Title

TRANSVRESE-MOMENTUM DEPENDENCE OF J/PSI PRODUCTION IN NUCLEAR COLLISIONS

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Transverse-Momentum Dependence of J/ψ Production in Nuclear Collisions†

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Abstract: The suppression of J/ψ production at transverse momenta $p_\perp < 2$ GeV/c in central $^{16}O + ^{238}U \rightarrow \psi + X$ at 200 AGeV has been interpreted as a possible signature of quark-gluon plasma formation. We show, however, that the observed $p_\perp$ dependence is consistent with extrapolations from $p + A \rightarrow \psi + X$ data, and that quasielastic initial-state parton scattering together with final-state inelastic hadronic reactions may explain the preliminary data.

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Ongoing experiments at CERN with 200 AGeV Oxygen and Sulphur beams on nuclear targets indicate a substantial suppression of the production of J/ψ's with transverse momenta $p_\perp < 2$ GeV in central collisions [1]. This suppression has been attributed to both screening in a quark-gluon plasma [2,3] and to final-state inelastic scattering in a dense hadron gas [4-7] (see also [8-10]). While the magnitude of the suppression can be explained by either effect, the rapid $p_\perp$ dependence is not easily described by final-state scattering alone. However, recent $p + A \rightarrow \psi + X$ data at SPS energies reveal a considerable increase in the mean $p_\perp$ with increasing A, e.g., $\langle {p_\perp}^2 \rangle_{p+Pt\rightarrow\psi+X} / \langle {p_\perp}^2 \rangle_{p+p\rightarrow\psi+X} \approx 1.3$ [11,12]. Significantly, similar results are found in Drell-Yan dimuon production [13] where screening and final-state scattering effects are negligible. These nuclear enhancements of $\langle {p_\perp}^2 \rangle$ in hadron-induced reactions can result from the quasielastic scattering of projectile and target partons before the hard $c\bar{c}$ or Drell-Yan production [14].

In this paper we emphasize the strong influence of initial-state scattering on the $p_\perp$ dependence of J/ψ production in nucleus-nucleus collisions, as suggested in Ref. [5]. We show that the $p_\perp$ variation in nuclear collisions is in fact consistent with the hadron-nucleus results, and that initial-state interactions together with final-state inelastic hadronic processes [4-7] can explain the preliminary nucleus-nucleus data.

The NA 38 experiment at CERN studies the J/ψ yield $dN_\psi/d^2p_\perp$ relative to the $p_\perp$-integrated continuum dimuon yield N_c in the central rapidity region, and reports the transverse momentum dependence of the ratio [1]

$$R(p_\perp) \equiv \frac{({N_c}^{-1} dN_\psi/d^2p_\perp)_{E_T^>}}{({N_c}^{-1} dN_\psi/d^2p_\perp)_{E_T^<}} \tag{1}$$

for several high transverse energy bins $E_T^>$, compared to the lowest bin $E_T^<$ (central collisions typically generate more hadronic transverse energy than do peripheral collisions). The preliminary data [1] together with the calculations discussed below are shown in Fig. 1a. In Fig. 1b we compare the normalized $p_\perp$ distributions ${N_\psi}^{-1} dN_\psi/dp_\perp$ from Ref. [1] with those measured using a 200 GeV proton beam on Platinum and Hydrogen targets [11]. We see that the Pt distribution is wider than the p distribution, and that the $O + U$ distribution is wider still. The difference in the Pt and p distributions corresponds to an increase in the $p_\perp$ dispersion

$$\langle {p_\perp}^2 \rangle_{p+Pt\rightarrow\psi} - \langle {p_\perp}^2 \rangle_{p+p\rightarrow\psi} = 0.34 \pm 0.06\,\mathrm{GeV}^2, \tag{2}$$

where $\langle {p_\perp}^2 \rangle_{p+p\to\psi} = 1.23 \pm 0.05\,\mathrm{GeV}^2$ [11].

Measurements of Drell-Yan production by NA 10 [13] in $\pi^- + A$ at 140 GeV show a similar increase of

$$\langle {p_\perp}^2 \rangle_{\pi^- + W \to \mu^+\mu^-} - \langle {p_\perp}^2 \rangle_{\pi^- + D \to \mu^+\mu^-} = 0.15 \pm 0.06\,\mathrm{GeV}^2, \tag{3}$$

where $\langle {p_\perp}^2 \rangle_{\pi^- + D \to \mu^+\mu^-} \approx \langle {p_\perp}^2 \rangle_{\pi^- + p \to \mu^+\mu^-} = 1.44 \pm 0.02$ GeV^2 [17]. The $p_\perp$ enhancement in Drell-Yan production can only be caused by initial-state interactions, since the final state does not interact strongly. This effect was predicted[14] due to the possible quasielastic scattering of the sea quark and anti-quark before their annihilation. Such scattering adds to the $\langle {p_\perp}^2 \rangle$ of the resulting dimuons but does not reduce the $p_\perp$-integrated yield, because it redirects the beam momentum transversely without changing the net parton flux. The enhancement is stronger in heavier nuclear targets because there is more opportunity for partons to scatter. The absence of an absorptive component of initial-state interactions is supported by the $A^{1.0\pm0.03}$ dependence of the $p_\perp$-integrated cross section. In Fig. 2a we show that a gaussian parametrization for the Drell-Yan continuum yield $dN_c/d^2p_\perp$ provides a good fit to the measured ratio of yields $(dN_c/d^2p_\perp)_{\pi^- + W \to \mu^+\mu^-}/(dN_c/d^2p_\perp)_{\pi^- + D \to \mu^+\mu^-}$ in Ref. [13].

To understand how initial-state and final-state interactions are manifested in the NA 38 ratio of relative yields, we express the J/ψ yield as the product of a formation distribution $\mathcal{N}_\psi F_\psi(p_\perp)$, and a survival probability $S(p_\perp)$,

$$dN_\psi/d^2p_\perp \approx \mathcal{N}_\psi F_\psi(p_\perp) S(p_\perp), \tag{4}$$

where all quantities implicitly depend on the global observable E_T through the impact parameter, and the formation probability F_ψ satisfies $\int F_\psi(p_\perp) d^2p_\perp = 1$. Final-state interactions such as $\rho + \psi \to D\overline{D}$ reduce the J/ψ's survival probability in high E_T events, as discussed in [5]. In analogy to (4), we write the Drell-Yan continuum yield as $dN_c/d^2p_\perp = \mathcal{N}_c F_c(p_\perp)$, i.e., $S \equiv 1$. We further assume that the ratio $\mathcal{N}_\psi/\mathcal{N}_c$ is independent of E_T, since both J/ψ and Drell-Yan dimuon production are hard processes. The ratio (1) is then

$$R(p_\perp) \approx \frac{(F_\psi(p_\perp) S(p_\perp))_{E_T^>}}{(F_\psi(p_\perp) S(p_\perp))_{E_T^<}}. \tag{5}$$

Initial-state scattering enhances the dispersion of F_ψ with increased centrality, so that the ratio $(F_\psi)_{E_T^>}/(F_\psi)_{E_T^<}$ rises with increasing $p_\perp$.

We assume that the initial-state scattering of the gluons prior to fusion contributes most of the $p_\perp$ enhancement evident in Fig. 1b, since the $S(p_\perp)$ varies by less than $\sim$ 20% in for $0 < p_\perp < 3$ GeV/c [4-7]. In Fig. 1b we compare our parametrization of $N_\psi{}^{-1} dN_\psi/d^2p_\perp \approx F_\psi(p_\perp)$ to the measured yields [11] for 200 GeV protons on Platinum and Hydrogen. We take F_ψ to be exponential in the transverse mass $m_\perp \equiv \sqrt{p_\perp{}^2 + M^2}$,

$$F_\psi(p_\perp) \approx \mathcal{A} e^{-\alpha m_\perp}, \tag{6}$$

where we use $\langle p_\perp{}^2 \rangle \equiv \int p_\perp{}^2 F(p_\perp) d^2p_\perp$ to relate the slope parameter α to the relevant experimental dispersion [11] (the gaussian parametrization for F_c used in Fig. 2a does not provide an adequate fit to the J/ψ data in the 0 to 3 GeV/c range).

To estimate the J/ψ yield (4) in a nucleus-nucleus collision, we use multiple scattering theory to relate $\langle p_\perp{}^2 \rangle$ in (6) to the mean number of inelastic nucleon-nucleon collisions $\overline{n}$ that occur as the projectile traverses the target. We use data on hadron-nucleus scattering to determine the parameters in the model, and then use the LUND Fritiof model [15,16] to relate $\overline{n}$ to E_T. This procedure determines $(F_\psi)_{E_T^>}/(F_\psi)_{E_T^<}$. Next, we incorporate final-state absorption following Ref [5], and estimate the ratio of relative J/ψ yields shown in Fig 1a. In addition, we compare the calculated $N_\psi{}^{-1} dN_\psi/d^2p_\perp$ to data on $O + U$ in Fig. 1b. Finally, we predict the distribution of Drell-Yan dimuons in the same E_T cuts shown in Fig. 2b.

To understand how $\langle p_\perp{}^2 \rangle$ varies with the number of inelastic nucleon-nucleon interactions and A, consider first hard Drell-Yan or J/ψ production in a proton-nucleus reaction at an impact parameter $\vec{b}$. Suppose that a total of n *inelastic* proton-nucleon collisions occur and that during the m^{th} collision, a parton i from the incident nucleon suffers a hard interaction. In any of the inelastic collisions prior to the m^{th}, this parton may have suffered an *elastic* interaction with a target parton. If the probability that such an elastic collision occurs is P_{iN}, then the average number of initial-state collisions of parton i is

$$\langle n_i \rangle = \frac{1}{n} \sum_{m=1}^{n} P_{iN}\{m-1\} = \frac{1}{2} P_{iN}\{n-1\}. \tag{7}$$

The probability P_{iN}, which we assume to be independent of momentum and m, is proportional to an effective parton-nucleon elastic cross section σ_i. In each of these initial-state elastic collisions the parton acquires a transverse momentum, $\delta\vec{p}_\perp$, of random direction with a dispersion $\delta p_{\perp}{}_i^2$. After n steps this random walk leads to

$$p_\perp(n)^2 = p_{\perp 0}{}_i^2 + \langle n_i\rangle \delta p_{\perp}{}_i^2 = p_{\perp 0}{}_i^2 + P_{iN}\delta p_{\perp}{}_i^2\{n-1\}/2, \tag{8}$$

where $p_{\perp 0}{}_i^2$ arises from the intrinsic motion of the partons inside the nucleon. In J/ψ production where the parton i is a gluon, $p+p$ data [11] fix the intrinsic dispersion $p_{\perp 0}{}_g^2 \approx \langle p_\perp{}^2\rangle_{p+p\to\psi+X} = 1.23 \pm 0.05\,\mathrm{GeV}^2$. Similarly, $p_{\perp 0}{}_q^2 \approx \langle p_\perp{}^2\rangle_{p+p\to\mu^+\mu^-+X} = 1.38 \pm 0.07\,\mathrm{GeV}^2$ from Drell-Yan data [17]. Averaging over impact parameters, we see that

$$\langle p_\perp{}^2\rangle \approx p_{\perp 0}{}_i^2 + \lambda_i{}^2\left\{\overline{n}-1\right\}, \tag{9}$$

where $\lambda_i \equiv \{P_{iN}\delta p_{\perp}{}_i^2/2\}^{1/2}$ is the effective transverse-momentum transfer per collision, and $\overline{n}$ is the impact parameter averaged number of inelastic interactions. We use (2), (3), and (9), and take $\overline{n}_{p+Pt} \approx \overline{n}_{p+W} \approx 3.7$ ($\overline{n}_{p+A} \approx 0.77\,A^{0.3}$), to find

$$\lambda_g{}^2 \approx 0.12 \pm 0.02\,\mathrm{GeV}^2, \quad \lambda_q{}^2 \approx 0.056 \pm .0.022\,\mathrm{GeV}^2. \tag{10}$$

Note that the ratio $(\lambda_g/\lambda_q)^2 \approx \sigma_g\delta p_{\perp}{}_g^2/\sigma_q\delta p_{\perp}{}_q^2 \approx 9/4$ agrees remarkably well with a simple perturbation theory estimate, assuming that parton-nucleon scattering is dominated by forward-angle parton-gluon scattering. We surmise that the λ_i are independent of the projectile hadron, since the A dependence of the $p_\perp$ shift for J/ψ is found to be the same for $\pi^\pm$ and p beams [11-13].

In a nucleus-nucleus collision the $p_\perp$ dispersion is increased by the scattering of target partons in the projectile as well as by that of projectile partons in the target. The total dispersion is then simply

$$\langle p_\perp{}^2\rangle_{AB} \approx p_{\perp 0}{}_i^2 + \lambda_i{}^2\left\{\overline{n}_A + \overline{n}_B - 2\right\}. \tag{11}$$

where $\overline{n}_A$ and $\overline{n}_B$ are the number of inelastic collisions suffered by nucleons in the projectile A and in the target B. The distribution F_ψ then varies with E_T through $\langle p_\perp{}^2\rangle_{AB}$, since $\overline{n}_A + \overline{n}_B$ and E_T are correlated via the impact parameter. We estimate this correlation using the ATTILA version [16] of the LUND Fritiof/JETSET 6.3 string fragmentation model [15]. This Monte Carlo nuclear collision event generator incorporates exact Glauber geometry and kinematics and generates exclusive events from which global observables such as E_T can be calculated incorporating the finite experimental acceptances. This and similar multi-string fragmentation models successfully reproduce many of the gross features the preliminary CERN data [18] and provide the only self-consistent way to calculate such correlations at present.

To simulate the acceptance of the NA 38's electromagnetic calorimeter, we calculate the E_T from the transverse energy of the neutral particles together with a 30% contamination of charged particles in the pseudorapidity range $2.0 \leq \eta \leq 4.2$. For $O + U$ at 200 AGeV, we find that

$$\overline{n}_O + \overline{n}_U \approx 2.5 + E_T/(11\,\mathrm{GeV}). \tag{12}$$

In addition, we find the correlation between the initial hadronic resonance rapidity density and the above defined E_T is

$$dN_H/dy \approx E_T/(1\,\mathrm{GeV}). \tag{13}$$

These linear correlations are a simple consequence of Glauber geometry and independent string fragmentation. The coefficients however depend sensitively on the exact definition of E_T, the beam energy and on A and B.

The sensitivity of (12,13) to the definition of E_T presents one the major obstacles in interpreting the NA 38 data. Our calculations suggest that the ATTILA/LUND model may underestimate the NA 38 E_T distribution by as much as 50% in central collisions. For example, we find that $\langle E_T \rangle \approx 60$ GeV in a central collision, while the highest NA 38 E_T bin has a centroid of roughly 94 GeV. Such a severe disagreement cannot be attributed entirely to dilepton trigger bias, and is inconsistent with the satisfactory agreement of ATTILA and similar models with the WA 80 and NA 34 E_T distributions [18]. In view of the possible inconsistency in the present experimental E_T scale, one can only confront the data at a qualitative level. In analogy with experiment, we calculate the ratio (3) for $E_T^{>} = 60$ GeV and $E_T^{<} = 15$ GeV rather than use the experimental centroids at 94 and 23 GeV, because the number of inelastic nucleon-nucleon collisions, which generate both $\langle {p_\perp}^2 \rangle$ and E_T, saturates at $b = 0$. This approach is consistent within the LUND model, and leads to a conservative estimate of initial state effects, since blind use of the measured E_T values in (12) gives a somewhat larger $\langle {p_\perp}^2 \rangle$.

To calculate the ratio of relative J/ψ yields (5), we specify the survival probability $S(p_\perp)$ as a function of E_T. Recall that the survival probability of a J/ψ in a dense gas of hadronic resonances of initial rapidity density dN_H/dy is [5]:

$$S(\vec{p}_\perp) \approx (t_{0\psi}/t_f)^\beta , \tag{14}$$

where t_f is the last time that the J/ψ can interact, and $t_{0\psi}$ is the Lorentz-dilated J/ψ formation time. The survival probability varies with E_T through the absorption parameter β, which is the ratio of the dissociative-collision frequency to the expansion rate, and is given by

$$\beta \approx \langle \sigma v_{\rm rel} \rangle \, (\pi {R_A}^2)^{-1} dN_H/dy. \tag{15}$$

where σ is the cross section for final-state interactions such as $\rho + \psi \rightarrow D\overline{D}$ that dissociate the J/ψ. Similar expressions are also derived in [4,6,7]. For concreteness, we take $t_{0\psi} \sim 2$ fm/c [3], and use the simple approximation for $t_f(p_\perp)$ from Ref. [5] with $R_A \sim 3$ fm and $c_s \approx 1/\sqrt{3}$. We assume that the dissociation cross section in the resonance-rich gas is momentum independent, so that $\langle \sigma v_{\rm rel} \rangle \approx \overline{\sigma}\, \overline{v}_{\rm rel}$, with $\overline{\sigma} \sim 3 - 5$ mb and $\overline{v}_{\rm rel} \approx 0.6$. Refinements of the estimate of $S(p_\perp)$, to be reported elsewhere, using a Monte Carlo cascade approach to incorporate a more realistic spacetime geometry and time dependent J/ψ cross sections [19] indicate that such refinements do not change the results significantly.

The magnitude of J/ψ suppression is determined by $\overline{\sigma}$. To get a handle on this parameter independent of the uncertainties in the transverse momentum distributions, we study the E_T dependence of the $p_\perp$-integrated J/ψ-to-continuum ratio $Y \equiv N_\psi/N_c$. Equation (4) implies that $Y(E_T) \propto \int d^2p_\perp F_\psi(p_\perp) S(p_\perp) \approx S(p_\perp = 0)$, provided that $S(p_\perp)$ varies sufficiently slowly compared to $F_\psi(p_\perp)$. We find that

$$Y(E_T) \propto \mathrm{e}^{-E_T/E_S(A)}, \tag{16}$$

where $E_S(A) \approx 15\,(5\,\mathrm{mb}/\overline{\sigma}) A^{2/3}$ GeV, plus small corrections of order $A^{2/3} \ln A$. Note that Y scales roughly with $E_T/A^{2/3}$ in accord with the preliminary observations [1]. We compare (16) with data in Fig. 3 and see that $\overline{\sigma} = 3$ mb provides a reasonable fit, if we take the NA 38 E_T scale literally. A recalibration of the E_T scale by a factor f would change the best fit cross section by a factor $1/f$; in particular, if we rescale the LUND model E_T in (16) to agree with the data as explained above, then we find $\overline{\sigma} = 5$ mb.

We now calculate the $p_\perp$ dependence of the ratio of relative yields (5). We use (12) and (13) to estimate dN_H/dy and $\overline{n}_A$ for the LUND model energies $E_T^> = 60$ GeV and $E_T^< = 15$ GeV analogous to the centroids of the highest and lowest experimental bins. Combining (6,11,12) with our estimate of $S(p_\perp)$, we obtain the solid curve in Fig. 1a. In contrast, a neglect of initial-state scattering gives the dashed curve in this figure. We see that initial-state scattering has a profound effect on the $p_\perp$-dependence: While the ratio of survival probabilities varies little for $p_\perp < 3$ GeV/c, the full R exceeds unity at a transverse momentum of ≈ 2.4 GeV/c. Fortunately, we find that the calculated ratio is not sensitive to changes in the overall E_T scale within our 50%-uncertainty range. Replacing the LUND E_T's with the NA 38 centroids and taking $\overline{\sigma} = 3$ mb (see Fig. 3.) results in an overall change of less than 10% in R. We also use (4) to calculate the normalized distribution $N_\psi{}^{-1} dN_\psi/dp_\perp$. In Fig. 1b we show the result for a central $O + U$ collision, and again find surprisingly good agreement with the preliminary data. Here, the normalized distribution does not agree with the data if we take the experimental E_T rather than the self-consistent LUND value. We again emphasize that a more rigorous comparison with data awaits better understanding of the E_T scale.

The effects of initial-state scattering must also show up in Drell-Yan production at the SPS, and should be accessible to NA 38. In analogy to (1), we calculate a Drell-Yan ratio $R_c(p_\perp)$ using (10,11,12) to determine the dispersion in the gaussian approximation to $F_c(p_\perp)$. In Fig. 2b, we predict the ratio obtained using the same E_T cuts as in 1a. We note that the statistics of the reported continuum data [1] are too poor to test our prediction.

We briefly comment on the preliminary $S + U$ data reported in Ref. [1], which exhibits a weaker $p_\perp$ dependence than that seen in Fig. 1a for $E_T^< < 51$ GeV and $E_T^> > 125$ GeV. Whether or not this flattening is accounted for by the larger $\overline{n}_U$ expected with the heavier S projectile critically depends on the absolute E_T scale. The ratio $(F_\psi)_{E_T^>}/(F_\psi)_{E_T^<}$ varies over the scale $\delta p_\perp \sim \{\langle p_\perp^2\rangle_>^{-1} - \langle p_\perp^2\rangle_<^{-1}\}^{-1/2}$, which depends on the E_T scale mainly through a factor $(E_T^> - E_T^<)^{-1/2}$. If we follow the Oxygen calculation and take $E_T^>$ to be the calculated $\langle E_T\rangle$ at $b = 0$, and $E_T^< = E_T^>/4$, then we find that R is indeed flatter.

In summary, we have calculated the effect of initial-state interactions on the transverse momentum dependence of J/ψ production at CERN. Our results are consistent with the preliminary NA 38 data only if the survival probability is *slowly* varying with $p_\perp$ as expected with final-state interaction models. Our study is motivated to a large extent by the NA 10 experimental results, which show a $p_\perp$ enhancement in Drell-Yan dimuon production. A study of the $p_\perp$ dependence of the NA 38 continuum would provide important information on initial-state scattering, as would a systematic study of Drell-Yan and J/ψ production with hadron beams as a function of target mass number.

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Note Added: After completing this paper, we learned that J. P. Blaizot and J. Y. Ollitrault are investigating similar questions.

References

[1] L. Kluberg, Proc. Third Int. Conf. on Nucleus-Nucleus Collisions, Saint-Malo, France, June 6-11, 1988, Nucl. Phys. in press; A. Bussiere *et al.*, Proc. Sixth Int. Conf. on Ultrarelativistic Nucleus-Nucleus Collisions, R. Stock, H. Specht, and H. Satz eds., Z. Phys. C., **38**(1988) 117.

[2] T. Matsui and H. Satz, Phys. Lett. **178B**(1986) 416; H. Satz, Quark Deconfinement and J/ψ Suppression, talk given at the Third International Conference on Nucleus-Nucleus Collisions, Saint-Malo, France, June 6-11, 1988, Bielefeld Preprint BI-TP/88-10.

[3] J.-P. Blaizot and J. Y. Ollitrault, Phys. Lett. **B199**(1987) 499; M. C. Chu and T. Matsui, Phys. Rev. **D37**(1988) 1851; F. Karsch and R. Petronzio, Phys. Lett. **B193**(1987) 105; CERN Preprint CERN-TH-5070/88 (1988).

[4] J. Ftáčnik, P. Lichard, and J. Pišút, Phys. Lett. **207B**(1988) 194.

[5] S. Gavin, M. Gyulassy, and A. Jackson, Phys. Lett. **208B**(1988) 257.

[6] R. Vogt, M. Prakash, P. Koch, and T. H. Hansson, Phys. Lett. **208B**(1988) 263.

[7] J.-P. Blaizot and J.-Y. Ollitrault, Saclay Preprint SPhT/88-111 (1988).

[8] C. Gerschel and J. Hüfner, Phys. Lett. **208B**(1988) 254.

[9] A. Capella *et al.*, Phys. Lett. **206B**(1988) 685.

[10] G. Röpke, D. Blaschke, and H. Schulz, Dresden/Rossendorf Preprint (1988); Phys. Lett. **202 B**(1988) 479.

[11] J. Badier *et al.*, Z. Phys. **C20**(1983) 101.

[12] S. Katsanevas *et al.*, Phys. Rev. Lett **60**(1988) 2121.

[13] P. Bordalo *et al.*, Phys. Lett. **B193**(1987) 373.

[14] C. Michael and G. Wilk, Z. Phys. **C10**(1981) 169; G. T. Bodwin, S. J. Brodsky, and G. P. Lepage, Phys. Rev. Lett. **47**(1981) 1799.

[15] B. Andersson, G. Gustafson and B. Nilsson-Almquist, Nucl. Phys. **B281**(1987) 289; T. Sjöstrand, Lund preprint LU-TP-86-22 (1986).

[16] M. Gyulassy, Proc. Eighth Balaton Conf. on Nucl. Phys., (ed. Z. Fodor, KFKI, Budapest 1987); CERN preprint CERN-TH.4794/87 (1987).

[17] J. Badier *et al.*, Phys. Lett. **117B**(1982) 372; M. L. Swartz *et al.*, Phys. Rev. Lett. **53**(1984) 32.

[18] M. Gyulassy, Proc. Sixth Int. Conf. on Ultrarelativistic Nucleus-Nucleus Collisions, ibid., p.361 and refs. therein.

[19] S. J. Brodsky and A. H. Mueller, Phys. Lett. **B206**(1988) 685.

Figure Captions

1. (a) The preliminary NA 38 data [1] on the relative J/ψ-to-continuum yield (1) with $E_T^> > 85$ GeV and $E_T^< < 34$ GeV are compared to our calculations for the analogous LUND model values $E_T = 60$ and 15 GeV including both quasielastic initial-state scattering and final-state inelastic J/ψ-hadron scattering for $\overline{\sigma} = 5$ mb. The dashed curve shows the suppression factor in the absence of initial state interactions. (b) Transverse momentum distributions of $p + A \rightarrow \psi + X$ at 200 GeV for ^{195}Pt (diamonds) and p (squares) targets from [11] are compared to those measured in $O + U$ (dots) for $E_T > 85$ GeV [1]. We use (6) and the measured values of $\langle p_\perp{}^2 \rangle$ [11] to obtain the $p + A$ curves. The $O + U$ curve is calculated using (4) for $E_T = 60$ GeV.
2. (a) Measured [13] ratio of Drell-Yan yields as a function of transverse momentum for a 140 GeV π^- beam on ^{184}W and Deuterium targets are compared to the gaussian fit (solid curve) with $\langle p_\perp{}^2 \rangle$ taken from [13,17]. (b) Shown is the expected $p_\perp$ variation of the Drell-Yan continuum ratio for the same E_T cuts as in 1a.
3. The ratio of the $p_\perp$-integrated J/ψ-to-continuum yield $Y(E_T)$ to $Y(E_T = 23\,\text{GeV})$ from [1] compared to eq. (16) for a J/ψ-dissociation cross section $\overline{\sigma} = 3$ mb. A recalibration of the E_T scale by a factor f changes the best-fit cross section by a factor $1/f$.

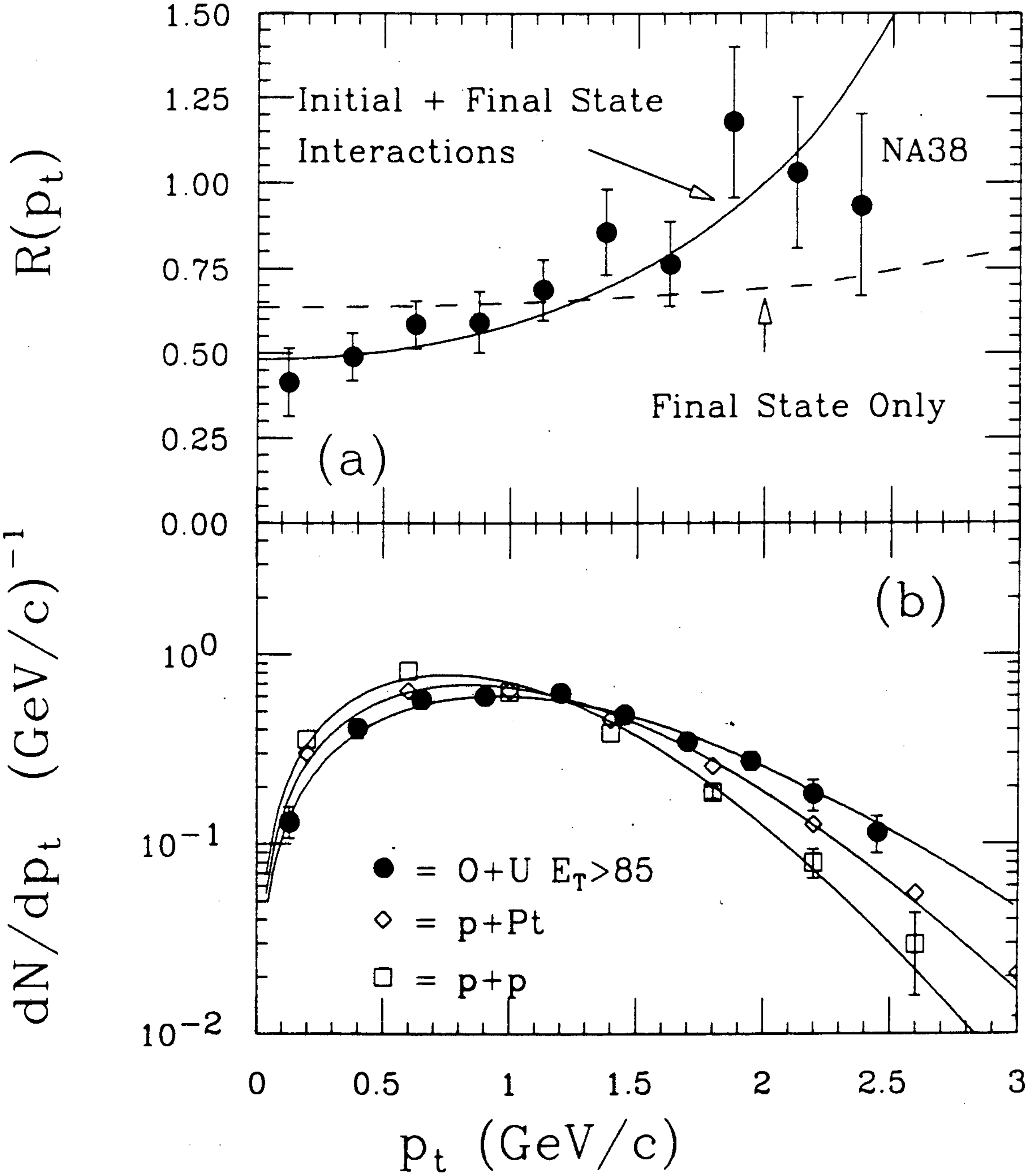

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Figure 1

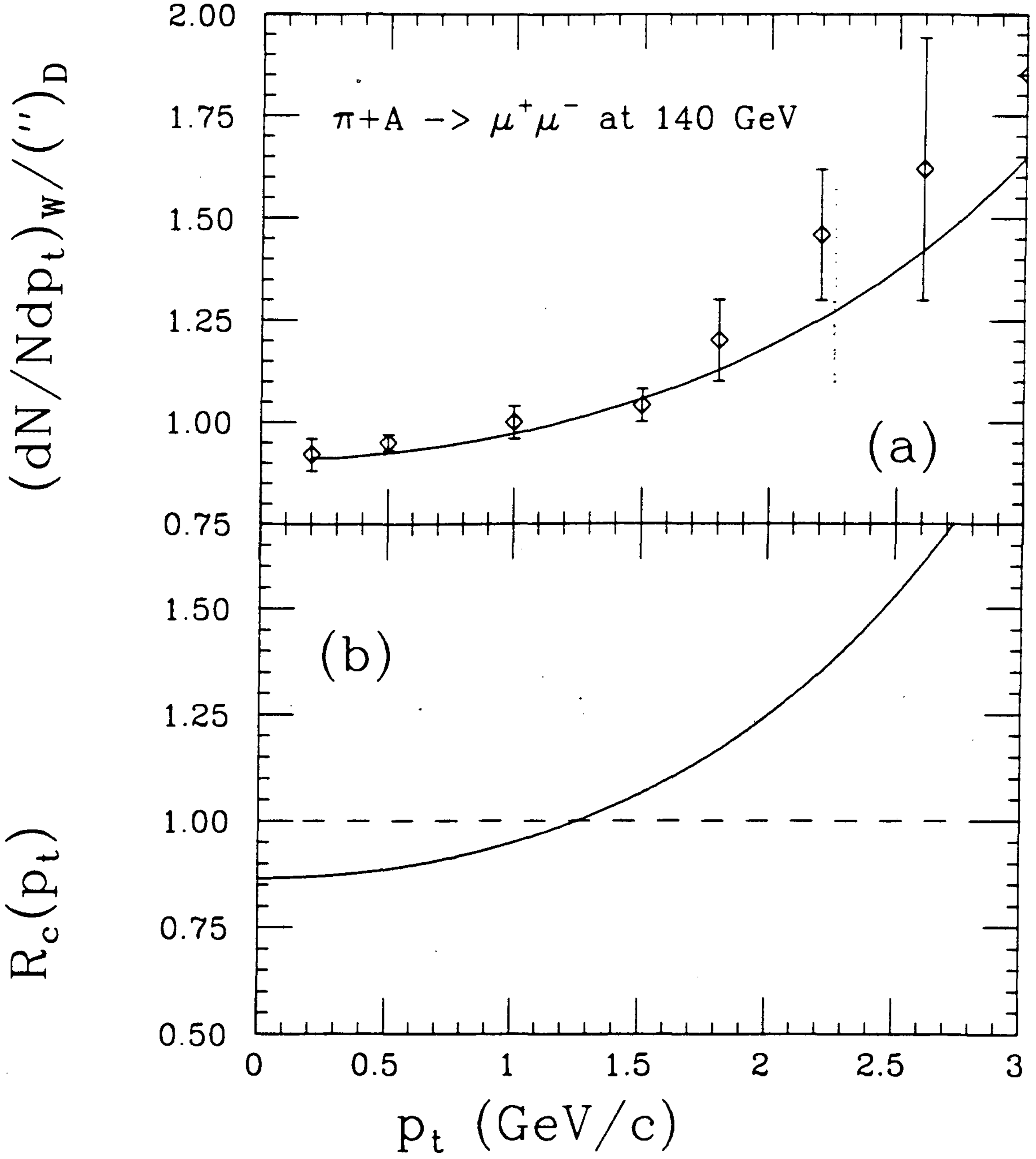

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Figure 2

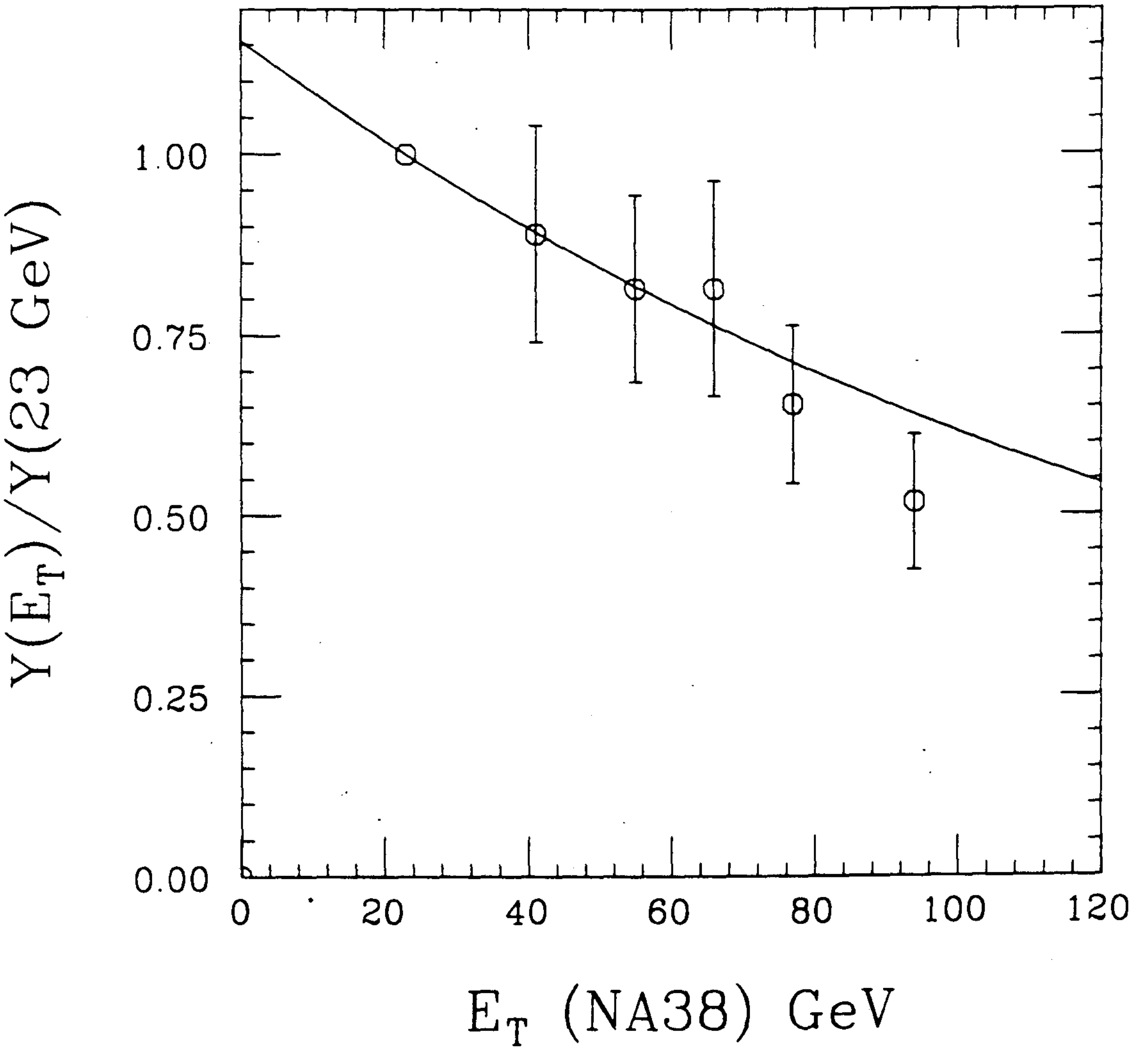

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Figure 3

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