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E771

Production of J/ψ in 800 GeV/c p-Si Interactions

The E771 Collaboration

Fermi National Accelerator Laboratory
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PRODUCTION OF J/ψ IN 800 GeV/c p-Si INTERACTIONS

T. Alexopoulos[1], L. Antoniazzi[2], M. Arenton[3], H.C. Ballagh[4], H. Bingham[4],A. Blankman[5], M. Block[6], A. Boden[7], G. Bonomi[2], S.V. Borodin[5], J. Budagov[8], Z.L. Cao[3], G. Cataldi[9], T.Y. Chen[10], K. Clark[11], D. Cline[7], S. Conetti[3], M. Cooper[12], G. Corti[3], B. Cox[3], P. Creti[9], C. Dukes[3], C. Durandet[1], V. Elia[9], A.R. Erwin[1], E. Evangelista[9], L. Fortney[13], V. Golovatyuk[3], E. Gorini[9], F. Grancagnolo[9], K. Hagan-Ingram[3], M. Haire[14], P. Hanlet[3], M. He[15], G. Introzzi[2], M. Jenkins[11], J. Jennings[1], D. Judd[14], W. Kononenko[5], W. Kowald[13], K. Lau[16], T. Lawry[3], A. Ledovskoy[3], G. Liguori[2], J. Lys[4], P.O. Mazur[17], A. McManus[3], S. Misawa[4], G.H. Mo[16], C.T. Murphy[17], K. Nelson[3], M. Panareo[9], V. Pogosian[3], S. Ramachandran[7], M. Recagni[3], J. Rhoades[7], J. Segal[3], W. Selove[5], R.P. Smith[17], L. Spiegel[17], J.G. Sun[3], S. Tokar[18], P. Torre[2], J. Trischuk[19], L. Turnbull[14], I. Tzamouranis[3], D.E. Wagoner[14], C.R. Wang[15], C. Wei[13], W. Yang[17], N. Yao[10], N.J. Zhang[15], S.N. Zhang[5] and B.T. Zou[13]

(The E771 collaboration)

[1] University of Wisconsin, Madison, Wisconsin, USA
[2] Pavia INFN and University, Pavia, Italy
[3] University of Virginia, Charlottesville, Virginia, USA
[4] University of California at Berkeley, Berkeley, California, USA
[5] University of Pennsylvania, Philadelphia, Pennsylvania, USA
[6] Northwestern University, Evanston, Illinois, USA
[7] University of California at Los Angeles, Los Angeles, California, USA
[8] JINR, Dubna, Russia
[9] Lecce INFN and University, Lecce, Italy
[10] Nanjing University, Nanjing, People's Republic of China
[11] University of South Alabama, Mobile, Alabama, USA
[12] Vanier College, Montreal, Quebec, Canada
[13] Duke University, Durham, North Carolina, USA
[14] Prairie View A&M, Prairie View, Texas, USA
[15] Shandong University, Jinan, Shandong, People's Republic of China
[16] University of Houston, Houston, Texas, USA
[17] Fermilab, Batavia, Illinois, USA
[18] Comenius University, Bratislava, Slovakia
[19] McGill University, Montreal, Quebec, Canada

ABSTRACT

We report on the analysis of high mass opposite sign dimuon states produced in pSi interactions at $\sqrt{s} = 38.7$ GeV. These data have been collected with an open geometry fixed target spectrometer in the Fermilab Experiment E771. J/ψ and $\psi(2S)$ total cross sections and J/ψ x_f and p_t differential cross sections have been measured and compared with extrapolations from data at lower energies. Evidence for Υ meson production is also presented.

1. Introduction

The hadronic production of the J/ψ and $\psi(2S)$ charmonium states has been, and still is, an important test of QCD. Given the energy scale of this process and the relatively small coupling constant, perturbative QCD is expected to produce a reliable description of the production. The leading production processes at Fermilab Tevatron fixed target energies are gluon-gluon (at low x_F) and quark-antiquark fusion (at high x_F). Because of the dominance of gluon-gluon fusion at low x_F, the study of J/ψ production can be used to determine the gluon structure function of the nucleon.

In this paper we present data on J/ψ production in p-Si interactions at 800 GeV/c. The data were taken by Experiment E771 in the High Intensity Laboratory at Fermilab. The J/ψ's were detected via their decay into a dimuon final state. During a short ($\sim$ 1 month) 1991 data run approximately 127 million dimuon triggers containing 12733 J/ψ events were collected.

2. E771 experimental setup

The E771 open geometry, large acceptance spectrometer[1] consisted of 22 planes of multiwire proportional chambers and 9 planes of drift chambers (DC) positioned upstream of the analysis magnet, and by a set of 12 DC planes and six drift/pad chambers (2 wire planes, 1 strip plane and 1 pad plane per chamber) located downstream of the magnet. The chambers were deadened in a region around the beam axis, resulting in a minimum acceptance angle of about 25 mrad. The spectrometer included a 12 plane silicon microstrip vertex detector and an electromagnetic calorimeter, neither of which were used in the following analysis. A 95$\times$185 cm^2 aperture dipole analysis magnet provided a p_T kick of 0.821 GeV/c in the horizontal plane. In order to identify and distinguish muons from charged hadrons, a muon detector was located downwstream of the tracking chambers. It consisted of three planes of scintillator and Resistive Plate Counters[2] (RPCs) interspersed among three steel and concrete shielding walls. The walls imposed a lower bound of approximately 6 GeV/c (10 GeV/c in the central region) on the muon momentum.

The average beam intensity during the E771 data run was approximately 4×10^7 protons/s per 23 second spill every 56 seconds, resulting in an integrated number of live protons on target of $(1.65 \pm 0.17) \times 10^{13}$. The target consisted of 12 silicon foils (each foil 2 mm thick) spaced 4 mm apart, representing a total of 4.1 % of an interaction length. The average interaction rate was about 2 MHz. Selective single and dimuon triggers using the muon detector were implemented, where a muon was defined by the triple coincidence of signals in an approximately projective set of pads in the three RPC planes[3].

3. Data Analysis

A sample of 1.27×10^8 events was accumulated on tape using the dimuon trigger. The events were reconstructed using all tracking elements of the E771 spectrometer except the silicon detector and calorimeter.

Muons candidates were first identified in the muon detector and a crude trajectory was reconstructed using the RPC pads and scintillators. Track segments downstream of the analysis magnet were then reconstructed using the downstream chambers hits within a search window defined by the RPC muon tracks. Once the muon segments behind the magnet had been determined, track segments upstream of the analysis magnet were reconstructed and matched to downstream muon segments to form momentum-determined muon tracks. Opposite sign dimuon pairs were required to originate from a common vertex. In a given event only the dimuon pair forming the best common vertex was selected for the J/ψ studies.

The dimuon mass spectrum of these best pairs is shown in Fig. 1. Clear J/ψ and $\psi(2S)$ peaks can been seen in the invariant mass spectrum, as well as a Υ signal.

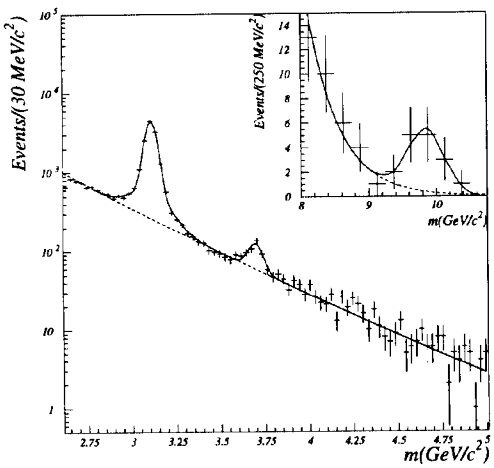

Fig. 1: Mass spectrum (fit described in text). In the small frame the Υ region is showed together with an exponential fit to the background.

4. J/ψ and $\psi(2S)$ Total Cross Sections

Superimposed on the dimuon mass spectrum in Fig. 1 is a fit to the data using the sum of two Gaussians for the J/ψ peak, a single Gaussian for the $\psi(2S)$ peak and an exponential form for the continuum background (dominately due to π and K decays). Two Gaussians produce a better fit to the J/ψ state because a sizable fraction of the decays muons inhabit regions of the detector with high track density producing non-Gaussian tails. From the fit of Fig. 1 we obtain $N_{J/\psi} = 12733 \pm 208$ and $N_{\psi(2S)}$=207±23 for the background subtracted number of events in the J/ψ and $\psi(2S)$ peaks, respectively.

To determine overall reconstruction efficiencies and acceptance, we generated 8×10^5 Monte Carlo J/ψ decays into dimuons. The x_F and p_T distributions for the Monte Carlo J/ψ's were taken from published data on J/ψ production at lower energies[4]. The dimuons were propagated through a GEANT simulation of the E771 detector, which incorporated measured detector and trigger efficiencies, multiple scattering, and other effects that degraded the tracks. The hit information from this simulation was superimposed onto real J/ψ events in order to provide a realistic estimate of the background from noise and other tracks associated with the events. The dimuon events were then processed with the same tracking programs as those used on the data. New x_F and p_T distributions, corrected by the resulting acceptance and efficencies, were then inserted into the Monte Carlo for more iterations. By this technique, global acceptance and efficiencies were obtained for the J/ψ decay into muon pairs.

The total inclusive cross section per nucleon has been evaluated assuming an atomic weight dependence[5] of $A^{\alpha}=A^{0.920\pm0.008}$ and the measured branching ratio[6] (Br) for $J/\psi \rightarrow \mu\mu$ of (5.97 ± 0.25) %. The inclusive J/ψ production cross section (σ) was determined to be $330 \pm 5 \pm 35$ nb/nucleon, where the first error is statistical and the second is systematic.

Applying a similar technique to the $\psi(2S)$ and assuming a measured branching ratio[6] for $\psi(2S) \rightarrow \mu\mu$ of $(7.7 \pm 1.7) \times 10^{-3}$ we determined the inclusive $\psi(2S)$ production cross section to be $36 \pm 4 \pm 10$ nb/nucleon, where again the first error is statistical and the second is systematic. From our measured total inclusive cross sections we also obtain a ratio $Br \cdot \sigma(\psi(2S) \rightarrow \mu^+\mu^-)/Br \cdot \sigma(J/\psi \rightarrow \mu^+\mu^-)$ of 0.014 $\pm$ 0.0015.

We have compared our J/ψ $Br{\cdot}\sigma$ to that of previous experiments (correcting them for the latest branching ratio measurement and atomic dependence) as a function of $\sqrt{s}$. The data have been fit[7] to the threshold production parameterization

$$Br \cdot \sigma(J/\psi \rightarrow \mu^+\mu^-) = \sigma_0 \cdot (1 - M_{J/\psi}/\sqrt{s})^N, \tag{1}$$

with $\sigma_0 = (59 \pm 6)$ nb/nucleon and $N = 11.7 \pm 0.5$.

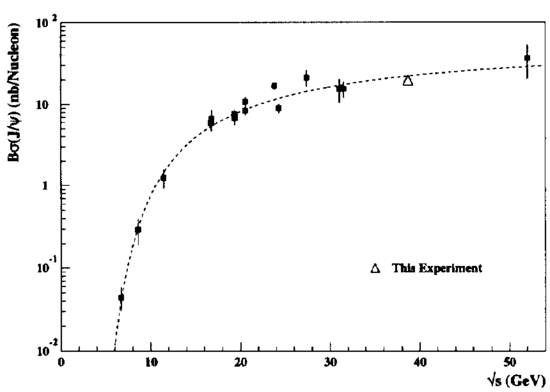

Fig. 2: Threshold production parametrization $Br{\cdot}\sigma(J/\psi)$ vs c.m. energy. The parametrization is described in the text.

5. Differential Cross Sections

We have also studied the x_F and p_T differential cross sections for J/ψ. These distributions were obtained by extracting the J/ψ signal in bins of x_F and p_T respectively. The data so obtained, corrected for acceptance and normalized by luminosity, are shown in Fig. 3a, where the parametrization used to fit the x_F curve is:

$$\frac{d\sigma}{dx_F} \propto (1 - |x_F|)^c. \tag{2}$$

We have used form (2) to fit our x_F distribution for the purpose of comparison with other experiments.

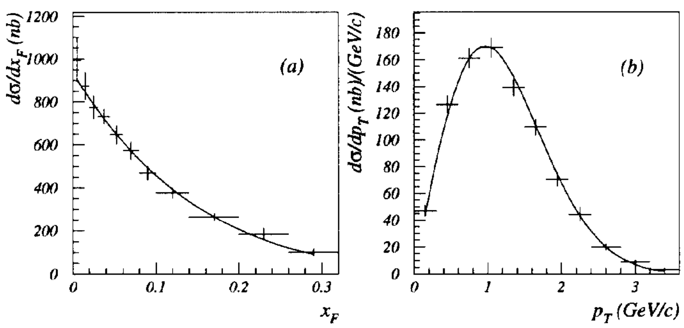

Fig. 3: J/ψ x_F (a) and p_T (b) distribution fitted with the parametrization described in the text.

Our fitted value c=6.8 $\pm$ 0.3 (the error is statistical) is in good agreement with an extrapolated value of c=6.2 $\pm$ 2.6, obtained from a parameterization[8] of the energy dependence of the c parameter based on data from experiments. These experiments cover a wide range of energies, targets, and configurations.

The J/ψ cross section as a function of transverse momentum (p_T), shown in Fig. 3b, has been fit to the following expression:

$$\frac{d\sigma}{dp_T} \propto p_T \cdot \exp(-bp_T^2). \tag{3}$$

The fitted values of the b parameter and of the mean and mean squared of the transverse momentum obtained are respectively b=0.54 $\pm$ 0.02, $< p_T >$=1.20 $\pm$ 0.02 and $< p_T^2 >$=1.85 $\pm$ 0.06. We have used the energy dependence parameterization of Ref.8 to compare our $< p_T >$ value to that of other experiments. Extrapolation to our $\sqrt{s}$=38.7 energy gives $< p_T >$=1.17 $\pm$ 0.05 in good agreeement with our data.

We have also investigated the x_F and p_T differential cross sections for the $\psi(2S)$. The distributions, obtained in the same manner as those of the J/ψ, are show in Fig. 4. In analogy with the J/ψ, we used the form of Eq. (2) to fit the x_F distribution and the form of Eq. (3) to fit the p_T curve. The fitted values of the c and b parameters are respectively c=6.2 $\pm$ 1.7 and b=0.6 $\pm$ 0.2.

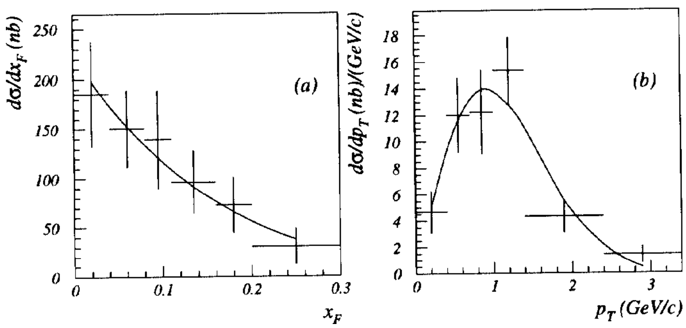

Fig. 4: ψ x_F (a) and p_T (b) distribution fitted with the parametrization described in the text.

6. Acknowledgments

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