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ABSTRACT

Differential cross sections $d^2\sigma/dtdM_X^2$ are presented for the inclusive reaction $p + p \rightarrow p + X$ in the range $0.01 < t < 0.05$ $(GeV/c)^2$, $1.3 < m_X^2 < 3.7$ GeV^2, and incident energies from 175 to 400 GeV. The results are compared with data in the 20 GeV energy region.

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In a study[1] of large angle recoil protons from an internal hydrogen gas jet target at the National Accelerator Laboratory, we have investigated the low mass diffraction dissociation process

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

in the momentum transfer range $|t| \lesssim 0.05$ $(GeV/c)^2$ and at incident proton energies from 175 to 400 GeV. Using the missing mass technique,

$$M_X{}^2 = (q_1 + q_2 - q_3)^2 \qquad (2)$$

where q denotes the four-momentum, and normalizing to elastic scattering, we have obtained absolute differential production cross sections for masses $M_X \lesssim 2$ GeV at various energy and momentum transfer values (s,t) within our range.

The experimental arrangement, designed primarily for the study of small angle p-p elastic scattering, was described in Ref. 1. A hydrogen gas jet target was pulsed to intercept the internal beam at predetermined times during the acceleration cycle, thus selecting the desired beam energies. Recoil protons from beam-jet interactions were detected by a set of Si(Li) solid state detectors mounted on a movable carriage at a distance of 2.5m from the target and at angles with respect to the beam near 90°. With the detectors collimated down to circular areas of 10mm in diameter and a jet FWHM of ∿12mm at the beam height, the resolution in the measurement of the recoil angle was about ±3 mrad. The protons were stopped in the detectors and their energy was determined to about ±0.05 MeV.

We have already described[1] the procedure we followed in the collection and in the initial analysis of the raw data in order to remove the background and isolate the inelastic contribution from the recoil energy spectra. The recoil-proton kinetic energy T registered by a detector placed at an angle $\theta = \pi/2-\omega$ to the beam direction is related to the four-momentum-transfer-squared by

$$|t| = 2M_pT \tag{3a}$$

where M_p is the mass of the proton, and to the missing-mass-squared by

$$M_x^2 \simeq M_p^2 + 2\, s\, \sqrt{T/2M_p}(\omega - \sqrt{T/2M_p}) \tag{3b}$$

where $s \simeq 2M_p\, p_1$ is the square of the c.m. energy. The approximation in eq. (3b) is excellent for our region of small ω and $M_x^2 << s$. The elastic scattering peak is centered at $T_{el} = 2M_p\omega^2$. As T decreases from T_{el}, M_x^2 increases until it reaches the value $(M_x^2)_{max} = M_p^2 + s\omega^2/2$ at $T_{(max)} = 1/4\ T_{el}$. A further decrease in T produces now a decrease in M_x^2, however the portion of our recoil spectra below 0.4 T_{el} will not be considered here because of the errors introduced by a large background subtraction.[1]

The counts ΔN in a given interval ΔT in the recoil energy spectrum registered by each detector were reduced to differential cross-sections using the formula

$$\frac{d^2\sigma}{dtdM_x^2} = \frac{\Delta N}{2M_p\Delta T} \cdot \frac{(d\sigma/d\Omega)el}{N_{el}} \frac{\pi}{p_o\sqrt{2M_pT}} \qquad (4)$$

where $(d\sigma/d\Omega)_{el}$ is the elastic differential cross-section at the angle $\theta = \frac{\pi}{2} - \omega$ and N_{el} is the total number of elastic events in the recoil spectrum. Using eq. (3b), a mass M_x was assigned to each given T, and the cross-sections (4) were obtained at various (M_x^2,t) bins at each of our three energies.

The results are plotted in Figure 1 in the form of histograms of $d^2\sigma/dtdM_x^2$ versus M_x^2 at fixed t. The mass resolution is mainly due to the angular spread of $\Delta\omega = \pm 3$ mrad and is given by

$$\Delta M_x^2 = 2p_1 \sqrt{|t|}\, \Delta\omega \qquad (5)$$

Thus, for $p_1 = 260$ GeV/c and $|t| = 0.025\ (\text{GeV/c})^2$, the resolution is $\Delta M_x^2 = \pm 0.25\ \text{GeV}^2$. The spread in the incident momentum is $\Delta p_1 = \pm 10$ GeV/c and contributes to the mass resolution an amount which is small compared to the amount due to the uncertainty in the angle, eq. (5). The errors attached to the data points include systematic uncertainties caused by variation in the hydrogen jet and beam conditions during the run and estimated by comparing different portions of the data at a given incident energy. The horizontal bars have been obtained from eq. (5) and are a measure of the mass resolution.

Our results in Figure 1 exhibit two striking features: (a) the cross sections at fixed t are energy independent to within about ±20% uncertainty, and (b) the data show a sharp peak at $M_x^2 \sim 1.8$ which falls very rapidly as $|t|$ increases. In order to directly compare our data with results on diffraction dissociation obtained[2,3,4] at energies below 30 GeV , we have made Breit-Wigner type fits similar to the fits performed on the data of these lower energy experiments[3,4]. For this purpose, we used our original "fixed angle" histograms, an example of which is shown in Fig. 2. In such a histogram, obtained by a detector placed at a fixed angle ω, the t-value varies with M_x^2 following eq. (3). However, it is better to perform the fits on these original histograms, since the rebinning of the data to yield values for the cross sections at fixed t causes some additional scatter of the points. In the fits, we included the N(1400), N(1520) and N(1688) isobars, but we did not include any background. The mass resolution was also taken into account. At first, we left the mass values and the widths of all isobars free and we obtained consistent results for the N(1400) with mass in the vicinity of 1350 MeV and width $\sim$165 MeV, where the spread due to the mass resolution has been unfolded. Then, to obtain a more accurate value for the cross sections, we fixed the mass (width) of the isobars at 1350(165), 1520(135), and 1688(105) MeV. The cross sections we obtained for p_0 = 175 and 260 GeV/c (the 400 GeV/c data do not extend to low enough masses to provide us with a meaningful fit for the N(1400) resonance) are plotted in

Figure 3 along with the low energy results. The solid line was obtained from a fit to our data of the form

$$d\sigma/dt = A\ e^{-b|t|} \tag{6}$$

which yielded $A = 6.60 \pm 0.45$ mb $(GeV/c)^{-2}$ and $b = 16.1 \pm 2.7$ $(GeV/c)^{-2}$. The agreement of our results with the low energy data is very good. While it is not clear whether the enhancement we observe at $M_x = 1350$ MeV is in fact due to a nucleon resonance, the constancy of its differential production cross section over the entire energy range 10-400 GeV is indeed a remarkable phenomenon, consistent with a diffraction picture for the dissociation of the incident proton.

We thank the many members of the National Accelerator Laboratory who supported our effort during the course of this experiment. We also thank Mr. Martin Lo for his assistance in computer programming. The Soviet members of the group would like, in addition, to express their deep gratitude to the State Committee for Utilization of Atomic Energy and to the Joint Institute for Nuclear Research (Dubna) for their generous assistance.

REFERENCES

1. V. Bartenev, et al, Phys. Rev. Letters 31, 1088 (1973).
2. G. Belletini, et al, Phys. Letters 18, 167 (1965).
3. R.M. Edelstein, et al, Phys. Rev D5, 1073 (1972).
4. J.V. Allaby, et al, Nucl. Phys. B52, 316 (1973). This article summarizes previous work in the subject.

FIGURE CAPTIONS

Figure 1 - Differential cross sections $d^2\sigma/dtdM_x^2$ versus M_x^2 for fixed t.

Figure 2 - Fixed angle inelastic data for p_o = 260 GeV/c and ω = 73.2mrad. The curve is a Breit-Wigner type fit.

Figure 3 - Differential cross section $d\sigma/dt$ for the bump at mass (width) = 1350(165) GeV.

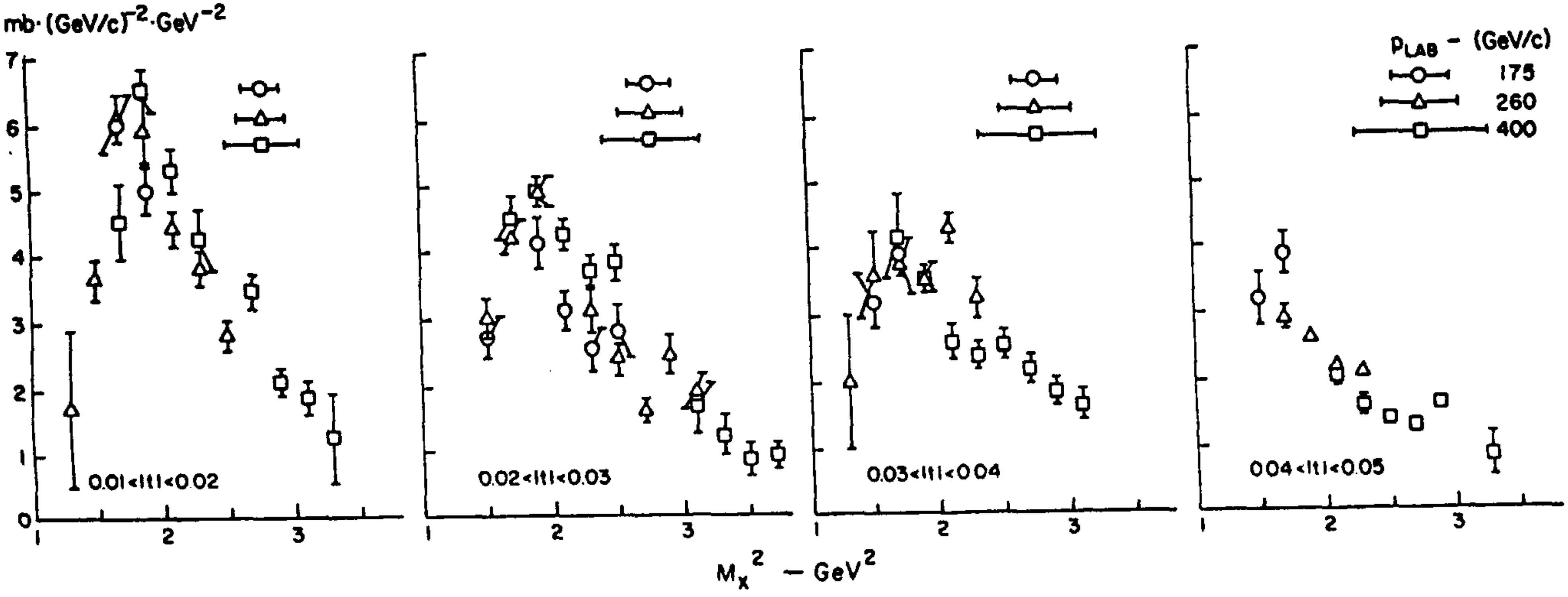

mb·(GeV/c)$^{-2}$·GeV^{-2}
0.01<|t|<0.02
0.02<|t|<0.03
0.03<|t|<0.04
0.04<|t|<0.05
p_{LAB} – (GeV/c)
175
260
400
M_x^2 – GeV^2

FIG. I

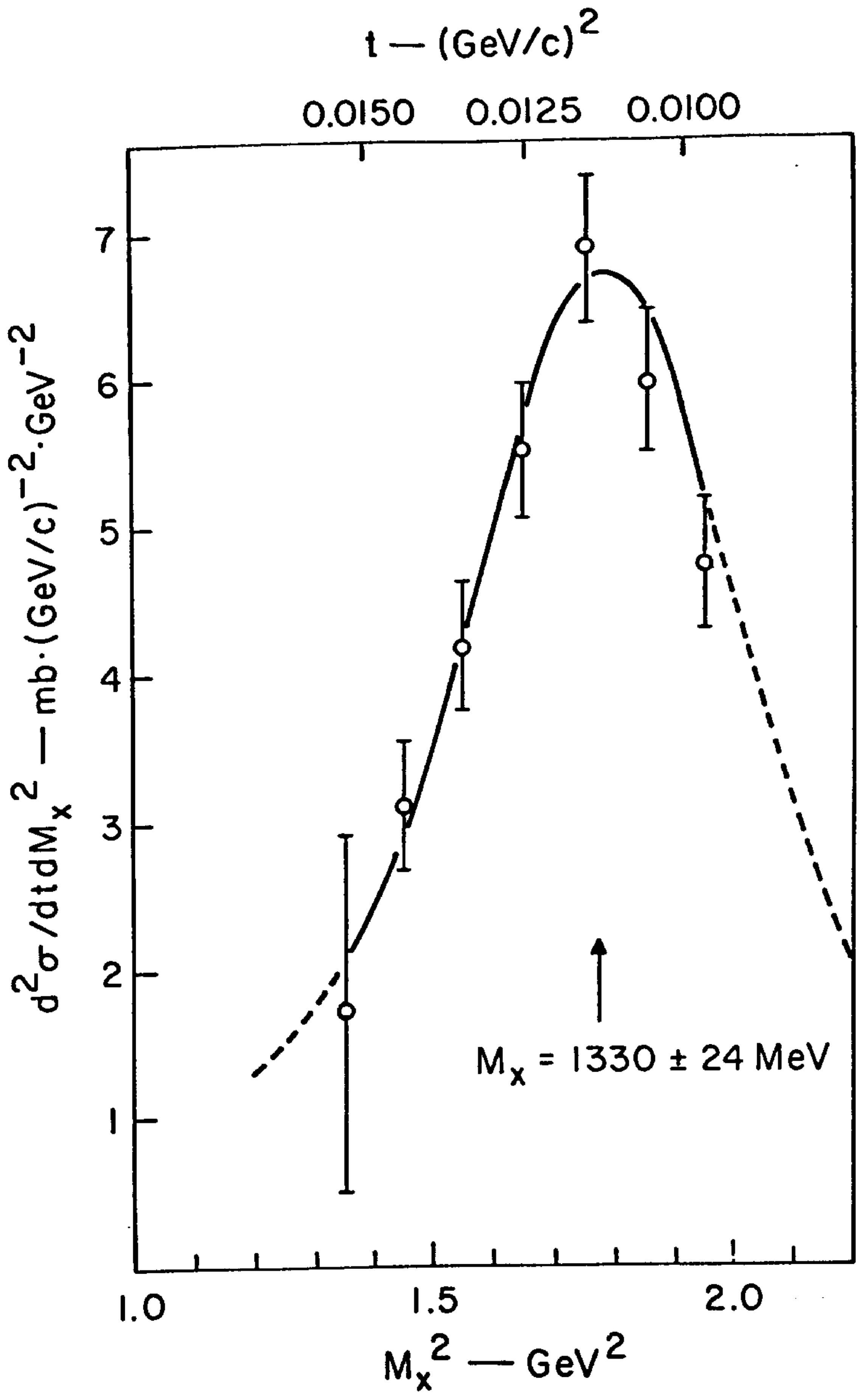
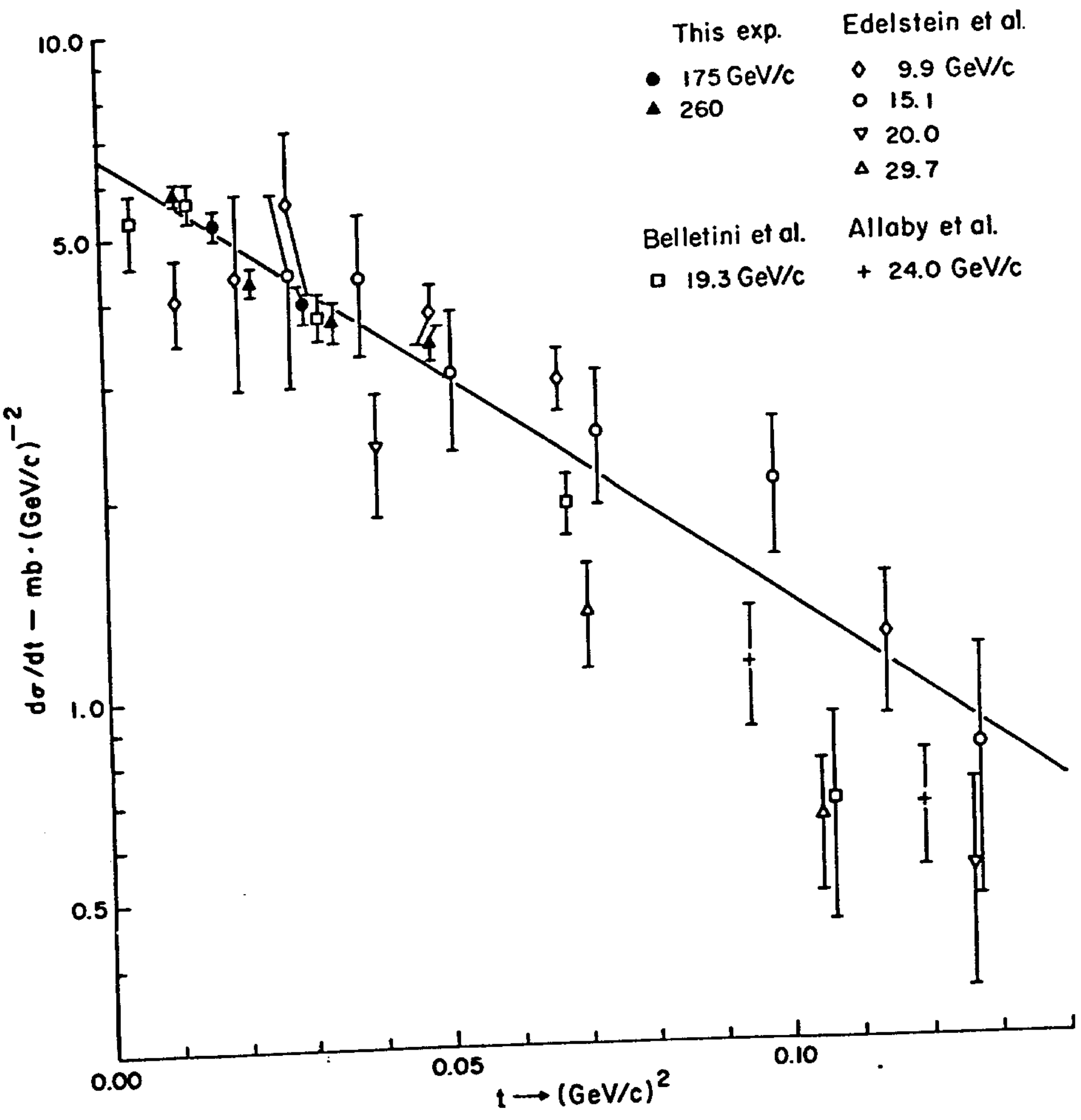

t — (GeV/c)²
0.0150
0.0125
0.0100
$d^2\sigma/dt\,dM_x^2$ — mb·(GeV/c)$^{-2}$·GeV^{-2}
7
6
5
4
3
2
1
M_x = 1330 ± 24 MeV
1.0
1.5
2.0
M_x^2 — GeV²

FIG. 2



This exp.
175 GeV/c
260
Edelstein et al.
9.9 GeV/c
15.1
20.0
29.7
Belletini et al.
19.3 GeV/c
Allaby et al.
+ 24.0 GeV/c
10.0
5.0
1.0
0.5
dσ/dt — mb · (GeV/c)^-2
0.00
0.05
0.10
t → (GeV/c)^2

FIG. 3