The atomic mass dependence of the transverse momentum distribution of massive muon pairs from 225 GeV/c π^--nucleus collisions.

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ABSTRACT

We have measured the atomic mass dependence of the P_T distribution of massive muon pairs produced in 225 GeV/c π^--nucleus collisions at Fermilab. We find that $<P_T{}^2>$ is consistent with being independent of the atomic mass A, with the value of 1.69 $\pm$ 0.10 $(\mathrm{GeV/c})^2$ for muon pairs of mass between 4.0 and 8.5 GeV/c^2. When the dependence of $<P_T{}^2>$ on A is parametrized as $<P_T{}^2> = a + b\,A^{1/3}$, we find that $b = -.079 \pm .073\ (\mathrm{GeV/c})^2$ which corresponds to an upper limit of .015 $(\mathrm{GeV/c})^2$ at the 90% confidence level.

Recently, two groups have predicted that the transverse momentum distribution of lepton pairs produced in hadron-nucleus collisions depends upon the size of the target nucleus. Bodwin, Brodsky, and Lepage[1] have used perturbative

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QCD to consider initial state interaction corrections to the Drell-Yan model. They predict that the second moment of the lepton pair transverse momentum distribution, $<P_T{}^2>$, should increase linearly with nuclear radius,

$$< P_T{}^2 > = a + b\, A^{1/3} \qquad (1)$$

where A is the atomic mass of the target nucleus and b is predicted to be in the range 0.01 to 0.25 $(\mathrm{GeV}/c)^2$. A very different model by Michael and Wilk[2] also predicts a monotonically increasing $<P_T{}^2>$ with nuclear radius. The magnitude of the effect for nuclei in the range $A^{1/3} = 2 - 6$ can be approximated by equation (1) with $b = .04$ $(\mathrm{GeV}/c)^2$.

Bodwin et al. claim some indication of the effect in the data of the Chicago-Illinois-Princeton collaboration[3]. Michael and Wilk claim that it is present in the data of the Columbia-FNAL-Stony Brook collaboration[4]. Measurements of $<P_T{}^2>$ by the CERN NA3 collaboration[5] on hydrogen and platinum targets show no effect. We have searched for this effect in the data sample used to measure the atomic mass dependence of the integrated muon pair cross-section in 225 GeV/c π^--nucleus collisions[6].

The experiment was performed in the Proton West High Intensity Area of the Fermi National Accelerator Laboratory. The pion beam was incident on targets of beryllium, copper, tin and tungsten. Muon pairs were detected by a magnetized solid iron toroidal spectrometer located just downstream of the target. The spectrometer was instrumented with seven planes of scintillation counter hodoscopes for the purpose of triggering and twenty-eight drift chamber planes for the precise measurement of the muon trajectories. The beam, targets, and spectrometer are described in detail in Refs. 6 and 7. Ref. 7 also contains details of this analysis.

In order to eliminate J/ψ and Υ resonance production from the sample, the invariant mass of the muon pairs was required to be between 4.0 and 8.5 GeV/c^2. The data were subtracted for background due to accidental coincidences of two muon tracks and to muon pairs produced in the collimator walls. The latter was measured directly from data taken with the target removed. Table I shows the number of events, the estimated background and the integrated flux for each target. The P_T distribution of the total data sample is shown in Fig. 1.

The acceptance of the spectrometer as a function of the muon pair transverse momentum was calculated with a Monte Carlo simulation, which included Fermi motion in the target, multiple scattering and energy loss in the iron toroids, and drift chamber resolution and efficiency. Monte Carlo simulated events were analyzed with the same reconstruction program used for the data. The acceptance was found to be independent of target lengths and composition. A plot of the acceptance as a function of transverse momentum is shown in Fig. 1.

The acceptance corrected values of $<P_T{}^2>$ are shown in Fig. 2 as a function of $A^{1/3}$. A fit of the form $<P_T{}^2>$ = constant yields a χ^2 of 2.81 for 3 degrees of freedom and a value of $<P_T{}^2> = 1.69 \pm .10$ (GeV/c)^2 in good agreement with previous measurements[3–5,8]. In order to establish an upper limit to the slope of the curve, the data were also fitted to the hypothesis $<P_T{}^2> = a + b\ A^{1/3}$. After a small correction for the impurity of the tungsten target, the fit gave the values of $a = 2.03 \pm 0.32$ (GeV/c)^2 and $b = -0.079 \pm 0.073$ (GeV/c)^2, with χ^2/D.O.F. = 1.64/2. This corresponds to a 90% confidence limit on b of 0.015 (GeV/c)^2.

The nature of the measurement, which compares data samples from different targets taken with the same apparatus and over the same kinematic range, makes the result insensitive to most systematic uncertainties. We estimate the systematic error to be approximately 5% of the statistical error. This produces a negligible change in the result.

In conclusion, we find that the data are consistent with the independence of $\langle P_T{}^2 \rangle$ on nuclear size. The data are not consistent with the model of Ref. 2 and can barely accommodate the lower values of b for Ref. 1.

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References

1. G.T. Bodwin, S.J. Brodsky, and G.P. Lepage, Phys. Rev. Lett., 47, 1799 (1981) and SLAC-PUB-2927 (May 1982).

2. C. Michael and G. Wilk, Zeit. fur Physik C 10, 169 (1981).

3. G. Hogan, Ph.D. Thesis, Princeton University, 1980 (unpublished).

4. A.S. Ito et al., Phys. Rev. D 23, 604 (1981).

5. J. Badier et al., Phys. Lett. 117B, 372 (1982).

6. H.J. Frisch et al., Phys. Rev. D 25, 2000 (1982).

7. M.L. Swartz, Ph.D. Thesis, University of Chicago, 1983 (unpublished).

8. K.J. Anderson et al., Phys. Rev. Lett. 42, 944 (1979); A.L.S. Angelis et al., Phys. Lett. 87B, 398 (1979); D. Antreasyan et al., Phys. Rev. Lett. 47, 12 (1981).

Table I

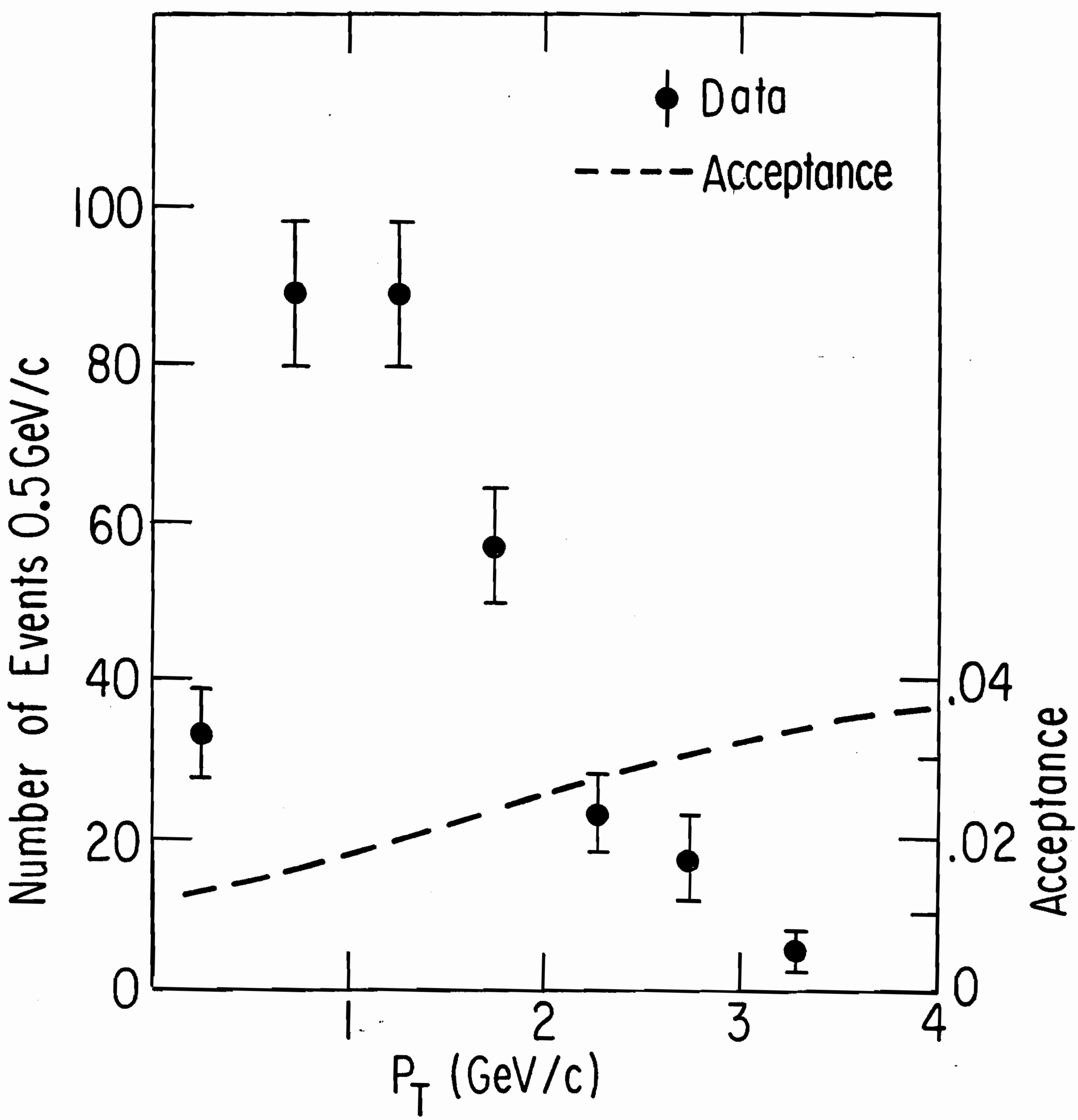
Event Sample (4.0 GeV/c^2 < $m_{\mu\mu}$ < 8.5 GeV/c^2)

Target	Integrated Pion Flux	Events	Accidental Background	Collimator Background
Beryllium	3.3×10^{12}	115	7.8±.7	10.2±5.8
Copper	5.7×10^{11}	32	2.8±.5	1.7±1.0
Tin	5.5×10^{11}	50	1.5±.3	1.7±.9
Tungsten	9.0×10^{11}	75	3.4±.5	3.0±1.7

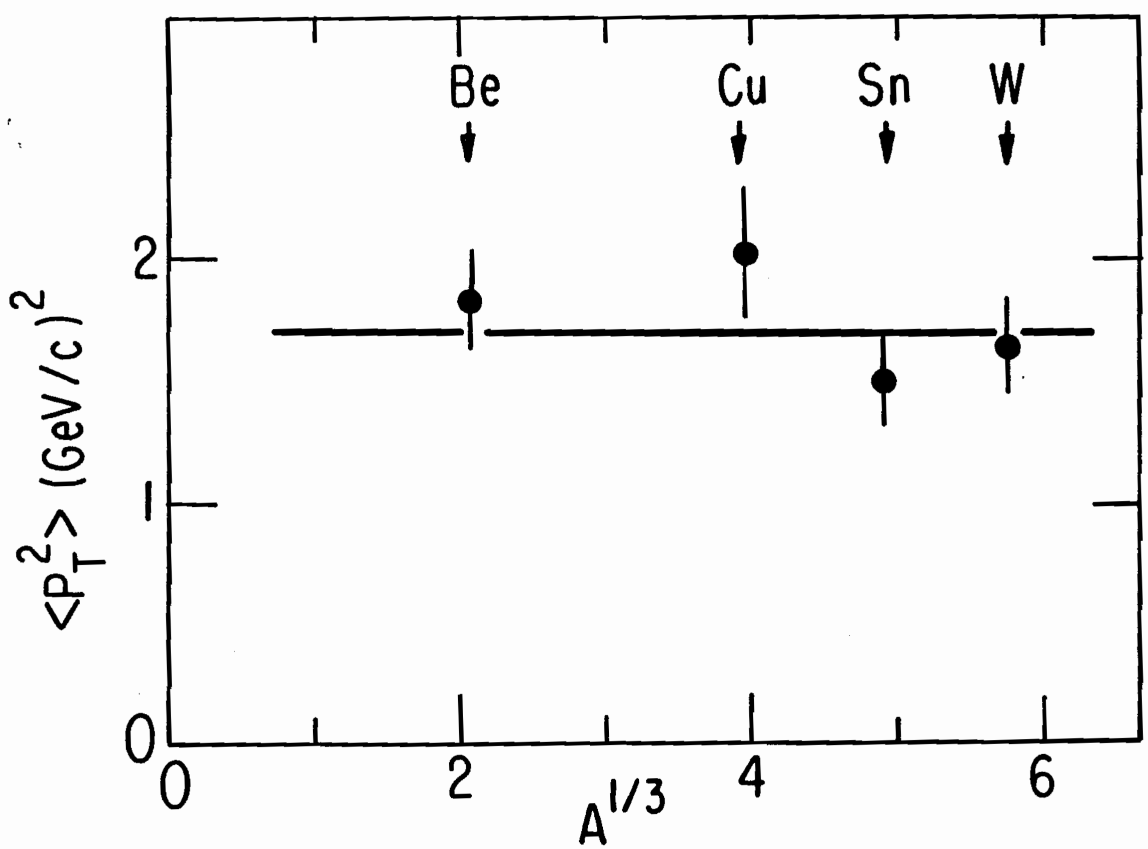
Figure Captions

1. P_T distribution for the total data sample and the acceptance as a function of P_T.

2. $<P_T{}^2>$ for each target subsample as a function of $A^{1/3}$. The line is the best fit to $<P_T{}^2> =$ constant.



Data
Acceptance
100
80
60
40
20
0
.04
.02
0
1
2
3
4
Number of Events 0.5 GeV/c
Acceptance
P_T (GeV/c)


Be
Cu
Sn
W
2
1
0
0
2
4
6
$A^{1/3}$
$\langle P_T^2 \rangle$ (GeV/c)^2