INCLUSIVE MUON AND B-QUARK CROSS SECTION AT DØ

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ABSTRACT

We report a measurement of the inclusive muon and b-quark production cross sections in $p\overline{p}$ collisions at $\sqrt{s}$ =1.8 TeV using the DØ detector at the Fermilab Tevatron collider. The inclusive muon spectrum, in the kinematic range $|\eta_\mu| < 0.8$ and $3.5 < p_T^\mu < 60.0$ GeV/c, is well described by the sum of all expected sources of muons. The extracted b-quark cross section is in good agreement with next-to-leading order QCD predictions for $|y^b| < 1.0$ and $p_T^b > 7\ GeV/c$.

1. Introduction

The study of b-quark production in high energy hadronic collisions is important for testing the perturbative QCD description of heavy quark production.[1] The fact that next-to-leading order (NLO) terms are as large as the leading order contribution and are very sensitive to the input normalization scale μ suggests that even higher order terms may be significant. A comparison with experimental data should reveal how reliable NLO predictions are. The b-quark integrated p_T cross section measured at $\sqrt{s}$ =0.63 TeV by UA1[2] is in agreement with the theoretical predictions. The corresponding data from CDF[3] at $\sqrt{s}$ =1.8 TeV are consistent with the upper extreme of the theoretical band but a discrepancy is observed for values of transverse momentum (p_T) less than 10 GeV/c. A measurement by DØ experiment provides an independent test of the reliability of the description of heavy quark production within the QCD framework.

This paper presents a measurement of the inclusive muon and b-quark production cross sections at $\sqrt{s}$ =1.8 TeV. The data, which correspond to an integrated luminosity $\int \mathcal{L}\, dt = 73 \pm 8\ nb^{-1}$, were taken in dedicated runs during the 1992-93 Tevatron collider run using the DØ detector.

2. The DØ Detector

DØ is a large multi-purpose detector[4] operating at the Fermilab $p\overline{p}$ collider. It features an inner tracking system, calorimetry for the detection of electrons, jets and missing transverse energy, and a muon system. The inner tracking covers the region $|\eta| < 3$ with wire drift chambers to detect charged tracks. The calorimeter is a uranium–liquid argon sampling device with a thickness of 7 - 9 interaction lengths (λ) and a

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measured fractional energy resolution for pions of $50\%/\sqrt{E}$. The muon system consists of three layers of chambers and 1.9 T magnetized iron toroids located between the first and second layers. The thickness of the calorimeter plus iron toroids varies from 14 λ in the central region to 19 λ in the forward region.

3. Data Sample

The data sample used in this analysis was streamed from two hardware trigger levels (level 0 and 1), and a software level 2. The level 0 trigger used scintillator hodoscopes to select inelastic collisions which occurred within 1 meter of the nominal interaction point along the beam direction. The level 1 muon trigger[5] required that hits in 60 cm wide roads from 2 or 3 layers of muon chambers be consistent with a track pointing to the interaction region. At level 2 at least one muon track must be reconstructed and have a minimum p_T of 3 GeV/c. Events were fully reconstructed offline and were retained for further analysis if they contained at least one muon track within the range $\mid \eta^{\mu} \mid < 0.8$ and $3.5 < p_T^{\mu} < 60.0$ GeV/c. Tracks were required to have a minimum of 1 GeV/c of associated energy in the calorimeter, and a matching track in the central tracking chambers. To ensure a better momentum measurement only tracks with hits in all three layers of chambers were kept and a minimum field integral of 0.6 GeV/c in the toroids was required. Furthermore, to reject cosmic ray muons, the reconstructed time of passage (T_0) through the muon chambers was required to be within 100 ns of the beam crossing.

4. Inclusive Muon Cross Section

The inclusive muon differential cross section was extracted according to the following expression:

$$\frac{d\sigma^{\mu}}{\Delta\eta^{\mu}\ dp_T^{\mu}} = \left(\frac{dN^{\mu}}{dp_T^{\mu}}\right) \frac{[1 - R_c]}{\int \mathcal{L}\ dt\ .\ \epsilon\ .\ \Delta\eta} \tag{1}$$

where N^{μ} is the number of muons passing the offline selection , $\Delta\eta = 1.6$ units of covered η range and R_c is the cosmic ray contamination, estimated to be $R_c = 13 \pm 4\%$. The resulting cross section as a function of the measured muon p_T (p_T^{μ}) is shown in Figure 1. The curves represent the expected different sources of muons using the ISAJET Monte Carlo package[6] convoluted with the muon momentum resolution. The solid curve, which represents the sum of all expected contributions, describes the data very well.

To determine the b-quark fraction (f_b) in the data, muon events from W decays were first removed on an event by event basis by requiring a maximum missing transverse energy ($\not{E}_T$) of 20 GeV/c. This cut rejects about 97% of W and 50% of Z events with an efficiency of $95 \pm 3\%$. Residual W and Z events were estimated and subtracted using Monte Carlo events run through the same offline selection as the data. The remaining events are from b-quark, c-quark, and π/K decays.

The fraction (f_b) was then determined from the Monte Carlo calculation of the spectra shown in Figure 1. Furthermore, it was cross checked using the transverse momentum of the muon (p_T^{rel}) with respect to the associated jet axis (which also includes the muon momentum) for that subset of events which contained a reconstructed jet

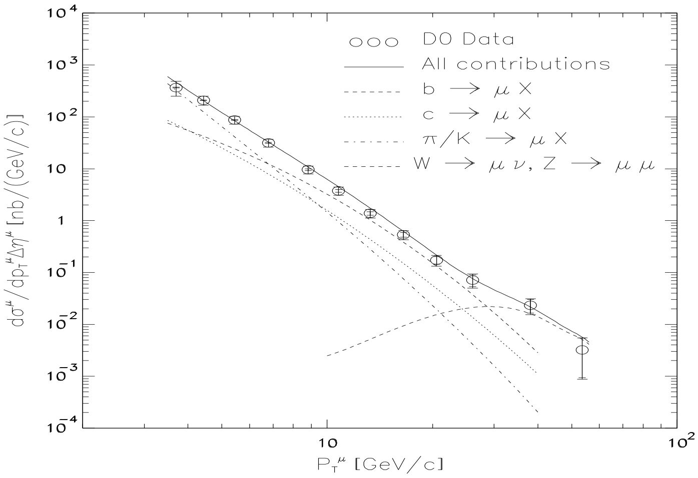

Fig. 1. Comparison between the expected and measured inclusive muon cross section. The errors on the data points are statistical only (inner bars) and total of statistical and systematic added in quadrature (outer bars).

near the muon with $E_T^{jet} > 10\ GeV/c$. The different p_T^{rel} shapes for different flavours were taken from Monte Carlo distributions. They were then fit to the data for different momentum ranges to determine f_b as a function of p_T^μ.

To convert the muon spectrum to a b-cross section, we followed the method previously used by UA1 and CDF.

The integrated b-quark cross section is determined from the following expression:

$$\sigma^b = \sigma^\mu \ . \ f_b \ . \ f_{\mu \to b} \tag{2}$$

where σ^μ is the measured muon cross section integrated over the studied p_T^μ range, and $f_{\mu \to b}$ is given by:

$$f_{\mu \to b} = \frac{\sigma_{MC}^b \left(p_T^b > p_T^{min}, |y^b| < 1.0\right)}{\sigma_{MC}^\mu \left(p_T^{\mu 1} < p_T^\mu < p_T^{\mu 2}, |\eta^\mu| < 0.8\right)} \tag{3}$$

In the above expression, p_T^{min} is the b-quark transverse momentum for which 90% of muons within the range $p_T^{\mu 1}$ - $p_T^{\mu 2}$ come from b-quarks with $p_T^b > p_T^{min}$, σ_{MC}^b is the b-quark production cross section and σ_{MC}^μ is the cross section for producing b-quarks which decay to muons within the concerned range.

The extracted cross section for b-quark production ($\bar{b}$ not included) as a function of p_T^{min}, for $|y^b| < 1.0$, is shown in Figure 2. The data are in good agreement with NLO QCD predictions over the entire measured p_T range. In the plot, both statistic and systematic erros are included. The main sources of systematic errors are the uncertainties in the muon detection efficiency, muon momentum resolution and the model dependence of equation(3).

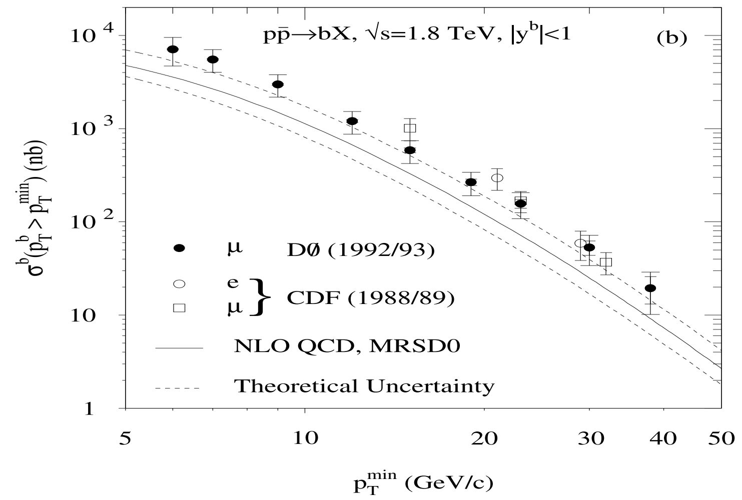

Fig. 2. b-quark production cross section extracted from the inclusive muon data compared to NLO QCD predictions.

5. Conclusions and Prospects

We have measured the beauty quark production cross section using the inclusive muon spectrum at DØ . We find good agreement between the data and theoretical calculations based on NLO QCD. In this sense the data indicates that the perturbative QCD description of the heavy quark production is reliable in our kinematic range.

We are presently using a trigger which includes a jet requirement,[7] in addition to the muon, to enhance the heavy quark content of the data being taken. We have also added scintillator coverage to the top and sides of the detector, to help in the cosmic ray rejection, and installed a new level of trigger(level 1.5) in the forward region to further reduce the rates. We expect to have about 10 times more data and extend the rapidity coverage down to $|\eta| < 3.3$ in the present collider run.

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