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Recent Results on Polarized PDFs and Higher Twist

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OUTLINE

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

- **Two new sets of very precise data on inclusive polarized DIS**

  - *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**

- **Spin of the proton, spin puzzle, flavor decomposition**

- **Summary**

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 !

LSS method of analysis

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

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

in model independent way

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

$h^p(x_i), h^n(x_i) - 10\ parameters\ \ (i=1,2,\ldots 5)$ 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

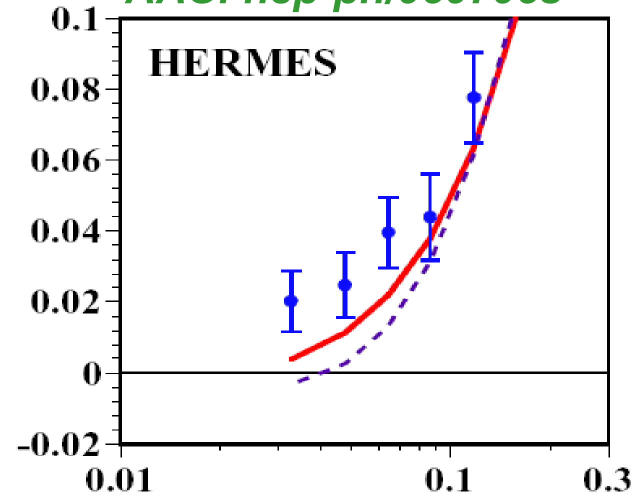
(CLAS'06 and COMPASS'06 not included)

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

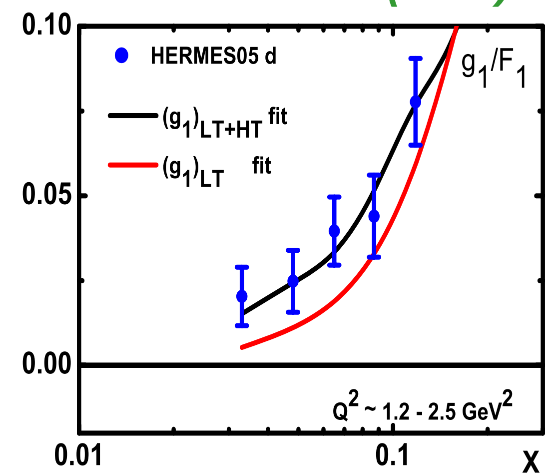
- **The low x and low Q^2 (1.2 ~ 2.5 GeV^2) HERMES/d data (*PR D71, 2005*) can not be described by the LT (logarithmic in Q^2) term in g_1 => red curves**

- **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 EG1b -** $\frac{g_1^p}{F_1^p},\ \frac{g_1^d}{F_1^d}$

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

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

Number of exp. points: 190 ⟹ 823

The analysis is performed in a collaboration with E. Leader and A. Sidorov

PR D75 (2007) 0740217

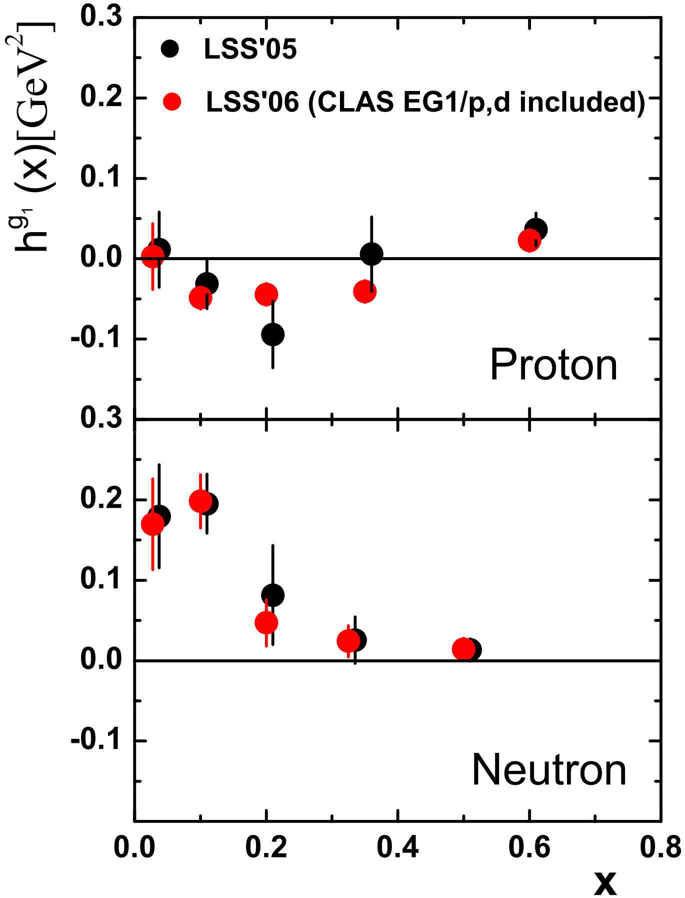
Effect of CLAS'06 p and d data *(PL B641, 11, 2006)* on polarized PD and HT

- 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)

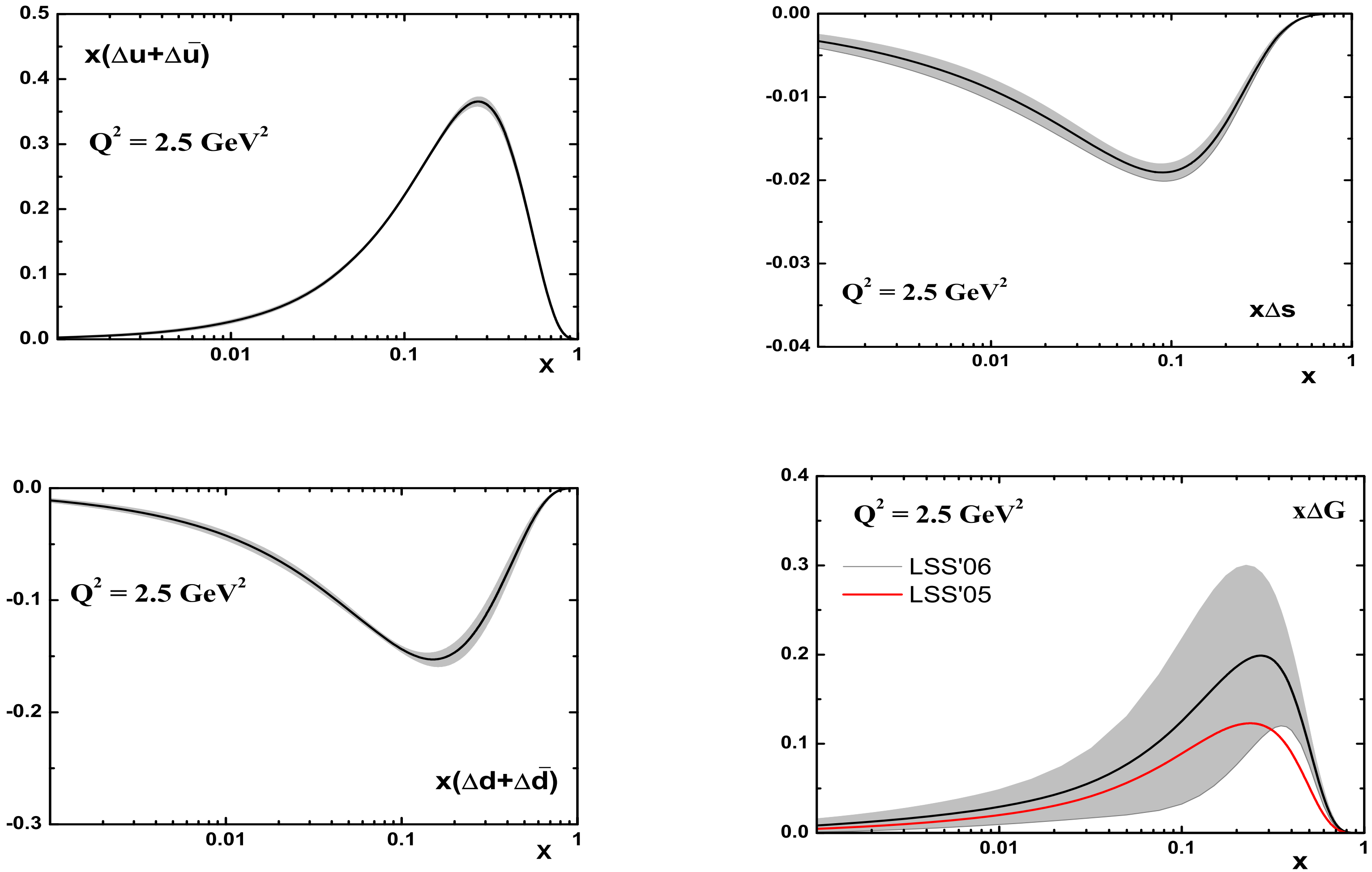
LSS'05: PR D73 (2006)



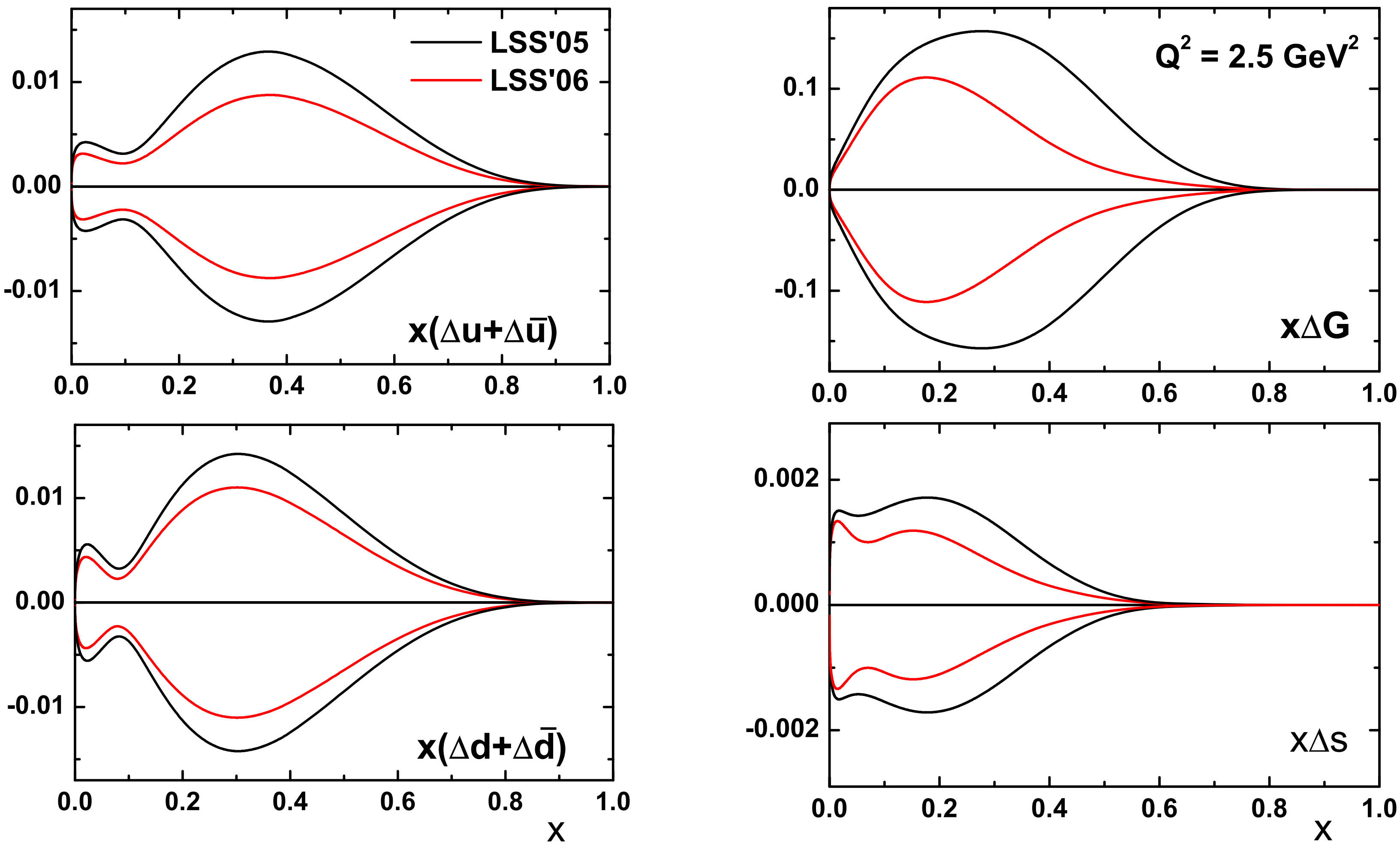
$$g_1 = (g_1)_{LT} + h^{g_1}(x)/Q^2$$

LSS'06 NLO($\overline{MS}$) polarized PDFs

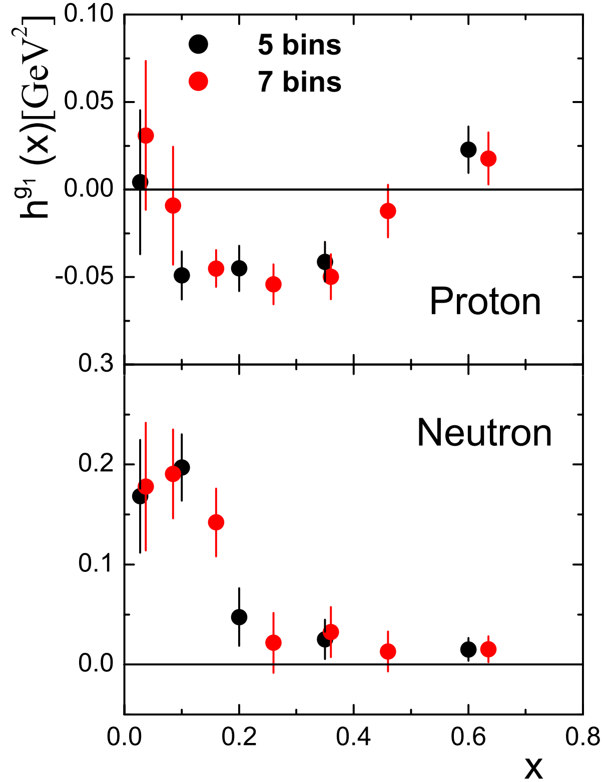
The quark densities (central values) are identical with those of LSS'05.



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

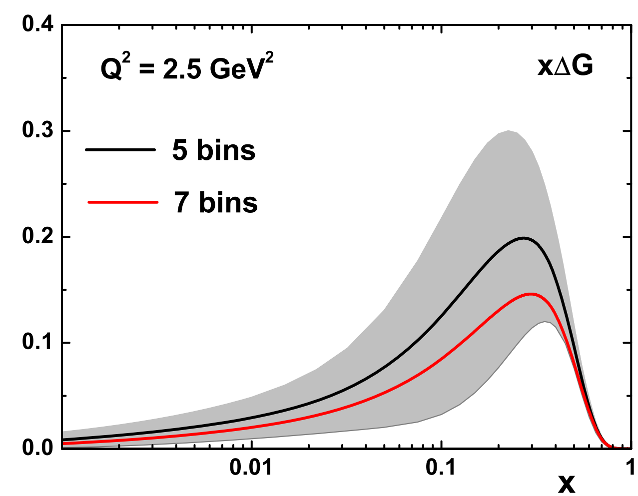


- Due to the good accuracy of the *CLAS* data, one can split the measured x region of the *world+CLAS* data set into 7 bins instead of 5, and to determine more precisely the x-dependence of HT



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

- The only exception is $x\Delta G$, but it lies within the error band of $x\Delta G$ (5 bins) → small correlation between gluons and HT



The main message from this analysis

→ **It is impossible to describe the very precise CLAS data if the HT corrections are NOT taken into account**

NOTE: If the low Q^2 data are not too accurate, it would be possible to describe them using only the leading twist term (logarithmic in Q^2) in g_1, *i.e.* to mimic the power in Q^2 dependence of g_1 with a logarithmic one (using different forms for the input PDFs and/or more free parameters associated with them) which was done in the analyses of another groups before the CLAS data have appeared.

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 EG1b - $\frac{g_1^p}{F_1^p}$, $\frac{g_1^d}{F_1^d}$

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

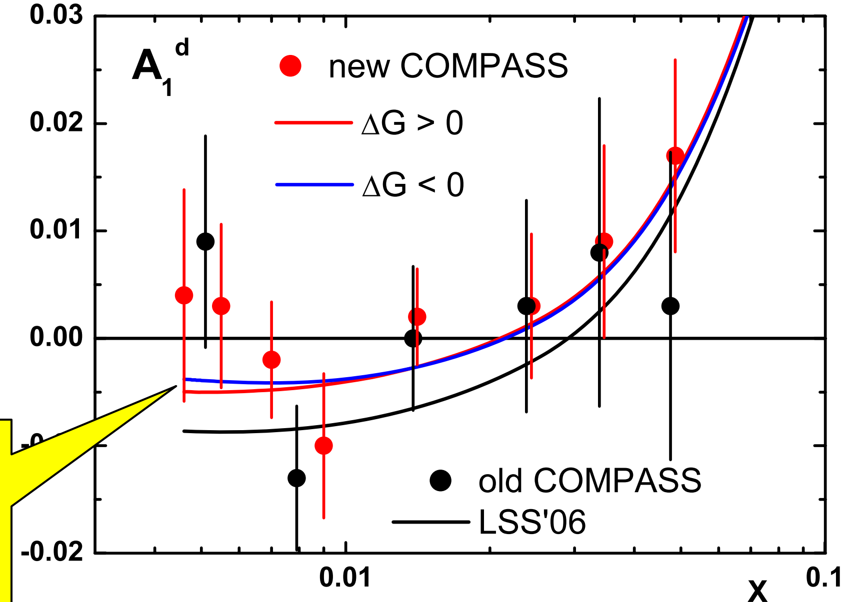
$\gamma^2 = 4M^2x^2/Q^2$ - kinematic factor

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*



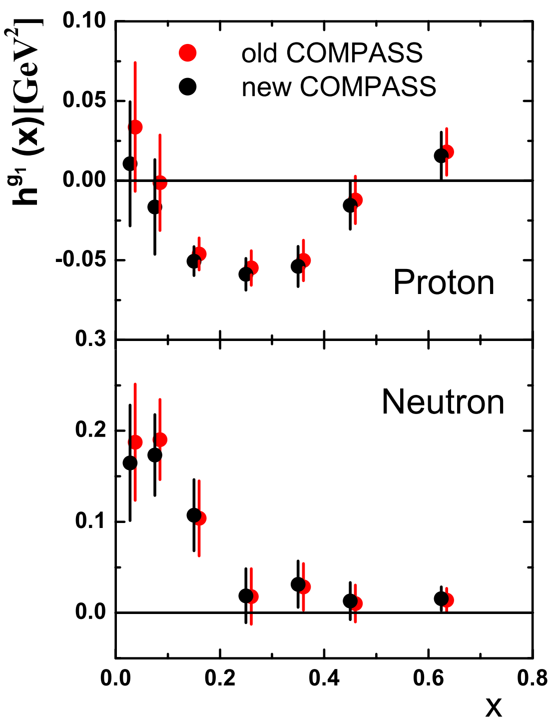
The new QCD curves corresponding to the best fits lie above the old one at x < 0.1

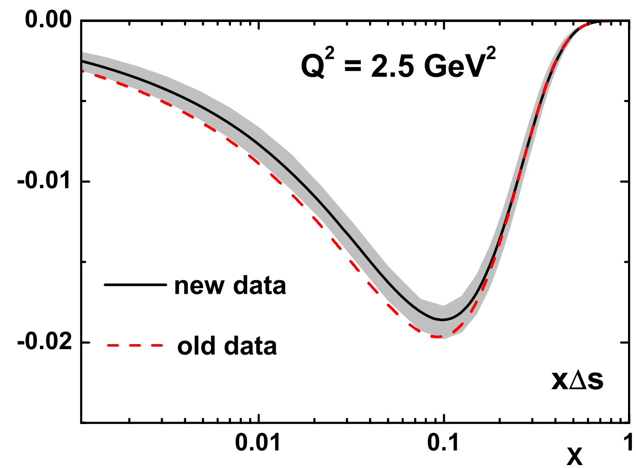
- $(\Delta u + \Delta\bar{u}),\ (\Delta d + \Delta\bar{d})$ **do NOT change**

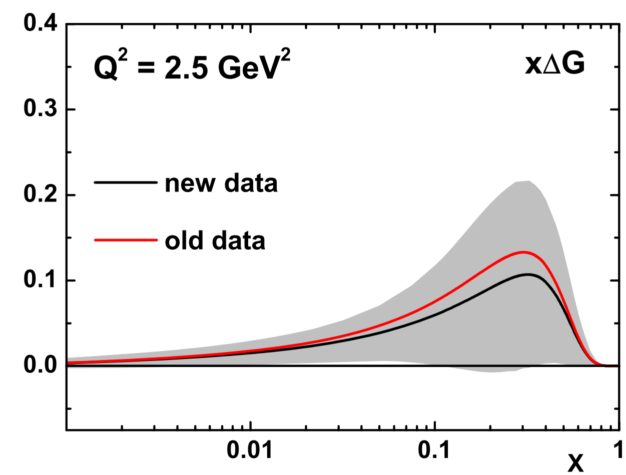
- **$x|\Delta s(x)|$ and $x\Delta G(x)$ and their first moments Δs and ΔG slightly decrease**

$Q^2 = 1\ GeV^2$

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





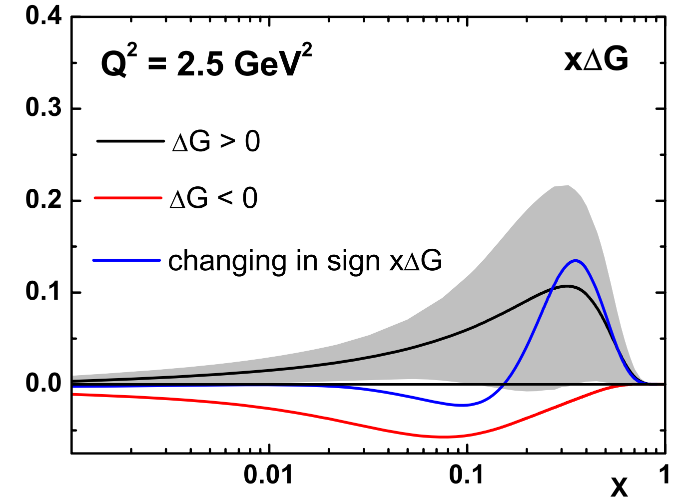


The values of HT are practically NOT affected by *COMPASS* data excepting the small x where Q^2 are also small

The sign of gluon polarization

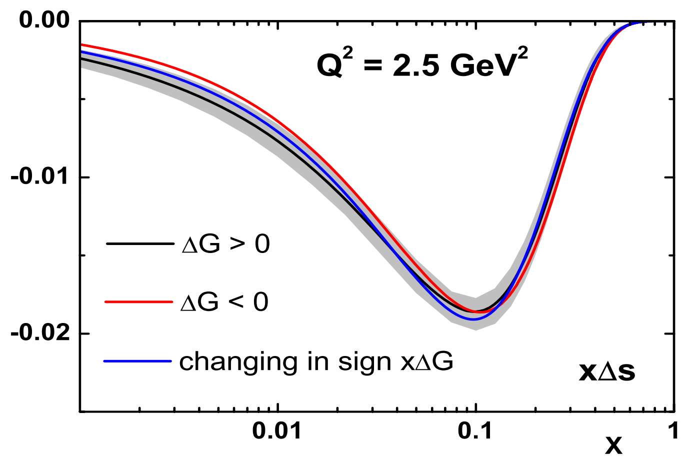
- The present **inclusive** DIS data **cannot rule out** the solutions with negative and changing in sign gluon polarizations

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



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

- In all the cases the magnitude of ΔG is small: $|\Delta G| < 0.25$



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

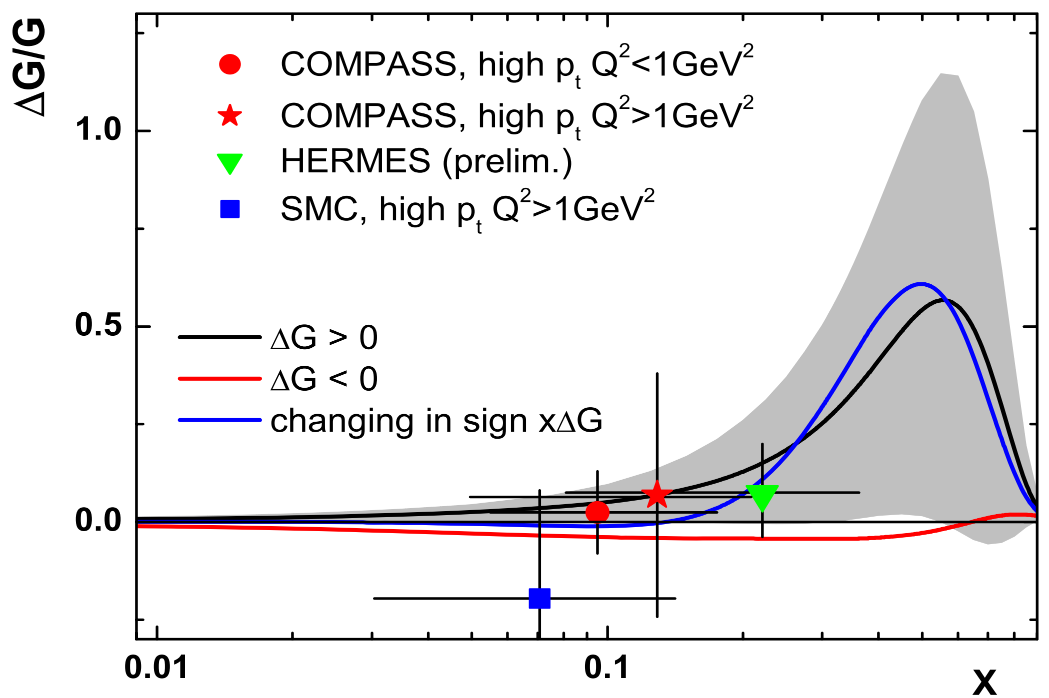
Comparison with directly measured $\Delta G/G$ at $Q^2 = 3$ GeV^2

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 $\Delta G/G$, the *COMPASS* one, is well consistent with any of the polarized gluon densities determined in our analysis



LSS'06 *vs* C0MPASS'06

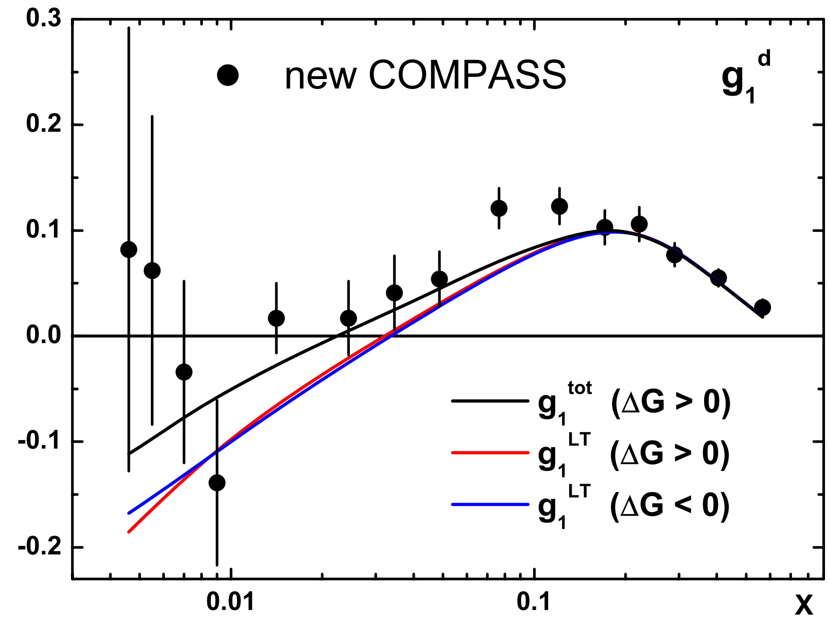
- At small x: 0.004 – 0.02 (Q^2 ~ 1-3 GeV^2) our results differ from those of *COMPASS*

$$(g_1)_{exp} \leftrightarrow (g_1)_{LT}(COMPASS) \approx (g_1)_{LT}(LSS) + h^d(x)/Q^2$$

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

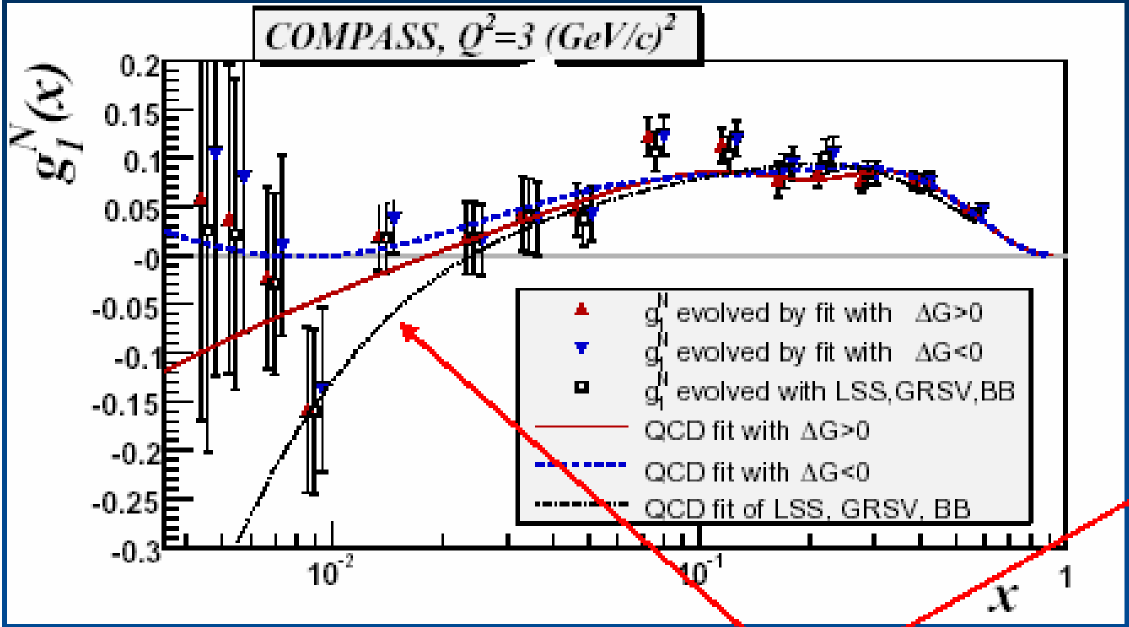
- *LSS'06* → the theoretical curves for both cases are very close to each other

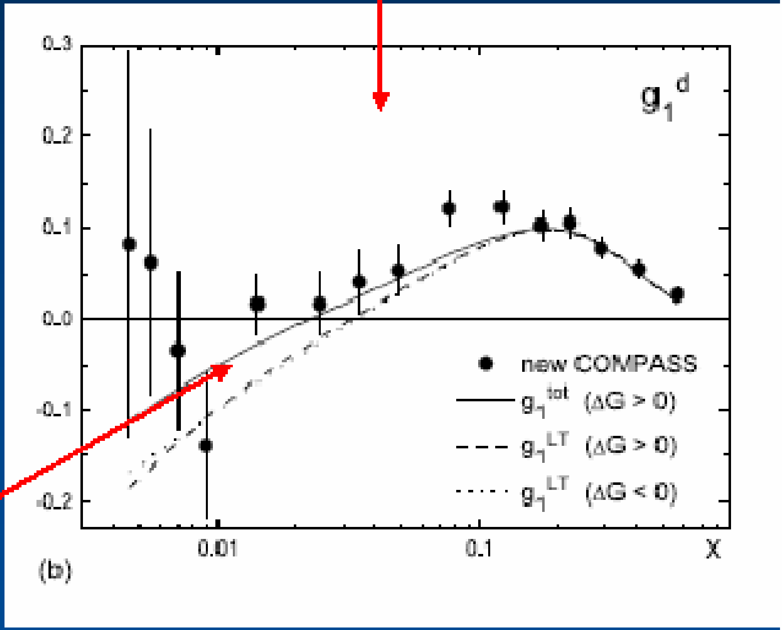
- The reason → HT effects (40% at small x) which are NOT taken into account by *COMPASS*



QCD analysis of the world data on structure function g_1

Comparison of data and fits - LSS06 (hep-ph/0612360

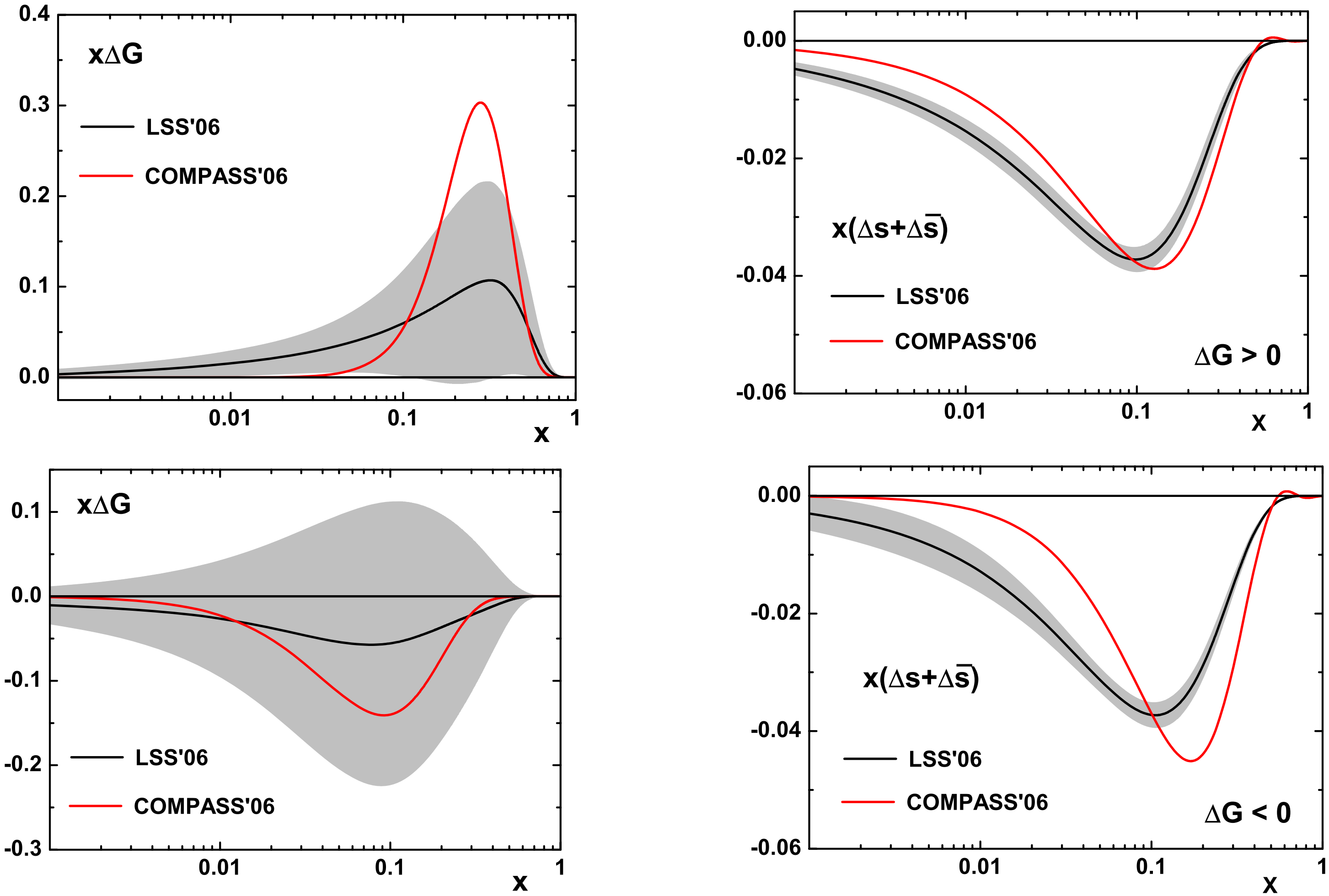




LSS05 vs LSS06

- $x\Delta s$ 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



Constraint on ΔG from π^0 production at RHIC *(AAC, hep-ph/0612037)*

$\vec{p} + \vec{p} \rightarrow \pi^0 + X$

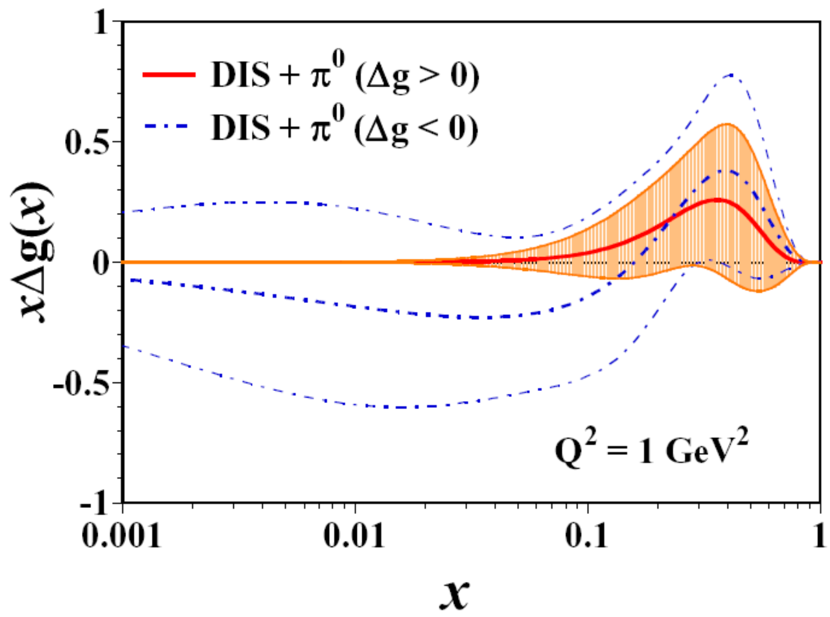
From DIS + π^0 analysis:

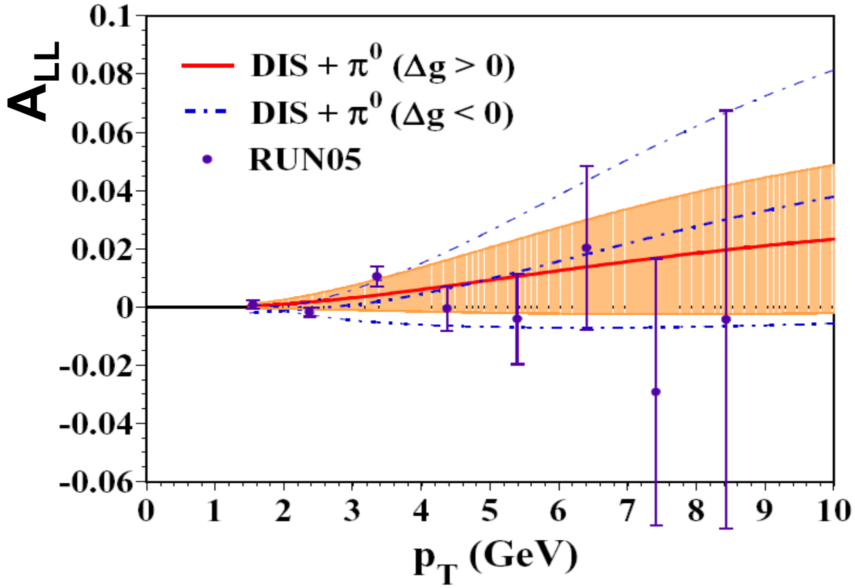
$\Delta G = \; 0.31 \pm 0.32$

$\Delta G = -\,0.56 \pm 2.16$

($Q^2 = 1$ GeV^2)

Note: In contrast to changing in sign $x\Delta G_{LSS}$, which for $Q^2 > 6$ GeV^2 is positive for any x, $x\Delta G_{AAC}$ becomes negative for large x too with increasing of Q^2.





$Q^2 = 1\ GeV^2$

COMPASS	Δs	ΔG	$a_0 = \Delta\Sigma_{MS}$
old	-0.070 ± 0.006	0.173 ± 0.184	0.165 ± 0.044
new ($\Delta G > 0$)	-0.063 ± 0.005	0.129 ± 0.166	0.207 ± 0.040
new ($\Delta G < 0$)	-0.057 ± 0.010	-0.200 ± 0.414	0.243 ± 0.065

Spin of the proton

$$S_z = 1/2 = 1/2\ \Delta\Sigma(Q^2) + \Delta G\ (Q^2) + L_q\ (Q^2) + L_g(Q^2)$$

$$= 0.23(-0.08) +/- 0.17(0.41) + L_q\ (Q^2) + L_g(Q^2)$$

The **big** uncertainty is coming from gluons

To be determined from forward extrapolations of **generalized** PD

$L_g \approx 0$, *Brodsky, Gardner: PL B643 (2006) 22*

Spin puzzle ?

$$\Delta\Sigma(Q^2 \sim \Lambda^2_{QCD}) = \begin{cases} 0.6 \leftarrow \text{relativistic constituent QM} \\ < 0.6 \leftarrow \text{Nonpert. vacuum spin effects (instanton models) - } \textit{Shore, Veneziano; Forte, Shuryak; Dorokhov, Kochelev} \text{ (negative quark sea)} \end{cases}$$

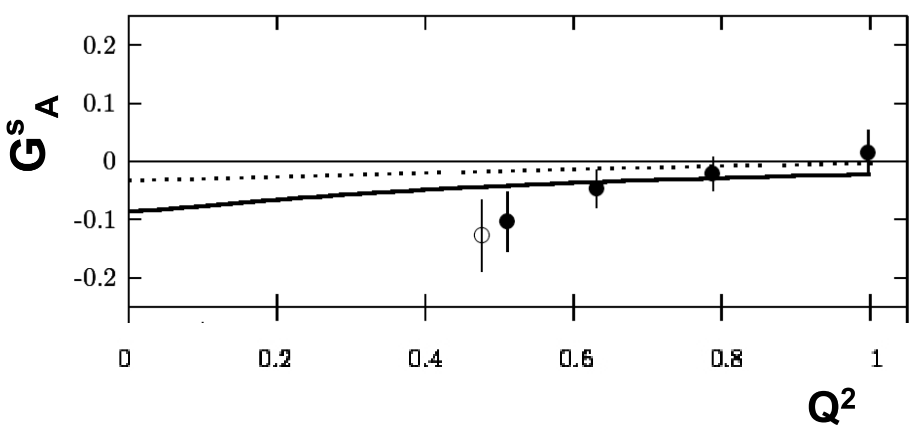
$\Delta\Sigma = \Delta u_V + \Delta d_V + \Delta q_{sea}$

$\Delta\Sigma(Q^2)$ in QCD is a scheme dependent quantity !

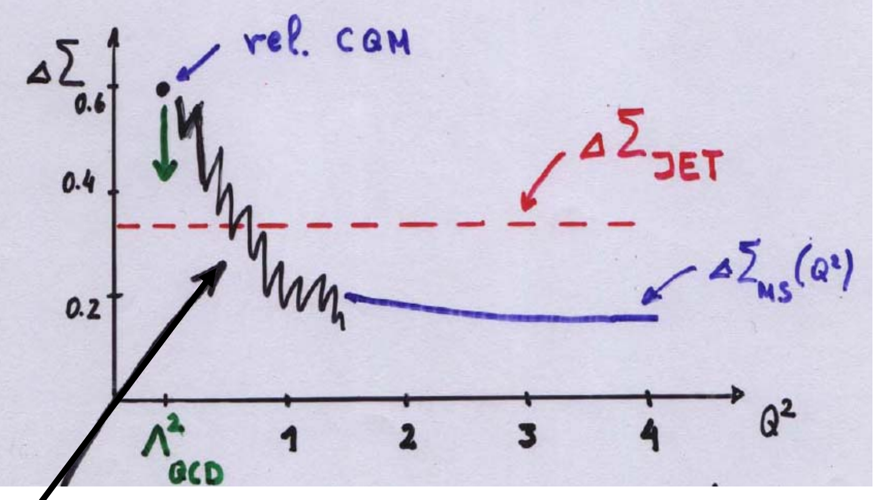
From combined analysis of elastic $\vec{e}p$, νp and $\bar{\nu}p$ data → the strange axial form factor $G^S_A(Q^2)$ at $Q^2 \leq 1$ GeV^2

$G^S_A(Q^2 = 0) = \Delta s$

$\Delta\Sigma_{JET}(DIS) \Leftrightarrow \Delta\Sigma(Q^2 \sim \Lambda^2_{QCD})$



S. Pate, hep-ex/0611053



Nonperturbative effects !

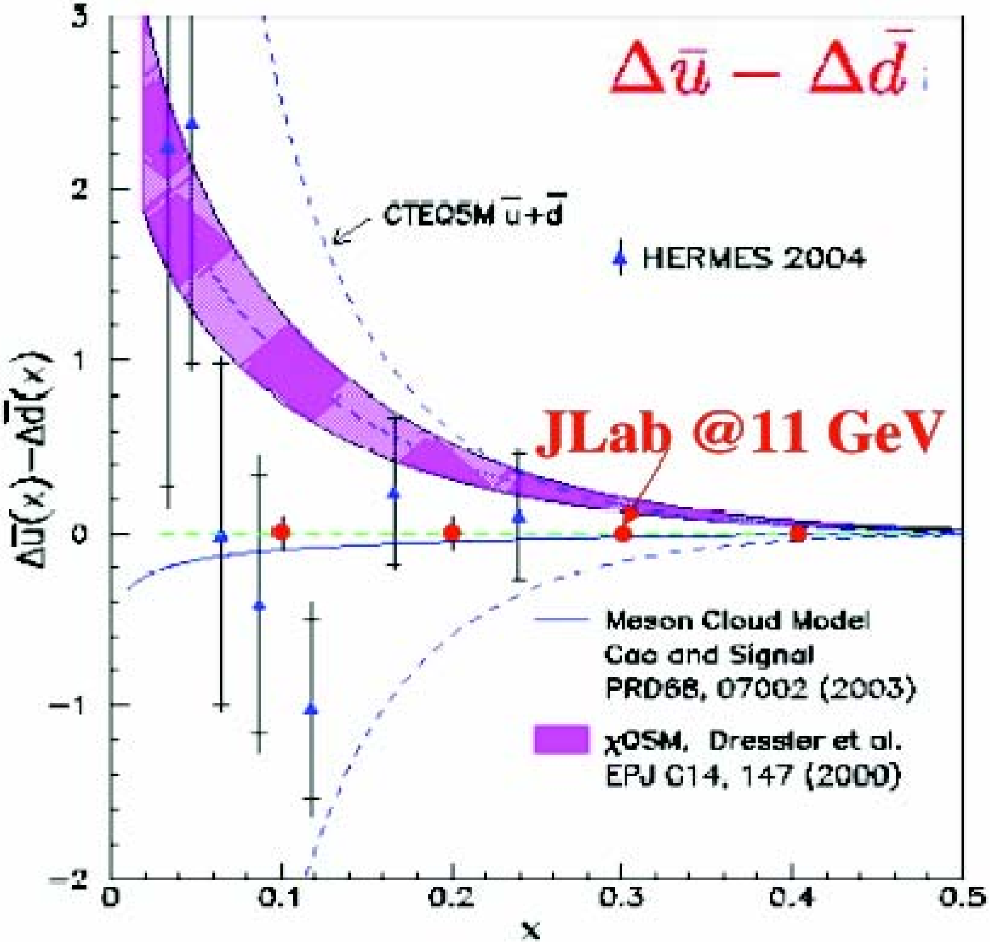
Flavor decomposition: polarized sea

- Predictions:
  - Instantons (χQSM):

$$\Delta\bar{u} \approx -\Delta\bar{d}$$

- First data from HERMES

$$\Delta\bar{u} - \Delta\bar{d} \approx 0$$



COMPASS *(A. Korzenev at DIS'07)*

From SIDIS → $\Delta u_V(x) + \Delta d_V(x)$ → $\Gamma_V \equiv \int_0^1 (\Delta u_V(x) + \Delta d_V(x))dx$ at $Q^2 = 10$ GeV^2

LO QCD treatment + assumption: $q_{LO} \rightarrow q_{LO}/(1 + R)$ in Eqs. for A_1^h

$$\Delta\bar{u} + \Delta\bar{d} = (\Delta s + \Delta\bar{s}) + 1/2\,(a_8 - \Gamma_V)$$

inclusive DIS   hyperon β decays → $a_8 = 0.585$

$\Gamma_V \equiv \int_{0.006}^{0.7} (\Delta u_V(x) + \Delta d_V(x))dx = 0.40 \pm 0.07(\text{stat})$ ⇒ $\Delta\bar{u} + \Delta\bar{d} = 0.0 \pm 0.04 \pm 0.03$

FNS (NLO analysis of incl. and SIDIS) ⇒ - 0.10 (KRE FF), ~ 0.0 (KKP FF)

⇒ **The flavor decomposition is NOT well determined at present**

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 $\Delta G/G$

OPEN QUESTIONS

- To constrain better ΔG ⟹ directly from *COMPASS, RHIC*;

  more precise experiments on g_1^d (*JLab Hall C*)

- $\Delta\bar{u}, \Delta\bar{d}$ ⟹ from SIDIS (*COMPASS, JLab*) and $A_L(W^{+(-)})$ at *RHIC*

- L_q (from generalized PD, *JLab*) and L_g

- a_8 ≠ 3F – D = 0.585 ? (how much $SU(3)_f$ is broken) → NA48 at CERN

- HT corrections in SIDIS, $O(\Lambda^4/Q^4)$ term in HT expansion in Bjorken x-space

  …*etc.*

Backup slides

Test of QCD and determination of PDFs and HT

$$(\Delta q_i, \Delta \overline{q_i}, \Delta G)(x, Q_0^2; a_k) \xrightarrow[\text{DGLAP eqs.}]{\text{pQCD}} (\Delta q_i, \Delta \overline{q_i}, \Delta G)(x, Q^2; a_k)$$

Input PD

a_k – 6 free par.

$Q_0^2 = 1\ GeV^2$

$$\Rightarrow g_1(x, Q^2; a_k)_{\rm LT}$$

$$\chi^2 = \sum_{i,j} \frac{[g_1(x_i, Q_j^2)_{\rm exp} - g_1(x_i, Q_j^2; a_k)_{\rm LT} - h_{(l)}(x_{(l)})/Q^2]^2}{\Delta g_1(x_i, Q_j^2)^2_{\rm exp}}$$

10 free parameters

$\Rightarrow$ $a_k \pm \Delta a_k, h_l \pm \Delta h_l \rightarrow$ 16 free parameters

Flavor symmetric sea convention

- From inclusive DIS only the sum $(\Delta q + \Delta\bar{q})$ can be determined

⇒ $\Delta\bar{u}$ and $\Delta\bar{d}$, as well as Δu_V and Δd_V **depend** on the assumption about the sea

- usually a symmetric sea convention is used at Q^2_0 (this is assumption for $\Delta\bar{u}$ and $\Delta\bar{d}$, **NOT** for $\Delta\bar{s}$)

- $\Delta\bar{u} = \Delta\bar{d} = \lambda\Delta\bar{s}$ ⇒ we have shown that $(\Delta q + \Delta\bar{q})$ as well as $\Delta\bar{s}$ do **NOT** depend on λ

- It was shown from a global inclusive and SIDIS analysis (*D. de Florian at al*.) that while $\Delta\bar{u}$ and $\Delta\bar{d}$ **strongly depend** on the fragmentation functions, $\Delta\bar{s}$ practically does **not** change.

KTeV experiment
Fermilab

$$\Xi^0 \rightarrow \Sigma^+ e \bar{\nu}$$

β-decay

SU(3)$_f$ prediction for the form factor ratio g_1/f_1

$$\frac{g_1}{f_1} = g_A = 1.2670 \pm .0035$$

Experimental result

$$\frac{g_1}{f_1} = 1.32^{+0.21}_{-0.17} \pm 0.05$$

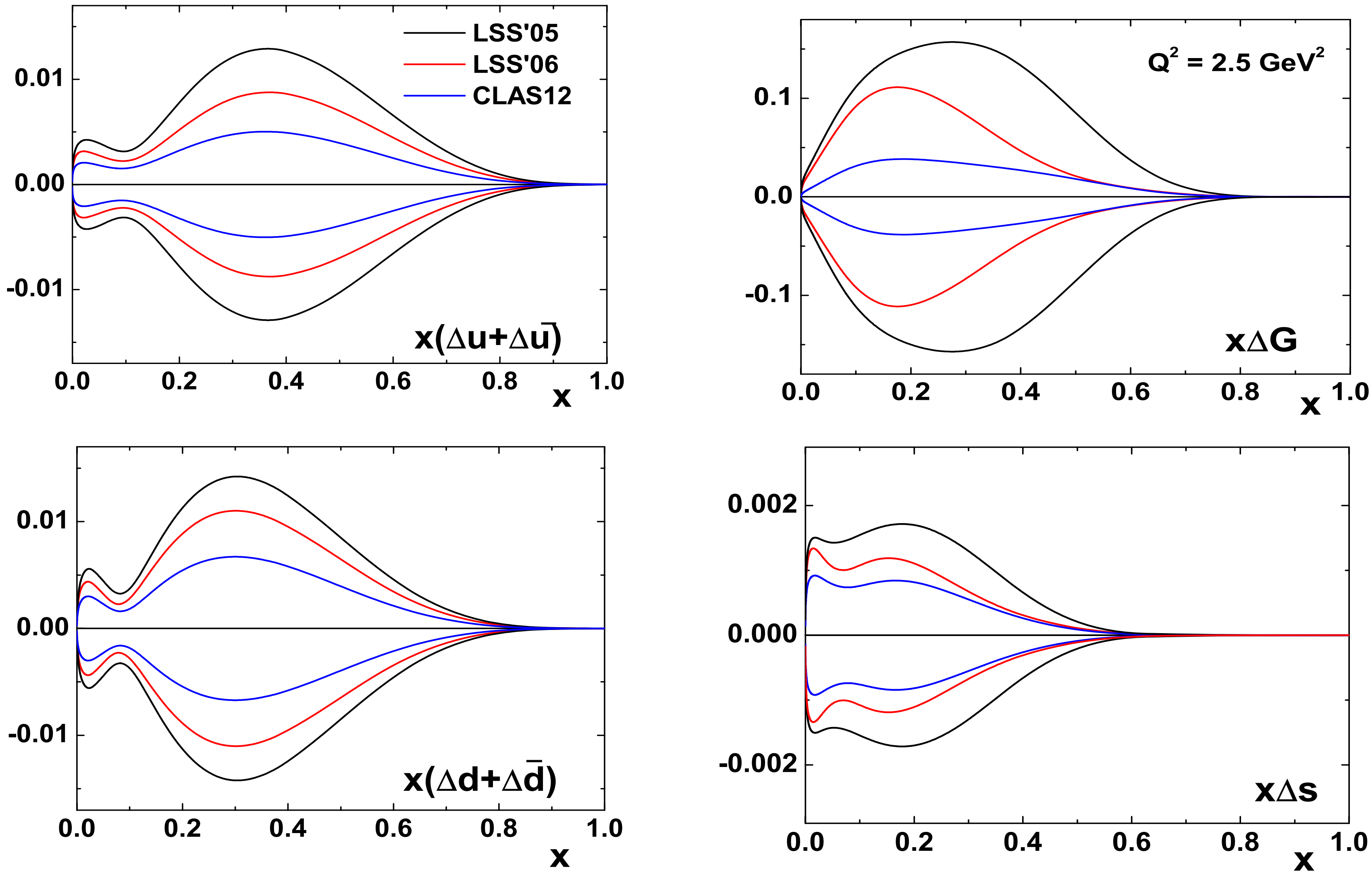
A good agreement with the ***exact*** SU(3)$_f$ symmetry !

From exp. uncertainties → SU(3) breaking is at most of order **20%**

NA48 at CERN → 3 times larger statistics → the results will be done soon

Indeed, if one calculates the χ^2 - probability for the combined *world + CLAS data set using the* LSS'05 polarized PDFs and HT, the result for χ^2 is 938.9 for 823 experimental points, which significantly decreases to 718.0 after the fit. This big change of χ^2 is achieved mainly through the changes in the HT values. Excepting the gluons the parameters for the input quark densities did NOT change. This strongly supports the theoretical framework in which the leading twist QCD contribution is supplemented by higher twist terms of *$O(\Lambda^2/Q^2)$*.

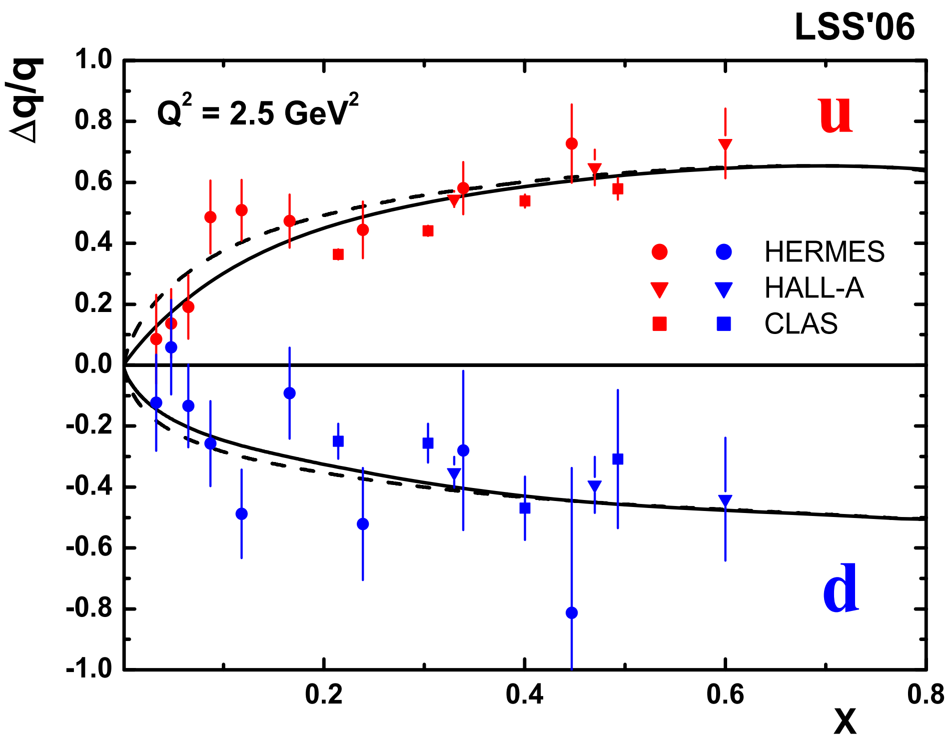
The expected uncertainties for NLO($\overline{MS}$) polarized PDFs including the CLAS12 "data" set



Comparison of $\Delta q/q$ with the data

- CLAS and Hall-A data are extracted in the **naive parton model** treatment
- HERMES data are extracted in **LO QCD** approximation
- In the preasymptotic region **HT corrections** should be taken into account !
- The **NLO LSS'06** PDFs are obtained in the presence of HT.

⇨ One has to be **careful** comparing the data on $\Delta q/q$ with the QCD curves



——— $(\Delta q+\Delta\bar{q})/(q+\bar{q})$

- - - - $\Delta q/q$

$q, \bar{q}$ → NLO MRST'02

CLAS, Hall-A data → $(\Delta q+\Delta\bar{q})/(q+\bar{q})$

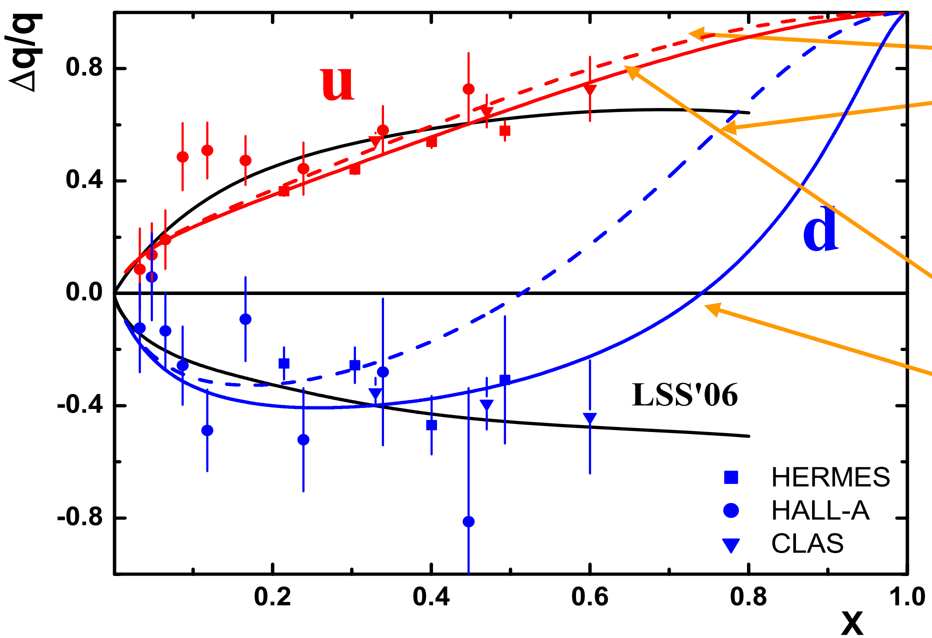
The behavior of $\Delta q/q$ at large x ⟹ a challenge to the experiment

LSS, as well as GRSV, AAC, BB:

$\Delta q/q \rightarrow$ *const* { + for u, - for d }
$x \rightarrow 1$

BBS model (*Brodsky et al*):

$\Delta q/q \rightarrow 1$ for q = u, d
$x \rightarrow 1$



LSS (BBS) → $L_q = 0$

$$q^+(x) \propto (1-x)^3$$
$$q^-(x) \propto (1-x)^5$$
$$x \rightarrow 1$$

BBS (modified) → $L_q \neq 0$

$$q^+(x) \propto (1-x)^3$$
$$q^-(x) \propto (1-x)^5 \ln^2(1-x)$$
$$x \rightarrow 1$$

$$\Delta q(x) = q_+(x) - q_-(x)$$
$$q(x) = q_+(x) + q_-(x)$$

H. Avakian et al., arXiv:0705.1553

The first moments of higher twist

- Thanks to the very precise CLAS data the first moments of HT corrections are now much better determined.

$$\bar{h}^N = \int_{0.0045}^{0.75} dx\, h^N(x), \quad \mathrm{N = p, n}$$

$$\bar{h}^p = (-0.014 \pm 0.005)\, GeV^2$$

$$\bar{h}^n = (0.037 \pm 0.008)\, GeV^2$$

$$\bar{h}^p - \bar{h}^n = (-0.051 \pm 0.009)\, GeV^2$$

$$\bar{h}^p + \bar{h}^n = (0.023 \pm 0.009)\, GeV^2$$

- $\bar{h}^p - \bar{h}^n < 0$ ← In agreement with the instanton model predictions and sum rules in QCD

- $\bar{h}^p + \bar{h}^n < |\bar{h}^p - \bar{h}^n|$ ← In agreement with $1/N_C$ expansion in QCD (*Balla et al., NP B510, 327, 1998*)

In our notations

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

HT (τ=3)   HT (τ=4)

Our numerical results are in a qualitative agreement with those obtained from the analyses of the first moments of g_1 at JLab [$O(\Lambda^4/Q^4)$ terms are also taken into account]:

A. Deur et al., PRL 93, 212001 (2004),
A. Z.-E. Meziani et al., PL B613, 148 (2005), etc.

Important: To study the next term $O(\Lambda^4/Q^4)$ in HT expansion in Bjorken x- space

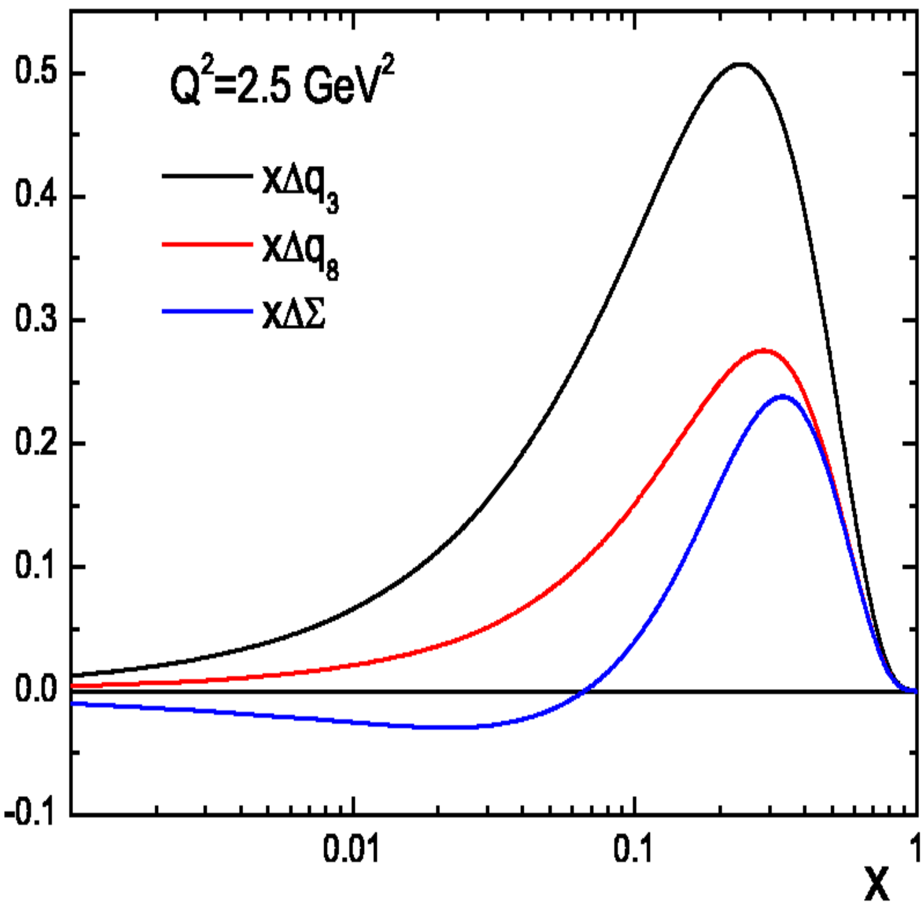
→ more precise data are needed

JLab Proposal PR-07-011 (Hall C):

A High Precision Measurement of the Deuteron Spin-Structure Function g1/F1

Why deuteron best for ΔG(x) ?

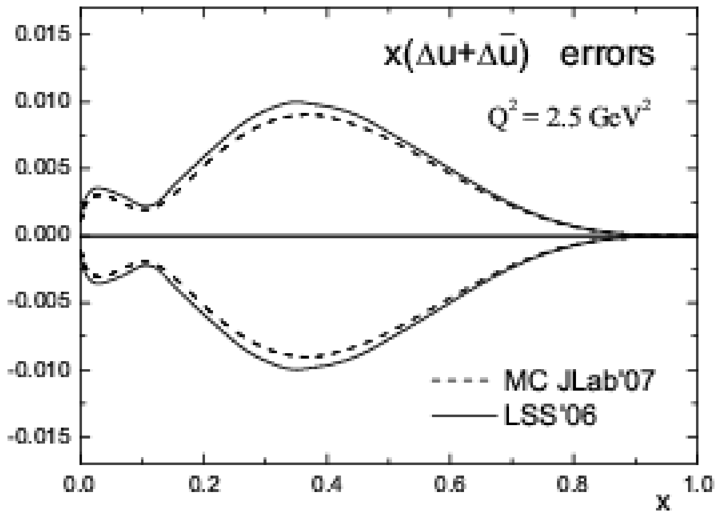
$$g_1^{p(n)}(x,Q^2) = \frac{1}{9}[(\pm\frac{3}{4}\Delta q_3 + \frac{1}{4}\Delta q_8 + \Delta\Sigma) \otimes (1 + \frac{\alpha_s(Q^2)}{2\pi}\delta C_q) + \frac{\alpha_s(Q^2)}{2\pi}\Delta G \otimes \delta C_G]$$

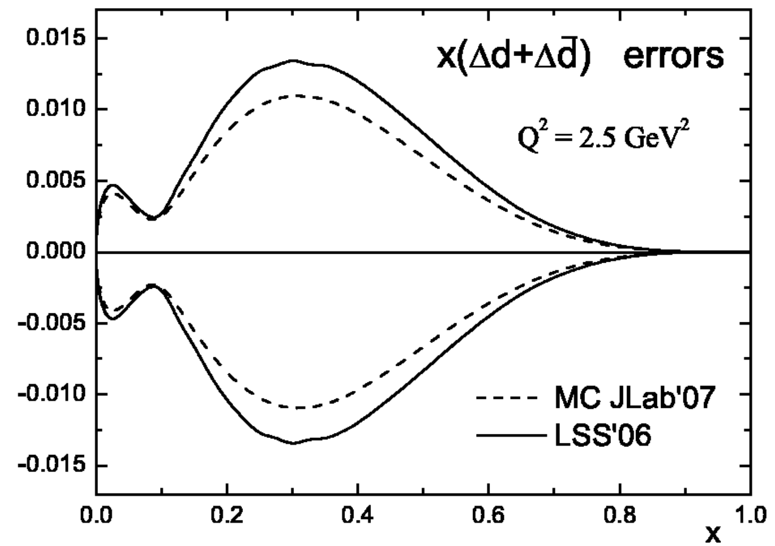


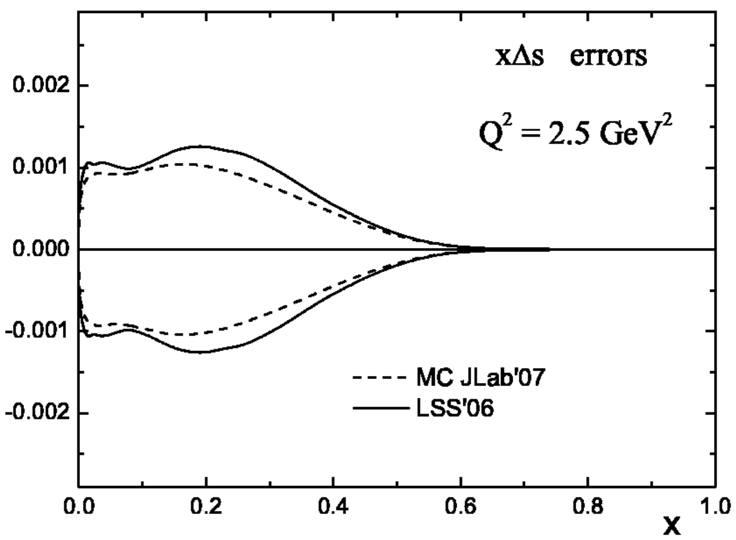
- **The Δq_3 terms from p and n about twice size of Δq_8 and $\Delta\Sigma$ terms, cancel in deuteron.**

- **Relative gluon contributions largest in deuteron: relevant because experimental errors dominated by systematic scale factors.**

Physics Impact in LSS framework

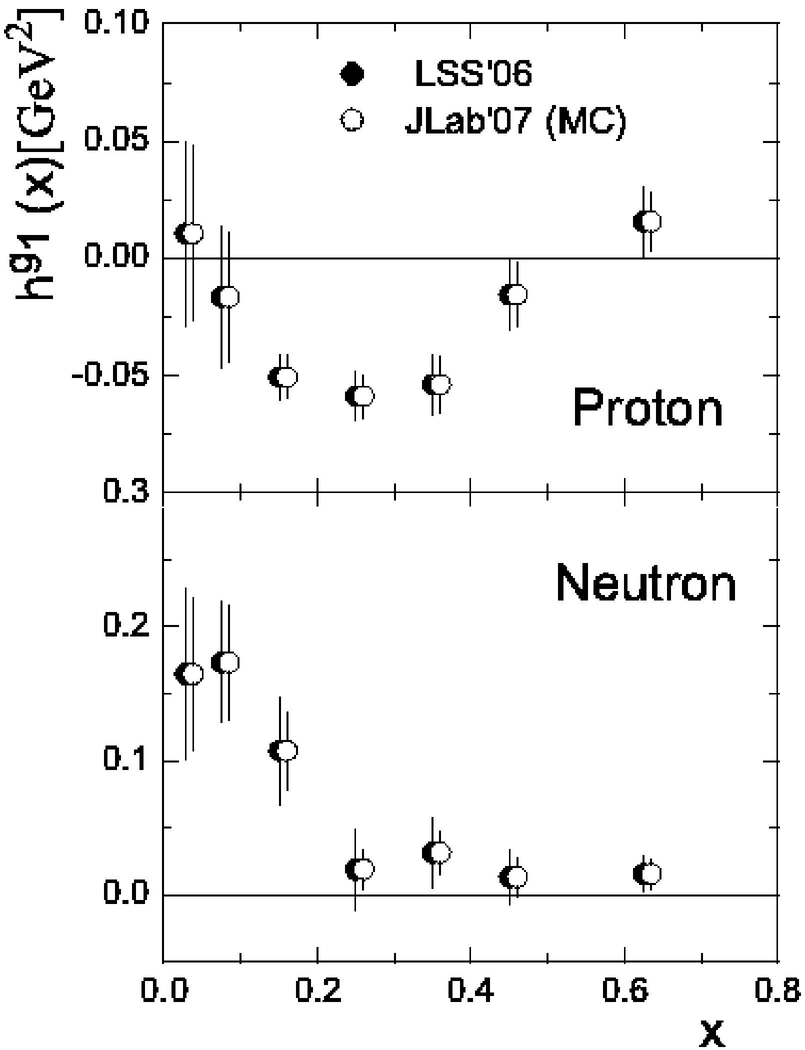


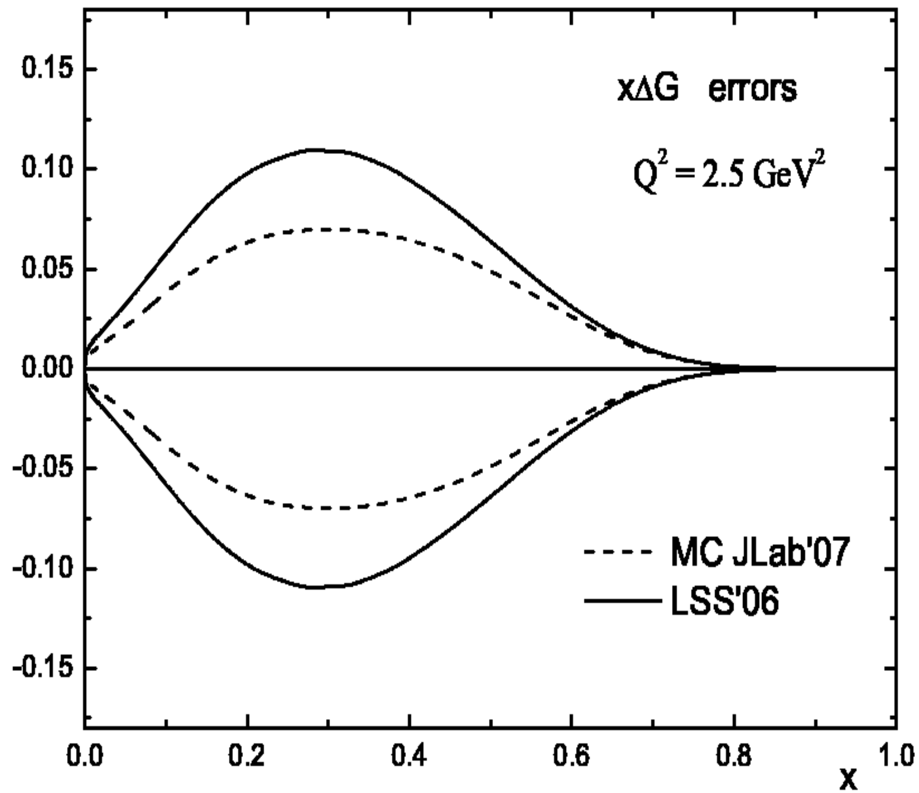




Impact on polarized quark distributions relatively small

Physics Impact





Significant improvement in ΔG(x) and neutron HT