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New analysis concerning the strange quark polarization puzzle

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OUTLINE

- The strange quark polarization puzzle

→ conflict between $\Delta s(x)_{DIS}$ and $\Delta s(x)_{DIS+SIDIS}$ if *de Florian, Sassot, Stratmann* (DSS) fragmentation functions (FFs) are used

- A new NLO QCD analysis of the world polarized inclusive DIS data including for the first time the new extremely precise *CLAS* data is presented

→ A more general input parametrization for $\Delta s(x)$ which allows for a change sign of the strange quark density is used

→ The results confirm that the polarized inclusive DIS data yield significantly negative values for the polarized strange quark density

- Summary

LSS, PR D91 (2015) 054017

Polarized inclusive DIS processes

Due to the lack of the charged current neutrino data *only* the sums

$$(\Delta q + \Delta \bar{q})\ (x, Q^2)$$

can be determined from the polarized inclusive DIS data !

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

LT – leading twist NLO QCD contribution

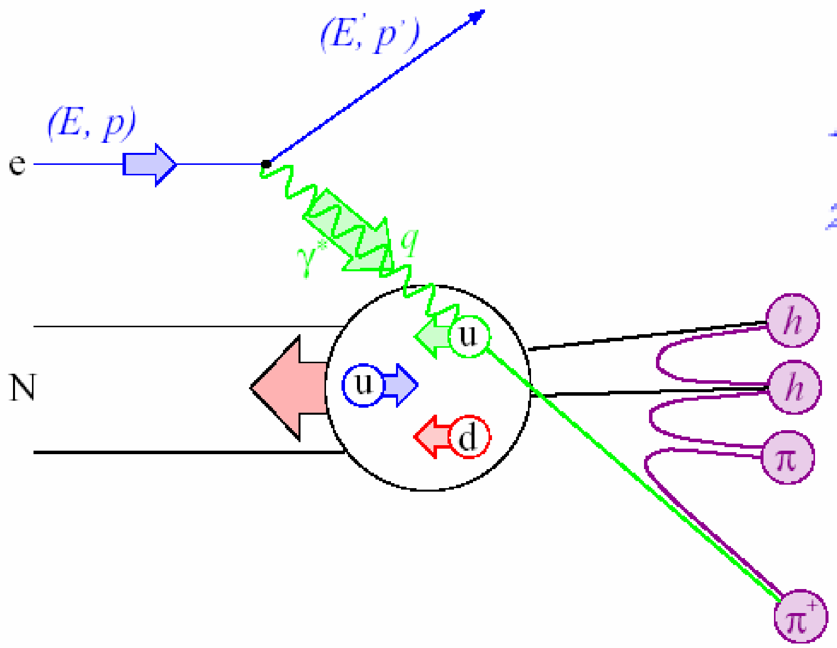
$\delta C_q, \delta C_G - Wilson$ coefficient functions

- **It is important that in contrast to the light sea quark densities $\Delta\bar{u}$ and $\Delta\bar{d}$, $(\Delta s + \Delta\bar{s})$ can be well determined only from the inclusive DIS experiments, if the data are sufficiently precise.**

Semi-inclusive processes

➡ allow to separate Δq and $\Delta \bar{q}$

Fragmentation functions – new quantities



D_q^h from quark q into hadron h

$z = \frac{E_h}{\nu}$ energy fraction carried by h

$$A_1^h(x,z,Q^2) = \frac{g_1^h - \gamma^2 g_2^h}{F_1^h}$$

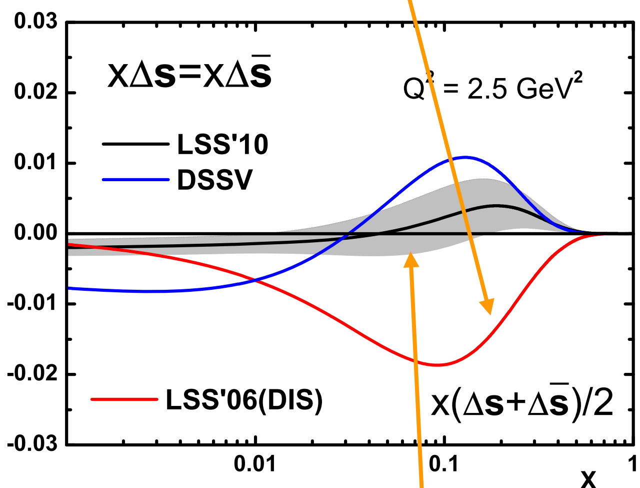
In LO QCD $$A_1^h(x,z,Q^2) \sim \frac{g_1^h}{F_1^h} = \frac{\sum_f e_f^2 \, \Delta q_f(x,Q^2) \, D_f^h(z,Q^2)}{\sum_f e_f^2 \, q_f(x,Q^2) \, D_f^h(z,Q^2)}$$

In NLO QCD the Wilson coefficients $\Delta C_{ij}(x,z)$ have to be included

The status of the strange quark polarization puzzle before this analysis

- $\Delta s(x)=\Delta\bar{s}(x)$ negative from all analyses of the inclusive DIS data !!!

→ **Disadvantage:** in all of them simple input parametrizations for the polarized strange quark density, which do not permit a sign change of the density, have been used (it was impossible to determine from the DIS data available at that time the parameter corresponding to the sign change).



Although their first moments are negative and almost equal, $\Delta s(x)$(*DIS*) and $\Delta s(x)$(*DIS+SIDIS*) are quite different

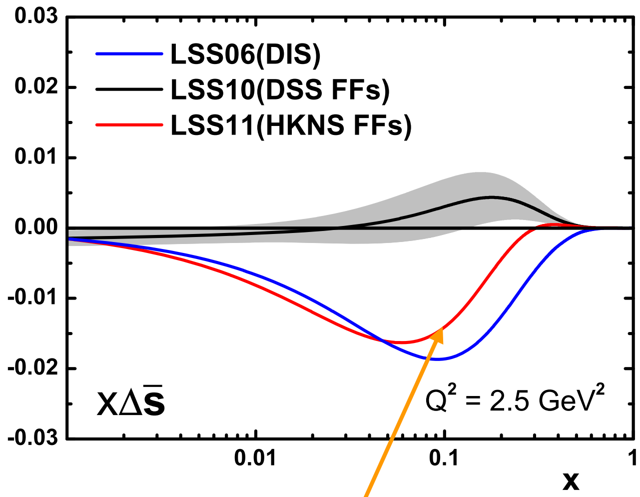
- The very small values of the strange quark density obtained from combined analyses of DIS and SIDIS data using the DSS FFs are in contradiction with significantly negative values of this quantity obtained from inclusive DIS data.

→ In the SIDIS analyses the results on $\Delta s(x)$ strongly depend on the kaon FFs used which are still not reliably determined.

Impact of the kaon FFs on polarized strange quark density

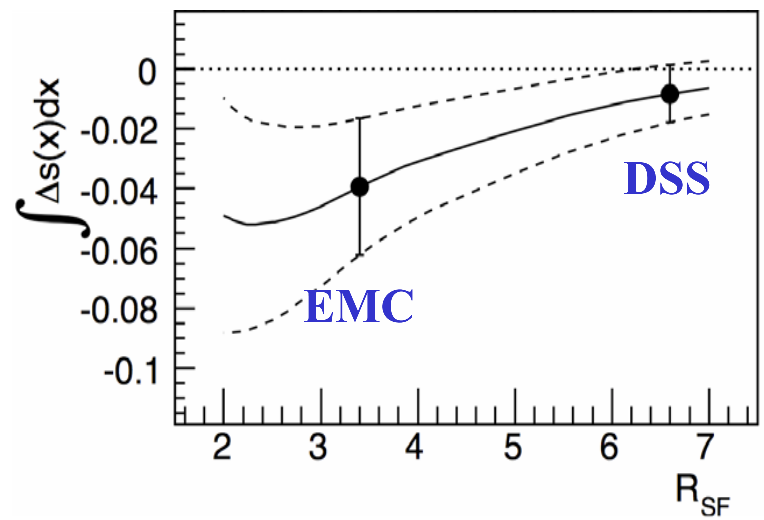
$$\Delta s(x) = \Delta \bar{s}(x)$$

LSS: PR D84 (2011) 014002



LSS results for Δs(x) from NLO QCD analyses of DIS+SIDIS polarized data using 2 sets of FFs (DSS and HKNS).

PLB 693 (2010) 227-235



COMPASS LO results for Δs integrated over x using measured spin asymmetries for SIDIS and 2 sets of FFs (DSS and EMC).

Note that Δs(x) extracted using the kaon HKNS FFs is negative and very close to that obtained from the inclusive DIS data.

$$R_{SF} \equiv \frac{\int D_{\bar{s}}^{K^+}(z,Q^2)dz}{\int D_u^{K^+}(z,Q^2)dz}$$

- **Keeping in mind that the present sets of kaon FFs are NOT consistent with the recently published *HERMES* and the preliminary *COMPASS* data on the hadron multiplicities, *one can conclude* now that the values of the polarized strange quark density $\Delta s(x)$ determined from the analyses in the presence of SIDIS data, cannot be correct.**

NB: Note also that in the extraction of the NLO DSS set of FFs there was a mistake for the longitudinal Wilson coefficient $C_{qg}^{L}(x,z)$ in the theoretical expression for the multiplicities.

- **New sets of pion NLO FFs were extracted by LSS from the HERMES data on multiplicities *(arXiv:1312.5200)* and by DSEHS (DSS+) from a global fit to e+e $\oplus$ SI pp (RICH) $\oplus$ HERMES data *(PR D91 (2015) 014035)*.**

NB: The version of the DSS+ analysis presented at HEP (arxiv:1410.6027) is wrong and NOT yet updated !?

- A reliable determination of kaon FFs (in progress) is badly needed in order to extract correctly the polarized strange quark density from the polarized SIDIS processes !

- In what follows we present our results of a NLO QCD analysis of the polarized inclusive DIS data including in the world data set for the first time the recent very precise JLAB CLAS data on the proton and deuteron spin structure functions.

  The aim of the analysis is to answer the question, if it is possible to determine the polarized strange quark density using a more general input parametrization which allows for a sign change of the density in Bjorken x.

Remark !

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

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

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

preasymptotic region

$$g_1(x,Q^2) = g_1(x,Q^2)_{\rm LT/NLO} + \frac{M^2}{Q^2} h^{\rm TMC}(x,Q^2) + \frac{h^{\rm HT}(x,Q^2)}{Q^2} + O(1/Q^4)$$

The higher twist (HT) corrections to g_1 are NOT negligible in the preasymptotic region and have to be accounted for

LSS: Phys. Rev. D75 (2007) 074027

NLO QCD fit to world polarized inclusive DIS data

$$\left[\frac{g_1}{F_1}\right]_{\exp} \overset{\chi^2}{\Leftrightarrow} \frac{(g_1)_{\mathrm{NLO}} + (g_1)_{\mathrm{TMC+HT}}}{(F_1)_{\exp}}$$

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

$$(g_1)_{TMC+HT}(x,Q^2) = \frac{M^2}{Q^2} h^{\mathrm{TMC}}(x,Q^2) + \frac{h^{\mathrm{HT}}(x,Q^2)}{Q^2}$$

$$2xF_1(x,Q^2)_{\exp} = F_2(x,Q^2)_{\exp}(1+\gamma^2)/(1+R(x,Q^2)_{\exp}), \quad \gamma^2 = 4M^2x^2/Q^2$$

$F_{2\exp}$ – NMC parametrization of F_2 data, $R_{\exp}$ – SLAC parametrization of R data

Input parametrization for the polarized PDFs at $Q^2 = 1\ GeV^2$:

$$x(\Delta u + \Delta \bar{u})(x) = N_u x^{\alpha_u} (1-x)^{\beta_u} (1 + \varepsilon_u \sqrt{x} + \gamma_u x)$$

$$x(\Delta d + \Delta \bar{d})(x) = N_d x^{\alpha_d} (1-x)^{\beta_d} (1 + \gamma_d x)$$

$$x(\Delta s + \Delta \bar{s})(x) = N_s x^{\alpha_s} (1-x)^{\beta_s} (1 + \gamma_s x)\ !$$

$$x\Delta G(x) = N_g x^{\alpha_g} (1-x)^{\beta_g} (1+\gamma_g)$$

$\beta_s = \beta_g = \beta_{sea}$*(MRST'02)* – to guarantee positivity constraints

Sum rules from hyperon β-decays

$$a_3 = g_A = (\Delta u + \Delta \bar{u})(Q^2) - (\Delta d + \Delta \bar{d})(Q^2) = F - D = 1.269 \pm 0.003$$

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

SU(3) symmetric value

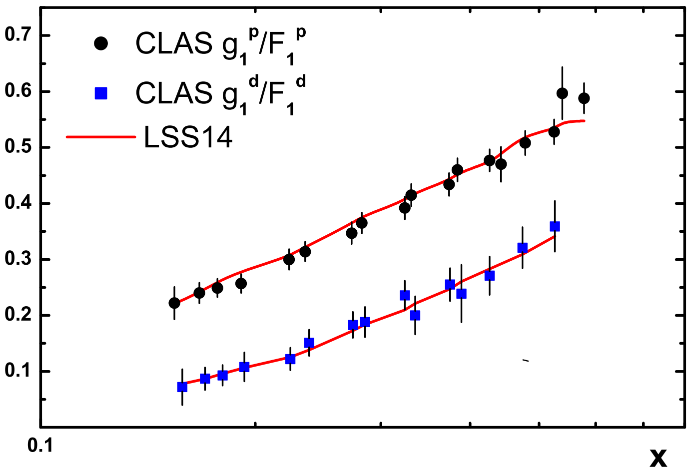
15 – 2(SR) = 13 free parameters

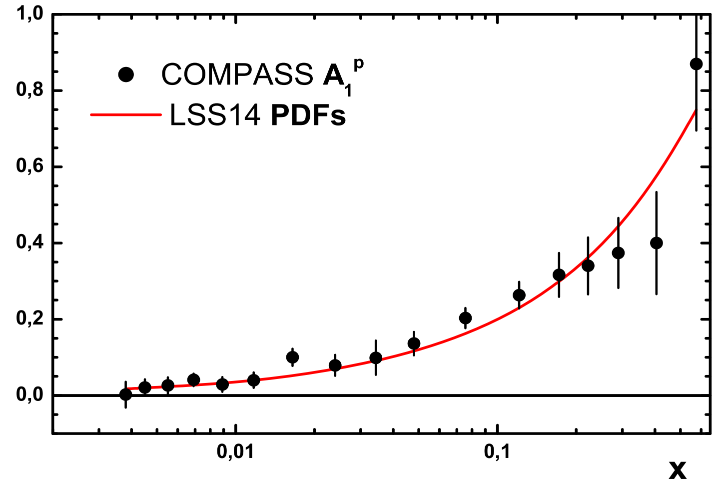
NB. Contrary to the previous analyses, additional assumptions about the sea quark densities $\Delta \bar{q}(x)$ are not made.

A good description of the data is achieved

$$\chi^2 / DOF = 0.842 \text{ for 902 exp. points}$$

The statistical and systematic errors are taken in qudrature





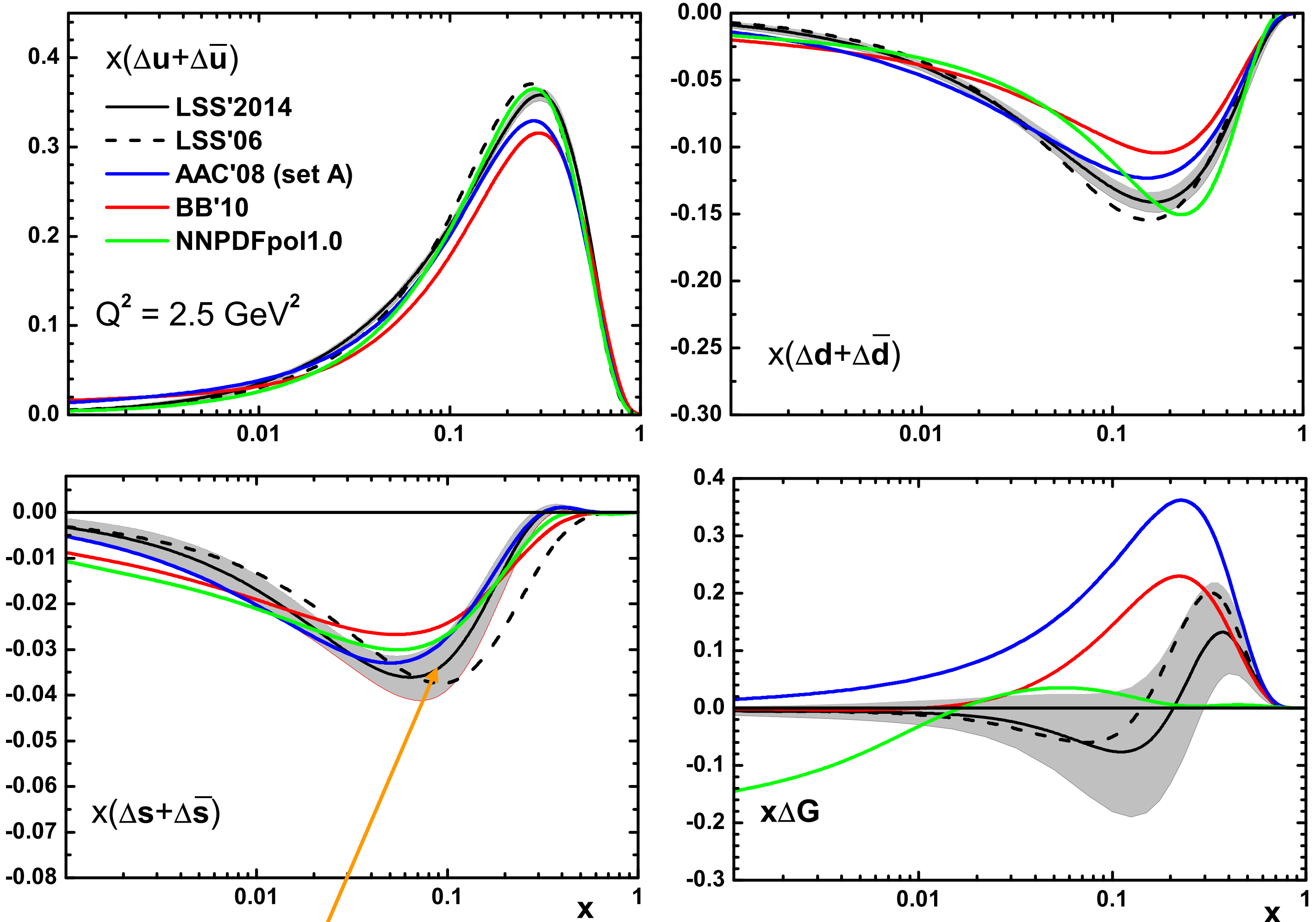
For CLAS p data: $\chi^2 / Nrp = 0.55$

For CLAS d data: $\chi^2 / Nrp = 0.23$

Comparison between the new COMPASS A_1^p data which were presented after our fit was made and the asymmetry calculated at the measured points using the LSS'14 PDFs.

⇒ **A very good description:** $\chi^2 / Nrp = 0.68$

Extracted NLO polarized PDFs – LSS'14



! The extracted **strange quark density** remains **significantly negative** even though the parametrization **allowed a sign change** as a function of *x*.

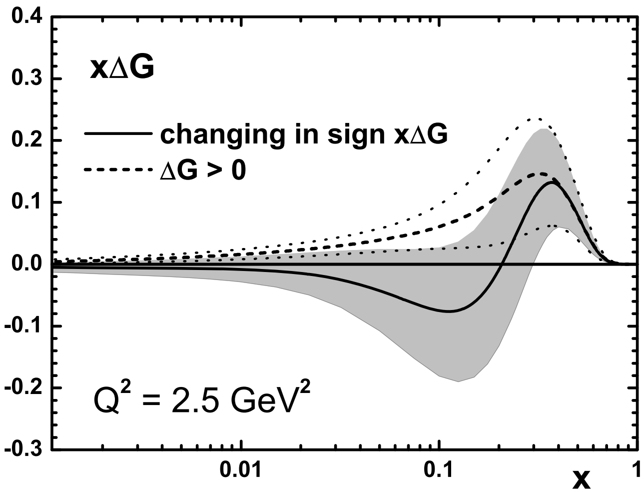
$$(\Delta s + \Delta\bar{s})(Q^2) = -0.106 +/- 0.023$$ at $Q^2 = 1$ GeV^2

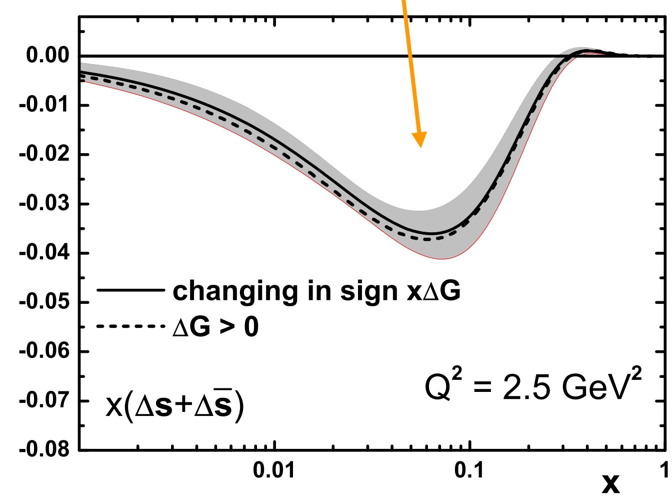
We have found that the present polarized inclusive DIS data still cannot rule out the solution with a positive gluon polarization.

$$\chi^2 / DOF)(node\ x\Delta G) = 0.842 \text{ and } \chi^2 / DOF)(x\Delta G > 0) = 0.845$$

and the data cannot distinguish between these two solutions.

The polarized strange sea quark densities obtained in the fits with sign-changing or positive gluons are almost identical





Sensitivity of the polarized strange quark density to flavor SU(3) symmetry breaking

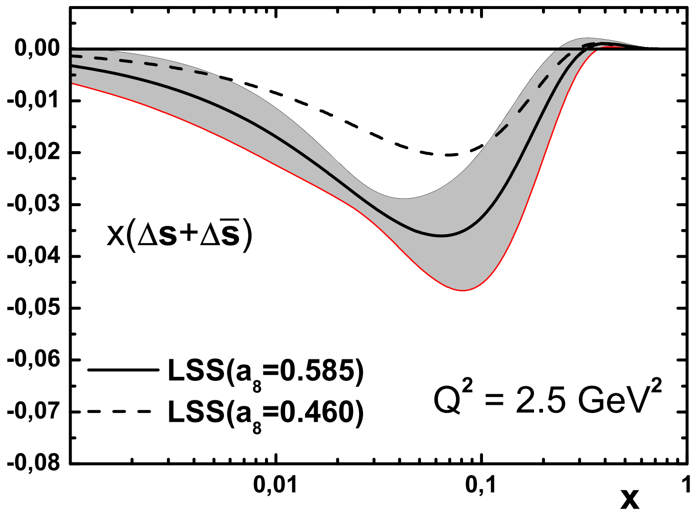
If SU(3) symmetry of the hyperon $\beta-decays$ **holds**

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

The question about the SU(3) symmetry breaking is still open.

There are different theoretical models. Here we present the result on the strange quark density, if instead of the SU(3) symmetric value of a_8**, the value 0.46 is used. This value corresponds to the maximal reduction of** a_8 **(*20%*) presented in the literature (*S. Bass, A.W. Thomas, PL B684 (2010)*).**

The key point is that the shape of the polarized strange quark density is the same.



SUMMARY

- A new NLO QCD analysis of the world polarized inclusive DIS data, including for the first time the new extremely precise *CLAS* data on the proton and deuteron spin str. functions, is presented

- Despite allowing in the parametrization of $(\Delta s + \Delta\bar{s})(x)$, for a possible sign change, we have confirmed the previous claim, namely, that the inclusive data yield significantly negative values for the polarized strange quark density.

We believe that the present disagreement between the SIDIS and DIS strange quark polarizations very likely results from a lack of correct information for the kaon fragmentation functions utilized and that the results from the inclusive analysis are correct.