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MEASUREMENT OF p + p → p + X BETWEEN 50 AND 400 GeV*

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Abstract

We have measured the s, t and x dependence of the invariant cross section for the inclusive reaction $p + p \rightarrow p + X$ in the region $108 < s < 752$ GeV^2, $0.14 < |t| < 0.38$ GeV^2 and $0.80 < x < 0.93$. The data were taken during the acceleration ramp of the National Accelerator Laboratory machine using the internal H_2 jet target facility.

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We have studied the single-particle inclusive reaction

$$p + p \rightarrow p + X \quad (1 + 2 \rightarrow 3 + X) \qquad (1)$$

(X = anything) at the National Accelerator Laboratory using the internal hydrogen jet[1] target at energies between 50 and 400 GeV. Recoil protons from Reaction (1) in the region $55° < \theta_{lab} < 65°$ with velocities $0.34 < \beta < 0.57$ pass through a scintillation counter telescope and stop in a total absorption scintillation counter. The experimental set-up is similar to that of an earlier experiment[2] in which the recoil proton momentum was determined by range in Al absorbers. In the present experiment the total absorption counter replaces the Al absorbers and the recoil momentum is determined by time of flight (TOF) over 186 cm. Both the TOF and the pulse height (PH) in the absorption counter are digitized and stored for each event. The scatter plot of TOF vs. PH has two distinct regions, one corresponding to protons, the other to pions. The PH information is used only to remove pions from the scatter plot. The remaining events in each TOF interval are summed over PH and represent the number of protons with a distinct momentum transfer squared t. This procedure avoids the loss of proton events due to interactions in the absoption counter which lead to inferior pulse heights. A small t-dependent correction to our data was necessary due to the higher probability of low momentum recoil protons being scattered out of our spectrometer

by the forward counters than scattered in. This effect was calculated by a Monte Carlo program and checked emperically by varying the amount of material between the target and absorption counter. The correction factor is 1.08 at $t = -0.16\ \mathrm{GeV}^2$ decreasing to 1.00 at $t = -0.33\ \mathrm{GeV}^2$.

Our results are expressed in terms of the invariant cross section $sd^2\sigma/dtdM_X^2$ which is a function of the three invariants[2]

$$s \simeq 2mE_1 \tag{2a}$$

$$t = 2m(E_3 - m) \tag{2b}$$

$$x \simeq 1 - M_X^2/s \simeq (E_3 - p_3\cos\theta_3)/m \tag{2c}$$

where s is the total energy squared, t is the momentum transfer squared, x is the Feynman variable $p^*_{\parallel}/p^*_{max}$, M_X^2 is the missing mass squared and m is the proton mass. Typical full-width resolutions in these quantities are: $\Delta s = 30\ \mathrm{GeV}^2$, $\Delta t = 0.05\ \mathrm{GeV}^2$ and $\Delta x = 0.01$.

We normalize our $pp \to pX$ data by monitoring the rate of elastically scattered protons in a solid state detector[3] at $\theta_{lab} = 85.5°$ ($t = -0.022\ \mathrm{GeV}^2$), i.e., we measure the ratio $sd^2\sigma/dtdM_X^2(pp \to pX):d\sigma/dt(pp \to pp)$ and use the known elastic cross section $d\sigma/dt$ to obtain $sd^2\sigma/dtdM_X^2$. By the optical theorem the forward differential elastic cross section is proportional to the square of the total pp cross section $\sigma(s)_{tot}$. We extrapolate our measured $d\sigma/dt(s)$ at $t = -0.022\ \mathrm{GeV}^2$ to $t = 0$ using the parameters determined by Bartenev et al.[4] and for $\sigma(s)_{tot}$ we use the parametrization

for this cross section of Bourely and Fischer[5]. Over our s range the square of the total cross section increases by 8% while the increasing elastic slope parameter causes a shrinkage of -3% so that our measured ratio $sd^2\sigma/dtdM_X^2(pp \to pX) : d\sigma/dt(pp \to pp)$ at $s = 752\ GeV^2$ must be increased by 5% relative to the ratio at $s = 108\ GeV^2$ in order to obtain the correct s-dependence of $sd^2\sigma/dtdM_X^2$. We estimate the uncertainty in our relative s normalization to be ± 4% and the uncertainty in the absolute normalization to be ± 15%.

Our data at five s values and four t values are plotted as a function of x in Fig. 1. In our kinematic region, $0.14 < |t| < 0.38\ GeV^2$, the t-dependence of the invariant cross section is well described by a simple exponential e^{bt} (see Fig. 2) where b is not a function of s and depends only very weakly on x. Fits of the form

$$sd^2\sigma/dtdM_X^2 = A(x)\ e^{b(x)t}\left[1 + B(x)s^{-1/2}\right] \qquad (3)$$

to our data at fixed x and t show almost no variation of the parameter B in Eq. (3) with t. We therefore make an overall fit of the form (3) to our data at all values of s and t and arrive at the parameters given in Table I.

Table I. The coefficients A, B and b resulting from a fit of the form (3) to the data of this experiment.

$x = 1-M_X^2/s$	A (mb/GeV^2)	B (GeV)	b (GeV^{-2})
0.83	71 ± 7	1.9 ± 0.7	5.9 ± 0.3
0.85	64 ± 6	2.5 ± 0.7	5.9 ± 0.3
0.87	61 ± 5	3.0 ± 0.6	5.9 ± 0.3
0.89	62 ± 4	3.6 ± 0.5	6.0 ± 0.3
0.91	66 ± 3	4.3 ± 0.4	6.1 ± 0.3

The dip in the x-distributions of Fig. 1 near x = 0.88 is reflected in the A parameters of Table 1 which also have a minimum near x = 0.88. The b parameter, within errors, is constant with x while the B parameter increases significantly with x indicating a relatively stronger s-dependence at large x. The s-dependence of our data is shown in Fig. 3 in which the invariant cross section at x = 0.83 and 0.91 is plotted vs. $s^{-\frac{1}{2}}$.

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References

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2. F. Sannes et al., Phys. Rev. Letters 30, 766 (1973).
3. The signal from the elastic monitor was provided by the USA-USSR collaboration at NAL, authors of Ref. 1 and 4.
4. V. Bartenev et al., Phys. Rev. letters 29, 1755 (1972).
5. Bourely and Fischer, CERN Preprint.
6. U. Amaldi et al., Phys. Letters 44B, 112 (1973); S. R. Amendolia et al., Phys. Letters 44B, 119 (1973).

Figure Captions

Fig. 1 Measured x-distributions at five values of s and four t ranges.

Fig. 2 The invariant cross section at two s values as a function of t. The curves are fits to the data of the form (3).

Fig. 3 The s-dependence of the invariant cross section at two x values and four t values plotted as a function of $s^{-\frac{1}{2}}$.

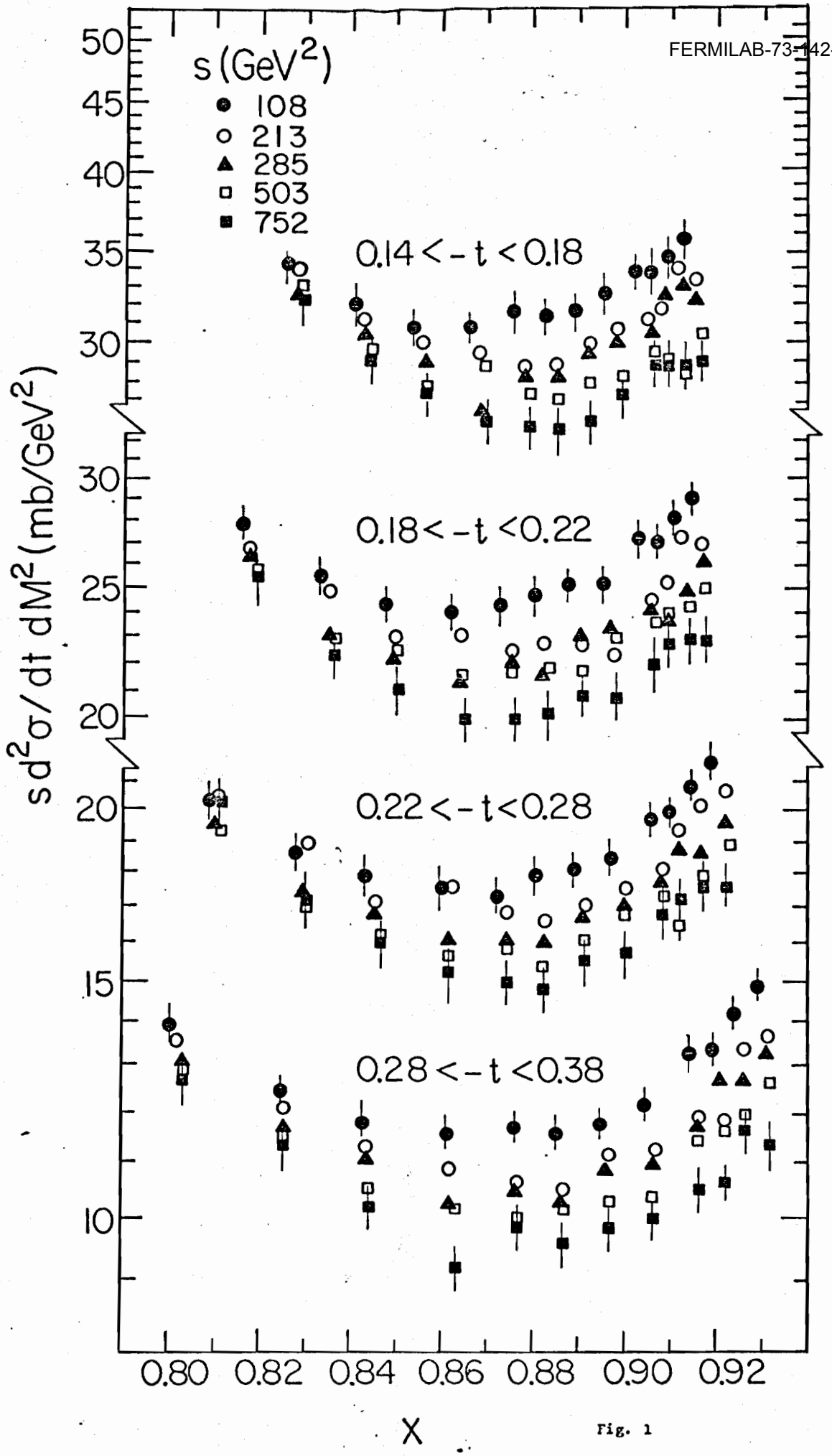
s (GeV^2)
108
213
285
503
752
0.14 < -t < 0.18
0.18 < -t < 0.22
0.22 < -t < 0.28
0.28 < -t < 0.38
s d^{2}σ/ dt dM^2 (mb/GeV^2)
X
0.80
0.82
0.84
0.86
0.88
0.90
0.92
50
45
40
35
30
30
25
20
20
15
10

Fig. 1

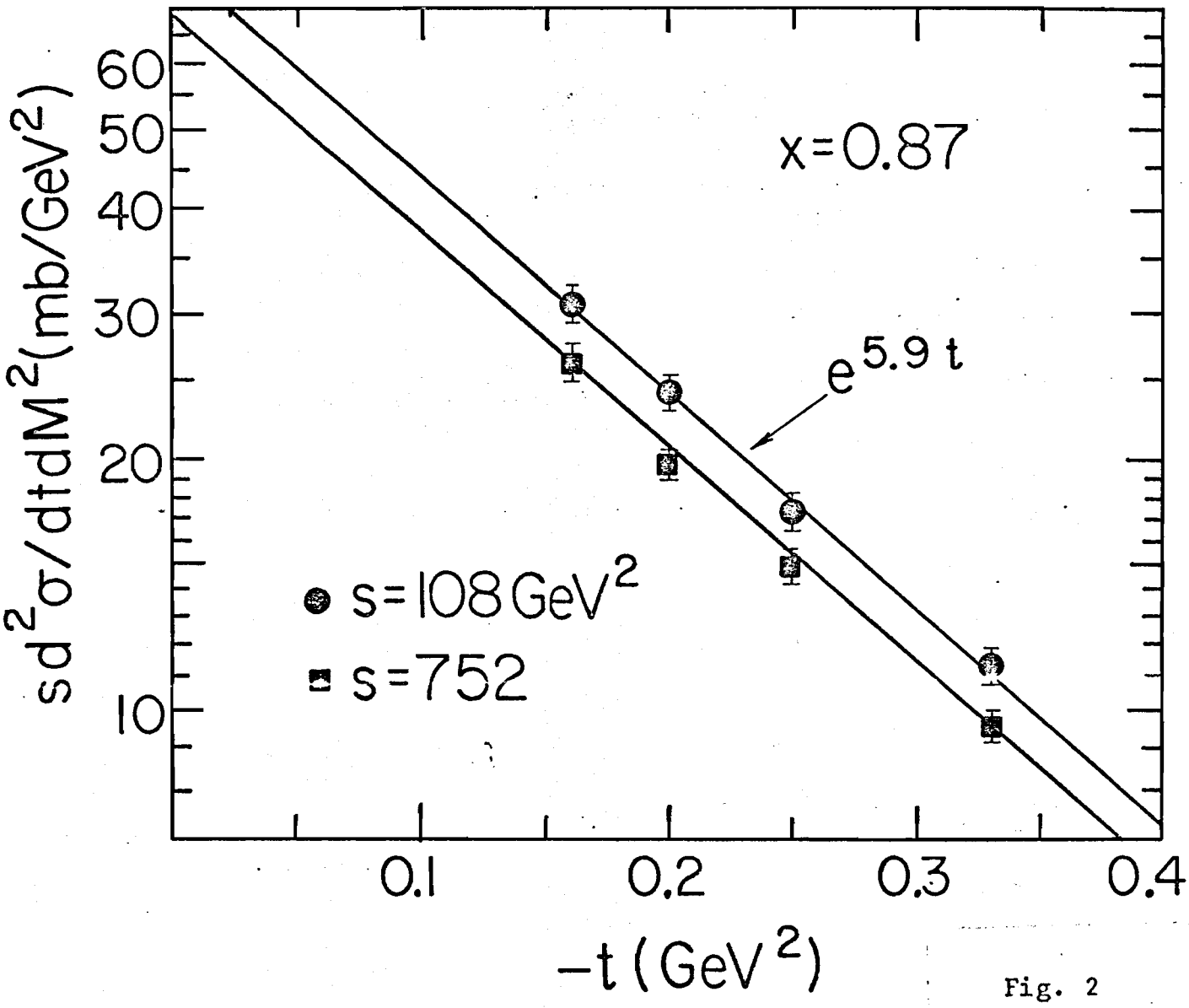
x=0.87
$e^{5.9\,t}$
s=108 GeV^2
s=752
$s\,d^2\sigma/dt\,dM^2$ (mb/GeV^2)
60
50
40
30
20
10
0.1
0.2
0.3
0.4
$-t$ (GeV^2)

Fig. 2

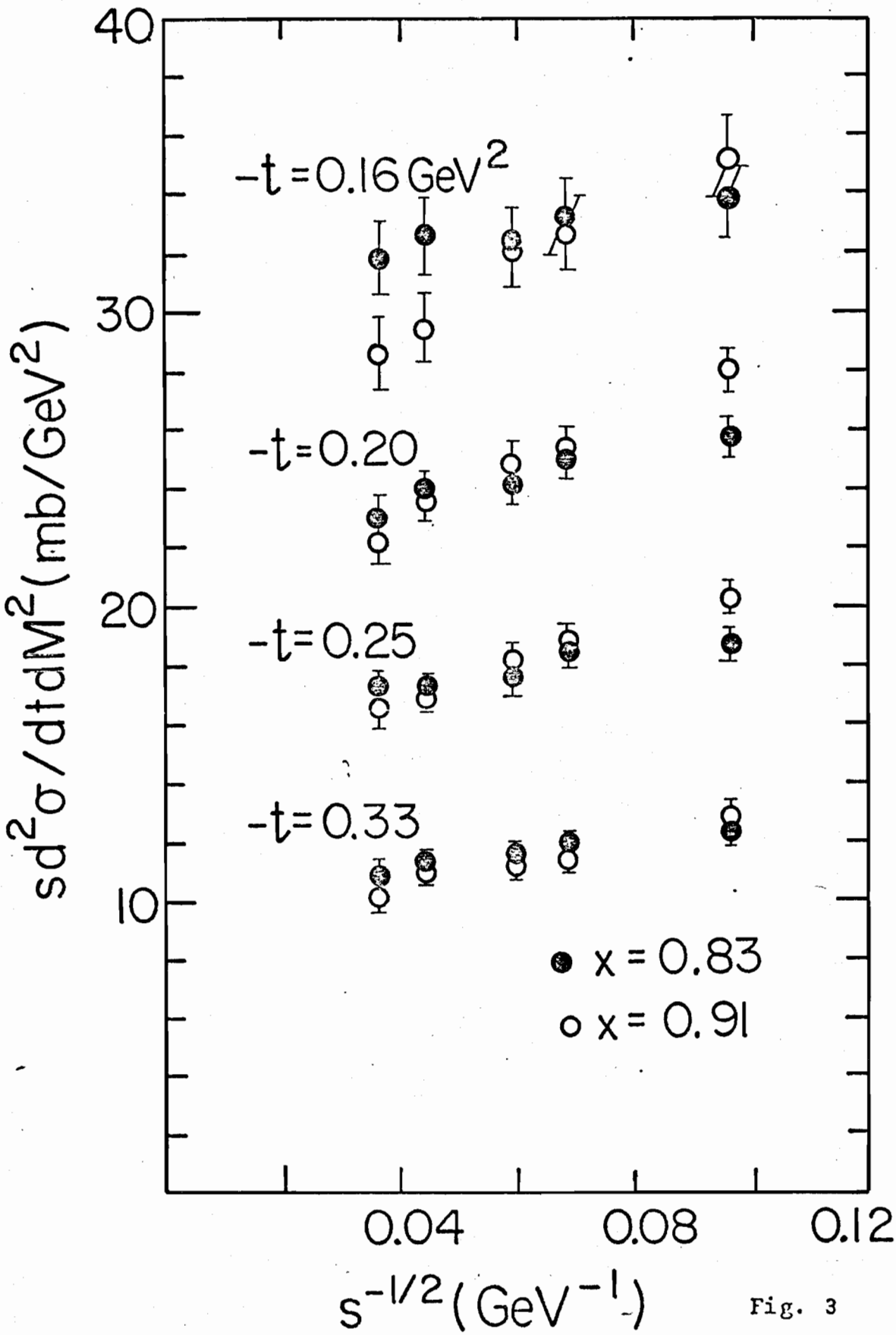
40
30
20
10
$-t = 0.16\ GeV^2$
$-t = 0.20$
$-t = 0.25$
$-t = 0.33$
$x = 0.83$
$x = 0.91$
$s d^2\sigma/dt dM^2 (mb/GeV^2)$
0.04
0.08
0.12
$s^{-1/2} (GeV^{-1})$

Fig. 3