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OBSERVATION OF STRUCTURE IN LARGE MOMENTUM TRANSFER $\pi^- p$ ELASTIC SCATTERING AT 200 GeV/c

W. F. Baker, D. P. Eartly, J. S. Klinger,
A. J. Lennox, and R. Rubinstein
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

R. M. Kalbach, K. W. Krueger, and A. E. Pifer
University of Arizona, Tucson, Arizona 85721

S. F. McHugh
University of California at San Diego
La Jolla, California 92093

and

D. H. Kaplan, P. Karchin, and J. Orear
Cornell University, Ithaca, New York 14853

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W. F. Baker, D. P. Eartly, J. S. Klinger*, A. J. Lennox, R. Rubinstein
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

R. M. Kalbach**, K. W. Krueger, A. E. Pifer
University of Arizona, Tucson, Arizona 85721

S. F. McHugh
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ABSTRACT

Results are presented on the measurement of 200 GeV/c $\pi^- p$ elastic scattering from -t of 0.8 to 11 $(GeV/c)^2$. As -t is increased, $d\sigma/dt$ falls by ~6 decades to a prominent dip at 4 $(GeV/c)^2$, followed by a second maximum and then a slow decrease with increasing -t.

Above ~10 GeV/c incident momentum, there is now a considerable amount of data on large -t proton-proton elastic scattering(1-4), giving information on both the energy dependence of the cross section out to -t ~15(5) and the prominent dip in the t distribution at -t ~1.4 which appears above ~150 GeV/c incident momentum. Recent $\bar{p}p$ data(6) at 50 GeV/c also show a dip at -t = 1.4. Many models have been proposed to explain features of these data - a few examples are given in references 7-12.

In contrast to baryon-proton scattering, not much large -t πp information is available at high energies; data exist near 20 GeV/c(13,14) and have recently become available at 50 GeV/c(15), but above that beam momentum existing data(16) extend out only to -t ~2. Some models for πp scattering exist(17-23); a few predict dips in the t distribution similar to the baryon-nucleon case, but with no consistency in the predicted location.

The experiment described here, which was carried out in the M6E secondary beam at Fermilab, was undertaken to measure $\pi^- p$ elastic scattering at 200 GeV/c out to $-t$ ~11, to compare with pp large $-t$ scattering. Data on other incident particles at both ±100 and ±200 GeV/c, which extend to a $-t$ of ~3, will be reported at a later time.

The experimental layout is shown in Figure 1. The beam, with about 10^7 particles per 1 second spill, was made almost parallel through the apparatus so that determination of individual particle directions was unnecessary. Magnetic spectrometers were used to detect the scattered and recoil particles over the range $0.8 < -t < 11$. Electronic logic for the four scintillation counter hodoscopes was arranged in matrices to strongly favor elastic events; 31 proportional wire chambers (PWC's) containing 7800 wires were used to record particle tracks. For the present data, a signal from the threshold Cerenkov counter, set just below the antiproton threshold, was required; in addition, there was a differential Cerenkov counter in the beam, and the absence of a signal from it was required when it was set on a particle other than a π^-. The typical trigger rate was ~40 per accelerator spill.

In the off-line analysis, the angles and momenta of the two outgoing particles were determined from the PWC data, and cuts were placed on these quantities around the expected elastic values to determine the number of elastic events at each t value. The remaining background was determined to be no more than 5% of the signal at any t, and at the current stage of the analysis has not been subtracted. The overall PWC and reconstruction efficiency was determined to be ~80%. Elastic events were found to be ~4% of all triggers.

Small corrections to the data were made for particle absorption in the hydrogen target and material in the spectrometers, contamination in the pion beam, pion decay, δ rays from the hydrogen target causing vetos, and dead-time effects of the veto counters. Radiative corrections were also applied[24]. A Monte Carlo simulation was used to evaluate the geometrical acceptance of the apparatus; this varied smoothly, with a maximum azimuthal acceptance of 5%.

We estimate that systematic uncertainties on the overall normalization of the data presented here are ±30%; this figure is expected to be reduced with further analysis.

Our results are shown in Figure 2, while Fig. 3 compares our results with earlier data[13-16]. We agree with the earlier 200 GeV/c data[16] up to $-t \approx 2$ within the quoted normalization uncertainties.

The data show a drop of ~6 decades from $-t = 1$ to a minimum at $-t = 4$, followed by a second maximum and then a slow fall with increasing $-t$. The $-t = 4$ dip has not previously been observed. From the t distribution of the individual elastic events observed, the probability that the cross section is flat in the $-t$ region 3.7 to 5.7 is only 1%. Figure 3 shows in addition that there is negligible incident momentum dependence of the cross section between $-t$ of 1 and 3, although there is considerable dependence in the dip region.

When our data are taken together with those of Ref. 16, the shape of $d\sigma/dt$ out to $-t$ of ~4 is considerably more complex than a simple exponential form Ae^{Bt}. Local values of B decrease from 10 to 6.5 to 4.5 $(GeV/c)^{-2}$ at $-t$ of 0, 0.6, 2.0 respectively. At $-t$ ~3, B increases to 5.5 $(GeV/c)^{-2}$ as the dip is entered[25]. For the region $5 < -t < 11$, the value of B is determined to be $0.65 \pm 0.20 (GeV/c)^{-2}$.

The observed diffraction-like shape of the π^-p t-distribution is not consistent with many of the model predictions, including QCD which gives a reasonable description of large -t pp data[7]. The dip location, if viewed as a simple diffraction effect, seems to occur at a larger -t value than might be naively expected from the πp total cross section; some eikonal models[19,23], however, do predict dips in the -t region around 3 to 5. The dip is not present in 20 or 50 GeV/c data, although an abrupt change of slope occurs there at 50 GeV/c. This behavior with increasing momentum is similar to that of the $-t = 1.4$ dip in pp scattering, which is not seen below ~150 GeV/c.

In conclusion, it appears now that a prominent dip in the elastic cross section, suggestive of a diffractive mechanism, may be a general phenomenon in the ~100 GeV/c region and above, having now been observed in pp, $\bar{p}p$ and π^-p scattering.

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*Present address: Fairchild Republic, Farmingdale, New York 11735

**Deceased

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25. This phenomenon of an increase in slope as the dip is entered is also seen in pp elastic scattering at the -t = 1.4 dip.

FIGURE CAPTIONS

Figure 1. Experimental layout. H_1 - H_4 are scintillation counter hodoscopes; P_1 - P_8 are proportional wire chamber arrays. The 72D18 field integral was 360 Kg-ins, while the total field integral of the two BM109 magnets was 2600 Kg-ins. Not shown are veto counters around the liquid hydrogen target, helium bags in the forward spectrometer, monitor telescopes, and apparatus in the incident beam such as scintillation counters, proportional wire chambers, SWIC's, and a differential Cerenkov counter.

Figure 2. Results from this experiment on 200 GeV/c $\pi^- p$ elastic scattering. Statistical errors only are shown. When no events were observed in a bin, the upper limit shown corresponds to one event.

Figure 3. Results from this experiment, together with earlier data: CERN 20 GeV/c[14], BNL 23 GeV/c[13], CERN 50 GeV/c[15], and Fermilab 200 GeV/c[16]. For clarity, not all data points are shown. The curves are drawn to guide the eye.

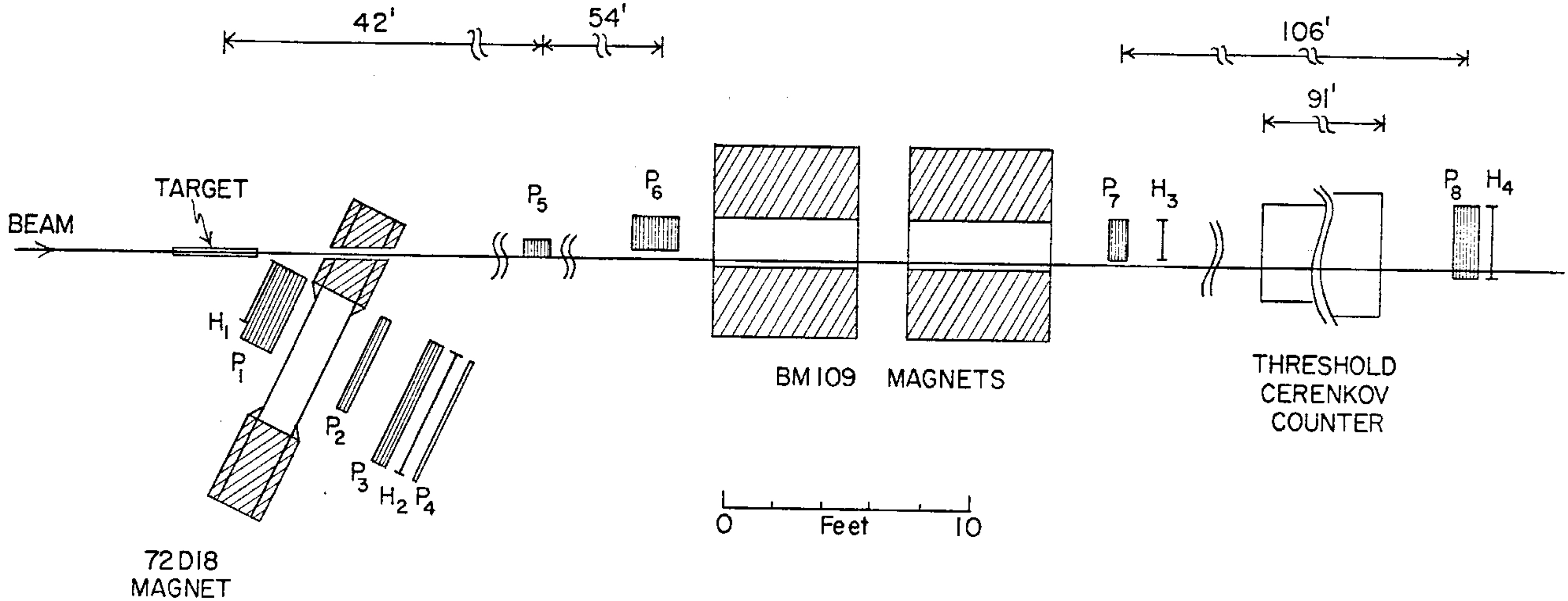
42'
54'
106'
91'
BEAM
TARGET
P5
P6
P7
H3
P8
H4
H1
P1
P2
P3
H2
P4
BM109
MAGNETS
THRESHOLD
CERENKOV
COUNTER
0
Feet
10
72D18
MAGNET

Fig. 1

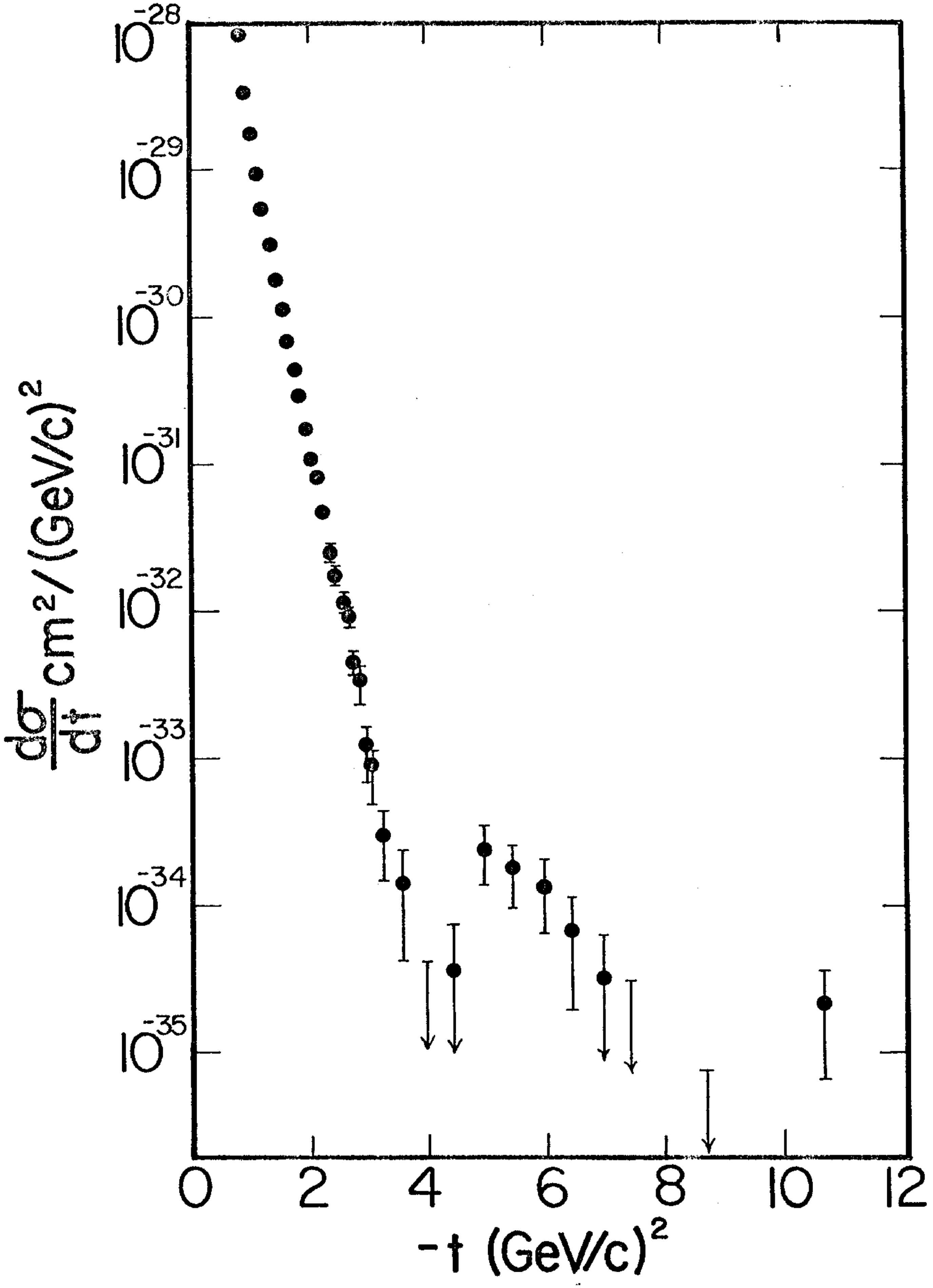
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
10^{-33}
10^{-34}
10^{-35}
$\frac{d\sigma}{dt}$ cm^2/(GeV/c)^2
0
2
4
6
8
10
12
-t (GeV/c)^2

Fig. 2

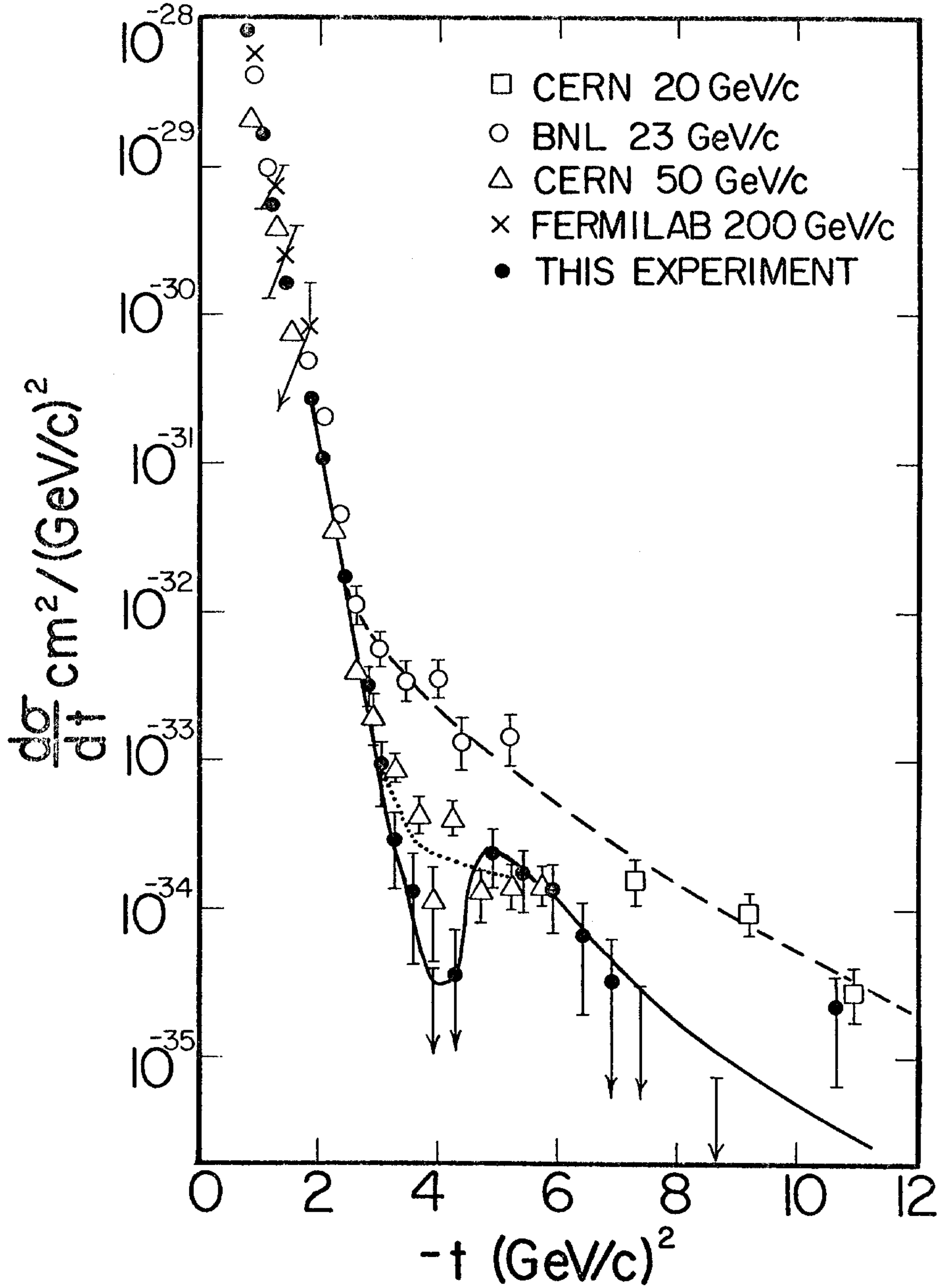
CERN 20 GeV/c
BNL 23 GeV/c
CERN 50 GeV/c
FERMILAB 200 GeV/c
THIS EXPERIMENT
$\frac{d\sigma}{dt}$ cm²/(GeV/c)²
-t (GeV/c)²
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
10^{-33}
10^{-34}
10^{-35}
0
2
4
6
8
10
12

Fig. 3