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Measurement of the Bottom Quark Cross Section in $\bar{p}$-p Collisions using the Exclusive Decay $B^0 \rightarrow J/\psi\ K^{0*}$

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MEASUREMENT OF THE BOTTOM QUARK CROSS SECTION IN $\overline{P}$-P COLLISIONS USING THE EXCLUSIVE DECAY $B^0 \to J/\psi K^{0*}$

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ABSTRACT

A measurement of the b quark cross section in $\bar{p}p$ collisions is presented for b quarks with P_T above 11.5 GeV/c and rapidity $|y| < 1.0$. The measurement is based on reconstruction of the exclusive decay $B^0 \to J/\psi\ K^{0*}$ in data taken with the CDF detector in the 1988-89 Collider run. The measurement is compared to other CDF preliminary results and to theoretical predictions.

1. Introduction

Measurements of the b quark cross section at colliders are of interest as a test of perturbative QCD. Predicted production cross sections for b quarks at collider energies have been available for several years now [1]. The predicted b quark production rates are characterized by two energy scales. On the one hand, the b quark mass is much larger than the QCD parameter Λ, so that there is some hope that perturbative QCD may be applicable to b quark production. On the other hand, the b quark mass is much smaller than the center of mass energy of the colliding hadrons. This means that the partons initiating the collision will typically carry low values of x, the fraction of the colliding hadron momentum carried by the parton. For b quark production at Tevatron energies, x can be as low as 0.01. At these values of x, the gluon distribution function in particular has not been well measured.

Experimentally, CDF has demonstrated the ability to reconstruct B mesons using the the decay $B^+ \to J/\psi K^+$ [2] The decay $B^0 \to J/\psi\ K^{0*}$ has been measured to have approximately the same branching fraction [3] and one would therefore expect to have success with this mode as well.

2. Detector and Trigger

The CDF detector has been described in detail elsewhere [4]. The central components ($|y| < 1$) of the detector which were used for this measurement include a vertex time projection chamber for measurement of the location of the interaction vertex, a drift chamber for measurement of charged particle momentum, electromagnetic and hadronic calorimetry, and muon chambers.

For the 1988-1989 run, CDF implemented a multi-level triggering system [5]. For the dimuon triggers used in this analysis to tag $J/\psi \to \mu\mu$ events, the Level

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One trigger decision was based on hits observed in the muon chambers which were consistent with a muon P_T above a preset threshold. At Level Two, muon candidates were required to be associated with tracks in the tracking chamber having P_T also above a preset threshold.

Two dimuon triggers were implemented during nonoverlapping portions of the run. The two triggers differed chiefly in the P_T requirements made on the muon candidates. These triggers were

- The 5_2 Trigger which required two muon candidates identified at Level One with P_T above 2 GeV/c. At Level Two, at least one muon must have been identified with a P_T above 5 GeV/c. An integrated luminosity of approximately 1.7 pb^{-1} was recorded with this trigger in use.
- The 3_3 Trigger required at least two muons identified at both Levels One and Two. Both muons were required to have P_T larger than 3 GeV/c. A luminosity of approximately 2.6 pb^{-1} was recorded while this trigger was in use.

3. Monte Carlo Studies

A Monte Carlo and full detection simulation were used to establish the cuts and efficiencies used to isolate the B^0 signal.

By studying the kinematics of reconstructed B^0's produced by the Monte Carlo, the following cuts were observed to be efficient for accepting B^0's while rejecting combinatoric background:

- The P_T of Kaons was required to be above 1 GeV/c.
- The P_T of Pions was required to be above 500 MeV/c.
- K^{0*} candidates were formed by combining oppositely signed charged tracks and assigning them Kaon and π mass hypotheses. A mass window was then defined around the world average mass of ± 50 MeV/c^2, or approximately twice the natural width of the K^{0*} .
- Trigger dependent P_T cuts on the muon candidates were required in order to ensure that the trigger efficiency was well understood. For muons which satisfied the 3_3 trigger, the P_T of both muons was required to be above 3 GeV/c. For muons which satisfied the 5_2 trigger, the muon with the larger(softer) P_T was required to have P_T above 5(2) GeV/c.

Since CDF cannot distinguish between charged pions and Kaons, any pair of charged tracks can lead to two K^{0*} candidates. The Monte Carlo studies indicated that after all cuts are imposed, approximately 20% of the reconstructed events contain two B^0 candidates with masses close to that of the B^0 and originating in double counted K^{0*} candidates. In real data, this would lead to an overestimate of the signal by about 10%. In order to avoid double-counting these events, only one B^0 candidate was considered for any pair of charged tracks forming K^{0*} candidates.

When more than one B^0 candidate was present, the combination with a K^{0*} mass closer to the world average K^{0*} mass was kept and the other combination discarded.

The effiency for the above selection procedure was found to be $1.55^{+0.34}_{-0.45}\%$ for the 5_2 trigger and $1.43^{+0.23}_{-0.35}\%$ for the 3_3 trigger. The main source of uncertainty stems from the trigger efficiencies. These efficiencies are quoted for $P_T(b) > P_T^{MIN} = 11.5$ GeV/c Since the shape of the b quark P_T distribution is assumed to be known, the value of P_T^{MIN} is a matter of convention. The value taken here is defined such that approximately 90% of the B^0's reconstructed from the Monte Carlo sample originate from b quarks with a P_T larger than P_T^{MIN}.

4. Data

With the above set of cuts, the combined J/ψ sample (4.3 pb^{-1}) from the 1988-1989 data was examined for evidence of a B^0 signal. In order to establish the presence of a signal, the P_T cuts on the muons were relaxed to 2 GeV/c. Without the removal of 'double-counted' events, the full data set showed an excess of 11.4 ± 4.9 events above background with a mass within 1.5 standard deviations of the world average mass and a width which was consistent with that expected from Monte Carlo studies.

The observed events were then sorted according to trigger and the remaining cuts required to obtain a cross section were imposed. From these events, individual cross sections were arrived at from each trigger sample. The number of events resulting from a fit to the mass distributions indicated 3.3 ± 2.8 and 5.8 ± 2.9 events on the 3_3 and 5_2 triggers respectively. The indiviual cross sections taken from each trigger were then averaged using a maximum likelihood technique to arrive at an average cross section of $3.8 \pm 1.2^{+1.7}_{-1.8}$ μb, where the errors represent the statistical and systematic errors respectively.

5. Conclusions

CDF has reconstructed B^0 mesons using the decay mode $B^0 \rightarrow J/\psi\ K^{0*}$. Using the observed signal, the b quark cross section was estimated for b quarks with P_T above 11.5 GeV/c and in the central region to be $3.8 \pm 1.2^{+1.7}_{-1.8}$ μb. As with other CDF measurements of the b quark cross section [6], this value exceeds the predicted value. The measurement presented here is approximately 1.4 standard deviations above that predicted by Nason, et al.

6. References

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