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Measurement of the B meson and b quark cross sections at $\sqrt{s} = 1.8$ TeV using the exclusive decay $B^0 \to J/\psi K^*(892)^0$

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This paper reports the measurement of the B meson and b quark cross sections through the decay chain $B^0 \to J/\psi K^*(892)^0$, $J/\psi \to \mu^+\mu^-$, $K^*(892)^0 \to K^+\pi^-$, using 4.3 pb^{-1} of data collected at the Collider Detector at Fermilab in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV. We obtain $\sigma_B = 1.5 \pm 0.7(\text{stat}) \pm 0.6(\text{syst})$ μb for B^0 mesons with transverse momentum $P_T > 9.0$ GeV/c and rapidity $|y| < 1.0$. Using this result, we find $\sigma_b = 3.7 \pm 1.6(\text{stat}) \pm 1.5(\text{syst})$ μb for b quarks with $P_T > 11.5$ GeV/c and rapidity $|y| < 1.0$. The b quark cross section is compared to next-to-leading order QCD calculations and previous measurements.

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This paper reports the measurement of the B^0 meson and b quark cross sections in $\bar{p}p$ collisions at $\sqrt{s} =$ 1.8 TeV through the decay chain $B^0 \to J/\psi\ K^*(890)^0, J/\psi \to \mu^+\mu^-, K^*(892)^0 \to K^+\pi^-$. Cross section measurements for b quark production using the charged B meson decay, $B^\pm \to J/\psi K^\pm$ [1], and inclusive B meson decays to J/ψ and $\psi(2S)$ [2] have been reported previously by this experiment. The cleanly identified J/ψ signal, in combination with associated charged tracks, allows the reconstruction of B meson final states with low branching ratios. The J/ψ final state has been shown previously by the UA1 experiment at CERN [3] to be a good signature for tagging the production of B mesons at a hadron collider. The measurement described here provides further evidence for the large B meson cross section at $\sqrt{s} = 1.8$ TeV in $\bar{p}p$ collisions.

The B mesons observed at the Fermilab Tevatron collider are a result of the production and fragmentation of b quarks formed in $\bar{p}p$ collisions. The b quark is assumed heavy enough that its production cross section can be calculated as a perturbation series in the QCD running coupling constant α_s. A calculation of the total and differential cross section for b quark production, including $O(\alpha_s^3)$ radiative corrections, is available [4,5]. This calculation is sensitive to a number of parameters, including the b quark mass, Λ_{QCD}, the choice of gluon structure function, and the contribution of higher order terms. The exact magnitude and shape of the gluon structure function for $x \sim 0.01$, the kinematic region appropriate to this experiment, is of considerable theoretical and experimental interest [6]. In this paper, we present a measurement of the b quark and B meson cross sections using two data samples obtained with separate triggers, having a combined integrated luminosity of 4.3 ± 0.3 pb^{-1}, and accumulated with the Collider Detector at Fermilab (CDF).

The CDF has been described in detail elsewhere [7,8]. The events used in this analysis were collected using a multilevel trigger system [9–12]. The first level required the presence of a track segment in the muon chambers. The second level required the muon chamber tracks to match charged tracks in the central tracking chamber (CTC). In addition, for the first data sample of 1.7 ± 0.1 pb^{-1} (the dimuon_5_2 sample), both muons in the level-one trigger were required to satisfy a threshold which had a P_T-dependent efficiency of $(54 \pm 9)\%$ at $P_T = 2.0$ GeV/c, rising to $(92 \pm 6)\%$ for $P_T > 5.0$ GeV/c. At level two, the requirement for this sample was that at least one muon match to a charged track which satisfied a trigger P_T threshold which was $(57 \pm 5)\%$ efficient at $P_T = 4.0$ GeV/c and rose sharply to $(97 \pm 2)\%$ for $P_T >$ 6.0 GeV/c. The second data sample had an integrated luminosity of 2.6 ± 0.2 pb^{-1} (the dimuon_3_3 sample) and slightly different trigger requirements. Here, both muons had a level-one trigger efficiency of $(44 \pm 4)\%$ at $P_T = 2.0$ GeV/c, increasing to $(92 \pm 4)\%$ for $P_T > 6.0$ GeV/c. For level two, both muons in this sample had to match with charged tracks which passed a trigger P_T threshold of $(10 \pm 5)\%$ efficiency at $P_T = 2.0$ GeV/c and $(99 \pm 1)\%$ efficiency for $P_T > 3.0$ GeV/c. In both cases, the trigger efficiency of a muon candidate, included as part of the reconstruction efficiency, was taken to be the product of the level-one and level-two efficiencies. The dependence of the individual trigger efficiencies on the P_T of the muons is shown in Fig. 1. The trigger efficiency of the muon pair was then the combined product of the

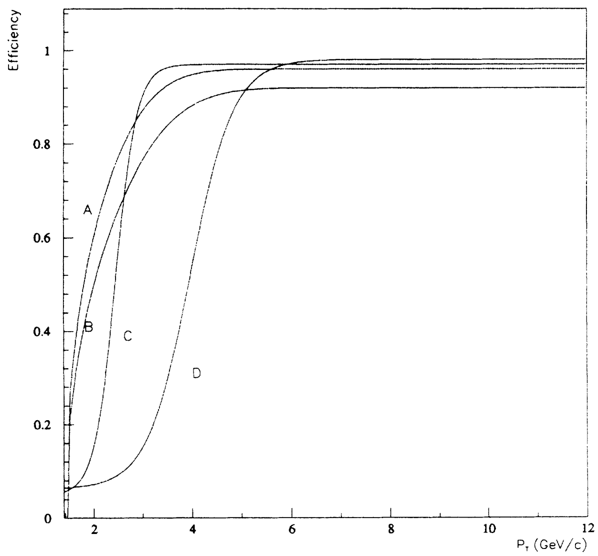

FIG. 1. Muon trigger efficiency parametrizations. Curves A and B show the parametrizations of the 2 and 3 GeV trigger requirements for level 1, respectively. Curves C and D show parametrizations of the 3 and 5 GeV/c charged track requirement for the muon triggers, respectively.

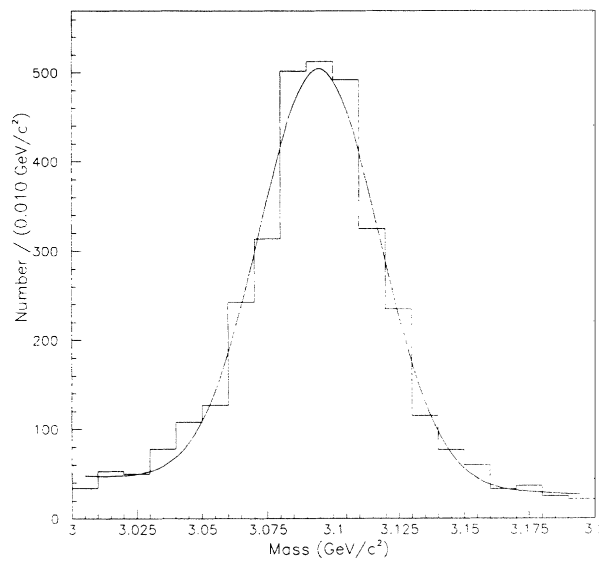

FIG. 2. $\mu^+\mu^-$ mass distribution after all cuts. The solid curve is a fit to a Gaussian signal plus a linear background giving $2649 \pm 51 J/\psi$'s above background.

trigger efficiencies of the two muon candidates.

The charged particle transverse momenta were calculated from the track curvature in the 1.4116 T axial magnetic field. There was an uncertainty in the magnetic field of $\pm 0.05\%$. Constraining the tracks of a multibody decay to come from a common vertex yielded a momentum resolution of $\delta P_T/P_T = \sqrt{(0.0014 P_T)^2 + (0.0066)^2}$. The resulting mass scale was checked by studying the following decays: $J/\psi \to \mu^+\mu^-, \psi(2S) \to \mu^+\mu^-, \Upsilon(1S) \to \mu^+\mu^-$, and $\Upsilon(2S) \to \mu^+\mu^-$ and the particle masses were found to agree well with world-average values [13].

The process of reconstructing B^0 mesons began with the reconstruction of the daughter J/ψ. The J/ψ was identified by requiring two oppositely charged muon candidates. For the dimuon_5_2 sample, one of the muons was required to have $P_T > 5$ GeV/c while the other muon had $P_T > 2$ GeV/c. For the dimunon_3_3 sample, both muons were required to have $P_T > 3$ GeV/c. The differences in position between the muon chamber track and the extrapolated CTC track were formed in the transverse and longitudinal directions, weighted by multiple scattering and measurement errors, and required to be less than 3.0 standard deviations from zero. The $\mu^+\mu^-$ mass distribution is shown in Fig. 2. J/ψ candidates were defined at $\mu^+\mu^-$ mass pairs within $\pm 3.0\sigma$ of the world-average mass value of 3.0969 GeV/c^2 [14], where σ is the observed width of 0.023 GeV/c^2. There are 2649 reconstructed J/ψ mesons above a background of $\sim 580 \mu^+\mu^-$ pairs.

The next step was to select $K^*(892)^0$ candidates. For each event containing a candidate J/ψ, oppositely charged tracks were combined assuming one track was a kaon and the other a pion. This random mass assignment was necessary since CDF had no charged kaon identification for this measurement. The track designated the kaon was required to have $P_T > 1.0$ GeV/c and the other track was required to have $P_T > 0.5$ GeV/c. The tracks associated with the muons forming the J/ψ candidate were excluded from consideration. Figure 3 shows that although there is some evidence of a peak at the broad $K^*(892)^0$ mass resonance, there exists a large combinatoric background. To search for the presence of a B^0 signal, $K^*(892)^0$ candidates were selected from those track combinations having an invariant mass between 0.846 and 0.946 GeV/c^2, corresponding to ± 1 natural widths of the $K^*(892)^0$. Only one $K^*(892)^0$ candidate was taken for each combination of tracks. For events in which both mass assignments to the track pair formed a candidate $K^*(892)^0$ meson, the mass combination closest to the

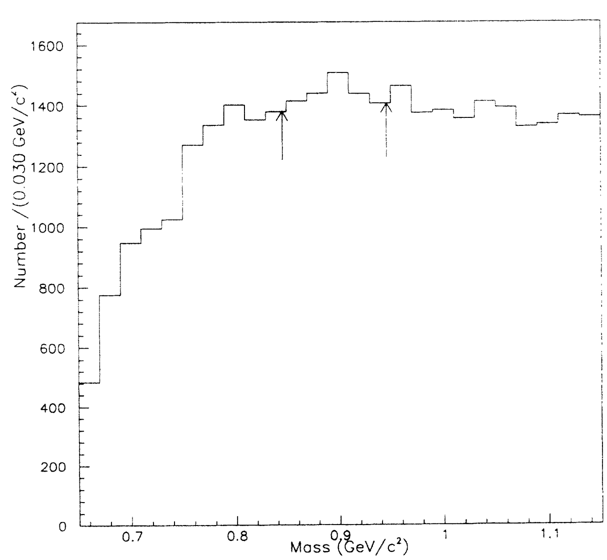

FIG. 3. Invariant mass distribution of track pairs with $K^\pm\pi^\mp$ mass assignments. Candidate $K^*(892)^0$ mesons were selected from the region within ± 0.050 GeV/c^2 of the $K^*(892)^0$ mass as shown by the location of the arrows.

$K^*(892)^0$ mass was chosen.

The B^0 candidates were selected by constraining the four tracks corresponding to the candidate $J/\psi K^*(892)^0$ combination to a common vertex and simultaneously requiring that the muon pair mass have the world-average J/ψ mass value. Figure 4 shows the invariant mass distribution of the $J/\psi K^*(892)^0$ combinations. Evidence for a signal is present in the expected mass range of 5.24 to 5.32 GeV/c^2. The peak bin contains 19 events with a fit background of 10.1 events. The probability that the observed number of events in the peak bin is due to a fluctuation is approximately 0.8%.

In order to measure the cross section, events were required to pass further cuts which defined a region of well-understood reconstruction efficiencies. These cuts included the trigger related P_T cuts on the muons. Figure 5 shows the invariant mass distribution of those events passing both triggers with the associated P_T cuts and requiring the B^0 to have $P_T > 9.0$ GeV/c and $|y| < 1.0$. The number of events on which the measurement of the cross section was based was determined by fitting the $J/\psi K^*(892)^0$ mass distribution to a Gaussian signal distribution plus a linear background using a binned maximum likelihood technique with a fixed B^0 mass resolution of $\sigma = 0.014$ GeV/c^2, the value obtained from a Monte Carlo study. The result of the fit was 9.6±4.6 events with a fitted mass of 5.281±0.018 GeV/c^2, which compares well with the world average B^0 mass of 5.2787 ± 0.0021 GeV/c^2 [14]. The nonresonant process $B^0 \to J/\psi/K^+/\pi^-$ has a comparable branching fraction [$B(B^0 \to J/\psi/K^+/\pi^-) = 0.0010 \pm 0.0004 \pm 0.0003$ [15] compared with $B(B^0 \to J/\psi/K^*(892)^0) = 0.00169 \pm$

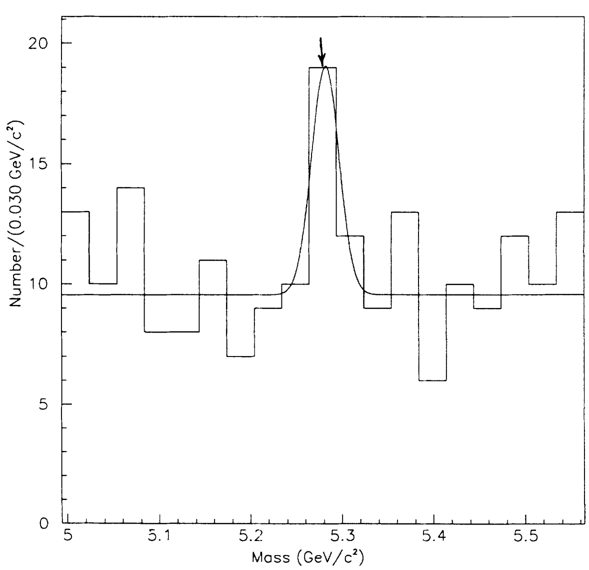

FIG. 4. $J/\psi\, K^*(892)^0$ mass distribution. The distribution includes those candidates with the initial cuts described in the text and before the final cuts required to measure the cross section. The arrow shows the world average value of the B^0 mass. The curve is a fit to a Gaussian signal plus a linear background. Based on the fit, the number of background events expected in the peak bin is 10.1 ± 0.8 with a signal of 11.1 ± 5.8 events.

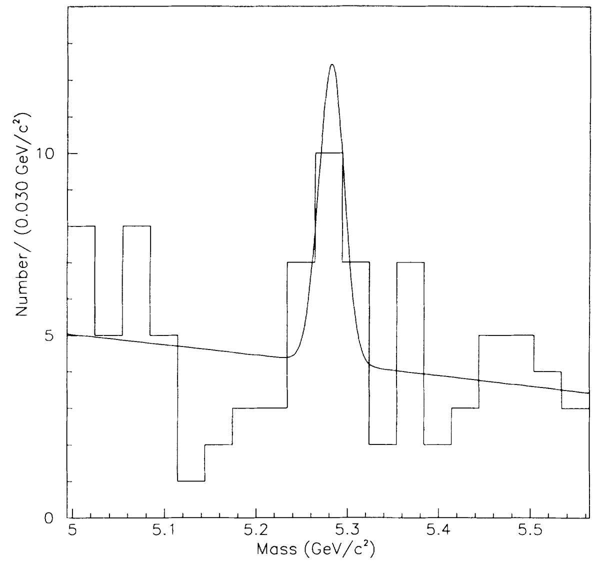

FIG. 5. $J/\psi\, K^*(892)^0$ mass distribution after all cuts required for the measurement of the cross section. The curve is a fit to a Gaussian signal (with the width fixed to 0.014 GeV/c^2) plus a linear background. The number of events fitted above the background is 9.6 ± 4.6 and the fitted mass is 56.281 ± 0.018 GeV/c^2.

0.00031 ± 0.0018 [19]] and could, in principle, contribute to the measured signal. The number of nonresonant decays contributing to the signal was estimated from the fitted number of events. By applying Monte Carlo determined correction factors for the decreased efficiency of the $K^*(892)^0$ mass cut and relative branching fractions, the nonresonant process was estimated to contribute 0.27 ± 0.15 events to the signal and is subtracted from the measured signal.

As additional evidence that the events from which the cross section is measured are associated with the decay of interest, the mass of the $K^*(892)^0$ candidates is plotted in Fig. 6, both for a $\pm 3\sigma$ mass window around the B^0 and for adjacent side bands of half-width 1.5σ. To avoid the false generation of a peak, both $K^+\pi^-$ and $K^-\pi^+$ combinations were plotted in Fig. 6. It is seen that those mass combinations in the B^0 mass window peak about the $K^*(892)^0$ mass.

The B^0 meson detection and reconstruction efficiency was determined from a Monte Carlo simulation which used the shape of the b quark P_T distribution provided by the $O(\alpha_s^3)$ calculation of Ref. [4] and a flat rapidity distribution. The b quarks were generated with $P_T > 6.0$ GeV/c and rapidity $|y| < 1.5$. By varying the P_T and rapidity distributions of the b quarks, systematic errors of 15% and 3%, respectively, in the acceptance were estimated. The energy and momentum of the B^0 meson along the b quark flight direction were determined using the Peterson fragmentation model [16] with the ϵ_P parameter varied over the range $\epsilon_P = 0.006 \pm 0.002$ [17]. An ansatz of the form $f(P_T) = 1/(1 + aP_T)$, where a was chosen to give a mean P_T of 350 MeV/c, was used to obtain the B^0 meson momentum perpendicular to the b quark direction [18]. After determining the laboratory four-momentum of the B^0 meson, the subsequent

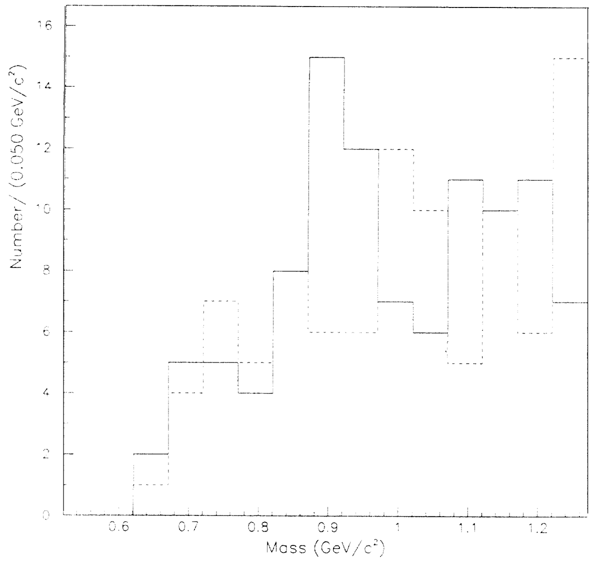

FIG. 6. $K^*(892)^0$ mass distribution for events in the B^0 mass window (solid line) and for events in the B^0 sideband region (dashed line). Both $K^+\pi^-$ and $K^-\pi^+$ combinations are plotted.

decay into a J/ψ and $K^*(892)^0$ was simulated. The simulation of the decays included the effects of the finite $K^*(892)^0$ width (50 MeV/c^2) and the finite B^0 meson lifetime (1.29 ± 0.08 psec) [14].

The simulated B^0 mesons were then reconstructed and the effects of detector acceptance, trigger efficiency, and kinematic cuts (including the muon, kaon, and pion P_T cuts, the $K^*(892)^0$ mass window cut and double-counting removal) were applied as in the data. The efficiency was calculated from the simulated events and additionally corrected for the efficiencies of the J/ψ mass window (0.98 ± 0.02), the muon matching cuts (0.94 ± 0.01), and the pattern recognition and tracking efficiency for the four B^0 daughters (0.83 ± 0.08), all of which were determined independently of the Monte Carlo simulation. An additional factor of 0.86 ± 0.06 attributed to hardware trigger losses was measured for the dimunon_5_2 sample. This inefficiency was not present for the Dimuon _3_3 sample.

Additional systematic uncertainties in the reconstruction efficiency also are listed below.

(1) A systematic uncertainty of $\pm 18\%$ (dimuon _5_2 and $\pm 12\%$ (dimuon _3_3) was assigned to the uncertainty in the trigger parametrizations used in the Monte Carlo simulation.

(2) A systematic uncertainty of $\pm 20\%$ in the number of events was assigned due to the uncertainty in the B^0 mass resolution based on the difference in the J/ψ mass resolutions observed in the data and Monte Carlo simulation and on the variation in the fitted number of B^0 mesons resulting from varying the constrained width of the Gaussian signal.

(3) The variations in ϵ_P in the Peterson fragmentation model led to a $\pm 6\%$ variation in the B^0 acceptance.

(4) The simulation predicts 8% of the kaons with $P_T > 1.0$ GeV/c decay before exiting the tracking chamber. Approximately half of these are successfully reconstructed as B^0 meson decays. A $\pm 4\%$ systematic due to kaon decays inside the CTC was assigned.

(5) The luminosity uncertainty has been measured to be $\pm 7\%$ and is included.

(6) The J/ψ and $K^*(892)^0$ are both vector mesons and could, in principle, be polarized in the B^0 decay, which would result in a variety of different angular distributions of the final state K, π, and μ pair. The CLEO Collaboration has measured the longitudinal polarization to be $\Gamma_L/\Gamma = 0.80 \pm 0.08(\text{stat}) \pm 0.05(\text{syst})$ [19], where Γ and Γ_L are the full decay width and the partial width into longitudinally polarized states, respectively. Using this value and our Monte Carlo data, we obtain a correction factor to our acceptance of 0.89 ± 0.05.

(7) The uncertainty in the number of events due to the choice of binning has been studied by varying both the width and positioning of the bins. We find that the fitted number of events varies by approximately 10% and assign this value as a systematic error in the number of fitted events.

The overall reconstruction efficiency was calculated for B^0 mesons with $P_T(B^0) > 9.0$ GeV/c and $|y| < 1.0$. From the Monte Carlo simulation and the above additional considerations this efficiency was found to be $(1.22 \pm 0.31)\%$ and $(0.97 \pm 0.21)\%$ for the dimuon _5_2 and dimuon _3_3 samples, respectively.

In the following results, the cross section for $\bar{p}p \to B^0 X$ only is quoted. The cross section including $\bar{B}^0$ mesons is twice as large. The B^0 cross section measurement is determined by the formula

$$\sigma(\bar{p}p \to B^0 X; P_T > 9.0\,\text{GeV}/c, |y| < 1.0) = \frac{(N/2)}{\epsilon\mathcal{L}B(B^0 \to J/\psi + K^*(892)^0) \times B(J/\psi \to \mu^+\mu^-) \times B(K^*(892)^0 \to K^+\pi^-)},$$

where N is the number of events observed in the combined data set, and $\epsilon\mathcal{L}$ is the sum of the luminosities for the two samples weighted by their respective efficiencies. The combined branching ratio $B(B^0 \to J/\psi + K^*(892)^0) \times B(J/\psi \to \mu^+\mu^-)$. $B(K^*(892)^0 \to K^+\pi^-)$ is $(6.6 \pm 1.4) \times 10^{-5}$ [19]. Since the observed sample includes contributions from both B^0 and $\bar{B}^0$ mesons, the number of events is divided by 2.

The result for the B^0 meson cross section is

$$\sigma(\bar{p}p \to B^0 X; P_T > 9.0\text{ GeV}/c, |y| < 1.0) = 1.5 \pm 0.7(\text{stat}) \pm 0.6(\text{syst})\mu\text{b},$$

where the first error is statistical and the second combines in the quadrature the systematics from the reconstruction efficiency determination, the luminosity measurement, and the branching ratio uncertainties. Alternatively, this result can be quoted as a limit of $\sigma_B < 2.7$ μb at 90% confidence level.

A $b(\bar{b})$ quark can fragment into $\bar{B}(B)$ mesons, or a variety of $b(\bar{b})$ flavored baryons. We choose to extract the b quark cross section by making the standard assumption [20] that $B^-, \bar{B}^0, \bar{B}^0_s$ mesons and b baryons are produced in the ratio 0.375 : 0.375 : 0.15 : 0.10. Equivalently, one could extract a $\bar{b}$ quark cross section by using B mesons and $\bar{b}$ baryons. The extreme cases where the b quark fragments either entirely to B^- and $\bar{B}^0$ mesons or where $B^-, \bar{B}^0, \bar{B}^0_s$ mesons and b baryons are produced in equal proportions would change the branching fraction by approximately 30%. Guided by this variation in the extreme cases, we include a 15% systematic uncertainty in the efficiency. Since the b quark is not observed directly, we quote the cross section for b quarks with $P_T > P_T^{\rm min}$, where $P_T^{\rm min}$ is defined as the b quark P_T such that 90% of our final sample of reconstructed B mesons comes from b quarks with $P_T > P_T^{\rm min}$. Using the Monte Carlo model described previously, we find that $P_T^{\rm min} = 11.5$ GeV/c. No cut on the B meson P_T or rapidity is imposed on the data for the extraction of the b quark cross section. The resulting number of reconstructed B mesons from which the b quark cross section is extracted is 10.3±4.9. The efficiencies for the decay chain $b \to \bar{B}^0 \to J/\psi\,\bar{K}^*(892)^0, J/\psi \to \mu^+\mu^-, \bar{K}^*(892)^0 \to K^-\pi^+$, are $(1.38 \pm 0.32)\%$ for the dimuon _5_2 sample and $(1.27 \pm 0.24)\%$ for the dimuon _3_3 sample. The difference between the b and B meson efficiencies reflects the different P_T requirements quoted in the cross sections.

From combining the two data samples, our result for the cross section is

$$\sigma(\bar{p}p \to bX; P_T > 11.5 \text{ GeV}, |y| < 1.0)$$

$$= 3.7 \pm 1.6(\text{stat}) \pm 1.5(\text{syst})\mu\text{b},$$

with a corresponding 90% confidence level limit of $\sigma_b <$ 6.5 μb. This result is in agreement with, but is somewhat lower than, the previously published $B^\pm \to J/\psi\,K^\pm, J/\psi \to \mu^+\mu^-$ measurement of $6.1 \pm 1.9 \pm 2.4$ μb for the same b quark P_T and rapidity [1]. Both measurements are noticeably above the order $O(\alpha_s^3)$ prediction of $1.1^{+0.5}_{-0.4}$ μb for the b quark cross section for $P_T > 11.5$ GeV/c and $|y| < 1.0$.

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[1] F. Abe *et al.*, Phys. Rev. Lett. **68**, 3403 (1992).
[2] F. Abe *et al.*, Phys. Rev. Lett. **69**, 3704 (1992).
[3] UA1 Collaboration, C. Albajar *et al.*, Phys. Lett. B **256**, 121 (1991).
[4] P. Nason, S. Dawson, and R. K. Ellis, Nucl. Phys. **B303**, 607 (1988); **B327**, 49 (1989); **B335**, 260 (1990).
[5] W. Beenakker, H. Kuijf, W. L. van Neeven, and J. Smith, Phys. Rev. D **40**, 54 (1989); Nucl. Phys. **B351**, 507 (1991).
[6] E. Berger, R. Meng, and W. Tung, Phys. Rev. D **46**, 1895 (1992).
[7] F. Abe *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **271**, 387 (1988).
[8] G. Ascoli *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **268**, 33 (1988).
[9] E. Barsotti *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **269**, 82 (1988).
[10] D. Amidei *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **269**, 51 (1988).
[11] G. Ascoli *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **269**, 63 (1988).
[12] G. W. Foster *et al.*, Nucl. Instrum. Methods Phys. Res. Sect. A **269**, 93 (1988).
[13] R. Hughes, Ph.D. thesis, University of Pennsylvania, 1992.
[14] Particle Data Group, K. Hikasa *et al.*, Phys. Rev. D **45**, s1 (1992).
[15] CLEO Collaboration, D. Bortoletto *et al.*, Phys. Rev. D **45**, 21 (1992).
[16] C. Peterson *et al.*, Phys. Rev. D **27**, 105 (1983).
[17] J. Chrin, Z. Phys. C **36**, 163 (1987).
[18] S. Vejcik, Ph.D. thesis, The Johns Hopkins University, 1992.
[19] CLEO Collaboration, M. S. Alam *et al.*, Phys. Rev. D **50**, 43 (1994).
[20] F. Abe *et al.*, Phys. Rev. Lett. **67**, 3351 (1991); **69**, 3704 (1992); **71**, 500 (1993); **68**, 3403 (1992).