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by

P. Brauel, T. Canzler, D. Cords, R. Felst, G. Grindhammer, M. Helm,
W.-D. Kollmann, H. Krehbiel, and M. Schädlich

Deutsches Elektronen-Synchrotron DESY, Hamburg

and

II. Institut für Experimentalphysik der Universität Hamburg

Abstract:

The reaction $e + p \rightarrow e' + n + \pi^+$ was studied detecting e' and π^+ in coincidence at an invariant hadronic mass of 2.19 GeV. The measurements were performed at electron four-momentum transfers squared of $Q^2 = 0.06, 0.28, 0.70$, and 1.35 GeV^2 in the range of $t = (\gamma_v - \pi)^2$ between t_{\min} and -1.0 GeV^2 . The cross section $d^2\sigma/dtd\phi$ was found to be roughly independent of Q^2 for $Q^2 > 0.7 \text{ GeV}^2$ and $|t| > 0.2 \text{ GeV}^2$.

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W.-D. Kollmann, H. Kreibiel, and M. Schädlich

Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
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II. Institut für Experimentalphysik der Universität Hamburg, Germany

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Abstract

$$\frac{d^4\sigma}{dQ^2 d\omega^2 dt d\phi} = \Gamma \cdot 2\pi \frac{d^2\sigma}{dt d\phi} = \Gamma \cdot \left[\frac{d\sigma_U}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \varepsilon \frac{d\sigma_P}{dt} \cos(2\phi) + \sqrt{2\varepsilon(\varepsilon+1)} \frac{d\sigma_I}{dt} \cos(\phi) \right] \quad (2)$$

The polarization parameter ε is defined as usual, the virtual photon flux parameter is $\Gamma = \alpha(W-M^2)/(16\pi^2 EM^2 Q(1-\varepsilon))$, and ϕ is the angle between the lepton and hadron scattering planes. ϕ is zero, when the pion is closest to the outgoing electron (s, ref.4). The cross sections $d\sigma/dt$ are, in general, functions of $s = W^2 = (n+\pi)^2$, $Q^2 = -(e-e')^2$, and $t = (Y_v - \pi)^2$. In the present experiment cross sections were measured at values of $s \approx 4.8 \text{ GeV}^2$ and $(Q^2, \varepsilon) = (0.06 \text{ GeV}^2, 0.44)$, $(0.28 \text{ GeV}^2, 0.76)$, $(0.7 \text{ GeV}^2, 0.86)$, and $(1.35 \text{ GeV}^2, 0.84)$ in the range $|t_{\min}| \leq |t| \leq 1.0 \text{ GeV}^2$.

The experimental arrangement is shown in Fig.1. An external electron beam from DESY with an energy spread of $\pm 0.25\%$ was focused onto a liquid hydrogen target 10cm long. The beam intensity was measured using a secondary emission monitor and a Faraday cup. Electrons and pions were detected in coincidence using two nearly identical magnetic spectrometers. Each spectrometer consists

In this letter we report the results of an experiment on the reaction



at an $(\pi^+ n)$ invariant mass above the resonance region extending previous measurements [1-3] to larger values of $|t|$. The previous data indicate that peripheral π^+ -production through one pion exchange from longitudinally polarized photons dominates for $|t| < 0.1 \text{ GeV}^2$. At larger values of $|t|$ and Q^2 possible contributions from short range interactions, as postulated to explain the approximate scaling behaviour of the total electroproduction cross section, are expected to be more pronounced. It therefore was the aim of the present experiment to study the Q^2 -dependence of reaction (1) for $|t| > 0.1 \text{ GeV}^2$.

In the one photon exchange approximation, the cross section of reaction (1) can be written [4]:

$$\frac{d^4\sigma}{dQ^2 d\omega^2 dt d\phi} = \Gamma \cdot 2\pi \frac{d^2\sigma}{dt d\phi}$$

The reaction $e + p \rightarrow e' + n + \pi^+$ was studied detecting e' and π^+ in coincidence at an invariant hadronic mass of 2.19 GeV. The measurements were performed at electron four-momentum transfers squared of $Q^2 = 0.06$, 0.28 , 0.70 , and 1.35 GeV^2 in the range of $t = (Y_v - \pi)^2$ between t_{\min} and -1.0 GeV^2 . The cross section $d^2\sigma/dtd\phi$ was found to be roughly independent of Q^2 for $Q^2 > 0.7 \text{ GeV}^2$ and $|t| > 0.2 \text{ GeV}^2$.

of three quadrupole magnets followed by a dipole magnet which bends the central trajectory vertically by 10° . Four multiwire proportional chambers, each having two planes of orthogonal readout wires, are located in front (1) and behind (3) the bending magnet. The chambers are followed by two scintillation-counter hodoscopes, a threshold Cerenkov counter, two further scintillation-counter hodoscopes (of which one is used for time-of-flight measurements), and a shower counter. The electron spectrometer was positioned at a fixed angle of 10° ($Q^2 = 1.35 \text{ GeV}^2$) with respect to the incident beam. The hadron spectrometer was rotated in the course of the measurement between 10° and 36° .

The momentum of a particle was measured by reconstructing its trajectory through the bending magnet, and the production angles were determined by tracing the trajectory back through the quadrupole magnets to the target position. The momentum resolution achieved was 1.2% (FWHM) and the accepted momentum band amounted to 45% (FWHM). The angular acceptance was 16mrad in the horizontal direction and 200mrad in the vertical. For the trigger, a coincidence between at least three of the four hodoscopes of each spectrometer was required. The information about an event satisfying this trigger requirement was collected by a small on-line computer and sent to a central computer for on-line analysis and for recording on magnetic tape. Electrons were identified by means of the threshold Cerenkov counter and the shower counter. The pressure of the Cerenkov counter in the hadron spectrometer was adjusted such that the counter was fully efficient for π -mesons and inefficient for K-mesons. The shower counter was used to separate π^+ from e^+ . The e^-e^- -coincidence rate was negligible. The time-of-flight system was used to separate true from random coincidences.

The $(\pi^+ n)$ -channel was separated from other final states by computing the mass M_X of the undetected particle. A typical missing mass spectrum is shown in fig.2. For each nominal value of Q^2 , events with $0.85 \text{ GeV} \leq M_X \leq 1.02 \text{ GeV}$ were grouped into several (ϕ, t) -bins and weighted with the appropriate acceptance function, as calculated by Monte Carlo techniques.

Corrections due to the following effects were applied:

- a) radiative effects⁵⁾: 21% - 39% depending on the nominal value of Q^2 ,
- b) event reconstruction inefficiency, which was continuously monitored: 15% - 20% per spectrometer, c) target-wall-background: $\lesssim 8\%$, d) background due to random coincidences: $\lesssim 4\%$, e) downtime of the read out system: $\lesssim 3\%$, f) pion absorption $\lesssim 3\%$. The correction for pion decay in flight are to a large extent covered by b). The overall uncertainty of these corrections was estimated to be less than 5%.

In fig.3 we show the cross section $2\pi d^2\sigma/dtd\phi$ as a function of $|t|$ for various values of Q^2 . For this figure, only the data within the range of $150^\circ \leq \phi \leq 210^\circ$ ($105^\circ \leq \phi \leq 225^\circ$ for $Q^2 = 0.06 \text{ GeV}^2$) were taken, since the acceptance of the two spectrometers was not large enough to cover the full ϕ -range at larger values of $|t|$. The low Q^2 data merge with the photoproduction values, and the data show the tendency of a decreasing Q^2 dependence with increasing Q^2 .

This behaviour is more clearly shown in fig.4 where we plotted the data of fig.3 together with recent data from the Harvard-Cornell group^{6,7)}. The small $|t|$ data of ref.6 were converted from $d\sigma/dt$ to $d\sigma/dt$ and scaled to the nominal value of s according to $(s/M)^{-2}$. The $|t| \geq 1 \text{ GeV}^2$ data of ref.7 were extrapolated to the nominal s value according to the functional dependence given in ref.7 and then converted to $d\sigma/dt$. The cross section $d^2\sigma/dtd\phi$ is roughly independent of Q^2 for $|t| \geq 0.2 \text{ GeV}^2$ and $Q^2 \geq 0.7 \text{ GeV}^2$. Qualitatively the same behaviour is shown at $s = 7.5 \text{ GeV}^2$ where the $|t| \leq 0.9 \text{ GeV}^2$ data were taken in the range of $-45^\circ \leq \phi \leq 45^\circ$.

Comparing the electro- and photoproduction data at large $|t|$ one should keep in mind that the value of $|t_{\max}|$ increases with Q^2 (at $s = 4.8 \text{ GeV}^2 |t_{\max}| = 3.2 \text{ GeV}^2$ for $Q^2 = 0 \text{ GeV}^2$ and $|t_{\max}| = 7.5 \text{ GeV}^2$ for $Q^2 = 4.0 \text{ GeV}^2$) and with it the position of a backward peak. Integrating the data in fig.4 over $|t|$ one finds that $\sigma(\gamma_V + p \rightarrow \pi^+ + n)$ shows roughly the same Q^2 -dependence as $\sigma_{\text{tot}}(\gamma_V + p)$ for $Q^2 \geq 0.7 \text{ GeV}^2$.

For the higher Q^2 data we were able to separate the ϕ -dependent terms of eq.(1) up to $|t| = 0.4 \text{ GeV}^2$. The results are shown in fig.5. The longitudinal-transverse interference term $d\sigma_I/dt$ is small for $0.1 \leq |t| \leq 0.4 \text{ GeV}^2$. The data imply $d\sigma_1/dt > d\sigma_0/dt$, since $d\sigma_0/dt = \frac{1}{2} (d\sigma_{||}/dt - d\sigma_{\perp}/dt)$, where $d\sigma_{||}/dt$ and $d\sigma_{\perp}/dt$ are the cross sections for transverse photons polarized parallel and

perpendicular to the hadron production plane. From $d\sigma_u/dt = \frac{1}{2} (d\sigma_H/dt + d\sigma_L/dt)$ we obtain for $|t| \approx 0.3 \text{ GeV}^2$ an upper limit for $d\sigma_L/dt$ of the order of $d\sigma_L/dt$.

The observed decreasing Q^2 -dependence with increasing $|t|$ and Q^2 was predicted by Gutbrod and Kramer⁸⁾ and by Actor, Körner and Bender⁹⁾. The authors of ref.8 conjectured from an analysis of the $|t| \leq 0.1 \text{ GeV}^2$ data in the framework of the generalized Born term model that $d\sigma_u/dt$ decreases only slowly with Q^2 , whereas the authors of ref.9 predicted this behaviour from a dual current model with an infinite number of vector mesons.

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Figure Captions

Fig.1 Perspective view of the apparatus.

Fig.2 Distribution of the missing mass $M_X = \sqrt{(e + p - e' - \pi)^2}$.

Fig.3 The cross section $2\pi d^2\sigma/dt d\phi$ versus $|t|$ for the four nominal values of Q^2 . The data shown were taken in the range $150^\circ \leq \phi \leq 210^\circ$, with the exception of $Q^2 = 0.06$ GeV 2 , where the range was $105^\circ \leq \phi \leq 225^\circ$.

Fig.4 Data of fig.3 together with data from the Harvard-Cornell Group 6,7). Error bars are only plotted at some representative points. The dashed lines are drawn to guide the eye.

Fig.5 $|t|$ -dependence of the cross sections $d\sigma_u/dt + \epsilon d\sigma_L/dt$, $d\sigma_F/dt$, and $d\sigma_p/dt$.

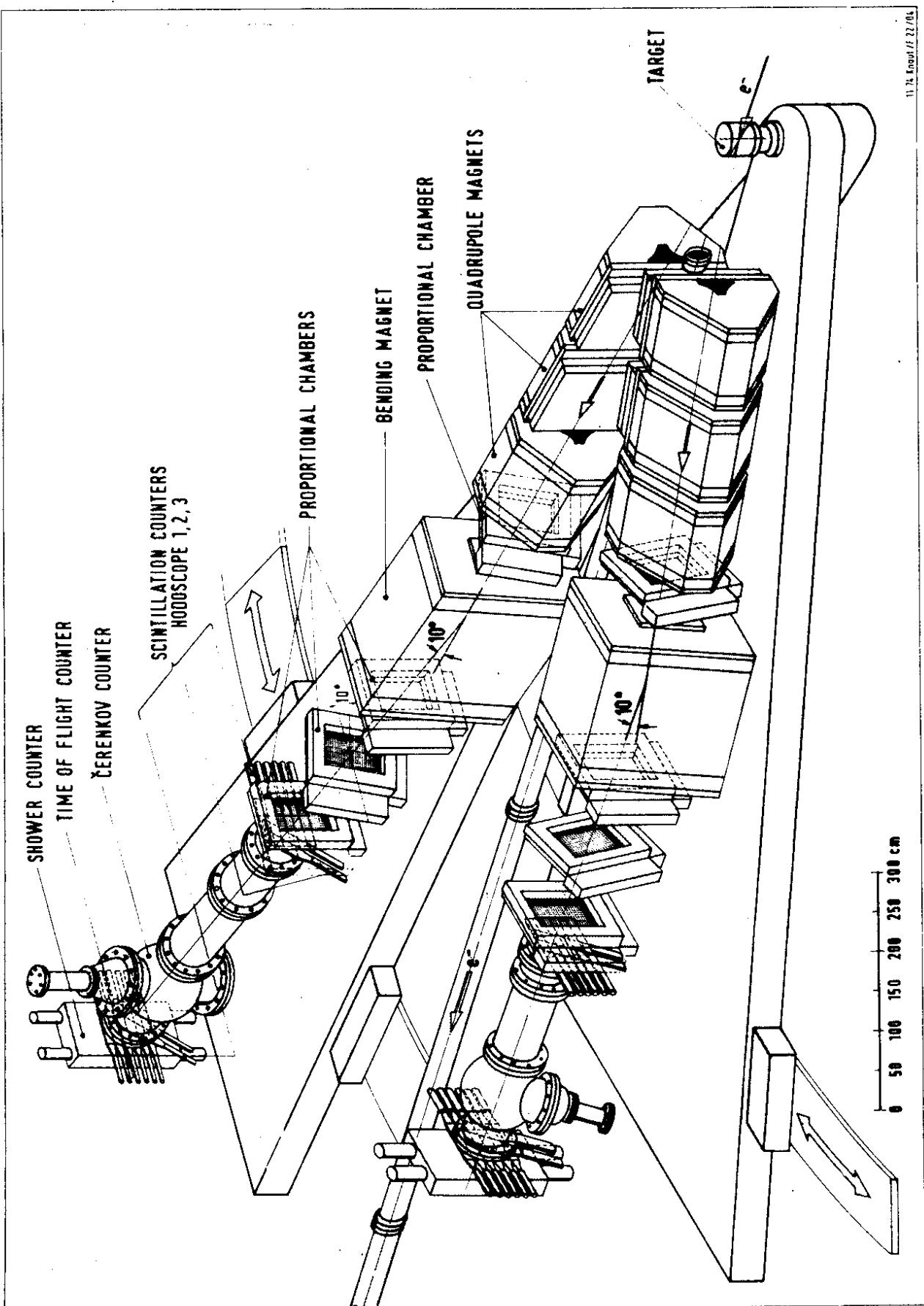


Fig. 1

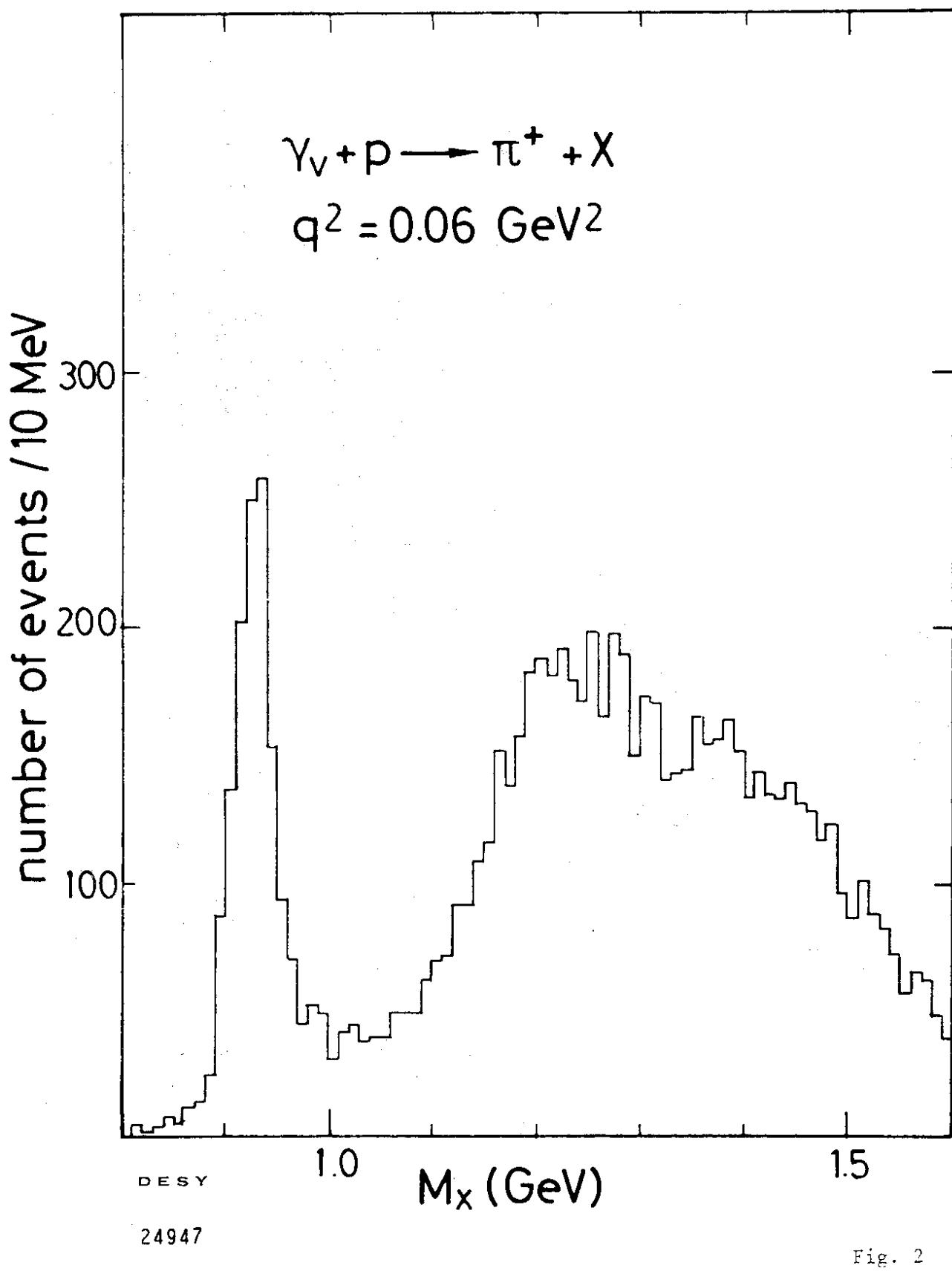


Fig. 2

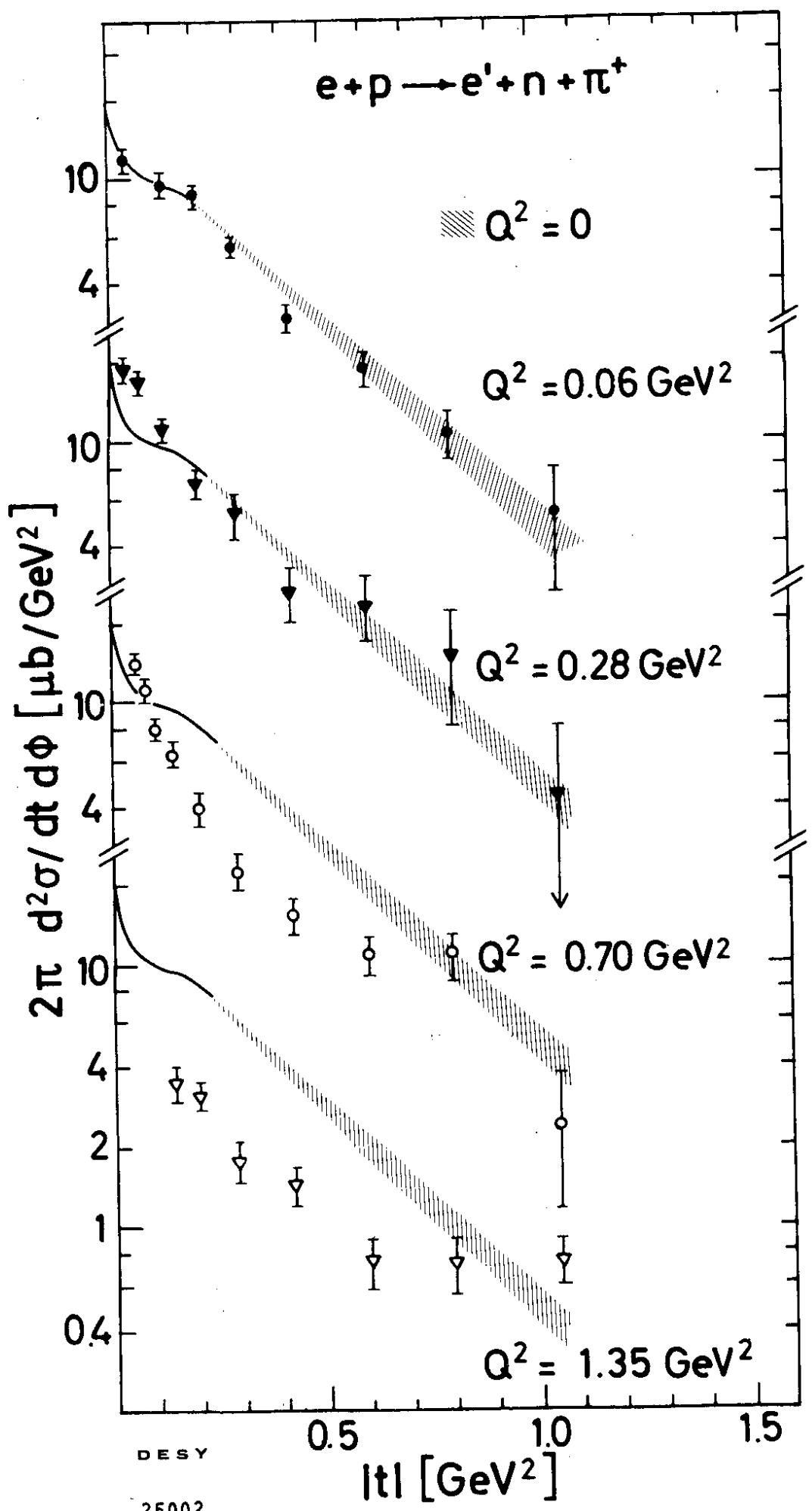
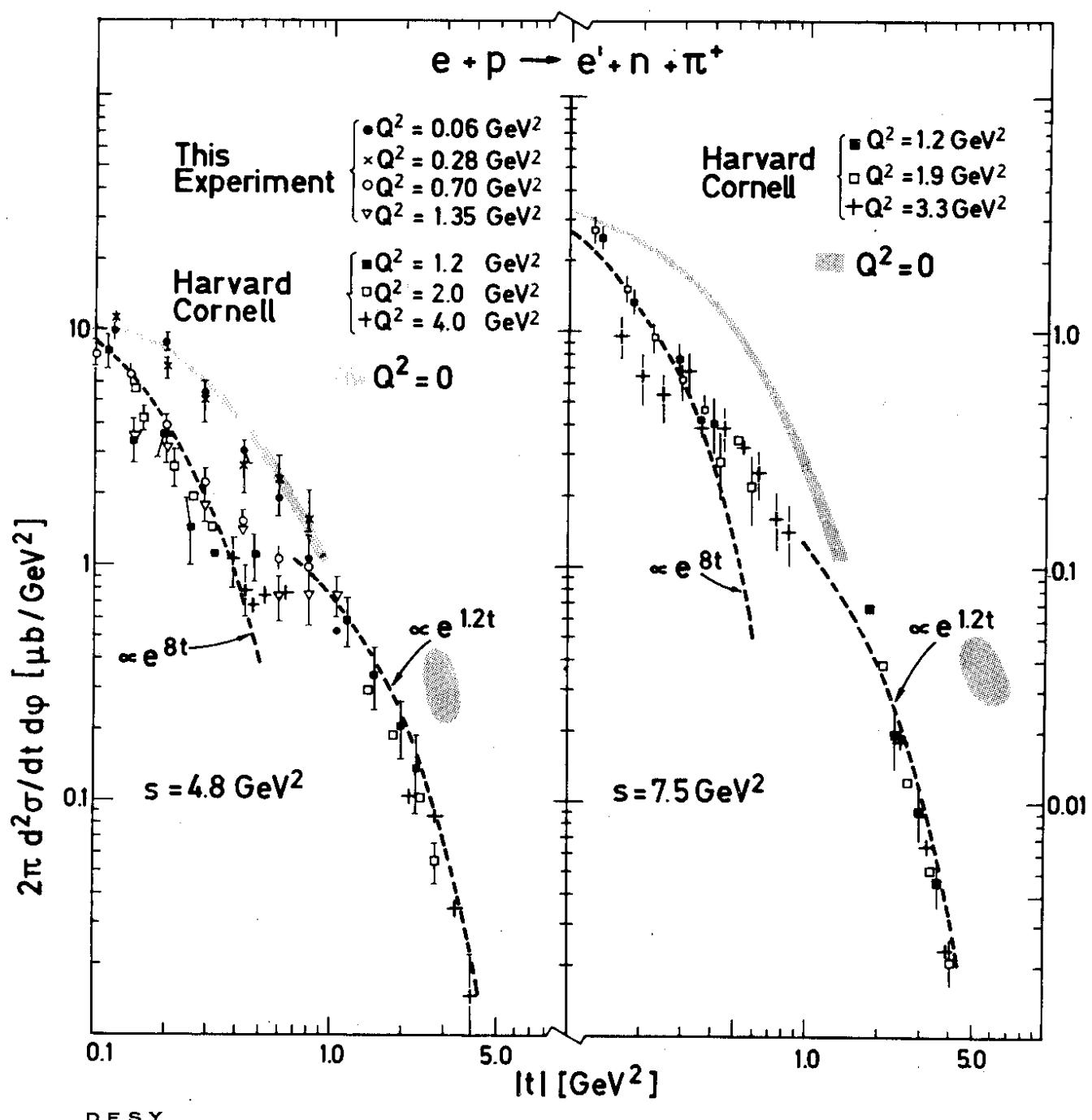


Fig. 3



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Fig. 4

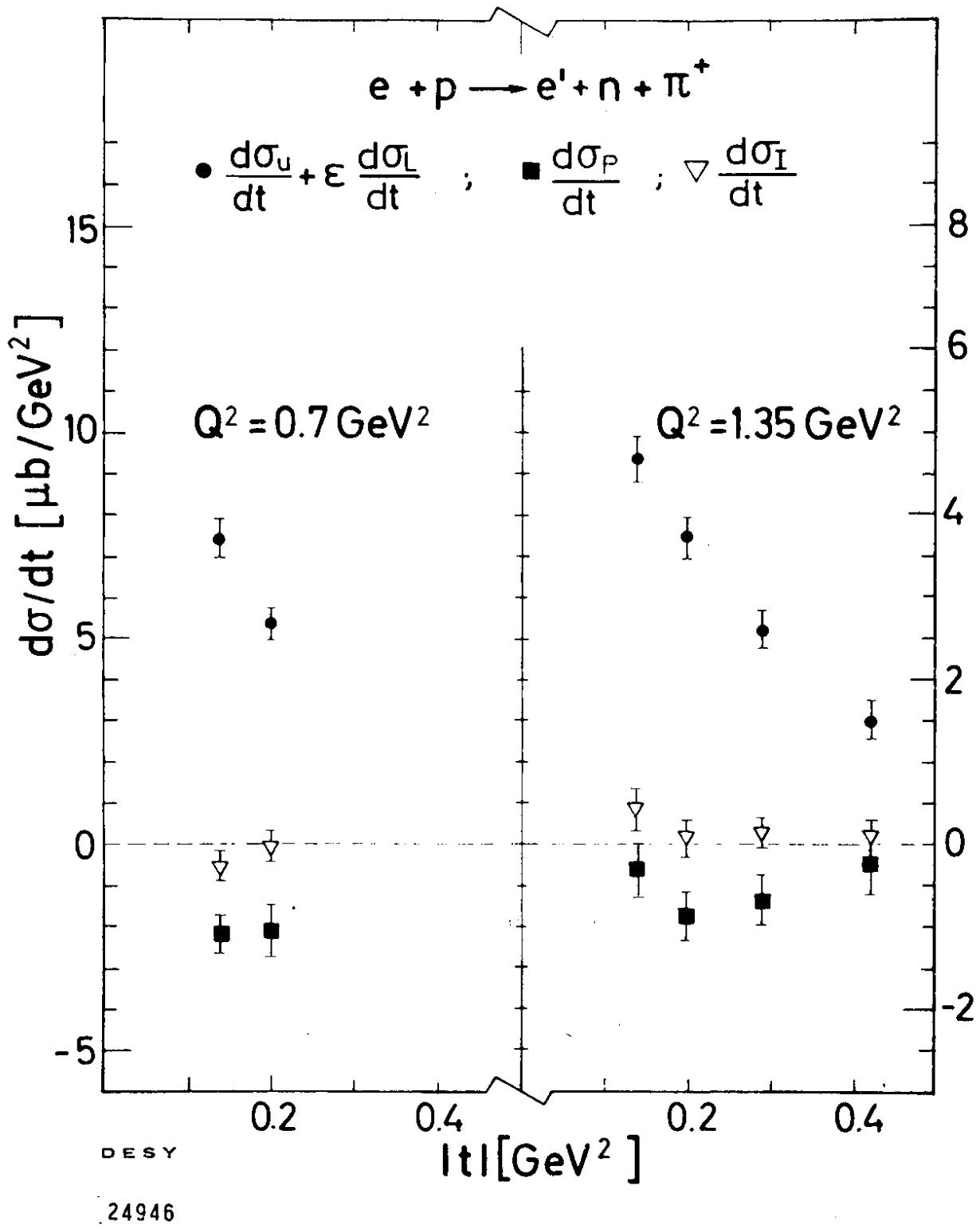


Fig. 5

