Observation of the Compton effect at the π^- meson

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(Submitted 2 March 1982)

Pis'ma Zh. Eksp. Teor. Fiz. **35**, No. 7, 302–304 (5 April 1982)

Elastic scattering of π^- mesons by photons (the Compton effect at the π^- meson) has been detected experimentally for the first time. The polarizability of the charged pion is estimated to be $\alpha_\pi = (5 \pm 4) \times 10^{-43}$ cm^3.

PACS numbers: 13.60.Fz, 14.40.Aq

Information on a fundamental structural constant—the polarizability of the charged pion—may be obtained by studying the elastic scattering of π mesons by photons. There has been no previous study of the polarizability of the pion, although it has been calculated in several places, on the basis of the quark, dispersion, chiral, and other theories (see the review by Petrun'kin[1]).

The basic difficulty confronting attempts to study the Compton effect at the pion is the lack of pion and photon targets. On the other hand, it is a well-known fact that the interaction of fast particles with nuclei is governed by the Coulomb potential at a sufficiently small momentum transfer.[2,3] Calculations by Gal'perin *et al.*[4] show that the reaction

$$\pi^- + \text{nucleus} \rightarrow \text{nucleus} + \pi^- + \gamma \qquad (1)$$

should be dominated by the scattering by the photons of the Coulomb field of the nucleus at 4-momentum transfers to the nucleus satisfying $|t| \lesssim 2 \times 10^{-4}$ (GeV/c)^2. The polarizability can be found by analyzing the hard part of the energy spectrum of the bremsstrahlung photons.

In the present experiments we studied reaction (1) at carbon nuclei at a beam momentum of 40 GeV/c. The scattered π^- mesons were detected over the energy range 4-16 GeV, and the photons were detected over the respective range 36-24 GeV. The kinematics of this experiment is equivalent to the scattering of photons with an energy of 60-600 MeV by pions at rest—the optimum situation for studying the polarizability.

The present experiment on the Compton effect at the π^- meson was carried out in a Sigma spectrometer. The experimental arrangement is shown in Fig. 1. The particle beam incident on the target is detected with scintillation counters S_1-S_4 and A_1, with gas-filled threshold and differential counters $\check{C}_1$ and D, with scintillation hodoscopes H_1 and H_2, and with beam proportional counters BPC_1 and BPC_2. The scattered π^- meson is detected by a magnetic spectrometer consisting of an SP-41G magnet, a system of proportional counters CPM_1 and CPM_2, a system of spark chambers CH, scintillation hodo-

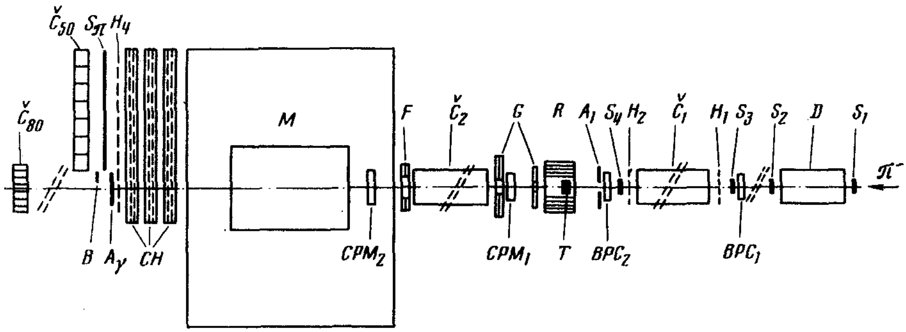

FIG. 1. The experimental arrangement. S_1-S_4, A_1 –Beam scintillation counters; $\check{C}_1$, $\check{C}_2$, D–gas-filled threshold and differential counters; H_1, H_2–beam scintillation hodoscopes; BPC_1, BPC_2 –beam proportional counters; T–nuclear target; R, G, F–sandwich counters; CPM_1, CPM_2 –proportional counters; M–spectrometric magnetic; CH–wire spark chambers; H_4, S_π–scintillation hodoscopes; A_γ, B–scintillation counters; $\check{C}_{50}$, $\check{C}_{80}$ –total-absorption Čerenkov counters.

scopes H_4 and S_π, and total-absorption Čerenkov counters, for an identification of the impurity electrons. The bremsstrahlung γ ray is detected with a γ spectrometer consisting of 80 total-absorption counters with a lead glass radiator. Sandwich counters R, G, and F (scintillator–tungsten and scintillator–lead counters) are used to suppress, at the trigger level, interactions involving breakup of the target nucleus and multiple-production reactions. These counters limit the angular acceptance of the spectrometer in the forward direction to ±12.5 mrad. A threshold Čerenkov counter $\check{C}_2$, with a threshold of 16 GeV/c for π^- mesons, is used to blank the part of the beam which has not interacted, elastic interactions, and electron bremsstrahlung. The part of the beam which has not interacted is also suppressed by scintillation counter B behind the magnetic spectrometer.

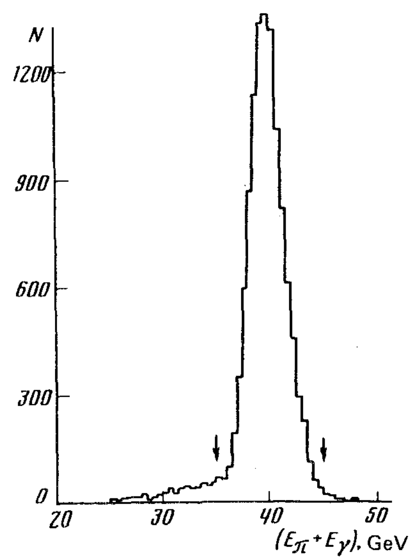

FIG. 2. Distribution of events in the total energy $E_\pi + E_\gamma$.

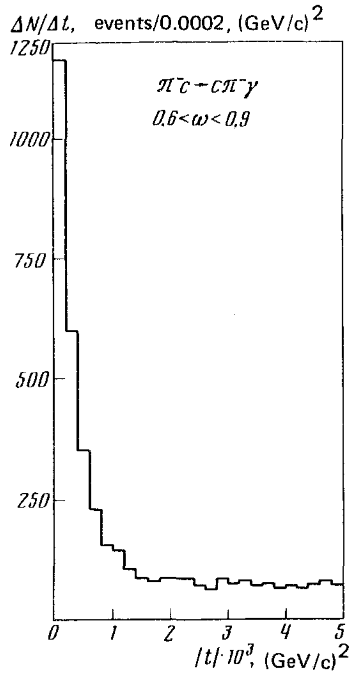

FIG. 3. Distribution of events in the square of the 4-momentum transfer to the nucleus, $|t|$.

In the experiment, $\sim 2 \times 10^{11}$ pions passed through the apparatus, and 2.1×10^{6} events were recorded on magnetic tape. The results which we will discuss here are based on an analysis of about 4×10^{5} events measured in a carbon target 12 g/cm^2 thick. The following criteria were used to identify events corresponding to reaction (1): The incident π^-meson is measured by the beam proportional counters; only one particle is detected in the magnetic spectrometer, and its momentum is less than 16 GeV/c; the tracks corresponding to the incident and scattered particles "join" in the target; and only a single γ ray is detected in the γ detector.

Figure 2 shows the distribution of events satisfying these criteria in the total energy $E_{\rm tot} = E_\pi + E_\gamma$. The peak at 40 GeV corresponds to reaction (1). We selected events from this peak for further study. The cutoff points are shown by the arrows in Fig. 2. Figure 3 shows the distribution in the square of the 4-momentum transferred to the nucleus. The peak at $|t| \lesssim 4 \times 10^{-4}$ (GeV/c)^2 corresponds to the Compton effect at the π^-meson.

We determined the cross section for the radiative scattering of pions in the Coulomb field of the carbon nuclei for momentum transfers $|t| \lesssim 1.2 \times 10^{-3}$ (GeV/c)^2 and for emitted-γ energies $\omega = E\gamma / E_{\rm tot}$ in the range $0.6 < \omega < 0.9$. This cross section turns out to be $\sigma_{\rm expt} = 210 \pm 60$ nb. The error in the cross section is due primarily to the systematic errors of the monitoring, the subtraction of the background due to interactions outside the target, and the error in the procedure used to extrapolate the strong-interaction background to small momentum transfers. In calculating the cross section, we took into account the acceptance of the apparatus (the geometric efficiency was ~80%) and corrections for the absorption of pions and γ rays in the medium. A theoretical cross section (in the Born approximation) was calculated from the equations of Refs. 4 and 5; this theoretical cross section corresponded to the Compton effect at a point pion. We found a ratio $\sigma_{expt}/\sigma_{teor} = 0.87 \pm 0.25$. From the differential ω distribution we estimate the polarizability of the pion to be $\alpha_\pi = (5 \pm 4) \times 10^{-43}$ cm^3. This polarizability is given in Gaussian units under the assumption[1] that the electric and magnetic polarizabilities are related by $\alpha_E = -\alpha_H$.

We wish to thank S. S. Gershteĭn, V. P. Dzhelepov, B. M. Pontekorvo, and L. D. Solov'ev for some fruitful discussions and for support of this study. We are deeply indebted to Yu. D. Prokoshkin and A. A. Tyapkin for some useful advice and for assistance in constructing the apparatus. We also thank A. Ts. Amatuni, V. A. Batarin, R. V. Pirtskhalava, and L. K. Lytkin for assistance in the measurements.

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Translated by Dave Parsons
Edited by S. J. Amoretty