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INCLUSIVE χ_c PRODUCTION IN $\bar{p}p$ COLLISIONS AT $\sqrt{s} = 1.8$ TeV

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ABSTRACT

We report the full reconstruction of χ_c mesons through the decay chain $\chi_c \to J/\psi\gamma$, $J/\psi \to \mu^+\mu^-$, using data obtained at the Collider Detector at Fermilab in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV. This sample, the first observed at a hadron collider, is then used to measure the χ_c meson production cross section times branching fractions. We obtain $\sigma \cdot Br = 3.2 \pm 0.4(\text{stat}) \pm 1.1(\text{syst})$ nb for χ_c mesons with $P_T > 7.0$ GeV/c^2 and pseudorapidity $|\eta| < 0.5$. From this and the inclusive J/ψ cross section we calculate the inclusive b-quark cross section.

1. Introduction

This talk reports the first full reconstruction of χ_c mesons at a hadron collider, through the decay chain $\chi_c \to J/\psi\gamma$, $J/\psi \to \mu^+\mu^-$. The technique exploits the easily implemented $\mu^+\mu^-$ trigger and cleanly identified $J/\psi \to \mu^+\mu^-$ signal to compensate for the small decay branching fraction. The observed χ_c sample is used to measure the χ_c production cross section times branching fractions. This value, in combination with the J/ψ production cross section measured previously by the authors [1], is then used to calculate the b-quark production cross section under the assumption that direct J/ψ production contributes negligibly to the total J/ψ rate. The results are based upon data from $\sqrt{s} = 1.8$ TeV $\bar{p}p$ collisions observed at the Collider Detector at Fermilab (CDF).

2. Data Selection

To reconstruct χ_c mesons, we first identified J/ψ mesons by requiring two oppositely charged muon candidates, each with $P_T > 3.0$ GeV/c. For each muon, we then calculated the difference in both the transverse and longitudinal directions between the position of the muon chamber track and the CTC track extrapolated to the muon chamber position. These differences were weighted by the uncertainty expected from measurement errors, energy loss and multiple scattering. Requiring these matching variables to be less than 3.0 removed the majority of the background to the $\mu^+\mu^-$ signal. We fit the resulting $\mu^+\mu^-$ mass distribution (Figure 1) to a Gaussian plus a constant background. The width of the Gaussian is $\sigma = 0.18$

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GeV/c^2. Defining our J/ψ sample as those events with dimuon mass between 3.05 and 3.15 GeVc^2, we observe 896±32 reconstructed J/ψ events above a background of 45±8.

Photon candidates were selected by demanding an electromagnetic energy cluster in excess of 1 GeV and a cluster in the central electromagnetic strip chambers. We rejected photon candidates that occurred in the same calorimeter tower traversed by one of the muons. The photon direction was determined from the position of the strip chamber cluster and the muon pair vertex. The energy and direction of the photon candidate were combined with the muon momenta to determine the invariant mass of the $\mu^+\mu^-\gamma$ system. The mass difference [ΔM = mass($\mu^+\mu^-\gamma$) - mass($\mu^+\mu^-$)] distribution is shown in Figure 2. A clear χ_c signal is present, although the individual angular momentum states cannot be resolved.

The shape of the background spectrum was estimated using real J/ψ events containing charged tracks other than muons. The momenta of these tracks were used as input to a Monte Carlo that generated decays of neutral pions to two photons. The ΔM spectrum of these simulated photons and the J/ψ, weighted by the photon finding efficiency, was normalized to the sideband region of the observed spectrum.

The number of events was determined using a binned maximum likelihood technique to fit the ΔM distribition to a Gaussian signal plus the independently determined background shape. The fit resulted in a mean mass difference of .406 ± .013 GeV/c^2 with 67 ± 8 (statistical) signal events within one standard deviation of the expected average value. Uncertainty in the background shape contributes to the uncertainty in the observed number of χ_c mesons.

3. Efficiency Determination

Photon reconstruction efficiencies were measured by examining a sample of conversion electrons in which one of the electrons was selected using only tracking information. We calculate the electron efficiency from the number of electron tracks that pass the calorimeter and strip chamber criteria for photons. The resulting electron efficiency was corrected for a difference in calorimeter response between electrons and photons.

The combined χ_c detection efficiency for $\chi_c \rightarrow J/\psi\gamma$, $J/\psi \rightarrow \mu^+\mu^-$ is 0.80±0.22% where the uncertainty represents the sum in quadrature of all the systematic effects listed in the preceding discussion.

4. χ_c Production Cross Section

The cross section times branching fractions is determined using the formula:

$$\sigma(\bar{p}p \rightarrow \chi_c X \rightarrow J/\psi\gamma X \rightarrow \mu^+\mu^-\gamma X) = \frac{N_{\chi_c}}{\epsilon L}$$

where N_{χ_c} is the number of observed number of χ_c events, ϵ is the χ_c detection efficiency and L is the integrated luminosity. We obtain

$$\sigma(\bar{p}p \rightarrow \chi_c X \rightarrow J/\psi\gamma X \rightarrow \mu^+\mu^-\gamma X) = 3.2 \pm 0.4(\mathrm{stat}) \pm 1.1(\mathrm{sys})\ \mathrm{nb},$$

where the result is the sum of the χ_c angular momentum states. The first uncertainty is statistical and the second combines in quadrature the systematic uncertainties due to the fitting procedure, the efficiency calculation, and the luminosity measurement.

5. b-quark Production Cross Section

To determine the b-quark cross section, recall that χ_c and B-meson decays dominate the total J/ψ production rate[1]. Thus, we can use the above result to subtract from the inclusive J/ψ cross section that portion due to χ_c decays, leaving the observed cross section times branching ratio for B-meson decay to J/ψ. The two cross sections can be compared directly since the two analyses used identical J/ψ samples. By multiplying the observed cross section by the ratio, obtained from Monte Carlo, of the b-quark cross section to the J/ψ cross section observed with a full detector simulation[1], we extract the b-quark cross section:

$$\sigma^b_{exp} = \frac{Br(J/\psi \rightarrow \mu^+\mu^-)\sigma(\bar{p}p \rightarrow J\psi X)R}{2Br(B \rightarrow J\psi X|_{no\chi_c})Br(J\psi \rightarrow \mu^+\mu^-)},$$

where

$$R = \frac{\sigma^b_{MC}(P^b_T > P^{min}_t, |y^b| < 1)}{\sigma^{J/\psi}_{MC}(P^{J/\psi}_T > 6\ GeV/c, |\eta^{J/\psi}| < 0.5)}.$$

This implies

$$\sigma^b(P^b_T > 8.5\ GeV/c, |y^b| < 1) = 12.0 \pm 4.5\ \mu b.$$

6. References

1. F. Abe et al., submitted to Physical Review Letters.

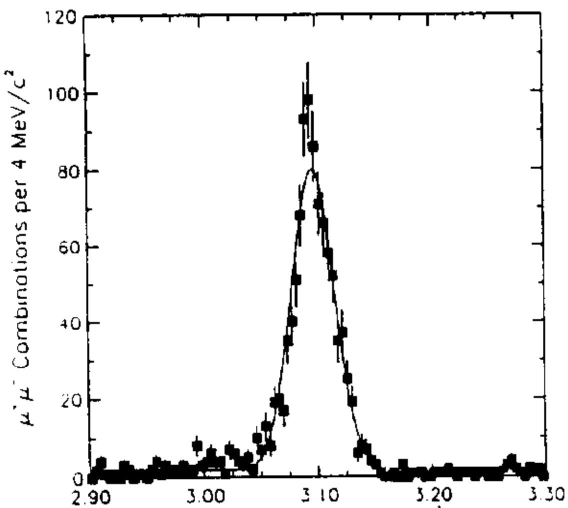

Figure 1 $\mu^+\mu^-$ mass (GeV/c^2)

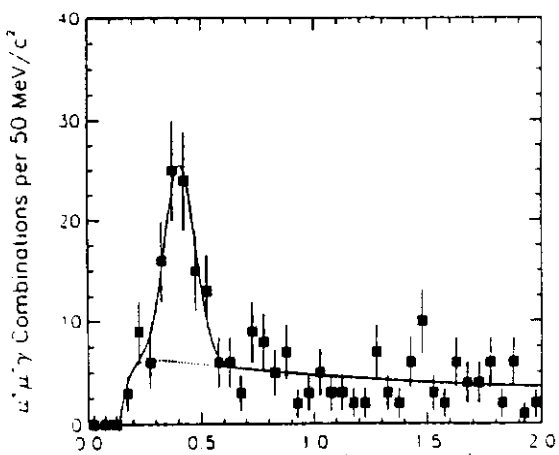

Figure 2. $M(\mu^+\mu^-\gamma)-M(\mu^+\mu^-)$ (GeV/c^2)