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201 GEV/C PROTON-PROTON ELASTIC SCATTERING AT LARGE MOMENTUM TRANSFER

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(Abstract)

Proton-proton elastic scattering has been measured in the region $4.9 < |t| < 12.1$ GeV^2 at a beam momentum of 201 GeV/c. If the form exp(At) is fit to the data, the exponent A gradually changes from 1.5 to 0.9 GeV^{-2} over our t range. The data are consistent with the form $\exp(-6.6 p_\perp)$. A comparison with ISR results shows that in this kinematical region the slopes are about the same, but $d\sigma/dt$ at fixed t is still dropping with energy.

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High momentum transfer proton-proton elastic scattering has previously been measured at the CERN ISR at equivalent beam energies up to 2000 GeV.[1, 2, 3] These measurements show a sharp dip at $|t|\sim 1.4$ GeV^2 followed by a secondary maximum at $|t|\sim 2$ GeV^2. $d\sigma/dt$ drops off as $\exp(1.8t)$ in the region $2<|t|< 5$ GeV^2. The results of the present experiment show that at 200 GeV this slope does not continue on to regions of higher $|t|$, but decreases gradually.

We report a measurement using the Fermilab proton synchrotron at 201 GeV/c which has 7904 elastic events in the region $4.9<|t|< 8.3$ GeV^2 and 1030 in the region $7.7<|t|<12.1$ GeV^2. The experimental layout is shown in Fig. 1. An external 201 GeV/c proton beam of $\sim 7\times 10^{11}$ protons per pulse passes through a 10cm long liquid hydrogen target in the Proton West area.

Forward and recoil protons are separately momentum analyzed and detected in coincidence. The forward protons are deflected 15 mrad by two dipole magnets and the typical recoil proton is deflected 300 mrad by one dipole. Three dimensional tracks are measured after deflection with multi-wire proportional chambers (MWPC).

The momentum-angle relation for the recoil protons is such that the entire t-region from 4.9 to 8.2 GeV^2 could be covered with the target in position (a). In order to cover the region $7.7 <|t|<12.1$ GeV^2, the target was moved from position (a) to position (b) and the magnet currents were reduced. In both geometries the azimuth bite was limited by the recoil arm magnet aperture to $\Delta\phi/2\pi \approx 0.009$. This geometrical acceptance varied by about 10% over the region $4.9<|t|<11.7$ GeV^2. In order to get the singles rates down to $\sim 10^6$ counts/sec special care was taken with shielding and collimation. These details will be described in a later paper.

The trigger consisted of at least one particle in the forward arm in coincidence with another particle in the recoil arm. An 8" slab of lead at the end of the forward arm eliminated electrons from the trigger. Most triggers consisted of particles which traced back to magnet polefaces or collimators. However, 43% of those remaining triggers which had a track in each arm coming from the target were elastic.

Cuts were made on target height and magnet aperture. Elastic peaks were observed in missing mass distributions for either arm, in the coplanarity distribution, and in the Δt distribution (difference in measured t-value for the two arms). Elastic events were obtained by making cuts on these quantities of 4 times full width at half-maximum. Momentum distributions for the forward arm are shown in Fig. 2 using only data at the high end of our momentum transfer region ($10.7 < |t| < 11.5$ GeV^2). Fig. 2a shows all events before making any cuts other than target cuts. This figure shows a rather sharp elastic peak separated from a broad region of inelastic events. The dashed line shows a possible extrapolation of inelastic events under the elastic peak leading to an estimate of $\sim$10% for inelastic background before making the remaining cuts. At lower momentum transfers this percentage was smaller. Fig. 2b shows that when coplanarity, Δt, and recoil missing mass cuts are made, the inelastic background level becomes less than 3% for our highest momentum transfer events. This rejection of inelastic background is confirmed by Monte-Carlo background studies which show that our system rejects large-angle isobar production compared to elastic scattering by several orders of magnitude.

The efficiency for each indivicual MPWC based on real tracks averaged about 95% during the run. The resulting probability that our system miss either the forward or recoil track was 7%. Cross sections were corrected for 7% loss due to chamber inefficiency and 13% loss due to particle absorption in air or detectors. The effects of inelastic background, counting losses, and reconstruction losses were determined to be small and no corrections were made. The beam was monitored by a secondary emission monitor calibrated by foil activation 55 meters down-stream of the target and by a 45° scintillation telescope. We estimate an overall 20% (rms) normalization error due mainly to the foil calibration. Resolution in t is ± 0.08 GeV^2 r.m.s. at $|t| = 6$ GeV^2 and ±0.1 GeV^2 at $|t|=9.5$ GeV^2.

Our results are shown in Figures 3 and 4. We note that the results shown in Fig. 3 cannot be fit by a single straight line (an attempt with the best fit slope of 1.22 GeV^{-2} yields a Chi-squared value of 249 for 34 points). In the region $5 \leq |t| \leq 6.2$ GeV^2 our data have a slope $d(\ell n\, d\sigma/dt)/dt$ of 1.5 GeV^{-2} which is consistent with the ISR results at an equivalent beam momentum of 1496 GeV/c.[4] However, in the region $9 \leq |t| \leq 12$ GeV^2, our data have a slope of 0.9 GeV^2. Our data are not consistent with a sudden change in slope near $|t|=6.5$ GeV^2 as reported at 1496 GeV/c.[4]

Our results along with those of References 4 to 7 are plotted vs. transverse momentum in Fig. 4. The results of this experiment have been fit with the form $d\sigma/dt = A\exp(-Bp_\perp)$ where $A = 1.6$ mb/GeV^2 and $B=6.7$ $(GeV/c)^{-1}$. This same dependence of large angle proton-proton elastic scattering on transverse momentum was observed when large angle measurements were made at the AGS.[5] The 20 to 30 GeV/c AGS data where $2.2<|t|<24$ GeV^2 were fit by $\exp(-6.6p_\perp)$ in Reference 5. This form also fits the 1496 GeV/c ISR results reasonably well with no need to invoke a break near $|t| = 6.5$ GeV^2.

Our absolute cross sections are about a factor of 2.5 higher than those of Reference 4 in the region where they overlap. Thus the s-dependence of $d\sigma/dt$ at fixed t is at least $s^{-.5}$ at 200 GeV when $5<|t|<9$ GeV^2.

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References:

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Figure Captions:

1(a) Spectrometer for recoil protons. Point (a) was target position for the $4.9<|t|<8.1$ GeV^2 results. Point (b) was target position for the $7.7<|t|<12$ GeV^2 results.

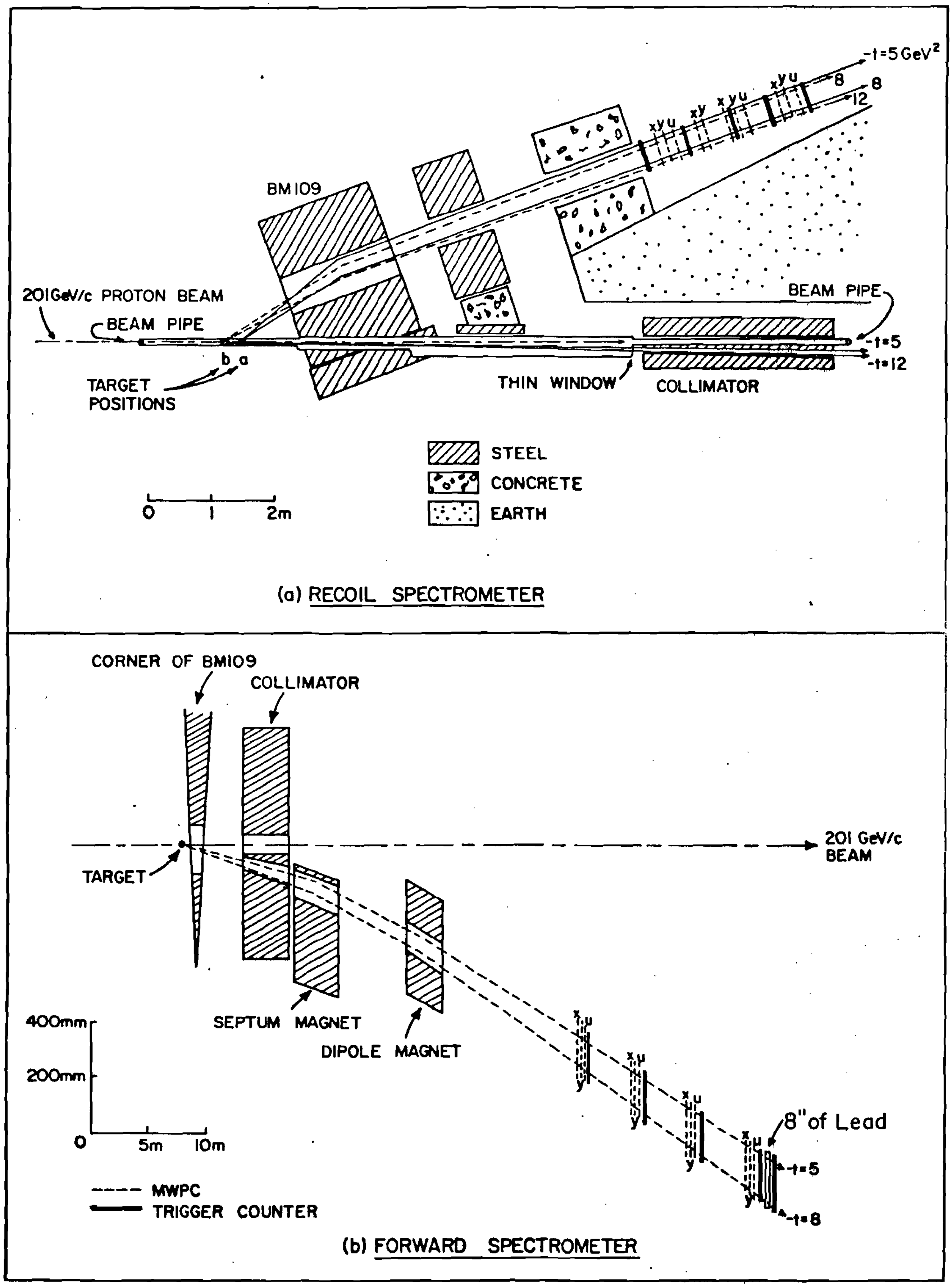
(b) Forward spectrometer. Note scale factor of 25 between the horizontal and vertical scales.

2(a) Momentum distribution in forward arm for events with $10.7<|t|<11.5$ GeV^2. Only the target height cut has been made. Dashed line is an "eyeball" extrapolation of inelastic background.

(b) Same as (a) except that coplanarity, Δt, and recoil missing mass cuts have been made.

3. Differential cross section vs. t. Only statistical errors are shown. There is an additional overall normalization error of ±20%. Bin width is 0.2 GeV^2 except for last 5 points which have 0.4 GeV^2 bin width. Results from Reference 4 are also shown.

4. Same data as in Fig. 3, but plotted vs. $p_\perp$. The results of References 4, 5, 6, and 7 are also shown.



$-t=5\,GeV^2$
8
8
12
x y u
x y
x y u
x y u
BM109
201GeV/c PROTON BEAM
BEAM PIPE
BEAM PIPE
b a
TARGET POSITIONS
THIN WINDOW
COLLIMATOR
-t=5
-t=12
STEEL
CONCRETE
EARTH
0 1 2m
(a) RECOIL SPECTROMETER
CORNER OF BM109
COLLIMATOR
201 GeV/c BEAM
TARGET
SEPTUM MAGNET
DIPOLE MAGNET
400mm
200mm
0 5m 10m
x u y
8" of Lead
-t=5
-t=8
MWPC
TRIGGER COUNTER
(b) FORWARD SPECTROMETER

Fig. 1

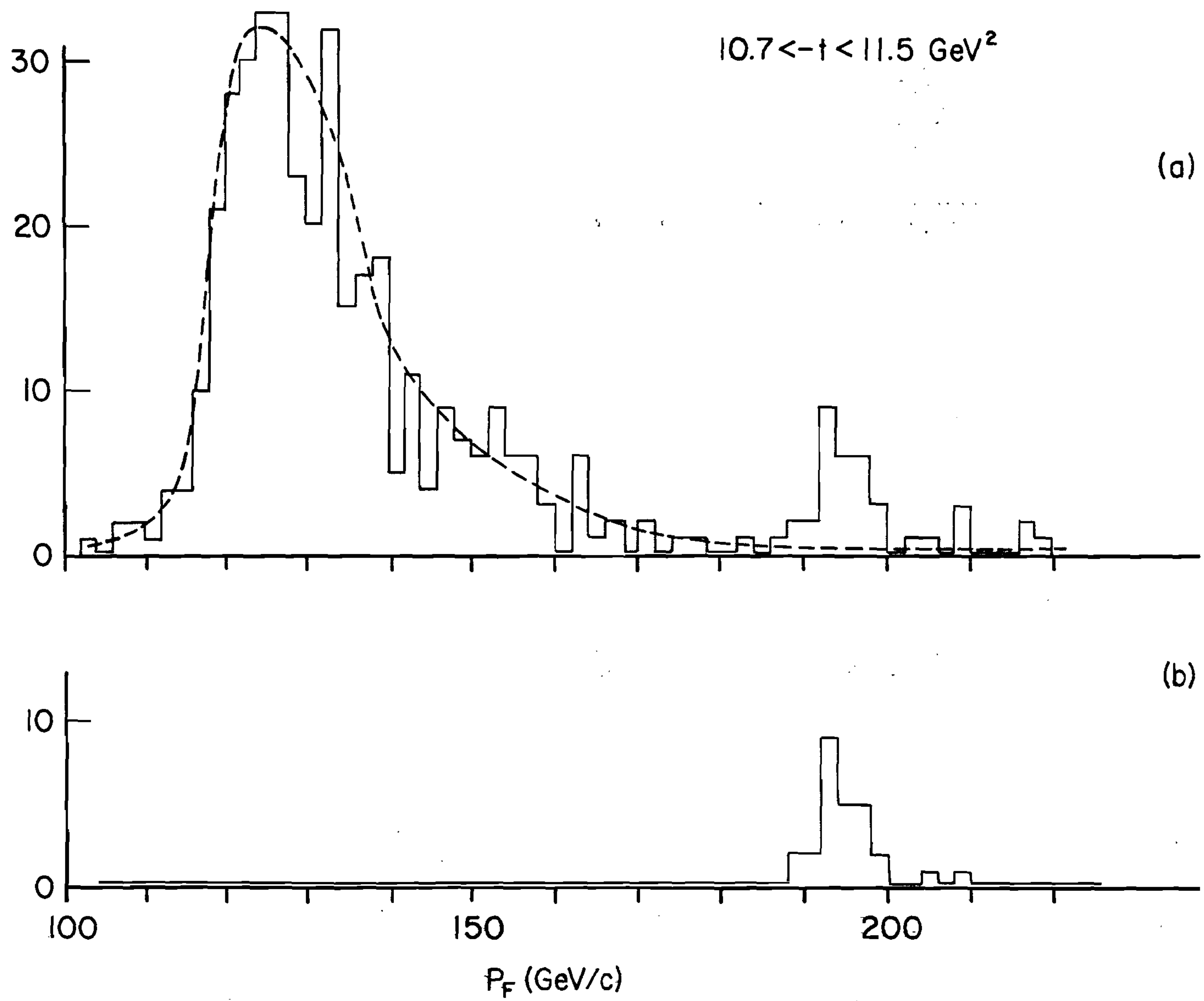


Fig. 2

058'077

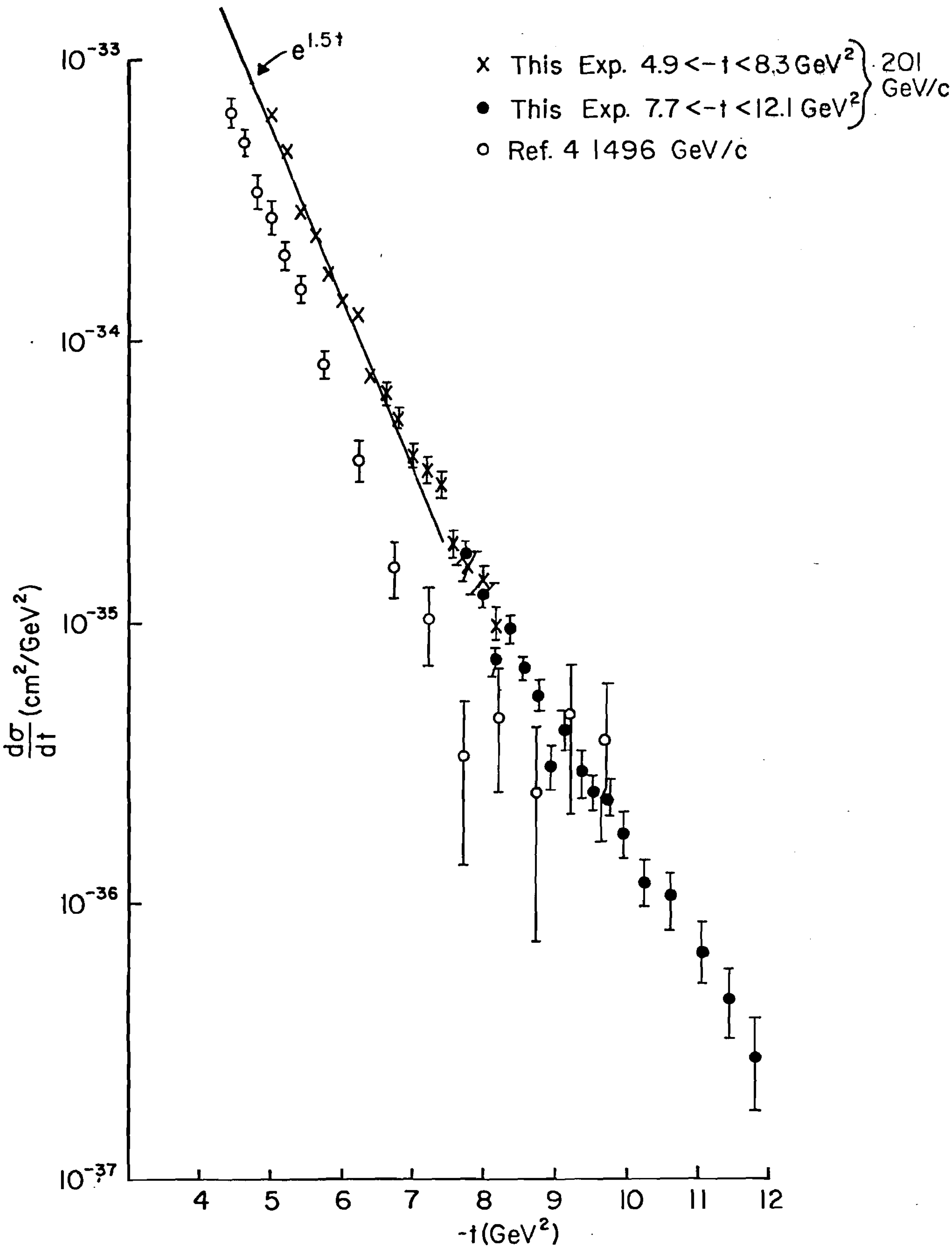
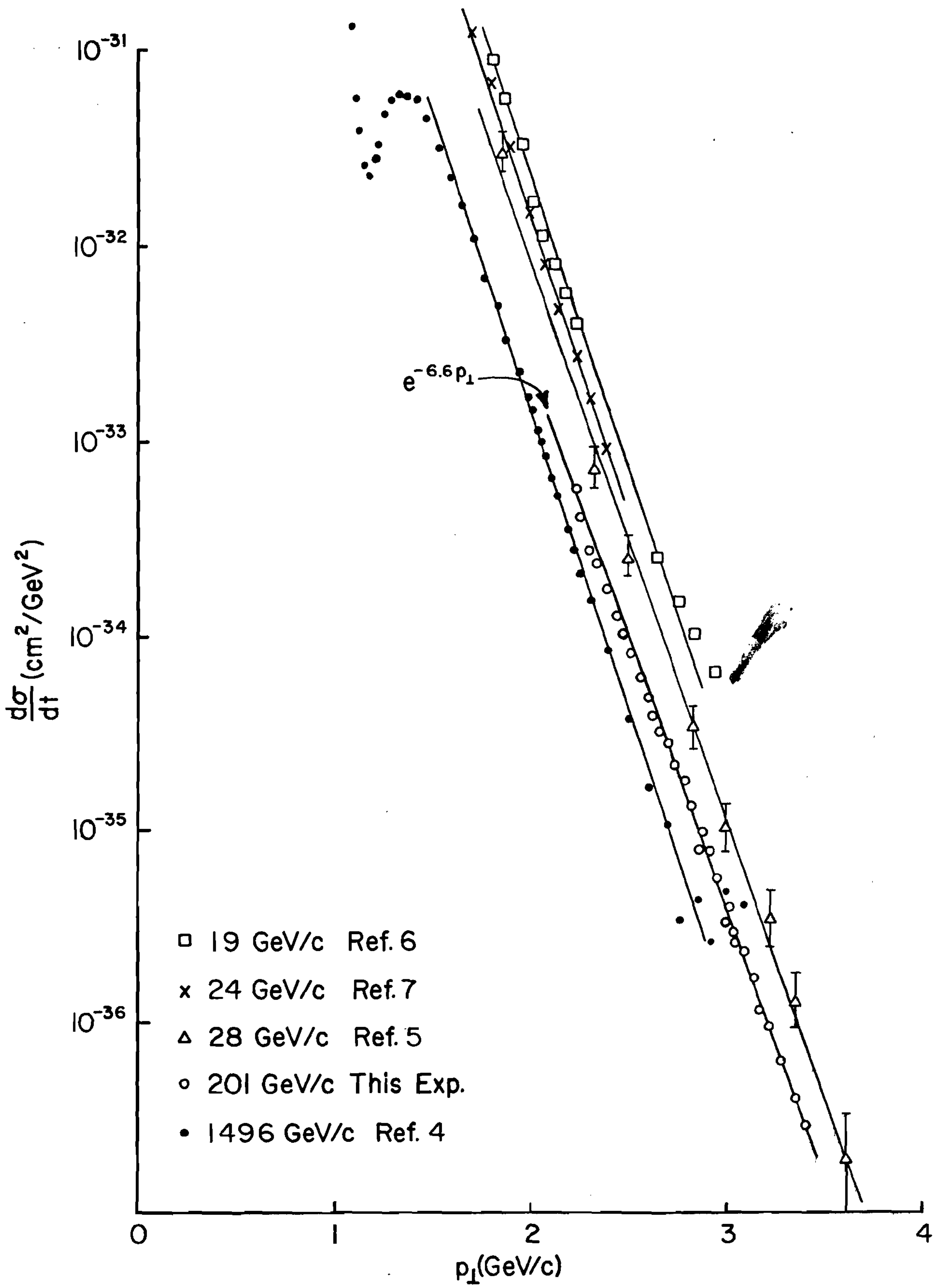

$e^{1.5t}$
x This Exp. 4.9<-t<8.3 GeV^2
• This Exp. 7.7<-t<12.1 GeV^2
201 GeV/c
o Ref. 4 1496 GeV/c
10^{-33}
10^{-34}
10^{-35}
10^{-36}
10^{-37}
$\frac{d\sigma}{dt}$ (cm^2/GeV^2)
4
5
6
7
8
9
10
11
12
-t(GeV^2)

Fig. 3



10^{-31}
10^{-32}
10^{-33}
10^{-34}
10^{-35}
10^{-36}
$\frac{d\sigma}{dt}$ (cm^2/GeV^2)
$e^{-6.6 p_\perp}$
□ 19 GeV/c Ref. 6
× 24 GeV/c Ref. 7
△ 28 GeV/c Ref. 5
○ 201 GeV/c This Exp.
• 1496 GeV/c Ref. 4
0
1
2
3
4
$p_\perp$(GeV/c)

Fig. 4