Virtual Compton scattering : First results from JLab

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Abstract. The Virtual Compton Scattering process off the proton has been studied at Q^2 -values of 1.0 and 1.9 (GeV/c)² using the Hall A facilities of JLab. Data were taken below and above the pion production threshold as well as in the resonance region. Preliminary results, especially in relation with the Generalised Polarisabilities, will be presented.

INTRODUCTION

The Virtual Compton Scattering (VCS) process has the potential for becoming an adequate probe for the study of the internal structure of the nucleon. Its interest lies in the fact that it allows access to the 6 new observables called Generalised Polarisabilities (GPs) [1, 2], which are extensions of the electromagnetic polarisabilities $\bar{\alpha}$ and $\bar{\beta}$ that have been studied with Real Compton Scattering (RCS). In practise, VCS off the proton is accessible through the photon electro-production reaction $ep \rightarrow e'p'\gamma$, which is the coherent sum of two processes, the Bethe-Heitler (BH) and the true VCS one. This means that the real photon γ (with q' the modulus of its *cm* three-momentum) can be emitted either by the incoming or the outgoing electron (BH contribution) or in the VCS process on the proton itself. In this VCS reaction the photon is produced by the proton as a charged point particle (Born term) or by the excited nucleon (Non-Born term); the latter can be parameterized in terms of these GPs. The first two contributions, Bethe-Heitler and Born (BH -f #), can be accurately calculated within QED with the use of the electromagnetic form factors of the proton. The $ep \rightarrow e'p'\gamma$ reaction cross section can then be conveniently arranged as

$$d^5\sigma_{exp} = d^5\sigma_{BH+B} + [M_0 - M_0^{BH+B}] * [\Phi q'_{cm}] + O(q'_{cm})$$

wherein $d^5\sigma_{BH+B}$ represents the [Bethe-Heitler + Born] cross section which has terms $O(1/q', 1/q'_{cm})$ and $[M_0 - M_0^{BH+B}] * [\Phi q'_{cm}]$ is the lowest order Non-Born contribution to the cross section while $[\Phi q'_{cm}]$ is a phase space factor; the term $[M_0 - M_0^{BH+B}]$ contains a linear combination of GPs. It is precisely

from this term that two new structure functions can be deduced: $P_{LL} - \frac{1}{\epsilon} P_{TT}$ and P_{LT} (unpolarised experiment at fixed Q^2 and ϵ , the latter quantity being the virtual photon's polarisation), which themselves consist of linear combinations of five (out of six independent) GPs [3]. From an analysis of the data below the pion production threshold, first such results were obtained at MAMI/Mainz [4, 5, 6] at $Q^2 = 0.33$ (GeV/c)². Meanwhile, there has been a new theoretical development by Pasquini *et al* [7], allowing an interpretation of the measured cross section data up to the A-resonance region. This is the more interesting as a new VCS experiment (E93050) has been performed at the 4 GeV *cw* electron accelerator of JLab (USA) for which first, preliminary results will be presented here. With the aim to deepen our knowledge about these GPs, measurements were performed at $Q^2 = 1.0$ and 1.9 (GeV/c)²; additionally, it was also the intention to search the cross section for so-called missing resonances.

EXPERIMENTAL METHOD AND DATA ANALYSIS

A measurement of the VCS reaction cross section [8] puts stringent requirements on the quality of the experimental equipment used, such as the duty factor of the accelerator, the energy spread of the electron beam, the presence of high-resolution magnetic spectrometers, etc. Those conditions could be met by the facilities available in Hall A at JLab [9] and using a cryogenic liquid hydrogen target. The identification of the VCS signal in the $e + p \rightarrow e' + p' + x$ reaction (with $x = \gamma$ or π^0) relies on a coincidence between the scattered electron and the recoil proton while the third particle is reconstructed from a missing mass separation technique. For the determination of the absolute cross section values, the accurate knowledge of the solid angles subtended by the spectrometers is required; these were estimated using an extensive Monte Carlo simulation [10] which generates events starting from the

$BH + B$ cross section behaviour and incorporates all resolution deteriorating effects. The procedure was checked by a determination of the elastic scattering cross section at $Q^2 = 1.0 \text{ (GeV/c)}^2$ and agreement within 3% was found with the theoretical prediction based on the Bosted parametrisation [11] complemented with the results from a recent measurement at TJNAF [12] of the ratio of $\mu G_E^p(Q^2)/G_M^p(Q^2)$.

PRELIMINARY RESULTS • DISCUSSION

In the present stage of the analysis, preliminary results are available for all kinematical settings but only those at $Q^2 = 1.0 \text{ (GeV/c)}^2$ will be discussed here. Figure 1 shows the values determined in the leptonic plane as a function of $\theta_{cm}^{*\gamma}$ for $q' = 45, 75$ and 105 MeV (solid points), the full curve representing the $BH+B$ cross section. A rather strong effect on the cross section caused by the polarisability effect is observed around 30° . An iteration procedure for the solid angle simulation in which these polarisabilities are taken into account, makes the effect also to become visible around -200° , as expected and indicating the importance of a meticulous analysis. This

further shows that the magnitude of the deduced structure functions $P_{LL} - \frac{1}{\epsilon} P_{TT}$ and P_{LT} is of the order of only 1/10 [13] of that at $Q^2 = 0.33 \text{ (GeV/c)}^2$ [4]. At $Q^2 = 1.9 \text{ (GeV/c)}^2$ [14] similar effects are being observed, be it that the deviation from the $BH + B$ cross section becomes apparent only above the pion production threshold giving support to the results from the recently developed DR approach [7]. In the resonance region no experimental data exist as yet for the magnitude of or the structure in the cross section for the VCS process. In the present measurement, this reaction was studied at $Q^2 = 1.0 \text{ (GeV/c)}^2$ and for a total centre-of-mass energy W ranging from 0.95 to 2.0 GeV [15, 16] with, among others, the aim to possibly identify

FIGURE 1. Absolute cross sections for the $ep \rightarrow e' p' \gamma$ process as a function of $\theta_{cm}^{*\gamma}$ and for different values of q' ; the solid line represents the $BH + B$ cross section

FIGURE 2. Deduced cross sections in the resonance region for $Q^2 = 1.0 \text{ (GeV/c)}^2$, $\cos\theta_{cm}^{\gamma\gamma} = -0.975$ and $\phi = 180^\circ$; the solid curve represents the $BH + B$ contribution while also the prediction from the DR formalism in the Δ -region is plotted (dashed line).

any of the so-called missing resonances. The experimental result for $\phi=180^\circ$ is depicted in Fig. 2. The solid curve shows the contribution to the cross section from the $BH + B$ process while the dashed curve is the result from a calculation in the Δ -resonance using the DR formalism [7]. It is evident that, also beyond this Δ -resonance, a net cross section contribution with pronounced structure is observed above the $BH + B$ value. Although the present data do not show any sign of "missing" resonances, the agreement in the Δ -resonance with the DR prediction is encouraging especially as there is no normalisation between theory and experiment.

As a conclusion it seems that a first pass analysis of the data from the E93050 experiment at JLab already suggests the strong Q^2 -dependence of the structure functions $P_{LL} - \frac{1}{\epsilon} P_{TT}$ and P_{LT} ; further analysis should confirm this finding. In the resonance region, one observes a pronounced structure in the cross section for the $ep \rightarrow e'p'\gamma$ reaction; its detailed interpretation, however, awaits further theoretical developments.

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