π^+-ELECTROPRODUCTION ABOVE THE RESONANCE REGION

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The reaction $e + p \to e' + n + \pi^+$ was studied detecting e' and 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 $Q^2 > 0.7$ GeV^2 and $|t| > 0.2$ GeV^2.

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

$$e + p \to e' + n + \pi^+ \qquad (1)$$

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 $|t| < 0.1$ 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 $|t| > 0.1$ GeV^2.

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

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

$$= \Gamma \cdot \left[\frac{d\sigma_U}{dt} + \epsilon \frac{d\sigma_L}{dt} + \epsilon \frac{d\sigma_P}{dt} \cos(2\phi) \right. \qquad (2)$$

$$\left. + \sqrt{2\epsilon(\epsilon+1)} \frac{d\sigma_I}{dt} \cos(\phi) \right].$$

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

The external electron beam from DESY with an energy spread of ±0.25% was focused onto a liquid hydrogen target 10 cm 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 described in ref. [5].

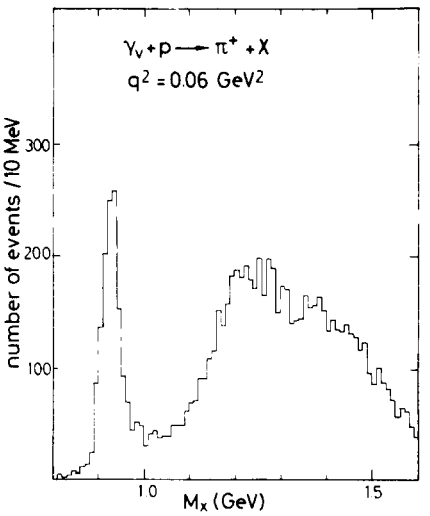

Fig. 1. Distribution of the missing mass $M_x = \sqrt{(e + p - e' - \pi)^2}$.

The electron spectrometer was positioned at a fixed angle of 10° (13° at $Q^2 = 1.35$ 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 resolution achieved was 1.2% (FWHM) and the accepted momentum band amounted to 45% (FWHM). The angular acceptance was 16 mrad in the horizontal direction and 200 mrad in the vertical. For the trigger, a coincidence between at least three of the four hodoscopes of each spectrometer was required. Electrons were identified by means of a threshold Cerenkov counter and a 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. A 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. 1. For each nominal value of Q^2, events with $0.85\ \text{GeV} \leqslant M_X \leqslant 1.02\ \text{GeV}$ 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 effects [6]: 17%–32% 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) deadtime of the read-out system: $\lesssim 3\%$, f) counter inefficiency; $\lesssim 1.5\%$, g) pion absorption: $\lesssim 3\%$. The corrections for pion decay in flight

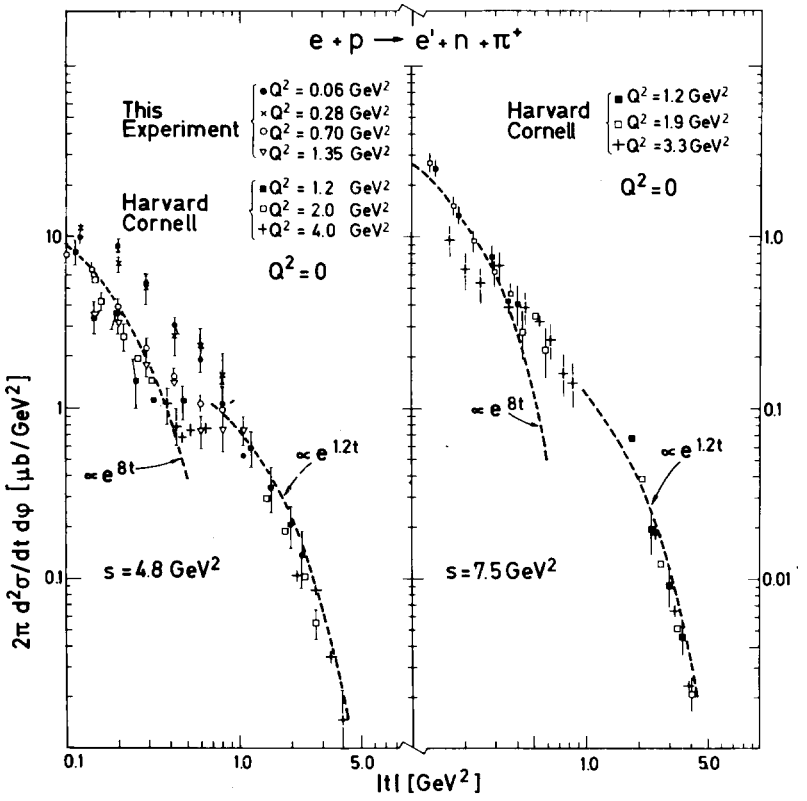

Fig. 2. The cross section $2\pi d^2\sigma/dt d\phi$ versus $|t|$ for the four nominal values of Q^2 together with recent data from the Harvard-Cornell Group [7, 8]. The data shown were taken in the range $135° \leqslant \phi \leqslant 225°$ ($-45° \leqslant \phi \leqslant 45°$ for $s = 7.5$ GeV^2, $|t| \leqslant 0.9$ GeV^2). Error bars are only plotted at some representative points. The dashed lines are drawn to guide the eye.

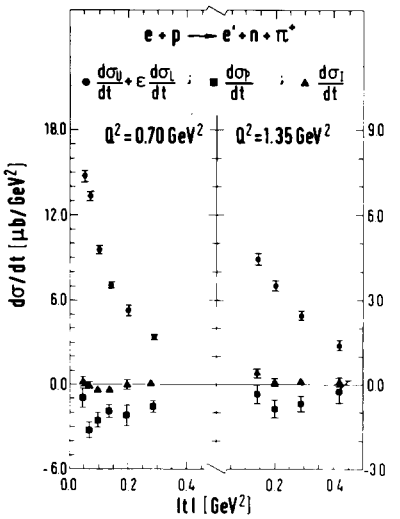

Fig. 3. $|t|$-dependence of the cross sections $d\sigma_U/dt + \epsilon d\sigma_L/dt$, $d\sigma_I/dt$, and $d\sigma_P/dt$.

are to a large extent covered by b). The overall uncertainty of these corrections was estimated to be less than 5%.

In fig. 2 we show the cross section $2\pi d^2\sigma/dtd\phi$ as a function of $|t|$ for various values of Q^2 together with recent data from the Harvard-Cornell group [7, 8]. For this figure, only the data within the range of $135° \leqslant \phi \leqslant 225°$ ($-45° \leqslant \phi \leqslant 45°$ for $s = 7.5$ GeV^2, $|t| \leqslant 0.9$ 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 small $|t|$ data of ref. [7] were converted from $d\sigma/d\Omega$ to $d\sigma/dt$ and scaled to the nominal value of s according to $(s - M^2)^{-2}$. The $|t| \geqslant 1$ GeV^2 data of ref. [8] were extrapolated to the nominal s value according to the functional dependence given in ref. [8] and then converted to $d\sigma/dt$.

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. The cross section $d^2\sigma/dtd\phi$ is roughly independent of Q^2 for $|t| \geqslant 0.2$ GeV^2 and $Q^2 \geqslant 0.7$ GeV^2. Qualitatively the same behaviour is shown at $s = 7.5$ GeV^2. 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 $s = 4.8$ GeV^2 $|t_{max}| = 3.2$ GeV^2 and $|t_{max}| = 7.5$ GeV^2 for $Q^2 = 4.0$ GeV^2) and with it the position of a backward peak. Integrating the data in fig. 4 over $|t|$ one finds that $\sigma(\gamma_v + p \to \pi^+ + n)$ shows roughly the same Q^2-dependence as $\sigma_{tot}(\gamma_v + p)$ for $Q^2 \geqslant 0.7$ GeV^2.

For the higher Q^2 data we were able to separate the ϕ-dependent terms of eq. (1) up to $|t| = 0.4$ GeV^2. The results are shown in fig. 3. The longitudinal-transverse interference term $d\sigma_I/dt$ is small for $0.1 \leqslant |t| \leqslant 0.4$ GeV^2. The data imply $d\sigma_\perp/dt > d\sigma_\parallel/dt$, since $d\sigma_p/dt = \frac{1}{2}(d\sigma_\parallel/dt - d\sigma_\perp/dt)$, where $d\sigma_\parallel/dt$ and $d\sigma_\perp/dt$ are the cross sections for transverse photons polarized parallel and perpendicular to the hadron production plane. From $d\sigma_u/dt = \frac{1}{2}(d\sigma_\parallel/dt + d\sigma_\perp/dt)$ we obtain for $0.2 \lesssim |t| \lesssim 0.4$ GeV^2 an upper limit for $d\sigma_L/dt$ of the order of $d\sigma_\perp/dt$.

The observed decreasing Q^2-dependence with increasing $|t|$ and Q^2 was predicted by Gutbrod and Kramer [9] and by Actor, Körner and Bender [10]. The authors of ref. [9] conjectured from an analysis of the $|t| \leqslant 0.1$ 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. [10] predicted this behaviour from a dual current model with an infinite number of vector mesons.

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