The Q^2 Dependence of the Generalized GDH Sum Rule for Proton, Deuteron and Neutron

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- **Motivation**
- **The experiment in 1997-2000**
- **Extraction of Spin Asymmetry**
- **Q^2 dependence of the GDH Integrals**
- **Conclusions**

Motivation:The GDH Sum Rule

- **The GDH sum rule**

$$I_{GDH} = \int_{\nu_0}^{\infty} [\sigma_{1/2}(\nu) - \sigma_{3/2}(\nu)] \frac{d\nu}{\nu} = -\frac{2\pi^2\alpha}{M^2} k^2$$

$I^P_{GDH} = -204\mu\text{b}$ ($\kappa_P = +1.79$)
$I^N_{GDH} = -233\mu\text{b}$ ($\kappa_N = -1.91$)
$I^D_{GDH} = -0.65\mu\text{b}$ ($\kappa_D = -0.143$)

- **The generalization of the GDH integral:**

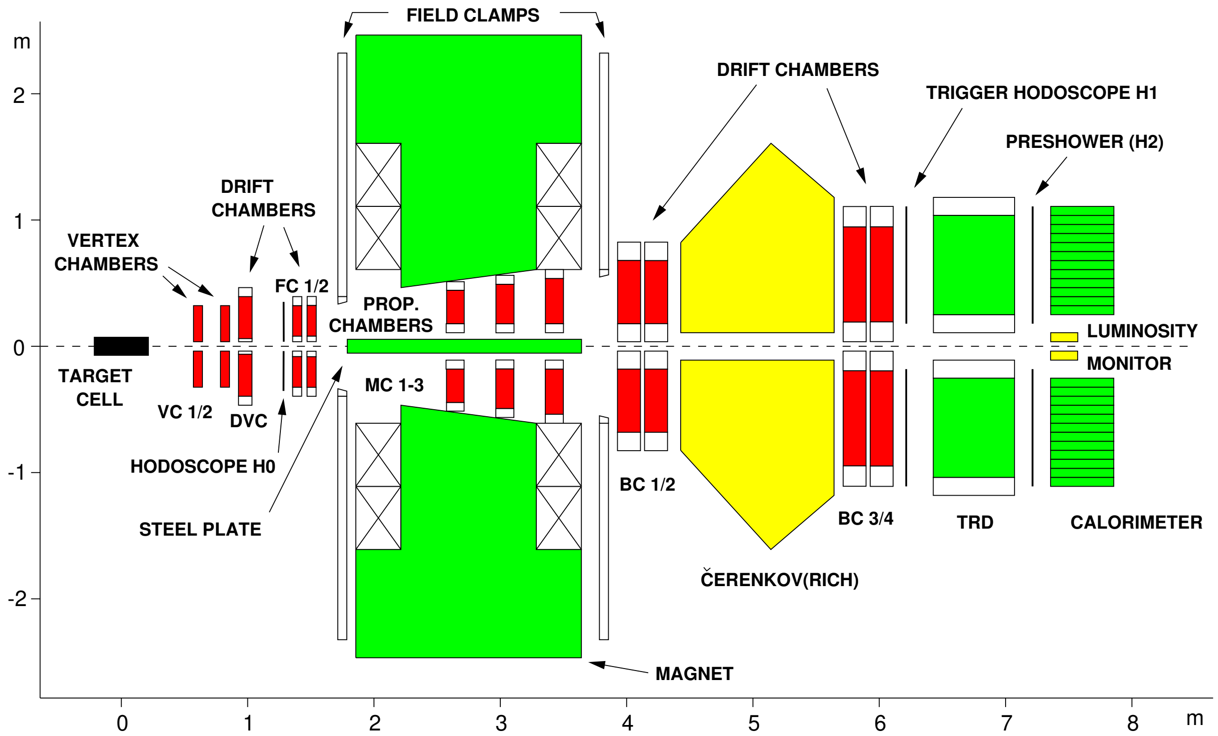
$$I_{GDH}(Q^2) = \frac{8\pi^2\alpha}{M} \int_0^{x_0} \frac{g_1(x,Q^2) - \gamma^2 g_2(x,Q^2)}{\nu\sqrt{1+\gamma^2}} \frac{dx}{x} \qquad (1)$$

- **In leading twist**

$$I_{GDH}(Q^2)_{\gamma^2 \to 0} = \frac{16\pi^2\alpha}{Q^2} \int_0^1 g_1(x)dx = \frac{16\pi^2\alpha}{Q^2} \Gamma_1 \qquad (2)$$

- **Examining the generalized GDH integral provides a way to study the transition from real-photon absorption (Q^2=0) on the nucleon to polarized deep inelastic scattering (DIS).**

The experiment in 1997-2000



- **Longitudinally polarized $e^{\pm}$ beam**
  in HERA storage ring
  P=27.6 GeV, current 40mA, $<P_{beam}>$=55%
- **Two identical halves of forward spectrometer**
  with acceptance $40 < \Theta < 220$mrad
- **Identification of scattered positron(electron)**
  with efficiency $>$ 99% at hadron contamination $<$ 1%
- **Internal storage cell gas target**
  with density for polarized H: $10^{13...14}$ nucl./cm^2,
  $P_{targ.}$~88(85)%
- **Integrated Luminosity**
  For deuteron (proton) data set: 111pb^{-1} (70pb^{-1}).

Extraction of Spin Asymmetry

- **Data were divided into six bins in Q^2: 1.2 – 12.0 GeV^2**
- **The kinematic requirements on the DIS scattered positrons:**
  $\theta > 0.04$ Rad and $y < 0.85$ and W^2 regions:
  - 1.0 GeV^2 $<$W^2 $<$4.2 GeV^2 : resonance region
  - 4.2 GeV^2 $<$W^2 $<$45.0 GeV^2 : DIS region
  - W^2 $>$45.0 GeV^2 : (extrapolation)
- **The spin asymmetry**

$$A_1 = \frac{A_{\|}}{D} - \eta A_2 \qquad A_{\|} = \frac{N^- L^+ - N^+ L^-}{N^- L_p^+ + N^+ L_p^-} \tag{3}$$

  $N^+(N^-)$ is the number of scattered positrons for target spin parallel(anti-parallel) to the beam spin orientation,
  $L^+(L^-)$ is the dead-time-corrected luminosity,
  $L^+_P(L^-_P)$ is the luminosity weighted by the product of beam and target polarizations.

- **Radiative corrections**
  POLRAD 2.0 was used. RC do not exceed 7%(4%) of the asymmetry $A_1 + \eta A_2$ for deuteron (proton).

- **MC contaminations**
  The contributions from elastic(quasielastic) for total GDH and from elastic(quasielastic) and DIS regions for resonance GDH were subtracted on A$_{\|}$ level.

Q^2 dependence of the Generalized GDH Integral

- **The GDH Integrals for proton and deuteron**

$$I(Q^2)_{GDH} = \frac{8\pi^2\alpha}{M}\int_0^{x_0}\frac{A_1F_1}{\nu\sqrt{1+\gamma^2}}\frac{dx}{x}, \tag{4}$$

  $F_1 = F_2(1+\gamma^2)/(2x(1+R))$

  DIS region: F_2 is taken from NMC P15 fit,
  R is taken from SLAC fit (R1990), $A_2^{p(d)} = 0.5(0.05)xM/\sqrt{Q^2}$.
  Resonance region: F_2 is taken from Bodek fit, R=0.18,
  $A_2^{p(d)}$=0.06 (0.0)

- **The unmeasured region (W^2 $>$45.0 GeV^2)**
  The contributions were estimated with parameterization from N.Bianchi and E.Thomas , Phys. Lett. B450 (1999), 439.

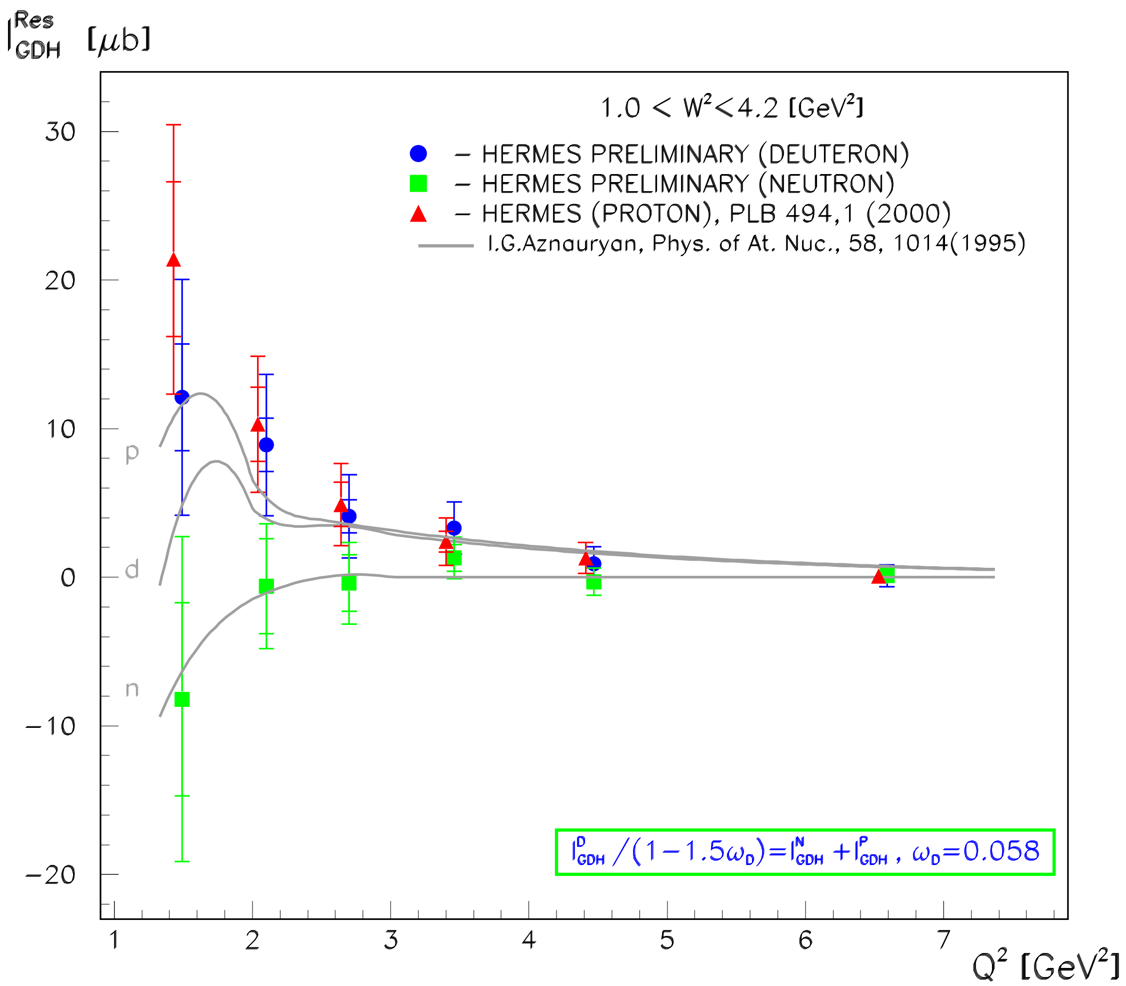
- **The GDH Integral for neutron**

$$\frac{I^D_{GDH}}{1-1.5\omega_d} = I^N_{GDH} + I^P_{GDH}, \tag{5}$$

  C. Ciofi degli Atti et al., nucl-th/9602026

- **The systematic uncertainties**
  - Beam and target polarizations (5.5%),
  - Spectrometer geometry (2.5%),
  - Smearing and radiative effects (up to 14%),
  - Knowledge of F_2^p (2%) and F_2^d (5%),
  - The lack of knowledge of A_2^p(up to 15%) and A_2^d(up to 20%),
  - The contribution from unmeasured region (5%).

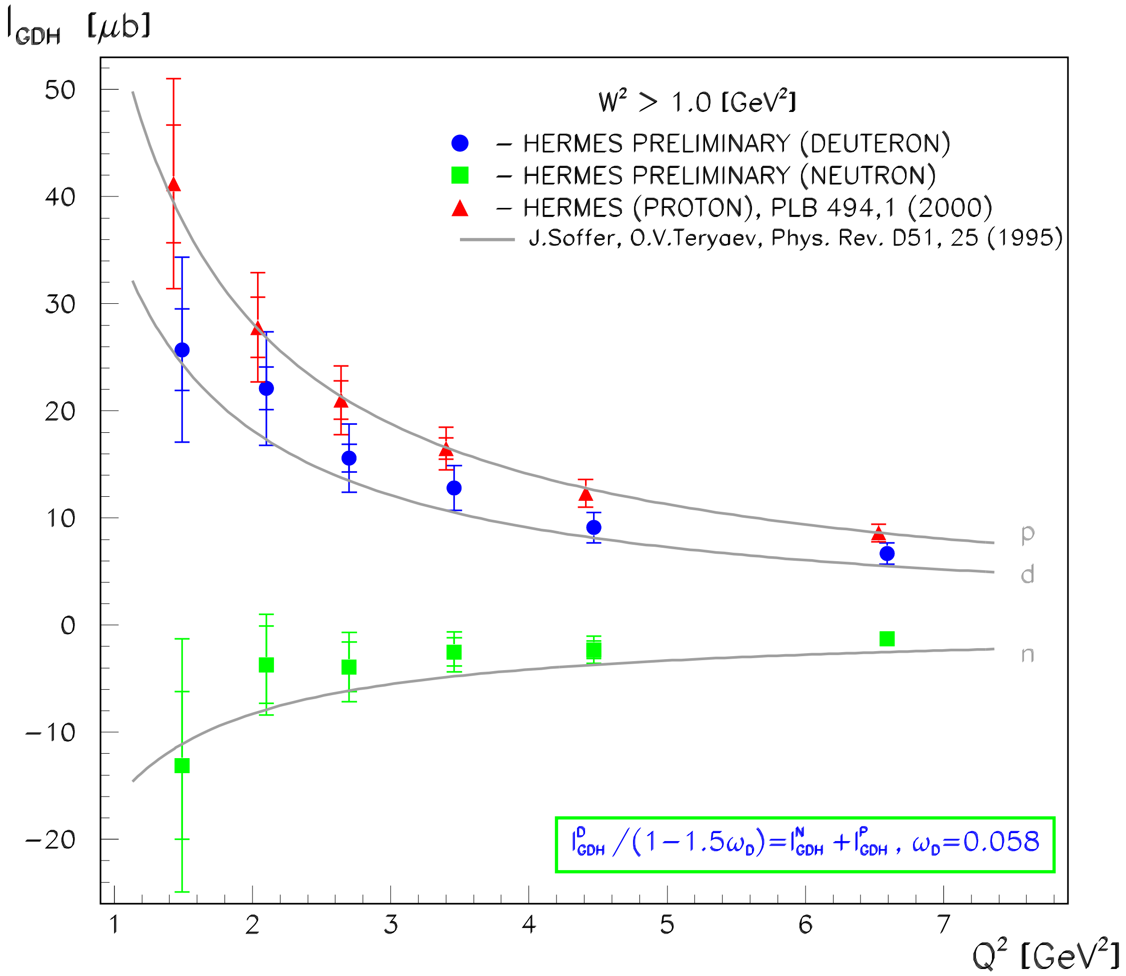
Q^2 dependence of the Generalized GDH Integrals in Resonance region



The GDH Integral as a function of Q^2 for the resonance region. The curves are predictions based on a Q^2–evolution of nucleon-resonance amplitudes.

- **the resonance contribution is small for $Q^2 > 3$ GeV^2**
- **the model describes the neutron data well**
- **the model describes proton and deuteron data well for $Q^2 > 2.5$ GeV^2, but underestimates them for lower Q^2**

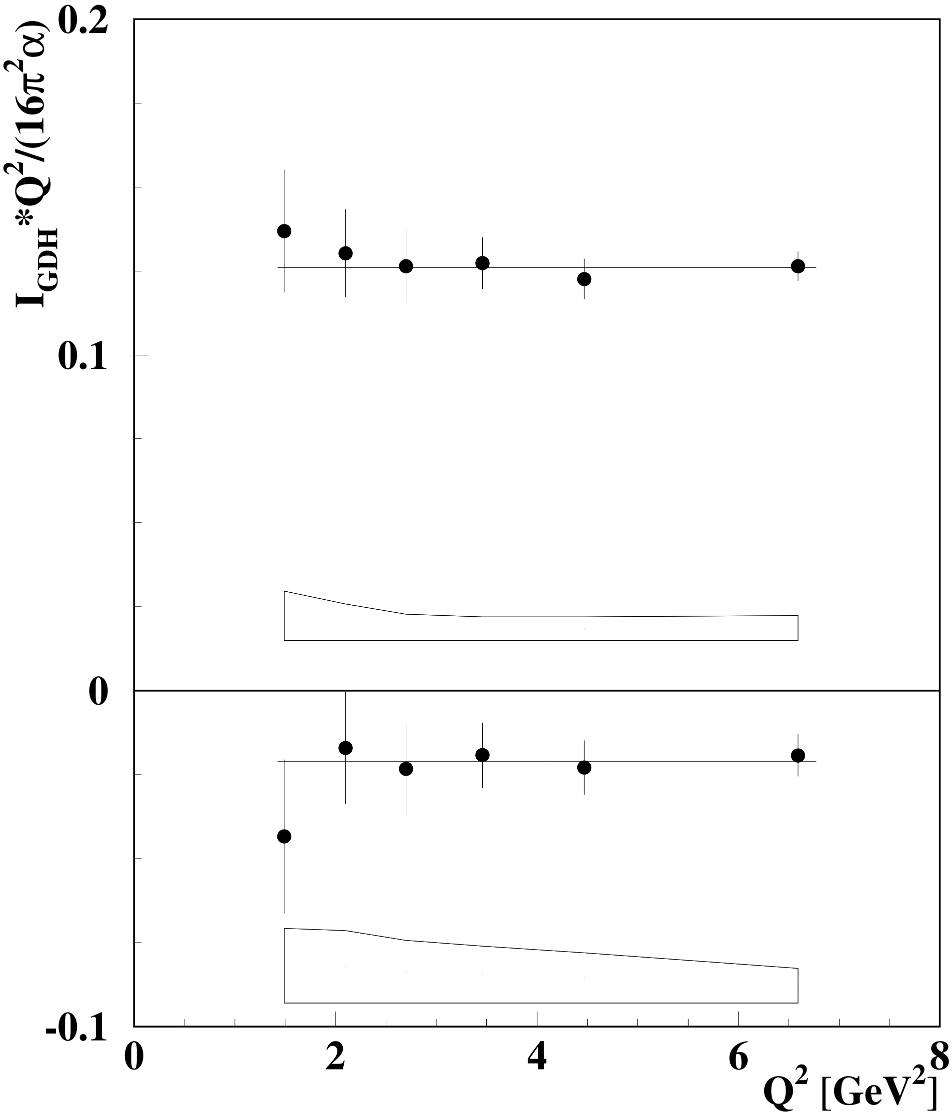
Q^2 dependence of the Generalized GDH Integral



The GDH Integral for proton, deuteron and neutron versus Q^2. The curves are predictions based on Q^2 evolution of g_1 and g_2.

- **proton data very well described**
- **deuteron data are in agreement within the exp. uncertainties**
- **neutron data are slightly underestimated (still OK within exp.uncertainties)**

Q^2 dependence of the Generalized GDH Integral



The Q^2 dependence of the generalized GDH integrals for the proton(top panel) and neutron(bottom panel) after the leading twist dependence, $Q^2/(16\pi^2\alpha)$, has been divided out. The dash-dotted lines are straight line to the data.

No deviation from the leading twist can be seen

Conclusions

- **The Generalized Gerasimov–Drell–Hearn Integrals for proton, deuteron and neutron are measured for the first time in both the resonance and DIS regions for the Q^2 range from 1.2 to 12.0 GeV^2.**

- **The parts of GDH Integrals in the resonance region for neutron is in agreement with predictions of Aznauryan model based on the Q^2 evolution of nucleon resonance helicity amplitudes. For proton and deuteron it does underestimated the data for Q^2 $<$2.5 GeV^2.**

- **Above Q^2=3 GeV^2 the DIS contributions to the Generalized GDH Integrals are dominant for all targets.**

- **The Generalized GDH Integral for proton is very well described by Soffer-Teryaev prediction and for deuteron and neutron it is in agreement within the uncertainties of the measurements.**
- **Data show no indication for large non-leading twist effects.**