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Measurement of the B Meson Differential Cross-Sections in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV Using the Exclusive Decays $B^{\pm}\rightarrow J/\psi K^{\pm}$ and $B^0\rightarrow J/\psi K^{*0}$

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MEASUREMENT OF THE B MESON DIFFERENTIAL CROSS-SECTIONS IN $p\bar{p}$ COLLISIONS AT $\sqrt{s} = 1.8$ TeV USING THE EXCLUSIVE DECAYS $B^{\pm} \rightarrow J/\psi K^{\pm}$ AND $B^0 \rightarrow J/\psi K^{*0}$

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ABSTRACT

This paper presents the first measurement of the differential $B^{\pm}$ and B^0 cross-sections, $d\sigma/dp_T$, in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. The data sample used represents an integrated luminosity of 19.3 ± 0.8 pb^{-1} accumulated by the Collider Detector at Fermilab(CDF). The cross-sections are measured over the p_T range 6-15 GeV/c in the central pseudorapidity region $|\eta| < 1$ by fully reconstructing the B meson decays $B^{\pm} \rightarrow J/\psi K^{\pm}$ and $B^0 \rightarrow J/\psi K^{*0}$, where the J/ψ is required to decay to two muons, and the K^{*0} is required to decay to $K^{\pm}\pi^{\mp}$. The results are compared to the theoretical QCD prediction calculated at next-to-leading order.

We present the first direct measurement of the differential B meson cross-section in transverse momentum(p_T) in $p\bar{p}$ collisions at $\sqrt{s}$= 1.8 TeV by measuring the mass and momentum of fully reconstructed B mesons decays. Such a measurement is free of the model-dependant procedures used to infer the b quark p_T from an inclusive lepton sample, for example, and thus provides a better test of the QCD prediction. The data sample used represents 19.3 ± 0.8 pb^{-1} collected by CDF during the 1992-93 run.

B mesons are reconstructed via the decays $B^{\pm} \rightarrow J/\psi K^{\pm}$ and $B^0 \rightarrow J/\psi K^{*0}$, with $J/\psi \rightarrow \mu^+\mu^-$ and $K^{*0} \rightarrow K^+\pi^-$, and their charge conjugates. By triggering on dimuons, we obtain a sample of J/ψ of which more than 15% comes from B decays.[1] Each muon is required to have $p_T \geq 1.8$ GeV/c, and at least one muon is required to have $p_T \geq 2.8$ GeV/c, to match the trigger requirements. The $K^{\pm}$ candidates from $B^{\pm} \rightarrow J/\psi K^{\pm}$ and the K^{*0} candidates from $B^0 \rightarrow J/\psi K^{*0}$ are required to have $p_T > 1.25$ GeV/c. The B meson transverse momentum is required to be greater than 6.0 GeV/c. The $K\pi$ invariant mass is required to be within 50 MeV/c^2 of the K^{*0} mass(896.1 MeV/c^2). The decay tracks are vertex constrained, and the muons are mass constrained to the J/ψ mass. The confidence level of the fit χ^2 is required to be greater than 0.5%, and the proper decay length of the B candidate is required to be greater than 100 μm.

The $B^{\pm}$ candidates are divided into subsamples in B p_T ranges 6-9, 9-12, 12-15, and > 15 GeV/c, while the B^0 candidates are divided into p_T ranges 7-11, 11-15, and

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Table 1. Differential B meson cross-sections, $d\sigma(|y| < 1.0)/dp_T$ (nb/GeV/c), for the p_T range 6-15 GeV/c and integrated cross-sections (nb) for $p_T > 15$ GeV/c.

	$p_T(B)$ GeV/c	$\langle p_T \rangle$ GeV/c	Acceptance %	No. of Events	Cross-section
B^+	6-9	7.4	1.29 ± 0.01	53 ± 12	$610 \pm 138 \pm 141$
	9-12	10.4	3.58 ± 0.04	29 ± 8	$121 \pm 33 \pm 28$
	12-15	13.4	5.71 ± 0.07	19 ± 5	$49 \pm 13 \pm 11$
	>15	19.7	9.03 ± 0.08	25 ± 6	$12 \pm 3 \pm 3$
B^0	7-11	8.8	1.18 ± 0.01	31 ± 11	$324 \pm 115 \pm 99$
	11-15	12.8	3.46 ± 0.04	22 ± 6	$79 \pm 22 \pm 24$
	>15	20.5	6.54 ± 0.06	8 ± 4	$15 \pm 8 \pm 5$

> 15 GeV/c. For each of these subsamples, the invariant mass distribution is fitted to a Gaussian plus a linear background over the signal region 5.2-5.6 GeV/c^2. The fitted numbers of $B^\pm$ and B^0 mesons are given in Table 1.

The differential cross-section is calculated from the following equation:

$$\frac{d\sigma}{dp_T} = \frac{N/2}{\mathcal{L} \cdot A \cdot e \cdot F \cdot \Delta p_T} \tag{1}$$

where N is the number of events observed, $\mathcal{L}$ is the integrated luminosity, A is the detector acceptance and selection cut efficiency, e is the combined tracking efficiency, F is the branching fraction, and Δp_T is the width of the p_T bin. The factor of 1/2 is included because decays involving both B and $\overline{B}$ mesons have been reconstructed, but the quoted cross-sections are for B mesons only. Integrated cross-sections are calculated for B $p_T > 15$ GeV/c.

A Monte Carlo employing the next-to-leading order QCD calculation[2,3], the MRSD_-'[4] proton structure functions, and the Peterson parameterization[5,6] for fragmentation was used to determine the acceptance. After simulating the detector response and the J/ψ trigger efficiency, the selection requirements were applied, with the resulting acceptance shown in Table 1.

The online tracking efficiency for the muon pairs was determined to be $93 \pm 2\%$, while the offline tracking efficiency was found to be $98.9 \pm 1\%$. The efficiency of the matching requirement between the CTC track and the muon chamber track segment was measured to be $98.7 \pm 1\%$. Branching fractions of $(1.12 \pm 0.17) \times 10^{-3}$, $(1.53 \pm 0.37) \times 10^{-3}$,[7] 0.0597 ± 0.0025,[8] and 2/3 were used for the $B^\pm \to J/\psi K^\pm$, $B^0 \to J/\psi K^{*0}$, $J/\psi \to \mu^+\mu^-$, and $K^{*0} \to K^+\pi^-$ decays , respectively.

Varying the b production and fragmentation parameters used in the Monte Carlo simulation indicates an uncertainty in the acceptance calculation of 9%. The systematic uncertainty in the J/ψ trigger efficiency parameterization was determined to be $\pm 4\%$. Additionally, a systematic uncertainty of $\pm 4\%$ is associated with the reconstruction of kaons which decay inside the CTC volume. A 10% uncertainty is associated with the pseudorapidity dependence of the tracking efficiency. The uncertainty in the $c\tau$ cut was determined to be 4%, and the vertex fit χ^2 cut had an additional 1% uncertainty. Varying the polarization of the $B^0 \to J/\psi K^{*0}$ decay products in the range $(84 \pm 10)\%$[7] changes the calculated acceptance by $\pm 7\%$. Combining these uncertainties in quadrature, the reconstruction efficiency has overall systematic errors of 17.6% for the B^+ decay and 19.0% for the B^0 decay. The branching fractions contribute additional uncertainties of 15% and 24%, respectively.

The differential B meson cross-section measurements are listed in Table 1 and plotted in Fig. 1. The integrated cross-sections for $p_T > 15$ GeV/c are given in the table but not plotted. Each measurement is quoted for the momentum $\langle p_T \rangle$, at which the cross-section integrated over the bin divided by the bin width is estimated to equal the differential cross-section. The solid curve shows the differential B meson cross-sections predicted by the Monte Carlo, which includes the assumption that 75%[9] of $\bar{b}$ quarks fragment in equal amounts to B^+ and B^0 mesons. While this theory correctly predicts the shape, as measured here, the predicted rate using the natural choice for the renormalization scale, $\mu = \sqrt{m_b^2 + {p_T}^2}$, remains low.

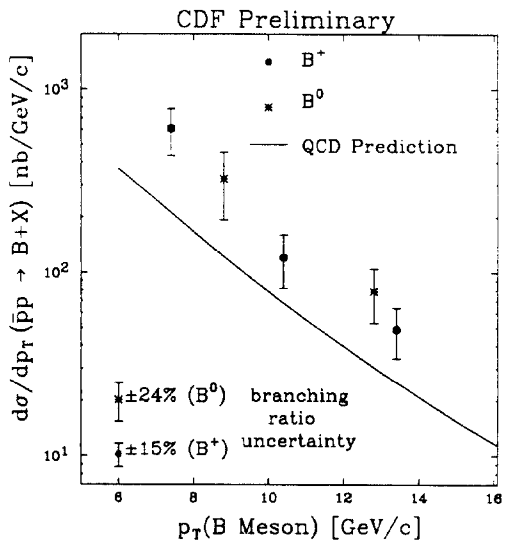

Figure 1: B meson differential cross-sections compared to the QCD prediction.

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