15th International Workshop on Deep Inelastic Scattering and Related Subjects
Munich, Germany, April 16-20, 2007

Polarized PDFs and Higher Twist in the Light of the Recent CLAS and COMPASS Data

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

OUTLINE

- Method of analysis – higher twist corrections are taken into account

- Two new sets of very precise data on inclusive polarized DIS are included in the analysis

  - *low* Q^2 *CLAS* data
  - *COMPASS* data mainly at *large* Q^2

  ⇐ *Very different kinematic regions*

- Impact of the new data on *LSS'05* polarized PD and HT

- The sign of the gluon polarization

- Summary

LSS: hep-ph/0612360 (PR D75, 2007)

Theory

In QCD

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

$$g_1(x,Q^2)_{LT} = g_1(x,Q^2)_{pQCD} + \frac{M^2}{Q^2} h^{TMC}(x,Q^2) + O(\frac{M^4}{Q^4})$$

$$g_1(x,Q^2)_{HT} = h(x,Q^2)/Q^2 + O(\frac{\Lambda^4}{Q^4})$$

dynamical HT power in Λ^2/Q^2 corrections (τ =3,4)
=> non-perturbative effects (model dependent)

target mass corrections which are calculable
A. Piccione, G. Ridolfi

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.

N_f (=3) - the number of flavors

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

- **A lot of the present data are at moderate Q^2 and W^2 :**

$$Q^2 \approx 1-5\,GeV^2,\ 4 < W^2 < 10\,GeV^2$$

preasymptotic region

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.

$$O(\Lambda^2/Q^2)$$

➡ **HT corrections** have to be **accounted for** in **polarized** DIS !

Method of analysis

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

F_2^{NMC}, R_{1998}(SLAC)

in model independent way

Input PD $\quad \Delta f_i(x,Q_0^2) = A_i x^{\alpha_i} f_i^{MRST}(x,Q_0^2) \quad Q_0^2 = 1\,GeV^2,\ A_i, \alpha_i - free\ par.$

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

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

SUM RULES

$$a_3 = g_A = (\Delta u + \Delta\bar{u})(Q^2) - (\Delta d + \Delta\bar{d})(Q^2) = F - D = 1.2670 \pm 0.0035$$

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

Flavor symmetric sea convention: $\Delta u_{sea} = \Delta\bar{u} = \Delta d_{sea} = \Delta\bar{d} = \Delta s = \Delta\bar{s}$

Higher twist effects

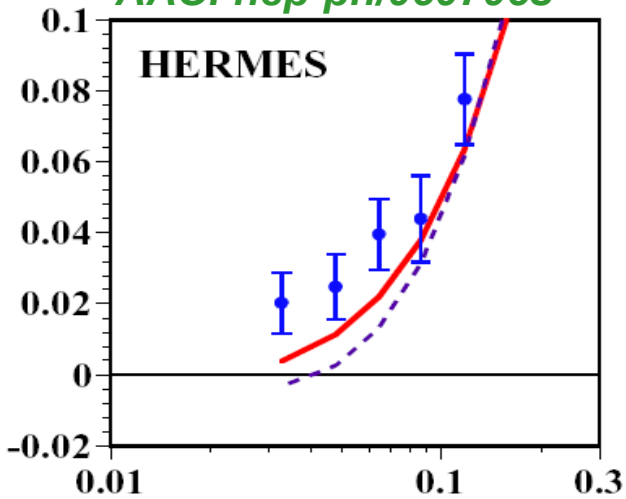
(CLAS'06 and COMPASS'06 not included)

$$g_1 = (g_1)_{LT} + h^{g_1}(x)/Q^2$$

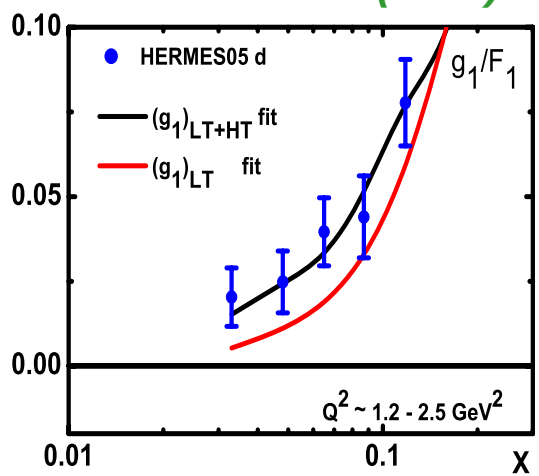
- **The low x and low Q^2 (1.2 ~ 2.5 GeV^2) HERMES/d data (*PR D71, 2005*) can not be described by the LT (logarithmic in Q^2) term in g_1 => red curves**

- **Excellent agreement with the data if the HT corrections to g_1 are taken into account in the analysis**

AAC: hep-ph/0607063



LSS: PR D73 (2006)



DATA
(old set)

CERN EMC - A_1^p SMC - A_1^p, A_1^d COMPASS'05 - A_1^d

DESY HERMES - $\frac{g_1^p}{F_1^p}$, $\frac{g_1^d}{F_1^d}$

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 - $\frac{g_1^n}{F_1^n}$

$$A_1^N \approx (1+\gamma^2)\frac{g_1^N}{F_1^N}$$

$\gamma^2 = 4M^2x^2/Q^2$ - kinematic factor

Number of exp. points: 190

LSS'05 polarized PD and HT ***(PR D73, 2006)***

DATA

CERN EMC - A_1^p SMC - A_1^p, A_1^d COMPASS'05 - A_1^d

DESY HERMES - $\frac{g_1^p}{F_1^p}, \frac{g_1^d}{F_1^d}$

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 - $\frac{g_1^n}{F_1^n}$ CLAS'06 - $\frac{g_1^p}{F_1^p}, \frac{g_1^d}{F_1^d}$

$$A_1^N \approx (1+\gamma^2)\frac{g_1^N}{F_1^N}$$

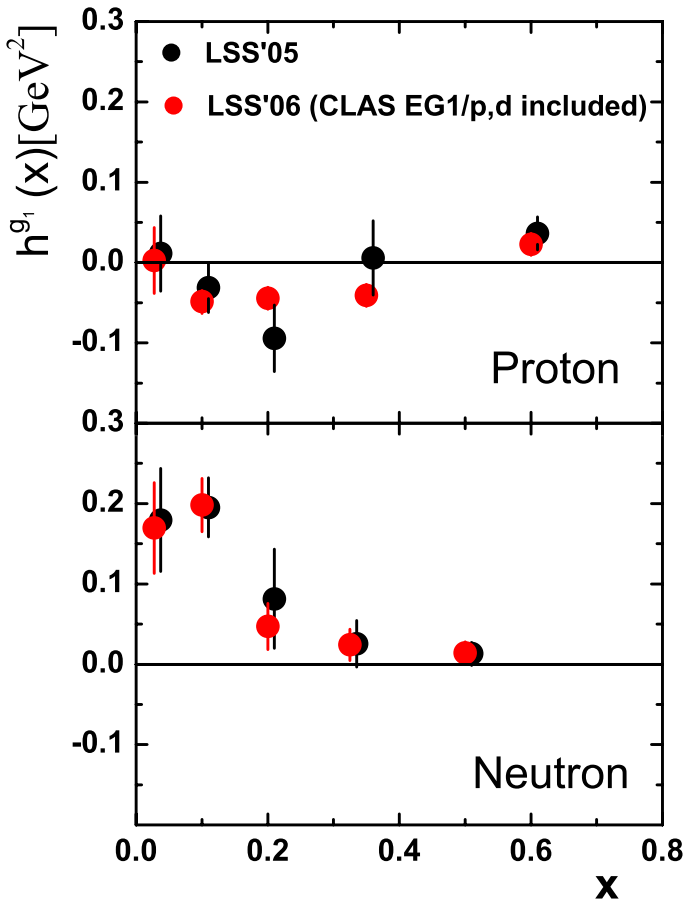
$\gamma^2 = 4M^2x^2/Q^2$ - kinematic factor

Number of exp. points: 190 ⟹ 823

Effect of CLAS'06 p and d data *(PL B641, 11, 2006)* on polarized PD and HT

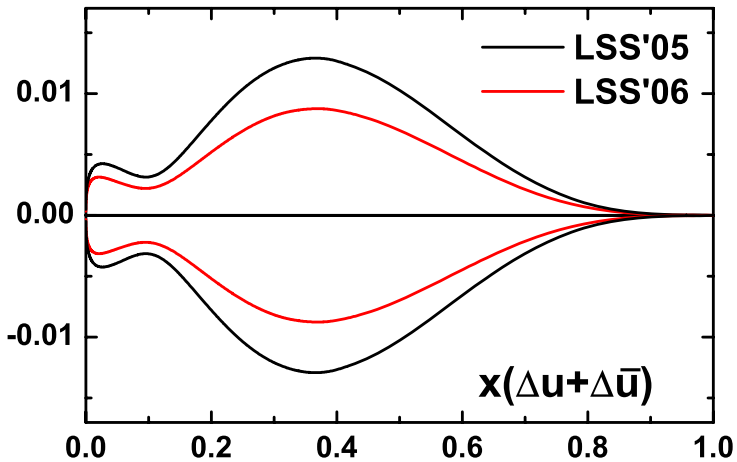
- Very accurate data on g_1^p and g_1^d at low Q^2: 1~ 4 GeV^2 for x ~ 0.1 - 0.6 (W > 2 GeV)
- The determination of HT/p and HT/n is significantly improved in the *CLAS* x region compared to HT(LSS'05)
- As expected, the central values of PPD are practically not affected by *CLAS* data, BUT the accuracy of its determination is essentially improved (a consequence of much better determination of HT corrections to g_1)

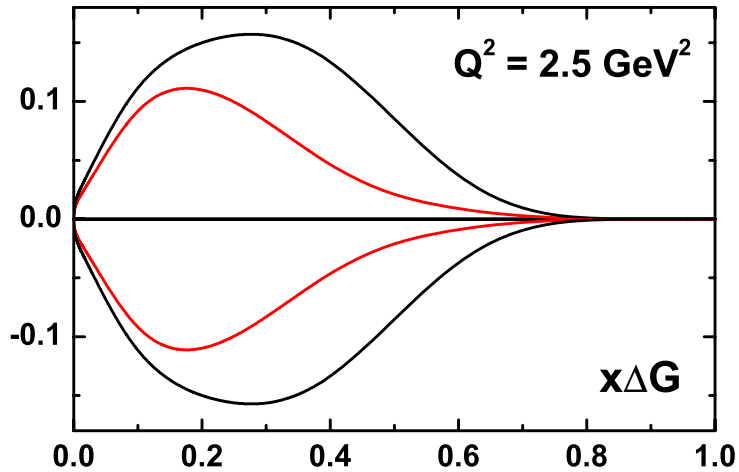
LSS'05: PR D73 (2006)

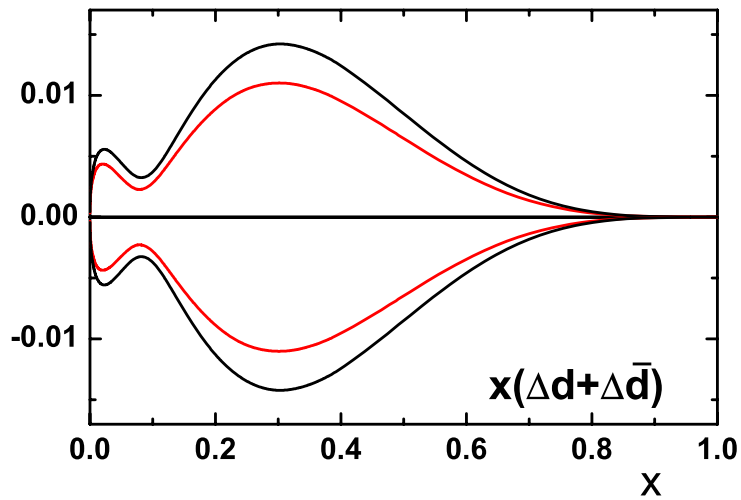


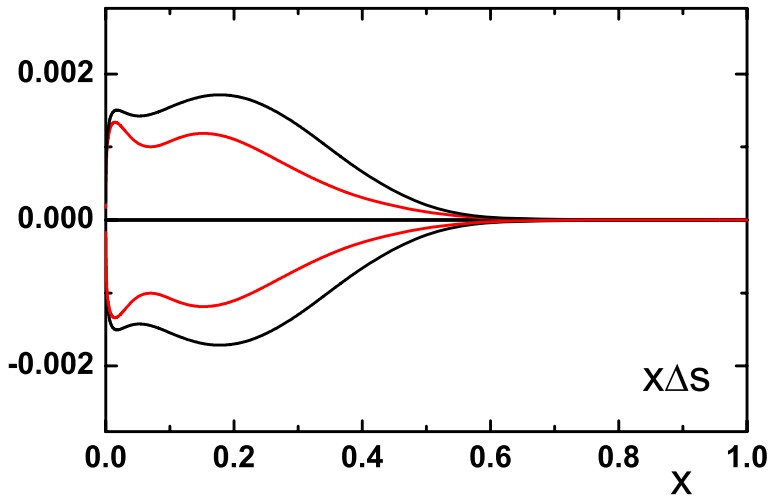
$$g_1 = (g_1)_{LT} + h^{g_1}(x)/Q^2$$

Impact of CLAS'06 data on the uncertainties for NLO($\overline{\text{MS}}$) polarized PD





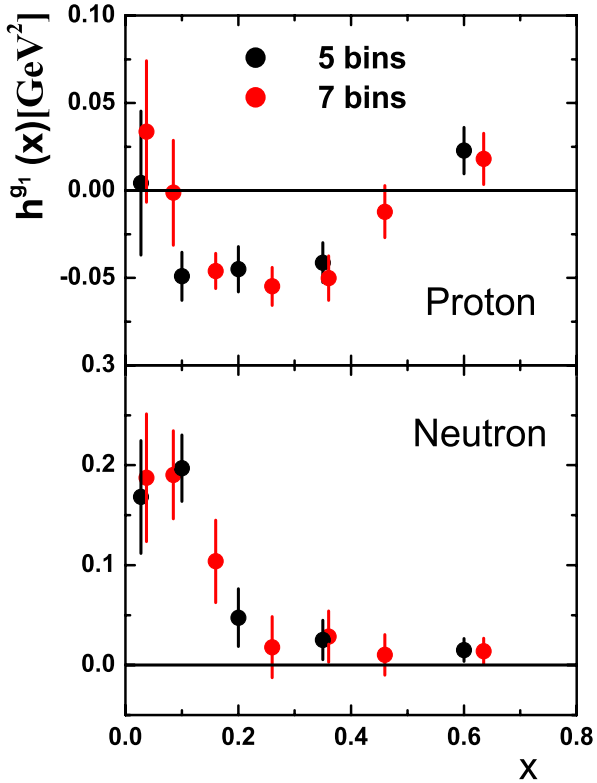


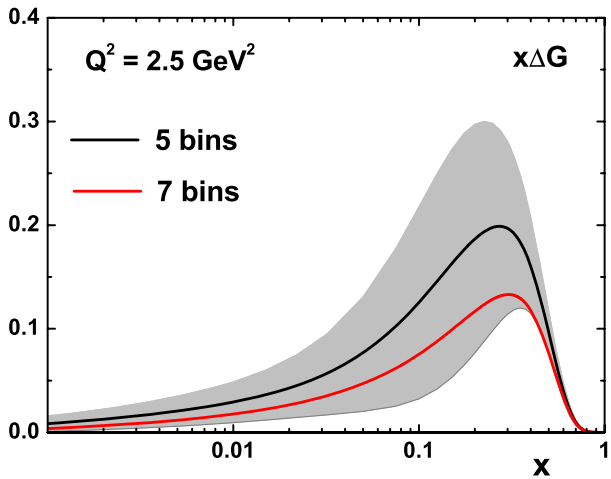


- Due to the good accuracy of the *CLAS* data, one can split the measured x region of the *world+CLAS* data set into 7 bins instead of 5, and to determine more precisely the x-dependence of HT

- The corresponding PPD are practically identical with those of LSS'06 (5 bins)

- The only exception is xΔG, but it lies within the error band of xΔG (5 bins) ⇒ small correlation between gluons and HT





DATA

CERN EMC - A_1^p SMC - A_1^p, A_1^d COMPASS'06 - A_1^d

DESY HERMES - $\frac{g_1^p}{F_1^p}$, $\frac{g_1^d}{F_1^d}$

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 - $\frac{g_1^n}{F_1^n}$ CLAS'06 - $\frac{g_1^p}{F_1^p}$, $\frac{g_1^d}{F_1^d}$

$$A_1^N \approx (1+\gamma^2)\frac{g_1^N}{F_1^N}$$

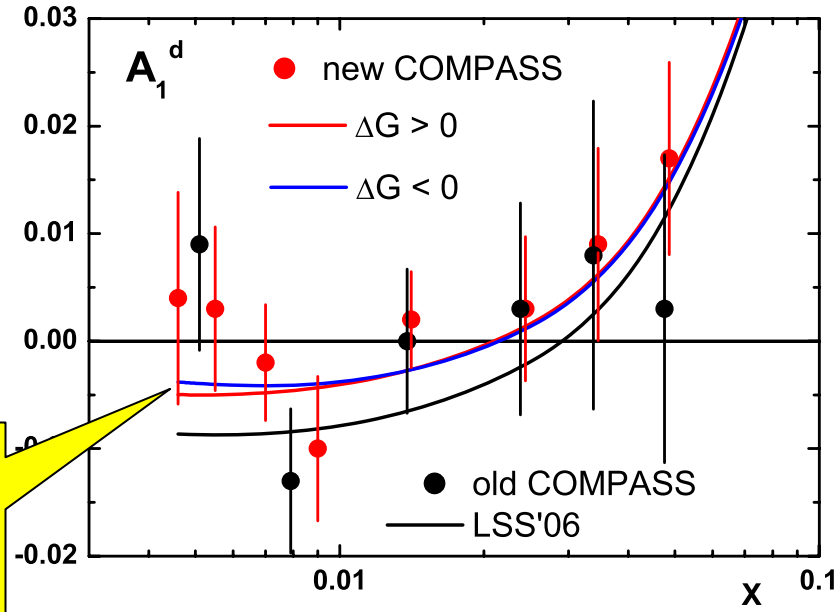
$\gamma^2 = 4M^2x^2/Q^2$ - kinematic factor

COMPASS'05 ⇒ **COMPASS'06**

Number of exp. points: 823 ⇒ 826

Effect of COMPASS'06 A_1^d data (*hep-ex/0609038*) on polarized PD and HT

In contrast to the *CLAS* data, the *COMPASS* data are mainly at large Q^2 and the only precise data at small x: $0.004 < x < 0.02$. The new data are based on 2.5 times larger statistics than those of *COMPASS'05*

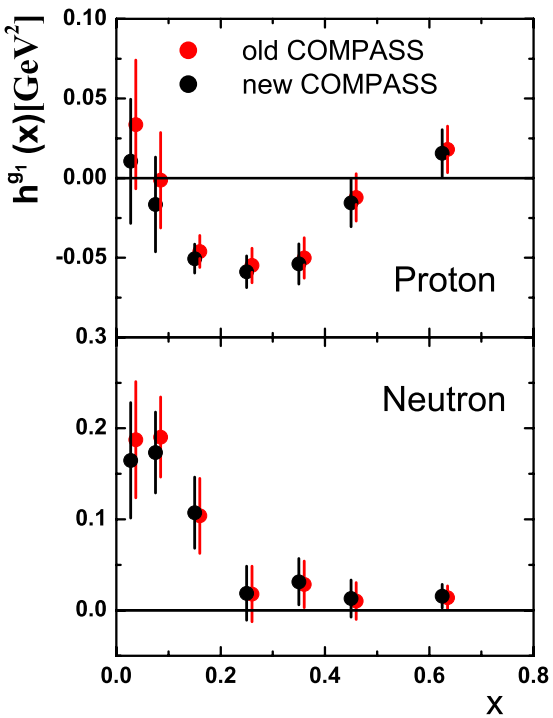


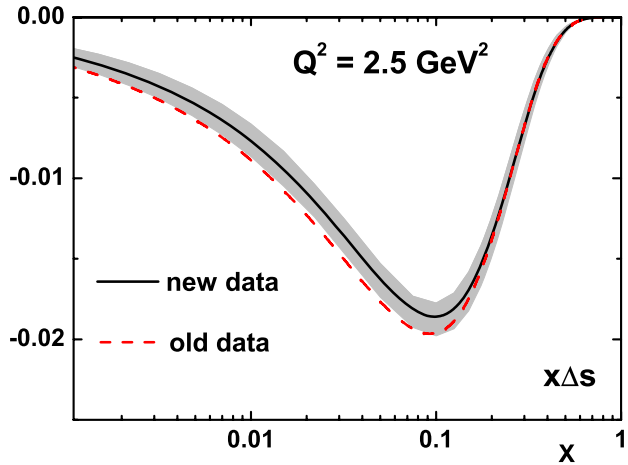
The new QCD curves corresponding to the best fits lie above the old one at $x < 0.1$

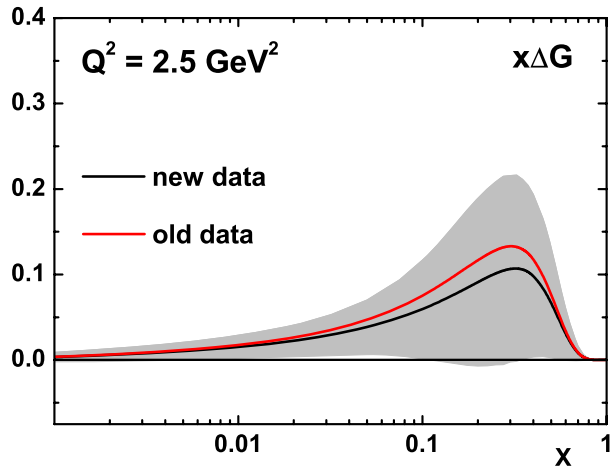
- $(\Delta u + \Delta \bar{u}),\ (\Delta d + \Delta \bar{d})$ **do NOT change**
- **$x|\Delta s(x)|$** and **$x\Delta G(x)$ and their first moments Δs and ΔG slightly decrease**

$Q^2 = 1\ GeV^2$

COMPASS	Δs	ΔG	$a_0 = \Delta\Sigma_{MS}$
old	-0.070 ± 0.006	0.173 ± 0.184	0.165 ± 0.044
new	-0.063 ± 0.005	0.129 ± 0.166	0.207 ± 0.040







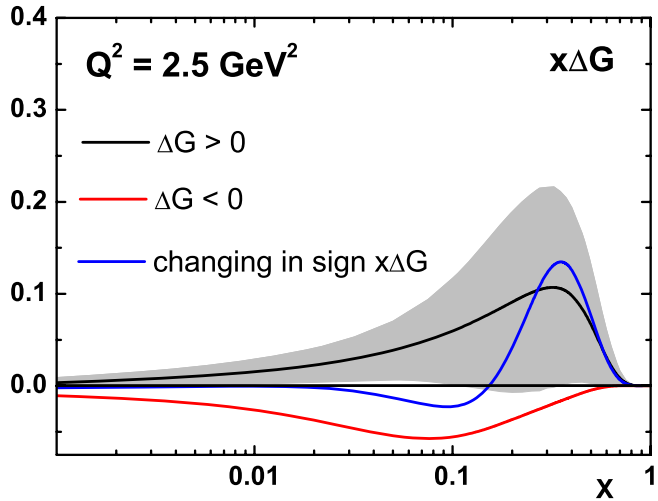
The values of HT are practically NOT affected by *COMPASS* data excepting the small x where Q^2 are also small

The sign of gluon polarization

- The present inclusive DIS data cannot rule out the solutions with negative and changing in sign gluon polarizations

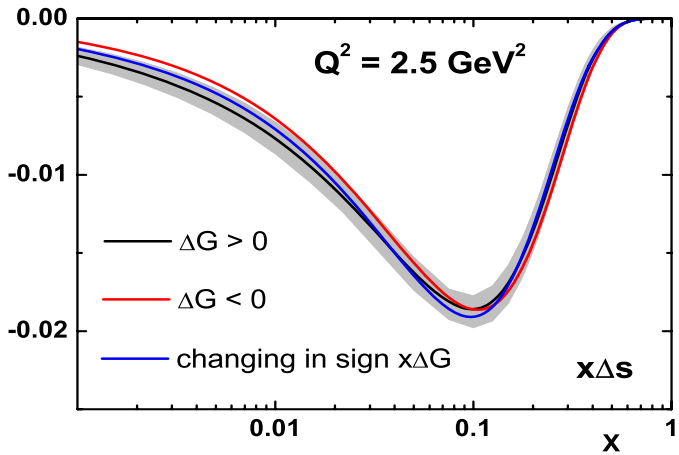
$$\chi^2_{DF}(\Delta G > 0) = 0.895$$

$$\chi^2_{DF}(\Delta G < 0) = 0.897,\ \chi^2_{DF}(x\Delta G / chsign) = 0.895$$



- The shape of the negative gluon density differs from that of positive one

- In all the cases the magnitude of ΔG is small: $|\Delta G| \leq 0.2$



- The corresponding polarized quark densities are very close to each other

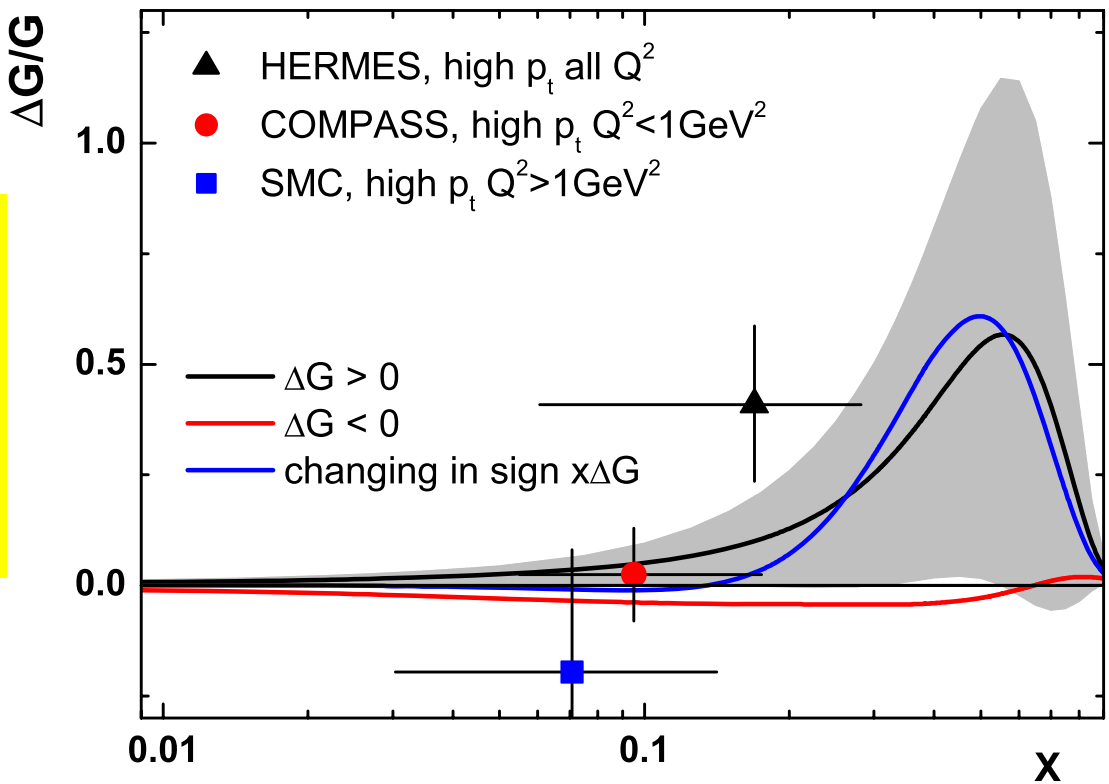
Comparison with directly measured ΔG/G at $Q^2 = 3\ GeV^2$

MRST'02 unpolarized gluon density is used for G(x)

The error band corresponds to statistic and systematic errors of ΔG

The error bars of the experimental points represent the total errors

The most precise value of ΔG/G, the *COMPASS* one, is well consistent with any of the polarized gluon densities determined in our analysis



LSS'06 *vs* C0MPASS'06

- At small x: 0.004 – 0.02 (Q^2 ~ 1-3 GeV^2) our results differ from those of *COMPASS*

$$(g_1)_{exp} \leftrightarrow$$

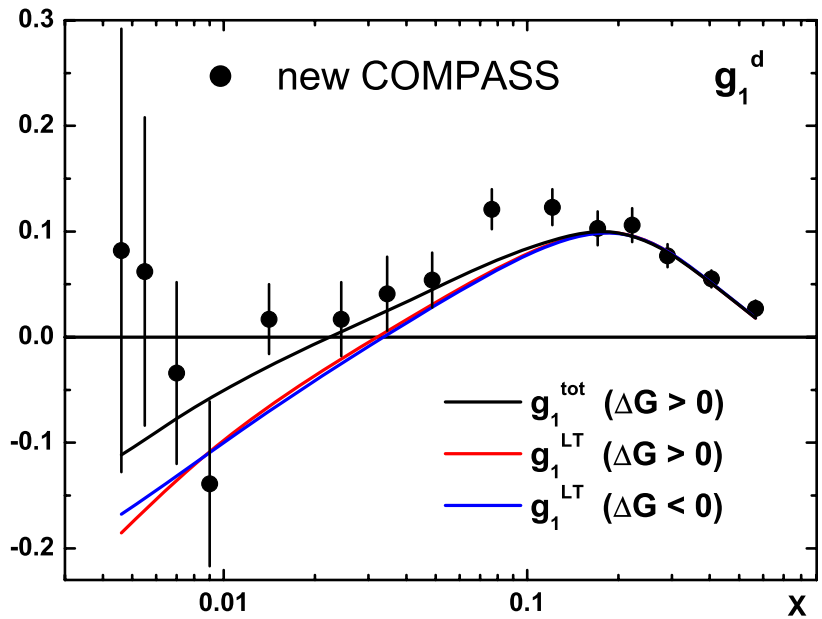
$$(g_1)_{LT}(COMPASS) \approx$$

$$(g_1)_{LT}(LSS) + h^d(x)/Q^2$$

- *COMPASS* → significant difference between $(g_1)_{th}$ corresponding to the best fits for $\Delta G > 0$ and $\Delta G < 0$

- *LSS'06* → the theoretical curves for both cases are very close to each other

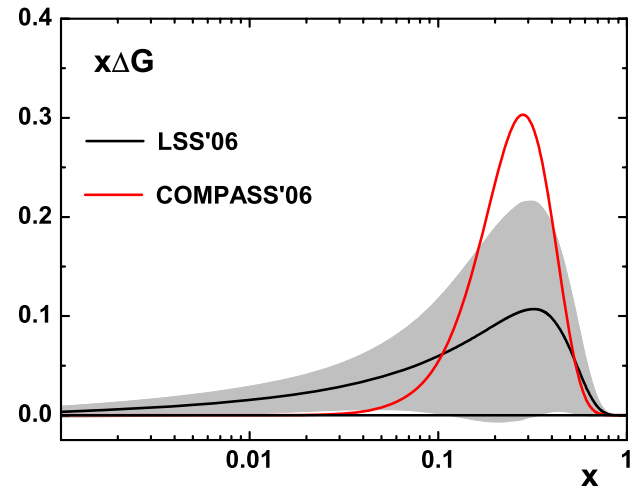
- The reason → HT effects (40% at small x) which are NOT taken into account by *COMPASS*

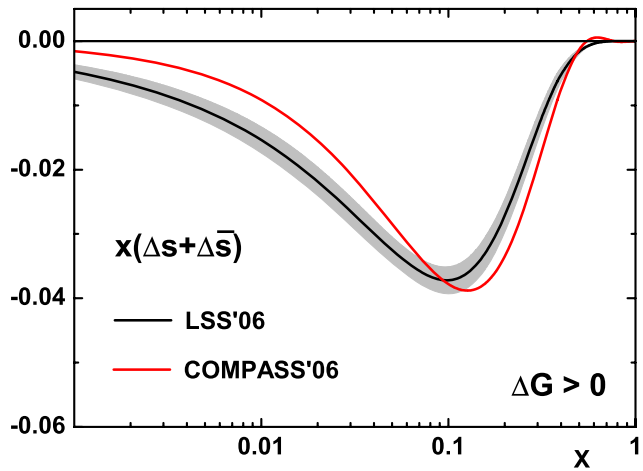


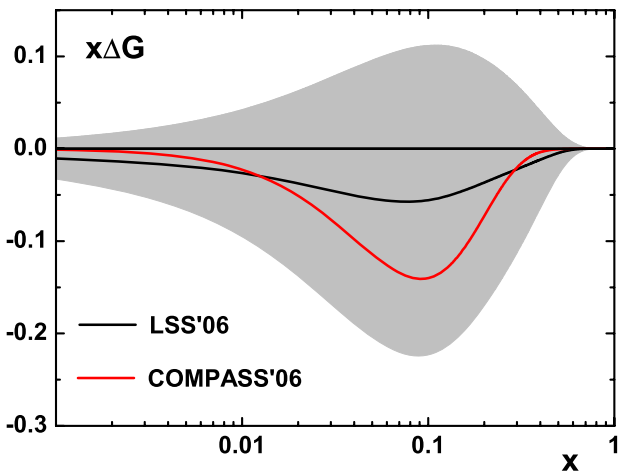
- **$x\Delta s$ are different, especially in the case of $\Delta G < 0$**

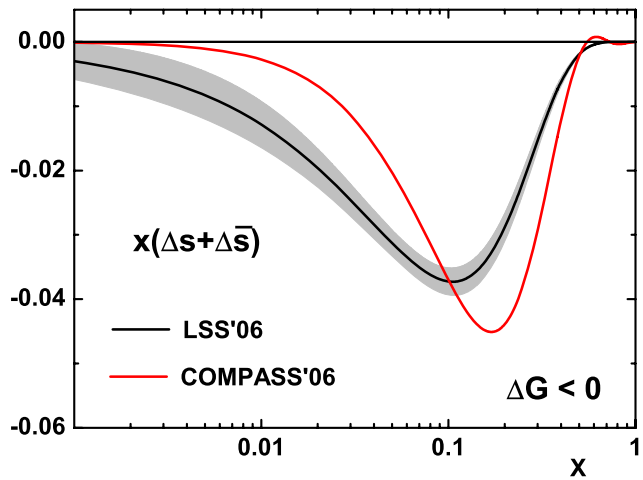
- **$x\Delta G$ obtaned by COMPASS in both fits are more peaked than ours**

$Q^2 = 3\ GeV^2$









SUMMARY

- The low Q^2 *CLAS* data improve essentially our knowledge of higher twist corrections to g_1 structure function
- The central values of polarized PD are NOT affected, but the accuracy of its determination is essentially improved
- The *COMPASS* data (mainly at large Q^2) influence $|\Delta s|$ and ΔG which slightly decrease, but practically do NOT change HT

→ Strong support of the QCD framework

- Large (40%) contribution of HT to $(g_1)^d$ at small x (low Q^2)
- The present inclusive DIS data cannot rule out the negative and changing in sign gluon densities
- Good agreement with the directly measured $\Delta G/G$