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BOTTOM-QUARK PRODUCTION FROM MUON-JET AND DIMUON EVENTS IN $p\bar{p}$-INTERACTIONS AT $\sqrt{s}$ =1.8 TeV

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ABSTRACT

Bottom quark production in $p\bar{p}$-interactions has been measured in the rapidity range $| y^b |< 1$ with the DØ detector at the Fermilab Tevatron collider. The cross section is determined from events containing a muon and jets as well as from dimuon events. Preliminary results are presented based on 197 nb^{-1} and 6.4 pb^{-1} of data for the muon-jets and dimuon analysis, respectively, and are compared to next-to-leading order QCD predictions. The measurements are consistent within errors and are in reasonable agreement with QCD predictions.

1. Introduction

We report measurements of the bottom quark production cross section in proton-antiproton collisions at a center of mass energy of 1.8 TeV. The data were collected at the Fermilab Tevatron Collider during the 1992/93 run. One measurement is based upon data recorded with a trigger requiring a muon-jet coincidence which selects the signal expected from hadronization of a b-quark, followed by a muonic decay of one of the B-hadrons. The second measurement is based on data collected with a dimuon trigger.

Bottom quark production was measured at 0.6 TeV by the UA1 collaboration.[1] The result is in good agreement with the $\mathcal{O}(\alpha_s^3)$ QCD prediction by Nason, Dawson and Ellis,[2] while the CDF experiment has measured b-quark production at the Tevatron collider[3] with results in general above the QCD predictions.

2. Experimental Details

The DØ detector is described in detail elsewhere.[4] Briefly, it is a hermetic large acceptance collider detector with successive layers of tracking, calorimetry, and muon detection. The calorimeter is a uranium-liquid argon sampling device with segmentation 0.1×0.1 in $\Delta\eta \times \Delta\phi$ and $\Delta E/E$ of $0.8/\sqrt{E}$ for jets.

The muon system is a toroidal magnetic spectrometer with 3 sets of proportional drift tubes, a four layer assembly of drift tubes inside and two sets of 3-layer modules separated by 1 m outside the toroid. The momentum of muons is determined from the bending of the track in the 1m thick magnetic field of 2T. The muon momentum

*Representing the DØ Collaboration.

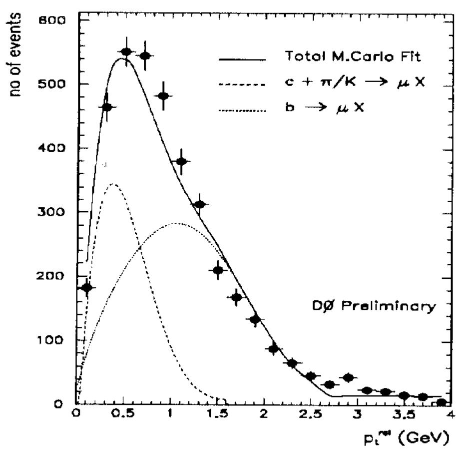

Fig. 1. p_t^{rel}-distribution fit to data

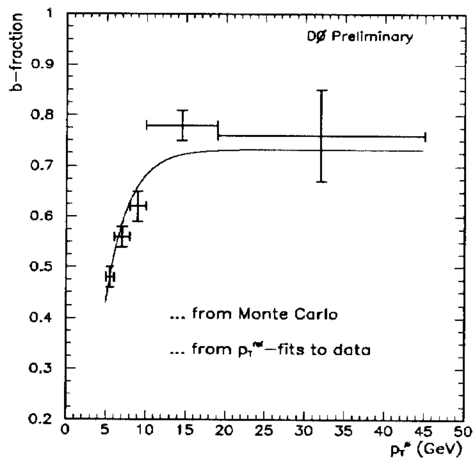

Fig. 2. b-fraction from μ-jets data

resolution is $\Delta p/p = 0.18(p-2)/p \oplus 0.008p$. Muon coverage extends down to $\mid \eta \mid = 3.3$

3. b-Production from Muon-Jets Events

A total of 197 nb^{-1} was collected in dedicated physics runs. The level 1 hardware trigger required 1) a hit pattern in the muon chambers $\mid \eta \mid < 1.7$ consistent with a track pointing back to the interaction region, 2) transverse energy E_t above 3 GeV in a trigger tower of 0.2 in both $\Delta\eta$ and $\Delta\phi$. The level 2 software trigger required at least one good muon track with $p_t^\mu > 3\,\mathrm{GeV/c}$, $\mid \eta^\mu \mid < 1.7$ and a jet with $E_t > 10$ GeV, using a cone algorithm of $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.7$.

Offline selection criteria were chosen to provide good momentum measurement and to reduce cosmic ray background. Muon tracks are restricted to $\mid \eta^\mu \mid < 0.8$, must have hits in all three layers of the muon system and traverse a minimum field integral of 1.9 Tm.

The muon track must be matched, within expected multiple Coulomb scattering deviation, by a track in the central tracking system. Similarly, the impact parameter relative to the interaction vertex must be compatible with a vertex origin for the track. Muon tracks were also required to have matching energy deposition in the calorimeter. To suppress cosmic rays, muons must traverse the muon system within $\Delta T_0 = 100$ ns of the beam crossing. A minimum p_t-cut of $p_t^\mu > 6\,\mathrm{GeV/c}$ was imposed to be above the muon trigger threshold and to ensure a reasonable b-fraction in the data. Standard jet quality cuts reject fake jets due to hot cells and noise in the calorimeter. The jet E_t-threshold was set to 12 GeV.

The extraction of the b-cross section requires knowledge of the efficiency, the fraction of b decays in the data, and a procedure to convert the muon spectrum into the parent b-quark cross-section.

Estimation of efficiencies for trigger, reconstruction and cuts on the data relies mainly on a Monte Carlo simulation which includes the ISAJET event generator,[5] the GEANT detector simulation, trigger simulation and the reconstruction process. The

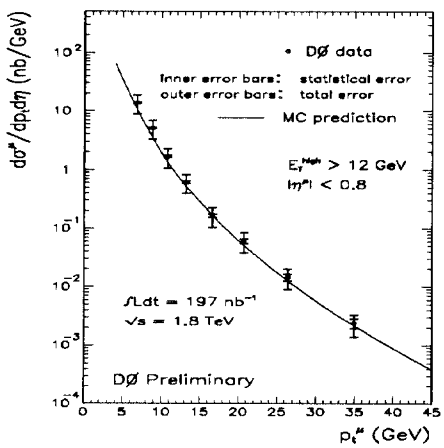

Fig. 3. Differential muon cross section from $b \to \mu X$ processes.

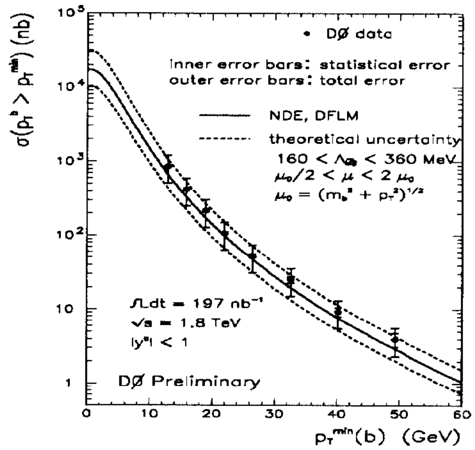

Fig. 4. b-quark cross section from μ-jets production.

triggering efficiencies were checked against appropriate data samples.

The transverse momentum of the muon relative to the jet axis, p_t^{rel}, is proportional to the Q-value of the c or b-decay and can be used to estimate the relative production rates for b and c quarks in the data. Figure 1 shows the measured p_t^{rel} for events with $\Delta R^{\mu-jet} < 1$. The curves show Monte Carlo calculations of p_t^{rel} for b-production and for c and π/K-production combined. The sum of these distributions was fit to the data, giving an overall b-fraction of about 60 %. Muons from W and Z^0-decays are suppressed by the jet requirement.

The b-fraction was taken from the Monte Carlo simulations of b, c, π/K and W-production and is shown in Fig. 2 (smooth line). The fraction was checked against fits of Monte Carlo b and $c + \pi/K$-decays to the data p_t^{rel}-distribution, obtained as in Fig. 1. The data points from the fits are in satisfactory agreement with the Monte Carlo estimate.

Figure 3 shows the differential cross section for muons from bottom quark decay, $d\sigma/dp_t d\eta(p\bar{p} \to bX \to \mu + jet + X)$, with $E_t^{jet} > 12 GeV$. The non-b contribution has been subtracted using the information in Fig. 2, and the momentum resolution has been unfolded using a Monte Carlo calculation. It is compared to an ISAJET prediction, where the b-quark cross-section has been scaled to an NLO calculation.[2]

The measured differential cross section shown in Fig. 3 is transformed into the integrated cross section for b-quark production, $\sigma(p_t^b > p_t^{min})$, for $|y| < 1$ according to the UA1 prescription:

$$\sigma(p_t^b > p_t^{min}, |y^b| < 1.0) = \sigma^{Data}(p_t^\mu > X, |\eta^\mu| < 0.8,\ E_t^{high} > 12\,\text{GeV}) \cdot f_{\mu\to b}^{MC}$$

$$\text{where} \quad f_{\mu\to b}^{MC} = \frac{\sigma^{MC}(p_t^b > p_t^{min}, |y^b| < 1.0)}{\sigma^{MC}(p_t^\mu > X,\ |\eta^\mu| < 0.8,\ E_t^{high} > 12\,\text{GeV})}.$$

Here p_t^{min} is the minimum momentum of b-quarks such that 90% of the decay muons satisfy the jet and muon kinematic cuts. The resulting b-quark cross section is shown in Fig. 4, along with a NLO QCD prediction by Nason, Dawson and Ellis.[2]

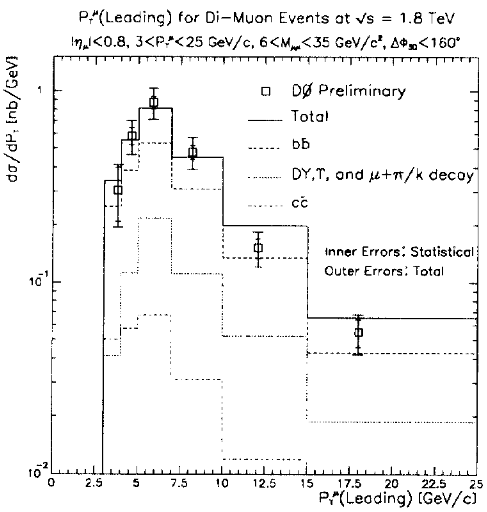

Fig. 5. Differential inclusive dimuon spectrum

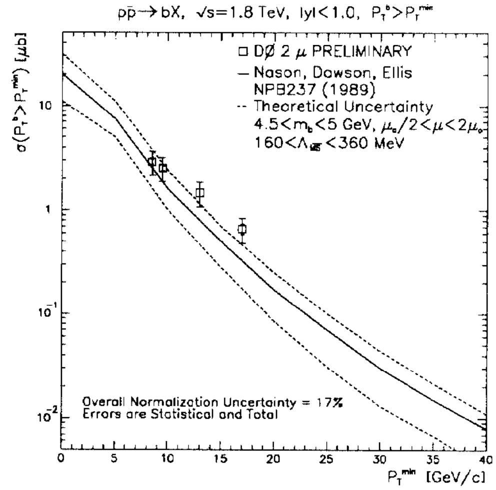

Fig. 6. b-quark production cross-section from dimuon events

Contributions to the systematic error come from uncertainties in the muon efficiency (11%), jet efficiency (30%), cosmic ray subtraction (4%), b-fraction (10%) and integrated luminosity (12%), totalling 36%. The b-cross section is subject to additional uncertainties in the p_t-shape of the b-spectrum in the Monte Carlo (12%), the Peterson fragmentation parameter(15%), the $b \rightarrow \mu$ branching ratio (5%), and the muon decay spectrum (10%), totalling 42%.

4. b-Quark Production from Dimuon Events

The dimuon selection criteria are similar to those applied to the muon-jets analysis, except that no jet requirement was imposed, and that two muons were required at both trigger levels and in the offline selection cuts. The dimuon analysis admits muons which have hits in 2 out of the 3 layers of the muon-system.

Kinematic cuts require both muons to have $3 < p_t^\mu < 25\,\text{GeV/c}$. The upper p_t^μ-cut excludes muons with degraded momentum resolution. A dimuon invariant mass requirement of $6 < M_{\mu\mu} < 35\,\text{GeV/c}^2$ suppresses J/ψ as well as Z^0-decays. Cosmic ray background has been suppressed by requiring a dimuon opening angle of less that 160°. A total integrated luminosity of 6.4 pb^{-1} yielded 562 events after all cuts. Residual cosmic background was estimated using fits to the ΔT_0-distribution.

The muon efficiencies were estimated in a similar way as described for the μ-jets analysis.

The resulting dimuon cross-section as a function of the leading muon p_t has been plotted in Fig. 5. Also shown in Fig. 5 are the ISAJET predictions for the predominant contributions to dimuon production. The muon momentum resolution in the data has been unfolded. The systematic errors on the muon spectrum are 17% due to uncertainties in the muon efficiency (12%), luminosity (12%) and cosmic subtraction (4%).

The b-quark cross section (Fig. 6) was obtained from the muon spectrum by the same method as for the μ-jets analysis. Systematic errors in the muon spectrum are due to the uncertainty in the muon cross-section, b-fraction (20%), b-quark p_t-shape (12%), fragmentation parameterization (15%), branching ratio for $b \rightarrow \mu$ (5%), and the spec-

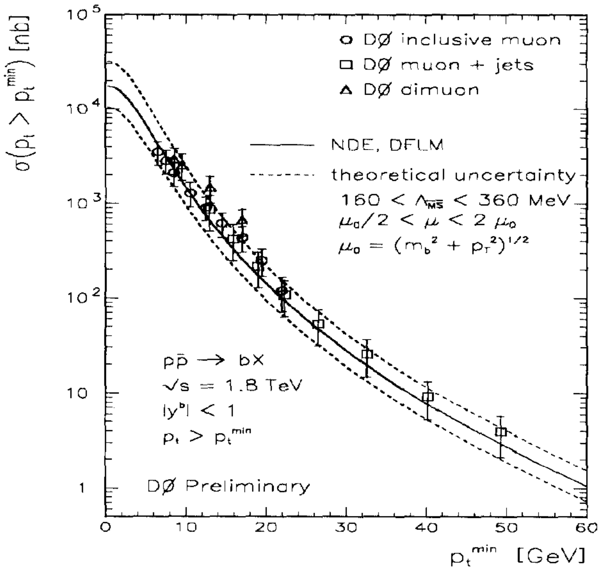

Fig. 7. b-cross section from inclusive muon, μ-jets and inclusive dimuon events

trum of the $b \rightarrow \mu$ decay (10%) in the Monte Carlo. The total systematic error is 34%.

5. Conclusion and Outlook

We have presented preliminary measurements of the b-quark production cross-section from muon-jets and inclusive dimuon events. Both cross-sections, as well as the one derived from DØ -inclusive muon data[6] are shown in Fig. 7. The measurements agree with each other within errors and are in reasonable agreement with NLO theory predictions.

The muon-jets analysis shows good agreement with theory predictions over a large range in p_t^b. The uncertainties are dominated by the error in the jet-efficiency at low E_t^{jet}, further understanding of which will reduce the systematic errors.

The b quark cross section obtained from dimuon events is in reasonable agreement with results from the inclusive muon and muon-jets analyses. Dimuon events can also be used to measure $b\bar{b}$-correlations and to directly separate LO and NLO contributions to be the b-quark cross section.[7]

References

1. C.Albajar *et. al.*, Phys. Lett. **B186** (1987) 237.
2. P. Nason, S. Dawson and R.K. Ellis, Nucl.Phys. **303** (1988); Nucl. Phys. **B327** (1989) 49.
3. F. Abe *et. al.*, Phys. Rev. Lett. **71** (1993) 2396.
4. S. Abachi *et. al.*, Nucl. Instr. Meth. **A338** (1994) 185.
5. F. Paige and S.D. Protopopescu, BNL (1986) 38034.
6. G. Alves, these proceedings.
7. L. Markosky, Proceedings, 27th International Conference on High Energy Physics, Glasgow, July 1994, in preparation.