Leading Order Determination of the Gluon Polarization from high-p_T Hadron Electroproduction

Even after many years of studying QCD in detail, the question ”***How do we understand the visible matter in our universe in terms of the fundamental quarks and gluons of QCD?”*** remains unanswered.

If it would be possible to answer the following questions, namely

- **What is the role of gluons and gluon self-interactions in nucleons and nuclei?**
- **What is the internal landscape of the nucleons?**
  - **What is the nature of the spin of the proton?**
  - **What is the three-dimensional spatial landscape of nucleons?**
- **What governs the hadronization process in the conversion of quarks and gluons into hadrons?**

these answers could provide the keys to understanding how matter is formed from the fundamental quarks and gluons of QCD.

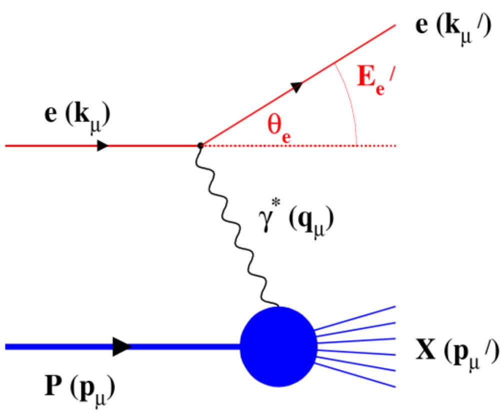

Figure 1: Schematic picture of the deep inelastic scattering process.

Answering these questions needs a tool, which probes the structure of nucleons with high resolution. This can be achieved by studying nucleons in deep-inelastic scattering (DIS), where a lepton scatters off the partons in a nucleon via the exchange of a virtual photon γ*, see Fig. 1. The squared four-momentum Q^2 of the virtual photon provides the resolution scale for probing the inner structure of nucleons and (increasing Q^2 = higher resolution).

Especially the question after the individual parton (quarks and gluons) contributions to the spin of the nucleon is even after 20 years of experimental efforts far from being solved. After several very precise measurements in polarized deep-inelastic scattering it is clear, that the spin of the nucleon cannot be explained by the contribution of the quark spins alone. This is affirmed by the newest results from COMPASS, HERMES and JLAB on the inclusive spin structure function g_1 and on the individual contributions from the different quark flavors from semi-inclusive deep-inelastic scattering data. Recently HERMES, COMPASS and RHIC have started to constrain the gluon polarization by either isolating the photon-gluon fusion process in semi-inclusive deep-inelastic scattering (HERMES & COMPASS) or by isolating gluon-gluon fusion by measuring inclusive neutral pion or jet production in polarized pp scattering.

Contrary to the unpolarized case, where the gluon distribution can be extracted form the scaling violations of the structure function F_2 (see Fig. 2), in the polarized case this is unfortunately only possible with much reduced precision. One reason for the limited precision for $\Delta g(x)$ from the scaling violation of the polarized structure function g_1 is due to the much smaller spanned $x - Q^2$ lever arm (see Fig. 3) as till today no polarized ep collider exists.

This paper describes the extraction of the gluon polarization from inclusive charged hadron asymmetries as function of the hadron transverse momentum p_t measured by the HERMES experiment using polarized proton and deuteron targets (see Figs. 2-4 in the paper). As the data has been taken in the photo-production kinematics, the scattered lepton was not detected.

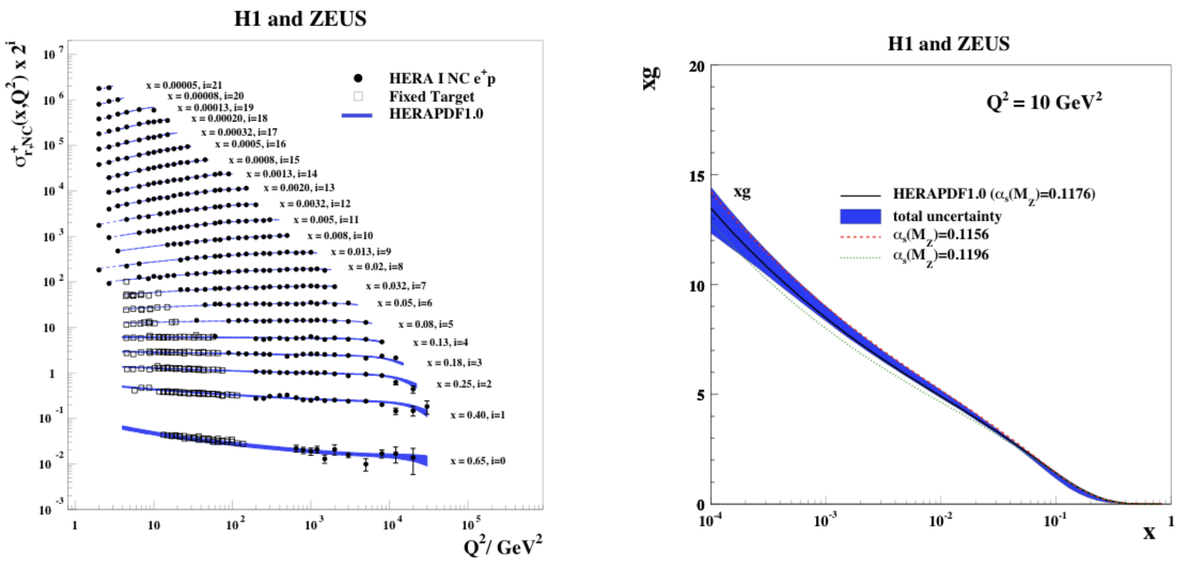

Figure 2: left: The unpolarized structure function F_2 as measured by H1 and ZEUS. Right: The Gluon distribution extracted from the scaling violation of F_2.

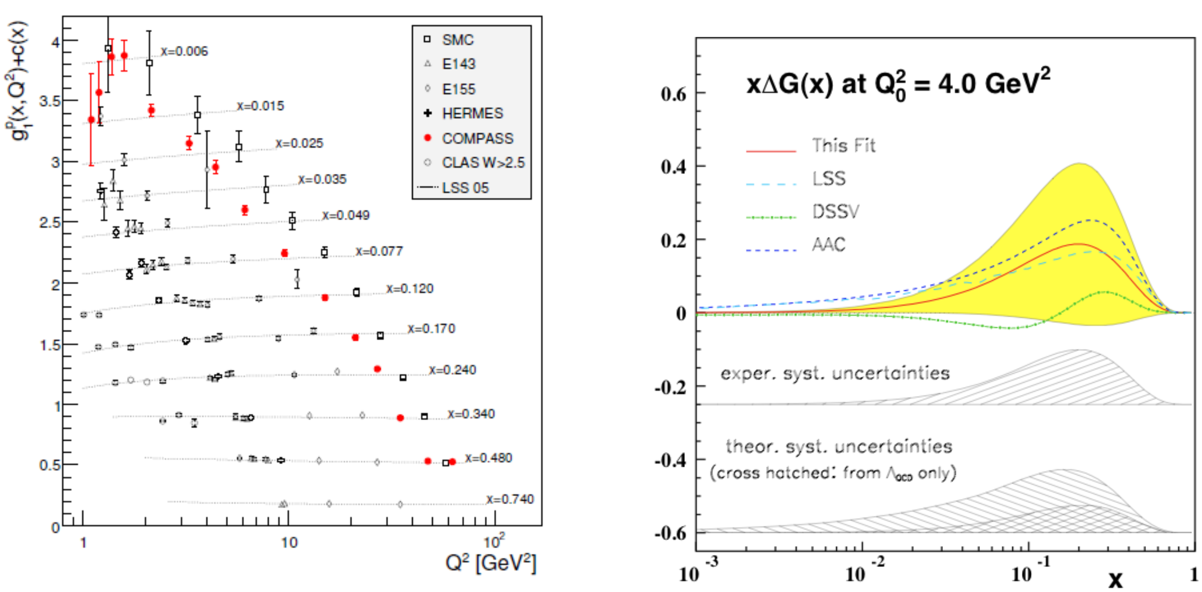

Figure 3: left: The world data on the polarized structure function g_1. Right: The polarized gluon polarization extracted from the scaling violation of g_1.

This has the advantage that the obtained statistical precision is much higher than if the scattered lepton is detected in coincidence with the hadron, but the disadvantage is that the different underlying subprocesses contributing to the asymmetry can only be disentangled by use of a Monte Carlo physics generator called PYTHIA. Figures 4 and 5 show the measured asymmetry vs. the hadron p_t with respect to the beam direction for positive and negative hadrons produced in quasi-real photoproduction on a polarized hydrogen and deuterium target.

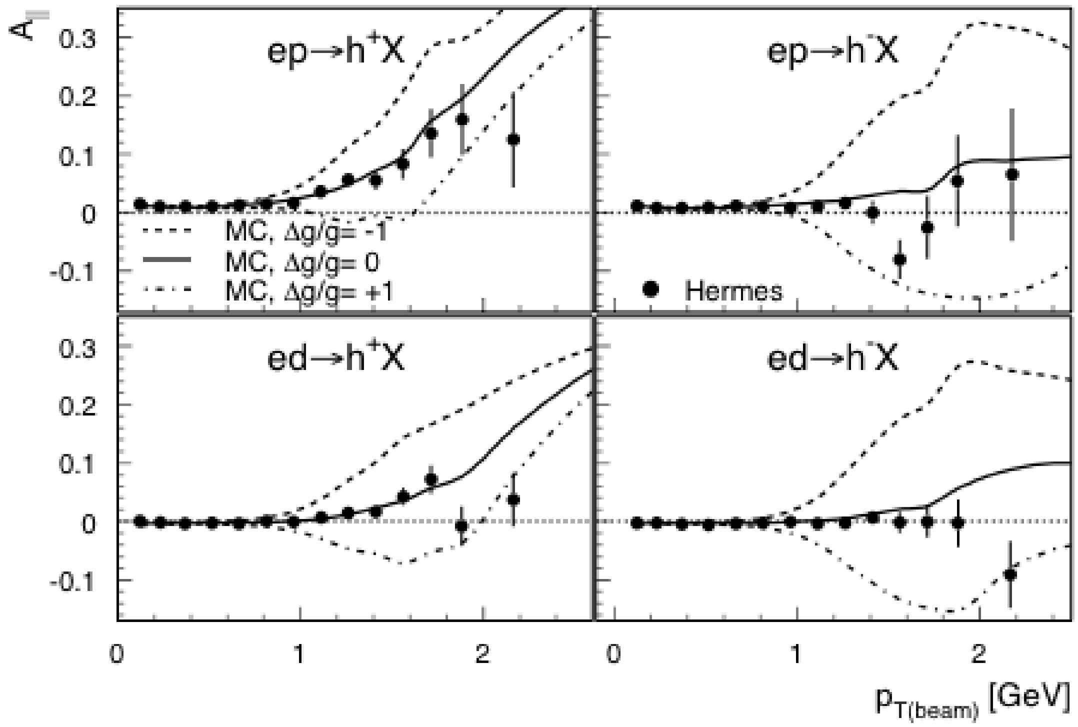

Figure 4: Measured asymmetries

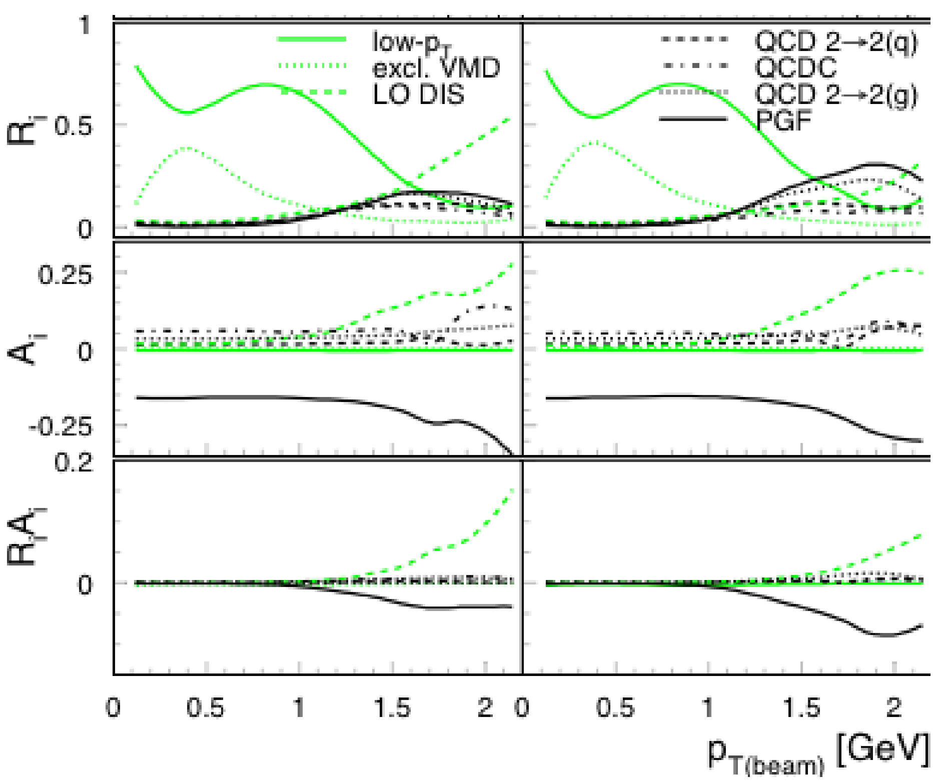

Figure 5: Upper panel: Underlying subprocess fraction as determined from PYTHIA; middle panel: the hard subprocess asymmetries; lowest panel: the product of both. These are used to unfold the Gluon polarization from the measured asymmetries.

The gluon polarization obtained from single inclusive hadrons in the p_T range 1 GeV < p_T < 2.5 GeV using a deuterium target is

$$\mathbf{\Delta g/g=0.049 \pm 0.034\ (stat) \pm 0.010\ (sys\text{-}exp)^{+0.126}_{-0.099}(sys\text{-}models)}$$

at a scale $\langle\mu^2\rangle$=1.35 GeV^2 and <x> = 0.22. The final result on the gluon polarization is shown in Fig. 6. The HERMES result is compared to the world data extracting the gluon polarization from semi-inclusive DIS data. The different data sets are in good agreement with each other. The curves presented on the plot represent the results (dotted curve) from the pQCD fit to the world data on the structure function g_1. The solid curve is the result from a pQCD fit to the world data on inclusive and semi-inclusive DIS as well as to the RHIC data. The red curve represents the fit done only to the HERMES inclusive hadron data (for details see the full paper).
Even neglecting the systematic uncertainties in the fits (not shown on this plot) the agreement with the data is good.

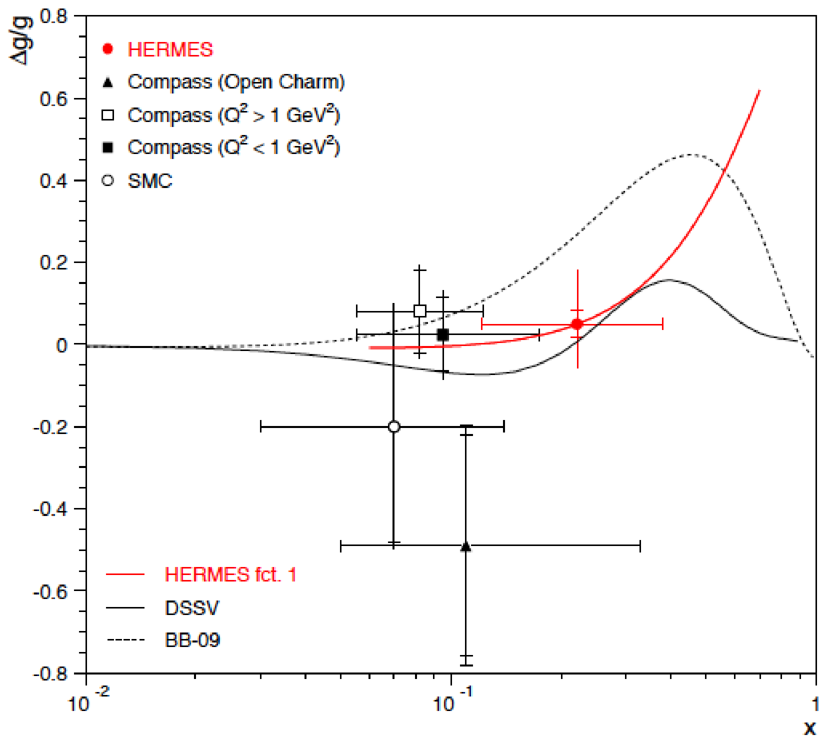

Figure 6: The world data on the gluon polarization extracted from semi-inclusive DIS data compared to different pQCD fits not including these data and to the fit done only to the HERMES data.