DIS contribution to the GDH sum rule

N. Bianchi for the HERMES Collaboration

Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati,
00044 Frascati, Italy

Abstract

We present the HERMES preliminary data of virtual photon absorption cross section difference $[\sigma_{1/2} - \sigma_{3/2}]$ for the proton and neutron in deep inelastic scattering of 27.6 GeV longitudinally polarised positrons from polarised ^{1}H and ^{3}He internal gas targets. The data were collected in the region above the nucleon resonances. The DIS contribution to the generalised Gerasimov-Drell-Hearn (GDH) integral for the nucleons is shown.

The GDH sum rule [1] was derived starting from a general dispersive relation for the forward Compton scattering amplitudes which follows causality, crossing symmetry and unitarity principles

$$\int_0^\infty \left[\sigma_{1/2}(\nu) - \sigma_{3/2}(\nu)\right] \frac{d\nu}{\nu} = -\frac{2\pi^2\alpha}{M^2}\kappa^2, \tag{1}$$

where $\sigma_{1/2}$ and $\sigma_{3/2}$ are the photo-absorption cross sections for total helicities 1/2 and 3/2, ν is the photon energy, M is the nucleon mass and κ is the anomalous contribution to the nucleon magnetic moment.

This sum rule has never been tested experimentally. Evaluations from single pion photo-production amplitudes in the resonance region suggested a possible violation of the sum rule, mainly in the isovector channel. For this reason, several real photon experiments are currently planned. (See G.Anton contribution to this workshop).

The integral defined in Eq. (1) can be generalised to the absorption of virtual photons with energy ν and squared four-momentum $-Q^2$

$$\begin{aligned} I(Q^2) &= \int_{Q^2/2M}^\infty \left[\sigma_{1/2}(\nu, Q^2) - \sigma_{3/2}(\nu, Q^2)\right] \frac{d\nu}{\nu} \\ &= \frac{8\pi^2\alpha}{M} \int_0^1 \frac{g_1(x, Q^2) - \gamma^2 g_2(x, Q^2)}{K} \frac{dx}{x}, \end{aligned} \tag{2}$$

where g_1 and g_2 are the polarised structure functions of the nucleon, x is the Bjorken variable and K is the flux factor of virtual photons, defined as $\nu\sqrt{1+\gamma^2}$, with $\gamma^2 = Q^2/\nu^2$.

The interest in the generalised GDH sum rule was raised by Anselmino *et al.* [2] which related this integral to the Ellis-Jaffe integral $\Gamma_1 = \int_0^1 g_1(x)dx$. In fact, for $\gamma \ll 1$ and with the approximation that g_1 depends only on x, the right side of Eq. (2) reduces to $I_1(Q^2) = 16\pi^2\alpha\Gamma_1/Q^2$. A strong variation of $I(Q^2)$, including a change of sign for the proton, is required in order to connect the Γ_1 measurement in the DIS region to the real photon limit. Several phenomenological models were developed in order to predict the low-Q^2 behaviour of the integrals $I(Q^2)$ and $I_1(Q^2)$.[3] It is worth stressing that in the low-Q^2 region $I_1(Q^2)$ is only an approximation of $I(Q^2)$ due to the effects of the flux factor K and of the second polarised structure function g_2. Furthermore, while the GDH sum rule for Q^2=0 is almost saturated by the resonance excitation processes and the Ellis-Jaffe integral and Bjorken sum rule for high-Q^2 are largely dominated by DIS processes, in the low-Q^2 region the contributions of resonance and DIS regions should be of the same order of magnitude.

The preliminary data of a measurement of $[\sigma_{1/2} - \sigma_{3/2}]$ for the neutron and proton in the DIS region are presented. The data were collected during the 1995 and 1997 years of operation of the HERMES experiment. The experimental details can be found in ref. [4] and in references therein.

The difference $[\sigma_{1/2} - \sigma_{3/2}]$ has been evaluated from the experimental virtual photon asymmetry A_1 and the unpolarised structure function F_1 derived from the literature[5]: $[\sigma_{1/2} - \sigma_{3/2}] = (8\pi^2\alpha/M)\cdot(A_1F_1/K)$. The preliminary cross section differences $[\sigma_{1/2} - \sigma_{3/2}]$ extracted from the measured values of A_1^{p} and A_1^{n} are presented in Fig. 1. Our preliminary results are compared to the values of $[\sigma_{1/2} - \sigma_{3/2}]$ that we have extracted from the published data for A_1^p from ^{1}H target and for A_1^n for ^{3}He target.[6] In Fig. 1 are also shown fits to our data, assuming the $a_1(1260)$ Regge trajectory with intercept $\alpha = 0$. The fit extrapolations seem to slightly underestimate the absolute values of most of the data at higher energy. Recent predictions of the QCD evolution of polarised parton densities show a larger contribution from the high energy region.

In each Q^2-bin we evaluated the GDH integral over the range $\nu_0 \leq \nu \leq 23.4$ GeV, being $\nu_0 = (W_0^2 - M^2 + Q^2)/2M$ where $W_0 = 1.8$ (2.0) GeV for the proton (neutron). The results shown in Fig. 2 represent the first direct determination of the DIS contribution $I^{\mathrm{DIS}}(Q^2)$ to $I(Q^2)$.

To estimate the order of magnitude of the full integral $I(Q^2)$ for the proton we have used two parameterisations of the polarised structure functions in the right side of Eq.(2). These estimates, in which the nucleon resonances excitation is not included and the second structure function $g_2(x)$ is calculated following the Wandzura-Wilczek expression are presented in Fig. 3. While at high Q^2 the difference between our data and the curves (about 4μb) can be mainly ascribed to the unmeasured high energy region, at low Q^2 also the contribution of the unmeasured low energy resonance region is important.

Up to now no measurement of the resonance region contribution to $I(Q^2)$ has been performed; the E143 collaboration measured the resonance part ($W \leq 2$

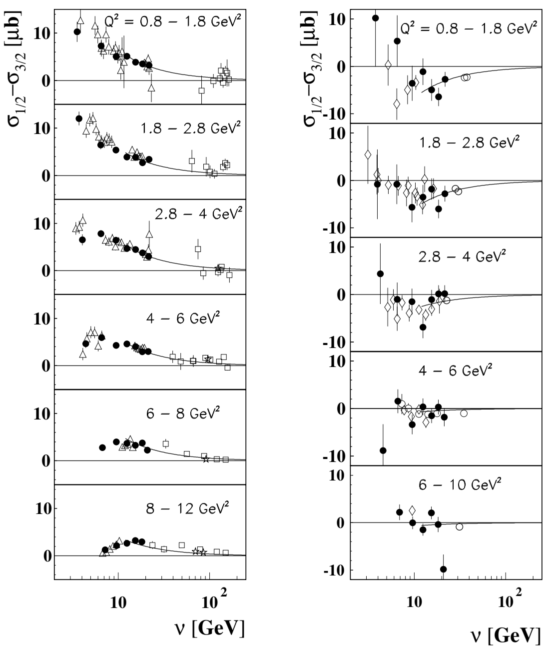

Figure 1: Cross section differences measured in different Q^2 bins for the proton (a) and the neutron (b). Close circles are our preliminary data. Open symbols are values derived from other experiments[6].

GeV) of $\Gamma_1(Q^2)$ for two values of Q^2 [7]. From their results at $Q^2 = 1.2$ GeV^2 it follows $I_1^p = 15\pm1\mu$b and $I_1^n = 6\pm5\mu$b for the resonance region contribution. These values are of the same order of magnitude of our determination of the DIS part of I at the lowest Q^2. Therefore our results together with the precise measurements of the resonance region contribution planned at TJNAF and with a more refined estimate of the high-energy extrapolation, will provide the Q^2 evolution of the entire GDH integral.

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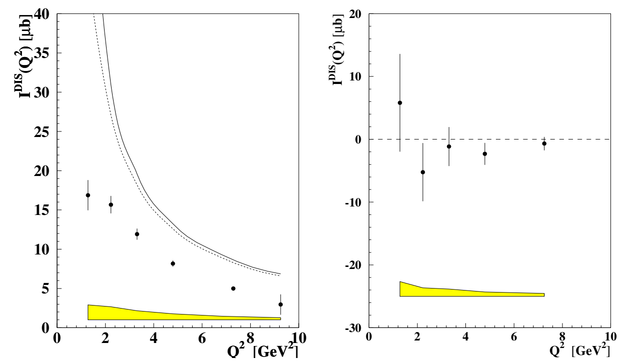

(a) (b)

Figure 2: $I^{\mathrm{DIS}}(Q^2)$ as measured from preliminary data in the range $\nu_0 \leq \nu \leq$ 23.4 GeV for the proton (a) and for the neutron (b). The bands are our estimates of the systematic errors. The two curves are two estimates of the complete integral $I(Q^2)$ for the proton, as described in the text.

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