CEA/SACLAY
DSM

DAPNIA/SPHN-98-70 10/1998

Virtual Compton Scattering at MAMI

$\gamma^* p \rightarrow \gamma' p'$

S. Kerhoas, R. Bartsch, J. Berthot, P.Y. Bertin, V. Breton, W.U. Boeglin, R. Böhm, N. D'Hose, T. Caprano, S. Derber, N. Degrande, M. Distler, J.E. Ducret, R. Edelhoff, I. Ewald, H. Fonvieille, J. Friedrich, J.M. Friedrich, R. Geiges, Th. Gousset, P.A.M. Guichon, H. Holvoet, Ch. Hyde-Wright, P. Jennewein, M. Kahrau, M. Korn, H. Kramer, K.W. Krygier, V. Kunde, B. Lannoy, D. Lhuillier, A. Lisenfeld, C. Marchand, D. Marchand, J. Martino, H. Merkel, K. Merle, P. Merle, G. De Meyer, J. Mougey, R. Neuhausen, E. Offermann, Th. Pospischil, G. Quemener, O. Ravel, Y. Roblin, J. Roche, G. Rosner, D. Ryckbosch, P. Sauer, H. Schmieden, S. Schardt, G. Tamas, M. Tytgat, M. Vanderhaeghen, L. Van Hoorebeke, R. Van de Vyver, J. Van de Wiele, P. Vernin, A. Wagner, Th. Walcher, S. Wolf.

DAPNIA

Couverture : Sylvie Cabrit et Marc Sauvage

Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée
CEA/Saclay F-91191 Gif-sur-Yvette Cédex

Few-Body Systems Suppl. 0, 1–4 (1998)

Few-Body Systems

Virtual Compton Scattering at MAMI $\gamma^* p \rightarrow \gamma' p'$

S. Kerhoas[a], P. Bartsch[d], J. Berthot[b], P.Y. Bertin[b], V. Breton[b], W.U. Boeglin[g], R. Böhm[d], N. d'Hose[a], T. Caprano[d], S. Derber[d], N. Degrande[c], M. Distler[d], J.E. Ducret[a], R. Edelhoff[d], I. Ewald[d], H. Fonvieille[b], J. Friedrich[d], J.M. Friedrich[d], R. Geiges[d], Th. Gousset[a], P.A.M. Guichon[a], H.Holvoet[c], Ch. Hyde-Wright[e], P. Jennewein[d], M. Kahrau[d], M. Korn[d], H. Kramer[d], K.W. Krygier[d], V. Kunde[d], B.Lannoy[c], D. Lhuillier[a], A. Liesenfeld[d], C. Marchand[a], D. Marchand[a], J. Martino[a], H. Merkel[d], K. Merle[d], P. Merle[d], G. De Meyer[c], J. Mougey[a], R. Neuhausen[d], E. Offermann[f], Th. Pospischil[d], G. Quemener[b], O. Ravel[b], Y. Roblin[b], J. Roche[a] , G. Rosner[d], D. Ryckbosch[c], P. Sauer[d], H. Schmieden[d], S. Schardt[d], G. Tamas[d], M. Tytgat[c], M. Vanderhaeghen[d], L. Van Hoorebeke[c], R. Van de Vyver[c], J. Van de Wiele[h], P. Vernin[a], A. Wagner[d], Th. Walcher[d], S. Wolf[d].

[a] *DAPNIA/SPhN, CEA/Saclay, F91191 Gif-sur-Yvette Cedex*
[b] *LPC, Univ. Blaise Pascal, IN2P3 Aubiere, France*
[c] *University of Gent, Belgium*
[d] *Institut für Kernphysik, Universität Mainz, Germany*
[e] *Old Dominium University, Virginia, U.S.A*
[f] *C.E.B.A.F, Virginia, U.S.A*
[g] *Florida International University, Miami,Florida, U.S.A*
[h] *IPN, IN2P3 Orsay, France*

1 Introduction

The virtual Compton scattering (VCS) is the electron scattering on a proton which radiates a real photon before being detected. The new observables, called generalized polarizabilities (GP), extracted from this VCS at threshold can be understood as the deformation of the charge and current distributions of the proton [1]. These GP are functions of the mass of the virtual photon Q^2. In real Compton scattering ($Q^2 = 0$), some polarizabilities of the nucleon are already measured [2]. With the VCS, we will generalized these observables by measuring them at different values of Q^2.

2 Formalism to extract Polarizabilities from cross sections

If we subtract on our experimental cross section ($d^5\sigma = \Phi\mathcal{M}$) the known cross sections[1] calculated from the Bethe Heitler (where the photon is emitted by the electrons BH) and Born (where the photon is emitted by a proton in the intermediate state) processes we obtain an interesting development in the final photon energy q' [1].

$$\frac{d^5\sigma^{exp} - d^5\sigma^{BH+Born}}{\Phi} = \mathcal{M}_0 - \mathcal{M}_0^{BH+Born} + (\mathcal{M}_1 - \mathcal{M}_1^{BH+Born})q' + \ldots \quad (2.1)$$

The extrapolation at q'=0 of our measurment gives us the constant term $\mathcal{M}_0 - \mathcal{M}_0^{BH+Born}$ (function of $Q^2, \epsilon, \theta, \phi$). This structure dependent term beyond the BH and Born processes was analyzed in terms of a multipole expansions which give 5 independent Generalized Polarizabilities (GP) [1][3]. This parametrization can be written as follow:

$$\frac{\mathcal{M}_0 - \mathcal{M}_0^{BH+Born}}{v_{LT}} = \frac{v_{LL}}{v_{LT}}(P_{LL}(Q^2) - \frac{1}{\epsilon}P_{TT}(Q^2)) + P_{LT}(Q^2) \quad (2.2)$$

where v_{LL}, v_{LT} are known kinematical coefficients (function of $Q^2, \epsilon, \theta, \phi$) and P_{LL}, P_{TT} and P_{LT} are linear combinations of 5 GP. With one value of ϵ, we can extract only two combinations of 5 GP, $(P_{LL} - \frac{1}{\epsilon}P_{TT})$ and P_{LT}.

3 Experimental results

Experimentally we performed the reaction $p(e, e'p')\gamma$ in two high resolution spectrometers in the A1 hall in Mainz. With a missing mass reconstruction we select our VCS events. For the first experiment [4], we decided to measure the GP at fixed $Q^2 = 0.33 GeV^2$. The other fixed kinematical quantities are ϵ=0.62 and φ=0,180 (in-plane measurement). Figure 1 presents five differential cross sections as a function of the angle θ between the two photons, for five photon energies q'. At low q', our data are in agreement with the QED calculation. When q' increases, we can see a deviation from this calcul which proves the effect of the polarizabilities. By using equation 2.1 at 15 different bins in θ, we extract the constant term in the development in q'. The 15 values of $\mathcal{M}_0 - \mathcal{M}_0^{BH+Born}$ should verify the equation 2.2, where the slope and the ordinate at origin are the unknown values that we want to extract from our data. Figure 3 presents this expected line and the table 1 the extracted values. For each observables, the first error is the statistical one coming out from the linear fit, and the second one is due to the method of extraction of the constant term in $q' = 0$. This systematic error will decrease very soon when the final analysis will finish. These experimental values are compared with different theoretical predictions [5],[6],[7],[8]. For this linear combination of GP, the best agreement is obtained for the Heavy Baryon Chiral Perturbation Theory, but the way to constraint really these models is to measure the GP independantly. This can be the next generation of VCS experiments at threshold.

[1]QED+ Elastic Form Factors

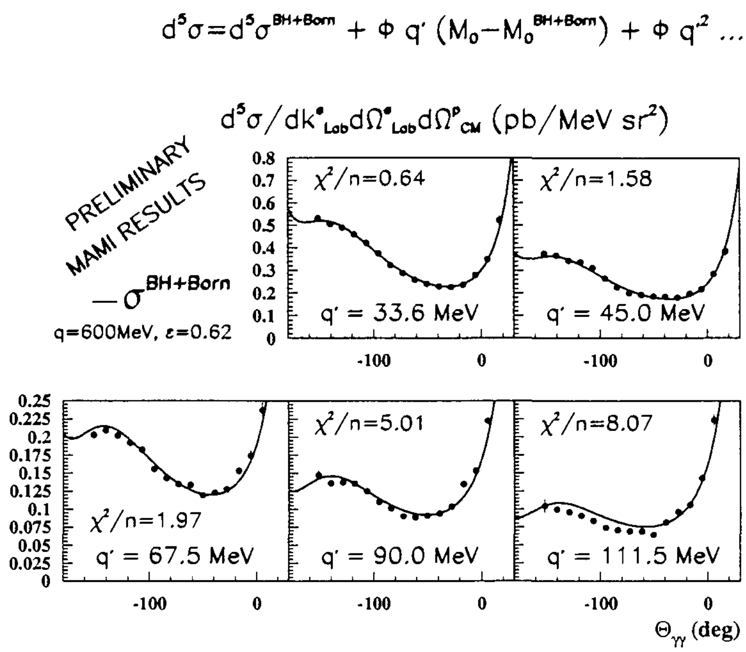

Figure 1. Five differential cross sections as a function of θ(angle between the 2 photons) for a fixed $q(\text{or}Q^2)$, ϵ, φ for five different values of q'. The agreement between the data and the curve is evaluated with a χ^2. When q' increases χ^2 increases also. This is the proof of the effect of the polarizabilities

4 Conclusion

The Virtual Compton Scattering at Mainz demonstrates that it is possible to measure 2 linear combinations : $P_{LL} - \frac{1}{\epsilon}P_{TT}$ and P_{LT} of 5 Generalized Polarizabilities. Two other experiments will soon give other values of the same linear combinations : at CEBAF with $Q^2 = 1$ GeV^2 and $Q^2 = 2$ GeV^2, and at MIT-BATES with $Q^2 = 0.05$ GeV^2. The dependence of the GP on the momentum transfer is predicted quite differently in various models so this measurement at different Q^2 will give strong constraints for describing non-perturbative structure of the proton. To measure independently the 6 Generalized Polarizabilities it is necessary to perform a double polarized experiment [9].

References

1. P. Guichon *et al*, Nucl Phys **A591** (1995) 606.
2. B.E. MacGibbon *et al*, Phys. Rev. C **52**, (1995) 2097.
3. D. Drechsel *et al*, Phys. Rev. **C55**, (1997) 424.
4. N. D'Hose and T. Walcher, *Nucleon Structure Study by Virtual Compton Scattering*, MAMI proposal, 1994.

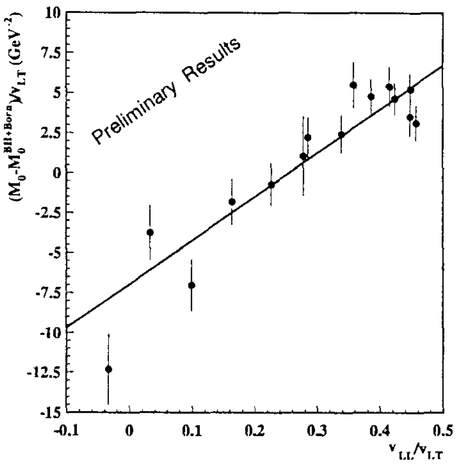

Figure 2. Parametrization of the structure term $\mathcal{M}_0 - \mathcal{M}_0^{BH+Born}$ beyond the LET, according to the equation 2.2

$Q^2 = 0.33$ $(\mathrm{GeV/c})^2$	$(P_{LL}(Q^2) - \frac{1}{\epsilon}P_{TT}(Q^2))$ GeV^2	$P_{LT}(Q^2)$ GeV^2
This experiment	27 ± 3 (± 12)	-7 ± 1 (± 4)
HBChPT	26.3	-5.7
LSM	10.9	0.
ELM	5.9	-1.9
NRQCM	17.0	-1.7

Table 1. The experimental results are compared to theoretical predictions (HBChPT for Heavy Baryon Chiral Perturbation Theory, LSM for Linear Sigma Model, NRQCM for Non Relativistic Quark Constituent Model and ELM for Effective Lagrangian Model)

5. G.Q.Liu, A.W.Thomas and P.Guichon, Aust. J. Phys.**49** (1996) 905
6. M. Vanderhaeghen, *Phys. Lett.* B **368**, 13 (1996)
7. A. Metz and D. Drechsel, Mainz Report No. MKPH-T-96-17
8. T.R. Hemmert, B.R. Holstein, G. Knöchlein and S. Scherer *Phys. Rev.* D **55**, 2630 (1997), *Phys. Rev. Lett.* **79**, 22 (1997),
9. P.A.M. Guichon et M. Vanderhaeghen, Progress in Particle and Nuclear Physics **Vol. 41**, (1998).