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INCLUSIVE J/ψ, $\psi(2S)$ AND b-QUARK PRODUCTION IN $\bar{p}p$ COLLISIONS AT $\sqrt{s} = 1.8$ TeV *

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ABSTRACT

Inclusive J/ψ and $\psi(2S)$ production has been studied in $\bar{p}p$ collisions at $\sqrt{s} =$ 1.8 TeV using the Collider Detector at Fermilab. The products of production cross section times branching fraction have been measured as functions of P_T for $J/\psi(\psi(2S)) \rightarrow \mu^+\mu^-$ in the kinematic range $P_T^{J/\psi(\psi(2S))} > 6$ GeV/c and $|\eta^{J/\psi(\psi(2S))}| \leq 0.5$. The products of the integrated cross section times branching fraction are calculated and used to obtain an inclusive b-quark production cross section.

1. Introduction

The reactions $\bar{p}p \rightarrow J/\psi(\psi(2S))X \rightarrow \mu^+\mu^-X$ at $\sqrt{s} = 1.8$ TeV were studied using 2.6 ± 0.2 pb^{-1} of data taken with the Collider Detector at Fermilab (CDF) during the 1988-1989 running period of the FNAL $\bar{p}p$ collider[1]. This is the first measurement of $J/\psi(\psi(2S))$ cross sections at Tevatron energies. These cross sections are important for the investigation of charmonium production mechanisms in $\bar{p}p$ collisions[2], for the study of the production of b-quarks at low P_T[3,4], and are used to obtain an inclusive b-quark production cross section.

2. The J/ψ and $\psi(2S)$ Data Sample

The components of the CDF detector[5] relevant to this analysis are the central tracking chamber which is in a 1.4116-T axial magnetic field, the central muon chambers which provide muon identification in the pseudorapidity region $|\eta^\mu| < 0.61$, and a multi-level central dimuon trigger. From events passing the trigger, pairs of opposite sign muons were selected with the following cuts: $P_T^\mu > 3.0$ GeV/c for each muon, $|\eta^{\mu^+\mu^-}| \leq 0.5$ and $6.0 < P_T^{\mu^+\mu^-} < 14.0$ GeV/c for each muon pair, and track quality criteria. The resulting J/ψ and $\psi(2S)$ mass distributions were each fit to

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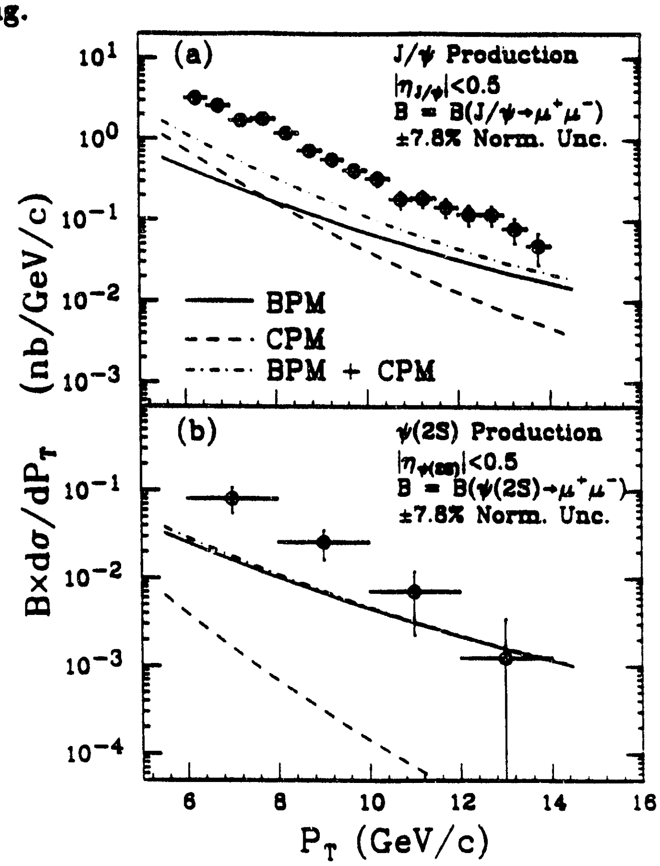
a Gaussian line shape plus a linear background. The number of J/ψ candidates above background is 889±30; the number of $\psi(2S)$ candidates above background is 35 ± 8.

3. The J/ψ and $\psi(2S)$ Cross Sections

The J/ψ and $\psi(2S)$ differential cross sections are displayed in the figure below together with the theoretical predictions for two processes expected to dominate J/ψ and $\psi(2S)$ production. The circles in the figure correspond to the data. The solid curve is the B-production model (BPM), a next-to-leading-order calculation of b-quark[6] production leading to B-mesons[7] which decay to $J/\psi(\psi(2S))$. The dashed curve, the charmonium production model (CPM), corresponds to $J/\psi(\psi(2S))$'s from direct charmonium production[2,8]. A fit of the sum, BPM plus CPM, to the J/ψ data with no normalization constraints suppresses the BPM contribution because of the difference in slope between the BPM curve and the data. However, another CDF study[4] found that the BPM calculation underestimates the b-quark cross section by a factor of 5.5 ± 2.8. When this datum is added to the fit we find that ~42% J/ψ's result from B-production. The 90% C.L. upper limit on the BPM contribution is ~60%. If future measurements exceed this value, then one must conclude that not only the normalization of BPM, but also the P_T-dependence of at least one of the models is wrong.



The products of the inclusive production cross section times branching fraction in the kinematic range $P_T^{J/\psi(\psi(2S))} > 6$ GeV/c and $|\eta^{J/\psi(\psi(2S))}| \leq 0.5$ are

$$\sigma(\bar{p}p \to J/\psi\, X) \times B(J/\psi \to \mu^+\mu^-) = 6.88 \pm 0.23(stat)\ {}^{+0.93}_{-1.08}\ (syst)\,\text{nb} \quad \text{and}$$

$$\sigma(\bar{p}p \to \psi(2S)X) \times B(\psi(2S) \to \mu^+\mu^-) = 0.232 \pm 0.051(stat)\ {}^{+0.029}_{-0.032}\ (syst)\,\text{nb}.$$

4. The b-Quark Cross Section

The b-quark inclusive production cross section is calculated using the $J/\psi(\psi(2S))$ inclusive production cross sections, the ratio of $J/\psi(\psi(2S))$ to b-quark cross sections as determined by the BPM Monte Carlo technique[6,7,9,10,11], and the fraction f_B of $J/\psi(\psi(2S))$'s from B meson decays. The b-quark P_T^{min} is chosen such that in the BPM, 90% of the $B \to J/\psi(\psi(2S))$ events having $P_T^{J/\psi(\psi(2S))} > 6$GeV/c also have $P_T^b > P_T^{min}$. In this analysis P_T^{min} is 8.5 GeV/c. Assuming the fraction f_B to be unity, believed to be true for $\psi(2S)$[2,8,12] but not for the J/ψ[13], we find

$$\sigma^b(P_T^b > 8.5\text{GeV/c}, |\text{y}^\text{b}| < 1) = 18.9\ {}^{+4.7}_{-5.0}\ \mu\text{b} \quad \text{using J/}\psi \quad \text{and}$$

$$\sigma^b(P_T^b > 8.5\text{GeV/c}, |\text{y}^\text{b}| < 1) = 10.5\ {}^{+5.0}_{-5.1}\ \mu\text{b} \quad \text{using } \psi(2\text{S}).$$

The b-quark cross section we get using $\psi(2S)$ is in reasonable agreement with other CDF measurements[4,13,14,15].

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