Separation of the transverse and longitudinal components of the cross section for pion electroproduction on a proton at the threshold

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We report the results of inelastic scattering of electrons by protons at the threshold at $k^2=5F^{-2}$. We determine the quantities $|E_0+|$ and $|S_0+|$, from which we obtain the values of the axial-vector form factor of the nucleon and the form factor of the pion.

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A number of experimental studies of electroproduction of pions on protons at threshold have demonstrated the applicability of current algebra in conjunction with the PCAC hypothesis and made it possible to determine the axial-vector form factor of the nucleon G_A. However, in all the preceding measurements they determined the sum of the contributions of the transverse component σ_t and the longitudinal component σ_l of the virtual photon. We present, for the first time, the results of their separation at a momentum transfer $k^2=5.9\ F^{-2}$. This turns out in essence to be a realization of the previously proposed[2,3] new method of determining the form factor F_π of the pion.

The experiment was performed with the Khar'kov linear electron accelerator. The spectra of the inelastically scattered electrons were measured with a magnetic analyzer and a multichannel telescope with a total momentum range 12.5%.[3]

To separate σ_t and σ_l, the measurements should be carried out at fixed k^2 and at invariant mass W of the πN system, but at different values of the polarization factor ϵ of the virtual photon. The wider the polarization interval, the lower the accuracy in the determination of σ_t and σ_l. In the region near the threshold of pion electroproduction, the contribution made to σ_t and σ_l is determined mainly by the s-wave, and the cross section can be characterized by the limit[2] 1)

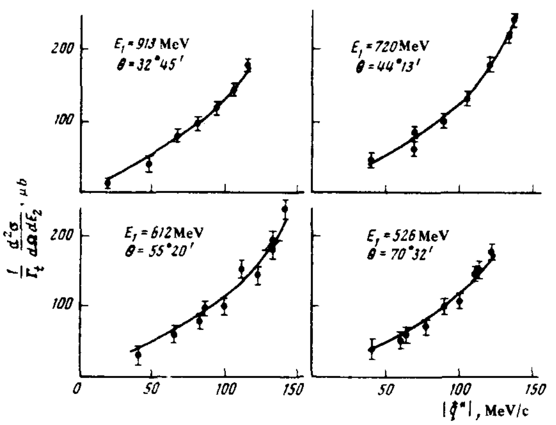

FIG. 1. Pion electroproduction cross section vs. the pion 3-momentum in the c.m.s. Curves—results of best fit.

$$\lim_{q^*\to 0}\frac{1}{q^*}\frac{d^2\sigma}{d\Omega\, dE_2}=\Gamma_t\frac{M}{WK}\left[\,|E_{0^+}|^2+\epsilon k^2|S_{0^+}|^2\,\right], \quad (1)$$

where Γ_t is the flux of virtual photons, K is the energy of the equivalent photon, M is the nucleon mass, q^* is the 3-momentum of the pion in the c.m.s., and E_{0^+} and S_{0^+} are the transverse and logitudinal multipoles of the S wave. From the value of the limit we determine the threshold value of the sum of the multipoles $A(k^2,\epsilon)=|E_{0^+}|^2+\epsilon k^2|S_{0^+}|^2$.

To find the varied parameter $A(k^2,\epsilon)$ by least squares the cross section was fitted to relation (1), in which a radiative correction was introduced.[4] In addition, account was taken of the correction for the angle spread (± 2°), the momentum spread in each channel (±1.25%), and the length of the liquid-hydrogen target (50 mm). We included in the data reduction the points with the c.m.s. pion 3-momentum $q^*<140$ MeV/c. Under these conditions, it was necessary to take into account the contribution of the p-wave, which we calculated in the Born approximation for the nonresonant multipoles. The contribution of the resonance calculated using the values of δ_{33} obtained in πN-scattering phase-shift analysis.

The measurement results are shown in Fig. 1. We introduced in the experimental data a radiative correction for the experimental resolution. The values of $A(k^2,\epsilon)$ obtained from these spectra are shown in Fig. 2 as functions of the polarization parameter ϵ. The point marked by a square was obtained by reducing one of the spectra that were measured by us with other apparatus.[5] The straight line was drawn by least squares and yields the values $|E_{0^+}|^2=114\pm15\ \mu b$ and $|S_{0^+}|^2=370\pm120\ \mu b$-GeV^{-2}. The ratio of the contribu-

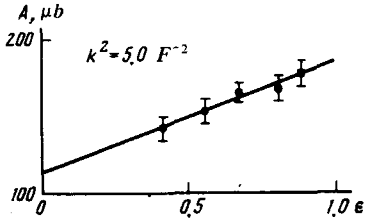

FIG. 2. Plot of $A=|E_{0^+}|^2+\epsilon k^2|S_{0^+}|^2$ against the virtual-photon polarization operator.

tions of the longitudinal and transverse components, $k^2|S_{0+}|^2/|E_{0+}|^2 = 0.63 \pm 0.20$. According to the model of[2], which is a pseudovector Born approximation with dispersion corrections, it follows from the obtained values of $|E_{0^+}|^2$ and $|S_{0+}|^2$ that $G_A = 0.71 \pm 0.04$ and $F_\pi = 0.90 \pm 0.16$.

The value of the axial-vector form factor of the nucleon agrees well with the data of other groups at $k^2 = 5.0\ F^{-2}$. The method itself used to determine G_A from E_{0+} has fewer model uncertainties, since there is no need to make any assumptions whatever concerning the longitudinal component of the cross section.

The value of F_π obtained by us lies higher than it would follow from the behavior of the isovector form factor of the nucleon F_1^V in the ρ-dominance model. This may indicate a smaller pion radius. More definite conclusions can be drawn only by investigating the behavior of F_π in a certain interval of k^2. We hope to obtain this formation in the nearest future.

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1) The quantities E_{0^+} and S_{0^+} differ from the corresponding quantities in[2] by the factor $\alpha = 1/137$.

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