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DIFFRACTION DISSOCIATION OF HIGH ENERGY PROTON ON HELIUM*

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Abstract

We report preliminary results from a measurement of the inclusive process $p + {}^4He \rightarrow x + {}^4He$ in the region $.04 \lesssim |t| \lesssim .5\ (GeV/c)^2$ and $Mx^2 \leqq 12. GeV^2$ for five incident proton momenta from 46 to 400 GeV/c. In this region the differential cross section $d^2\sigma/dtdMx^2$ shows a t dependence of the type $e^{b_1 t} + \alpha e^{b_2 t}$ and a dominant $1/Mx^2$ behavior for $Mx^2 > 5\ GeV^2$. The measurement was performed at Fermilab by detecting slow recoil α -particles from helium gas jet target placed at the internal beam of the accelerator.

1. Experimental method

We have measured the differential cross section $d^2\sigma/dtdMx^2$ for the inclusive reaction

$$p + {}^4He \longrightarrow X + {}^4He \qquad (1)$$

in the region $.04 \lesssim /t/ \lesssim .5\ (GeV/c)^2$ and $Mx^2 \lesssim 12\ GeV^2$ for incident proton momenta 46, 200, 260, 300 and 400 GeV/c. In the region of small /t/ and Mx^2 the reaction (1) is expected to be dominated by diffraction dissociation of the incoming proton.

The apparatus and experimental technique was similar to that described by Akimov et al./1/ Slow recoil α -particles were detected by stacks of two surface barrier silicon solid stat detectors placed on a movable carriage at a distance 7 m from the helium gas jet target near 90° to the beam. Angle and kinetic energy of recoils were measured. Since only the recoils that stop in the rear detector were used for the cross section determination, α -particles were identified unambiguously by measuring their energy loss in each detector. The resolution in Mx^2 is determined by the uncertainty in the recoil angle ~.8 mr, proton momenta ~ .1 + 6.GeV/c and t-resolution $.005\ (GeV/c)^2$ and varies from .1 to .8 GeV^2.

Monitoring was made with accuracy better than 1.5% by two stacks fixed at a small angles detecting recoils from elastic and inelastic scattering. The cross section were normalized using elastic differential cross section that is not well known yet and our normalization may containe an error of the order of 10%.

2. Preliminary results

In Fig. 1 the double cross section $d^2\sigma/dtdMx^2$ is ploted versus Mx^2 with the elastic peak for the lowest incident momentum.

Typical differential cross section for fixed t is shown in Fig. 2. These cross sections decrease constantly with Mx^2 up to 12 GeV^2 for all energies. The statisfically significant enhancements around $Mx^2 \simeq 3$ GeV^2 is observed.

The examples of the cross section behaviour as function of t for fixed Mx^2 is shown in Fig. 3. The interesting features are

1. The t-dependence is very sharp and the cross saction decreases almost 2 ÷ 3 orders of magnitude when /t/ increases one order of magnitude.

2. The kink appears in the region of /t/ ~ .15 ÷ .25 $(GeV/c)^2$ for all energies and Mx^2 accesible. There is a tendency of kink moving towards the greater /t/ with mass increasing.

3. There is no significant energy dependence in measuring Mx^2 and t intervals.

We have fitted the differential cross section using one exponential function

$$\frac{d^2\sigma}{dt\,dM_x^2}(t) = a \exp\left(-b|t| + ct^2\right) \qquad (2)$$

and two exponential functions

$$\frac{d^2\sigma}{dt\,dM_x^2}(t) = A_1 \exp\left[-b_1(|t|-.1)\right] + A_2 \exp\left[-b_2(|t|-.3)\right] \qquad (3)$$

Only formula (3) fits the data with satisfactory χ^2 which supports the presence of kink in the cross section t dependence.

The mass dependence of parameter b_1 [illegible] found in the fit by (3) is shown in Fig. 4 for different incident momenta. There is some structure of mass dependence of b_1 around $Mx^2 \simeq 1.8$ GeV^2 at 46 GeV/c. May be there is an indication of an other structure in the region of $Mx^2 \sim 3$ GeV^2. Possibly they reflect the well known phenomena in the cross section: Deck. effect and 1680 isobara.

Parameter b_1 descreases from $\sim$ 50 $(GeV/c)^{-2}$ at $Mx^2 \sim 2 GeV^2$ to $\sim$ 32 $(GeV/c)^{-2}$ at $Mx^2 \gtrsim 5\ GeV^2$ and remains constant and independent on incident momentum within errors. Similarly parameter b_2 decreases from $\sim$ 10 to 5 $(GeV/c)^{-2}$ and rests constant for $Mx^2 \gtrsim 5\ GeV^2$. The average values of parameters over all energies and $5 < Mx^2 \lesssim 12\ GeV^2$ are

$$\langle b_1 \rangle = (32.6+.3)\ (GeV/c)^{-2} \text{ and } \langle b_2 \rangle = (5.0 \pm .3)\ (GeV/c)^{-2}.$$

For one experimental fit in $p + d \to x + d$ Akimov et al /2/ found $\langle b_{pd} \rangle = (32.9 \pm .3)\ (GeV/c)^{-2}$ in the range of Mx^2 $5 \div 40\ GeV^2$.

Our results for mass dependence of b_1 agree with the recent CERN results of Ekelöf et al /3/ from reaction $p + {}^4He \to p\pi^+\pi^-\ {}^4He$ at 18.6 GeV/c. They found that the slope in one experimental fit decreases from 70 $(GeV/c)^{-2}$ at $M_{(p\pi^+\pi^-)} \simeq 1.4$ GeV to 35 $(GeV/c)^{-2}$ at $M_{(p\pi^+\pi^-)} \simeq 2$ GeV.

Supposing a dominant contribution of three pomeron exchange in the diffraction dissociation beyond resonance region one gets the cross section decreasing as $1/Mx^2$ at t fixed. For $Mx^2 > 5\ GeV^2$ the cross was fitted as

$$\frac{d^2\sigma}{dt\,dM_x^2}(M_x^2) = A/(M_x^2)^{\alpha} \qquad (4)$$

where A and α are parameters to be fitted. The values of α from fit over all energies and t ranges are ploted in Fig. 5. Our data prouve that parameter α is statisfically consistent with 1 and does not depends on t and energy in the investigated ranges.

If the cross section at Mx^2 fixed is divided by the 4 form factor the kink transforms into minimum in the same region of $/t/ \sim .15(\mathrm{GeV}/c)^2$ which slightly moves towards the larger /t/ with the mass increasing. It is illustrated in Fig. 6.

FIGURE CAPTIONS

Fig. 1. Differential cross section $d^2\sigma/dtdMx^2$ ($p + {}^4He \rightarrow X + {}^4H$ versus Mx^2 at fixed /t/ (p_{lab} = 46 GeV/c).

Fig. 2. Differential cross section $d^2\sigma/dtdMx^2$ versus Mx^2 at $.045 \leq /t/ \leq .050$ $(GeV/c)^2$ and incident momenta 200, 260, 300 and 400 GeV/c.

Fig. 3. t dependence of $d^2\sigma/dtdMx^2$ for different ranges of Mx^2 (p_{lab} = 300 GeV/c).

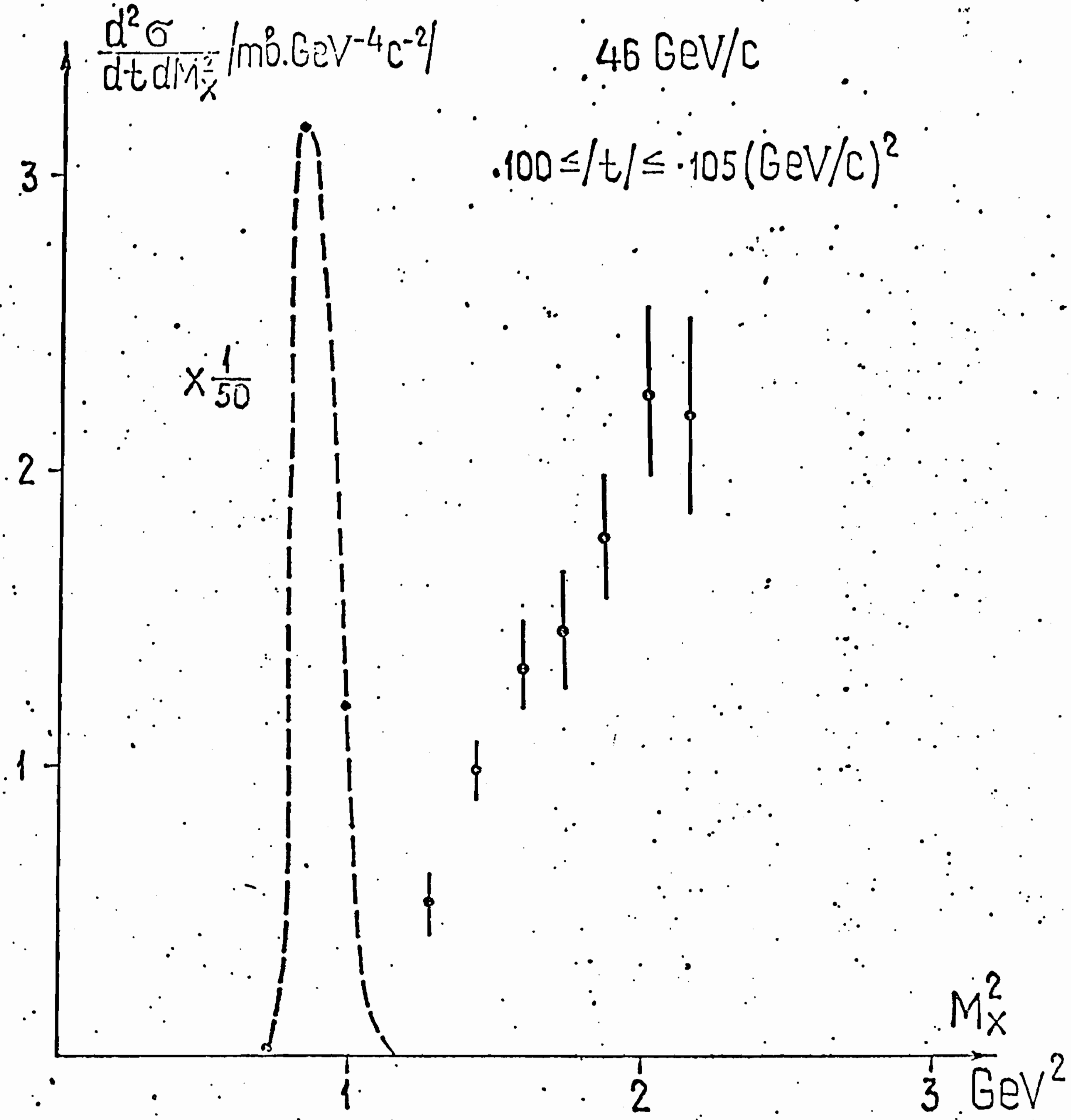
Fig. 4. Mass dependence of parameter b_1 (formula (3)) for different incident momenta.

Fig. 5. Mass dependence of parameter α (formula (4)) for different incident momenta.

Fig. 6. Differential cross section $d^2\sigma/dtdMx^2$ divided by ${}^4He$ form factor $F_{He}(t)$ versus t for different mass ranges.

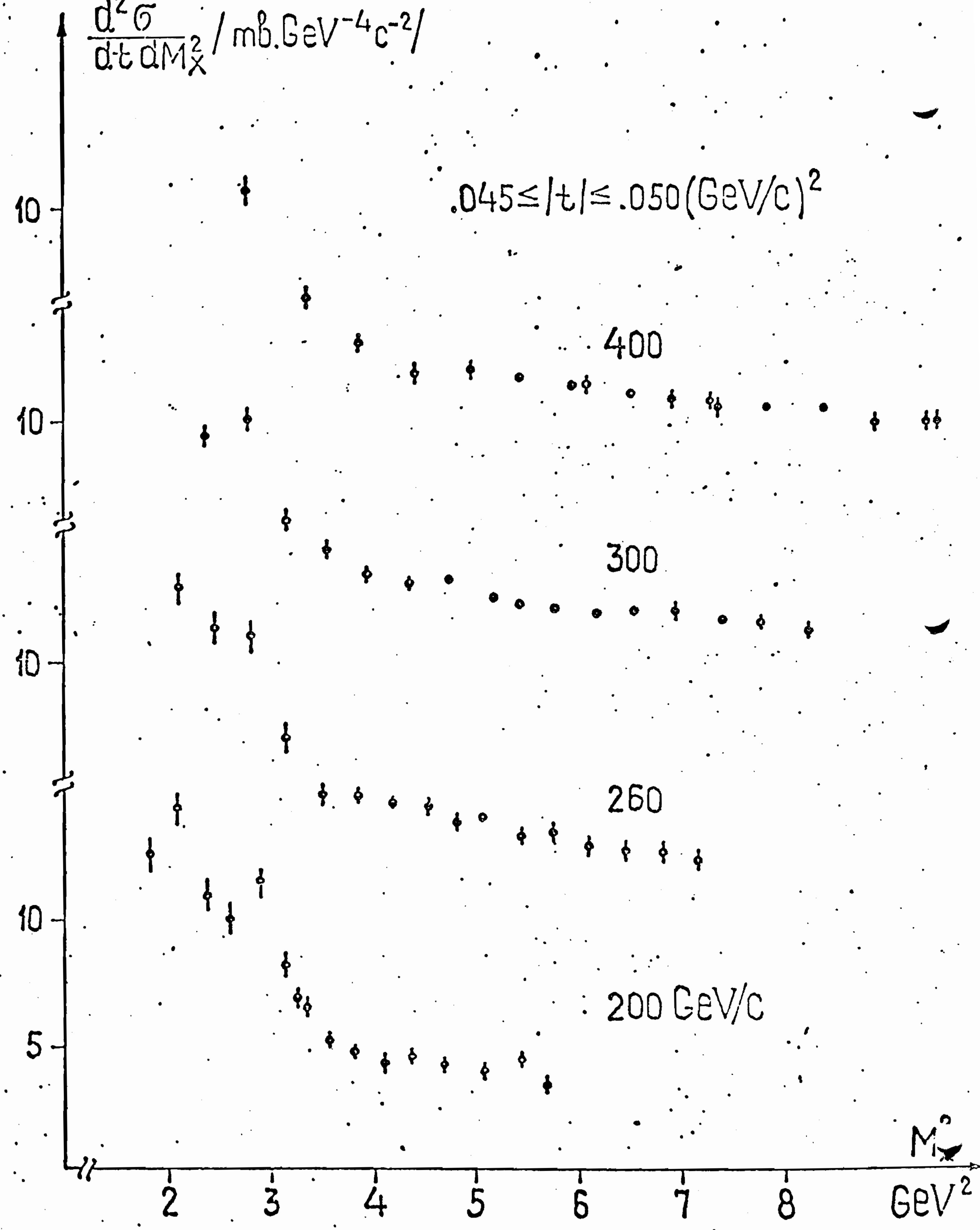
References

1. Y.Akimov et al., Phys. Rev. D 12, 3399 (1975).
2. Y.Akimov et al., Preprint Fermilab 75/26, 1975.
3. T.Ekelöf et al., Nucl. Phys. B132, 212 (1978).



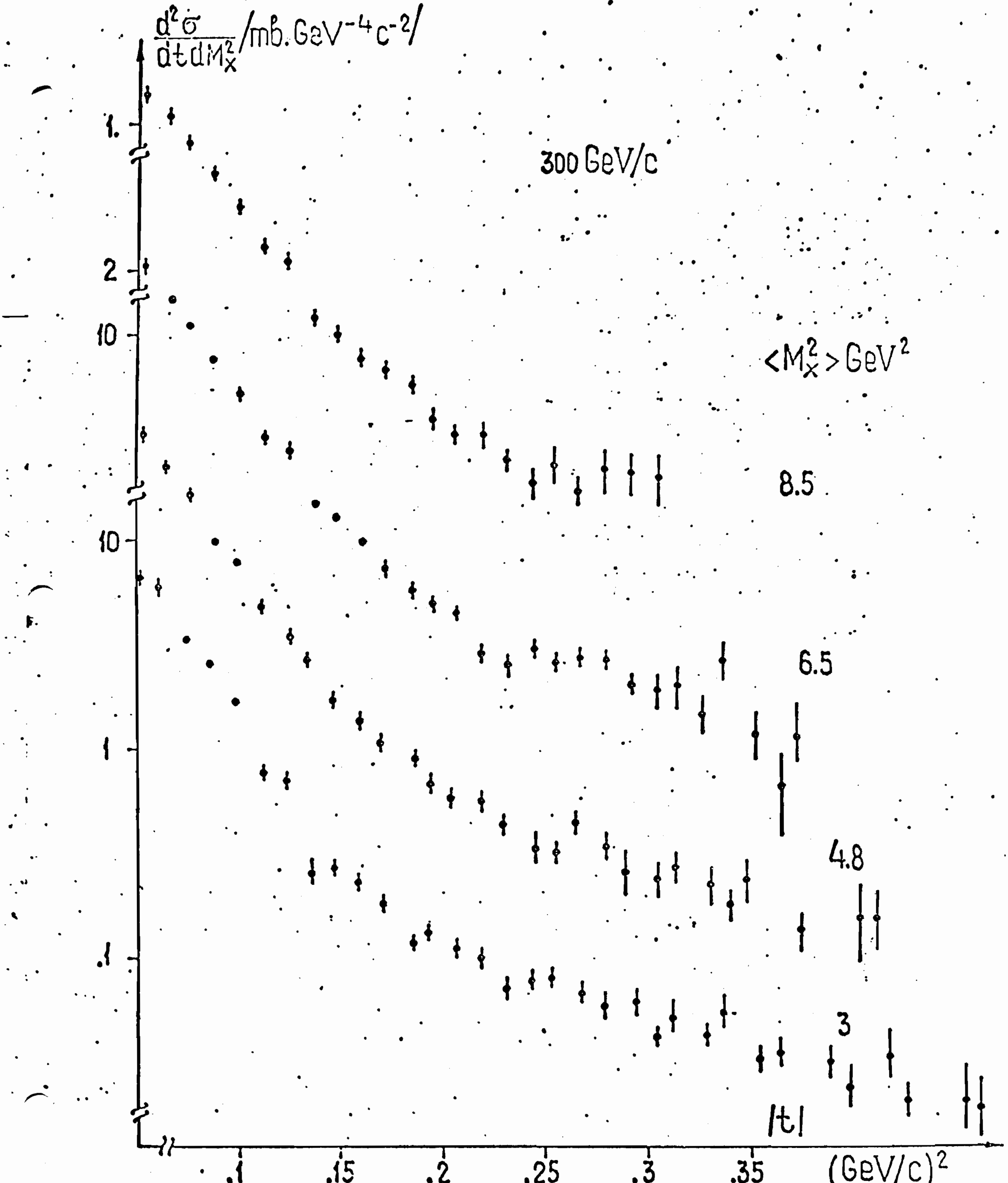
d²σ/dtdM²x /mb.GeV⁻⁴c⁻²/
46 GeV/c
.100 ≤ /t/ ≤ .105 (GeV/c)²
X 1/50
3
2
1
M²x
1
2
3 GeV²

FIG.1



d²σ/dt dM²x /mb.GeV⁻⁴c⁻²/
.045≤|t|≤.050(GeV/c)²
10
10
10
10
5
400
300
260
200 GeV/c
M²x
2
3
4
5
6
7
8
GeV²

FIG. 2



$\frac{d^2\sigma}{dt\,dM_x^2}$ /mb.GeV^{-4}c^{-2}/
1.
2
10
10
1
.1
300 GeV/c
$<M_x^2>$ GeV^2
8.5
6.5
4.8
3
/t/
.1
.15
.2
.25
.3
.35
(GeV/c)^2

FIG. 3

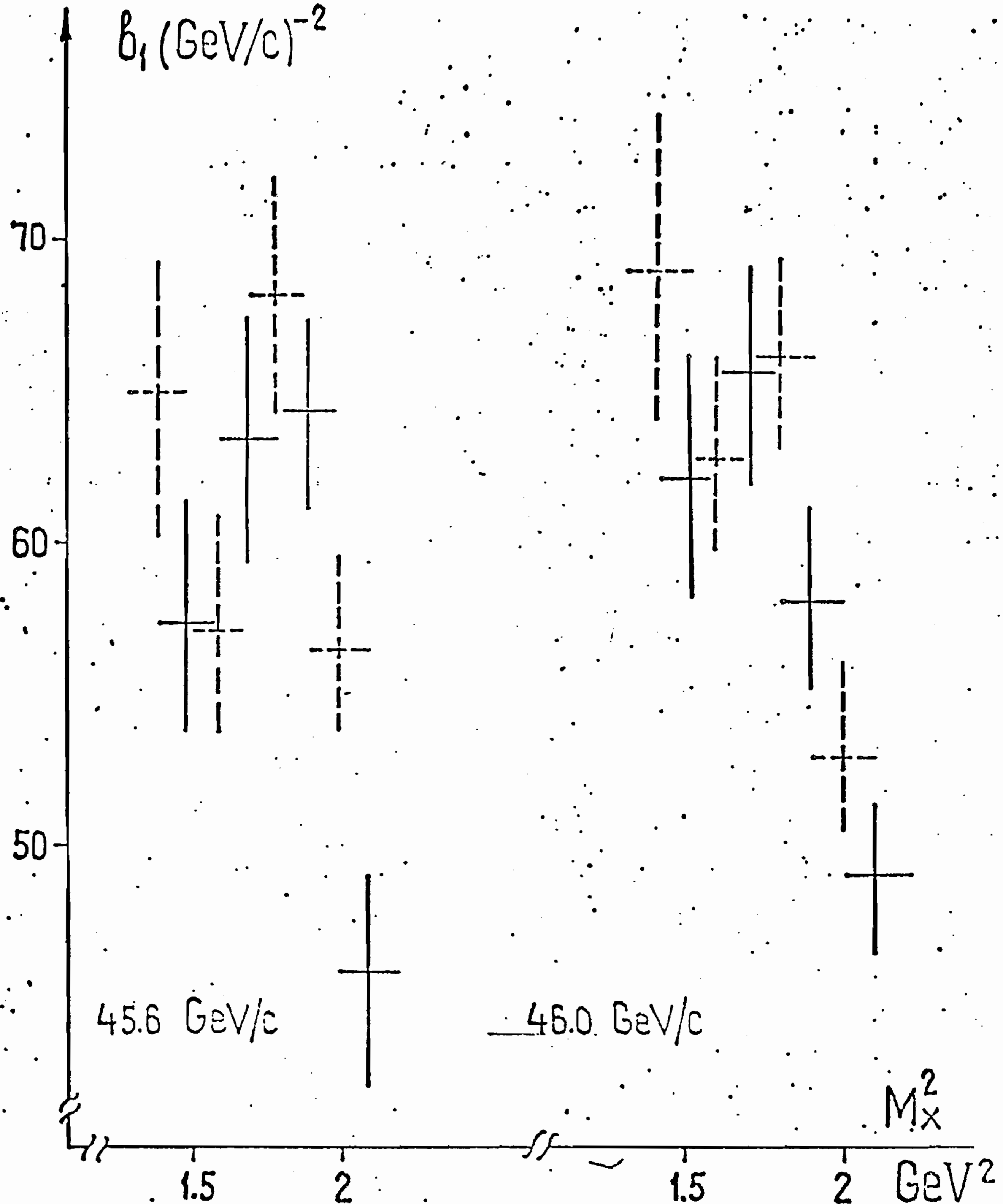


FIG. 4a

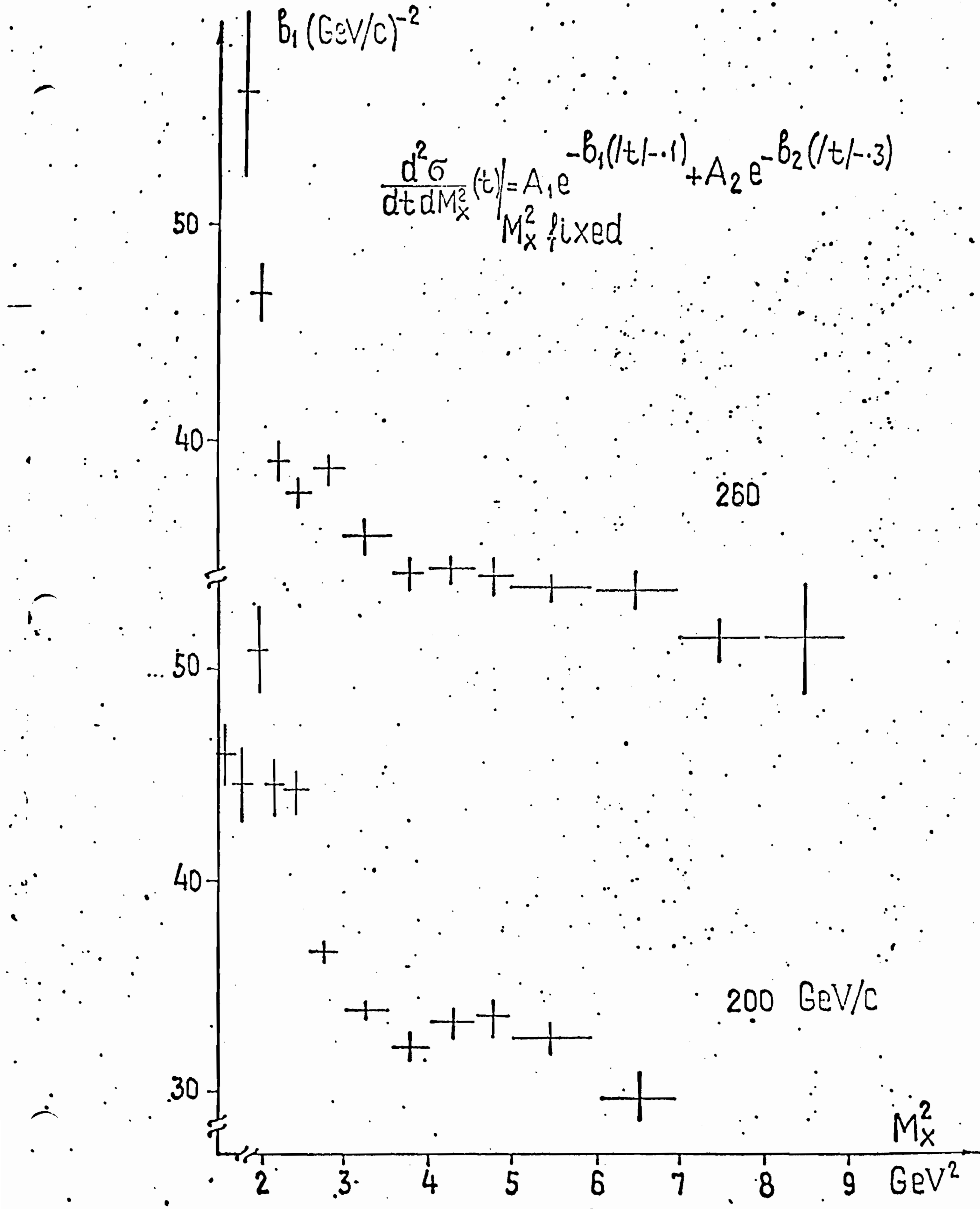
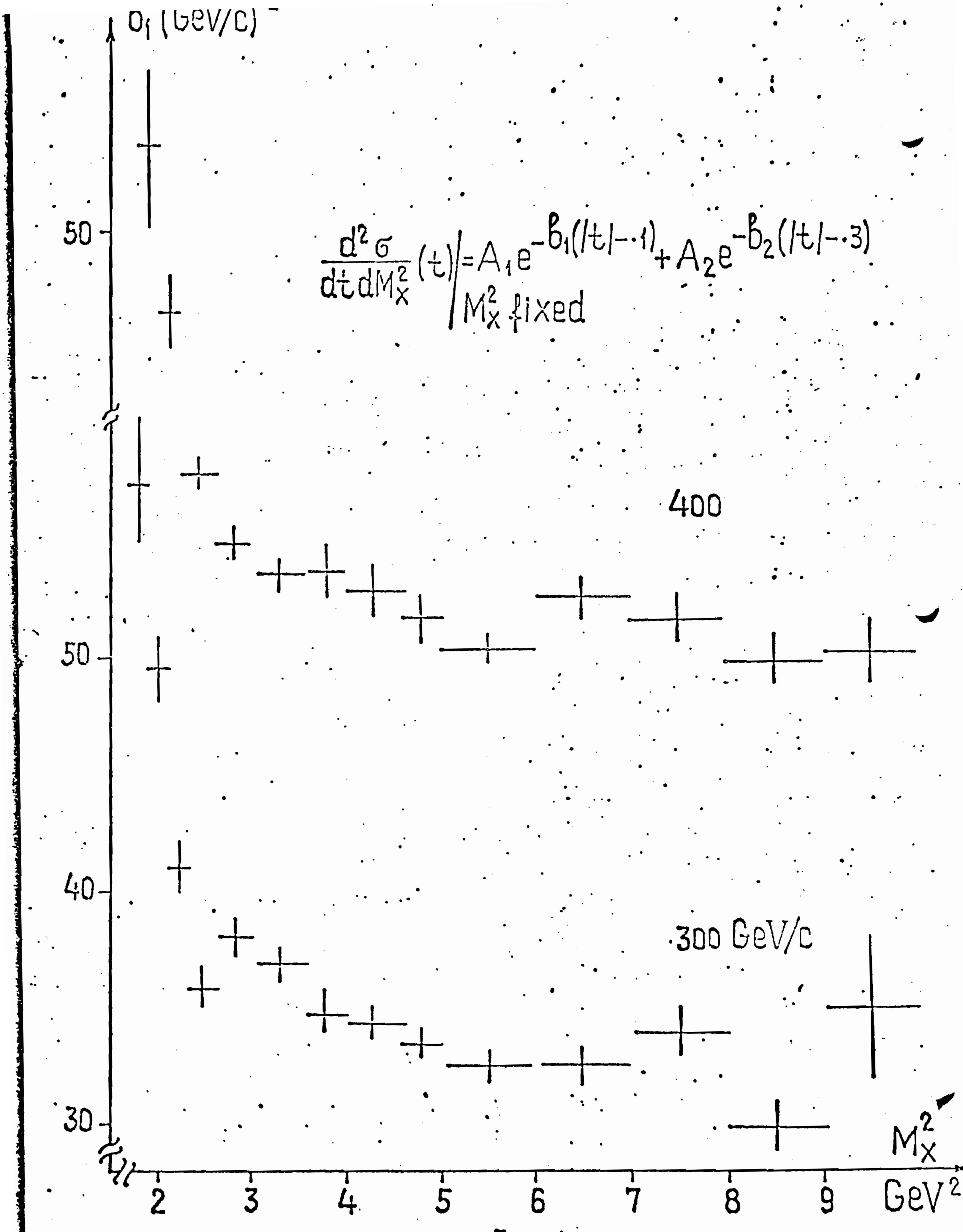
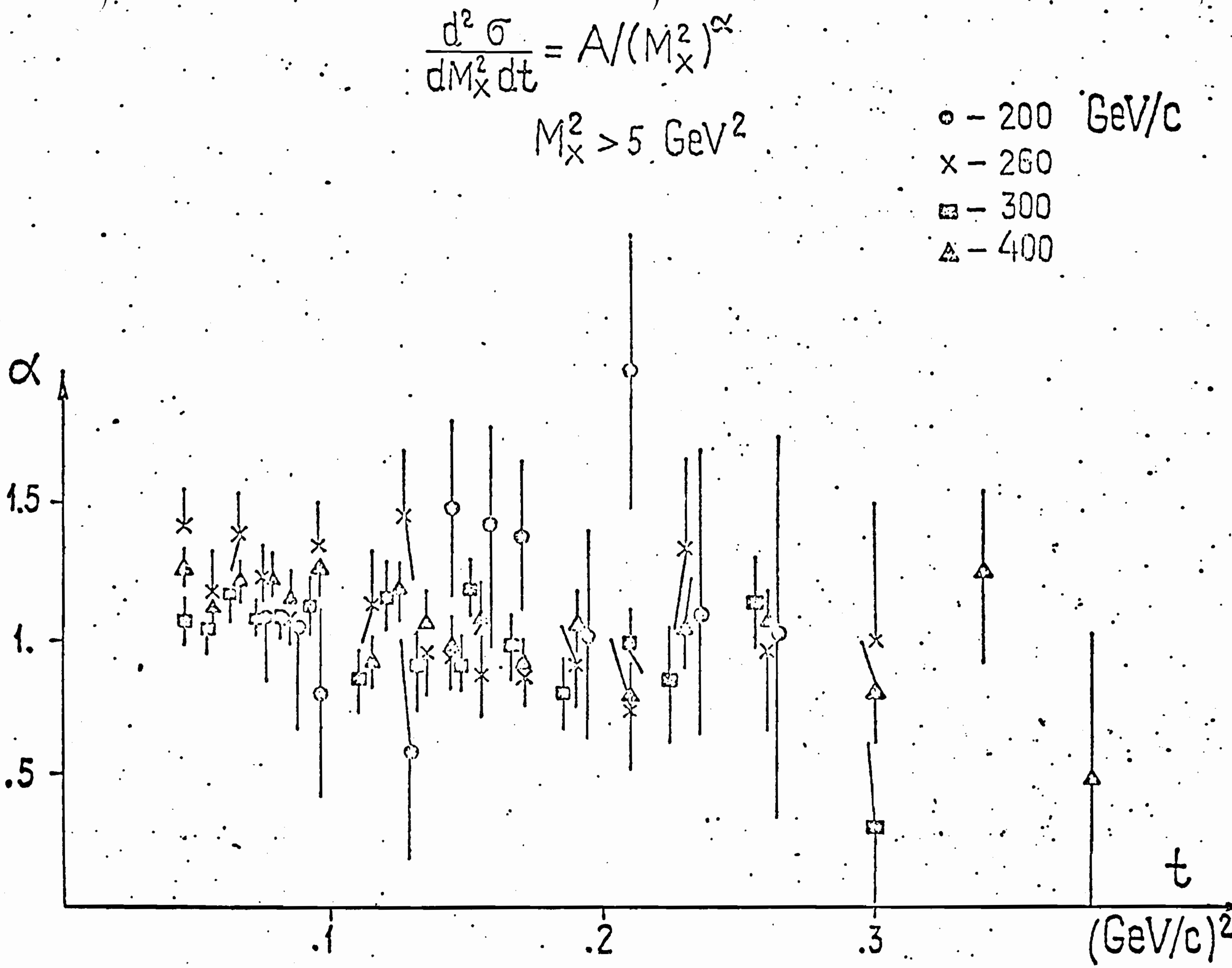

$b_1\ (GeV/c)^{-2}$
$\frac{d^2\sigma}{dt\,dM_x^2}(t)\Big|_{M_x^2\ \text{fixed}} = A_1 e^{-b_1(|t|-.1)} + A_2 e^{-b_2(|t|-.3)}$
50
40
260
50
40
200 GeV/c
30
M_x^2
2 3 4 5 6 7 8 9 GeV^2

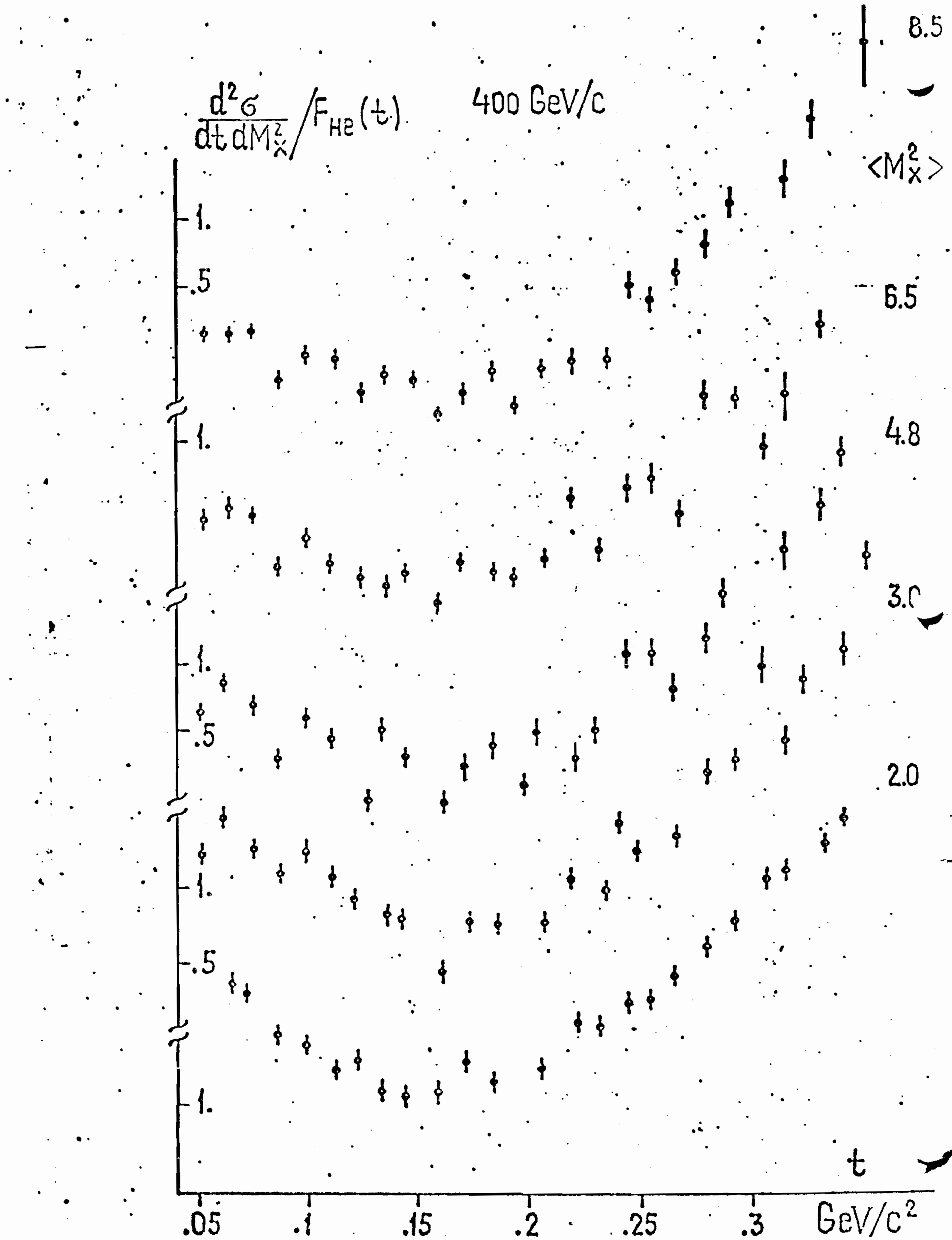
FIG. 4B


b_1 (GeV/c)$^{-2}$
$\frac{d^2\sigma}{dt\,dM_x^2}(t)\Big|_{M_x^2 \text{ fixed}} = A_1 e^{-b_1(|t|-.1)} + A_2 e^{-b_2(|t|-.3)}$
400
300 GeV/c
50
50
40
30
M_x^2
2
3
4
5
6
7
8
9
GeV^2



$\frac{d^2\sigma}{dM_X^2\,dt} = A/(M_X^2)^{\alpha}$
$M_X^2 > 5$ GeV^2
o – 200 GeV/c
x – 260
□ – 300
△ – 400
α
1.5
1.
.5
t
.1
.2
.3
$(GeV/c)^2$

FIG. 5



$\frac{d^2\sigma}{dt\,dM_X^2}/F_{He}(t)$
400 GeV/c
8.5
$\langle M_X^2 \rangle$
6.5
4.8
3.0
2.0
1.
.5
.05
.1
.15
.2
.25
.3
t
GeV/c²

Fig. 6