REAL PHOTON SCATTERING ON THE PROTON

C. W. DE JAGER AND B. WOJTSEKHOWSKI

Physics Division, Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News, VA 23606, USA
E-mail: kees@jlab.org, bogdanw@jlab.org

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The physics of real photon exclusive scattering on the proton and JLab experiment E99-114 is discussed. Data on Compton form factors at s up to 11 $(\mathrm{GeV/c})^2$ and t up to 6.5 $(\mathrm{GeV/c})^2$ have been obtained. The polarization transfer parameter K_{LL} is found to be in fair agreement with the handbag diagram prediction. Possible additional polarization transfer measurements are outlined.

1. Introduction

The power of the lepton probe in unveiling the structure of matter has been used very productively in experiments on the nucleon. For several decades, mainly elastic and deep inelastic electron (also muon and neutrino) scattering (DIS) provided new information on the partons inside the nucleon, for which pQCD offers a well-developed framework of the parton distribution functions $q_a(x)$. At the same time almost all real photon beam experiments were limited to the diffractive regime. Until recently, the Cornell experiment [1] was the only one, which provided data on elastic photon scattering with large transverse momentum, where nucleon structure plays a dominant role. JLab experiment E99-114 [2] took data a few months ago in a wide kinematical range, shown in Figure 1. The spin crisis in the polarized parton distribution functions $\Delta q_a(x)$ motivated the development of the concept of generalized parton distributions (GPD) [3,4,5]. This phenomenology offers a unified description of exclusive processes, like elastic electron scattering, photon scattering, meson lepto-production, and DIS, which corresponds to the forward Compton scattering of the virtual photon.

2. Mechanism of Real Compton Scattering

Two sets of diagrams contributing to the real photon Compton scattering (RCS) reaction are shown in Figure 2. At the limit of large momentum

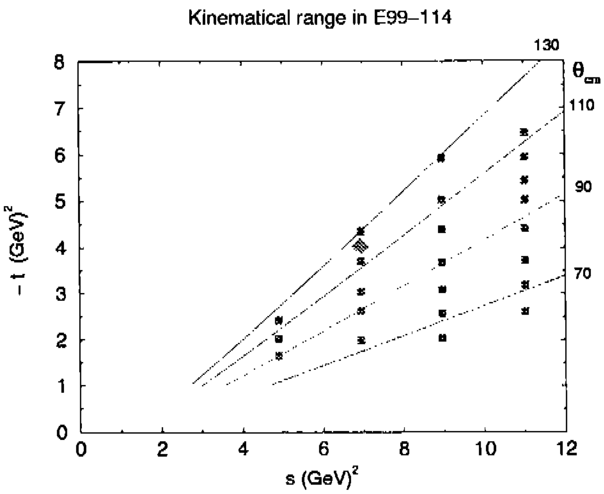

Figure 1. The kinematical coverage in JLab experiment E99-114.

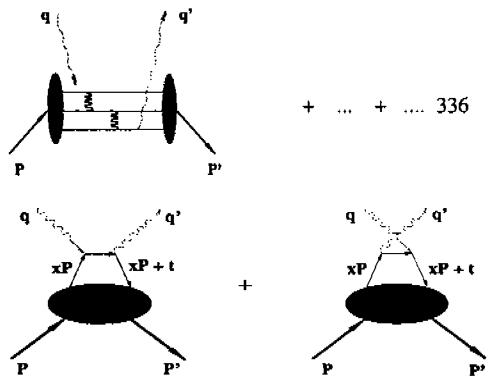

Figure 2. The RCS diagrams in pQCD (upper) and hand-bag approach (lower).

transfer pQCD predicts that two-gluon exchange will dominate. Several calculations, in the pQCD framework [6,7,8], found that the data [1] can not be explained by two-gluon exchange with available versions of parton distribution amplitudes. At the same time data show that the s and t dependences of the cross section are in fair agreement with the prediction of the pQCD constituent counting rule [9]: $d\sigma/dt = f(\theta_{cm}) \cdot s^{-n}$, where $n = 6$ for RCS (see Figure 3).

Calculations [10] show that in the regime of wide-angle Compton scattering (WACS) ($\sin(\theta^{\gamma}_{cm}) \sim 1$) at moderate momentum transfer the soft mechanism dominates. However, the soft mechanism almost mimics the

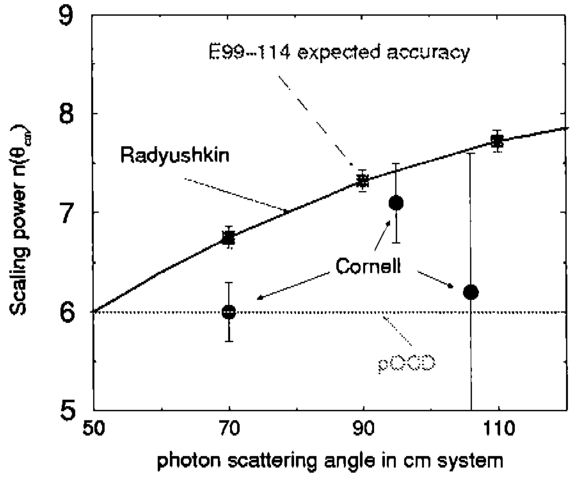

Figure 3. The scaling power prediction in hand-bag approach.

scaling power predicted in pQCD (see Figure 3), so much more accurate experimental data are needed to resolve the question of pQCD applicability. In the hand-bag mechanism only one quark interacts with the photons, no gluon exchange happens between the struck quark and the rest of the partons between the two quark-photon vertices. The physical factorization of the hand-bag diagram in hard and soft parts in the framework of GPD leads to a description of RCS with two form factors R_V and R_A [10,11]. The cross section can be presented as:

$$d\sigma/dt = (d\sigma/dt)_{\rm KN}\left[f_V R_V^2(t) + (1-f_V)R_A^2(t)\right],$$

where, $R_V(t) = \Sigma_a e_a^2 \int_0^1 F^a_{\zeta=0}(x;t)\frac{dx}{x}$ and $R_A(t) = \Sigma_a e_a^2 \int_0^1 G^a_{\zeta=0}(x;t)\frac{dx}{x}$, $F^a_{\zeta=0}(x;t)$ and $G^a_{\zeta=0}(x;t)$ are generalized parton distributions; $(d\sigma/dt)_{\rm KN}$ is the Klein-Nishina cross section; $f_V = (\tilde{s}-\tilde{u})^2/2(\tilde{s}^2+\tilde{u}^2)$ is a kinematic factor, $\tilde{s} = s - M^2$, $\tilde{u} = u - M^2$.

In the WACS regime f_V is close to 1, so the vector form factor R_V gives the dominant contribution to the cross section. According to the hand-bag approach [10] the ratio $d\sigma_{RCS}/d\sigma_{KN}$ at fixed t should have only very small s dependence. This can be used as a direct test of factorization.

With a circular polarized photon beam and a polarimeter for the proton the present experiment measured the polarization transfer parameter $K_{LL} = [d\sigma(++) - d\sigma(-+)]\,/\,[d\sigma(++) + d\sigma(-+)]$, where the indexes $++, -+$ refer to the photon helicity and proton longitudinal polarization.

In the hand-bag approach the value of K_{LL} can be related to the form

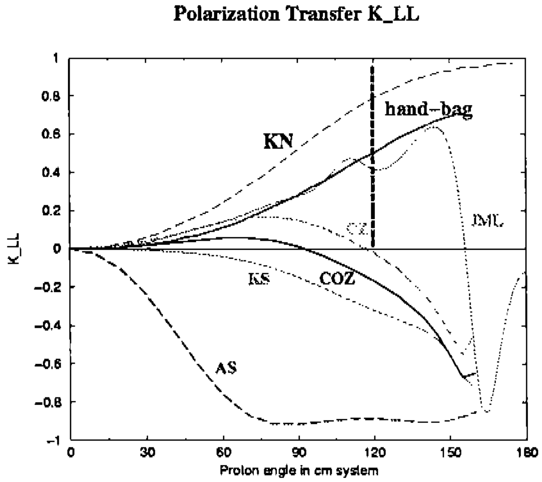

Figure 4. Predictions for K_{LL} polarization transfer. The labels on the curves refer to pQCD calculations with distributions - asymptotic (AS), Chernyak-Zhitnitsky (CZ), Chernyak-Ogloblin-Zhitnitsky (COZ), King-Sachrajda (KS); for Regge approach calculation by Cano-Laget (JML); for Klein-Nishina hard subprocess (KN); and hand-bag approach calculation by Kroll. Vertical line indicates where the measurement was done.

factors as $K_{LL} = \left[(\tilde{s}^2 - \tilde{u}^2)/(\tilde{s}^2 + \tilde{u}^2)\right] \frac{R_A}{R_V} \cdot f_V^{-1}$, where the bracket gives polarization transfer parameter for the hard subprocess. Figure 4 shows K_{LL} predictions in pQCD with different parton distribution functions, Regge and hand-bag models. Because of large differences between predictions K_{LL} gives unique possibility to find the dominant reaction mechanism.

3. Wide Angle Compton Scattering Experiment

The experiment used a bremsstrahlung photon beam, a liquid hydrogen target, a proton spectrometer and a photon calorimeter with sweep magnet. The intensity of the photon beam was 10^{13} equivalent quanta per second or about 1000 times higher than used in an earlier experiment [1]. Such a large progress was possible because of several factors: 100% d.f. of the electron beam, excellent beam quality which allowed to use mixed electron-photon beam, high segmentation of the calorimeter. High polarization of the electron beam (75%) and an efficient proton polarimeter with large luminosity allow to realize a measurement of the K_{LL}at $\theta^{\gamma}_{cm} = 120°$ with a statistical accuracy of ± 0.1.

By detecting the proton and photon in coincidence most of the background was eliminated. Through kinematic correlations between energies and angles of scattered photon and recoil proton, RCS events were separated from single-pion production which has about 100 times larger cross section.

It is feasible to measure K_{LL} at additional scattering angles. Special interest will be at $\theta_{cm} \sim 160°$, where a Regge calculation [13] predicts a large effect from the u-channel exchange diagram. Such a measurement requires detection of the proton at very forward angles which is possible in JLab Hall A with the septum magnet in front of the HRS spectrometer.

Summary

Preliminary result of RCS experiment on polarization transfer parameter K_{LL} agrees well with prediction [12] based on GPD approach.

Accumulated data in E99-114 will allow determination of the scaling power n of the cross section at three values of θ^{γ}_{cm} with accuracy of ± 0.1, which should be another decisive test of GPD qprediction [10].

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