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Results from the JLab CLAS EG4 experiment

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The purpose of the EG4 experiment with the CLAS detector at Jefferson Lab was to measure integral quantities related to the spin structure function g_1. In this presentation I will describe the general features of the experiment along with preliminary results for the deuteron target.

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1. Introduction.

The main goal of the EG4 experiment is the study of the generalized Gerasimov-Drell-Hearn (GDH) Sum Rule (SR) for the proton and deuteron at low Q^2. The experiment, labeled with the JLab experiment number E03-006 [1] for the proton target (NH_3) and E06-017 [2] for the deuteron target (ND_3) ran from Feb. to May 2006.

A SR is a relation between an integral of a dynamical quantity (cross section, structure function,...) and a global property of the target (mass, spin,...) [3]. SRs can be used to test a theory (e.g. QCD) and the hypotheses under which they are derived. In addition, SRs can be used to measure the global property involved (e.g. spin polarizability sum rules). A famous example is the GDH SR [4] which is derived for real photons (Q^2=0):

$$\int_{\nu_{th}}^{\infty} \frac{\sigma_A - \sigma_P}{\nu} d\nu = \frac{-4\pi S \alpha \kappa^2}{M^2} \quad (1.1)$$

where σ_A and σ_P are the total photoproduction cross sections with photon spin anti-parallel and parallel to the target spin, respectively, ν is the photon energy and ν_{th} is the inelastic threshold, α is the fine structure constant, κ is the target anomalous magnetic moment, S and M are the target spin and mass, respectively. The SR was generalized to virtual photons in [3] [5] as

$$\Gamma_1\left(Q^2\right) = \int_0^{x_{th}} g_1\left(x,Q^2\right) dx = \frac{Q^2}{2M^2} I_1\left(Q^2\right) \quad (1.2)$$

where g_1 is the first spin structure function, I_1 is the first covariant polarized doubly-virtual Compton scattering amplitude, Q^2 and x are the usual invariant momentum transfer of electron scattering and the Bjorken variable, respectively, and x_{th} corresponds to the pion production threshold. The generalized GDH SR therefore involves the first moment of g_1. Considering higher moments, another interesting quantity is the generalized spin polarizability, defined as

$$\gamma_0\left(Q^2\right) = I_\gamma\left(Q^2\right) \equiv \frac{4e^2M^2}{\pi Q^6} \int_0^{x_{th}} x^2 \left(g_1 - \frac{4M^2}{Q^2} x^2 g_2\right) dx = \int_0^{x_{th}} x^2 A_1 F_1 dx \quad (1.3)$$

where e is the elementary charge, g_2 is the second spin structure function, whose contribution is manifestly suppressed in this SR, A_1 is the spin asymmetry for parallel and antiparallel photon-target spins and F_1 is the first unpolarized structure function. Experiment EG4 used a special configuration of the CLAS detector [6] (see Fig. 1) where a new Cherenkov detector was installed in one sector of the spectrometer, to be able to cover scattering angles down to 6^o. The polarized target could be used either with NH_3 or ND_3 material and was installed in a retracted position with respect to the standard one, to help reaching the low scattering angles necessary to access very low momentum transfers. The proton part of EG4 ran at 3.0, 2.3, 2.0, 1.3 and 1.0 GeV beam energies, while the deuteron part ran at 2.0 and 1.3 GeV. The structure function g_1 was extracted directly from polarized cross-section differences (not from asymmetries, as in most experiments). This yields the advantage that the significant dilution from the unpolarized target material cancels out. In this approach, we consider the theoretical cross-section difference

$$\frac{\Delta d\sigma^{theor}}{d\Omega dE'} = \frac{d\sigma^{\rightarrow\Rightarrow}}{d\Omega dE'} - \frac{d\sigma^{\leftarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'^2}{M E \nu Q^2}\left[\left(E - E'cos\theta\right) g_1\left(x,Q^2\right) - 2Mxg_2\left(x,Q^2\right)\right] \quad (1.4)$$

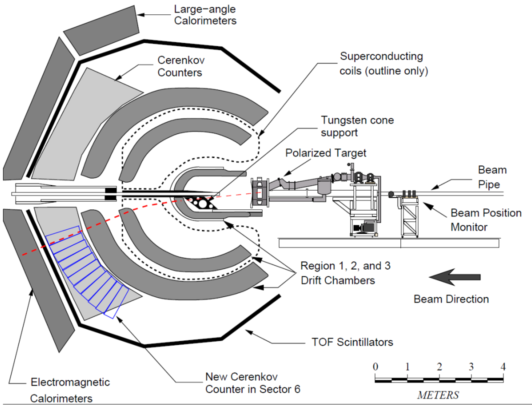


Figure 1: Side view of the CLAS detector showing the polarized target assembly and the new Cherenkov module (blue). An outbending electron track (dashed red curve) is also shown.

(the single and double arrows indicate the relative orientation of the electron and target spin along the incoming beam) where the g_2 contribution is suppressed due to Q^2 and x being small. The actual experimental quantity measured is

$$\Delta N^{exp}\left(\Delta E',\Delta\Omega\right) = N^{\rightarrow\Rightarrow}\left(\Delta E',\Delta\Omega\right) - N^{\leftarrow\Rightarrow}\left(\Delta E',\Delta\Omega\right) = P_f L P_b P_T \frac{\Delta d\sigma^{theor}}{d\Omega dE'} \Delta E' \Delta\Omega \varepsilon_{det} \quad (1.5)$$

where P_f is the target filling factor (or packing fraction), L is the integrated luminosity[1], P_b is the beam polarization (85 $\pm$ 2 %), P_T is the target polarization (59 to 71 % for H, 30 to 45 % for D), and ε_{det} is the detector acceptance/efficiency. The whole factor P_fL $P_b P_T$ is extracted from elastic (proton case) or quasi-elastic (deuteron case) scattering (correcting for the appropriate ε by a Monte Carlo simulation in the right kinematics), then used for the inelastic expression (again applying the corresponding ε via inelastic Monte Carlo simulation).

2. Results and Discussion.

In calculating the SR from the data, we used the following approach. With deuteron target data, the integral is performed according to

$$\int_0^{x_{th}} \ldots \rightarrow \int_{0.001}^{x_{min}} Model + \int_{x_{min}}^{x(W=1.15\ GeV)} data + \int_{x(W=1.15\ GeV)}^{x(W=1.07\ GeV)} Model \quad (2.1)$$

where x$_{min}$ is the lowest x reached by the experiment for a given Q^2 bin and, in the 3rd integral, the model is used rather than data to avoid quasielastic scattering and radiative tail contaminations. For the proton data, one can simply use

$$\int_0^{x_{th}} \ldots \rightarrow \int_{0.001}^{x_{min}} Model + \int_{x_{min}}^{x(W=1.08\ GeV)} data \quad (2.2)$$

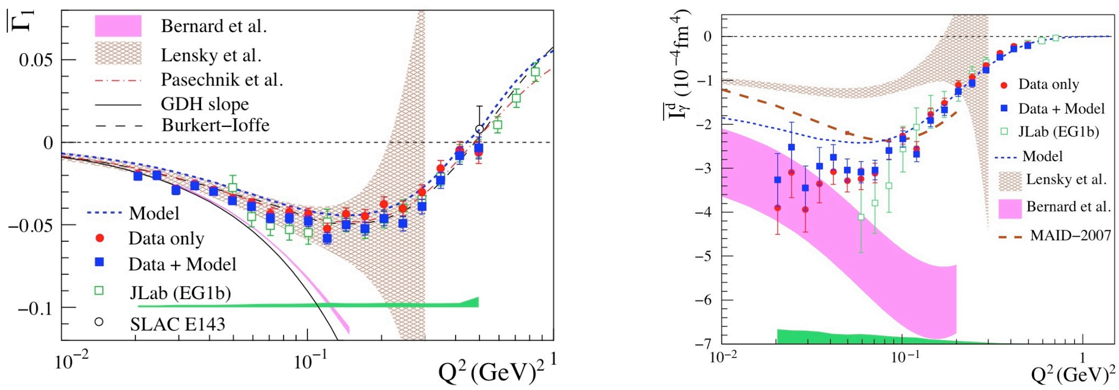
For the deuteron case [7], given the above integration range, the integrals we obtained can be considered truncated moments (in the following indicated by over-bars) which contain solely

[1] there is a small correction due to the beam charge asymmetry, not shown here.

the contributions to the full moments above pion production threshold and exclude the two-body breakup channel. They can be approximated as incoherent sum of the proton and neutron moments, and hence all theory comparisons are with the sum of the corresponding proton and neutron moments, modified by the nucleon effective polarization in the deuteron ([7] and references therein).

In Fig. 2 (a), the EG4 results for $\bar{\Gamma}_1$ of the deuteron are shown [7]. The lowest Q^2 is decreased by a factor of about 2.5 relative to earlier experiments. The data have in general much improved precision with respect to the previous measurements. Moreover, the unmeasured low-x and large-x contributions appear to be small. EG4 and previous EG1 $\bar{\Gamma}_1$ data [8] agree well. The EG4 data agree well with the χPT results of Lensky et al. [9], while the Bernard et al. most recent χPT calculations [10] agree only for the lowest Q^2 points. Phenomenological models [11] agree well with our data. In Fig. 2 (b), the EG4 results for $\bar{I}_\gamma$ of the deuteron are shown. In this case and with the above definition of $\bar{I}_\gamma$, the χPT results of Lensky et al disagree with our data, while the Bernard et al χPT calculation agrees for lowest Q^2 points only. The MAID model [12] (relevant here since the low-x contribution, not included in MAID, is largely suppressed in $\bar{I}_\gamma$) disagrees with our data at low Q^2.

In this summary, we only presented inclusive data on the deuteron. Work is in progress on the proton data, while an analysis on the exclusive pion electroproduction was published in [13].



(a) (b)

Figure 2: Sum rule results from the EG4 experiment on deuteron. (a) The first moment $\bar{\Gamma}_1\left(Q^2\right)$. The solid circles are the EG4 data integrated over the covered kinematics. The fully integrated $\bar{\Gamma}_1$, using a model to supplement data, is shown by the solid squares. The error bars are statistical. The systematic uncertainty is given by the horizontal band. The open symbols show data from the CLAS EG1b and SLAC E143 [14] experiments. The other bands and lines show various models and χPT calculations as described in the text. The short-dash line (Model) does not include the EG4 data, to reveal the new knowledge gained. (b) The generalized spin polarizability $\bar{I}_\gamma\left(Q^2\right)$. See (a) for legends and theoretical calculations.

References

[1] Spokespeople: M. Battaglieri, A.Deur, R. De Vita, M. Ripani; students: H. Kang (Seoul U.), K. Kovacs (UVa).

[2] Spokespeople: A. Deur, G. Dodge, M. Ripani, K. Slifer; students: K. Adhikari (ODU).

[3] D. Drechsel, B. Pasquini, M. Vanderhaeghen, Phys. Rep. **378** 99 (2003).

[4] K. Helbing, Prog. Part. Nucl. Phys. **57**, 405 (2006) and references therein.

[5] X. D. Ji and J. Osborne, J. Phys. G **27**, 127 (2001).

[6] B. A. Mecking et al., Nucl. Instrum. Methods Phys. Res., A **503**, 513 (2003).

[7] K. P. Adhikari et al. (CLAS Collaboration) Phys. Rev. Lett. **120**, 062501 (2018).

[8] N. Guler et al. [CLAS Collaboration], Phys. Rev. C **92**, 055201 (2015).

[9] V. Lensky, J. M. Alarcon and V. Pascalutsa, Phys. Rev. C **90**, 055202 (2014).

[10] V. Bernard, N. Kaiser and U. G. Meissner, Phys. Rev. D **48**, 3062 (1993); V. Bernard, T. R. Hemmert and U. G. Meissner, Phys. Lett. B **545**, 105 (2002); V. Bernard, T. R. Hemmert and U. G. Meissner, Phys. Rev. D **67**, 076008 (2003); V. Bernard, E. Epelbaum, H. Krebs and U. G. Meissner, Phys. Rev. D **87**, 054032 (2013).

[11] V. Burkert and Z. j. Li, Phys. Rev. D **47**, 46 (1993); V. D. Burkert and B. L. Ioffe, Phys. Lett. B **296**, 223 (1992); J. Exp. Theor. Phys. **78**, 619 (1994) [Zh. Eksp. Teor. Fiz. **105**, 1153 (1994)]; R. S. Pasechnik, J. Soffer and O. V. Teryaev, Phys. Rev. D **82**, 076007 (2010).

[12] D. Drechsel, S. Kamalov and L. Tiator. Nucl. Phys. A **645**, 145 (1999).

[13] X. Zheng et al. (CLAS Collaboration), Phys. Rev. C **94**, 045206 (2016).

[14] K. Abe et al. (E143 Collaboration), Phys. Rev. D **58**, 112003 (1998).

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