Measurement of the inclusive b production cross section in pp collisions at √s=7TeV

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Introduction

This poster presents the measurement of **inclusive b production cross section** at the central mass energy of 7TeV in CMS from the *PAS BPH-10-007* and *BPH-10-009*. The measurements are based on two different methods. The first method (*PAS BPH-10-009, right side*) uses inclusive jets with secondary vertex tagging and the b-jet reconstruction efficiency, while the second method (*PAS BPH-10-009, left side*) selects a sample of events containing jets and at least one muon, where the transverse momentum of the muon with respect to the closest jet axis discriminates b events from the background. The results from data are compared with QCD Monte Carlo predictions at next-to-leading order (NLO).

In the past, Tevatron and HERA experiments have measured the b cross section using b quark decaying into muons and jets. Muons of high quality provide for a clean signal in CMS and jets reconstructed using charged tracks only have a good angular resolution and efficiency, even in the low pT region.

In QCD theory, this cross section is predicted up to the next-to-leading order (NLO) model in perturbation theory. The theoretical uncertainties are, however, sizable and measurement on the b hadron production at LHC under a higher energy is another opportunity to test these theoretical models and the QCD.

Event selection – muon+jets

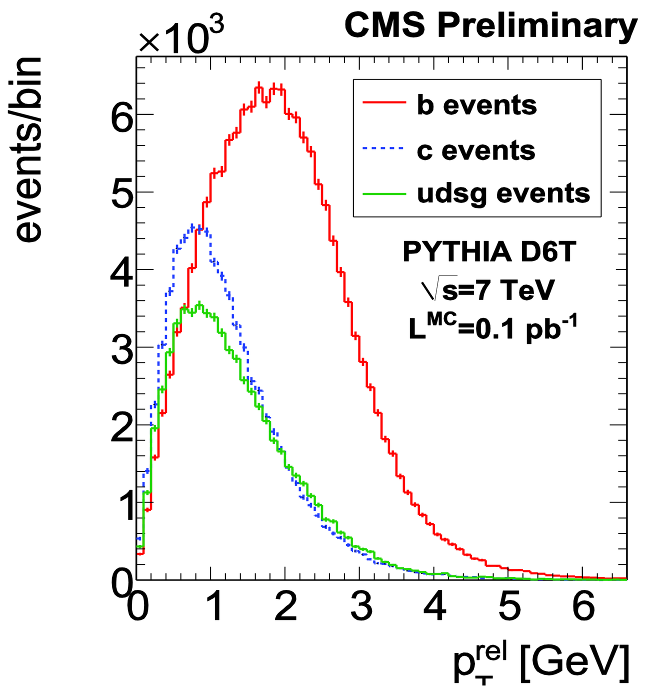


Figure a-1: Distribution of the muon $p^{rel}_{\perp}$ in MC.

A muon reconstructed well is selected with $p^{T}_{\mu}>6GeV$, $|\eta_{\mu}|<2.1$, $|z_0|<20cm$, at least 2 pixel hits plus 12 hits in the tracker of both pixel and strip, $\chi^2/dof<10$ for both the inner track fit and the global muon track fit. A jet is also required in this event. Such a kind of combination could be from b-quark, c-quark and light decay. The relative transverse muon momentum respect to the muon's closest track jet $p^{rel}_{\perp}$ *(shown in Fig. a-1)* is defined as,

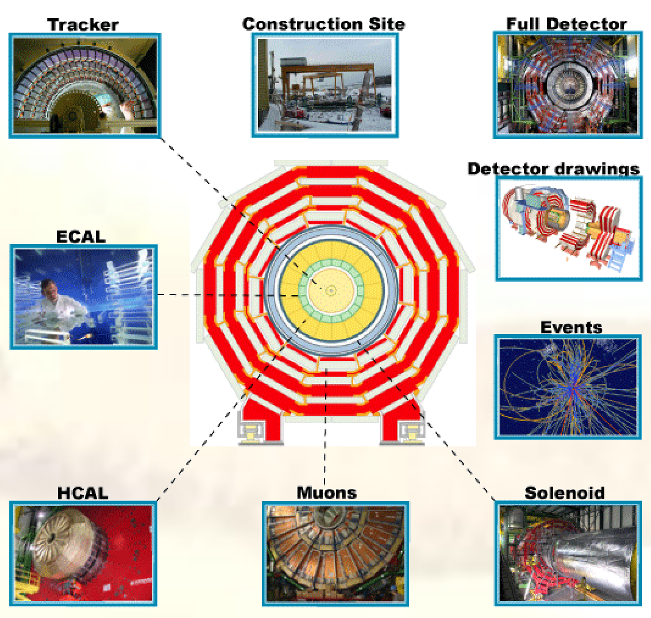
$$p_{\perp}^{rel} = \left|\vec{p}_{\mu} \times \vec{p}_{jet}\right| / \left|\vec{p}_{jet}\right|$$

The inclusive b-jet cross section is calculated as,

$$\frac{d^2\sigma_{b-jet}}{dp_T \cdot dy} = \frac{N_{tagged}\, f_b C_{smear}}{\varepsilon_{jet} \cdot \varepsilon_b \cdot \Delta p_T \cdot \Delta y \cdot L}$$

Where,

- *L is the integrated luminosity,*
- *Δp_T is the size of transverse momentum bin,*
- *Δy is the size of rapidity bin,*
- *ε_{jet} are reconstruction efficiencyof jet,*
- *ε_b are reconstruction efficiency of b,*
- *f_b is fraction of tagged jets containing a b-hadron,*
- *C_{smear} is the unfolding correction,*
- *N_{tagged} is measured number of tagged jets per bin.*



Fit the number of b-events – muon+jets

The $p^{rel}_{\perp}$ template is used to fit the $p^{rel}_{\perp}$ spectrum of experiment data to measure the fraction of b-signal among all events, shown in Fig. a-2. The fit also finds the scale fractor between the selected b-events in data and that in MC.

Number of b-events over the integrated luminosity (8.1nb⁻¹) and efficiencies of trigger (82%), muon reconstruction (97%) and jet (76%) achieve the inclusive b quark cross section.

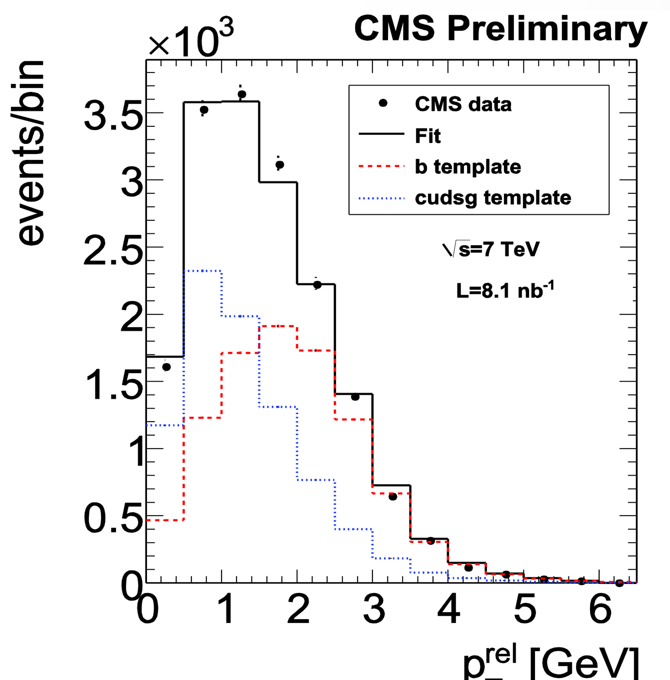


Figure a-2: Muon $p^{rel}_{\perp}$ distribution in data and the results of the maximum likelihood fit.

Systematic uncertainties – muon+jets

source	Uncertainty
Trigger	3-5%
Muon reconstruction	3%
Tracking efficiency	2%
Background template shape uncertainty	1-10%
Background composition	3-6%
Production mechanism	2-5%
Fragmentation	1-4%
Decay	3%
MC statistics	1-4%
Underlying Events	10%
Luminosity	11%
Total	16-20%

Table a-1: Systematic uncertainties of the $pp \to b+X \to mu+X'$ cross section measurement .

Jet events selection and b-tagging – b tagged jets

The inclusive jet data is collected and trigger 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 is selected by fitting the secondary vertex, by requiring at least 3 charged particle tracks in pixel. The b-tagging efficiency is 6%~60% (Fig. b-1) in region of $|y|<2.0$ and $p_T>18GeV/c$ from MC.

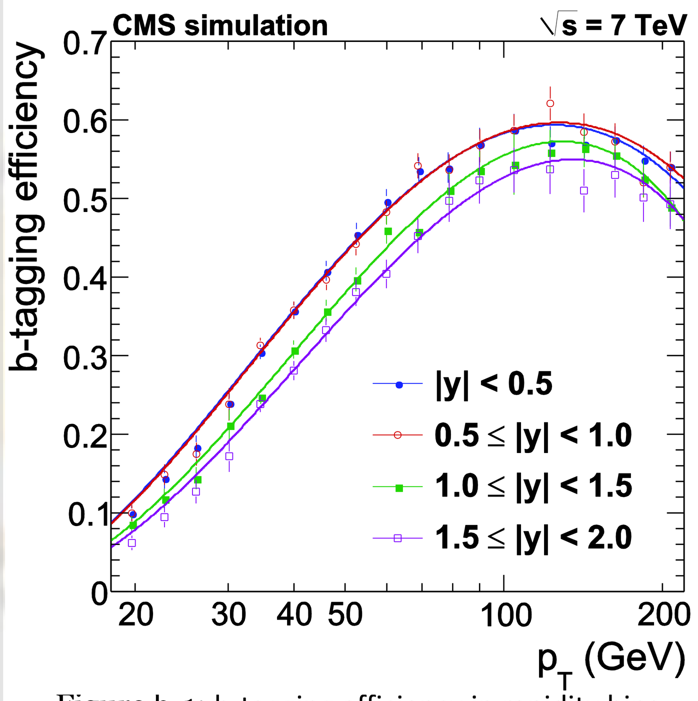


Figure b-1: b-tagging efficiency in rapidity bins.

b-tagged sample purity – b tagged jets

There are two complementary approaches to measure the b-tagged sample purity, one of which is to fit the invariant mass of the tracks associated to the secondary vertex (Fig. b-2, left). The data and MC prediction match with each other well, shown in Fig. b-2 right.

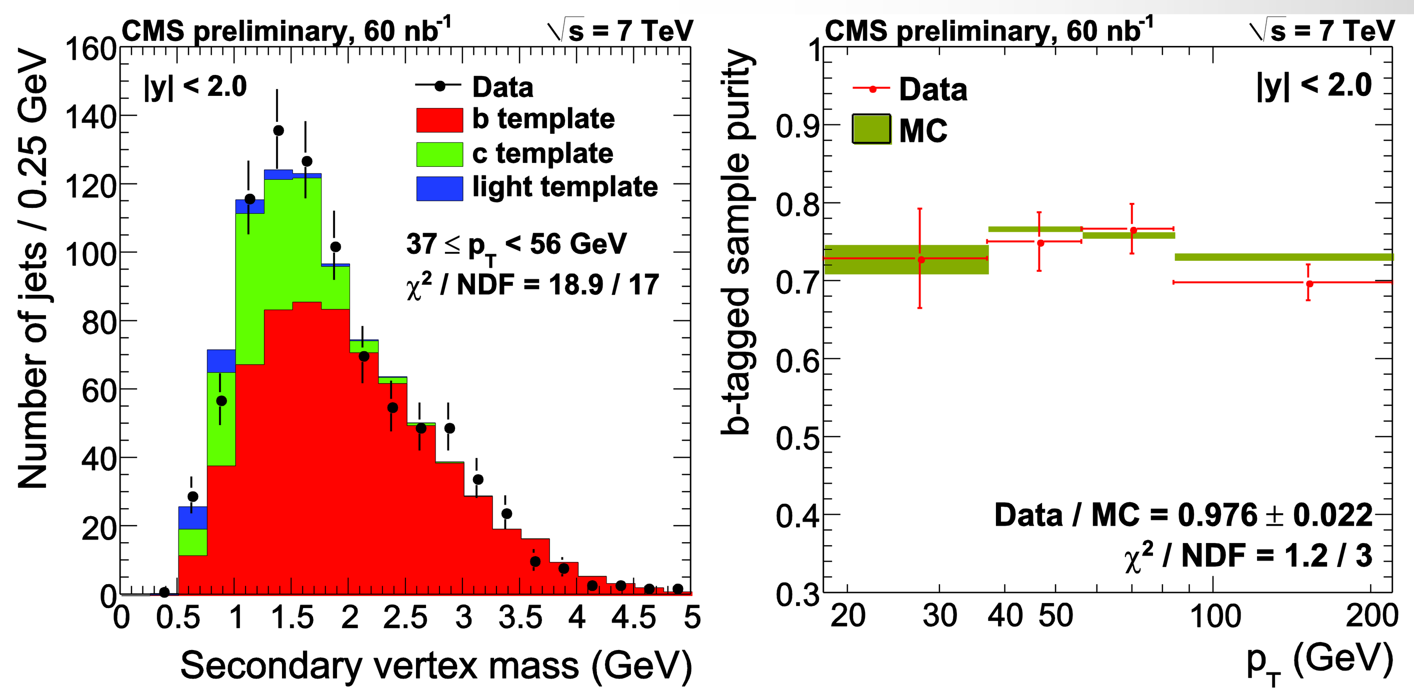


Figure b-2: Distribution of the secondary vertex mass fits (left) and the obtained b-tag sample purity (right).

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

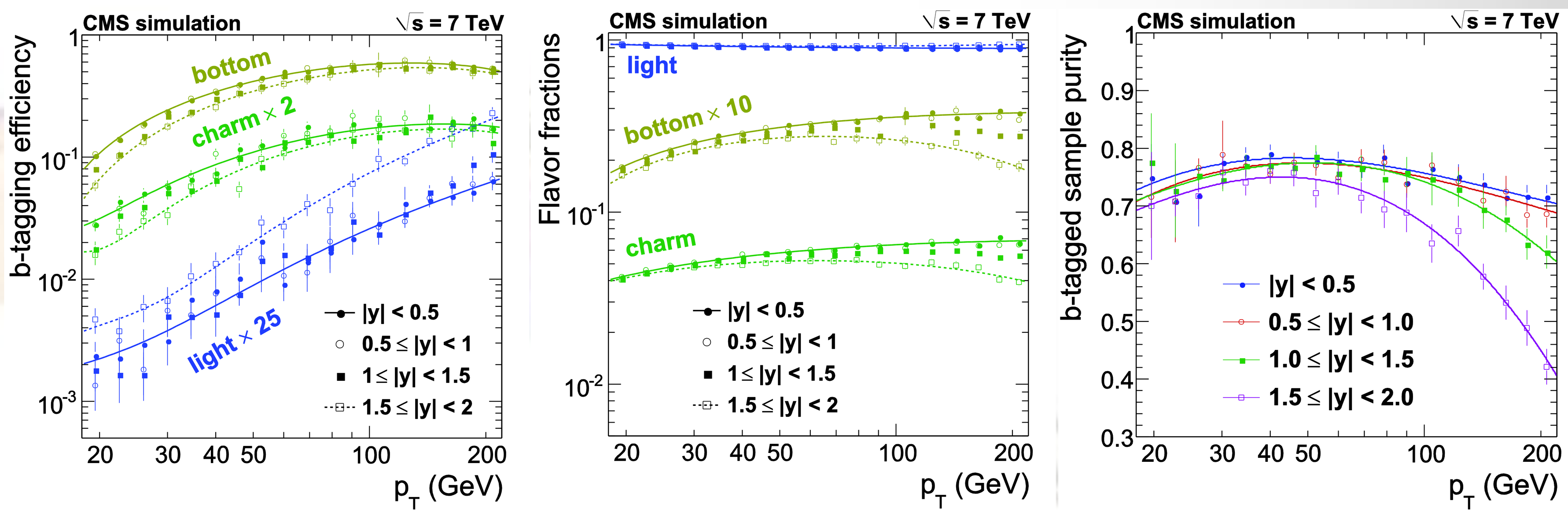


Figure b-3: Efficiency of b-tagging and light, charm mistag rates (left), flavor fractions (middle) and the b-tag sample purity (right).

Within this 60nb⁻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 uncertainties resources are b-jet energy scale relative to inclusive jets (4-5%) and light flavor jets mistag rate(≈1-10%).

Conclusions

The production cross sectiones of $pp \to b+X \to mu+X'$ and *b-jets* are studied separately at the CMS central mass energy of 7TeV in two different methods from 8.1nb⁻¹ and 60nb⁻¹ data and compared with several theoratical model predictions, e.g. the MC@NLO using the CETQ6M PDF set and PYTHIA.

For the 8.1nb⁻¹ data, shown in Fig.c left, the data tends to be higher than the theoretical prediction and the **systematic uncertainty** is at 20% level, see Table a-1, since the binned likelihood fit is used to limit the statistical uncertainty. For the 60nb⁻¹ data, shown in Fig.c right, the measured data results, on both of the b-tagged sample purity and b-jet cross section, meets the MC@NLO and pythia theoretical prediction well and the **systematic uncertainty** is estimated to be 21% and the statistical one is 2%.

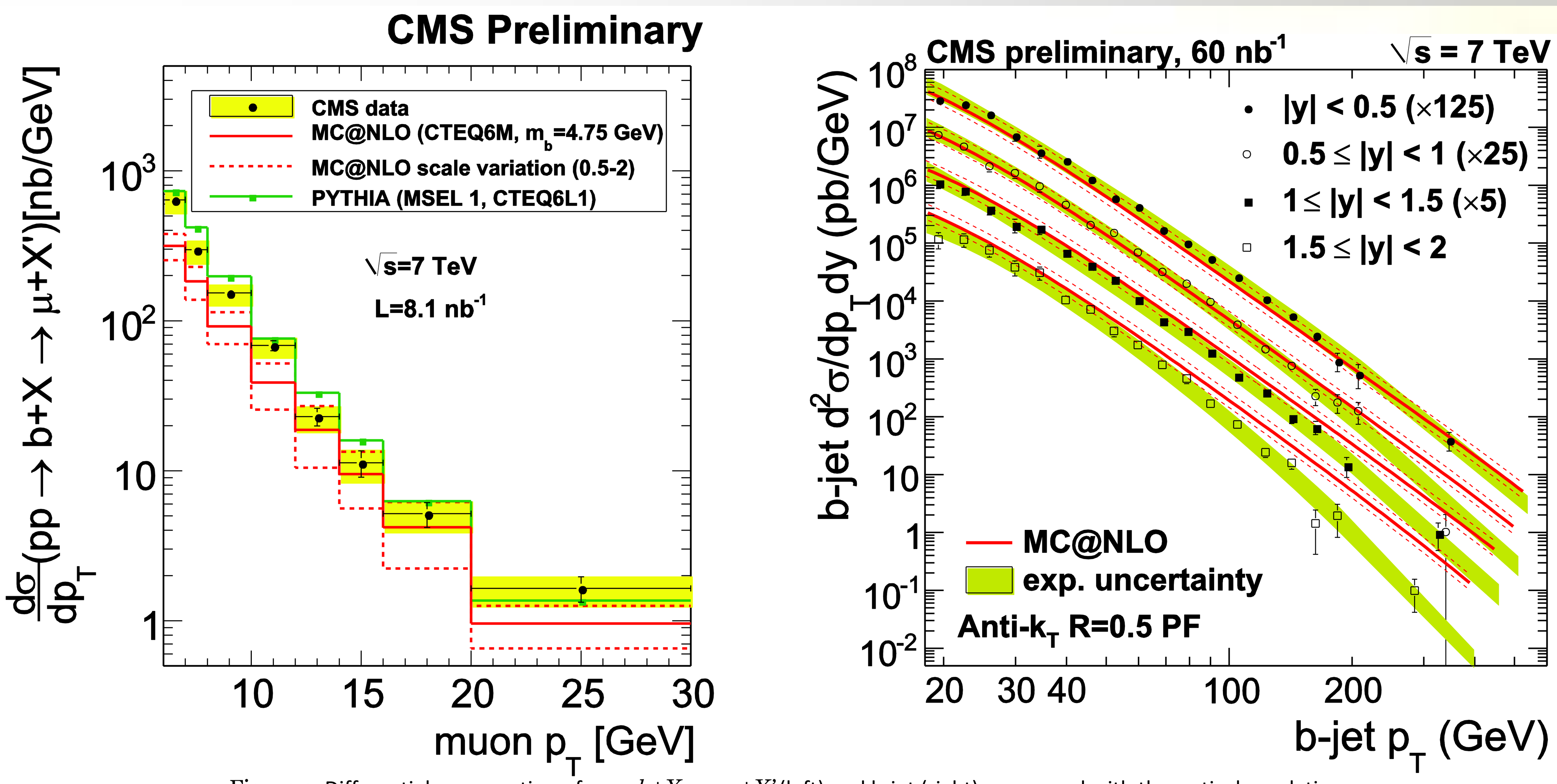


Figure c: Differential cross section of $pp \to b+X \to mu+X'$ (left) and b-jet (right), compared with theoretical caculations.