CHARM AND BEAUTY PRODUCTION FROM FERMILAB EXPERIMENT 789

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Abstract

Fermilab E789 is a fixed-target charm and beauty experiment which uses a 2-arm spectrometer outfitted with a silicon vertex detector to look for 2-body decays of charm and beauty. We have measured the differential cross section for production and the nuclear dependence of neutral D meson production, and the $D^0/\overline{D^0}$ production asymmetry. We have also seen evidence for beauty production via the inclusive decay $B \rightarrow J/\psi X$, by observing J/ψ decays well downstream of the target, and have measured a differential cross section for J/ψ from b or $\bar{b}$ for 800 GeV pN collisions.

1 Apparatus and Running Conditions

E789 uses an upgraded 2-arm spectrometer originally built for E605. The spectrometer has two large analyzing magnets operated at opposite polarities, and is divided into two arms by a beam dump in the upstream analyzing magnet. A silicon vertex spectrometer was part of the upgrade; it consisted of 8 silicon planes for each arm, all with 50 μm strip spacing, between 40 and 115 cm downstream of the target, giving angular acceptance from about 20-60 mr above and below the beam axis. The mass acceptance of the spectrometer can be adjusted by varying the current in the upstream analyzing magnet. Some data data were taken with acceptance optimized for charm, taking about 10^{10} 800 GeV protons per 20-second spill on a 1.5-mm-thick gold target part of the time and a 1.5-mm-thick beryllium target the rest of the time. Another data set was taken with acceptance optimized for J/ψ from b or $\bar{b}$, taking about 5×10^{10} protons per spill on a 3 mm gold target.

2 Charm Results

The results in this section are presented in more detail in [1]. Figure 1 shows $K^{\pm}\pi^{\mp}$ mass spectra for various charm data samples. Our charm analysis uses a lifetime significance cut of $\tau/\sigma > 7.2$, as in three of the plots; the other plot, with $\tau/\sigma > 3.5$, is shown to illustrate the background-rejection power of the lifetime significance cut. The currents listed are for the upstream analyzing magnet.

A corrected, background-subtracted lifetime distribution gives a lifetime consistent with the world average, and the shape of the corrected, background-subtracted p_T distribution is well fit by the form $p_T e^{-np_T^2}$, with $n = 0.91 \pm 0.12\,(\mathrm{GeV}/c)^{-2}$.

Using D^0 and $\overline{D^0}$ mesons in $0 < x_F < 0.08$ ($< x_F >= 0.031$) and $p_T < 1.1$ GeV ($< p_T >=$ 0.5 GeV), we find $d\sigma(D^0)/dx_F + d\sigma(\overline{D^0})/dx_F = 58 \pm 3 \pm 7$ μb/nucleon, assuming A^1 nuclear dependence. If we extrapolate this over all phase space, we find $\sigma(D^0)+\sigma(\overline{D^0}) = 17.7\pm0.9\pm3.4$ μb/nucleon. We see no evidence for any asymmetry in production: $\sigma(D^0)/\sigma(\overline{D^0}) = 0.97\pm0.12$. Comparing data from the gold and beryllium targets, we find the nucleon-number exponent of the nuclear dependence to be $\alpha = 1.02 \pm 0.03 \pm 0.02$, i.e. there appears to be no nuclear suppression of D^0 meson production in our x_F range. Our D A-dependence number is shown in Fig. 2, along with J/ψ data from E772 [2], high-x_F data from E789 and preliminary J/ψ results at small x_F from E789. The differences in the E772 and E789 values at high x_F may be due to the different p_T ranges to which the two experiments were sensitive. It can be seen that the A-dependence for D mesons is significantly different from that for J/ψ at similar x_F values.

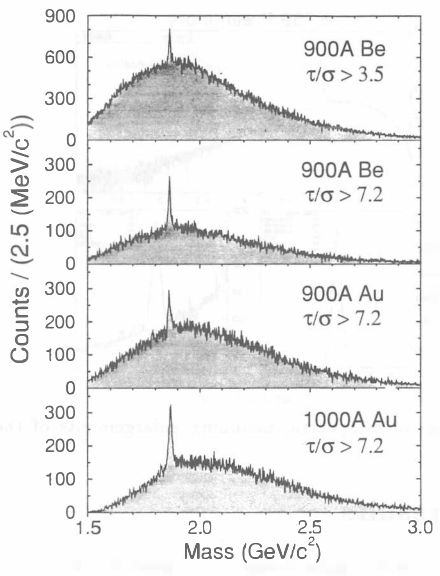

Figure 1: Dihadron invariant mass spectra: a) Be target, 900 Amps, $\tau/\sigma > 3.5$ b) Be target, 900 Amps, $\tau/\sigma > 7.2$ c) Au target, 900 Amps, $\tau/\sigma > 7.2$ d) Au target, 1000 Amps, $\tau/\sigma > 7.2$.

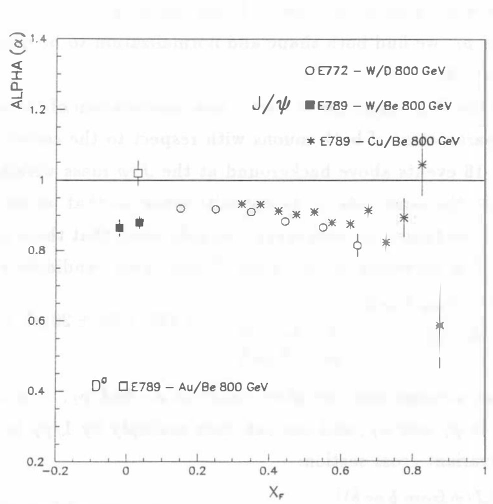

Figure 2: A-dependence exponent values for D^0 and J/ψ [2].

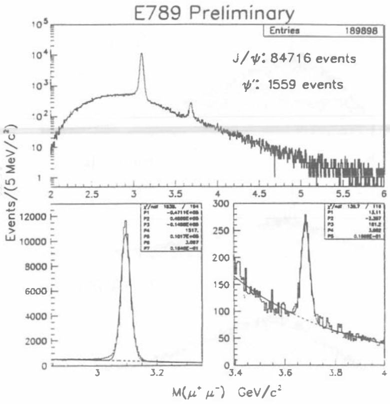

Figure 3: Dimuon invariant mass spectra, including enlargements of the J/ψ and ψ' mass regions.

3 J/ψ and $b\bar{b}$ Results

Figure 3 shows a mass spectrum for opposite-sign muon pairs for the beauty running condition. Enlarged versions of the J/ψ and ψ' mass peaks are also shown; there are about 85000 J/ψ and about 1600 ψ' in the sample, and the R.M.S. width of both mass peaks is about 16 MeV, dominated by multiple scattering in the target. Using the data to measure $Ed^3\sigma(J/\psi)/dp^3$ at $x_F = 0$ as a function of p_T, we find both shape and normalization to be quite similar to results at $\sqrt{s} = 52$ and 63 GeV [3].

If we demand that the J/ψ vertex lie at least 7 mm downstream of the center of the target, and that the impact parameters of both muons with respect to the center of the target be at least 152 μm, we find 16 events above background at the J/ψ mass within $0 < x_F < 0.1$ and $p_T < 2$ GeV. If we make the same cuts in the opposite sense, so that we are demanding decays that occur *upstream* of the target, no events survive, indicating that these cuts are well beyond the resolution tail for J/ψ produced in the target. Using these candidate events, we find that

$$\left.\frac{d^2\sigma(J/\psi \text{ from } b \text{ or } \bar{b})}{dx_F dp_T}\right|_{\substack{0 < x_F < 0.1, \\ p_T < 2\text{ GeV}}} = 127 \pm 35 \pm 20 \text{ pb/GeV}$$

This cross section is an average over the given range of x_F and p_T. A model can be used to interpolate to a point in p_T and x_F, and one can then multiply by $1/p_T$ to get a result that is proportional to the invariant cross section:

$$\left.\frac{1}{p_T}\frac{d^2\sigma(J/\psi \text{ from } b \text{ or } \bar{b})}{dx_F dp_T}\right|_{\substack{x_F = 0.05, \\ p_T = 1\text{ GeV}}} = 159 \pm 44 \pm 25 \text{ pb/GeV}^2.$$

We believe this interpolation to be model independent within the error given. This point is shown in Fig. 4, along with the prediction of a model based on NLO QCD [4], with Peterson fragmentation with $\epsilon = 0.006$ and CLEO decay distributions. This is the first measurement of the beauty cross section at fixed-target energy using a proton beam.

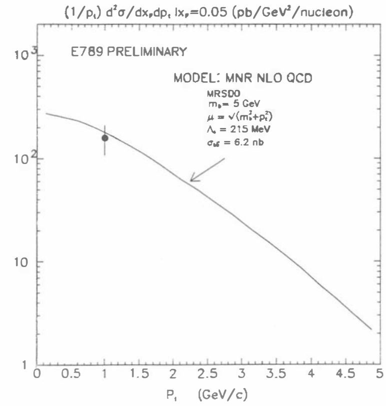

Figure 4: Doubly-differential cross section for $b\bar{b}$ pairs, with prediction of NLO QCD.

References

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