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THE NEXT VIRTUAL COMPTON SCATTERING EXPERIMENT AT MAMI

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A new $ep \to ep\gamma$ experiment is foreseen at MAMI in order to study the Q^2-dependence of the structure functions $P_{LL} - P_{TT}/\epsilon$ and P_{LT} and the generalized polarizabilities $\alpha_E(Q^2)$ and $\beta_M(Q^2)$ of the proton.

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1. *Introduction*

Low-energy virtual Compton scattering (VCS) $\gamma^* p \to \gamma p$ allows to access the generalized polarizabilities (GPs) of the proton. The GPs are fundamental quantities characterizing the electromagnetic structure of a nucleon that is deformed by an applied EM field. A series of dedicated VCS experiments have been performed [1 − 4] via the photon electroproduction reaction $ep \to ep\gamma$. After a little more than a decade of measurements, a picture emerges for the electric and magnetic GPs, $\alpha_E(Q^2)$ and $\beta_M(Q^2)$, as a function of the four-momentum transfer Q^2 or the distance scale. When confronted to theoretical models (for a review see Refs. [5, 6]), these observables show a non-trivial Q^2-behavior, which calls for further investigation. This is the goal of the next VCS experiment at MAMI [7].

2. *Photon electroproduction and VCS analysis techniques*

VCS on the proton is performed by exclusive photon electroproduction $ep \to ep\gamma$. The amplitude for this process is the coherent sum of the Bethe-Heitler, Born and non-Born contributions. The Bethe-Heitler and Born amplitudes are known and depend only on the elastic form factors G_E^p, G_M^p. The sum of these two amplitudes is noted (BH+Born). The non-Born amplitude is the unknown part, parametrized at low energy by the GPs.

There are two techniques which allow to extract information on the GPs from a VCS experiment: the LEX (low-energy expansion) [8−11] and dispersion relations (DR) [12,13]. In the LEX approach, the cross section is developed as an expansion in q'_{cm}, the CM momentum of the outgoing photon. The first term is the BH+Born cross section, while the second term depends on two structure functions, $P_{LL} - P_{TT}/\epsilon$ and P_{LT} which contain the electric and magnetic GPs. These structure functions are fitted from the experimental cross section. In the DR approach, the cross section is calculated including all orders in q'_{cm}; it has some free parameters related to the unconstrained part of the electric and magnetic GPs. By adjusting these parameters on experimental data, one has access to the structure functions $P_{LL} - P_{TT}/\epsilon$ and P_{LT} and the electric and magnetic GPs.

3. *World data on VCS unpolarized observables*

The various measurements have been made from low Q^2 (0.06 GeV^2 at Bates [3]) up to 0.9 and 1.8 GeV^2 at JLab [4]. The MAMI data [1,2] were up to now concentrated at $Q^2 = 0.33$ GeV^2.

Figure 1 shows our present knowledge of the structure functions $P_{LL} - P_{TT}/\epsilon$ and P_{LT}. The filled squares and filled circles are obtained according to LEX and DR analyses, respectively. The data agree rather well with the HBChPT calculation (solid curve) at order p^3 [14], in the low-Q^2 region where the theory is applicable. The dashed curve is an example of DR calculation, assuming one single dipole shape for the unconstrained part of the GPs. Here the free parameters of the model have been adjusted on the Jlab data. Up to a small term containing the spin-flip GPs, these structure functions are proportional to α_E and β_M, therefore they give an almost direct image of the electric and magnetic GPs.

Two main conclusions can be drawn from the figure.

- First, regarding $P_{LL} - P_{TT}/\epsilon$, or as well α_E, it is not possible to account for all data points with a simple shape (e.g. a $\sim$ dipole for α_E in the DR model). The comparison of the experimental data with the dashed curve is suggestive of a possible "structure" in the region of $Q^2 \sim 0.3$ GeV^2, for which physical interpretations are open. It could be due to the contribution of some specific resonances in the polarizabilities, or to the meson cloud surrounding the nucleon. A recent work [15] has advised a new parametrization of the electric GP to account for the whole data set; induced polarizations in the nucleon are then calculated using the light-front formalism.

- Second, the behavior of P_{LT}, or as well β_M, is rather poorly known experimentally; values are small and they are measured with large relative error bars. The extremum predicted at low Q^2, originating from a cancellation of large paramagnetic and diamagnetic contributions, would need to be better identified.

The above statements have been the guidelines for designing a new VCS experiment at MAMI.

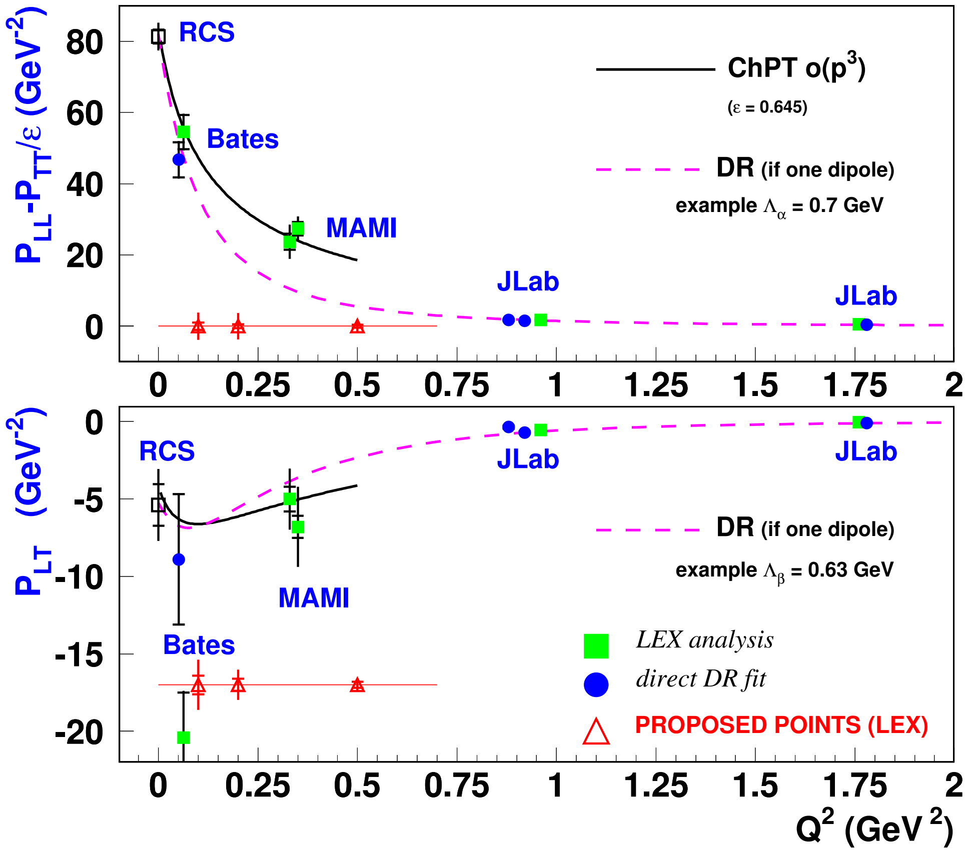

Fig. 1. Existing measurements [1–4] of the VCS structure functions $P_{LL} - P_{TT}/\epsilon$ (top) and P_{LT} (bottom). The inner (resp. outer) error bar is statistical (resp. total). Curves show calculations from HBChPT [14] and dispersion relations [12] with some fixed value of the free parameters (Λ_α, Λ_β). The open triangles show the projected points of the experiment foreseen at MAMI.

4. The proposed experiment

More data are needed to improve our knowledge of the electric and magnetic GPs. We propose to further explore their Q^2-dependence by performing high-precision measurements of the unpolarized $ep \to ep\gamma$ cross section at three new values of $Q^2 = 0.1$, 0.2 and 0.5 GeV^2. For more details we refer the reader to Ref. [7].

The strategy is to work at the highest q'_{cm} or W below the pion threshold and the highest value of the virtual photon polarization ϵ. Angular bins will be chosen in a way that allows both LEX and DR extractions of the observables. The kinematical settings will also make use of the OOP capability of the A1 equipment (spectrometer B) and the beam energy of MAMI-C. The experiment requires a careful study of systematics, which are often the dominant error. Precise measurements of the proton form factors G_E^p, G_M^p at low Q^2 [16] will improve the determination of the VCS observables. Indeed the GP effect is always determined by a deviation to the Bethe-Heitler+Born cross section, which depends intrinsically on these form factors.

5. Conclusion

In summary, the GPs are new observables of the nucleon, sensitive in an original way to the pion cloud and the nucleon resonance spectrum. The electric and magnetic GPs can be measured more extensively and more precisely at low Q^2 using the knowledge acquired from previous experiments. The exploration of their non-trivial Q^2-dependence will help building a consistent picture of these fundamental observables. MAMI with its A1 equipment provides unique conditions in the world to perform this experiment successfully.

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SLJEDEĆE MJERENJE VIRTUALNOG COMPTONOVOG RASPRŠENJA U MAMI

Predviđamo novo mjerenje $ep \to ep\gamma$ u MAMI radi proučavanja Q^2-ovisnosti strukturnih funkcija $P_{LL} - P_{TT}/\epsilon$ i P_{LT} te poopćenih polarizabilnosti $\alpha_E(Q^2)$ i $\beta_M(Q^2)$ protona.