



OBSERVATION OF A DIP AT  $|t| = 1.5$  (GeV/c)<sup>2</sup> IN  
 $\bar{p}p$  ELASTIC SCATTERING AT 50 GeV/c

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ABSTRACT

The  $\bar{p}p$  elastic differential cross-section at 50 GeV/c has been measured in a two-arm spectrometer experiment at the CERN SPS. The  $|t|$ -range covered extends from 0.7 to 5 (GeV/c)<sup>2</sup>. A pronounced dip-bump structure is observed with a sharp minimum at  $|t| = 1.5$  (GeV/c)<sup>2</sup>.

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We present the result of a measurement of  $\bar{p}p$  elastic scattering at 50 GeV/c in the four-momentum transfer range  $0.7 < |t| < 5$  (GeV/c)<sup>2</sup>. These data come from an experimental programme at the CERN SPS, in which we are measuring hadron-proton elastic scattering over a wide range of four-momentum transfer and incident beam momentum. Results on  $\pi^{\pm}p$  elastic scattering at incident momenta of 20 and 30 GeV/c at large angle ( $7 < |t| < 17$  (GeV/c)<sup>2</sup>) have already been published<sup>(1)</sup>. Previous studies of  $\bar{p}p$  elastic scattering for incident momenta above 10 GeV/c<sup>(2-5)</sup> have been limited to  $|t| \lesssim 1$  (GeV/c)<sup>2</sup>.

The double-arm spectrometer shown schematically in fig. 1 is an extended version of the apparatus described in ref. 1. The incident antiproton was identified with a differential Čerenkov counter (CEDAR). The high intensity ( $2 \cdot 10^7$  ppp) unseparated beam contained 2% antiprotons. The scattered particles were detected in hodoscope counters (PR1 and PR2), with elements ranging from  $15 \times 15$  cm<sup>2</sup> to  $30 \times 30$  cm<sup>2</sup>. With these counters relatively rough kinematic correlations were imposed. The particle trajectories were determined with multiwire proportional chambers (MWPC, CHO-CH10). The momentum of the forward going particle was measured with an error  $\pm 15\%$  using a spectrometer magnet with an integrated field of 1.8 Tm. The forward scattered particle was detected by two threshold Čerenkov counters (Č1 and Č2) filled with N and He mixture giving the thresholds at 8 GeV/c, 29 GeV/c and 53 GeV/c for  $\pi$ , K and p respectively. In the recoil arm a silica-aerogel Čerenkov counter with a refractive index 1.03 was mainly used to veto  $\pi$  mesons. The trigger included geometrical constraints from the hodoscope counters, Čerenkov information for incident and scattered particles, and a rough threshold energy requirement for the forward scattered particle, which was imposed by an iron-scintillation-counter calorimeter. Veto counters were arranged around the target to eliminate multiparticle inelastic-events.

The off-line analysis included track reconstruction from MWPC digitizations in the forward and recoil arms, and from the beam hodoscopes<sup>(1)</sup>. Elastic candidates were selected on the basis of a fit combining geometrical (3-prong vertex) and kinematical constraints. The background estimate

was based on the  $\chi^2$ - distribution of reconstructed events, the coplanarity distribution, and a comparison of the scattering angle measured in the forward arm, with the prediction from the measured recoil-proton angle. 5135 events survived the final  $\chi^2$ - cut. The remaining background is estimated to increase, roughly linearly, from 1% at  $|t| = 0.7$  to 30% at  $|t| > 4$  (GeV/c)<sup>2</sup>.

After subtracting the background, and correcting for geometrical acceptance and detection efficiency, we obtain the differential cross-section shown in fig. 2 and compared with data from references 6,7,8 at lower energies. The data are compared with existing data<sup>(2,3)</sup> at 50 GeV/c, in the overlapping region  $0.7 < |t| < 1$  (GeV/c)<sup>2</sup>. Our data are systematically lower. However, allowing for the different normalization errors ( $\pm 30\%$  in our case) the overall agreement is satisfactory. Although we have acceptance up to  $|t| = 12$  (GeV/c)<sup>2</sup> no event has been observed above  $|t| = 5$  (GeV/c)<sup>2</sup>.

The most salient feature is the sharp dip at  $|t| = 1.5 \pm 0.1$  (GeV/c)<sup>2</sup>. Near this  $|t|$ -value the measured differential cross-section is compatible with zero, as illustrated by the  $\chi^2$  distributions for different  $|t|$ -ranges shown in figure 3. At both smaller and larger  $|t|$ -values, the elastic signal is very clear. A similar dip exists in pp elastic scattering for momenta above 150 GeV/c<sup>(9-11)</sup>. Our  $\bar{p}p$  data at 50 GeV/c almost coincide with pp ISR data at 1064 GeV/c (fig. 4).

Figure 2 shows that the structure visible at  $|t| = 0.5$  (GeV/c)<sup>2</sup> in  $\bar{p}p$  cross sections at low energies cannot be seen at 50 GeV/c, or is reduced to a mere break. From this figure it is conceivable that a new structure starts to develop around  $|t| \sim 2$  (GeV/c)<sup>2</sup> at 10 GeV. It is not clear if either of these two structures has evolved to the dip that we observe at  $|t| = 1.5$  (GeV/c)<sup>2</sup> at 50 GeV/c. Data at intermediate energy would be of crucial importance to clarify this point.

Three theoretical models dealing with the dip structure in elastic scattering could be mentioned. The first one<sup>(12)</sup> invokes pure diffraction.

With this model, using the proton shape derived from ep scattering, the experimentally observed  $|t|$ -values of the dips in pp and  $\bar{p}p$ , are quite well predicted from the measured values of the total cross-sections. The second model<sup>(13)</sup> invokes Regge-mechanism involving an imaginary Pomeron-exchange amplitude P and Reggeon- ( $\omega, f$ ) exchange amplitude R. For pp elastic scattering at PS and SPS energies, the total amplitude is  $|P + \text{Im}(R)|^2 + |\text{Re}(R)|^2$  and a shoulder is observed. At ISR energies, R becomes negligible, and the dip (fig. 4) is due to P going through zero. For our  $\bar{p}p$  data at 50 GeV/c,  $\text{Re}(R) \sim 0$  due to the cancelling  $\omega$ - and f contributions. The observed dip would therefore correspond to  $P + \text{Im}(R)$  going through zero at 50 GeV/c. In these two models the dip is associated with the structure around  $0.5 (\text{GeV}/c)^2$  at lower energies. The third approach comes from ref. 14, 15 which describe pp data from PS to ISR energies and our  $\bar{p}p$  data in terms of interference between diffraction which dominates the forward peak, and hard scattering, which dominates at large angles. In the hard process the hadrons are viewed as a core of valence-quarks surrounded by a cloud of gluons and sea-quarks: the cores interact through vector-meson exchange, and the clouds through Regge exchange. To fit the data, the radius of the interaction region has to be considerably larger for  $\bar{p}p$  than for pp, and the  $\bar{p}p$  dip at  $|t| = 1.5 (\text{GeV}/c)^2$  is interpreted as the second destructive interference between diffraction and the hard process, while the pp dip is due to the first destructive interference. According to this model the dip could be associated with the structure around  $2 (\text{GeV}/c)^2$  at 10 GeV/c. We are looking forward to taking new data in order to clarify the situation.

The energy dependence of the differential cross section has been parametrized as

$$\frac{d\sigma}{dt} = \text{const} \times p_{\text{lab}}^{-\alpha}$$

at two fixed values of  $|t| = 2$  and  $4 (\text{GeV}/c)^2$ . The energy dependence is weaker than for  $90^\circ$  scattering where  $\alpha \sim 10$ , as illustrated in fig. 5 where the straight lines correspond to  $\alpha = 2.5$  for  $|t| = 2 (\text{GeV}/c)^2$  and  $\alpha = 1.6$  for  $|t| = 4 (\text{GeV}/c)^2$ .

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Figure Captions

Fig. 1 The experimental set-up.

Fig. 2  $\bar{p}p$  elastic differential cross sections at 50 GeV/c compared with results of ref. 6,7,8. The data from ref. 6,7 are presented as smoothed curves.

Fig. 3  $\chi^2$ - distribution for reconstructed events in three adjacent  $t$  bins showing the absence of elastic signal at  $t = 1.5 \text{ (GeV/c)}^2$ .

Fig. 4 The  $\bar{p}p$  differential cross sections at 50 GeV/c compared with  $pp$  cross sections at ISR energies (ref. 9).

Fig. 5 The energy dependence of the  $\bar{p}p$  differential cross section at fixed angles. The straight lines are an eye-fit through the data points: 3.6 GeV/c<sup>(16)</sup>, 5 GeV/c<sup>(6)</sup>, 6.2 GeV/c<sup>(7)</sup>, 5.8 and 9.7 GeV/c<sup>(17)</sup>, 10.1 GeV/c<sup>(8)</sup>, 50 GeV/c (this experiment).



WA 7 EXPERIMENTAL SET-UP.

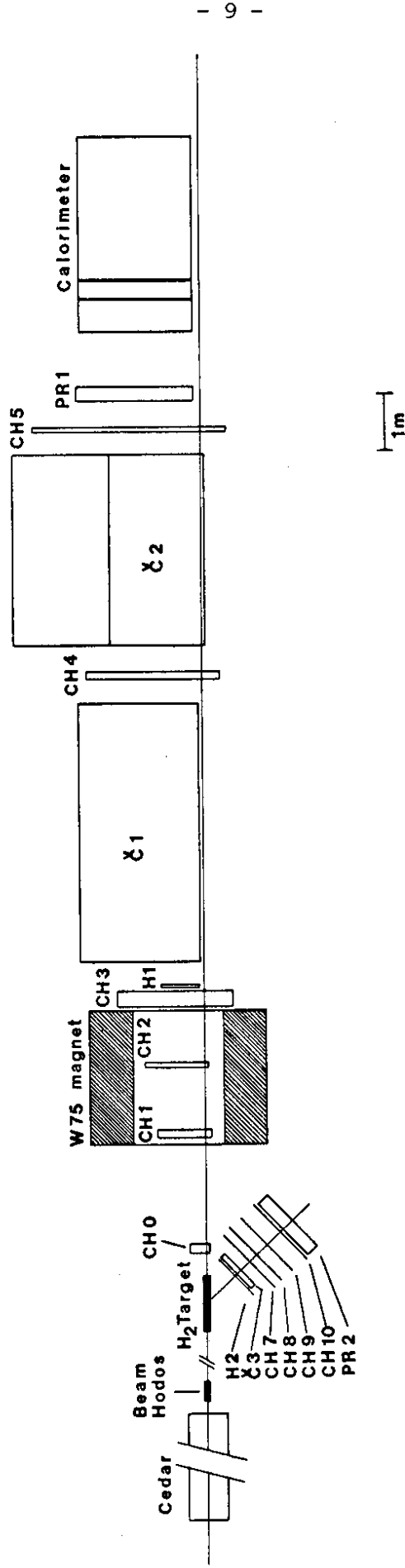


Fig. 1

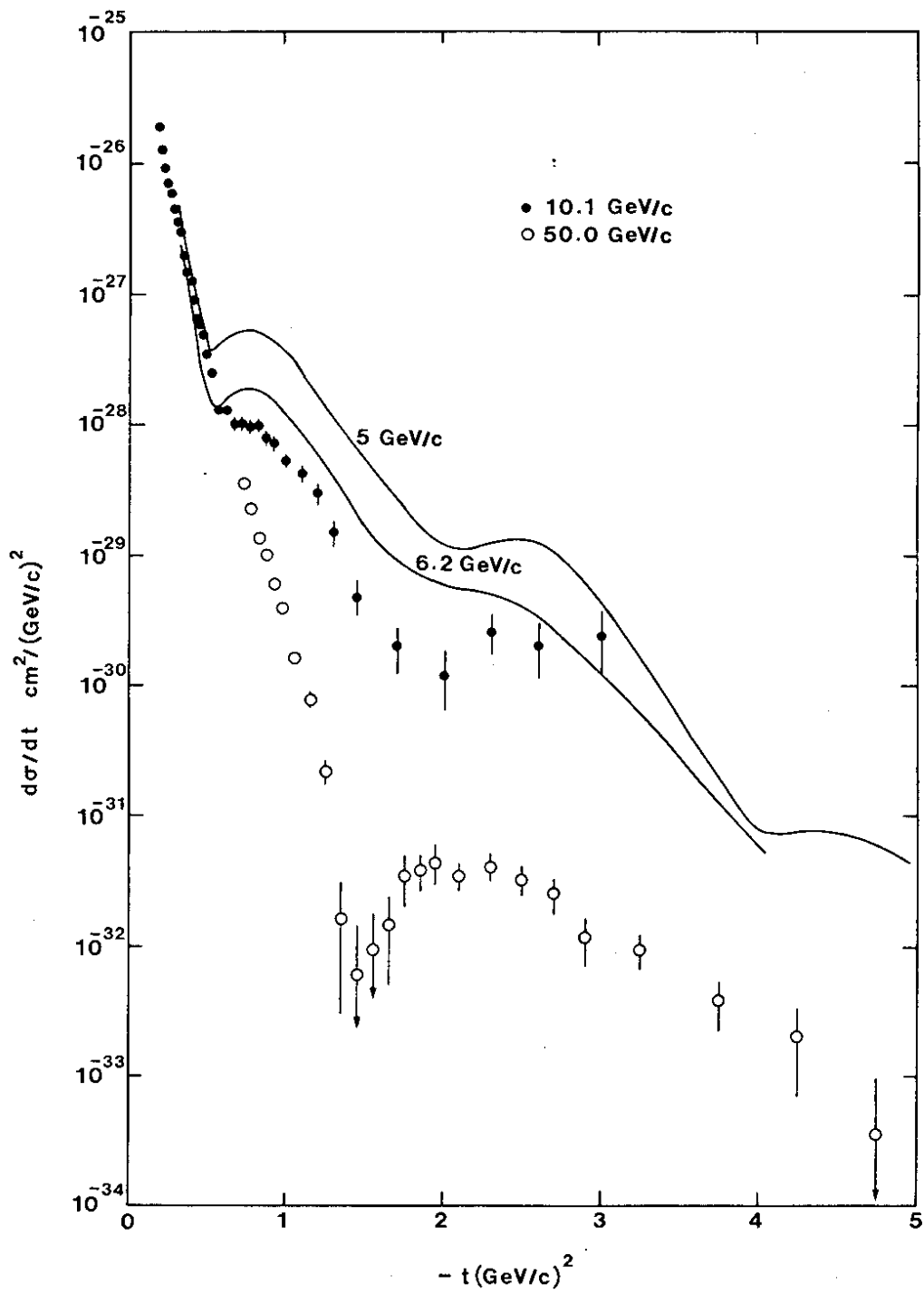


Fig. 2

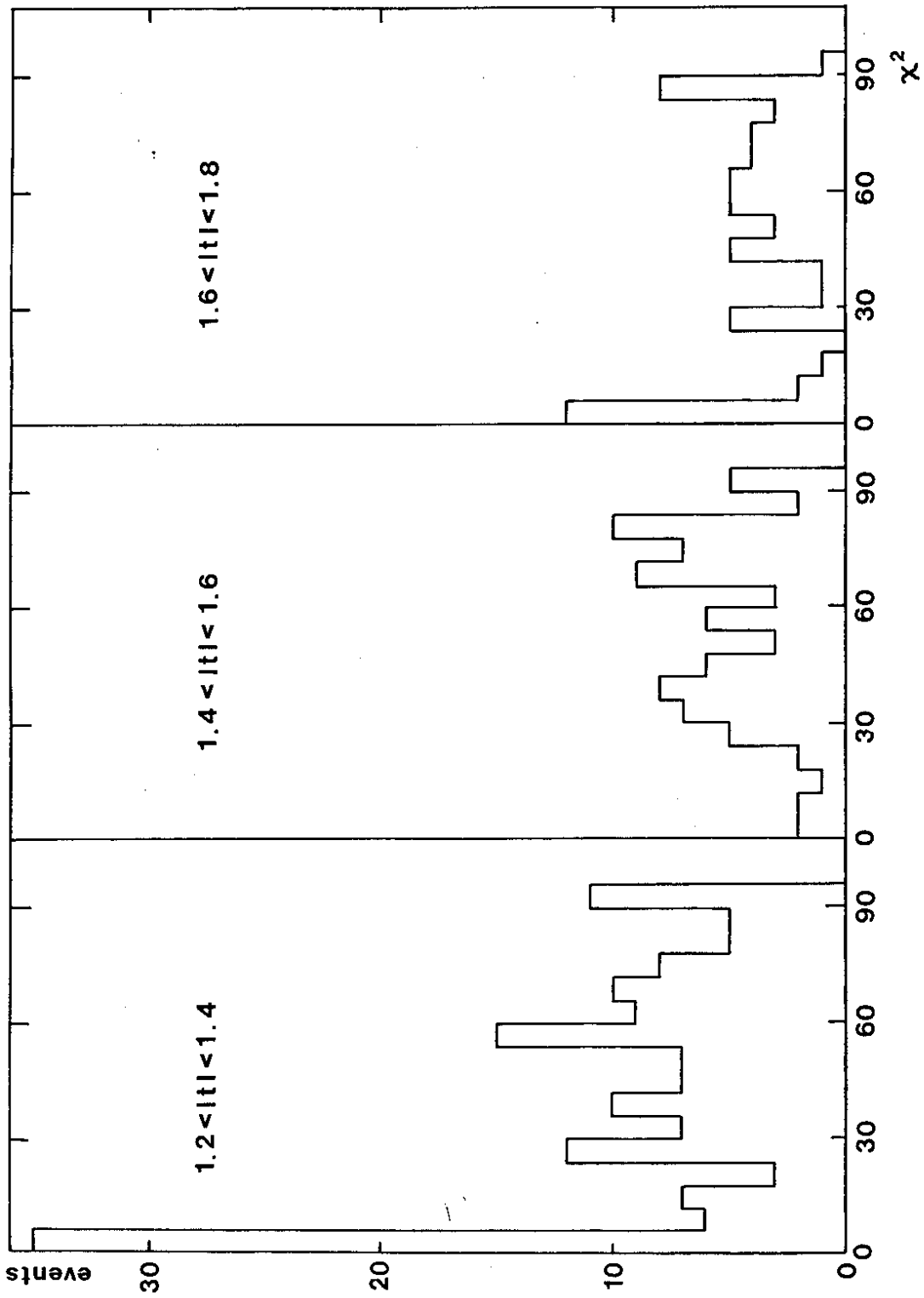


Fig. 3

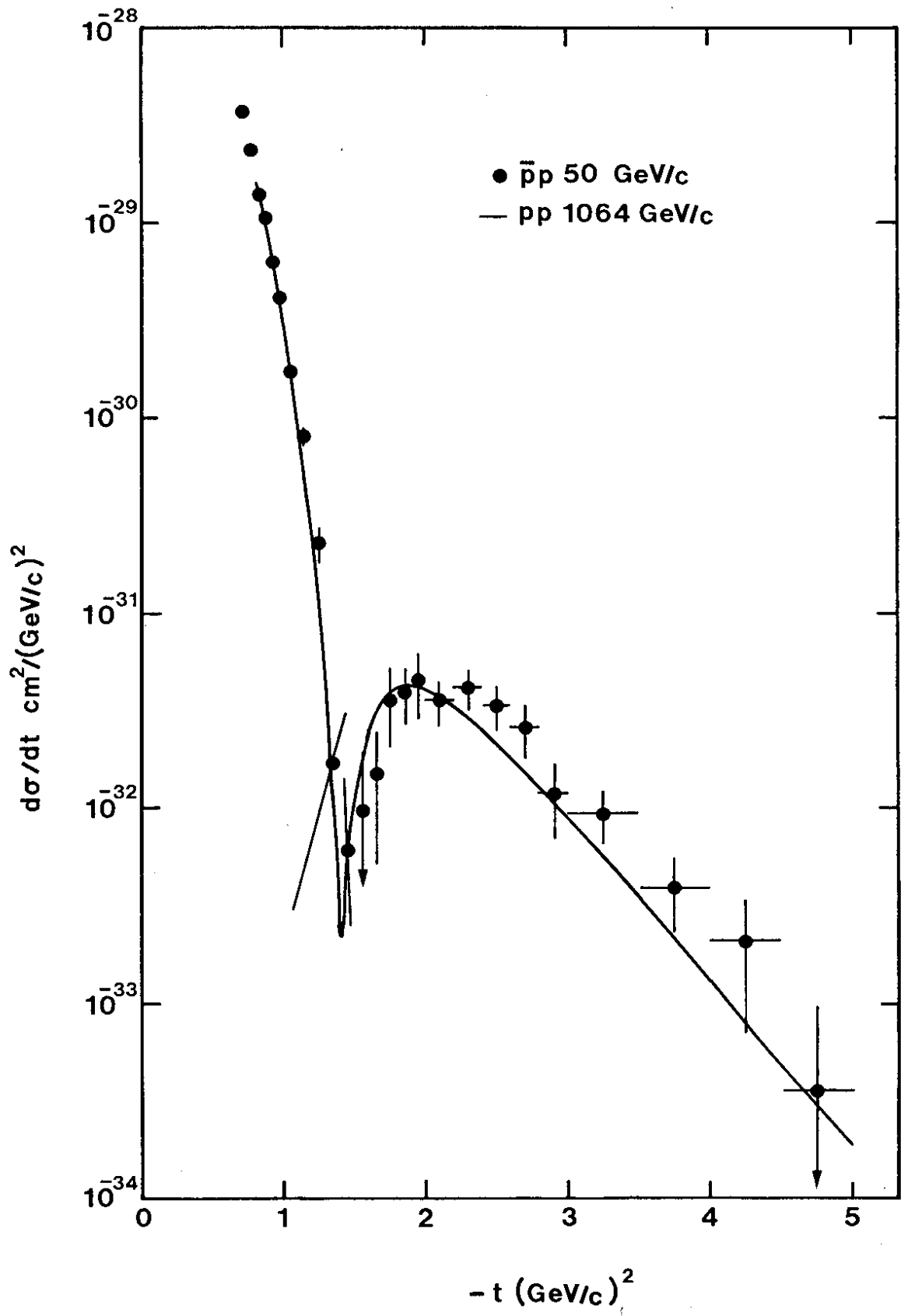


Fig. 4

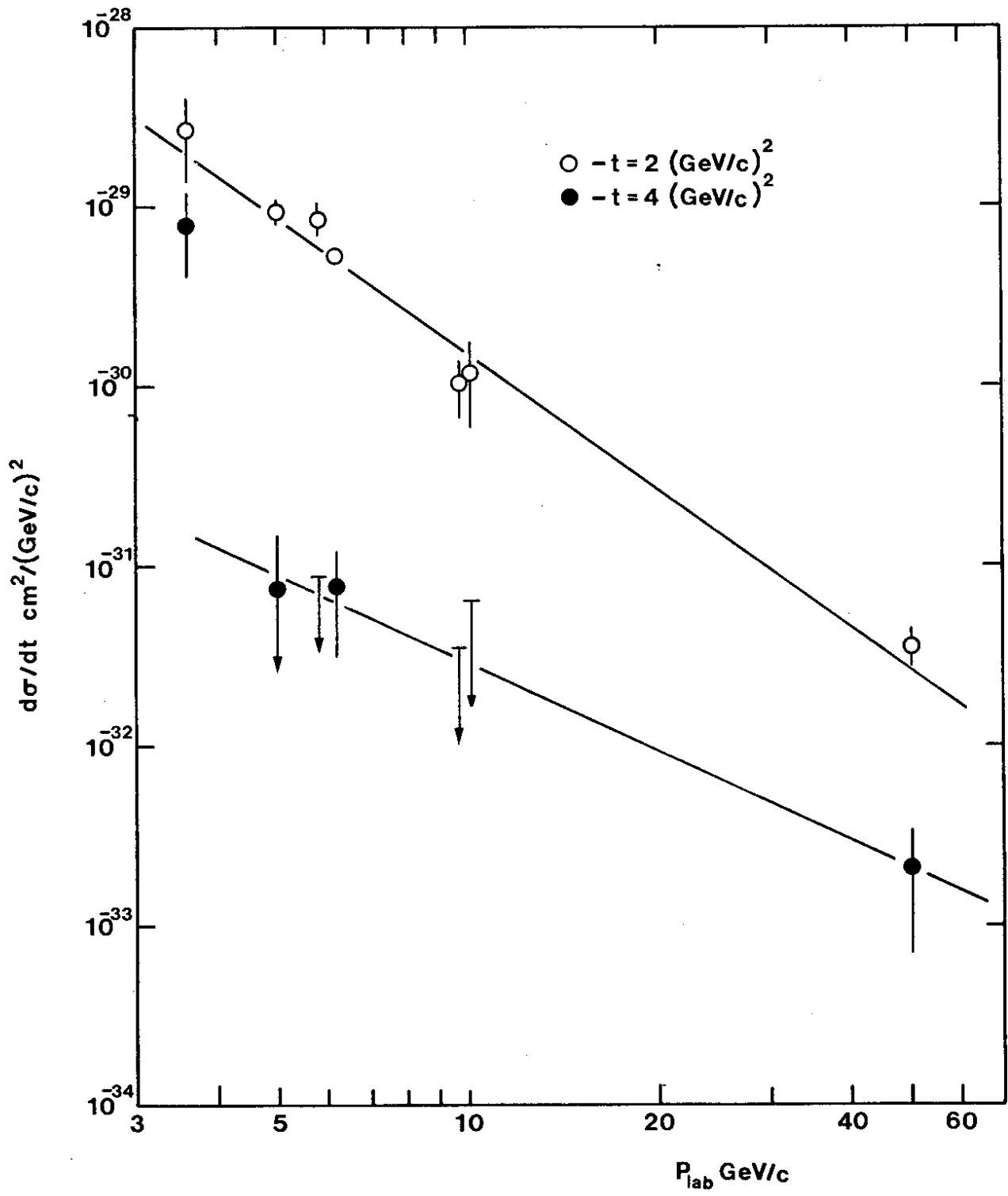


Fig. 5

