Fermi National Accelerator Laboratory

FERMILAB-Pub-85/34-E
7550.537
(Submitted to Phys. Rev. Lett.)

CONTINUUM DIMUON PRODUCTION IN $\bar{p}$-W COLLISIONS AT 125 GeV/c

E. Anassontzis, S. Katsanevas, P. Kostarakis, C. Kourkoumelis, A. Markou,
L. K. Resvanis, and G. Voulgaris
University of Athens, Athens, Greece

and

M. Binkley, B. Cox, J. Enagonio, C. Hojvat, D. Judd, R. D. Kephart,
P. K. Malhotra, P. O. Mazur, C. T. Murphy, F. Turkot, R. L. Wagner,
D. Wagoner, and W. Yang
Fermi National Accelerator Laboratory, Batavia, Illinois 60510 USA

and

H. Areti, S. Conetti, P. Lebrun, D. G. Ryan, T. Ryan,
W. Schappert, and D. G. Stairs
McGill University, Montreal, Quebec H3A 2T8, Canada

and

C. Akerlof, X. Cui, P. Kraushaar, D. Nitz, R. Thun, and L. Wang
University of Michigan, Ann Arbor, Michigan 48109 USA

and

He Mao and Zhang Nai-jian
Shandong University, Jinan, Shandong, Peoples Republic of China

February 1985

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

Continuum Dimuon Production in $\bar{p}$-W Collisions at 125 GeV/c

E. Anassontzis, S. Katsanevas, P. Kostarakis, C. Kourkoumelis,
A. Markou, L.K. Resvanis, and G. Voulgaris

University of Athens, Athens, Greece

M. Binkley, B. Cox, J. Enagonio, C. Hojvat, D. Judd, R.D. Kephart,
P.K. Malhotra, P.O. Mazur, C.T. Murphy, F. Turkot, R.L. Wagner,
D. Wagoner, and W. Yang

Fermi National Accelerator Laboratory, Batavia, Illinois 60510

H. Areti, S. Conetti, P. Lebrun, D.G. Ryan, T. Ryan,
W. Schappert, and D.G. Stairs

McGill University, Montreal, Quebec H3A 2T8, Canada

C. Akerlof, X. Cui, P. Kraushaar, D. Nitz, R. Thun, and L. Wang

University of Michigan, Ann Arbor, Michigan 48109

He Mao and Zhang Nai-jian

Shandong University, Jinan, Shandong, Peoples Republic of China

Abstract

The cross section for the reaction $\bar{p}N \rightarrow \mu^+\mu^- X$ with muon pairs in the mass range $4<M<9$ GeV/c^2 and $x_F>0$ was measured to be $\sigma=0.104\pm0.005\pm0.008$ nb/nucleon. The distributions $d\sigma/dx_F$ and $M^3 d\sigma/dM$ were compared to the QCD improved Drell-Yan model and to calculations including first order QCD corrections using deep inelastic structure functions. Excellent agreement with the data was obtained if the calculations were multiplied by factors of 2.45 and 1.41 respectively.

Many predictions of the Drell-Yan model[1] for high mass dimuon production by hadrons have been confirmed by measurements with proton and pion beams.[2] The integrated polar angle decay distribution of the muon pairs is consistent with $1+\cos^2\theta$. Scaling in $\tau=M^2/s$ has been verified in proton produced data over the energy range spanned by Fermilab and the ISR. The measured dependence of the cross section on the atomic number of the target is very close to $A^{1.0}$. These features along with the observation that the ratio of π^+ to π^- dimuon production tends toward 1/4 give confidence that high mass muon pair production is an electromagnetic process of the type hypothesized by Drell and Yan. However, comparisons of the measured absolute cross sections to the model are more difficult since the predictions for the proton induced reaction are affected by uncertainties in the nucleon sea structure functions and the pion structure function cannot be measured independently at large Q^2. In contrast, data with incident antiprotons can be directly compared to the absolute predictions of the Drell-Yan model since the valence quark structure functions of the nucleon (and hence the valence antiquark structure functions of the antiproton) have been independently determined in deep inelastic lepton scattering (DIS) experiments.[3]

The present experiment was performed at Fermi National Accelerator Laboratory using a tertiary beam[4] of 1.5×10^7 particles/sec and consisting of 18% $\bar{p}$ and 82% π^- resulting from $\bar{\Lambda}^0$, Λ^0 and K^0_S decays. Particle type was determined using two Cerenkov counters resulting in less than 0.5% pion contamination of the antiproton data. Counter hodoscopes and proportional chambers were used to determine the trajectory and momentum of each incident beam particle. Only one experiment[5] has previously reported significant $\bar{p}$ data, but because the antiproton content of the beam was only a few percent of the total flux of 5×10^7 particles/sec, a 25% subtraction for π^- contamination in the $\bar{p}$ data sample was required.

The experimental spectrometer[6] is shown in Figure 1. It included a tungsten target, a copper hadron absorber (10.3 absorption lengths), 20 proportional and drift chamber planes, a large aperture analysis magnet, an X-Y charged particle scintillation counter hodoscope, and a 13.2 absorption length steel and concrete muon detector with three imbedded muon trigger planes of 60 counters each. The fast dimuon trigger required at least two threefold coincidences among aligned counters in each of the three muon hodoscope planes, at least two hits in the X-Y charged particle hodoscope, and a $\bar{p}$ signal from the beam tagging system. Events which produced a fast trigger were sent to an ECL-CAMAC trigger processor.[7] This processor used hits from the drift chambers downstream of the analysis magnet to calculate the momenta of muon candidates and the masses of all possible muon pairs. Events with candidates of invariant mass greater than 2.0 GeV/c^2 were recorded on magnetic tape.

The data presented here consists of 380 $\bar{p}$ produced muon pairs with masses between 4 and 9 GeV/c^2. Corrections have been applied to our data to take into account trigger processor inefficiency (1%), scintillation counter inefficiency and gaps between adjacent counters (10%), reinteraction in the target (3.5%), vertex cut inefficiency

(1%), accidental coincidences (1.5%), reconstruction inefficiency (10%), and ψ' contamination (2.4%). Our overall systematic normalization error of 8% includes the uncertainties in all of these corrections as well as the uncertainty in the acceptance calculation. In calculating the spectrometer acceptance we have assumed the $1+\cos^2\theta$ distribution which is expected from the Drell-Yan model and is consistent with our data, where θ is the angle between the positive muon and the beam in the muon pair rest frame. To extract a cross section per nucleon from our tungsten data, we have assumed a linear A dependence, since high statistics proton and pion experiments[2] currently measure $A^{1.00\pm0.02}$. With these assumptions we find the total cross section for $4<M<9$ GeV/c^2 and $x_F>0$ to be $\sigma=0.104\pm0.005\pm0.008$ nb/nucleon. The first error is statistical only and the second is the estimated systematic uncertainty in our measurement. An additional error of 11% is contributed by the experimental uncertainty in the A dependence.

In the QCD improved parton model, the cross section for hadronic muon pair production, integrated over the transverse momentum of the pair, is given by[8]

$$\frac{d^2\sigma}{dMdx_F} = \frac{8\pi\alpha^2}{9M^3}\,\frac{(1-\tau)}{\sqrt{x_F{}^2(1-\tau)^2+4\tau}}\cdot \sum_{q=u,d,s} e_q{}^2[\bar{q}_B(x_1,Q^2)\cdot q_T(x_2,Q^2) + q_B(x_1,Q^2)\cdot\bar{q}_T(x_2,Q^2)], \quad (1)$$

where M is the invariant mass of the muon pair, $\tau=M^2/s$, $x_F=2p_L/[\sqrt{s}(1-\tau)]$ is the ratio of the longitudinal momentum of the pair to the maximum allowable momentum in the center of mass frame, e_q is the quark charge, x_1 (x_2) is the momentum fraction of the beam (target) particle carried by the interacting quark, and the $q(x_i,Q^2)$'s are the quark structure functions of the interacting hadrons. The structure functions have been measured at space-like values of Q^2 and are continued to time-like Q^2 by making the identification $Q^2=M^2$.

Figure 2(a) shows our data compared to the prediction of (1) for $d\sigma/dx_F$ after integrating over M and using the structure function parameterizations obtained by Duke and Owens[9] from a QCD fit to neutrino, muon, and electron DIS data. Component terms are also shown, indicating that the valence-valence interaction accounts for 87% of the predicted cross section. The curves have been multiplied by $K=2.45\pm0.12\pm0.20$ in order to reproduce the measured total cross section for $x_F>0$. The errors represent our statistical and systematic uncertainties. Additional uncertainties of up to 11% and 20% can be attributed to the A dependence and the normalization differences among the DIS experiments.[3,9]

Figure 2(b) shows our data compared to the cross section calculated when next to leading logarithm (of $O(\alpha_S)$) QCD corrections are included.[11] We have used the same structure functions as above and a value of the QCD scale parameter, $\Lambda=0.2$ GeV/c, consistent with these parameterizations. In this case the prediction must be multiplied by a factor of $1.41\pm0.07\pm0.11$ to reproduce the integrated cross section for $x_F>0$. The first order calculation is also sensitive to the choice for Λ. Using $\Lambda=0.4$ GeV/c, a value also consistent with the DIS data,[9] increases the first order QCD prediction by 11%.

Figure 3 shows the scaling cross section $M^3 d\sigma/dM$ with $x_F>0$ as a function of $\sqrt{\tau}$ for our antiproton data and the 150 GeV/c antiproton data of the NA3 experiment.[5] The two measurements agree within errors and are consistent with the shape predicted by either formula (1) or the first order QCD calculation.

In conclusion, we have measured the cross section for the reaction $\bar{p}N\rightarrow\mu^+\mu^-X$ with muon pairs in the range $4<M<9$ GeV/c^2 and $x_F>0$ and compared the result to the Drell-Yan model and a calculation including first order QCD corrections, using the deep inelastic structure function parameterizations of Duke and Owens.[9] We find excellent agreement between the measured differential cross sections $d\sigma/dx_F$ and $M^3 d\sigma/dM$ and these calculations provided we multiply the predictions by 2.45 and 1.41 respectively.

This work was performed at Fermi National Accelerator Laboratory and supported by the U.S. Department of Energy, the International Programs and High Energy Physics Divisions of the National Science Foundation, the Natural Sciences and Engineering Research Council of Canada, the Quebec Department of Education, and the Hellenic Science and Technology Agency.

References

1. S.D. Drell and T.M. Yan, Phys. Rev. Lett. 25, 316 (1970).

2. I.R. Kenyon, Rep. Prog. Phys. 45, 1261 (1982).

3. F. Eisele, Proceedings of the 21st International Conference on High Energy Physics, ed. P. Petiau and M. Pourneuf, Paris (1982).

4. B. Cox, Fermilab Report 79/1, 6 (1979)

5. J. Badier et al., Phys. Lett. 96B, 422 (1980).

6. E. Anassontzis et al., Fermilab Pub-85/35-E to be submitted to Nucl. Instr. and Meth.

7. H. Areti et al., Nucl. Instr. and Meth. 212, 135 (1983).

8. H.Politzer, Nucl. Phys. B129, 301 (1977).

9. D.W. Duke and J.F. Owens, Florida State Preprint FSU/HEP/83-11-15 (1983).

10. H.G. Fischer and W.M. Geist, Zeit. f. Physik C19, 159 (1983).

11. J. Kubar, M. LeBellac, J.L. Meunier, and G. Plaut, Nucl. Phys. B175, 251 (1980).

Figure Captions

FIG. 1 General layout of the large acceptance spectrometer.

FIG. 2 $d\sigma/dx_F$ vs x_F for dimuons produced by 125 GeV/c antiprotons. compared to (a) the prediction of the Drell-Yan formula (1), calculated using the structure functions of Ref. 9, together with the component contributions, and (b) the first order QCD prediction calculated using the same structure functions. The errors shown are statistical only.

FIG. 3 $M^3\, d\sigma/dM$ vs $\sqrt{\tau}$ for dimuons produced by antiprotons in this experiment and the data of Ref. 5 at 150 GeV/c. The solid curve is the prediction of (1) integrated over x_F.

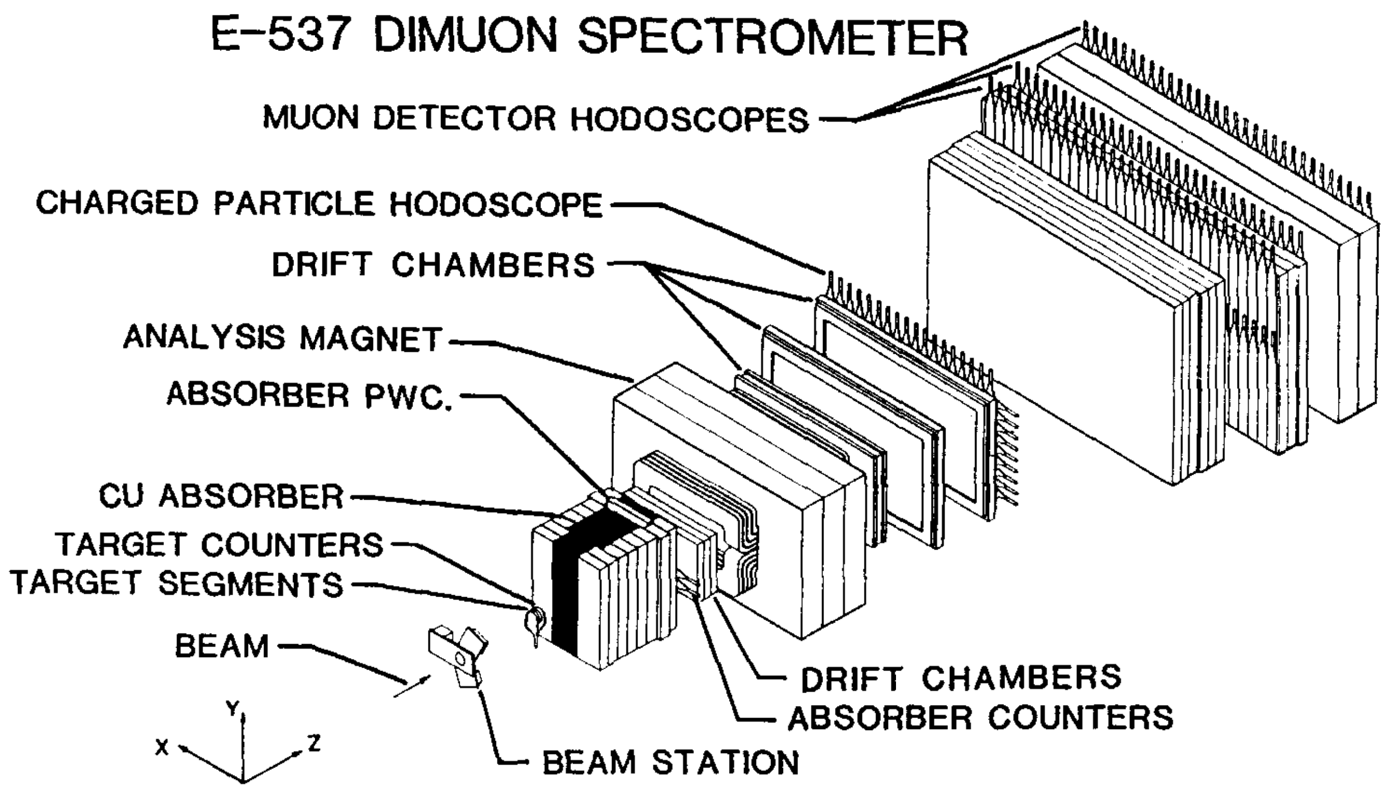

E-537 DIMUON SPECTROMETER
MUON DETECTOR HODOSCOPES
CHARGED PARTICLE HODOSCOPE
DRIFT CHAMBERS
ANALYSIS MAGNET
ABSORBER PWC.
CU ABSORBER
TARGET COUNTERS
TARGET SEGMENTS
BEAM
Y
X
Z
DRIFT CHAMBERS
ABSORBER COUNTERS
BEAM STATION

Fig. 1

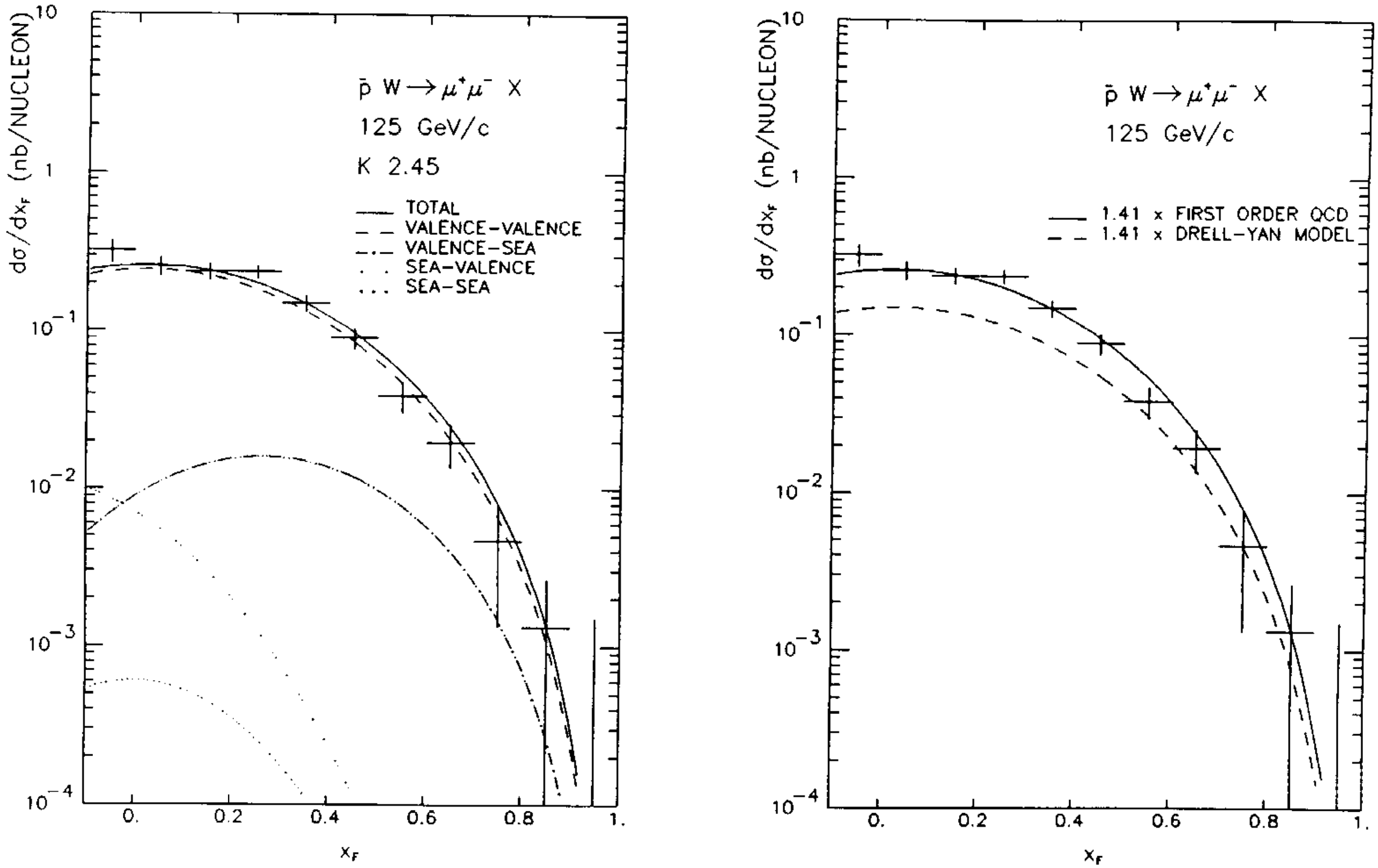
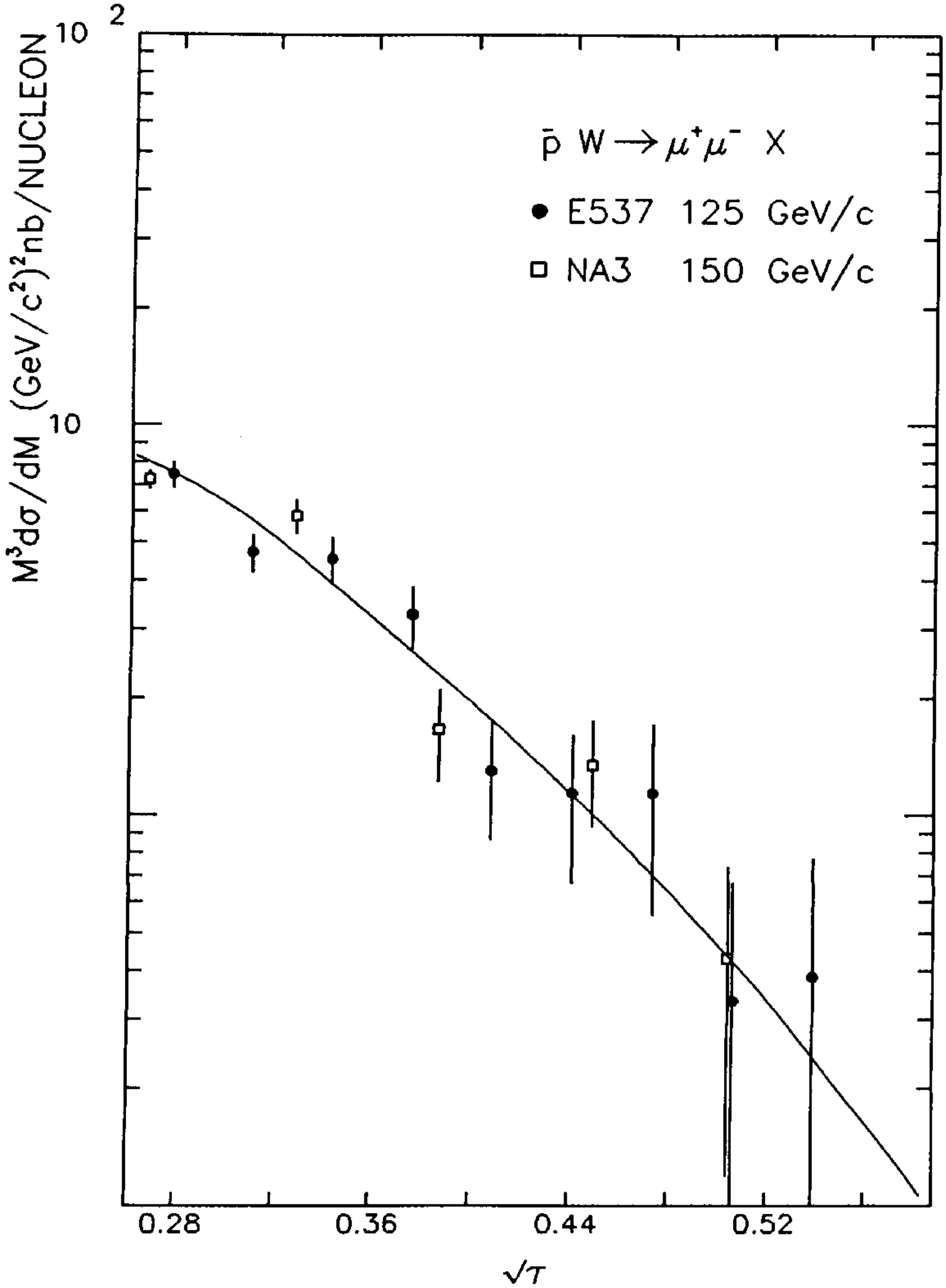

p̄ W → μ⁺μ⁻ X
125 GeV/c
K 2.45
TOTAL
VALENCE-VALENCE
VALENCE-SEA
SEA-VALENCE
SEA-SEA
dσ/dx_F (nb/NUCLEON)
x_F
p̄ W → μ⁺μ⁻ X
125 GeV/c
1.41 x FIRST ORDER QCD
1.41 x DRELL-YAN MODEL
dσ/dx_F (nb/NUCLEON)
x_F

Fig. 2



10^2
10
$M^3 d\sigma/dM$ $(GeV/c^2)^2$nb/NUCLEON
$\bar{p}\ W \rightarrow \mu^+\mu^-\ X$
● E537 125 GeV/c
□ NA3 150 GeV/c
0.28
0.36
0.44
0.52
$\sqrt{\tau}$

Fig. 3