EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

HIGH MASS SINGLE DIFFRACTION EXCITATION IN $dp \to dX$ AT $s = 2800$ GeV^2

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Abstract

Data on $dp \to dX$ at $s = 2800$ GeV^2 are presented. The measurements were performed with a single arm magnetic spectrometer at momentum transfers t between $-.20$ and $-.35$ (GeV/c)^2 . The data are compared with proton spectra in $pp \to pX$ at the same energy for the kinematic region $M_X^2 < 360$ GeV where M_X^2 denotes the mass of the system X recoiling against the measured particle.

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Data on the inclusive reaction $dp \to dX$ at $\sqrt{s} = 52$ GeV are presented. The deuteron is detected in the kinematic region $.85 < x < 1.0$ and $-.4 < t < -.2$ $(GeV/c)^2$ where x is the Feynman variable ($x = \frac{2p_L}{\sqrt{s}}$) and t is the square of the four momentum transfer between the initial and final state deuterons.

The data were taken with a magnetic spectrometer consisting of one magnet, 14 planes of magnetostrictive spark chambers and 4 trigger counters. The spectrometer was placed downstream of the intersection region, under the circulating deuteron beam in Intersection 2 of the CERN ISR. The mean angle which the spectrometer accepted could be varied from 15 to 90 mrad with respect to the primary beam (Fig. 1). The momentum resolution of the spectrometer was $\frac{\Delta p}{p} \sim 3\%$ (FWHM). For the data presented here the spectrometer was set to accept particles produced between 15 and 25 mrad and with a momentum greater than $\sim$ 10 GeV/c. Furthermore the intersection region was surrounded by hodoscopes consisting in total of 186 scintillation counters covering 95% of the full solid angle, one of which was positioned directly opposite the spectrometer and had a fine angular binning ($\Delta\theta \sim 12$ mrad). A second spectrometer (described in ref. 5), situated above ring 1, was briefly used for a calibration run, described below. The relevant part of this spectrometer was an ethylene Cerenkov which could be pressurised to 30 atmospheres, and used for deuteron-proton separation.

The main aim of this experiment was to obtain a more accurate measurement of the Pomeron (diffractive) contribution to high-x inelastic scattering at ISR energies. One well known theoretical model used in the analysis of high x scattering is the Triple-Regge model. This relates the contribution of the exchange of a given Reggeon R_i in the quasi-two-body process

$$ab \to cX$$

(see Fig. 2a)), to a Triple-Reggeon coupling diagram (see Fig. 2b)) via the generalised optical theorem[1]. If the $ab \to cX$ is diffractive i.e. a and c have identical quantum numbers then R_i can be equated to the

Pomeron. Many measurements of the process pp → pX have been performed and attempts to fit these have been made using the Triple-Regge picture. Since the proton may also be produced non-diffractively a complete fit must take into account all possible $(R_i R_j R_K)$-couplings. A typical fit is shown in Fig. 3 from T. Inami and R.G. Roberts[2]. One sees that the most significant non-PPP background is a term classified as 'π exchange'. If this picture holds then in dp scattering the 'π exchange' term should vanish because of Isospin conservation. Thus in dp scattering the non-PPP background should be smaller and should yield a cleaner diffractive signal.

Fig. 4 shows the observed momentum spectrum integrated over the angular range of the spectrometer and not corrected for its momentum acceptance. One sees two clear peaks one centered at the momentum of the primary beam (coherently scattered deuterons), the second centered around half the primary beam momentum. The second peak consists of protons from scattering processes in which the deuteron has broken up. The detected proton is either a spectator from a proton-neutron scattering event or a product of a proton-proton scattering event. The two processes can be written as

$$pn(p_s) \rightarrow X(p_{s,d})$$

$$pp(n_s) \rightarrow Xp_d(n_s)$$

(subscripts s-spectator, d-detected).
The recoil proton can occur with a momentum in the deuteron region due to the effect of Fermi motion of the target nucleons. The transverse component of this momentum enables spectator protons to leave the ISR vacuum chamber and to be detected in the spectrometer. The absence of any deuteron identification in the spectrometer makes it essential to estimate the contamination of break up protons with $x > .85$. In the frame work of the spectator model the shape of the scattered proton spectrum was calculated, via the Monte Carlo method for the two different channels:

$$pp(n_s) \rightarrow pp_d(n_s) \qquad (1)$$

$$pn(p_s) \rightarrow p_{s,d}X \qquad (2)$$

The Fermi momentum distribution in the deuteron was obtained from the Hamada-Johnston[3] wave function in the parametrization of Mc Gee[4]. In both cases the detected proton was restricted to be produced within the angular range of the spectrometer. Fig. 5a) shows the momentum spectrum calculated for process (1); it is compared with the data for elastic events with spectrometer momentum less than 23 GeV/c. The criterion for an elastic event is that only one particle is detected (apart from the spectrometer particle), and is the near collinear direction. The two spectra are normalised to one another at $\sim$ 14.5 GeV/c and show good agreement on the high side of the peak. The slight discrepancy on the low momentum side is due to the falling acceptance, which has not been taken out of the data.

The spectra from process (2) can also be compared and this is shown in Fig.5b) Again the spectra are normalised to one another at $\sim$ 14.5 GeV/c and again good agreement exists on the high side of the peak. For both cases one finds that above 23 GeV/c, corresponding to a deuteron x = 0.85, there is a negligible amount of proton contamination. There is of course the possibility that the spectator proton momentum distribution is distorted by final state interactions, leading to an exaggerated Fermi momentum tail. Evidence against this possibility was obtained from the second spectrometer situated in Intersection 2. Data were taken using this spectrometer during a period when deuterons were circulating in both ISR beams. The reaction

$$dd \rightarrow cX$$

(where c represents a positively charged particle) was studied at a mean production angle of 40 mrad. The ethylene Cerenkov was set to a

pressure of 5 atmospheres, so that protons and deuterons could be distinguished by pulse height measurements above 10 GeVc. The momentum spectrum of protons and deuterons identified in this way is shown in Fig.6. The contamination of protons above 22 GeV/c is seen to be negligible.

Fig. 7 shows the differential elastic cross-section versus t, as measured in this experiment, for deuteron-proton and proton-proton scattering. In Fig. 8 we present the invariant inelastic differential cross-section for the reaction dp $\rightarrow$dX versus the mass squared of X at three fixed values of t. For comparison we also plot the spectrum versus M_x^2 at the same values of t for the reaction pp $\rightarrow$ pX scaled down by the measured ratio of the differential elastic cross-sections for the two reactions. All errors are purely statistical. Analysis is still in progress especially concerning systematic errors. But even though the absolute normalisation may be incorrect the internal relative normalisation is believed to be very good.

The striking feature of this graph is the resemblance between the proton-proton and proton-deuteron spectra over the whole M_x^2 range. this is not a priori expected, as discussed above. It thus casts some doubts on the Triple Regge analysis which has been performed so far and may indicate that also the assumed non-diffractive background in high x p-p interactions is dominated by Isospin zero exchanges.

References

1. A.H. Mueller, Phys. Rev. D2 2963 (1970).

2. T. Inami, R.G. Roberts, RL-75-025.

3. T. Hamada, I.D. Johnston, Nucl. Phys. 34 (1962) 382.

4. I.J. McGee, Phys. Rev. 151 (1966) 772.

5. M.G. Albrow et al., Phys. Letters 42B (1972) 279.

Figure captions

Fig. 1 Schematic drawing of the magnetic spectrometer and scintillation counter hodoscopes.

Fig. 2a) Diagram of the quasi-two-body process $ab \to cX$.

2b) The associated Triple Regge diagram.

Fig. 3 Fit to inelastic proton spectrum at $s = 551$ and $t = -.15$ performed by T. Inami and R.G. Roberts.

Fig. 4 Observed momentum spectrum integrated over the angular range of the spectrometer not corrected for momentum acceptance.

Fig. 5a) Calculated momentum distribution for the reaction $pp(n_s) \to pp_d(n_s)$ compared with elastic data. The two spectra are normalised so as to coincide 14,5 GeV/c.

5b) Comaprison between calculated spectrum for the reaction $pn(p_s) \to (p_{s,d})X$ and data. (Again normalised at 14,5 GeV/c).

Fig. 6 Spectrum obtained from the reaction $dd \to cX$. The positively charged particle c was identified as indicated, using pulse height information from an ethylene Cerenkov counter.

Fig. 7 Differential elastic cross-section versus t for the reactions

● : $dp \to dp$

O : $pp \to pp$.

Fig. 8 Inelastic invariant differential cross-section versus M_x^2 at

a) $t = -.22$ $(GeV/c)^2$

b) $t = -.26$ $(GeV/c)^2$

c) $t = -.30$ $(GeV/c)^2$.

● $pp \to pX$

O $pd \to dX$

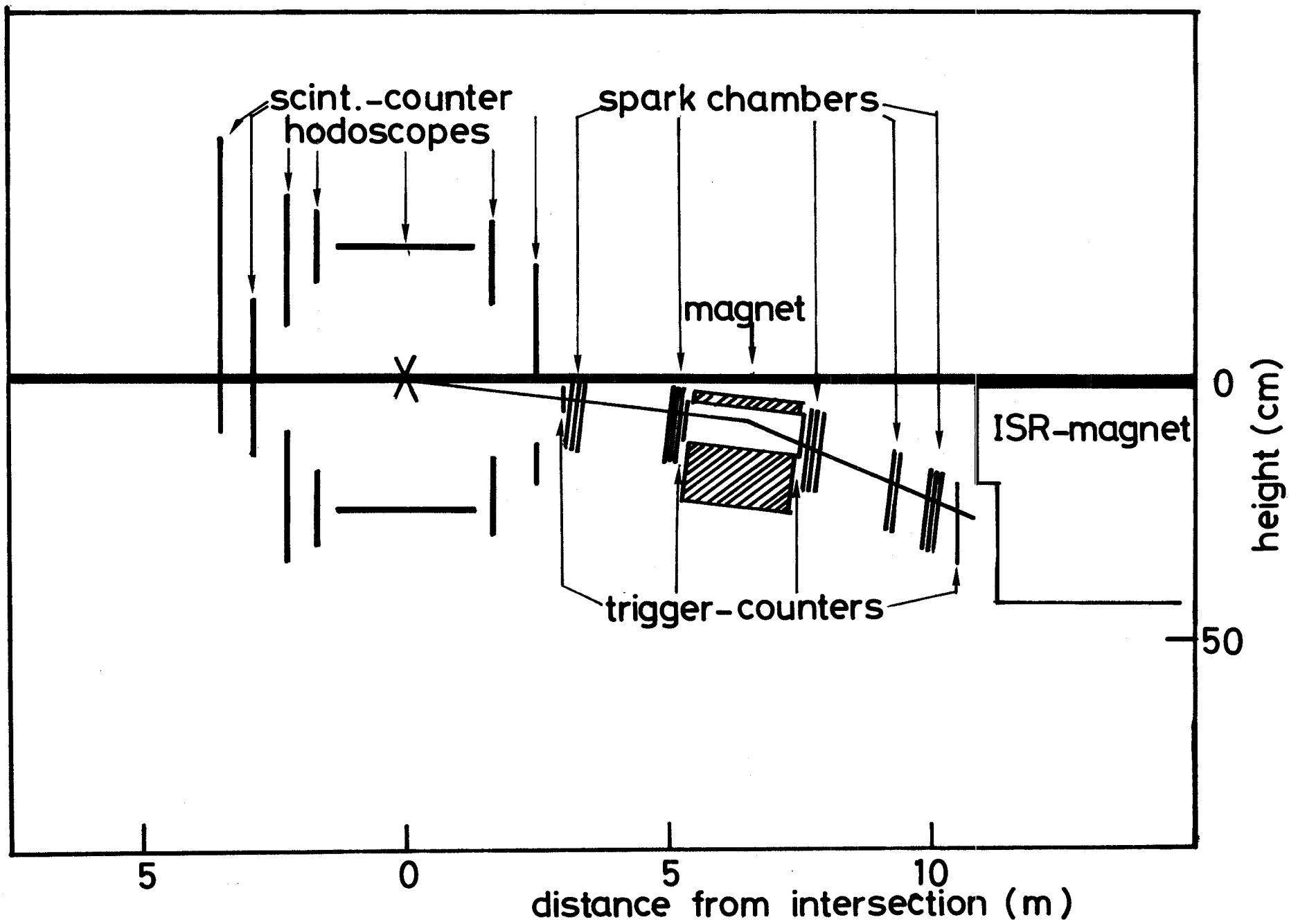

scint.-counter
hodoscopes
spark chambers
magnet
ISR-magnet
trigger-counters
0
50
height (cm)
5
0
5
10
distance from intersection (m)

Fig.1

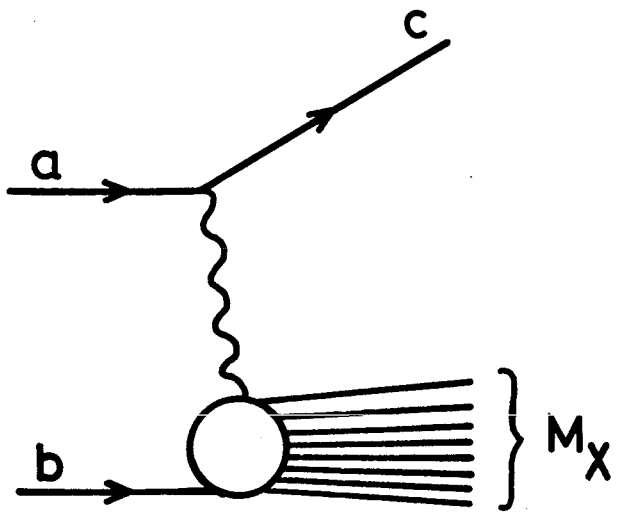


Fig.2a)

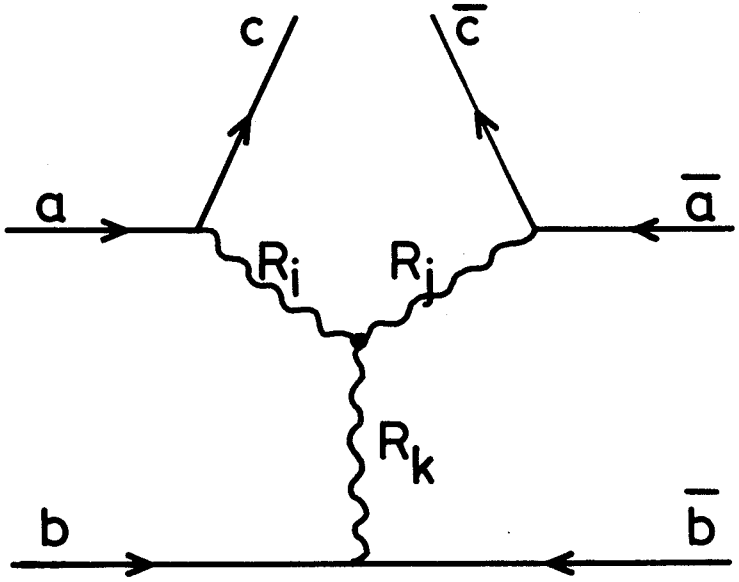


Fig.2b)

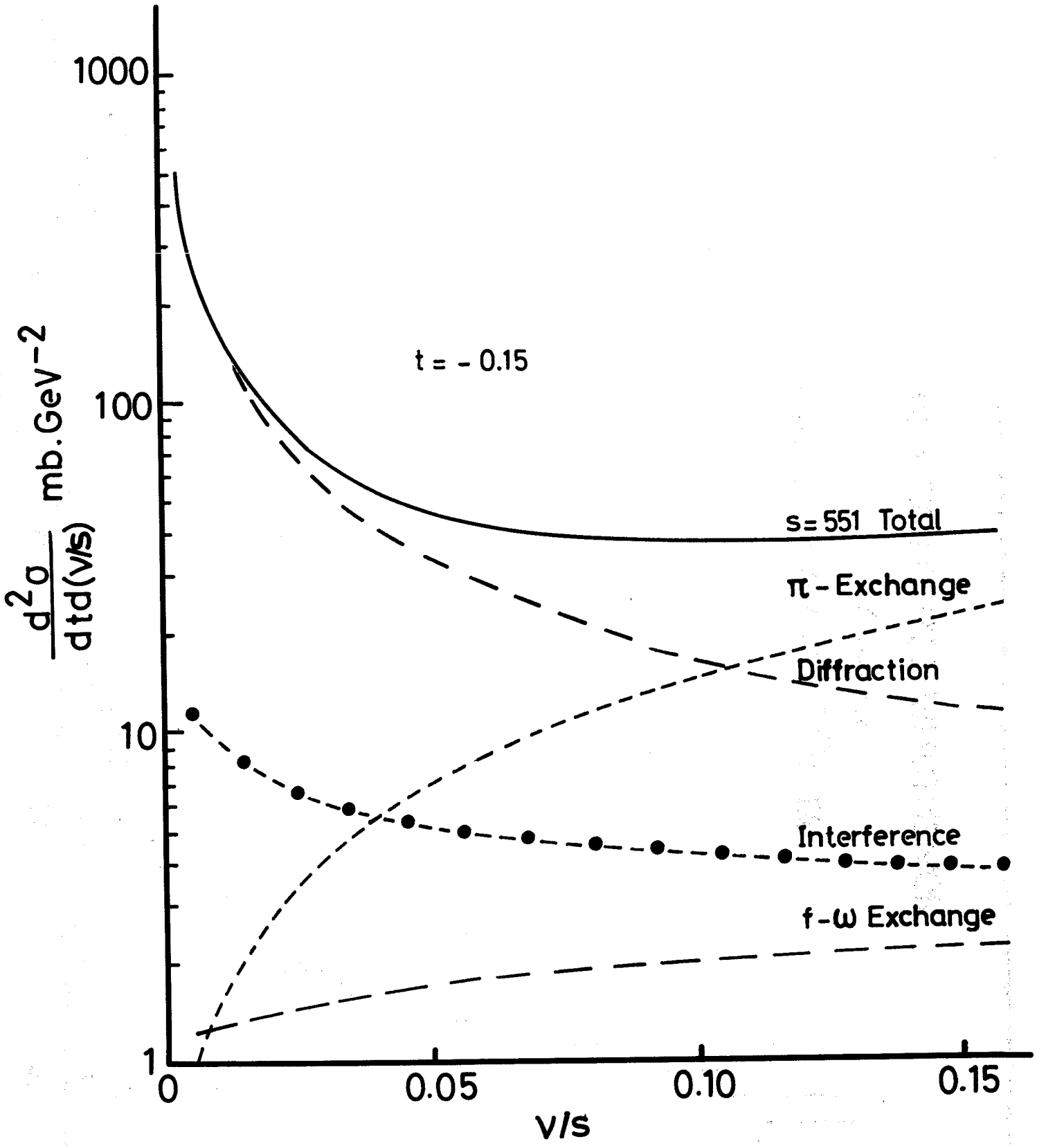

1000
100
10
1
$\frac{d^2\sigma}{dtd(\nu/s)}$ mb.GeV^{-2}
t = - 0.15
s= 551 Total
π - Exchange
Diffraction
Interference
f - ω Exchange
0
0.05
0.10
0.15
ν/s

Fig.3

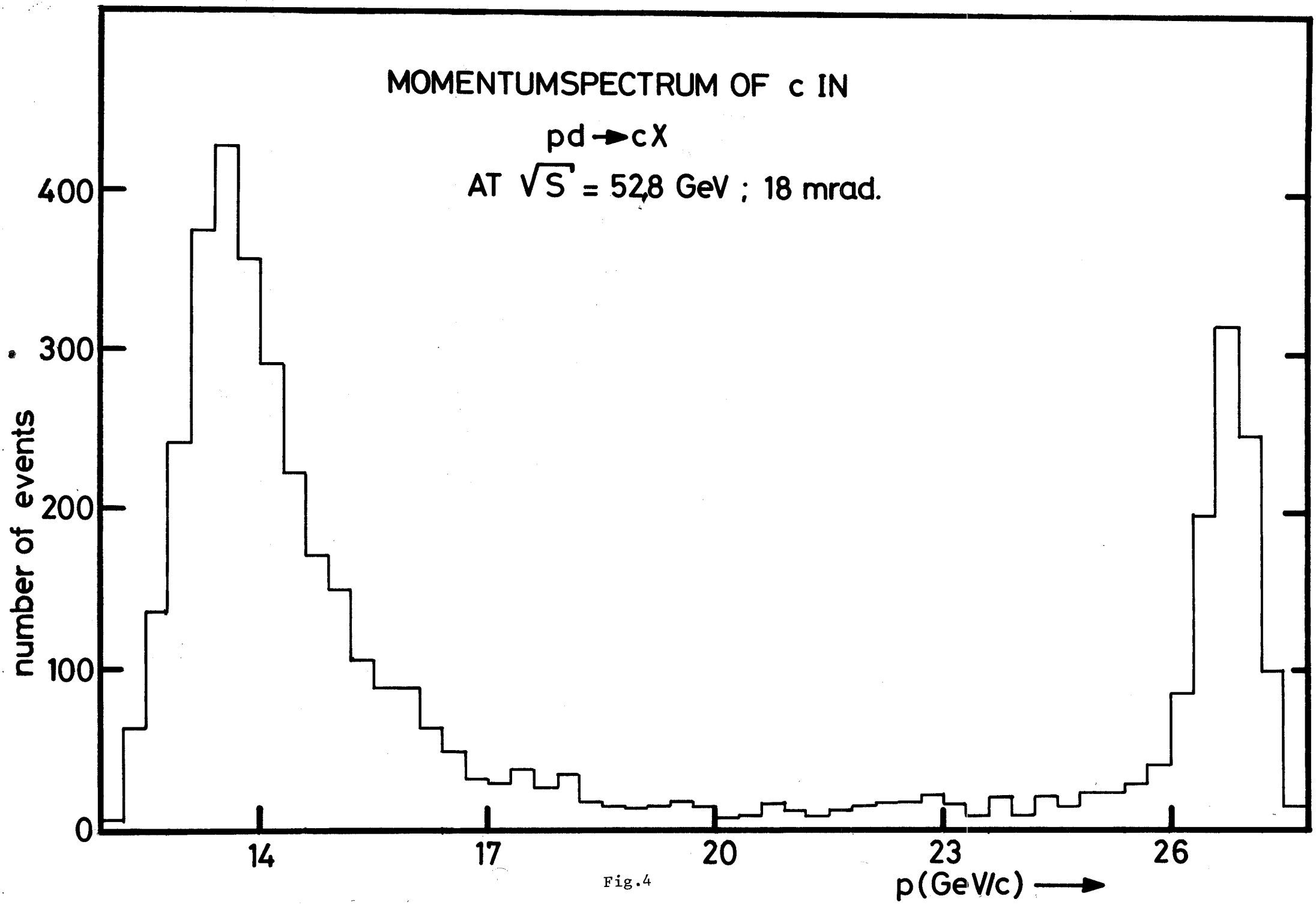
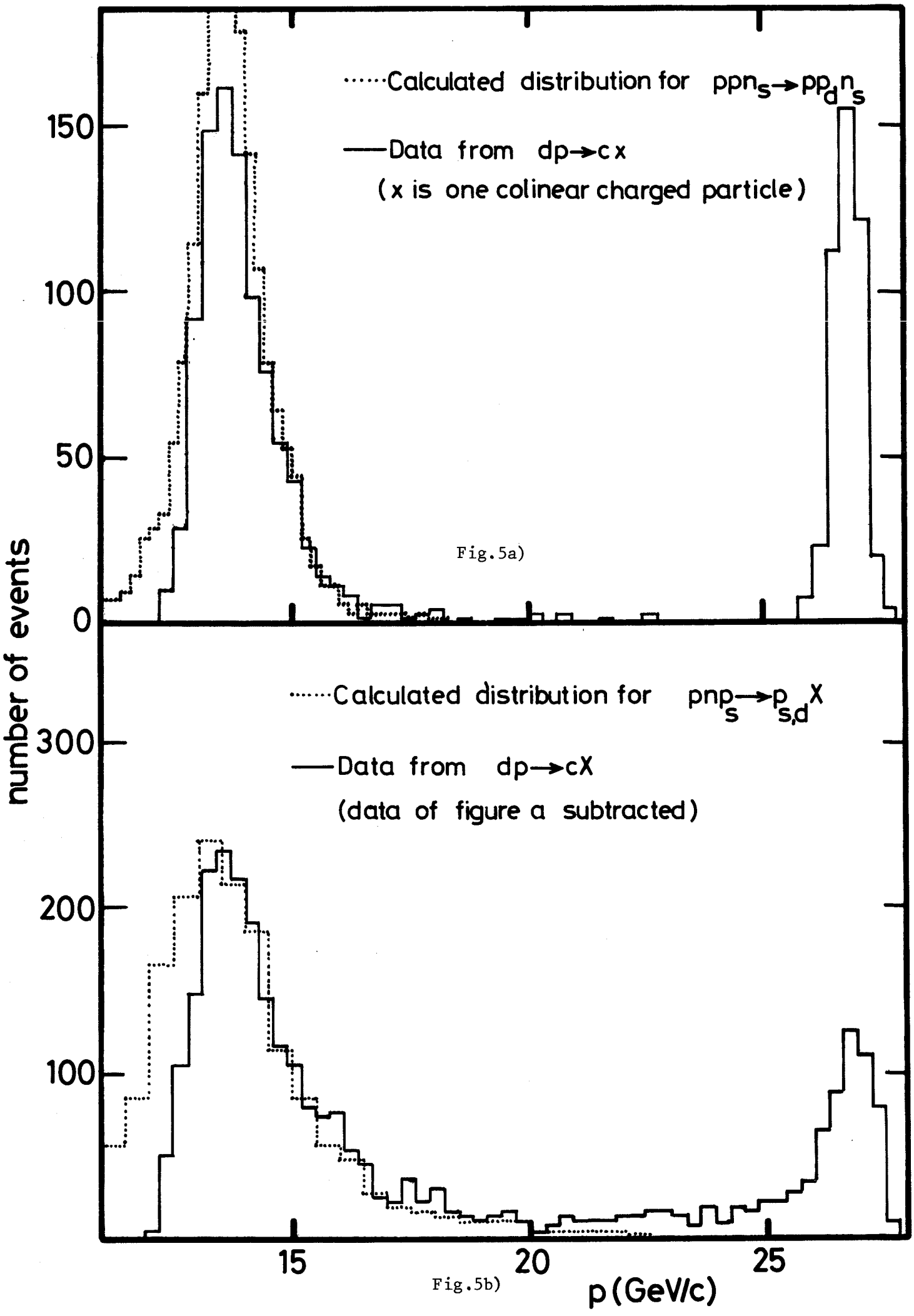

MOMENTUMSPECTRUM OF c IN
pd → cX
AT √S = 52,8 GeV ; 18 mrad.
number of events
0
100
200
300
400
14
17
20
23
26
p(GeV/c) →

Fig.4


·····Calculated distribution for $ppn_s \rightarrow pp_d n_s$
——Data from $dp \rightarrow cx$
(x is one colinear charged particle)
150
100
50
0
Fig.5a)
·····Calculated distribution for $pnp_s \rightarrow p_{s,d} X$
——Data from $dp \rightarrow cX$
(data of figure a subtracted)
300
200
100
number of events
15
20
25
p (GeV/c)
Fig.5b)

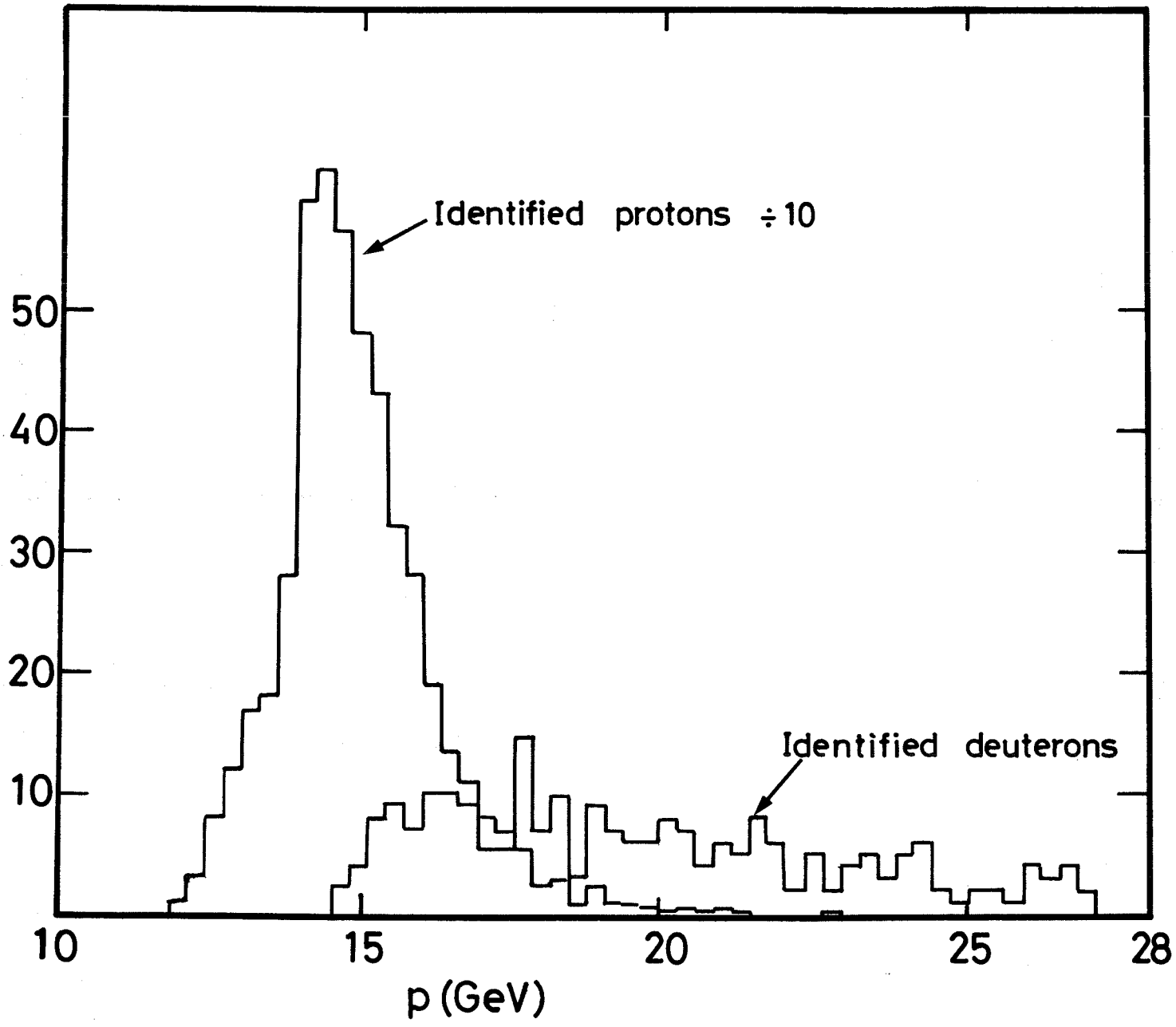

Identified protons ÷10
Identified deuterons
50
40
30
20
10
10
15
20
25
28
p (GeV)

Fig.6

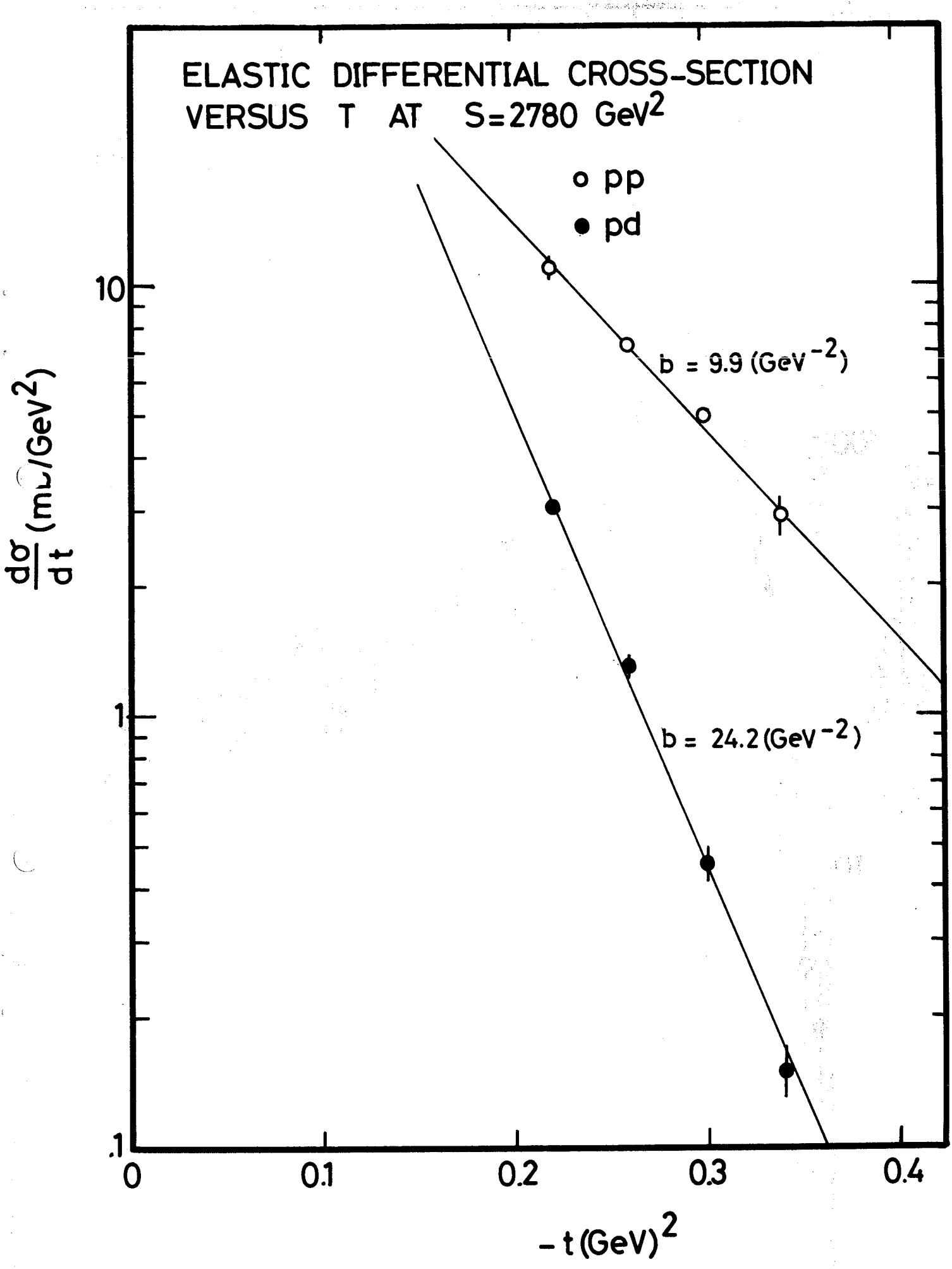

ELASTIC DIFFERENTIAL CROSS-SECTION
VERSUS T AT S=2780 GeV2
o pp
● pd
b = 9.9 (GeV-2)
b = 24.2 (GeV-2)
dσ/dt (mb/GeV2)
10
1
.1
0
0.1
0.2
0.3
0.4
-t (GeV)2

Fig.7

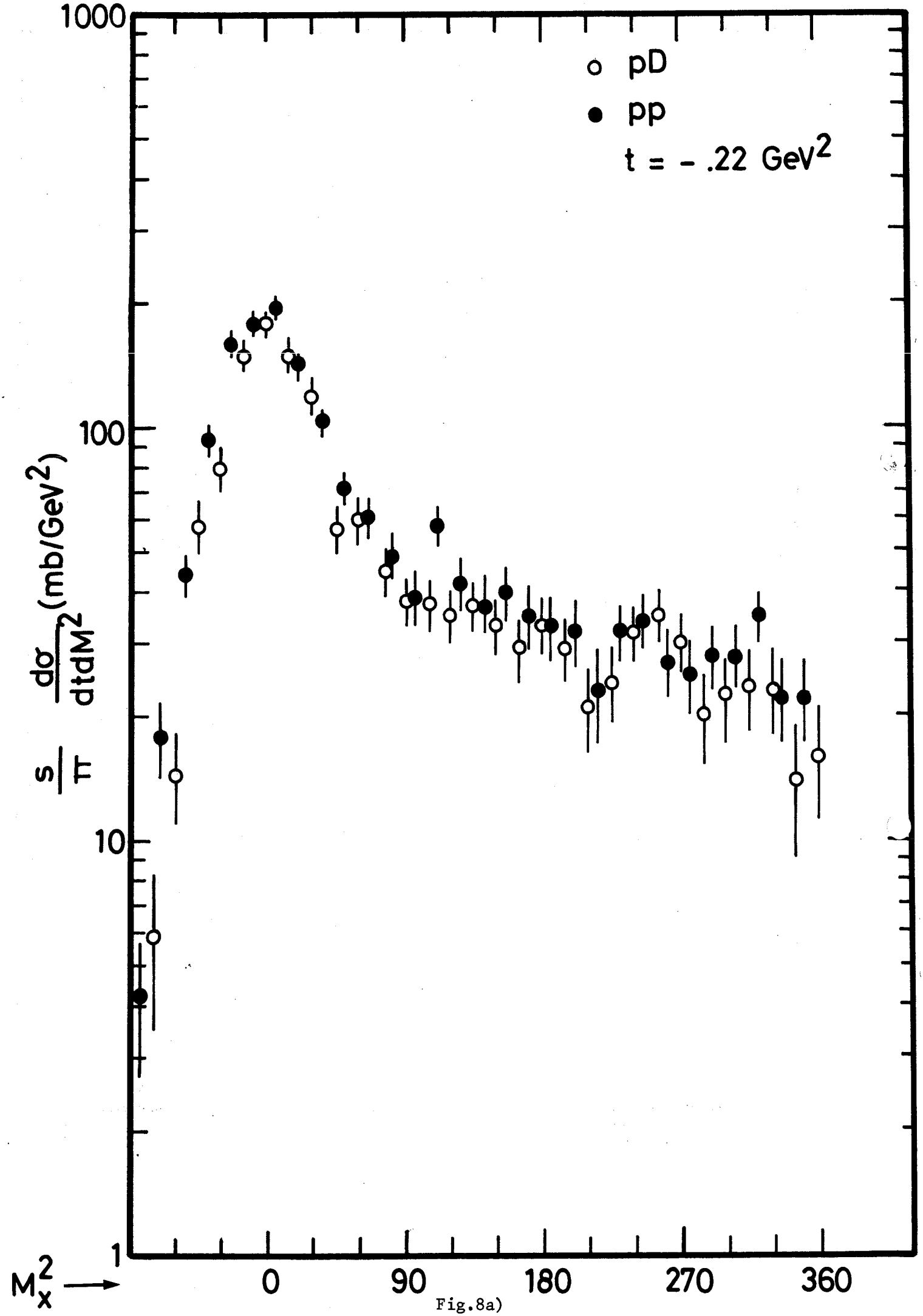

1000
100
10
1
pD
pp
t = - .22 GeV²
s/π dσ/dtdM² (mb/GeV²)
M²x →
0
90
180
270
360

Fig.8a)

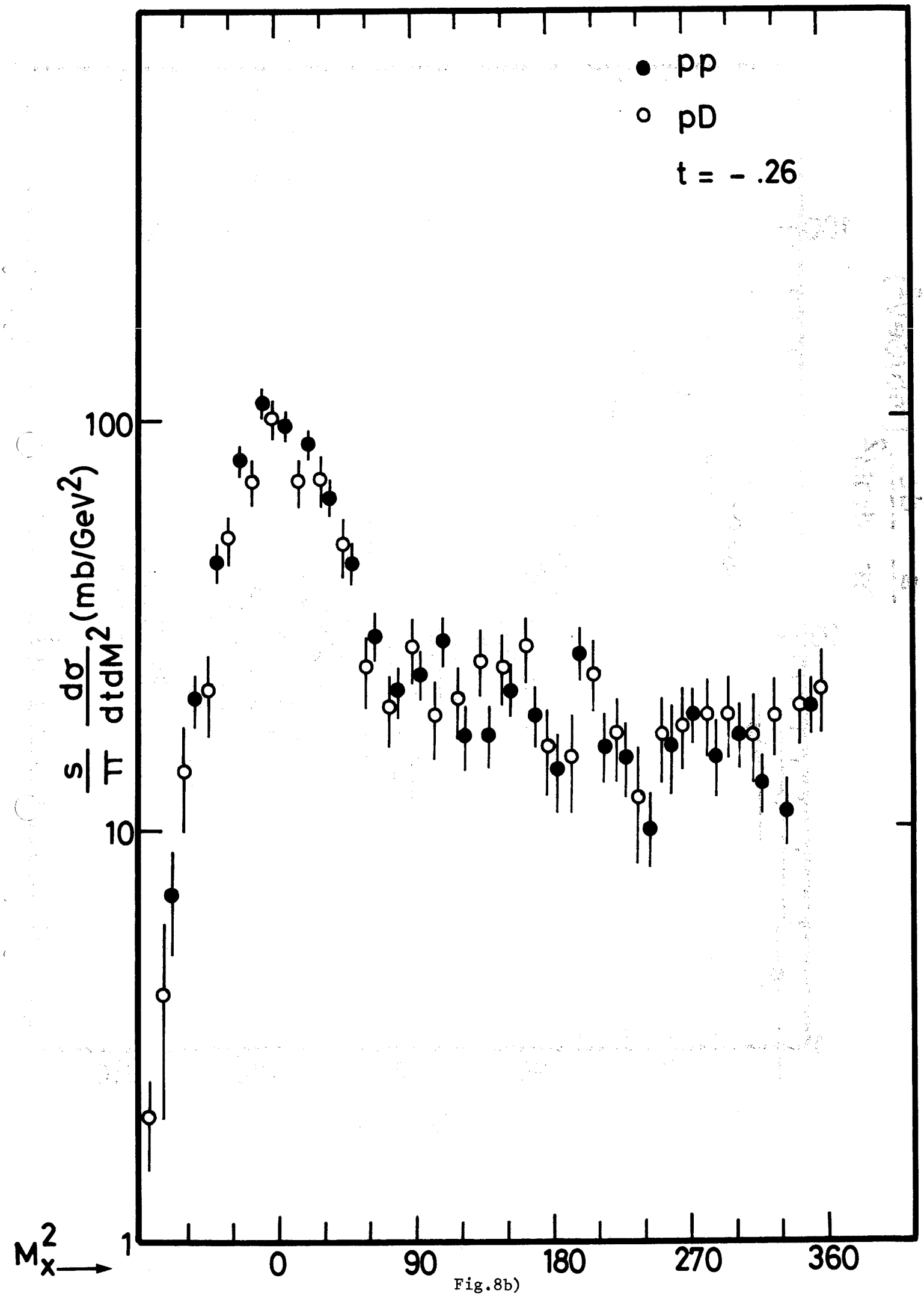

pp
pD
t = - .26
100
10
1
$\frac{s}{\pi}\frac{d\sigma}{dtdM^2}$(mb/Gev^2)
M_x^2
0
90
180
270
360

Fig.8b)

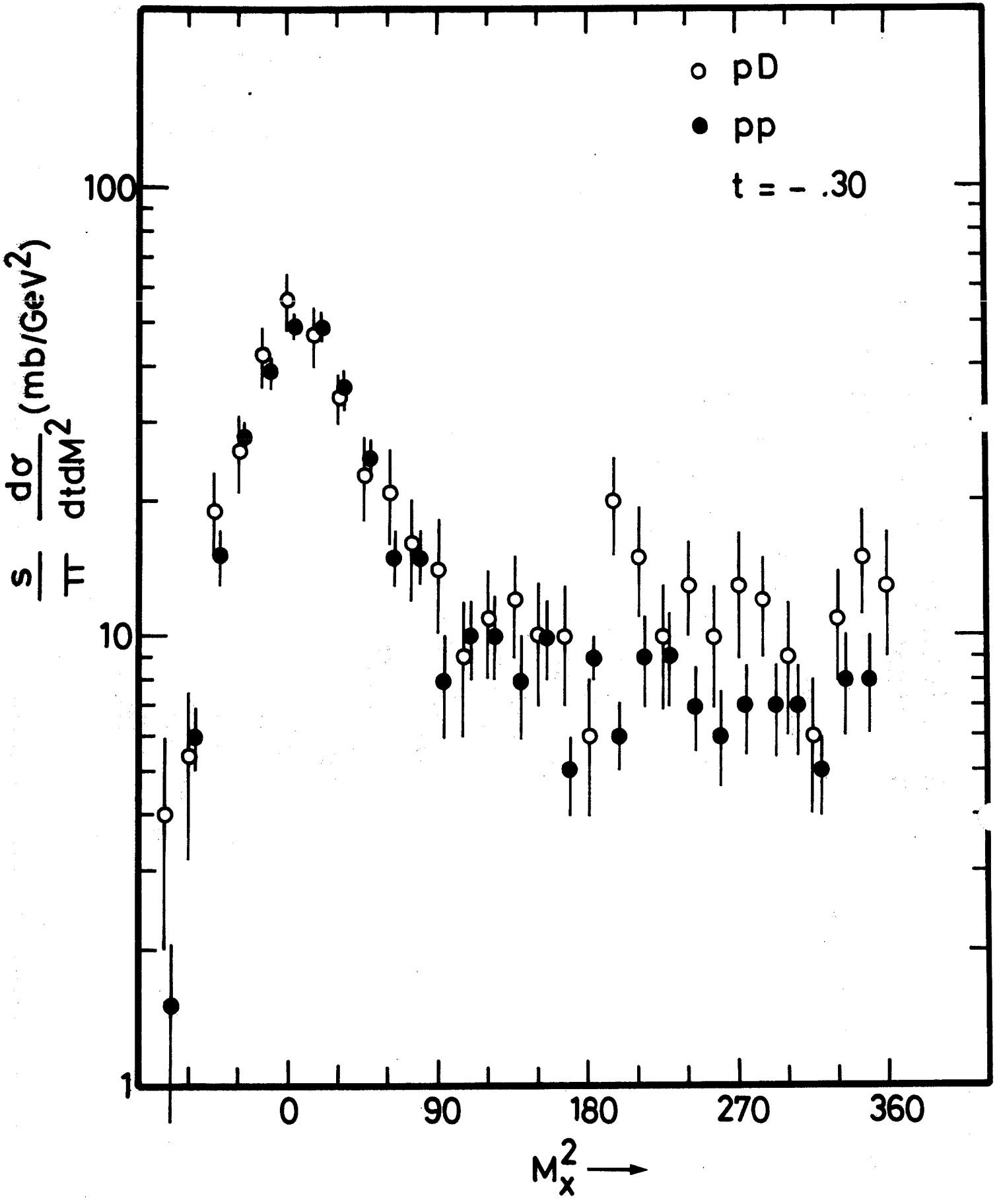

o pD
● pp
t = - .30
100
10
1
0
90
180
270
360
M_x^2 ⟶
$\frac{s}{\pi}\frac{d\sigma}{dtdM^2}$ (mb/GeV^2)

Fig.8c)