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The Role of Higher Twist in Determining Polarized Parton Densities from DIS data

E. Leader (London), A. Sidorov (Dubna), D. Stamenov (Sofia)

OUTLINE

- Peculiarity of the **polarized** DIS

A lot of the present data are at low Q^2 ⇨
the role of **HT effects** could be important

- Connection between theory and experiment
$\Rightarrow$ different approaches to the data fit

- Method of analysis: $g_{1\exp} \Longleftrightarrow g_1{}^{pQCD} + HT$

- Results - HT effects, NLO polarized parton densities

- Conclusions

Theory

In QCD

$$g_1(x,Q^2) = g_1(x,Q^2)_{LT} + g_1(x,Q^2)_{HT}$$

$$g_1(x,Q^2)_{LT} = g_1(x,Q^2)_{pQCD}$$

$$g_1(x,Q^2)_{HT} = h(x,Q^2)/Q^2 + h^{TMC}(x,Q^2)/Q^2$$

target mass corrections which are calculable *J. Blumlein, A.Tkabladze*

dynamical HT power corrections
=> non-perturbative effects (model dependent)

In NLO pQCD

$$g_1(x,Q^2)_{pQCD} = \frac{1}{2}\sum_q^{N_f} e_q^2[(\Delta q + \Delta\bar{q}) \otimes (1 + \frac{\alpha_s(Q^2)}{2\pi}\delta C_q) + \frac{\alpha_s(Q^2)}{2\pi}\Delta G \otimes \frac{\delta C_G}{N_f}]$$

$\delta C_q, \delta C_G$ – *Wilson* coefficient functions

polarized PD evolve in Q^2

according to **NLO DGLAP** eqs.

- An important difference between the kinematic regions of the unpolarized and ***polarized*** data sets

A lot of the present data are at low Q^2 and W^2

$$Q^2 \approx 1-5\, GeV^2,\ \ W^2 > 4 GeV^2$$

While in the determination of the PD in the unpolarized case we can cut the low Q^2 and W^2 data in order to eliminate the less known non-perturbative HT effects, it is impossible to perform such a procedure for the present data on the spin-dependent structure functions without loosing too much information.

$$O(1/Q^2)$$

⇨ **HT corrections** should be **important !**

DATA

185 exp. p.

206 exp. p.

CERN **EMC -** A_1^p **SMC -** $A_1^p,\ A_1^d$

DESY **HERMES -** $\frac{g_1^p}{F_1^p},\ A_1^n,\ \frac{g_1^d}{F_1^d}$ (preliminary)

SLAC **E142, E154 -** A_1^n **E143, E155 -** $\frac{g_1^p}{F_1^p},\ \frac{g_1^d}{F_1^d}$

JLab **Hall A** $\frac{g_1^n}{F_1^n}$

The data on A_1 ***are really the experimental values of the quantity***

$$\frac{A_{||}^N}{D} = (1+\gamma^2)\frac{g_1^N}{F_1^N} + (\eta-\gamma)A_2^N$$

$$= A_1^N + \eta A_2^N$$

$\gamma \approx \eta$ and A_2 small

very well approximated with even when $\gamma(\eta)$ ***can not been neglected***

$$(1+\gamma^2)\frac{g_1^N}{F_1^N}$$

Connection between Theory and Experiment

- Fit to g_1/F_1 data - *Gluck et al. (GRSV); Leader et al. (LSS)*

$$\left[\frac{g_1(x,Q^2)}{F_1(x,Q^2)}\right]_{\exp} \overset{\chi^2}{\underset{158.3}{\Longleftrightarrow}} \frac{g_1(x,Q^2)_{LT}}{F_1(x,Q^2)_{LT}}; \qquad \chi^2_{dof} = 0.884$$

$$\left[\frac{g_1(x,Q^2)}{F_1(x,Q^2)}\right]_{\exp} \Longleftrightarrow \frac{g_1(x,Q^2)_{LT}}{F_1(x,Q^2)_{LT}} + \frac{h^{g_1/F_1}(x)}{Q^2} \quad \Rightarrow \quad h^{g_1/F_1}(x) \approx 0$$

- Fit to g_1 data - *SMC; Blumlein, Bottcher (BB); AAC*

$$g_1(x,Q^2)_{\exp} = \left[\frac{g_1(x,Q^2)}{F_1(x,Q^2)}\right]_{\exp} F_1(x,Q^2)_{\exp} \overset{\chi^2}{\underset{240.7}{\Longleftrightarrow}} g_1(x,Q^2)_{LT}$$

from g_1/F_1 fit

$(F_2)_{\exp}$, $R_{\exp}$

$$g_1(x,Q^2)_{\exp} \overset{\chi^2}{\underset{212.5}{\Longleftrightarrow}} g_1(x,Q^2)_{LT}$$

$$g_1(x,Q^2)_{\exp} \overset{\chi^2}{\underset{149.8}{\Longleftrightarrow}} g_1(x,Q^2)_{LT} + h^{g_1}(x)/Q^2; \qquad \chi^2_{dof} = 0.886$$

important

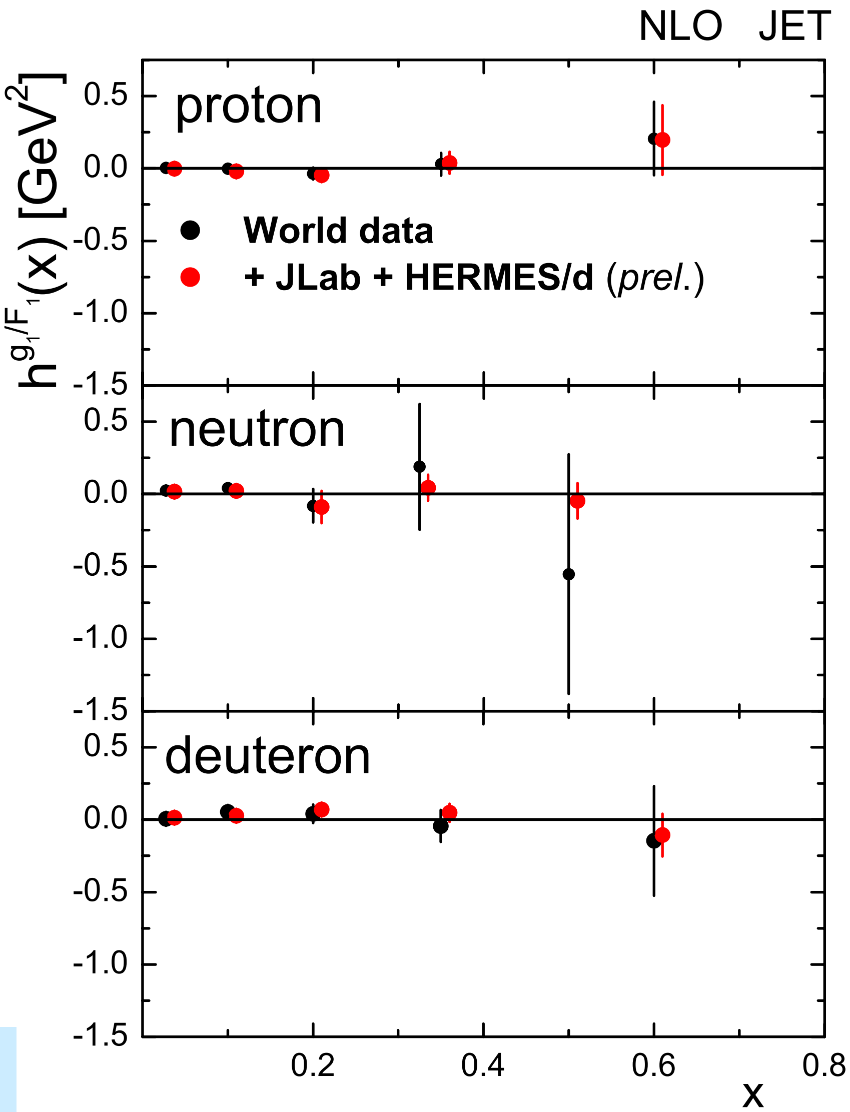
$$(g_1)_{QCD} = (g_1)_{LT} + (g_1)_{HT}$$

$$(F_1)_{QCD} = (F_1)_{LT} + (F_1)_{HT}$$

$$\left[\frac{g_1(x,Q^2)}{F_1(x,Q^2)}\right]_{\exp} \Longleftrightarrow \frac{g_1(x,Q^2)_{LT}}{F_1(x,Q^2)_{LT}} + \frac{h^{g_1/F_1}(x)}{Q^2}$$

$$\Rightarrow h^{g_1/F_1} \approx 0 \Rightarrow \frac{(g_1)_{HT}}{(g_1)_{LT}} \approx \frac{(F_1)_{HT}}{(F_1)_{LT}}$$

E.Leader, A.Sidorov, D.Stamenov
[hep-ph/0309048]



The HT corrections to g_1 and F_1 approximately compensate each other in the ratio g_1/F_1 and the PPD extracted by this way are less sensitive to HT effects

$$h^{g_1/F_1}(x) \approx 0$$

METHOD of ANALYSIS

HT to g_1 included in model independent way

$$\left[\frac{g_1(x,Q^2)}{F_1(x,Q^2)}\right]_{exp} \Leftrightarrow \frac{g_1(x,Q^2)_{LT}+h^N(x)/Q^2}{F_2(x,Q^2)_{exp}} 2x\frac{[1+R(x,Q^2)_{exp}]}{(1+\gamma^2)}$$

NMC

R_{1998} (SLAC)

$$A_1(x,Q^2)_{exp} \Leftrightarrow \frac{g_1(x,Q^2)_{LT}+h^N(x)/Q^2}{F_2(x,Q^2)_{exp}} 2x[1+R(x,Q^2)_{exp}]$$

$h^p(x_i), h^n(x_i) - 10\ parameters\ (i=1,2,\ldots 5)$ to be determined from a fit to the data

Input parton densities

$$\Delta f_i(x,Q_0^2) = A_i x^{\alpha_i} f_i^{MRST}(x,Q_0^2)$$

$$Q_0^2 = 1\,GeV^2,\ A_i, \alpha_i - free\ par.\ (\mathrm{i}=1,2,\ldots 4)$$

➡ **8-2(SR) = 6 par. associated with PD; MRST'02 positivity bounds imposed**

The inverse Mellin-transformation method has been used to calculate $g_1^N(x,Q^2)_{LT}$ from its moments

SR for n=1 moments of PD

$$g_A = (\Delta u + \Delta \bar{u})(Q^2) - (\Delta d + \Delta \bar{d})(Q^2) = 1.2670 \pm .0035 \qquad (1)$$

$$a_8 = (\Delta u + \Delta \bar{u})(Q^2) + (\Delta d + \Delta \bar{d})(Q^2) - 2(\Delta s + \Delta \bar{s})(Q^2) = 3F - D = 0.585 \pm 0.025 \qquad (2)$$

The sum rule (1) reflects the isospin SU(2) symmetry, whereas the relation (2) is a consequence of the SU(3) flavour symmetry treatment of the hyperon β-decays.

While isospin symmetry is not in doubt, there is some question about the accuracy of assuming $SU(3)_f$ symmetry in analyzing hyperon β-decays. The results of the recent KTeV experiment at Fermilab on the β-decay of Ξ^0, $\Xi^0 \to \Sigma^+ e \bar{\nu}$, **however, are all *consistent* with *exact* $SU(3)_f$ symmetry. Taking into account the experimental uncertainties one finds that $SU(3)_f$ breaking is at most of order 20%.**

RESULTS OF ANALYSIS

LSS 2004

Kinematic region - 185 exp. p.

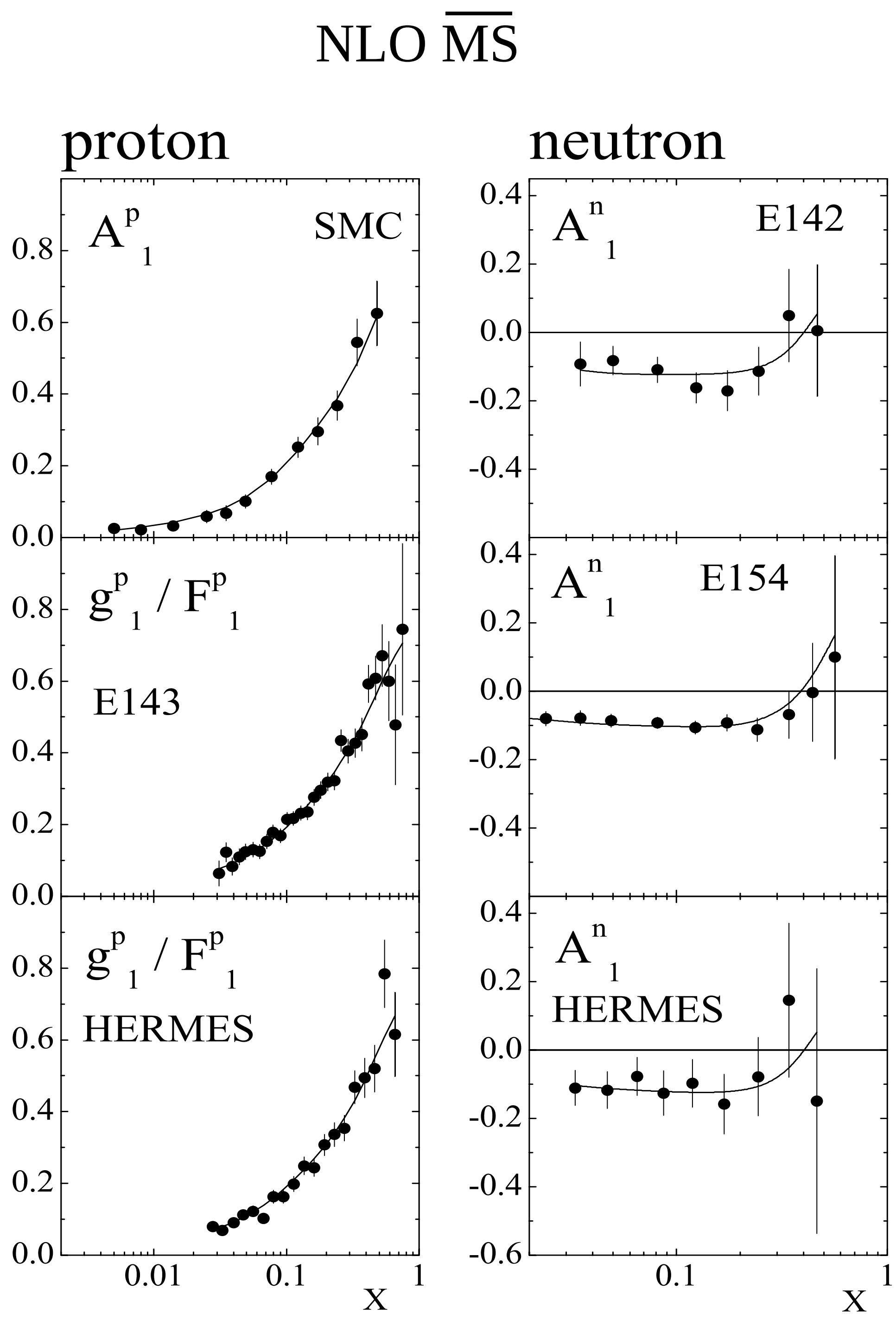
$0.005 \leq x \leq 0.75 \quad 1 < Q^2 \leq 58 \ \mathrm{GeV}^2$

Quality of the fits

A very good description of the world A_1 and g_1 data is achieved.

$$\mathrm{LO} \Rightarrow \chi^2_{DF,LO} = 0.910$$

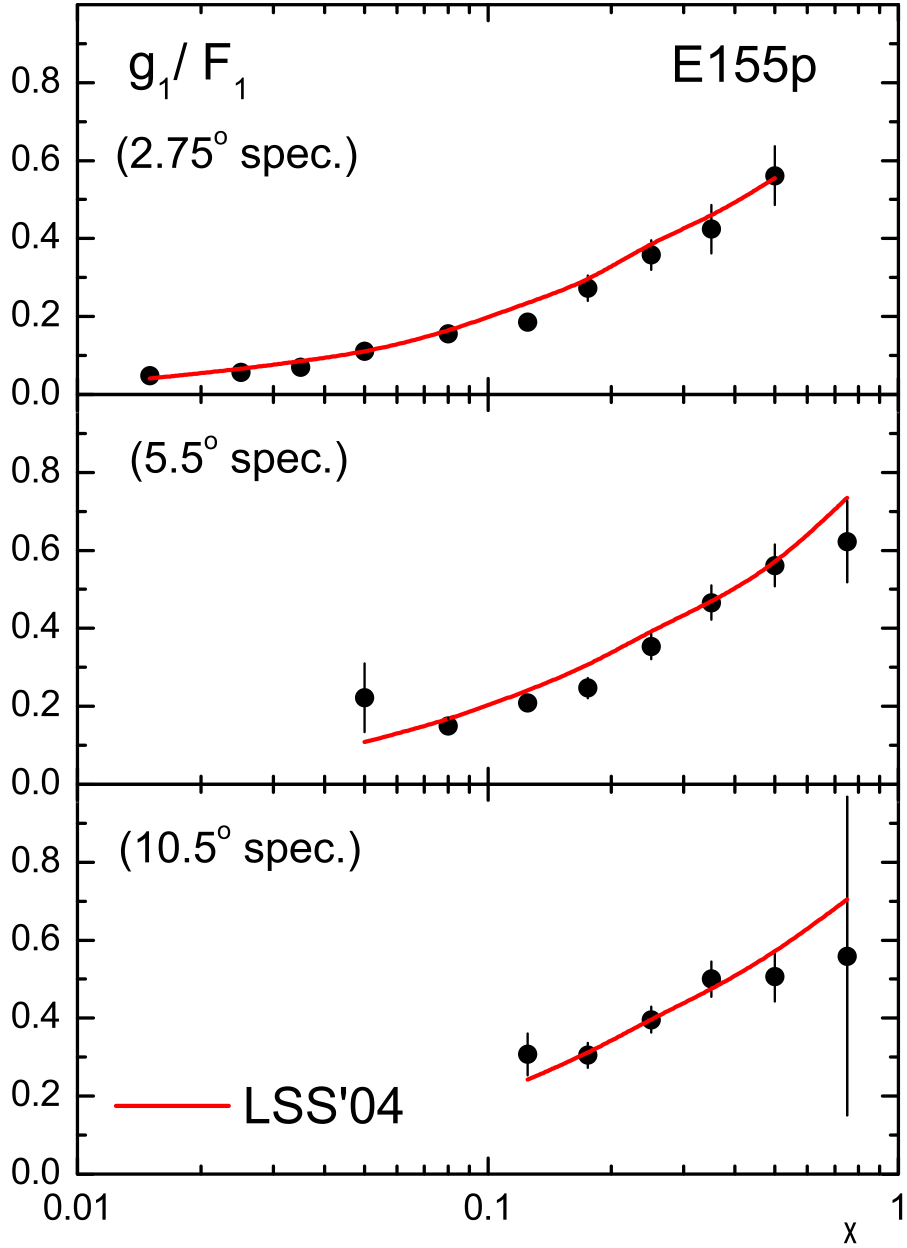
$$\mathrm{NLO}(\overline{MS}) \Rightarrow \chi^2_{DF,NLO} = 0.886$$



NLO $\overline{MS}$

Comparison of our NLO($\overline{MS}$) result for g_1^p / F_1^p with SLAC/E155 proton experimental data.

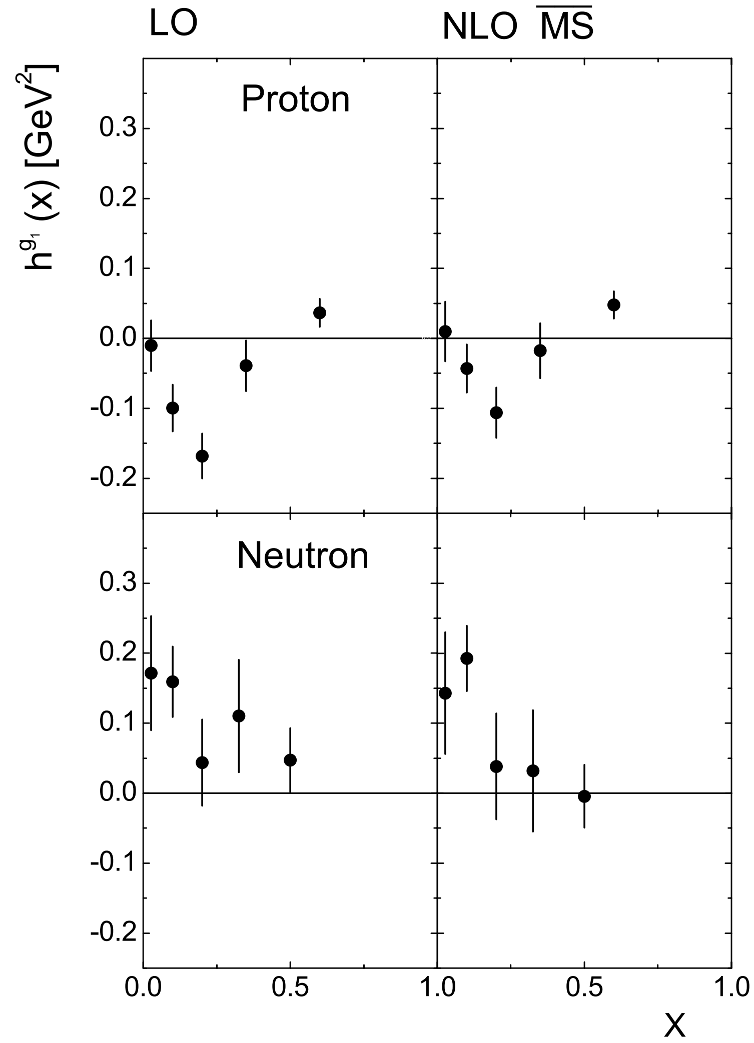
Error bars represent the total errors.



Higher twist effects

Dependence of χ^2 on HT corrections

Fit	LO HT=0	NLO HT=0	LO+HT	NLO+HT
χ^2	249.8	212.5	153.8	149.8
DF	185-8	185-6	185-16	185-16
χ^2 / DF	1.41	1.19	0.910	0.886



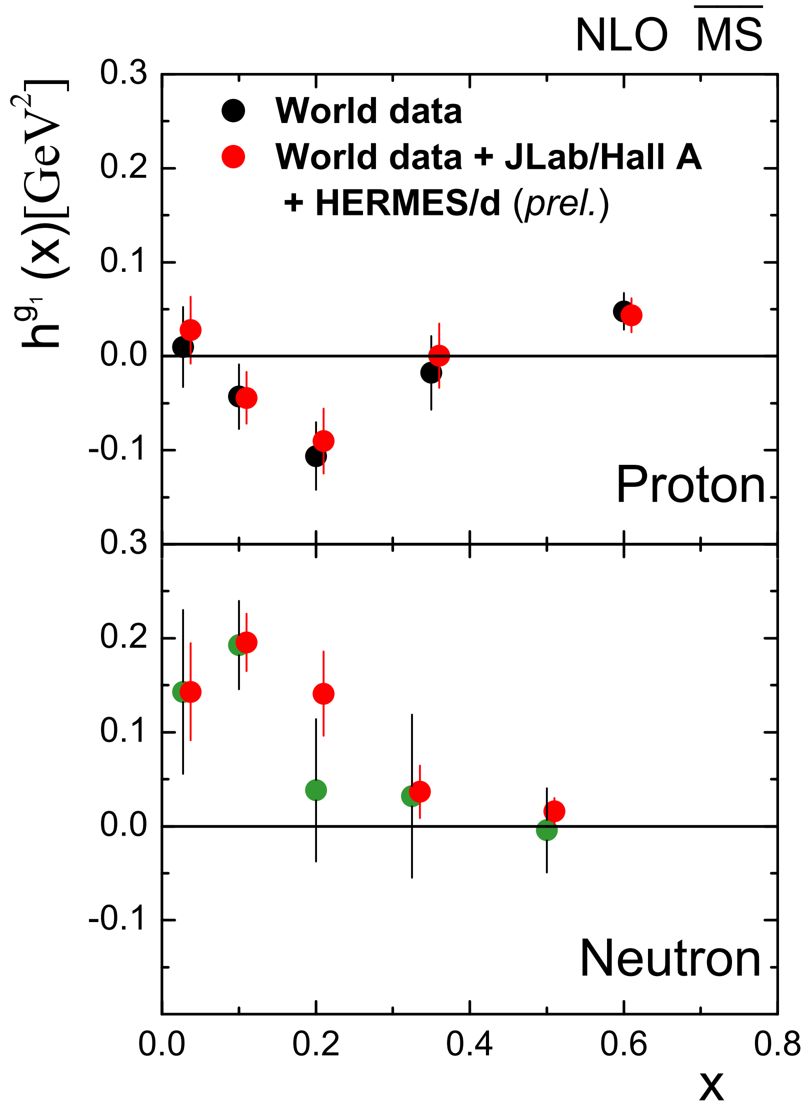
The size of HT corrections to g_1 is NOT negligible

The shape of HT depends on the target

$$g_1(x,Q^2) = g_1(x,Q^2)_{LT} + \frac{h^{g_1}(x)}{Q^2}$$

- If JLab/Hall A and HERMES/d data are included in the analysis, the HT corrections to g_1 are better determined, especially for the neutron target

- HERMES **final** results on g_1^d/F_1^d are very important for better understanding of HT effects



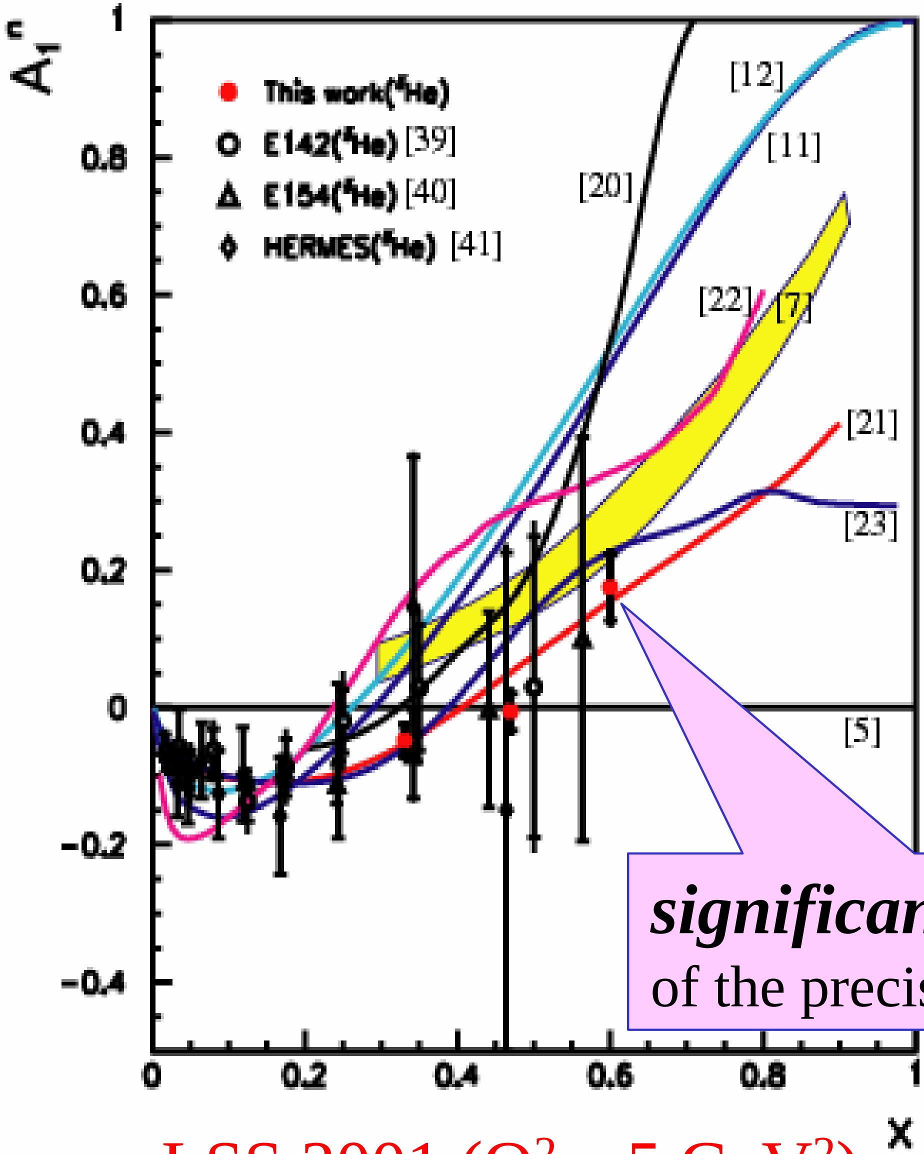
$$\int_0^1 dx\, h^{g_1}(x) = \frac{4}{9} M^2 (d_2 + f_2)$$

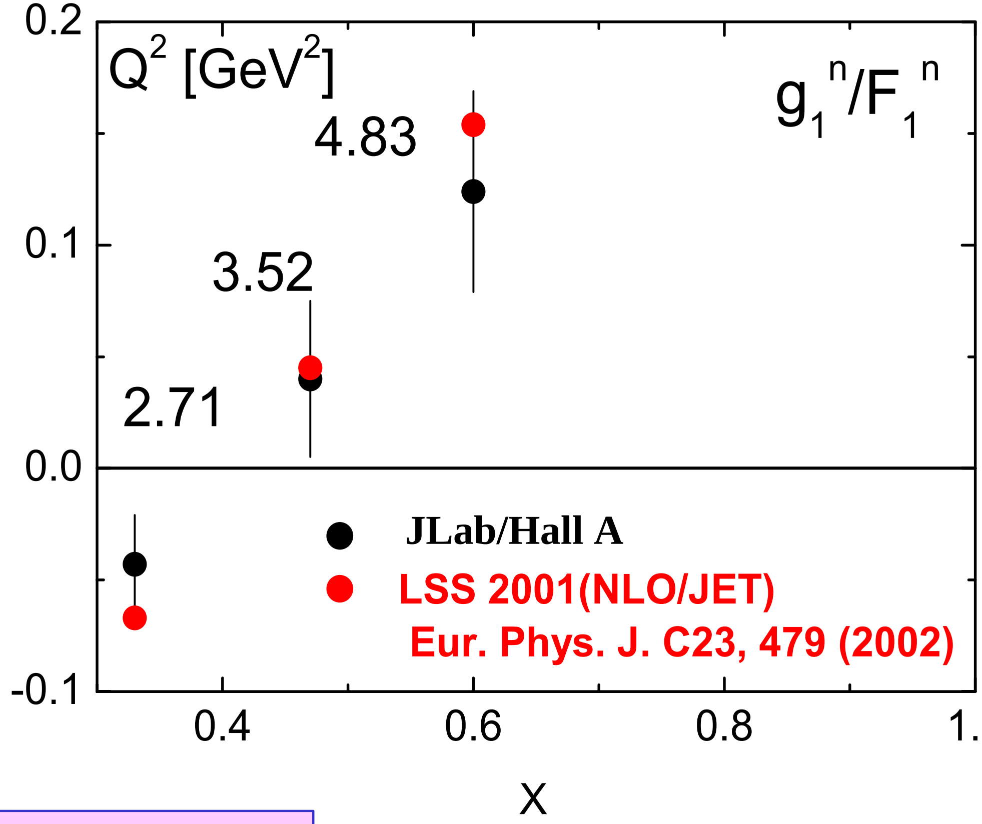
HT (τ=3) — HT (τ=4)

$d_2 = 0$ if WW approximation for g_2 is assumed

JLab/Hall A: PRL 92 (2004) 012004

Our predictions for the JLAB experimental values of g_1^n/F_1^n using the LSS'2001 NLO(JET) polarized PD





significant improvement of the precision of the data

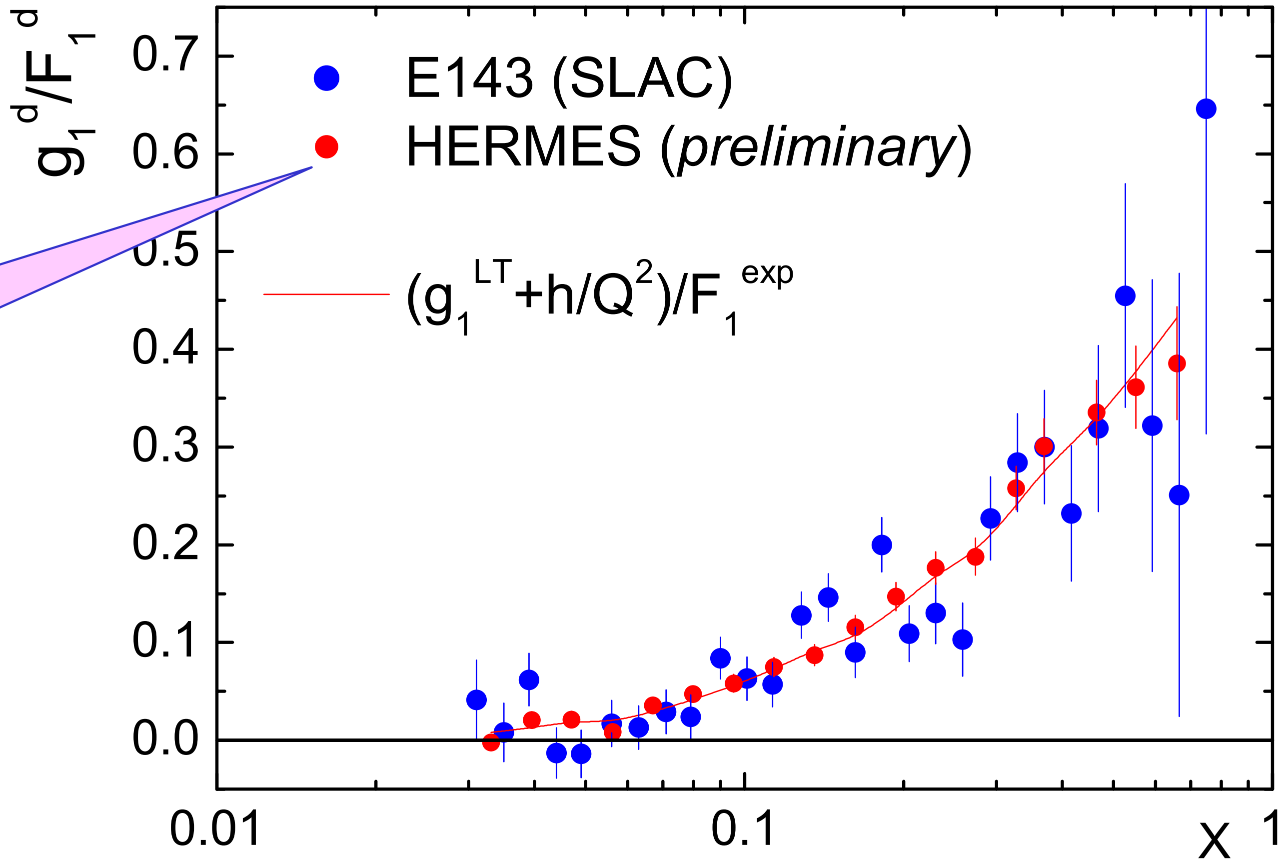
-LSS 2001 (Q^2 = 5 GeV^2)

[21] *Leader,Sidorov,Stamenov, Euro Phys. J. C23, 479 (2002)*

Recent results from the fit to the world data including the **JLab** and **HERMES/d** data

- a very good description of the HERMES/d data
  χ^2=11.8 for 18 points
- PD(g_1^{NLO}+ HT) practically do **NOT** change !!

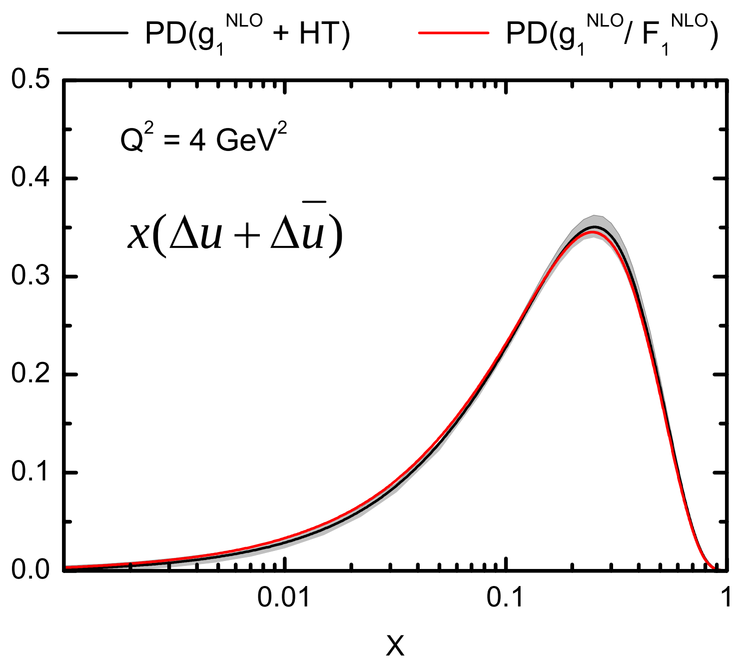
Ch. Weiskopf
02-043 Thesis (2002)

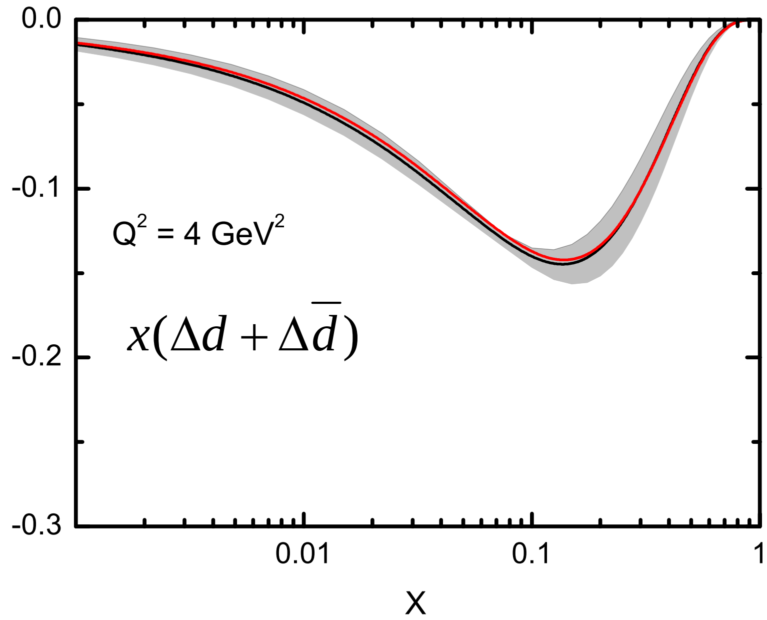


NLO ($\overline{MS}$) polarized PD ($Q^2 = 4$ GeV^2)

From inclusive DIS data $\Rightarrow (\Delta q + \Delta\bar{q})$ and ΔG

- $(\Delta u + \Delta\bar{u}), (\Delta d + \Delta\bar{d})$ well determined





NLO ($\overline{MS}$) polarized PD ($Q^2 = 4$ GeV^2)

- $(\Delta s + \Delta\bar{s})$ reasonably well determined and negative if accept for a_8 its SU(3) symmetric value a_8 = 3F-D = 0.58

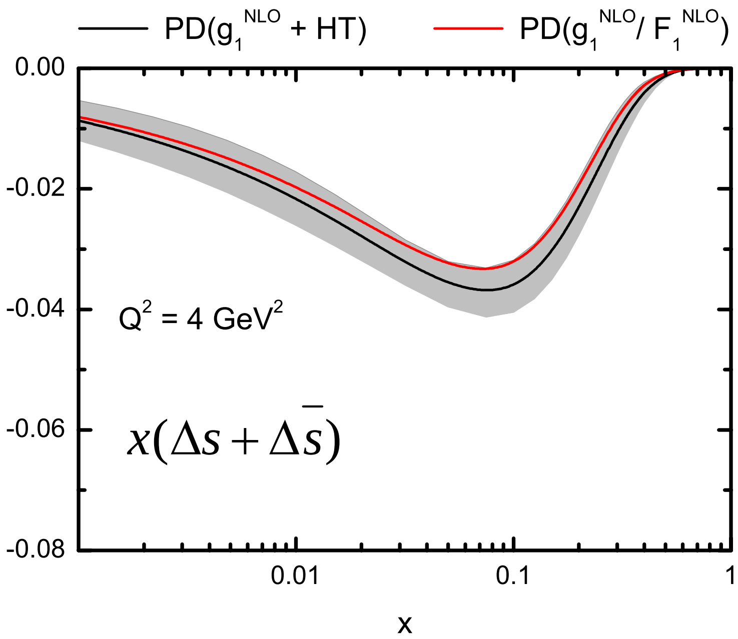
- ΔG not well constrained

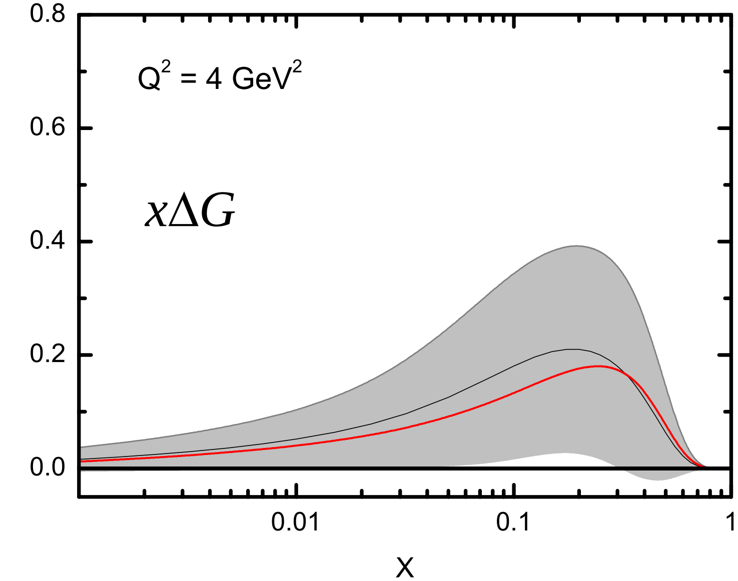
$$PD(g_1^{NLO} + HT) \Leftrightarrow PD(g_1^{NLO} / F_1^{NLO})$$

$$\chi^2_{DF,NLO} = 0.886 \Leftrightarrow \chi^2_{DF,NLO} = 0.884$$

⬇

In g_1 data fit HT corrections are important !





CONCLUSIONS

- The fit to the ***present*** data on g1 is **essentially improved**, especially in the LO case, when the higher twist terms of g_1 are included in the analysis

- The size of **HT** corrections have been extracted from the data in ***model independent*** way and found to be NOT negligible

- The HT corrections to g_1 and F_1 compensate each other in **g1/F1**

- $PD(g_1^{LT} + HT)$ **well consistent with** $PD(g_1^{LT} / F_1^{LT})$

➡ **To extract *correctly* the polarized PD from the g_1 data,**

the HT corrections to g_1 *have* to be taken into account in the analysis.