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The Bottom Quark Cross Section in p-$\bar{p}$ Collisions from Inclusive Decays to Muons

Presented by B. Todd Huffman
for the CDF Collaboration

Fermi National Accelerator Laboratory,
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THE BOTTOM QUARK CROSS SECTION IN P-$\overline{P}$ COLLISIONS FROM INCLUSIVE DECAYS TO MUONS

CDF Collaboration Presented by
B. TODD HUFFMAN
Physics Department, Purdue University
West Lafayette, IN 47907, USA

ABSTRACT

The study of b quarks at high energy hadron colliders tests the Standard Model in regions of small x and high transverse momentum. The method used to measure the b quark cross section using the semileptonic decay to muons is outlined. A preliminary CDF muon cross section is given using data from the 88-89 run, and a plot of the measured b quark cross section compared to other CDF preliminary results is shown.

1. Introduction

1.1. Motivation

The physics of heavy quarks in hadron colliders is calculable in the Standard Model.[1] At CDF the region of small x and high p_t is explored. The measurement of the b quark cross section provides experimental tests of the Standard Model in this region. In these proceedings we present the preliminary measurement of the b quark and muon cross sections using a data sample with an integrated luminosity of $3.79 \pm .26$ pb^{-1}.

1.2. Muon Data Set

The CDF detector is described elsewhere.[2, 3] Muons are collected by a multilevel trigger system.[4, 5, 6] The first level required a track in the muon chamber above a p_t threshold. The second required the muon chamber track to match a charged track in the central tracking chamber (CTC) within $\pm 15°$. Level 3 required the intercepts of the CTC track and the muon track be within 10 cm in the local muon coordinate system.[5]

The following cuts were applied to the muon sample. We required the muon track had $p_t > 12$ GeV/c, that the z position of the track was within 10 cm of the event vertex, and that the impact parameter was less than .15 cm. Additionally the tower traversed by the muon candidate was required to have less than 5.0 GeV of hadronic energy.

Two other cuts required a match between the CTC and the muon tracks. A χ^2 variable was formed of the difference in slope and intercept in the r-ϕ plane weighted by the expected variance from multiple scattering. Additionally we cut on the weighted intercept difference in the r-z plane. We required $\chi^2 < 10.0$ and

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Table 1: The fraction of muons measured using a fit to muon and hadron distributions in $|\eta|$. The χ^2 per degree of freedom is also shown (there are 18 degrees of freedom).

p_t bin	muon+DIF frac.	fit error	χ^2 per D.O.F.
12 – 17 GeV/c	.55	±.01	.69
17 – 22 GeV/c	.47	±.04	.64

$|\Delta I_z/\sigma_{Iz}| < 3.0$.

2. Backgrounds

2.1. Non-interacting Punch-through

A kaon or pion may pass through the calorimeter without showering. In order to measure this background one uses the fact that a track with larger $|\eta|$[1] passes through more steel. The punch-through probability (P) goes as:

$$P = \exp(-\Lambda/\sin\theta) \tag{1}$$

where Λ is the number of absorption lengths at normal incidence. After correcting for edge effects, Eq.(1) plus a line function with a slope of $-.17$ are fit to the data distribution in $|\eta|$ yielding the relative proportion of hadrons and muons+decays (DIF). Table 1 shows the fit results for the two muon transverse momentum bins. There is an additional estimated systematic uncertainty of ±.027 in the muon fractions.

2.2. Decays-in-Flight

There is no straightforward method of measuring the decay background in the muon data. Using the inclusive charged particle spectrum one can, however, calculate the decay-in-flight background. The inclusive charged particle spectrum was collected under a special trigger that required a track in the CTC above a p_t threshold of 7 GeV/c.

5000 kaons and pions were each simulated at integer p_t and forced to decay prior to reaching the inner wall of the muon chamber. Hadrons showering before decaying were not included. The tracks were reconstructed and the offline cuts applied. The result was weighted by the inclusive charged particle spectrum and is insensitive to the K/π ratio. This is corrected for the offline cut efficiencies and subtracted from the muon candidates after removal of the hadronic background.

3. The Muon Cross Section

The background subtracted sample of muons must be divided by the trigger efficiency (ϵ_{trig}), the offline cut efficiency (ϵ_{off}), the acceptance in $-1 < y < 1$, and the integrated luminosity of the muon data. Additionally, the fraction of muons from charm decays must be estimated and removed.

[1] $\eta = \ln\cot(\theta/2)$ where θ is measured from the beam line.

Table 2: The preliminary muon cross section from b quarks integrated over 5 GeV/c bins.

σ_μ from $b+\bar{b}$ quarks integrated over 5 GeV/c	
p_t	σ_μ
12 – 17 GeV/c	$3.83 \pm .27 \pm .51$ nb
17 – 22 GeV/c	$.54 \pm .13 \pm .08$ nb

The offline cut efficiency was measured using cosmic rays, W and Z bosons, and J/Ψ decays. The hadron energy cut was estimated using a detector simulation and the ISAJET b-$\bar{b}$ Monte Carlo. The combined cut efficiency is about 75% based on those sources. The trigger efficiency was measured elsewhere[7] and a value of $\epsilon_{trig} = .90 \pm .02$ was used here. The detector acceptance is $.421 \pm .002 \pm .011$ in a rapidity range from $-1 < y < 1$.

The charm fraction was estimated at $N_c/N_b = .15 \pm .08$ using the ISAJET Monte Carlo and varying the relative fragmentation of b and c quarks to B and D mesons. The muon cross section from b quark decays is shown in Table 2 with the statistical and estimated systematic errors.

4. b Quark Cross Section

$$\sigma_{p_t^b > p_t^{min}} = \frac{1}{2}\sigma_{\mu\, data}\frac{\sigma_{MC}(p_t^b > p_t^{min})}{\sigma_{MC}(12 < p_{t\mu^-} < 17)} \tag{2}$$

Eq.(2) shows the method used to convert a muon cross section into a b cross section.[8] The value of p_t^{min} is set by running ISAJET and requiring 90% of the b quarks have $p_t^b > p_t^{min}$ that decayed into muons with transverse momentum in the given range. The factor of 1/2 corrects for using both μ^+ and μ^- in the data. The final result with other CDF measurements is displayed in Figure 1. This is also shown in the DPF conference proceedings by Avi Yagil.

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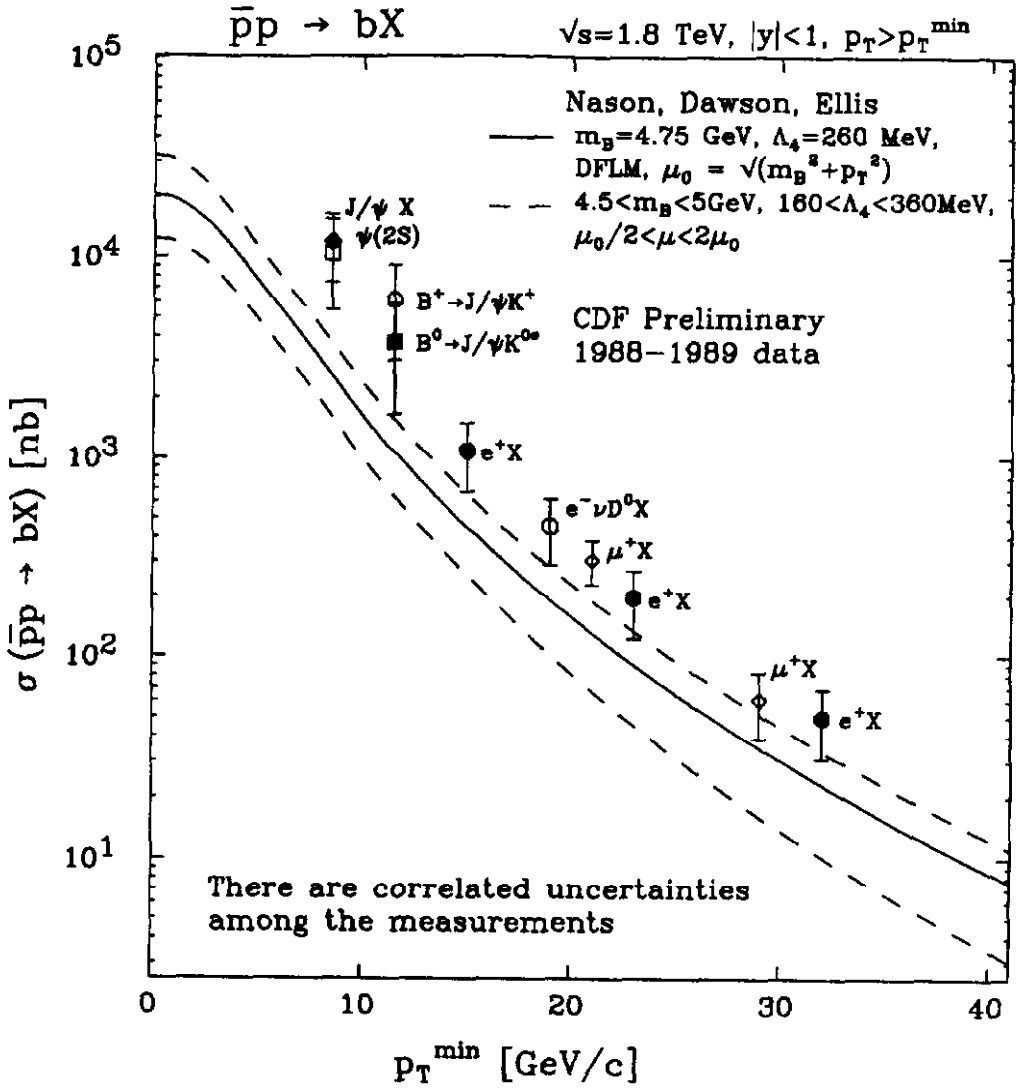

Figure 1: Preliminary cross section for the production of b quarks with $p_t^b > p_t^{min}$ from inclusive muon decays. The data points are shown along with the theoretical plot from Nason, Dawson, and Ellis. The data points from inclusive muons include the muon cross section statistical and systematic errors added in quadrature.