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Nuclear Dependence of J/ψ and ψ' Production

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FNAL E866/NuSea has made a number of measurements of J/ψ and ψ' production by 800 GeV protons on fixed targets of Be, Fe and W. Preliminary results are presented and discussed in the context of nuclear effects such as energy loss and multiple scattering of the partons, absorption of the produced $c\bar{c}$ pairs, and shadowing. Production mechanisms involving color-singlet or color-octet states for the $c\bar{c}$ pair which eventually forms a J/ψ or ψ' have implications on the strength of absorption in the nucleus. These nuclear dependence studies are critical in furthering our understanding of these processes towards future measurements at RHIC and the LHC, where J/ψ suppression is predicted to be an important signature of the creation of quark-gluon plasma in heavy-ion collisions.

1. Introduction

Here we present results from the E866/NuSea experiment, an 800 GeV/c proton fixed-target experiment done at Fermilab in 1996 and 1997. The primary goal of this exper-

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iment, a measurement of the $\bar{d}/\bar{u}$ asymmetry in the nucleon sea, will not be discussed here, and is already published [1]. The nuclear dependence results which are discussed here are preliminary, and are expected to change in detail, but not qualitatively, as the analysis of the data progresses.

2. FNAL Meson East Spectrometer

E866 used a 3-dipole magnet pair spectrometer employed in previous experiments (E605, E772, and E789) [2], modified by the addition of new drift chambers and hodoscopes with larger acceptance at the first tracking chamber and a new trigger system [3]. For the nuclear dependence measurements, an 800 GeV/c extracted proton beam of up to 2×10^{12} protons per 20 s spill bombarded thin solid targets of Be, Fe, and W in a rotating wheel. After passing through the target, the remaining beam was absorbed in a copper beam dump located inside the large second magnet. Following the beam dump was a 13.4 interaction length absorber wall which filled the entire aperture of the magnet and helped stop hadrons and assured that only muons traversed the spectrometer's detectors. These muons were then tracked through a series of detector stations composed of drift chambers and hodoscopes. Because of improvements in the trigger system, the coverage in p_T was much broader than in previous experiments using this spectrometer (e.g. E772) and extended to over 4 GeV/c.

3. Nuclear Dependence of J/ψ and ψ' Production

The suppression of J/ψ production in nuclei is probably a result of many different effects including absorption on nucleons or on co-moving light quarks or hadrons, energy loss, and shadowing and other nuclear effects. Also the question of whether the $c\bar{c}$ pairs are produced in color-singlet or octet states has an important implication on the strength of the absorption since an octet state will be more readily absorbed than a singlet state. In order to distinguish these different sources of suppression it is important to have data over broad ranges in x_F and p_T. The data presented here broadens the range in these kinematic variables and increases the statistics over previous measurements in p-A collisions. A thorough understanding of this physics is also essential towards future studies at RHIC and the LHC where the suppression of charmonia production in heavy-ion collisions is thought to be an important signature for the formation of the quark-gluon plasma.

Over three million J/ψ's and 150 thousand ψ''s have been observed over a range in x_F of -0.15 to 0.95 and p_T up to more than 4 GeV/c. For convenience we will present our data in terms of α, where α is defined by, $\sigma_A = \sigma_p * A^{\alpha}$. In this representation a value of $\alpha = 1$ means that there is no suppression (or enhancement) of the J/ψ cross section per nucleon in a heavy nucleus compared to a light nucleus.

The p_T dependence of α is shown in Fig. 1 for two portions of our data. Two different spectrometer settings were used to obtain data over the measured x_F range. The small-x_F (SXF) data in Fig. 1 has a smaller suppression than the large-x_F (LXF) data because of the strong decrease of α for larger values of x_F. It is important to note that the shapes versus p_T are approximately the same for the two regions of x_F. The general increase in α with p_T is a typical nuclear effect in production processes such as this and in the Drell-Yan process. This increase is thought to be a result of multiple scattering of the incident

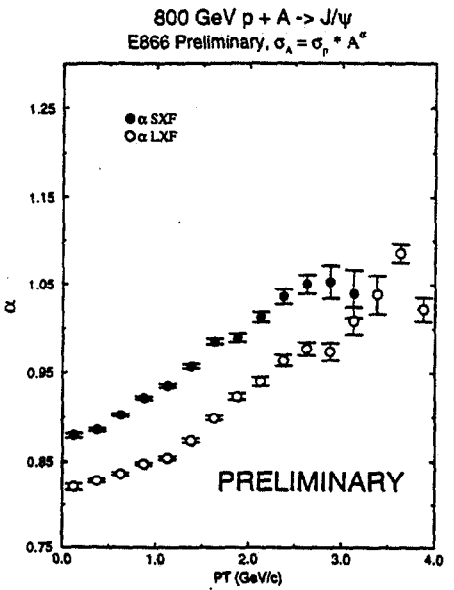

Figure 1. Preliminary results for α versus p_T for J/ψ. Results are shown for two ranges in x_F: $-0.15 \leq x_F \leq 0.3$ (SXF) and $0.3 \leq x_F \leq 0.95$ (LXF).

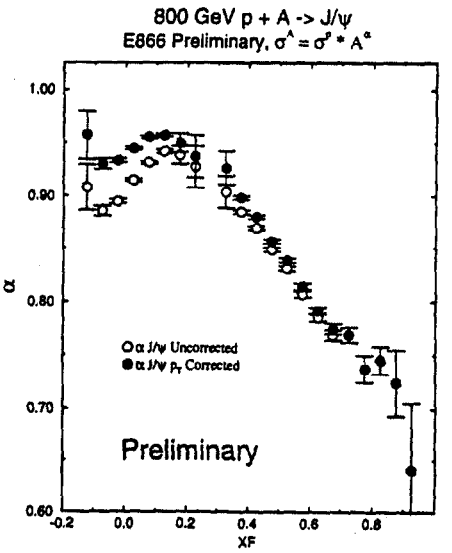

Figure 2. Preliminary values of α versus x_F for J/ψ production with and without a correction for the p_T acceptance, as described in the text.

parton and, in the case of resonance production, the resonance or nascent resonance.

Previous experiments such as E772 [4] have had a limited acceptance in p_T which varied with x_F. Since the value of α depends strongly on p_T this can distort of the observed shape of α versus x_F. In E866, while our p_T acceptance is much broader than in the older experiments, at the lowest values of x_F for each of the two spectrometer settings our p_T acceptance narrows. To remove this p_T acceptance bias, we assumed that α was separable in x_F and p_T. We then made a correction to α using the known p_T acceptance for each x_F bin and the universal shape of α versus p_T. The results are shown in Fig. 2 along with the uncorrected α values. The correction is quite important for values of x_F below about 0.15 and near 0.37 where our p_T range is limited. It makes little difference elsewhere. A similar correction was made to the ψ'.

We have also extracted the x_F dependence of α for the ψ'. Since the ψ' peak is much smaller than that for the J/ψ much more care in extracting the yield must be taken. At this time we are still working to improve our fitting techniques, but already the general features seem stable. These are shown in Fig. 3, where one sees that the ψ' is suppressed about the same as the J/ψ for positive values of x_F but for x_F below zero the ψ' is more strongly suppressed. This is the first time that a stronger suppression of ψ' has been seen in p-A production, but it is not completely unexpected. It is natural to expect that for large x_F, where the J/ψ and ψ' are not hadronized in the nucleus but rather are a nascent $c\bar{c}$ pair, their absorption would be the same. But for a small enough x_F one would expect

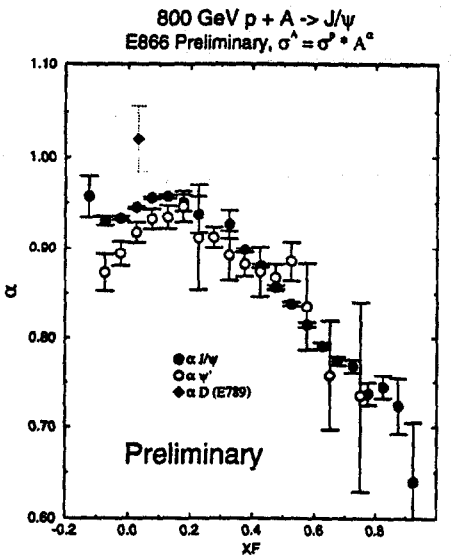

Figure 3: Preliminary values of α from E866 versus x_F for production of J/ψ and ψ' by 800 GeV/c protons. Also shown is the result from E789 for the D meson.

them to become physical, in which case the ψ' would be absorbed more strongly than the J/ψ since its size is larger and its binding energy smaller.

Also in Fig. 3 is the α obtained in E789 for the production of D mesons [5], which illustrates that, at least near $x_F = 0$, the mechanism that causes the suppression of the charmonia resonances does not affect open charm. This probably means that absorption effects are the main source of the suppression of the J/ψ and ψ' near $x_F = 0$. However, the increasing suppression for J/ψ and ψ' for larger values of x_F is probably due to other effects such as energy loss [6] or coherence lengths [7].

REFERENCES

1. E. A. Hawker *et al.*, Phys. Rev. Lett. 80 (1998) 3715 and J. C. Peng *et al.*, Phys. Rev. D 58 (1998) 092004.
2. G. Moreno *et al.*, Phys. Rev. D 43 (1991) 2815.
3. C. A. Gagliardi *et al.*, Nucl. Instrum. Methods A 418 (1998) 322.
4. D. M. Alde *et al.*, Phys. Rev. Lett. 66 (1991) 133 and Phys. Rev. Lett. 66 (1991) 2285.
5. M. J. Leitch *et al.*, Phys. Rev. Lett. 72 (1994) 2542.
6. S. Gavin and J. Milano, Phys. Rev. Lett. 68 (1992) 1834.
7. J. Hufner and B. Kopeliovich, private communication and Phys. Rev. Lett. 76 (1996) 192.