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A High Statistics Study of Dimuon Production by 400 GeV/c Protons

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ABSTRACT

The reaction $p+W \rightarrow \mu^+\mu^- + X$ has been measured using a high intensity 400 GeV/c proton beam, a magnetized iron beam dump, and a wide acceptance detector. The μ-pair invariant mass spectrum contains 225,000 events above 6 GeV. The Drell-Yan model predicts a connection between the shape of the mass spectrum at $x_F = 0$ and the shape of the x_F distribution at fixed mass. The data compare favorably with this prediction. The p_T spectrum is also presented as a function of mass and x_F. The $\langle p_T \rangle$ does not follow the QCD predicted fall off with x_F. The data sample includes about 12,000 $\Upsilon \rightarrow \mu^+\mu^-$ events but the resolution precludes separation into the various excitations. The Υ production cross section has a steeper dependence on x_F than does the μ-pair continuum at masses just above or below the Υ.

An experiment to study dimuon production by 400 GeV protons on a tungsten target was carried out at Fermilab using the M2 beam of the Meson Laboratory. Preliminary results have been reported.[1]

The apparatus consisted of a solid iron spectrometer together with four planes of hodoscope Cherenkov counters and three planes of PWC's, each containing three sets of wires with 2 mm wire spacing. The proton beam of $\sim 2 \times 10^{11}$ per one second pulse was incident on the 32 cm tungsten target. The spectrometer consisted of three separate magnets with a combined path length in iron of 5.5 m and a field which produced $p_\perp = 3.5$ GeV/c. The equipment is diagrammed in Figure 1.

Three settings of the hodoscope system were used in data collection; these corresponded to three lower limit dimuon invariant mass cuts. Matrix logic circuits selected muon pairs which projected back to the target in the non-bend (horizontal) projection and whose momenta exceeded a predetermined threshold.

The sample of like-charge pairs ($\mu^+\mu^+$ and $\mu^-\mu^-$) was used to make a background subtraction; it was determined that these were essentially all accidentals. As the target was many interaction lengths thick, secondary hadrons produced by the incident protons could give rise to μ-pairs. This effect was estimated to be about 25% of the 400 GeV proton yield at $x_F = 0$, and approximately independent of mass for intermediate and high dimuon masses.

A Monte Carlo program was used to correct the data for acceptance as well as multiple coulomb scattering in the iron, fluctuations in energy loss, finite target volume, and MWPC resolution. The mass resolution function was nearly Gaussian with an r.m.s. width of about 7.5% over dimuon masses between 3 and 15 GeV. At this time the absolute normalization of the data is not complete

The mass spectrum, corrected for acceptance, is presented in Figure 2. The peak at 0.7 GeV is the unresolved mixture of μ-pair decays of ρ°,ω, and ϕ and from secondary gamma production of μ-pairs. The Ψ/J peak at 3.1 GeV and the ϒ-group peak at 9-11 GeV are apparent; there is no evidence of structure above 11 GeV. The data includes 225,000 events with mass above 6 GeV and 12,000 events in the ϒ peak.

The Drell-Yan model relates the cross section for production of dileptons of invarient mass q to the colliding hadrons' quark functions $f_i(x,q^2)$ as follows:

$$\frac{d^2\sigma}{dq^2 dx_F} = \frac{1}{3s^2}\,\frac{4\pi\alpha^2}{3\tau^2\sqrt{x_F^2+4\tau}}\sum_i e_i^2 x_A f_i^A(x_A,q^2)\,x_B f_{\bar{i}}^B(x_B,q^2)$$

where $\tau = x_A x_B = q^2/s$, $x_F = x_A - x_B$, and i extends over quarks and antiquarks. This model may be used to extract the ocean quark distribution from the dimuon data using $F_2(x,q^2)$ from lepton scattering experiments. Two different parameterizations for the nucleon ocean-quark distributions have been employed; the

symmetric and asymmetric cases. For the symmetric ocean, $xf_{\bar{u}}(x) = xf_{\bar{d}}(x) = a(1-x)^b$, where a and b are parameters. In the asymmetric ocean, $xf_{\bar{d}}(x) = a(1-x)^b$ and $f_{\bar{u}}(x) = (1-x)^3 f_{\bar{d}}(x)$. In both cases $f_s(x) = f_{\bar{s}}(x) = \frac{1}{2}[f_{\bar{u}}(x) + f_{\bar{d}}(x)]$ and higher mass quarks are neglected. For $F_2(x,q^2)$ the parameterization of T. Kirk[2] was used, and it is assumed that F_2^n/F_2^p is independent of q^2. The fit to the continuum data gave for the symmetric ocean $a = 0.56 \pm 0.05$, $b = 9.0 \pm 0.5$, and for the asymmetric ocean $a = 0.65 \pm 0.05$, $b = 8.0 \pm 0.5$.

As a test of the Drell-Yan model, it was compared with the data for $x_A \neq x_B$, i.e. for $x_F \neq 0$. The data for two different mass regions are graphed in Figures 3 and 4 vs $x'_F = x_F/(1-\tau)$, where the smooth curves are the D.-Y. predictions. The agreement appears remarkably good.

The values of $\langle p_t \rangle$ for the dimuon system have been evaluated vs. x for several mass intervals. Little or no fall off of $\langle p_t \rangle$ with x is seen. A simple quark model predicts a significant fall off; however the Fermi motion of quarks may smear the expected $\langle p_t \rangle$ to largely remove the expected x dependence. These results are plotted in Figure 5.

The behavior of the x'_F dependence of the cross section in the Υ region may be compared with neighboring regions of the continuum. This is done in Figure 6, where it may be seen that the Υ production falls rather more steeply with x'_F than the continuum.

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References

1. W.P. Oliver et al., Proc. 3rd Intl. Conf. on New Results in High Energy Physics, Vanderbilt, p. 93. Amer. Inst. of Physics Conference Proceedings No. 45 (1978).
P.M. Mockett, p. 187, Proc. 19th Intl. Conf. on High Energy Physics, Tokyo (1978).
2. T.B. Kirk, Fermilab Report TM-791 (1978).
3. K. Ueno et al., Phys. Rev. Lett. 42, 486 (1979).
4. F. Halzen and D.M. Scott, Phys. Rev. Lett. 40, 1117 (1978).

Figure Captions

1. Experimental arrangement. A 400 GeV proton beam is incident from the left. The magnets are solid iron.
2. μ-pair production cross section (arbitrary units) as a function of dimuon mass. The insert at the upper right shows the Ψ region with continuum subtracted, plotted on a linear scale.
3. Cross section as a function of x_F' for dimuon masses between 8 and 9 GeV. The curves are Drell-Yan predictions (Ref. 4) with a symmetric or asymmetric sea.
4. Same as Fig. 3 for masses between 11 and 13 GeV.
5. Mean P_t vs. x_F' for various mass ranges. (MNTW = this experiment, CFS = Ref. 3.)
6. Ratio of Υ production to continuum vs. x_F'. The continuum cross sections are interpolated from masses above and below the Υ region.

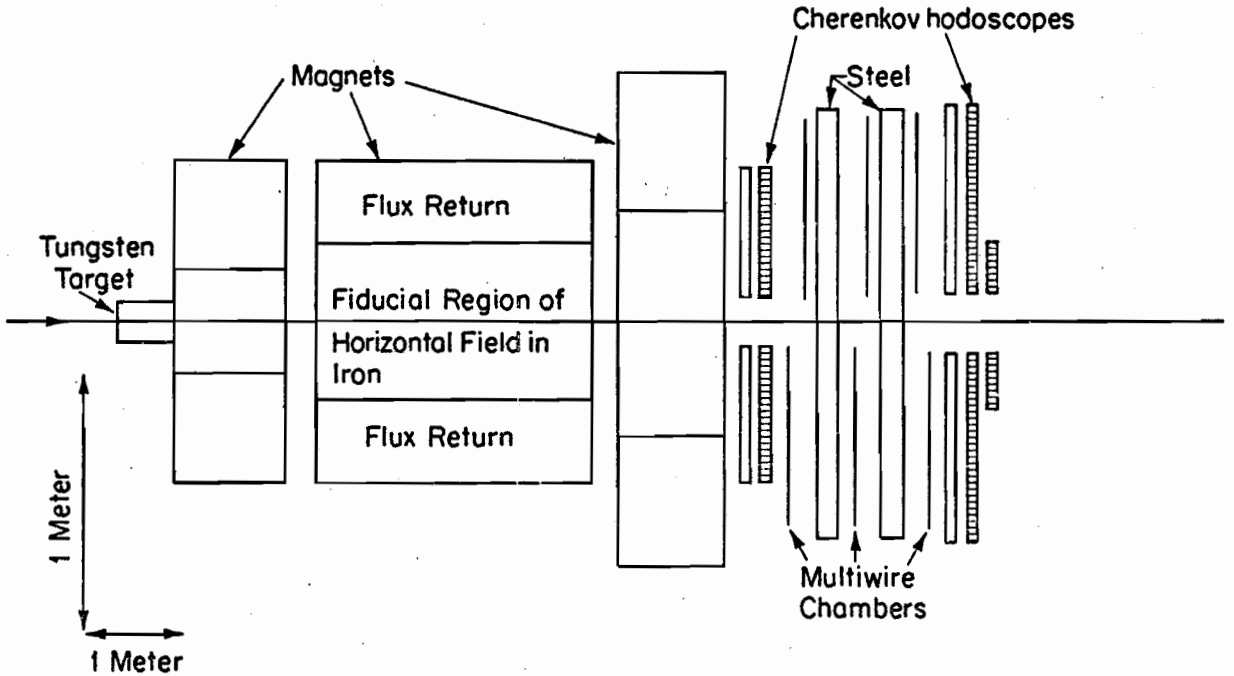
Cherenkov hodoscopes
Magnets
Steel
Flux Return
Tungsten Target
Fiducial Region of Horizontal Field in Iron
Flux Return
1 Meter
1 Meter
Multiwire Chambers

Figure 1

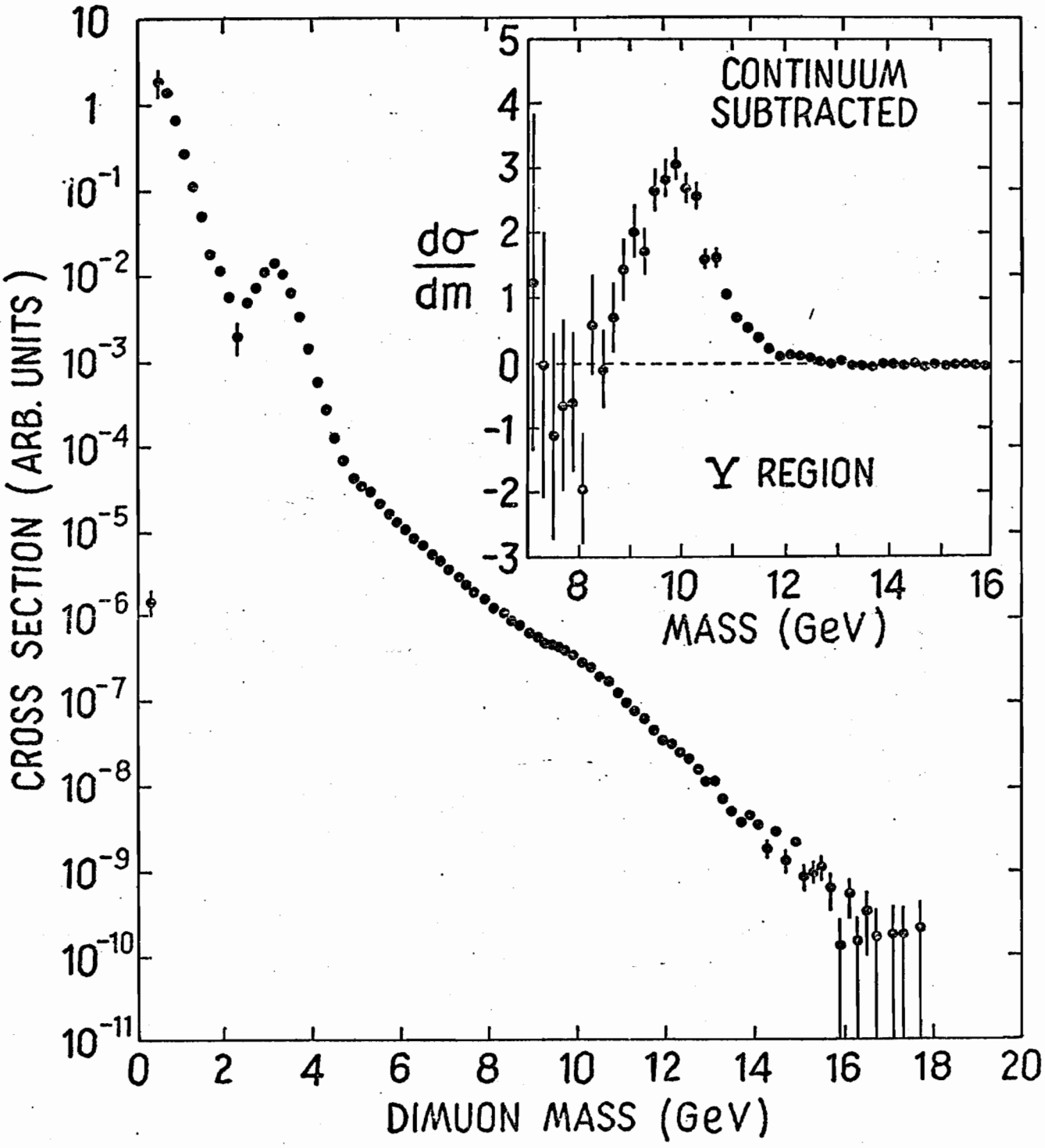
CROSS SECTION (ARB. UNITS)
DIMUON MASS (GeV)
CONTINUUM SUBTRACTED
dσ/dm
Υ REGION
MASS (GeV)

Figure 2

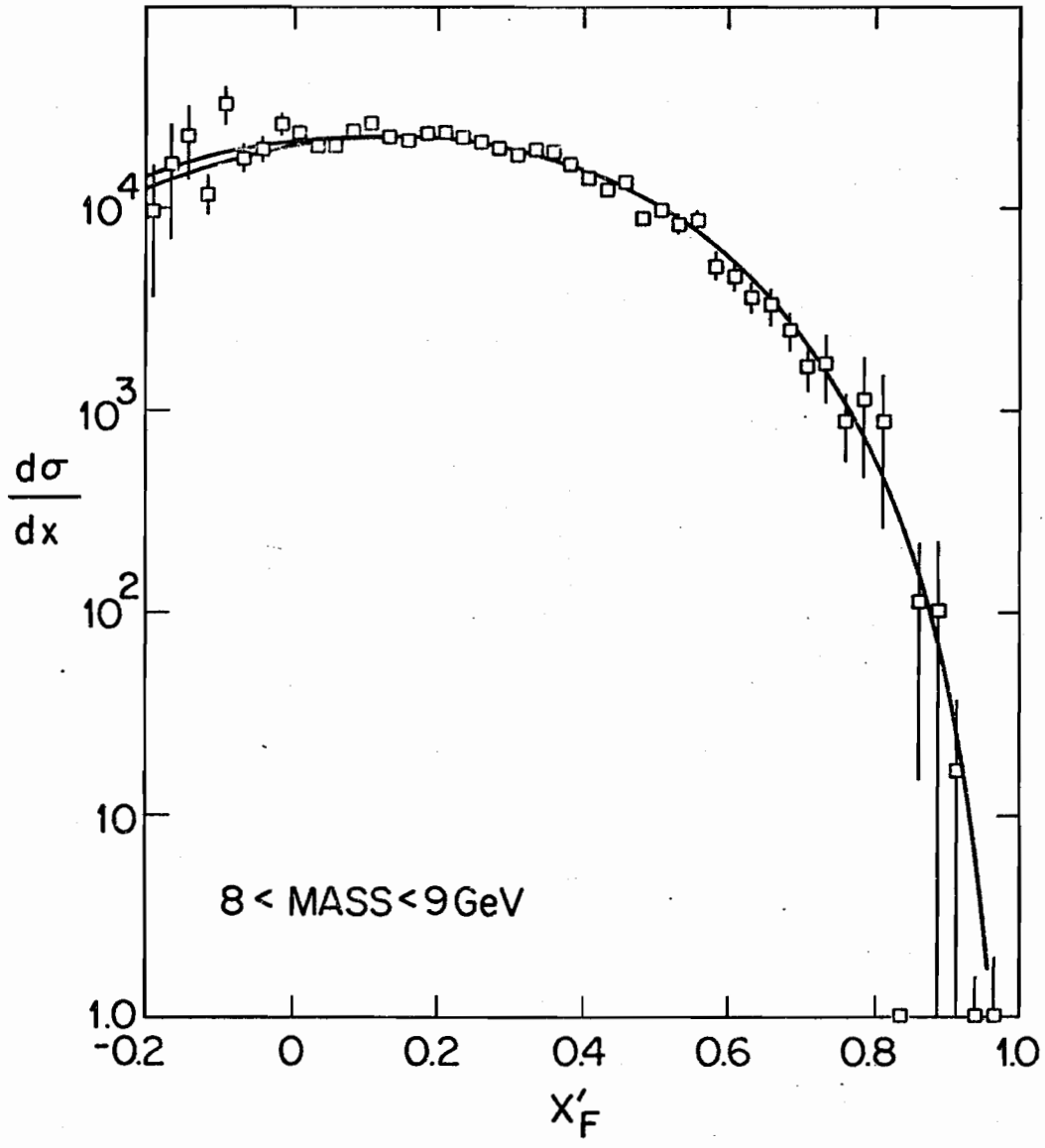

Figure 3

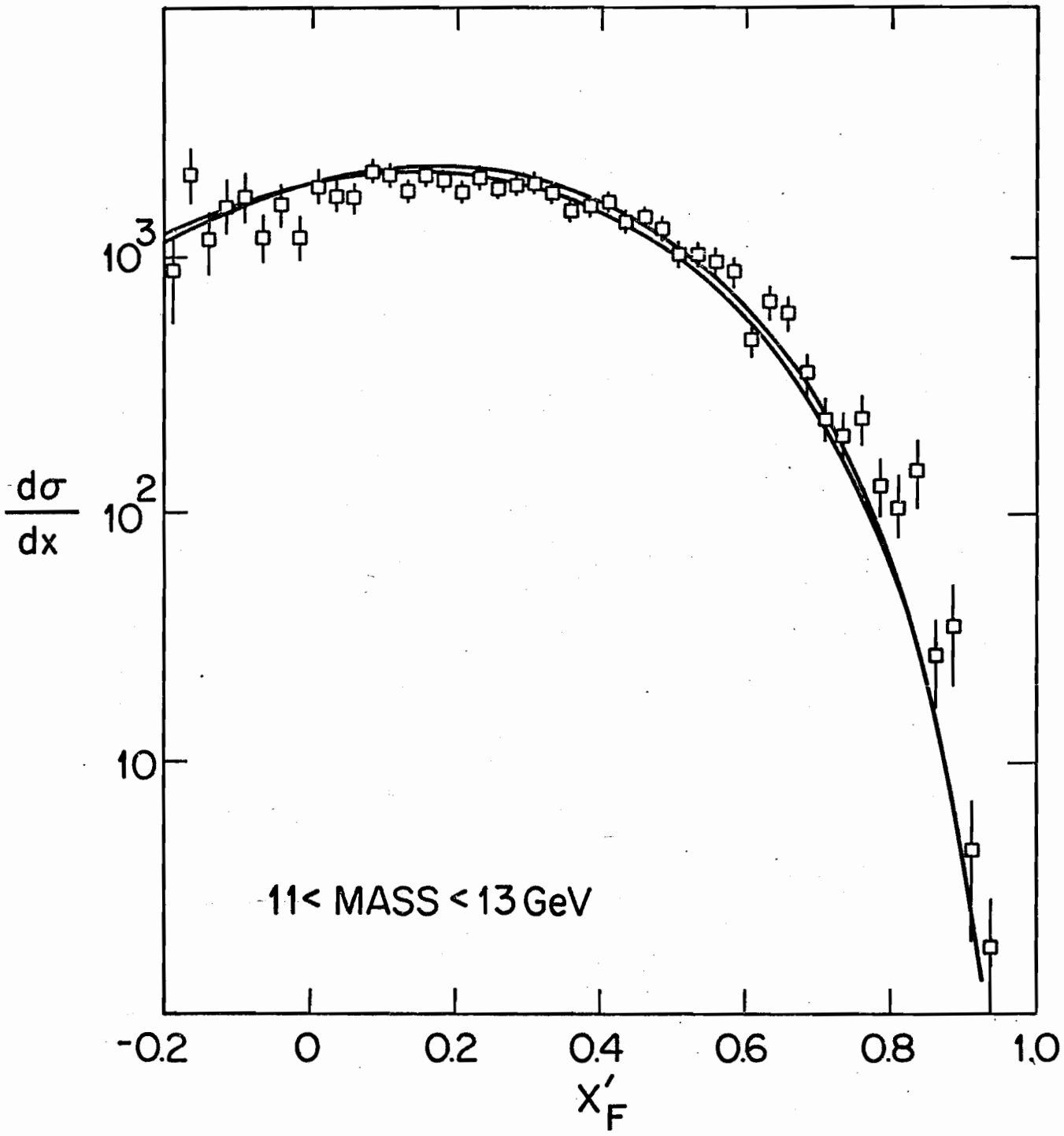

Figure 4

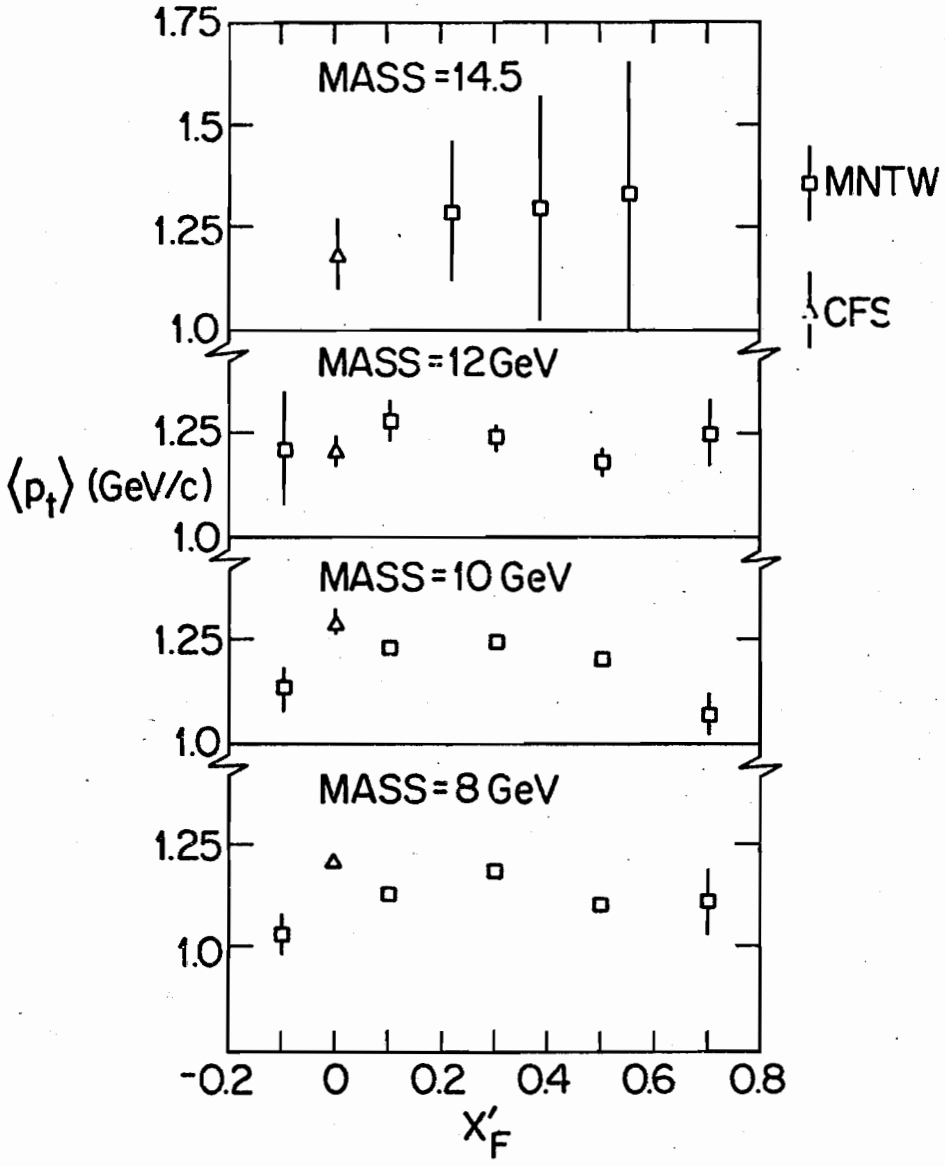
MASS = 14.5
MASS = 12 GeV
MASS = 10 GeV
MASS = 8 GeV
MNTW
CFS
⟨p_t⟩ (GeV/c)
X'_F
1.75
1.5
1.25
1.0
-0.2
0
0.2
0.4
0.6
0.8

Figure 5

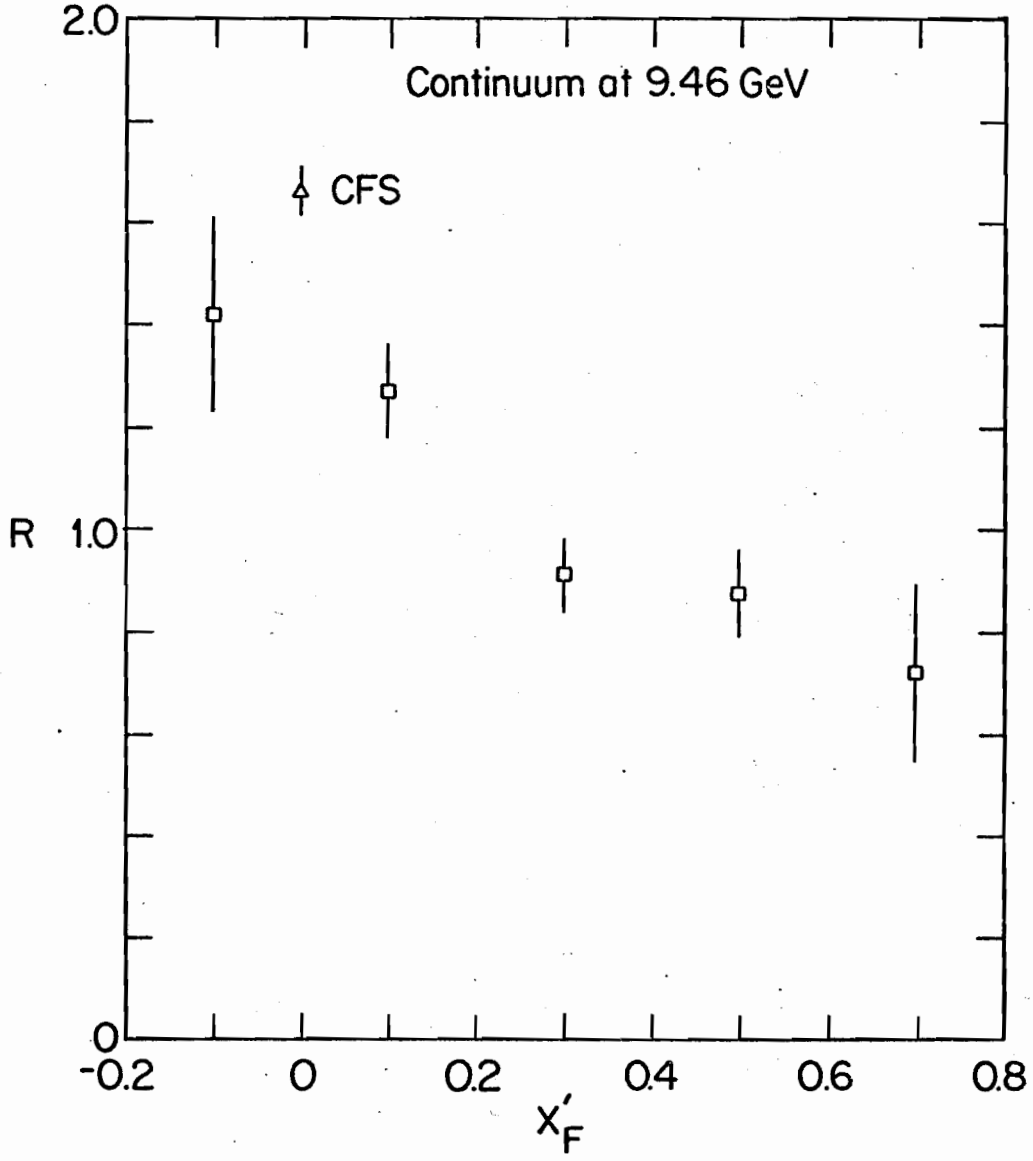

Figure 6