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ELASTIC SCATTERING OF $\pi^{\pm}$ AND $K^{\pm}$ ON PROTONS AT 100 AND 200 GeV/c

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

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, and R. Rubinstein
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

and

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

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R.M. Kalbach,* K.W. Krueger and A.E. Pifer
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A.J. Lennox and R. Rubinstein
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

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

ABSTRACT

Data are presented on elastic πp and Kp scattering for values of $-t$ up to 2.5 and 3.5 $(GeV/c)^2$ at incident momenta of 100 and 200 GeV/c respectively. All of the cross sections are found to be nearly identical, although there is some momentum dependence of the $\pi^+ p$ data; a small systematic difference observed between pion and kaon data cannot be explained by geometrical scaling.

We report here measurements of hadron-proton elastic scattering using the M6 beam at Fermilab. The apparatus acceptance was $0.5 < -t < 2.4$[1] and $0.9 < -t < 11$ at 100 and 200 GeV/c respectively. Data were obtained for incident $\pi^{\pm}$, $K^{\pm}$ and $p^{\pm}$ at each momentum, and some results have already been reported.[2,3] In this paper we present data for $\pi^{\pm}p$ at 100 GeV/c, $\pi^{+}p$ at 200 GeV/c and $K^{\pm}p$ at 100 and 200 GeV/c. Details of the experimental technique have been given previously[2,3], and only differences specific to these measurements will be noted here.

The incident particle was identified using information from a differential gas Cerenkov counter[4] (C_B) in the incident beam and a threshold gas Cerenkov counter (C_F) in the (scattered particle) forward spectrometer. The helium gas pressure in C_F was set just below the proton threshold, so that proton events had no signal in C_F. Elastic events with C_B set on π's, K's and p's were used in order to derive the appropriate C_F photomultiplier pulse height cuts and resulting contaminations.

At 100 GeV/c, the C_F photomultiplier pulse height distributions for K's and π's were sufficiently separated so that an appropriate cut on pulse height provided π and K identification with negligible contamination; C_B information was not required. At 200 GeV/c, there was significant overlap between the C_F pulse height distributions for π's and K's. The π data were corrected for the K's still remaining in the signal by assuming that the K and π elastic cross sections were equal (a good approximation, as we shall see later), and using the measured K/π ratios in the incident beam. These ratios were in the range 4 to 7% for negative beams and 8 to 18% for positive beams. For 200 GeV/c K's, only data with C_B set on K's were used. However, a beam π could occasionally accompany a K within the equipment resolving time. Using information from hodoscopes in the incident beam, it was determined that the contamination of pions in the kaon signal was 25% at -200 GeV and under 2% at +200 GeV/c; corrections were made to the data for this contamination.

Because of the high ($\sim 10^7$/sec) incident beam rates needed in order to measure small cross sections, rate dependent effects were observed in the veto and beam counters. The absolute normalization of pion data was obtained by extrapolating to zero beam intensity. Kaon results were normalized by measuring the relative K to π cross sections (with C_B set on K's) and then using the absolute pion normalization described above.[5]

With the uncertainties in the above procedures, we estimate that systematic uncertainties in the overall normalization of the data presented here are ± 15% for $\pi^{\pm}$, ±20% for $K^{\pm}$ at 100 GeV/c and ± 25% for $K^{\pm}$ at 200 GeV/c.

Our results are presented in Figure 1; in the region of overlap they agree well with data from previous lower -t experiments[6,7,8]. All of the cross sections have smooth behavior with -t over our -t range, without marked structures such as occur in pp, np and $\bar{p}p$ scattering at $-t \sim 1.5$ [3,9,10,11] or in $\pi^- p$ scattering at $-t \sim 4$.[2]

Our data show a small decrease in the magnitude of the π^+p cross sections between 100 and 200 GeV/c; 50 GeV/c data[12] are also consistent with this trend. Within the experimental uncertainties, there is no momentum or charge dependence of any of the other cross sections in the momentum and -t range measured here. The data also show only small differences between kaon and pion cross sections in the range $1 \lesssim -t \lesssim 2.5$ at 100 and 200 GeV/c. Such approximate equality has been observed previously at 14 GeV/c over the same t range,[13] and at 50 - 200 GeV/c for $0.8 \lesssim -t \lesssim 1.5$.[6]

Hadron-hadron elastic scattering has been used, via the Chou-Yang model[14], to obtain particle form factors[15,16]. Results obtained in the past for pions and kaons gave reasonable agreement with measured electromagnetic form factors[17] and radii[18]; little difference was observed between pion and kaon form factors, although the kaon radius obtained was slightly less than that of the pion. We have derived pion and kaon form factors out to $-t \sim 2.5$ using the data presented here, and also observe little difference between them. The form factor obtained from our 200 GeV/c π^-p data[2], extending to $-t \sim 10$, has already been reported.[19]

The small difference between our K and π cross sections is illustrated in Figure 2 by the -100 GeV/c data of this experiment together with lower -t data[6] and the optical point (calculated using references 20, 21 and 22). Although the π and K cross sections are always close in value, the K^- data fall more slowly with -t than π^-; the π and K cross sections cross near $-t \sim 1$. These same features are observed at -200 GeV/c, and also for positive mesons at the same two momenta. In the past, differences between π and K data above 30 GeV/c have been explained by geometrical scaling[23,24]: the π and K data became identical when $d\sigma/dt$ normalized to the optical point was plotted against $t\sigma_T$ for each incident particle (where σ_T is the particle-proton total cross section). We observe significant deviations from such geometrical scaling behavior in our ± 100 GeV/c results, as illustrated in Figure 3 for -100 GeV/c; the statistical accuracy of these data, however, is higher than used in the previous comparisons.[25] At 200 GeV/c, the results are in closer agreement with geometrical scaling, but the statistical accuracy of the 200 GeV/c kaon data does not allow a definitive statement.

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References

* Deceased

** Present address: Physics Department, Colgate University, Hamilton, New York 13346

\+ Present address: Physics Department, University of California at Santa Barbara, Santa Barbara, California 93106

\+\+ Present address: Fairchild Republic, Farmingdale, New York 11735

1. In this paper, the units for t are $(GeV/c)^2$

2. W.F. Baker et al. Phys. Rev. Lett <u>47</u>, 1683 (1981)
3. D.H. Kaplan et al. Phys. Rev. <u>D26</u>, 723 (1982)
4. M. Benot et al. Nucl. Instr. and Meth. <u>105</u>, 431 (1972)
5. Additional details are contained in the Ph.D. theses of P. Karchin (Cornell University) and K.W. Krueger (University of Arizona)
6. C.W. Akerlof et al. Phys. Rev. <u>D14</u>, 2864 (1976)
7. D.S. Ayres et al. Phys. Rev. <u>D15</u>, 3105 (1977)
8. A. Schiz et al. Phys. Rev. <u>D24</u>, 26 (1981)
9. A. Böhm et al. Phys. Lett. <u>49B</u>, 491 (1974)
10. C. DeHaven et al. Nucl. Phys. <u>B148</u>, 1 (1979)
11. Z. Asa'd et al. Phys. Lett. <u>108B</u>, 51 (1982)
12. Z Asa'd et al. Phys. Lett. <u>118B</u>, 442 (1982)
13. R. Rubinstein et al. Phys. Rev. Lett. <u>30</u>, 1010 (1973)
14. T.T. Chou and C.N. Yang. Phys. Rev. <u>170</u>, 1591 (1968)
15. D.S. Ayres et al. Phys. Rev. <u>D14</u>, 3092 (1976)

16. T.T. Chou. Phys. Rev. D19, 3327 (1979)

17. C.J. Bebek et al. Phys. Rev. D13, 25 (1976) and D17, 1693 (1978)

18. E.B. Dally et al. Phys. Rev. Lett. 45, 232 (1980) and 48, 375 (1982)

19. P. Karchin and J. Orear. Cornell University Preprint CLNS-82/543 (to be published)

20. A.S. Carroll et al. Phys. Lett. 61B, 303 (1976) and 80B, 423 (1979)

21. L.A. Fajardo et al. Phys. Rev. D24, 46 (1981)

22. J.P. Burq et al. Phys. Lett. 77B, 438 (1978) and 109B, 111 (1982)

23. V. Barger et al. Nucl. Phys B88, 237 (1975)

24. C. Bruneton et al. Nucl. Phys. B124, 391 (1977)

25. Recent data at 20 and 50 GeV/c (Z. Asa'd et al. CERN Preprint CERN-EP/82-205) also show deviations from geometrical scaling.

Figure Captions

Figure 1 Data from this experiment on $\pi^{\pm}p$ and $K^{\pm}p$ elastic scattering at 100 and 200 GeV/c. Note that the π^{+} and K^{+} data have been multiplied by a factor of 1000. Statistical errors only are shown. Where no events were observed in a bin, the upper limit shown corresponds to one event.

Figure 2 $\pi^{-}p$ and $K^{-}p$ elastic scattering at 100 GeV/c. Data are from this experiment and reference 6, together with the optical point obtained from references 20, 21 and 22. For clarity, not all data of reference 6 is plotted. Statistical errors only are shown.

Figure 3. The same data as in Figure 2, but with $d\sigma/dt$ normalized to the optical point plotted against $t\sigma_T$.

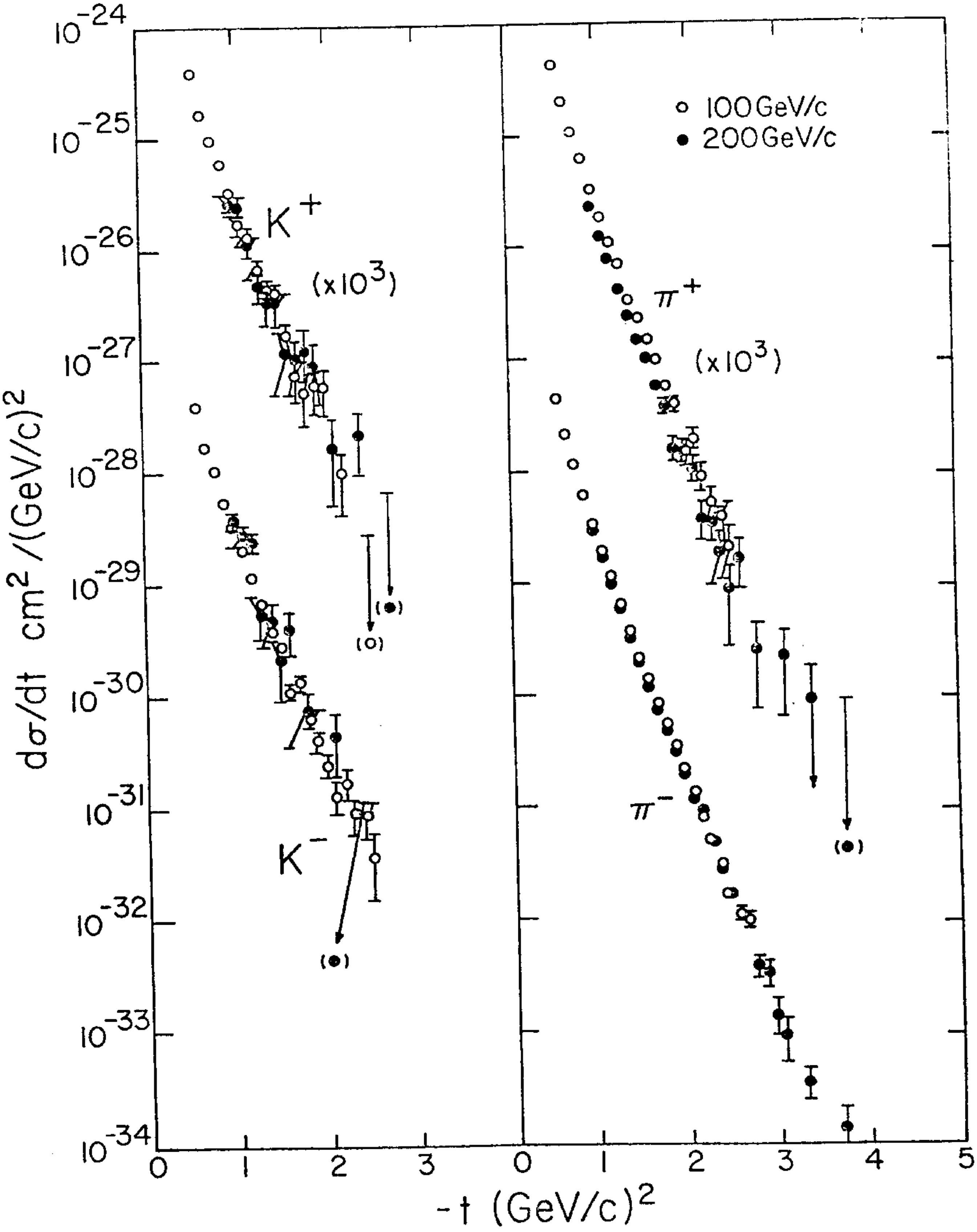

Figure 1

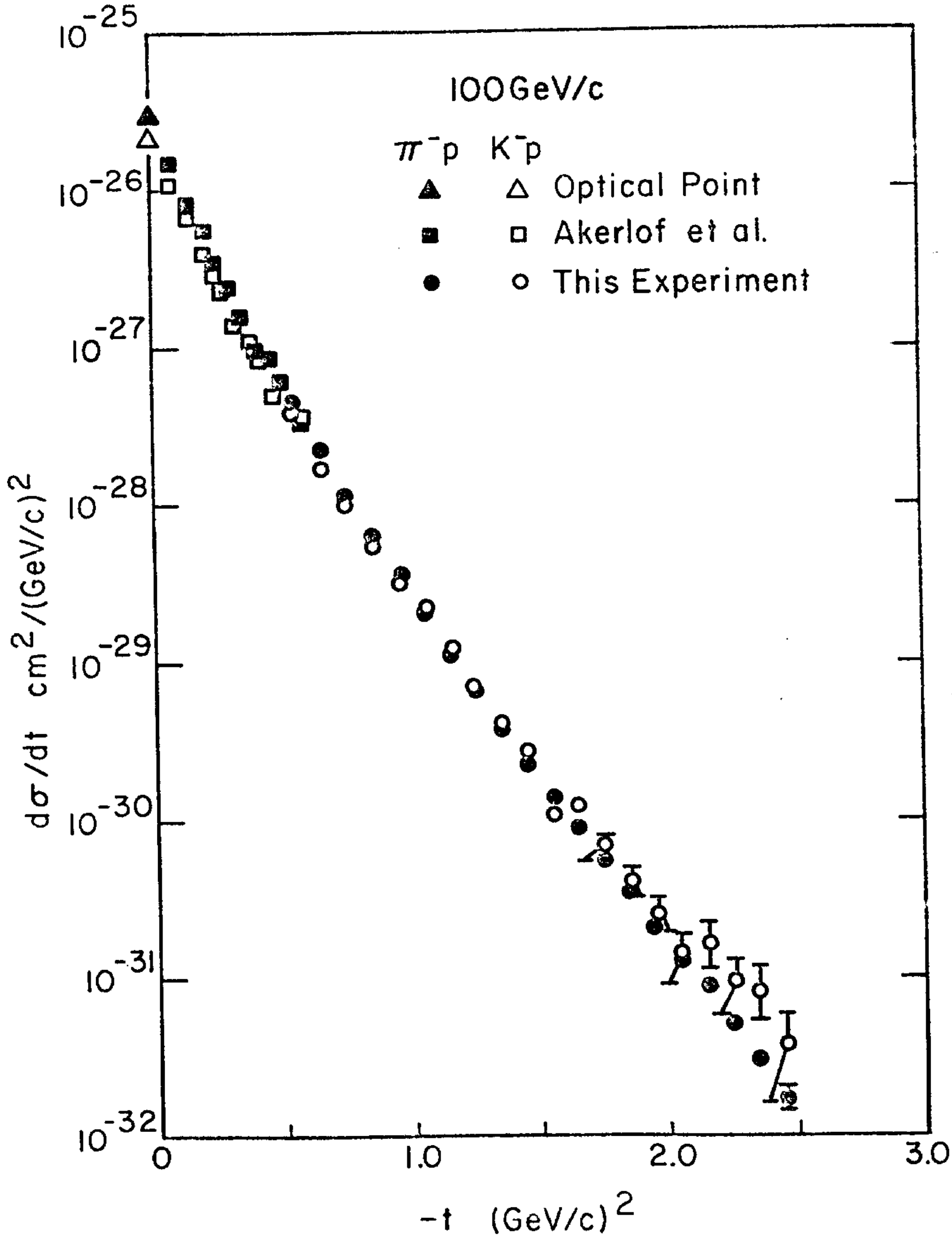
100GeV/c
π^-p K^-p
Optical Point
Akerlof et al.
This Experiment
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
$d\sigma/dt$ $cm^2/(GeV/c)^2$
0
1.0
2.0
3.0
$-t$ $(GeV/c)^2$

Figure 2

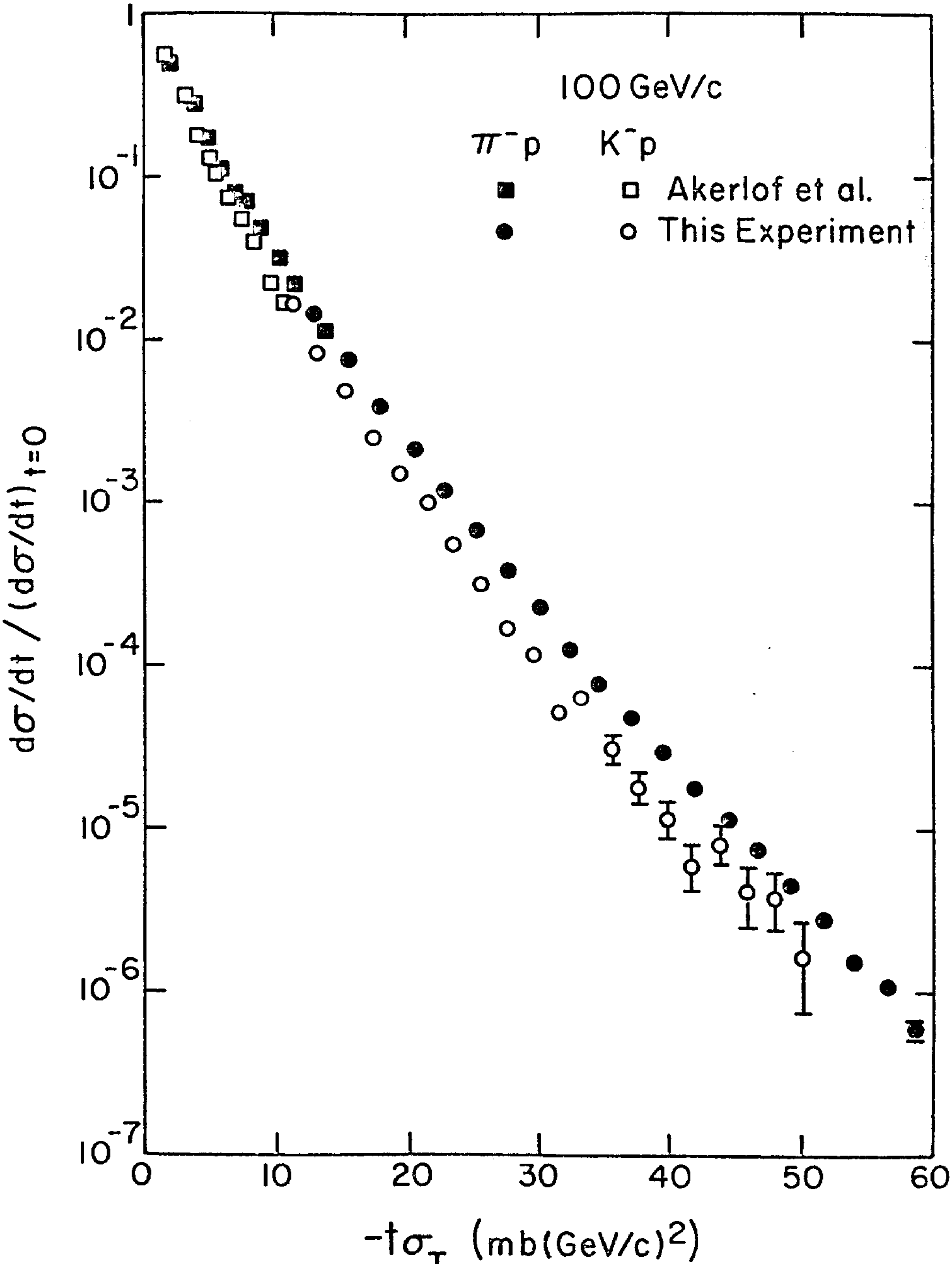
100 GeV/c
π^-p K^-p
Akerlof et al.
This Experiment
$d\sigma/dt\,/\,(d\sigma/dt)_{t=0}$
$-t\sigma_T$ (mb(GeV/c)^2)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
10
20
30
40
50
60

Figure 3