

**OBSERVATION OF A NUCLEAR DEPENDENCE
OF THE TRANSVERSE MOMENTUM DISTRIBUTION
OF MASSIVE MUON PAIRS PRODUCED IN HADRONIC COLLISIONS**

NA10 Collaboration

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We present the first clear evidence for a nuclear dependence of the transverse momentum distribution of massive muon pairs produced in hadronic interactions. Comparing the cross sections for high-mass dimuon production by incident negative pions (140 and 286 GeV) off tungsten and deuterium, we find that their ratio increases with the dimuon transverse momentum. The resulting difference in the mean transverse momentum squared amounts to $0.15 \pm 0.02(\text{stat}) \pm 0.03(\text{syst}) \text{ GeV}^2/c^2$ and is shown to be independent of the dimuon mass and longitudinal momentum.

Anomalous A -dependence has been observed [1] in high transverse momentum (P_T) production of hadrons. It has been argued [2,3] that such effects, i.e. a nuclear dependence of the P_T -distributions, should also occur for high-mass muon pairs produced in hadronic collisions (Drell-Yan process).

While theoretical calculations involving initial state interactions, either in a phenomenological approach [2] or within the framework of QCD [3], predict an effect, the existing data [4,5] provide no conclusive evidence. A good review on this subject can be found in ref. [6]. The experimental clarification of this question is important for a better understanding of the interaction of quarks in extended nuclear matter. Moreover, it could imply appreciable corrections to the P_T data published up to now, which were obtained with heavy targets and extensively used for QCD tests.

In this study, we perform a detailed comparison of

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the P_T distributions of high-mass dimuons produced in π^- -tungsten and π^- -deuterium interactions. The data were taken at the CERN SPS with π^- 's of 140 and 286 GeV. The muon pairs were detected with the NA10 spectrometer [7], using simultaneously a deuterium and a tungsten target. Details on the detector as well as on data collection and analysis procedure are given in ref. [8].

Events in the continuum were selected by excluding dimuons with masses $M < 4.2 \text{ GeV}/c^2$ (286 GeV) or $M < 4.35 \text{ GeV}/c^2$ (140 GeV), and $8.5 < M < 11 \text{ GeV}/c^2$, i.e. those contaminated by the J/ψ and Υ family resonances, respectively. At 286 GeV, the numbers of events retained are 49600 for W and 7800 for D, at 140 GeV, 29300 and 3200, respectively. It should be stressed that our D sample is ten times larger than the samples available from light targets up to now. The acceptance of the apparatus, which varies very weakly with P_T , has been computed separately for the W and D events with a Monte Carlo program that allows for multiple scattering, energy loss and for Fermi motion, whose effect on $\langle P_T^2 \rangle$ turns out to be negligible. The difference of acceptance for W and D events is very small and was checked using J/ψ events produced in an auxiliary W target placed immediately upstream of the deuterium. The values of $\langle P_T^2 \rangle$ measured with the W targets in the two positions are in good agreement.

$$\begin{aligned} & \langle P_T^2 \rangle_{\psi \text{ W standard position}} - \langle P_T^2 \rangle_{\psi \text{ W D position}} \\ &= 0.00 \pm 0.04 \text{ GeV}^2/c^2 \end{aligned}$$

The main correction applied to the data is that for nuclear reinteractions. These can produce events with lower $\langle P_T^2 \rangle$ because of the lower mean CM energy. This correction changes $\langle P_T^2 \rangle$ of W events by $+0.02 \pm 0.01 \text{ GeV}^2/c^2$ at 286 GeV and is negligible at 140 GeV.

We compare the shapes of the P_T distributions of the muon pairs, normalizing the W and D samples to the same number of events. The dependence of the P_T -integrated cross section on the mass number A of the target nucleus was discussed in the preceding paper [8]. The comparison is limited here to values of P_T lower than 4 GeV/c (286 GeV) or 3.2 GeV/c (140 GeV), i.e. the range for which it is statistically meaningful. The ratios of the P_T distributions for the W and D events are displayed in fig. 1. For both

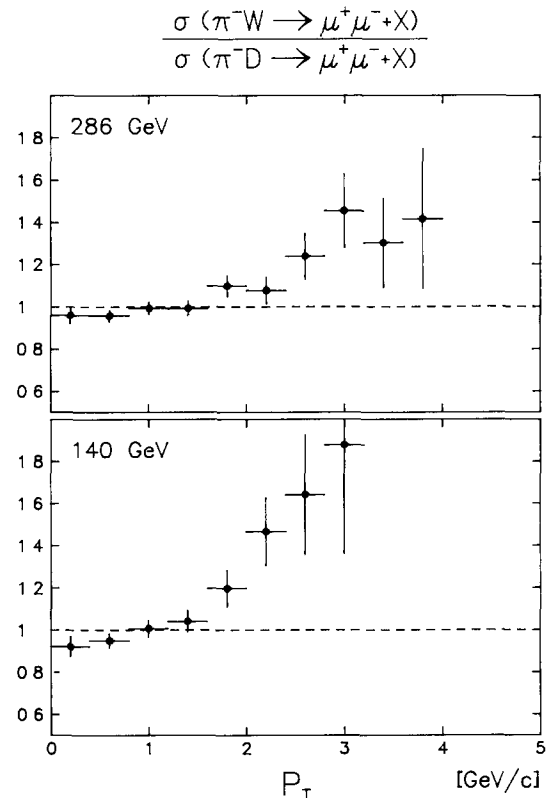


Fig. 1. Ratios of the P_T distributions of dimuons produced in W and D. The W and D samples are normalized to the same number of events. Only statistical uncertainties are shown.

energies, they clearly increase with P_T and lead to a significant difference in $\langle P_T^2 \rangle$.

$$\langle \Delta P_T^2 \rangle \equiv \langle P_T^2 \rangle_W - \langle P_T^2 \rangle_D$$

$$= 0.15 \pm 0.03(\text{stat}) \pm 0.03(\text{syst}) \text{ GeV}^2/c^2$$

at 286 GeV,

$$= 0.16 \pm 0.03(\text{stat}) \pm 0.03(\text{syst}) \text{ GeV}^2/c^2$$

at 140 GeV.

This is the first time that such a difference is established, previous results being inconclusive [4,5]. It should be stressed that the same $\langle \Delta P_T^2 \rangle$ leads to a steeper increase of the 140 GeV ratio because data at that energy lie at lower P_T 's.

Speculating about the origin of this effect, one can affirm that it is not due to scattering of the incident pion in the W target, since data taken with two dif-

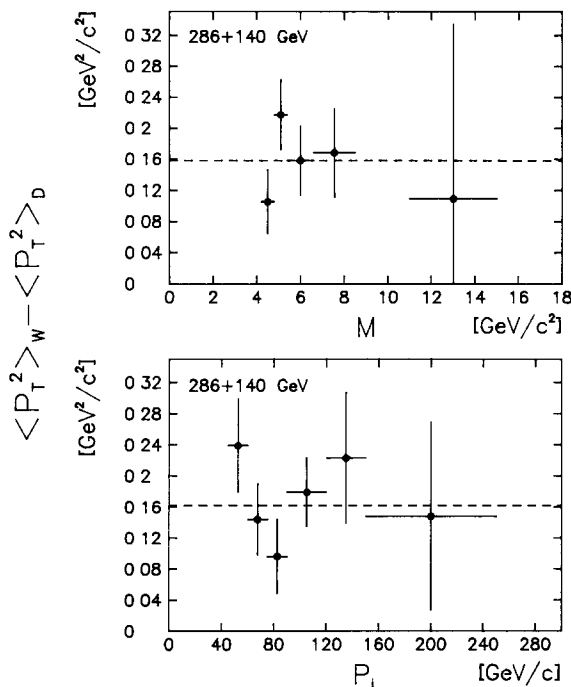


Fig. 2 $\langle P_T^2 \rangle_W - \langle P_T^2 \rangle_D$ versus dimuon mass M and longitudinal momentum P_L . The horizontal line represents the weighted average of the data points. Only statistical uncertainties are shown.

ferent target lengths (12 and 5.6 cm) show no significant difference

$$\langle P_T^2 \rangle_{W12} - \langle P_T^2 \rangle_{W5.6} = (-0.01 \pm 0.03) \text{ GeV}^2/c^2$$

The increase of $\langle P_T^2 \rangle$ therefore occurs within that nucleus in which the quark-antiquark annihilation takes place.

This effect is most likely to be attributed to the scattering of the incident quark within the target nucleus. This explanation is supported by the fact that $\langle \Delta P_T^2 \rangle$ is independent of the dimuon mass and longitudinal momentum, as illustrated in fig. 2 where the 286 and 140 GeV data were combined to improve the statistical accuracy^{#1}. Calculations [2,3] based on this interpretation indeed do predict increases of $\langle P_T^2 \rangle$ from hydrogen to heavy nuclei by a few tenths of GeV^2/c^2 , in qualitative agreement with our result.

^{#1} This decoupling also makes unlikely any correlation of the increase of $\langle P_T^2 \rangle$ with the nuclear effect on the structure functions, the "EMC effect" observed in deep inelastic lepton scattering [9] and also indicated by our dimuon data [8].

The model also implies that the J/ψ resonance should exhibit a difference of $\langle P_T^2 \rangle$ roughly twice as large as the continuum, since in that case scattering of both the incident quark and the outgoing J/ψ is expected. This is in fact what we observe.

$$\langle P_T^2 \rangle_{\psi W} - \langle P_T^2 \rangle_{\psi D} = 0.29 \pm 0.02 \text{ GeV}^2/c^2,$$

in good agreement with previous results on light targets [4,10]^{#2}.

In conclusion, the comparison of high-mass muon pairs produced by π^- 's incident on W and D gives first clear evidence for a nuclear dependence of the dimuon transverse momentum distribution. The ratio of the cross sections measured on W and D increases with P_T and leads to a difference in $\langle P_T^2 \rangle$ of $0.15 \pm 0.02 \pm 0.03(\text{syst}) \text{ GeV}^2/c^2$. This effect is shown to be independent of the dimuon mass and longitudinal momentum, and is likely due to the scattering of the incoming quark in the target nucleus. An important consequence is that corrections should be applied to all results on P_T obtained with heavy targets before comparing them to QCD predictions.

We would like to thank the group of L. Mazzone for providing us with the D target and in particular C. Gregory for its operation.

^{#2} For J/ψ events produced by π^- 's of 280 GeV, the NA3 Collaboration measure an increase of $\langle P_T^2 \rangle$ of $0.33 \pm 0.06 \text{ GeV}^2/c^2$ from hydrogen to platinum.

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