

**DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY**

DESY 77/64  
September 1977



Determination of the Longitudinal and  
the Transverse Part in  $\pi^+$ -Electroproduction

by

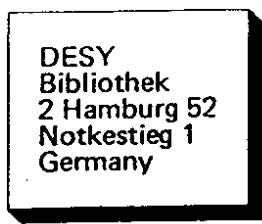
J. Ackerblom, I. Zepelin, M. Gabriele, H.D. Meitner,  
H.D. Reich, G. Specht

Deutsches Elektronen-Synchrotron DESY, Hamburg

F. Janata, D. Schmidt  
Gesamthochschule Wuppertal

**NOTKESTRASSE 85 · 2 HAMBURG 52**

To be sure that your preprints are promptly included in the  
HIGH ENERGY PHYSICS INDEX ,  
send them to the following address ( if possible by air mail ) :



The detailed knowledge of the transverse and longitudinal cross sections for the reaction  $e^- p \rightarrow e^- \pi^+ n$  offers a new opportunity to probe the nature of the inelastic electron-proton scattering. The results which are presented here extend the available data on the transverse longitudinal separation of the cross section for the above reaction (ref. 1, ref. 2) to  $|q^2|$ -values below .5 GeV<sup>2</sup> at  $W = 2.1$  GeV. In the one-photon exchange approximation the electroproduction is treated as photoproduction by spacelike virtual photons whose flux,  $\Gamma$ , is determined by the energy, energy loss and the scattering angle of the electron. The cross section for  $\gamma_V p \rightarrow \pi^+ n$  is then given by

$$2 \pi \frac{d^2\sigma}{dt d\phi} = \frac{d\sigma_U}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \varepsilon \cos 2\phi \frac{d\sigma_P}{dt} + \sqrt{2\varepsilon(1+\varepsilon)} \cos \phi \frac{d\sigma_T}{dt} \quad (1)$$

where  $\varepsilon$  is the degree of the transverse polarization of the virtual photon and  $\phi$  is the angle between the electron scattering plane and the pion-production plane. The subscripted terms describe the contributions to the cross section from the unpolarized transverse photons, the longitudinal polarization, the transverse polarization and the transverse-longitudinal interference, respectively. Generally, they depend on  $W$ , the centre of mass energy of the virtual photon and target proton, on  $q^2$ , the square of the virtual photon mass and on  $t$ , the square of the four-momentum transfer from the virtual photon to the pion. For a detailed description of the notation see ref. 3.

It is clear from eq. 1 that the four components of the cross section can be determined only if there is sufficient acceptance in  $\phi$  and large variation in  $\varepsilon$ . The first requirement was already fulfilled in a previous experiment (ref. 3) where data were taken at high values of  $\varepsilon$  in the full  $\phi$ -range. The second requirement, namely acquiring data with low values of  $\varepsilon$  at the same point in the  $W-q^2$  plane was accomplished by accepting large scattering angles of the electron at low incident electron energies ( $E_\nu = 2.5$  and 2.9 GeV). To this end a second bending magnet (fig. 1) with opposite polarity with respect to the first one was introduced in the electron arm of the spectrometer which was powered only for the low- $\varepsilon$  runs.

## DETERMINATION OF THE LONGITUDINAL AND THE TRANSVERSE PART IN $\pi^+$ -ELECTROPRODUCTION

H. Ackermann, T. Azemoon, W. Gariel, H.D. Mertens,  
H.D. Reich, G. Specht<sup>xx</sup>

Deutsches Elektronen-Synchrotron DESY, Hamburg

F. Janata, D. Schmidt

Gesamthochschule Wuppertal

### Abstract

We report on an experiment where the different contributions from the transversal and longitudinal polarization of the virtual photon are measured separately for the reaction  $e^- p \rightarrow e^- \pi^+ n$ . The data taken above the resonance region at small  $|t|$ -values in the  $q^2$ -range of  $|q^2| < .5$  GeV<sup>2</sup> show a clear dominance of the longitudinal part of the cross section and are well described by a generalized Born-term model. Using this model the electromagnetic form factor of the pion is determined. At  $q^2 = -.35$  GeV<sup>2</sup> one gets

$$F_\pi = .598 \pm .021.$$

<sup>xx</sup> Now at Fachhochschule Hamburg, Berliner Tor 21, 2000 Hamburg 1

In separating  $d\sigma_u/dt$  and  $d\sigma_L/dt$  it is crucial that the relative systematic error of the low- $\epsilon$  and high- $\epsilon$  data is as small as possible. Since there was a feeling that part of high- $\epsilon$  data were too high we repeated the experiment at incident electron energy of  $E_o = 4.0$  GeV. Careful checks showed that the higher values of the old experiment were due to wrong recording of the random triggers for that particular run. In the subsequent analysis only the new data were used.

Single  $\pi^+$ -production was separated from other channels by applying cuts in the invariant mass of the unobserved particles. The missing mass spectra for the three incident energies are shown in fig. 2.

The cross sections were corrected for the efficiency loss of the trigger, shower and Čerenkov counters, strong interaction of the  $\pi^+$ , target walls and the missing mass cuts. The overall corrections varied between 3 % and 6 % depending on the incoming electron energy. The momentum dependent corrections for the decay of pions ranged from 1.5 % to 4.5 %. The radiative corrections were calculated using the method proposed by Calan and Fuchs (ref. 4). They were about 15 % and showed no strong dependence on  $\epsilon$ . The systematic error introduced by the uncertainties in the above corrections including that in the intensity of the primary beam is estimated to be less than 5 % which is not included in the errors given in this report.

Fig. 3 shows the dependence of the four components of the cross section on  $t$  for a centre of mass energy of  $W = 2.1$  GeV and  $q^2 = -35$  GeV<sup>2</sup>. In forward direction ( $|t_{\min}| < |t| < .05$  GeV<sup>2</sup>) the longitudinal component is dominant. Its behaviour is compatible with  $e^{1/4}t$ . On the other hand  $d\sigma_u/dt$  and  $d\sigma_p/dt$  which are an order of magnitude smaller than  $d\sigma_L/dt$  show little dependence on  $t$ .  $d\sigma_L/dt$  is very small and within the errors it is compatible with zero.

$d\sigma_p/dt$  and  $d\sigma_u/dt$  can be expressed in terms of  $d\sigma_{\perp}/dt$  and  $d\sigma_{\parallel}/dt$  where

$\perp$  and  $\parallel$  refer to the virtual photon with the electric vector perpendicular and parallel to the hadron-production plane.

$$\frac{d\sigma_u}{dt} = \frac{1}{2} \left[ \frac{d\sigma_{\perp}}{dt} + \frac{d\sigma_{\parallel}}{dt} \right], \quad \frac{d\sigma_p}{dt} = \frac{1}{2} \left[ \frac{d\sigma_{\perp}}{dt} - \frac{d\sigma_{\parallel}}{dt} \right]$$

It can be seen in fig. 3 that  $d\sigma_u/dt \approx -d\sigma_p/dt$  and therefore  $d\sigma/\partial t$  is compatible with zero and the transverse cross section is almost entirely due to  $d\sigma/\partial t$  as it is observed in photoproduction of  $\pi^+n$  (ref. 5). Our data show little variation of  $d\sigma_u/dt$  with  $t$ . This observation is supported by the data in a larger  $t$ -range (fig. 4),  $|t_{\min}| < |t| < .2$  GeV<sup>2</sup>, where the cross section was averaged over  $\phi$  in the range  $0^\circ < |\phi| < 60^\circ$  at a slightly larger  $W$  and  $|q^2|$ ,  $W = 2.2$  GeV and  $q^2 = -.45$  GeV<sup>2</sup>. The contribution of  $d\sigma_p/dt$  and  $d\sigma_L/dt$  to the averaged cross section is small so that the resulting  $t$ -dependence shown in fig. 4 is mainly due to  $d\sigma_u/dt + \epsilon d\sigma_L/dt$ . The exponential fall has a slope of  $5.6 \pm 1.0$  which is well below the one observed for  $d\sigma_L/dt$ . This suggests that  $d\sigma_u/dt$  becomes increasingly important at higher  $|t|$ . Such a behaviour has also been noted in another electroproduction experiment (ref. 2) at the higher value of  $|q^2| = .7$  GeV<sup>2</sup>.

Assuming that at small  $|t|$  the  $d\sigma_L/dt$  is dominated by the  $\pi$ -exchange the data can be used to determine the electromagnetic form factor of the pion. For this purpose we have used the generalized Born-term model of Gutbrod and Kramer (ref. 6) who treat the pion and the off-mass shell nucleon-form factors as free parameters. As shown in fig. 3 the model describes our data well except that it slightly overestimates the contribution of  $d\sigma_u/dt$ . The fitted value of  $F_\pi = .598 \pm .021$  at  $q^2 = -.35$  GeV<sup>2</sup> is slightly below the prediction of the vector meson dominance model of  $(1 + |q^2/m^2)^{-1} = .631$  and is compatible with the isovector Dirac nucleon form factor  $F_V = .599$ . This is in agreement with the findings of ref. 2 at  $|q^2| = .7$  GeV<sup>2</sup>, where the same model was used to extract  $F_\pi$ , and with the low- $|q^2|$  part of the results reported by another group (ref. 7) who have analysed their data using a different version of the Born term model.

Fig. 5 shows the four components of the cross section as a function of  $q^2$ . In the covered range of  $q^2$  no change in the dominance of  $d\sigma_L/dt$  can be seen. The measured values of  $d\sigma_u/dt$  are in agreement with the predictions of a simple vector meson dominance model (broken line) normalized to the photoproduction value taken from ref. 8.

Acknowledgements

The valuable cooperation of the Synchrotron crew, the Hallendienst, the Kälte-technik and the Rechenzentrum is gratefully acknowledged.  
We also want to thank Mr. G. Augustinski, Mr. P. Burmeister, Mr. G. Hase, Mr. K. Maschidlauskas and Mrs. R. Siemer for their excellent assistance.  
F. Janata and D. Schmidt are indebted to the DESY Directorium for their kind hospitality.

References

1. C.J. Bebek et al., Phys. Rev. Lett. 37 (1976) 1326.
2. P. Brauel et al., preprint DESY 77/22 (1977).
3. C. Driver et al., Nucl. Phys. B30 (1971) 245.
4. C.D. Calan and Fuchs, Nuovo Cimento 38 (1965) 1594; Nuovo Cimento 41 (1966) 286.
5. P. Heide et al., Phys. Rev. Lett. 21 (1968) 248; C. Geweniger et al., Phys. Lett. 29B (1969) 41.
6. F. Gutbrod and G. Kramer, Nucl. Phys. B49 (1972) 461.
7. C.J. Bebek et al., Phys. Rev. D13 (1976) 25.
8. G. Buschhorn et al., Phys. Rev. Letters 17 (1966) 1027.

Figure Captions

Fig. 1 Experimental layout.

Fig. 2 Spectra of missing mass  $m_X = \sqrt{(e + p - e' - \pi^+)^2}$  for the reaction  $e p \rightarrow e \pi^+ + (\text{anything})$  obtained with the primary electron energies 2.5, 2.9 and 4.0 GeV, respectively.

Fig. 3 The  $t$ -dependence of the cross sections  $d\sigma_L/dt$ ,  $d\sigma_u/dt$ ,  $d\sigma_p/dt$ ,  $d\sigma_I/dt$ . The lines are the results of a generalized Born term model (ref. 6).

Fig. 4 The  $t$ -dependence of the cross section averaged over the  $\phi$ -range  $-60^\circ < \phi < +60^\circ$ . The line corresponds to  $e^- p$ .

Fig. 5 The  $q^2$ -dependence of the cross sections  $d\sigma_L/dt$ ,  $d\sigma_u/dt$ ,  $d\sigma_p/dt$ ,  $d\sigma_I/dt$ . The broken line was calculated using a simple vector meson dominance model ( $(q^2 - m_Q^2)^{-2}$ ) normalized at  $q^2 = 0$  to photoproduction values taken from ref. 8.

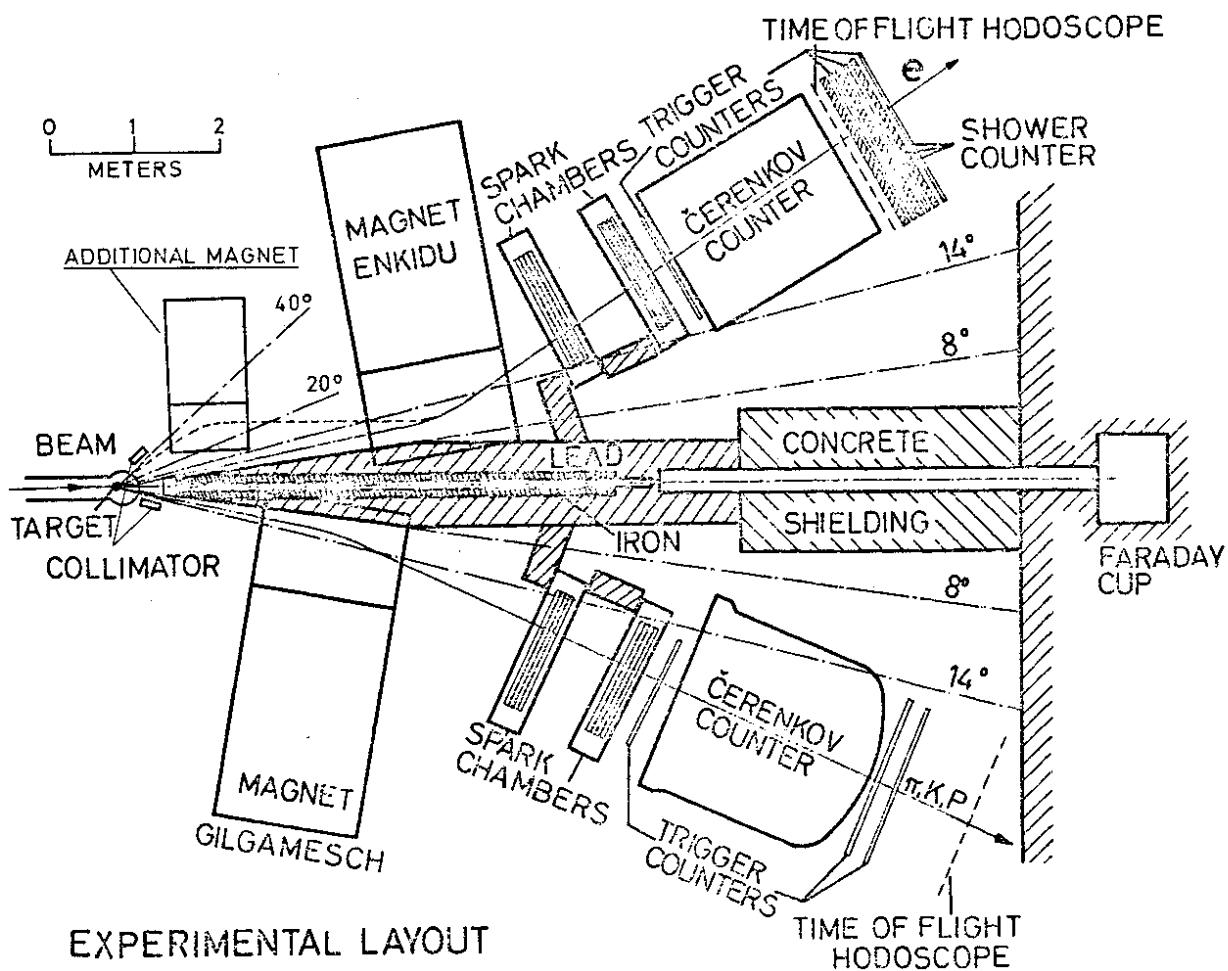


Fig. 1

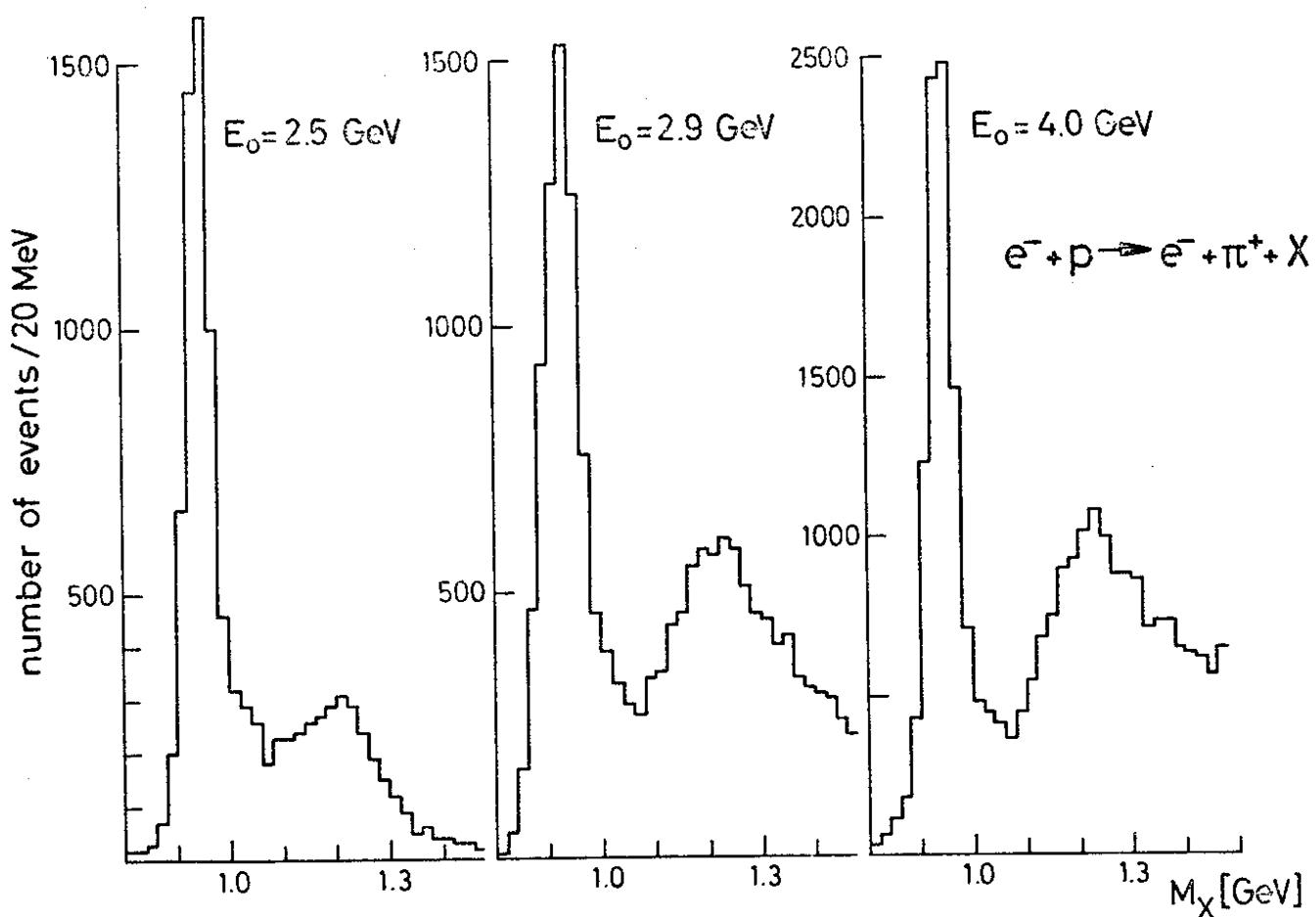


Fig. 2

Fig. 4

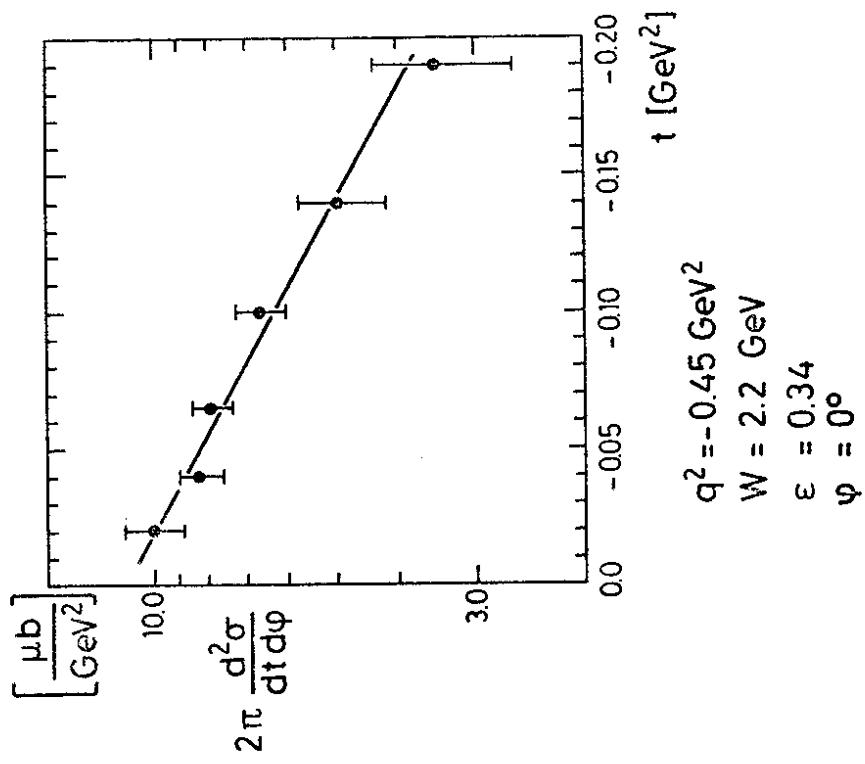


Fig. 3

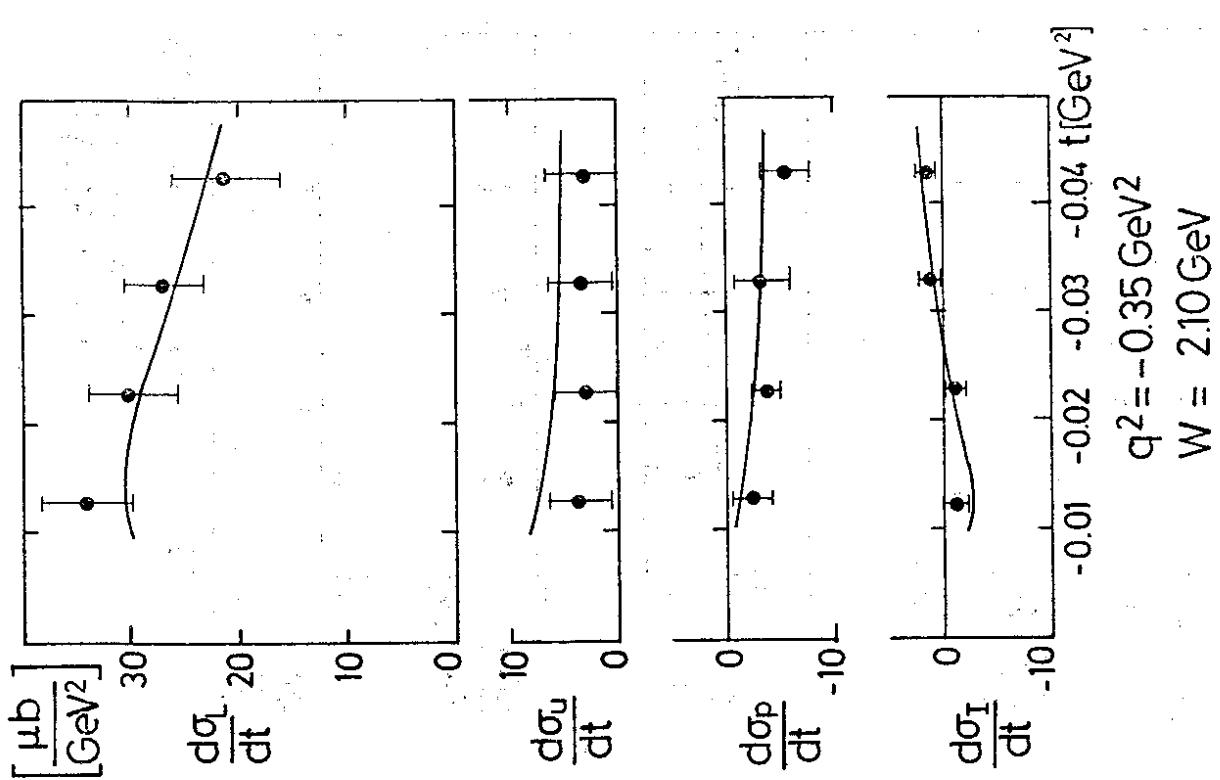


Fig. 5

