poster at HQL10 conference, the contents are from two parts, that using inclusive jets with secondary vertex tagging and the b-jet reconstruction efficiency (PAS BPH-10-009[6]) and selecting a event sample containing jets and at least one good muon (PAS BPH-10-007[7]). The transverse momentum of the good muon with respect to the closest jet axis ($p_{\perp}^{\mu}$) discriminates b events from the background. These two papers offer two different methods to measure the inclusive b production.

2. b tagged jets method

The inclusive jet data is collected and triggered from the Minimum Bias data. Jets are reconstructed with the anti-k_T algorithm, with a clustering corn $R = 0.5$ in Particle Flow objects. The b jets are selected by fitting the secondary vertex, by requiring at least 3 charged particle tracks in pixel. The b-tagging efficiency is from 6% to 60% in region of $|y| < 2.0$ and $p_T > 18\,\mathrm{GeV}/c$ from Monte Carlo (MC) simulation, shown in Fig. 1.

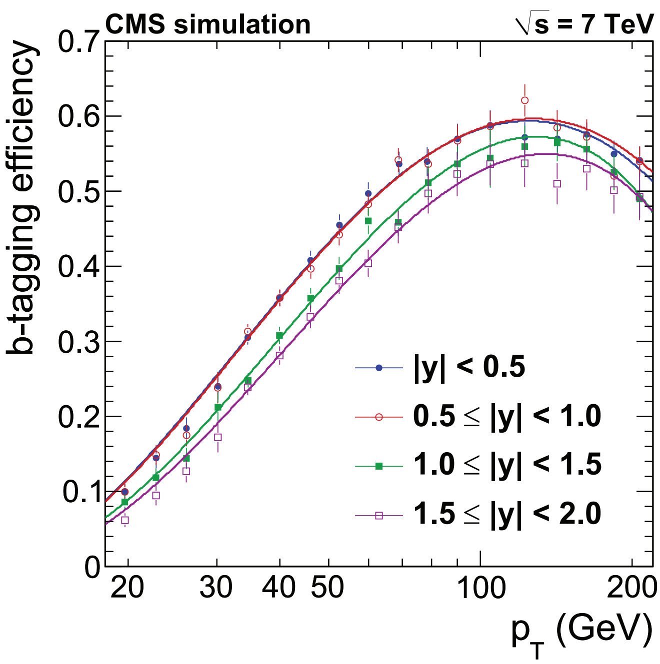

Figure 1: b-tagging efficiency in different rapidity bins.

There are two complementary approaches to measure the b-tagged sample purity. One is to fit the invariant mass of the tracks coming from the same secondary vertex. The data and MC prediction match with each other well, shown in Fig. 2.

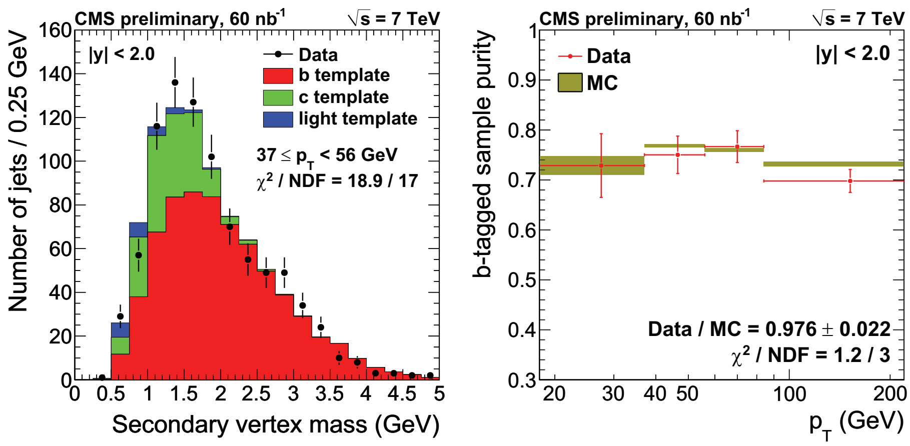

Figure 2: Distribution of the secondary vertex mass fit (left) and the obtained b-tag sample purity (right).

Another method is to calculate the efficiencies and the relative fractions of the signal (b-tag) and background (c-quark and light quark components) from MC simulation. Then the purity could be calculated, as shown in Fig. 3.

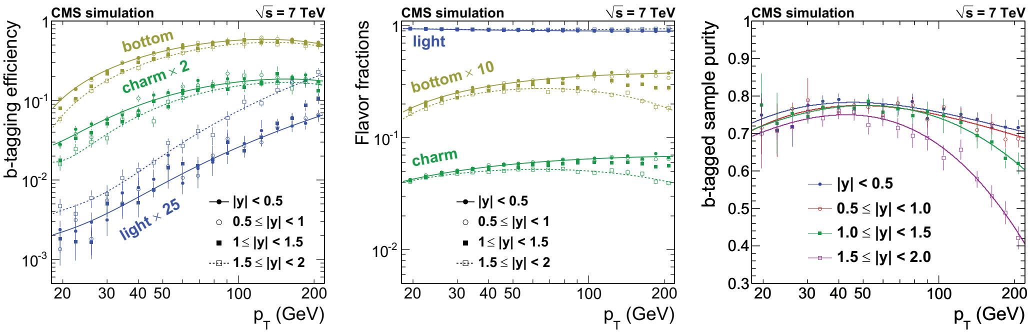

Figure 3: Efficiency of b-tagging and light, charm mistag rates (left), flavor fractions (middle) and the b-tag sample purity (right).

2.1 b cross section

The production cross section for b-jets is calculated as a double differential,

$$\frac{d^2\sigma_{b-jets}}{dp_T dy} = \frac{N_{\text{tagged}} f_b C_{\text{smear}}}{\varepsilon_{\text{jet}} \varepsilon_b \Delta p_T \Delta y \mathscr{L}} \tag{2.1}$$

where $\mathscr{L}$ is the integrated luminosity, N_{tagged} is the measured number of tagged jets per bin, f_b is the fraction of tagged jets containing a b-hadron, C_{smear} is the correction unfolding the measured p_T back to particle level using the ansatz method, ε_{jet} is reconstruction efficiency of jet, ε_b is the reconstruction efficiency of tagging b jets, Δp_T and Δy are the size of transverse momentum and rapidity bin.

Within this 60 nb^{-1} integrated luminosity data, the main systematic uncertainties are the b-tag efficiency (20%) and the charm mistag rate ($3-4\%$), both of which are strongly related to the statistical error from the data-based method. Not only the b-tagging efficiency, but also the b-tagged sample purity and the b-jet energy correlation are constrained by this uncertainty. Other systematic uncertainty sources are b-jet energy scale relative to inclusive jets ($4-5\%$) and light flavor jets mistag rate ($\approx 1-10\%$). Also the correction from data to Pythia is fitted to be a global scale factor of $0.99 \pm 0.02(stat) \pm 0.21(syst)$ in the phase space window $30 < p_T < 150\,\text{GeV}/c$ and $|y| < 2.0$.

The total b cross section of 238μb from the MC@NLO is compared with the measured result, shown in Fig. 4. Also the Pythia prediction is plotted for comparison.

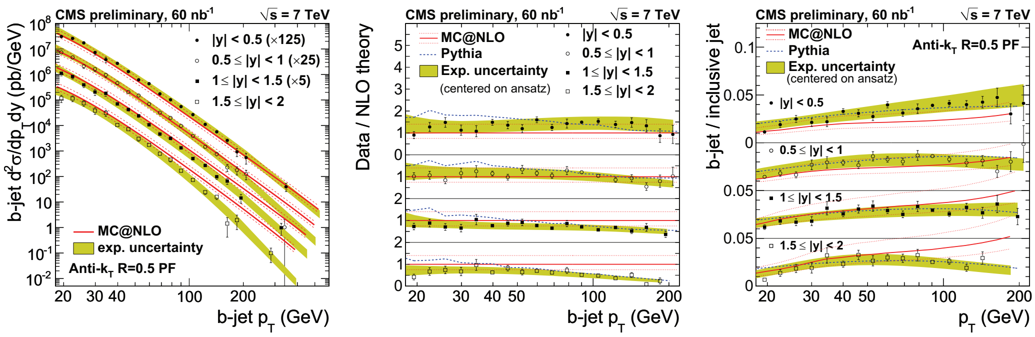

Figure 4: b-jet cross section, compared to the MC@NLO calculation overlaid (left), as a ratio to NLO theory (middle) and as a ratio to inclusive jet cross section (right). The NLO theory and Pythia MC prediction is also shown for comparison.

3. Jets with muon method

In this muon plus jets method, a jet is required firstly. Also a muon reconstructed well is selected with $p_T^{\mu} > 6\,\text{GeV}/c$, $|\eta^{\mu}| < 2.1$, $z_0 < 20$cm, at least 2 pixel hits plus 12 hits in the tracker of both pixel and strip subsystems, $\chi^2/dof < 10$ for both the inner track fit and the global muon track fit. Such a kind of combination could be from b-quark, c-quark and light quark decay. The relative transverse muon momentum with respect to the muon's closest track jet $p_{\perp}^{\text{rel}}$ (shown in Fig. 5) is defined as,

$$p_{\perp}^{\text{rel}} = \frac{|\vec{p_{\mu}} \times \vec{p_{\text{jet}}}|}{|\vec{p_{\text{jet}}}|} \tag{3.1}$$

The $p_{\perp}^{\text{rel}}$ templates are used to fit the experimental data $p_{\perp}^{\text{rel}}$ spectrum for measuring the fraction of b-signal among all events, shown in Fig. 5. The fit also finds the scale factor between the selected b-events in data and that in MC.

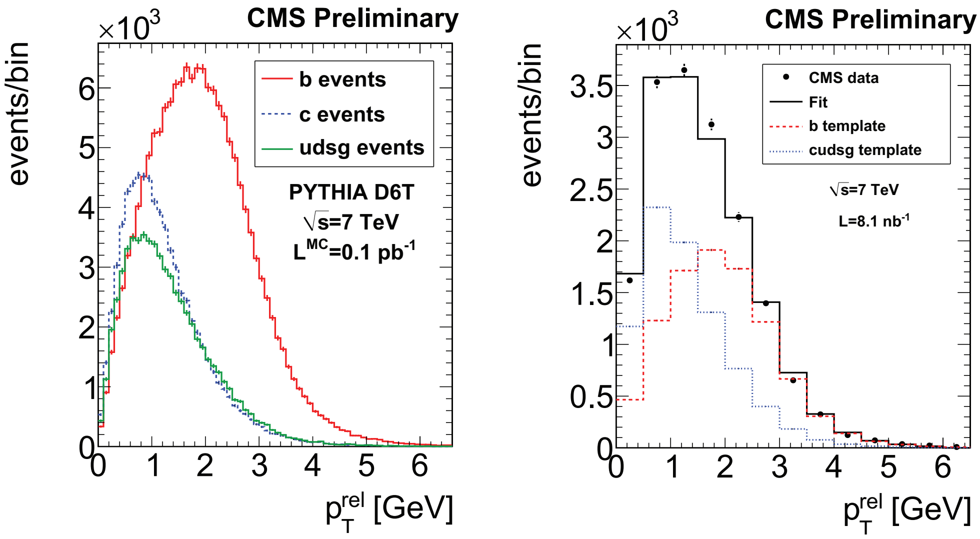

Figure 5: Distribution of the muon $p_{\perp}^{\rm rel}$ in MC (left) and the maximum likelihood fit to data results (right).

3.1 Cross section of $b \to \mu + X'$

The inclusive b-quark production cross section σ is defined as,

$$\sigma \equiv \sigma(pp \to b + X \to \mu + X', p_{\perp}^{\mu} > 6GeV, |\eta^{\mu}| < 2.1) = \frac{N_b^{\rm data}}{\mathscr{L}\varepsilon} \tag{3.2}$$

Number of b-events ($N_b^{\rm data}$) over the integrated luminosity ($\mathscr{L} = 8.1$ nb^{-1}) and efficiencies (ε) of trigger (82% from date), muon reconstruction (97% from MC) and jet (76% from MC) achieve the inclusive b quark cross section, shown in Fig. 6.

Table 1: Summary of systematic uncertainties in the jets with muon method.

source	uncertainty
Trigger	$3-5\%$
Muon reconstruction	3%
Background template shape uncertainty	2%
Background composition	$1-10\%$
Production mechanism	$3-6\%$
Fragmentation	$2-5\%$
Decay	3%
MC statistics	$1-4\%$
Underlying Event	10%
Luminosity	11%
total	$16-20\%$

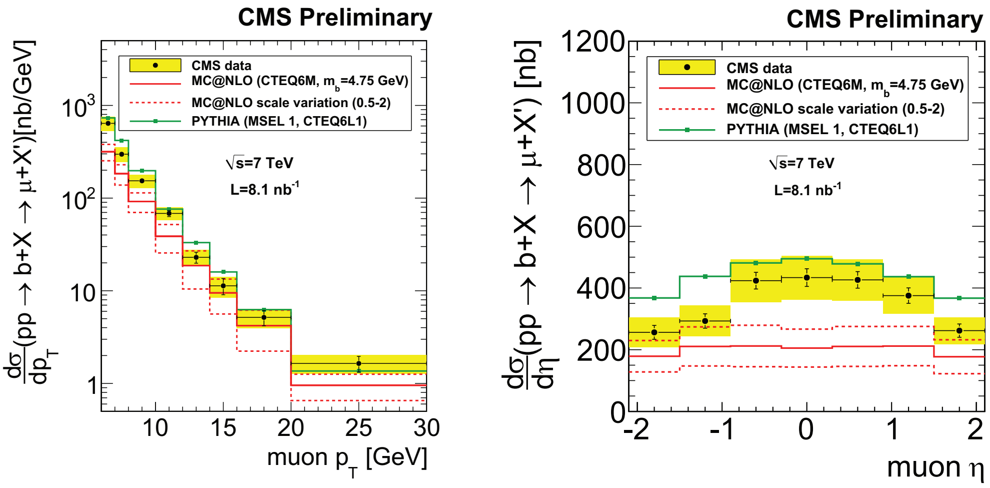

Figure 6: Differential cross section of $pp \to b+X \to \mu+X'$ as a function of muon $p_\perp^{\rm rel}$ (left) and muon pseudorapidity (right). The systematic uncertainty of luminosity (11%) is not included.

4. Conclusion

The production cross sections of b-jets and $pp \to b+X \to \mu+X'$ are studied separately at the CMS central mass energy of $\sqrt{s} = 7$ TeV in two different methods from 60 nb^{-1} and 8.1 nb^{-1} experimental data and compared with several theoretic model predictions, e.g. the MC@NLO using the CETQ6M PDF set and Pythia.

For the 60 nb^{-1} data, the measured results, on both of the b-tagged sample purity and b-jet cross section, meet the MC@NLO and pythia theoretical calculations well, and the systematic uncertainty is estimated to be 21% and the statistical one is 2%. For the 8.1 nb^{-1} data, measured results tends to be higher than the theoretical prediction and the systematic uncertainty is at 20% level, shown in Table. 1.

References

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