π°-ELECTROPRODUCTION ON HYDROGEN NEAR THRESHOLD AT FOUR-MOMENTUM TRANSFERS OF 0.2, 0.4 AND 0.6 GeV²

P. BRAUEL, F.-W. BÜSSER *, Th. CANZLER, D. CORDS, W.R. DIX, R. FELST,
G. GRINDHAMMER, W.-D. KOLLMANN, H. KREHBIEL, J. MEYER and G. WEBER

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

The reaction $e + p \rightarrow e + \pi° + p$ was measured near the one pion threshold, detecting the final electron and proton in coincidence for values of $q^2 = 0.2$, 0.4 and 0.6 GeV². The slope of the cross section at threshold is determined. The data are compared with those of the $e + p \rightarrow e + \pi^+ + n$ reaction, measured simultaneously, and with the results of pseudovector Born approximation and with dispersion theoretical calculations.

We report on an experiment, in which the reactions

$$e + p \rightarrow e + n + \pi^+ , \tag{1}$$

and

$$e + p \rightarrow e + p + \pi° , \tag{2}$$

were studied at squared foi ·momentum transfers of $q^2 = 0.2, 0.4$ and 0.6 GeV² and at invariant masses W of the pion-nucleon system between threshold and 1.13 GeV. From the results of reaction (1), published previously [1], we deduced within a theoretical framework based on PCAC and current algebra, values of the axial vector nucleon form factor. For this analysis, the Born-term-model of ref. [2], with pseudovector pion-nucleon coupling, was used. The same model, without contact and pion exchange term, also predicts the cross section of reaction (2) near threshold. The results for reaction (2) therefore provide a check on the validity of some of the theoretical assumptions on which the model of ref. [2] is based. In the following we present the cross section of reaction (2) and compare the data with those of reaction (1) as well as with the results of the pseudovector Born approximation [2] and dispersion theoretical calculations [3,4].

The (n π⁺) and (p π°) channels were measured simultaneously and the experimental set up was identical to the one described in ref. [1]. Electrons scattered at an angle of 8.5° were detected together with the coincident protons, whose flight direction was measured by
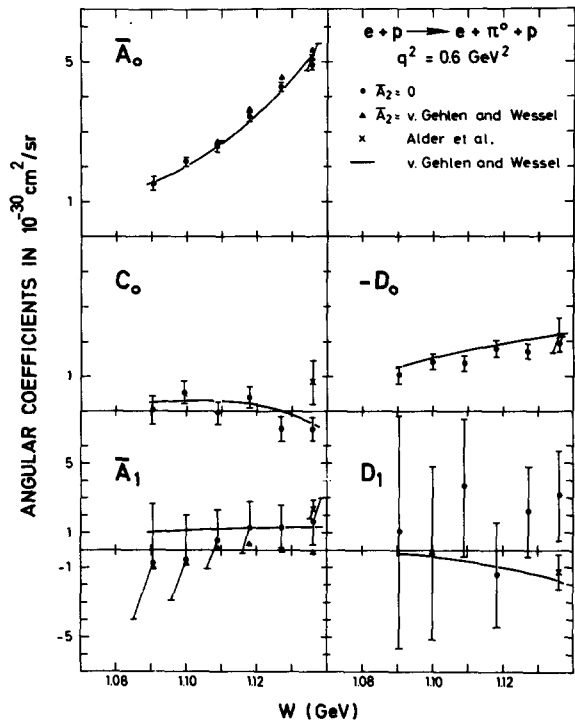

Fig. 1. Angular coefficients obtained from the fits to the $q^2 = 0.6$ GeV² data are plotted versus W for two different sets of $\bar{A}_2$. The results coincide where only one symbol is plotted. The curves drawn are from the dispersion theoretical calculation of ref. [4]. The data of Alder et al. [11] are plotted for comparison.
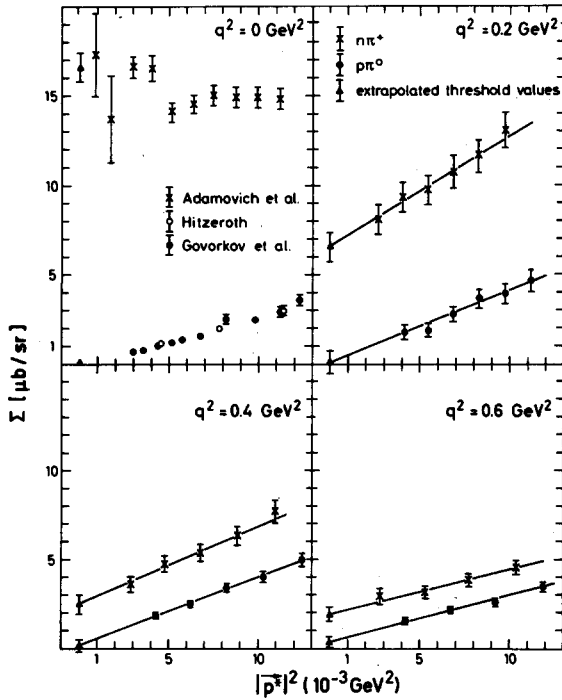
* Present address: CERN, Geneva, Switzerland.

Fig. 2. Σ of the $(n\pi^+)$ and $(p\pi^\circ)$ channels versus $|p^*|^2$. Σ is proportional to the slope of integrated cross section. The photoproduction values are plotted for comparison. The extrapolated threshold values are specially indicated.

a 9×6 array of large volume plastic scintillation counters. The proton efficiency of this counter system was about 90%. It was calibrated via elastic (e-p)-scattering. Only protons going backward in the CMS at $q^2 = 0.2$ GeV^2 were of too short range to be registered.

As discussed in ref. [1] the differential cross section of reactions (1) or (2) can be specified by

$$d^3\sigma/dE'\,d\Omega_e\,d\Omega_\pi^*$$

$$= \Gamma_t \frac{W|p^*|}{E_\gamma M} \left[\bar{A}_0 + \bar{A}_1 \cos\theta^* + \bar{A}_2 \cos^2\theta^* \right.$$

$$+ \epsilon \sin^2\theta^* \cos 2\phi^* C_0$$

$$\left. + \sqrt{\epsilon(\epsilon+1)/2} \, \sin\theta^* \cos\phi^* (D_0 + D_1 \cos\theta^*) \right] .$$

(3)

This follows from the one photon exchange approximation and from taking only s- and p-waves of the π-N-system into account.

The data analysis was very similar to the one described in ref. [1]. It was performed by fitting the rates calculated from eq. (3) by Monte Carlo techniques to the measured proton rates in each of the various nucleon detector elements. In these calculations the angular coefficients $\bar{A}_0, \bar{A}_1, C_0, D_0, D_1$ were treated as free parameters. $\bar{A}_2$ was inserted from theory, in order to keep the errors small. Separate fits were made for each W bin.

In fig. 1 the angular coefficients obtained from the fits are plotted versus W for the $q^2 = 0.6$ GeV^2 measurements as an example. Fits for two different sets of $\bar{A}_2$ values are shown. $\bar{A}_2 \equiv 0$ and $\bar{A}_2$ as calculated by v. Gehlen and Wessel [4] are used ($\bar{A}_2 = 0.0, -0.2, -0.6$ μb/sr at $W = 1.080, 1.10, 1.12$ GeV respectively are the values). The coefficients C_0, D_0 and D_1 turn out to be independent of $\bar{A}_2$, and $\bar{A}_0$ is only weakly correlated with $\bar{A}_2$. The error bars in fig. 1 do not include an overall normalisation error of about 4% and the errors due to the uncertainties of the W scale. The curves shown in fig. 1 which are the results of a dispersion theoretical calculation by v. Gehlen and Wessel [4] fit the data quite well within the errors. The $q^2 = 0.2$ and 0.4 GeV^2 data show the same qualitative features. The full results will be published elsewhere.

Table 1

Threshold values Σ^{thr} as a function of q^2. The total errors are split into uncorrelated errors and errors which are correlated between both channels. The latter are mainly due to the uncertainty of the W scale.

q^2 (GeV^2)	$e + p \rightarrow e + n + \pi^+$			$e + p \rightarrow e + p + \pi^\circ$		
	$\Sigma^{thr}_{(\mu b/sr)}$	error (μb/sr) uncorrelated	correlated	$\Sigma^{thr}_{(\mu b/sr)}$	error (μb/sr) uncorrelated	correlated
0.2	6.55	± 0.82	± 0.70	0.09	± 0.66	± 0.50
0.4	2.50	± 0.50	± 0.50	0.15	± 0.31	± 0.60
0.6	1.91	± 0.38	± 0.40	0.36	± 0.27	± 0.50
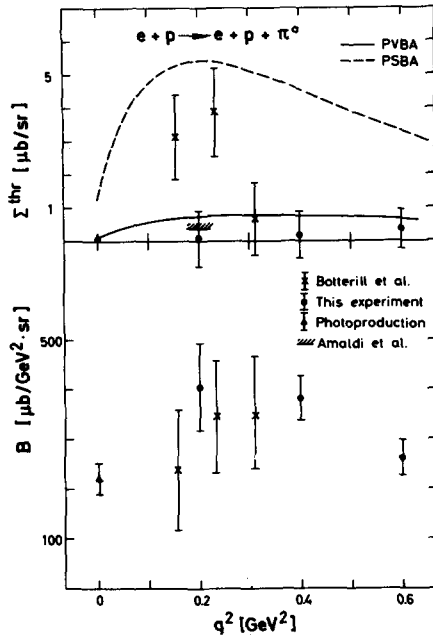
Fig. 3. The threshold value Σ^{thr} and the slope B of Σ determined from the π° data of the present experiment versus q^2. The full errors are shown. Results of the experiments at Frascati [10] and Daresbury [9] are also shown as well as the photoproduction value [5–8]. The curves drawn are the results obtained from the Born terms only, using pseudoscalar (PSBA) and pseudovector (PVBA) pion nucleon coupling.

The integrated cross section for each channel is given by

$$\frac{d^2\sigma}{dE'd\Omega_e}\, \Gamma_t\, \frac{W|p^*|}{E_\gamma M}\, 4\pi\, \Sigma \,, \qquad (4)$$

$$\Sigma = \bar{A}_0 + \tfrac{1}{3}\bar{A}_2 \,. \qquad (5)$$

The quantity Σ was found to be independent of our assumptions about $\bar{A}_2$. This is to be expected since in the present experiment the integrated cross section (4) is measured almost independently of the angular distribution (3). The quantity Σ, which is plotted versus $|p^*|^2$ in fig. 2 (p^* is the pion momentum in the CMS of the outgoing hadrons), is therefore proportional to the slope of the integrated cross section. For comparison the Σ values obtained from the π^+ data [1] are shown in fig. 2 together with those from positive [5, 6] and neutral [7, 8] pion photoproduction. The error

bars shown include the statistical and normalisation errors except for the error due to the uncertainty of the W scale, which is correlated for both channels and is listed separately in table 1. Threshold values were obtained by fitting a straight line

$$\Sigma = \Sigma^{thr} + B|p^*|^2 \,, \qquad (6)$$

to the data points. The numerical values of Σ^{thr} are listed in table 1. The q^2 dependence of Σ^{thr} and B for the $(\pi^\circ p)$ channel is shown in fig. 3. Also shown are the photoproduction values [7] and the results of the Frascati [10] and the Daresbury [9] experiments. In the latter the $(p\pi^\circ)$-channel was not measured directly but the data were obtained by subtracting the $(n\pi^+)$-channel from the total cross section. The curves shown are calculated in Born approximation using pseudoscalar (PSBA) and pseudovector (PVBA) pion nucleon couplings and proton form factors given by the relations

$$G_M^P(q^2)/\mu_p = G_E^P(q^2) = (1+q^2/0.71)^{-2} \,.$$

Summarizing our results we conclude the following:

a) The slope of the π° cross section at threshold

$$\Sigma^{thr} = \lim_{|p^*|\to 0} \frac{ME_\gamma}{4\pi\Gamma_t W|p^*|}\, \frac{d^2\sigma}{d\Omega_e dE'} \,,$$

b) Near threshold the ratio $\Sigma^{\pi^\circ}/\Sigma^{\pi^+}$ increases with increasing q^2. The data even indicate that Σ^{π° near threshold rises with increasing q^2 reaching a maximum at about $q^2 = 0.3\ \mathrm{GeV}^2$.

c) Within the errors the dispersion theoretical calculations of v. Gehlen and Wessel [4] fit the π° data quite well. The pseudovector Born approximation results are consistent with the values of Σ^{thr} measured in the present experiment. Therefore its application is justified for the case of π^+ electroproduction.

References

[1] P. Brauel et al., Phys. Letters 45B (1973) 389.

[2] N. Dombey, B.J. Read, Nucl. Phys. B60 (1973) 65.

[3] G. v. Gehlen, Nucl. Phys. B9 (1969) 17 and Nucl. Phys. B20 (1970) 102.

[4] G. v. Gehlen, H. Wessel, Bonn Univ. PI 2-94 (1971).

[5] M.I. Adamovich et al., Sov. Journal of Nucl. Phys. 7 (1968) 643.

[6] M.I. Adamovich et al., Sov. Journal of Nucl. Phys. 2 (1966) 95.

[7] B.B. Govorkov, S.P. Denisov and E.V. Minarik, Sov. Journal of Nucl. Phys. 4 (1967) 265.

[8] W. Hitzeroth, Nuovo Cimento 60A (1969) 467.

[9] D.R. Botterill et al., Lett. Nuov. Cim., 8 (1973) 910.

[10] E. Amaldi et al., Nuovo Cimento 65A (1970) 377.

[11] J.C. Alder et al., Nucl. Phys. B46 (1972) 573.