Nuclear Suppression of Vector Meson Production in FNAL E866/NuSea

R.S. Towell
for the
FNAL E866/NuSea Collaboration

Los Alamos National Laboratory, Los Alamos, NM 87545, USA
E-mail: towell@lanl.gov

Abstract
Measurements of the suppression of the yield per nucleon of J/ψ and ψ' production for 800 GeV/c protons incident on nuclear targets have been made with very broad coverage in x_F and p_T. Over 3×10^6 J/ψ's and 10^5 ψ''s with x_F between -0.10 and 0.93 and p_T up to 4 GeV/c were observed. Data for Be, Fe and W targets were used to determine the cross section ratio per nucleon between heavy and light targets for both the J/ψ and the ψ'. The largest suppression is observed at large x_F and small p_T values. The suppression for the ψ' is stronger than that for the J/ψ for x_F near zero, but becomes comparable to that for the J/ψ for $x_F > 0.5$.

Strong suppression of the yield per nucleon of heavy vector mesons produced in heavy nuclei relative to that in light nuclei has been observed in proton- and pion-nucleus collisions [1, 2, 3, 4]. Similar effects have also been observed in heavy-ion collisions [5]. This suppression exhibits strong kinematic dependences, especially with Feynman-x (x_F) and transverse momentum (p_T) of the produced vector meson. Since the suppression of heavy vector meson production in heavy-ion collisions is predicted to be an important signature for the formation of the quark-gluon plasma (QGP), it is important to understand the mechanisms that can produce similar effects in its absence.

Many effects, such as absorption, parton energy loss, shadowing and feeddown from higher mass resonances, have been considered [6, 7, 8, 9] in attempting to describe the observed proton-induced charmonium yields from nuclear targets. However, an adequate understanding of the problem has not been achieved. Even the absolute cross sections are poorly understood due to poor knowledge of the production mechanism. Recognizing that the production and suppression mechanisms can be identified by their strong kinematic dependences, it is crucial to have data with broad kinematic coverage. Such descriptions are essential if the charmonium yield is to be used as a signature of a QGP.

Fermilab E866/NuSea has made a measurement of the nuclear dependence of J/ψ and ψ' production for proton-nucleus collisions on Be, Fe, and W targets. Over 3×10^6 J/ψ's and 10^5 ψ''s with x_F between -0.10 and 0.93 and p_T up to 4 GeV/c were observed. E866/NuSea used a 3-dipole magnet pair spectrometer employed in previous experiments (E605[10], E772, and E789), modified by the addition of new drift chambers and hodoscopes with larger acceptance at the first tracking chambers and a new trigger system [11].

An 800 GeV/c extracted proton beam of up to 6×10^{11} protons per 20 s spill bombarded one of the thin solid targets of Be, Fe or W. Because of improvements in the trigger system, the coverage in p_T was much broader than in previous experiments on this spectrometer (e.g. E772). Three magnetic field and target location configurations were used to span the full range in x_F: small-x_F (SXF, $-0.1 \leq x_F \leq 0.3$), intermediate-x_F (IXF, $0.2 \leq x_F \leq 0.6$) and large-x_F (LXF, $0.3 \leq x_F \leq 0.93$).

The results presented here are in terms of α, where α is obtained by assuming the cross section dependence on nuclear mass, A, to be of the form $\sigma_A = \sigma_N \times A^\alpha$, where σ_N is the cross section on a nucleon. The p_T dependence of α is shown in Fig. 1 for all three data sets as well as for the 200 GeV/c NA3 data[3]. This increase is characteristic of multiple scattering of the incident parton and of the nascent $c\bar{c}$ in the final state.

Previous experiments such as E772 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 cause a distortion of the apparent shape of α versus x_F. The improvements in the E866/NuSea trigger

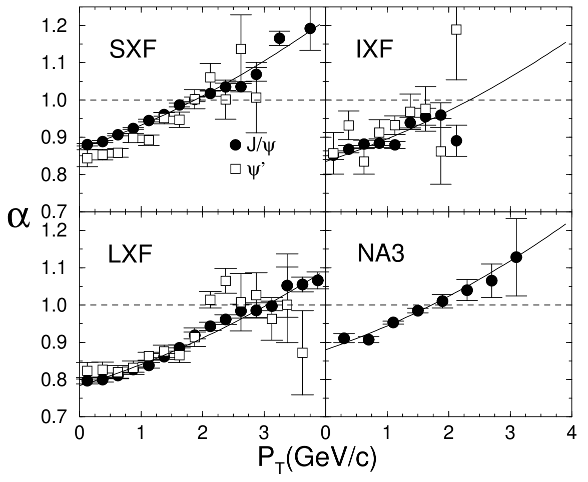

Figure 1. α versus p_T for J/ψ (solid circles) and ψ' (open boxes) production by 800 GeV/c protons. Results are shown for the three data sets – SXF, IXF and LXF – whose x_F ranges are described in the text and have $\langle x_F \rangle$ = 0.055, 0.308 and 0.480, respectively. Only statistical uncertainties are shown. An additional systematic uncertainty of 0.7% is not included. Also shown are the NA3 [3] results at 200 GeV/c.

allowed for a much broader p_T acceptance than in these earlier measurements. However, for the lowest values of x_F at each spectrometer setting our p_T acceptance still becomes somewhat restricted. The $\alpha(x_F)$ results presented here have been corrected using a detailed simulation of the acceptance and a differential cross section shape versus p_T derived from the data. The resulting dependence of α on x_F is shown in Fig. 2. The systematic uncertainty of 1% in the corrected α is dominated by the p_T acceptance correction.

The suppression of and differences between the ψ' and J/ψ near $x_F = 0$ are commonly thought to be caused by the dissociation of the $c\bar{c}$ pair by interactions with the nucleus or with comovers[6] into a separate charmed quark and anti-quark which would eventually hadronize into D mesons. At these small values of x_F the velocity of a nascent $c\bar{c}$ in the nuclear medium is lower and it may tend to hadronize while still in the nucleus. If this is so, the larger ψ' would naturally be absorbed more strongly than the J/ψ, as seen in our data. Comparison of these results with the lack of suppression seen for D mesons near $x_F = 0$[12], where this dissociation mechanism is not available, support this general picture. On the other hand, faster $c\bar{c}$'s at larger x_F would experience similar absorption.

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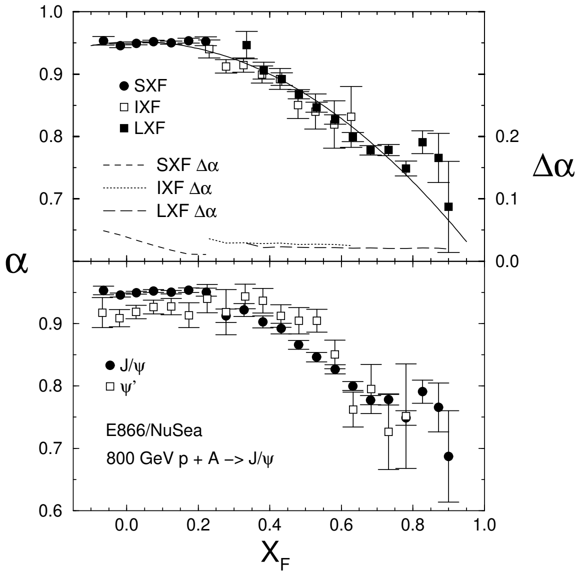

Figure 2. α for the J/ψ versus x_F for the three different data sets (top) and for the J/ψ and ψ' after the data sets are combined (bottom). Values are corrected for the p_T acceptance, as discussed in the text. These corrections ($\Delta\alpha$) have a maximum value of 0.05 and are shown using the right-hand vertical scale in the top panel as dotted or dashed lines for the three different data sets. An additional systematic uncertainty of 1% is not included.

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