19th International Workshop on
DEEP-INELASTIC SCATTERING and RELATED SUBJECTS
Newport News, VA, April 11 – 15, 2011

The Role of Fragmentation Functions in Determining the Polarized Sea Quark Densities

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

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 are used**

- **A new NLO QCD analysis of the polarized inclusive and *semi* inclusive DIS data is presented**

→ **using another set of FFs – the *Hirai at al.* (HKNS) one**

- **Impact of new FFs on polarized *sea* quark densities**

→ **a resolution of the strange quark polarization puzzle ?**

- **Summary**

LSS, arXiv:1103.5979

Polarized inclusive DIS processes

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

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

can be determined from 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 QCD contribution

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

Longitudinal polarized PDFs from inclusive DIS data

- The sums $(\Delta q + \Delta \bar{q})$ are well determined !

NB: x(Δs+Δs̄) negative from all analyses of the inclusive DIS data !!!

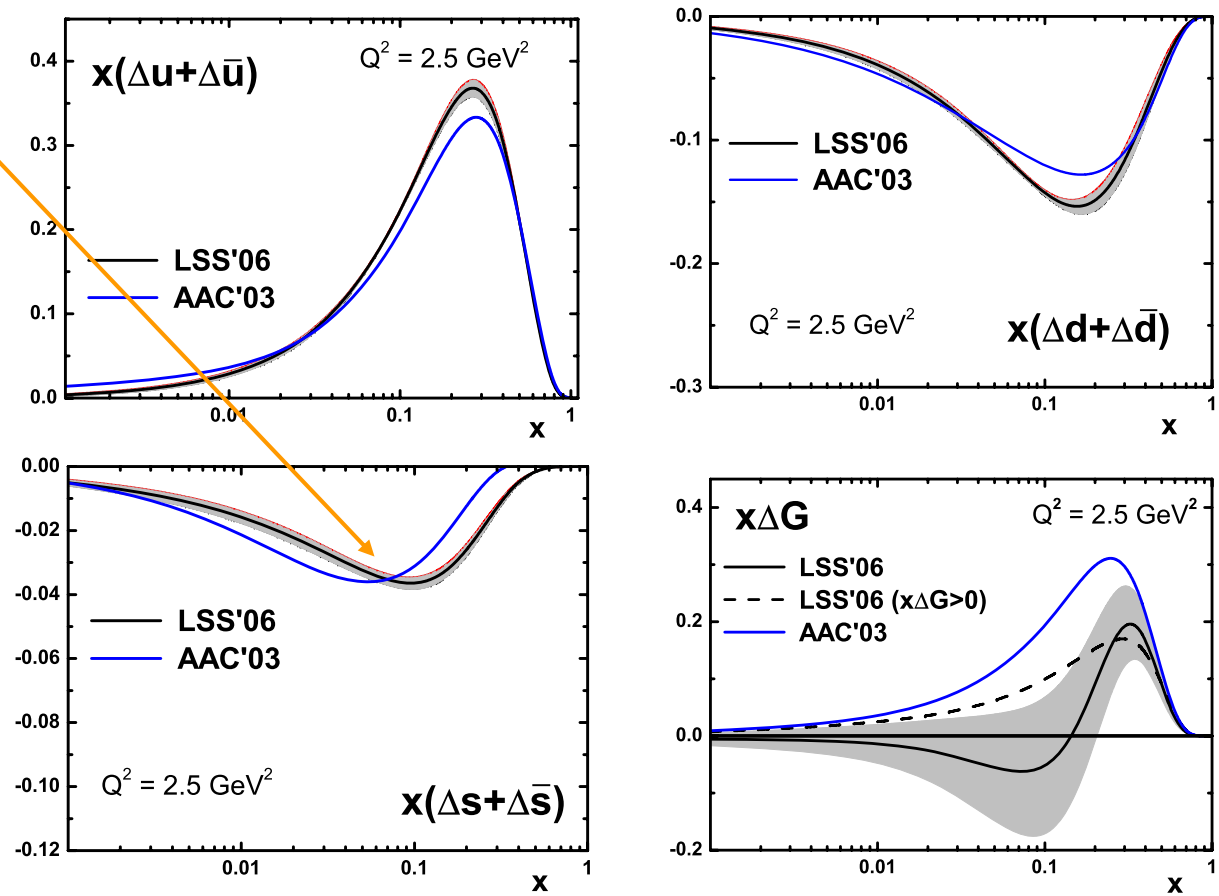
Error bands → $\Delta\chi^2 = 1$

GRSV, PR D63 (2001)

AAC03, PR D69 (2003)

LSS06, PR D75 (2007)
(CLAS and COMPASS data included)

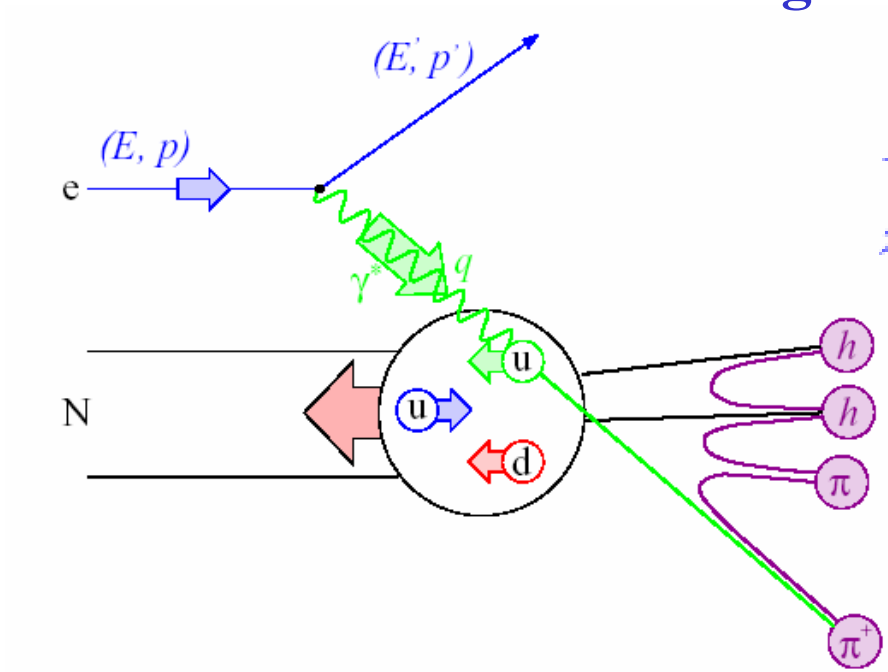
BB, NP B841 (2010)



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

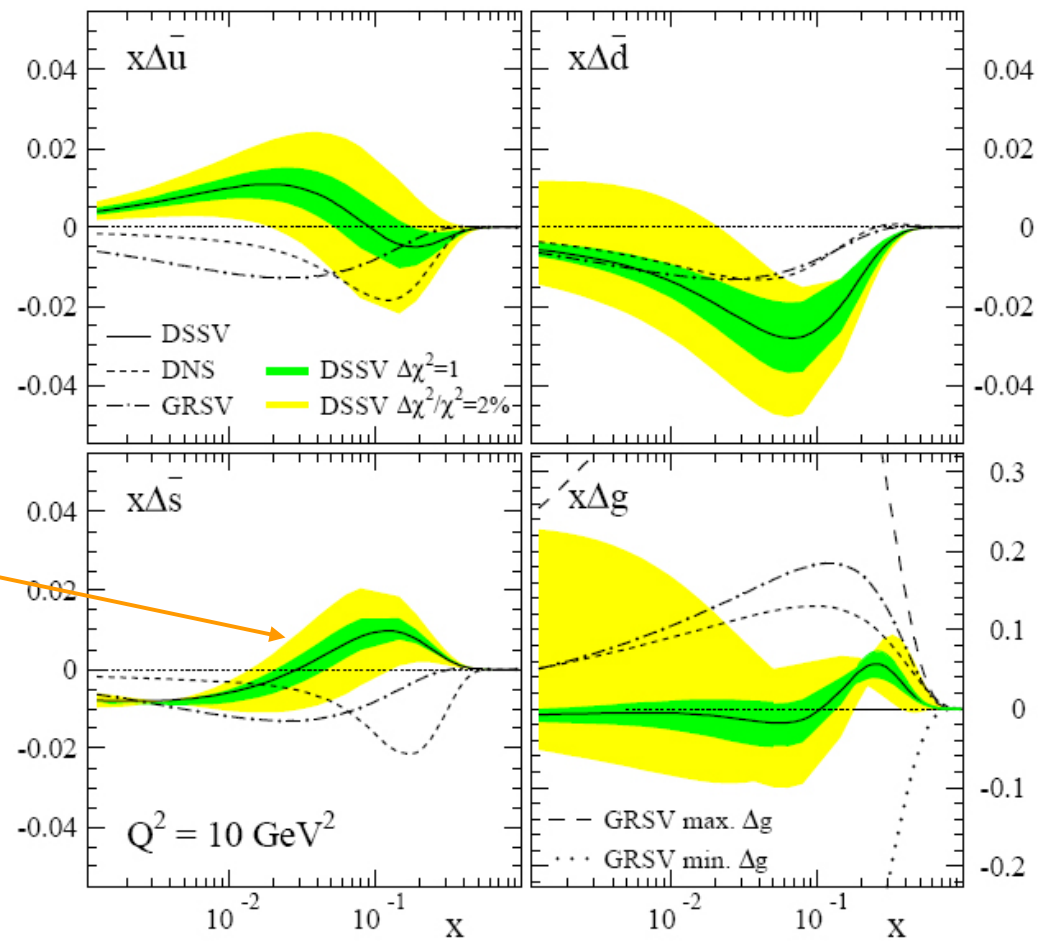
$$A_1^h(x,z,Q^2) = \frac{g_1^h - \gamma^2 g_2^h}{F_1^h}$$

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**

PDFs – from a first global NLO QCD analysis of DIS, SIDIS and RHIC polarized pp scattering data

DSSV, PRL 101 (2008) 072001



➡ **Flavor decomposition of the sea**

sign changing $x\Delta\bar{s}$!! ??

- **For the FFs the DSS set (*DSS, PRD 75, 2007*) has been used in the analysis**

It turned out that the DSS FFs are crucial for such unexpected behavior of $\Delta\bar{s}(x)$

$$\Delta\bar{u} \neq \Delta\bar{d} \neq \Delta\bar{s} = \Delta s \;!$$

Fit to the world data

(*COMPASS* SIDIS pion and kaon data included)

LSS 2010

PR D82 114018

- **Inclusive DIS**

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

- **Semi-inclusive DIS**

$$A_1^h(x,Q^2)_{\text{exp}} = \left[\frac{g_1^h(x,Q^2)}{F_1^h(x,Q^2)}\right]_{\text{exp}} \overset{\chi^2}{\Leftrightarrow} \frac{g_1^h(x,Q^2)_{\text{NLO}}}{F_1^h(x,Q^2)_{\text{NLO}}}$$

N.B. It is NOT known at present how to account for the HT and TMC corrections in SIDIS processes. Fortunately, they should be less important due to the kinematic region of the present SIDIS data.

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

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

The TM and HT corrections to g_1 are NOT negligible in the preasymptotic region and have to be accounted for

LSS: Phys. Rev. D75 (2007) 074027

LSS'10 NLO PDFs (*DIS+SIDIS*, *DSS FFs*)

- A good description of both the DIS and SIDIS data

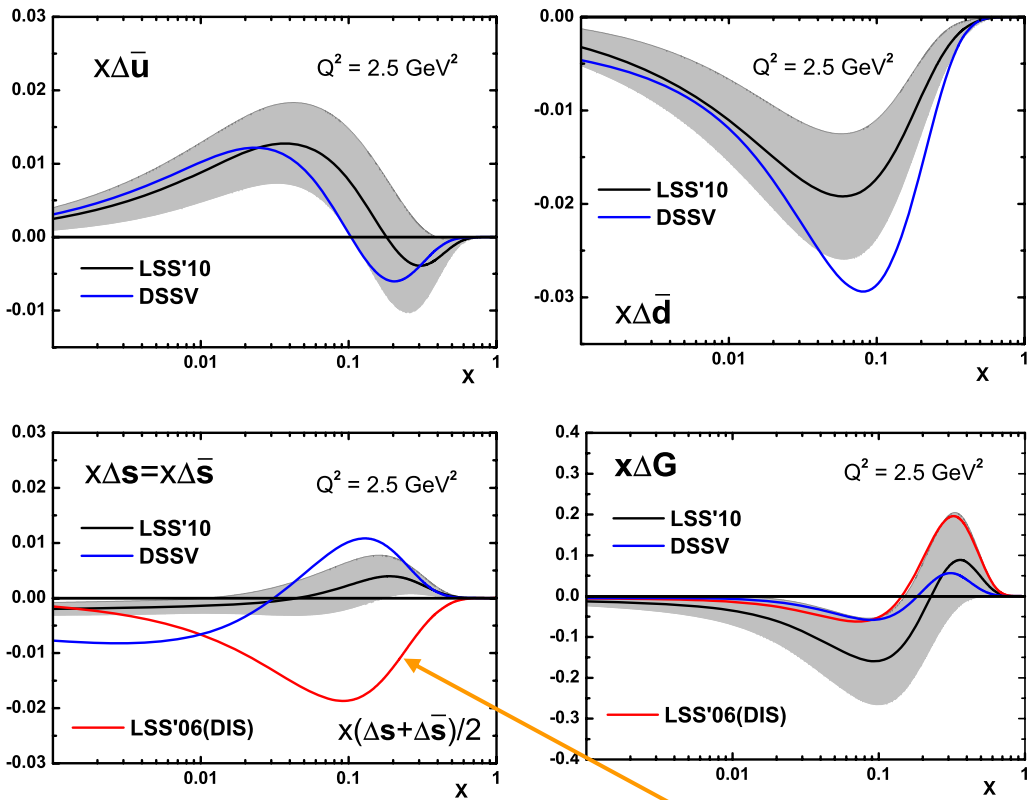
  DIS: $\chi^2_{NrP} = 0.85$

  SIDIS: $\chi^2_{NrP} = 0.90$

- Substantial agreement with DSSV

- We confirm the sign changing behavior of $\Delta\bar{s}(x)$ - although our $\Delta\bar{s}(x)$ is less negative at $x < 0.03$ and less positive for large x and compatible with zero within errors

Error bands → $\Delta\chi^2 = 1$



from inclusive DIS

→ Δs(x) is controversial !

(*If the DSS set of FFs is used*)

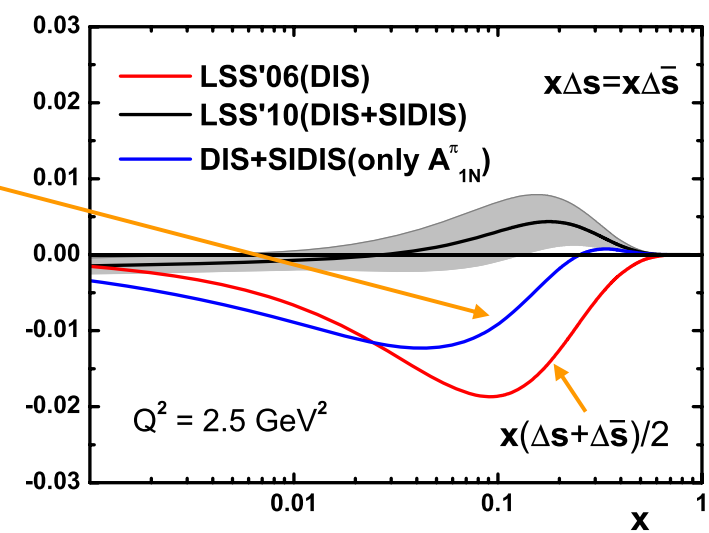
The strange quark polarization puzzle

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

In order to understand the issue of this contradiction we carried out a combined NLO analysis of the polarized DIS data and just the *pion* SIDIS data, using the DSS FFs.

LSS, arXiv:1012.5033

Result: **In the presence only of A_{1N}^{π} data the strange sea quark density $\Delta\bar{s}(x)$ is still negative and close to $(\Delta s+\Delta\bar{s})(x)/2$(*DIS*)**



Conclusion: **The lesson from this study is that the kaon FFs are the source of the significant change of $\Delta\bar{s}(x)$**

Sensitivity of polarized sea quark densities to FFs

There are 3 modern versions of FFs based on different data sets:

- **Hirai et al. (HKNS)**
  Phys. Rev. D75, 094009 (2007)
  SI e^+e^- annihilation data

- **Albino et al. (AKK)**
  Nucl. Phys. B803, 42 (2008)
  $e^+e^- \oplus$ SI pp (RHIC) data

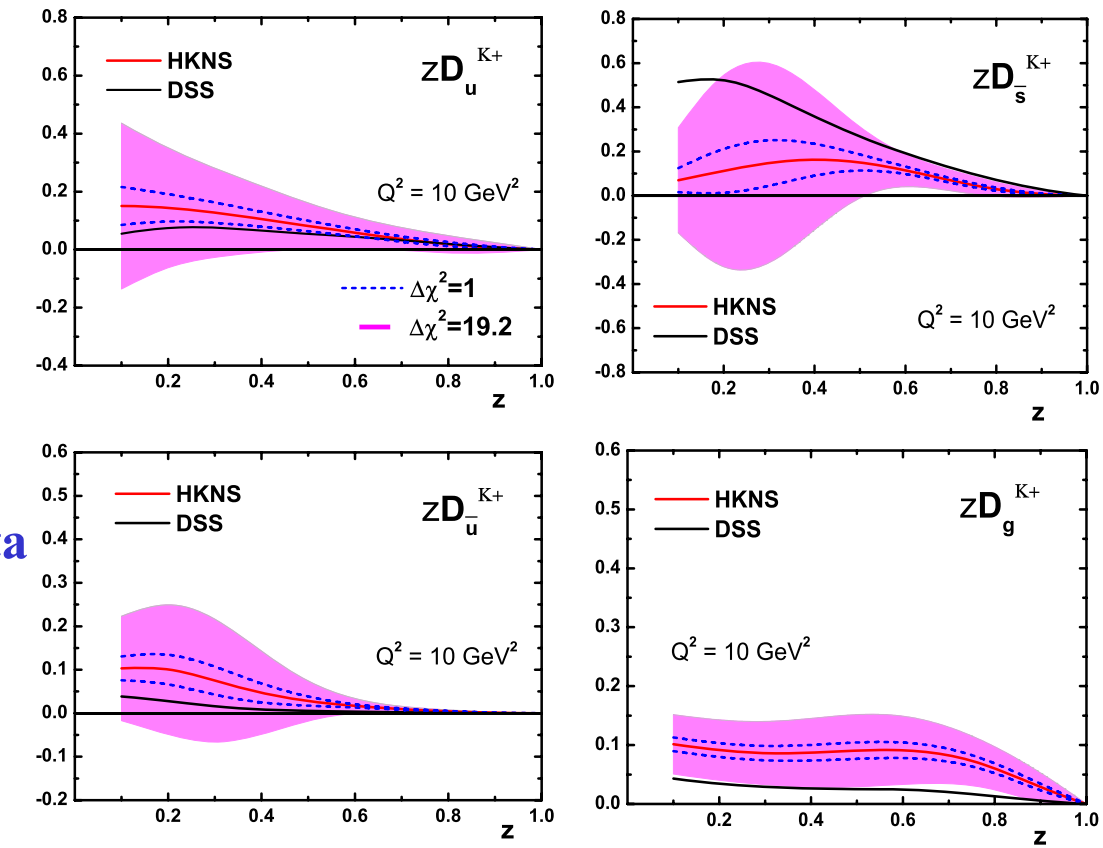
- **De Florian et al. (DSS) PR D75, 114010; D76, 074033 (2007)**
  $e^+e^- \oplus$ SI pp $\oplus$ SIDIS unpol. data

HERMES'05 (still unpublished)

bad χ^2_{NrP} :

3.8 for π^- and 3.3 for K^- data

The central values of FFs differ significantly

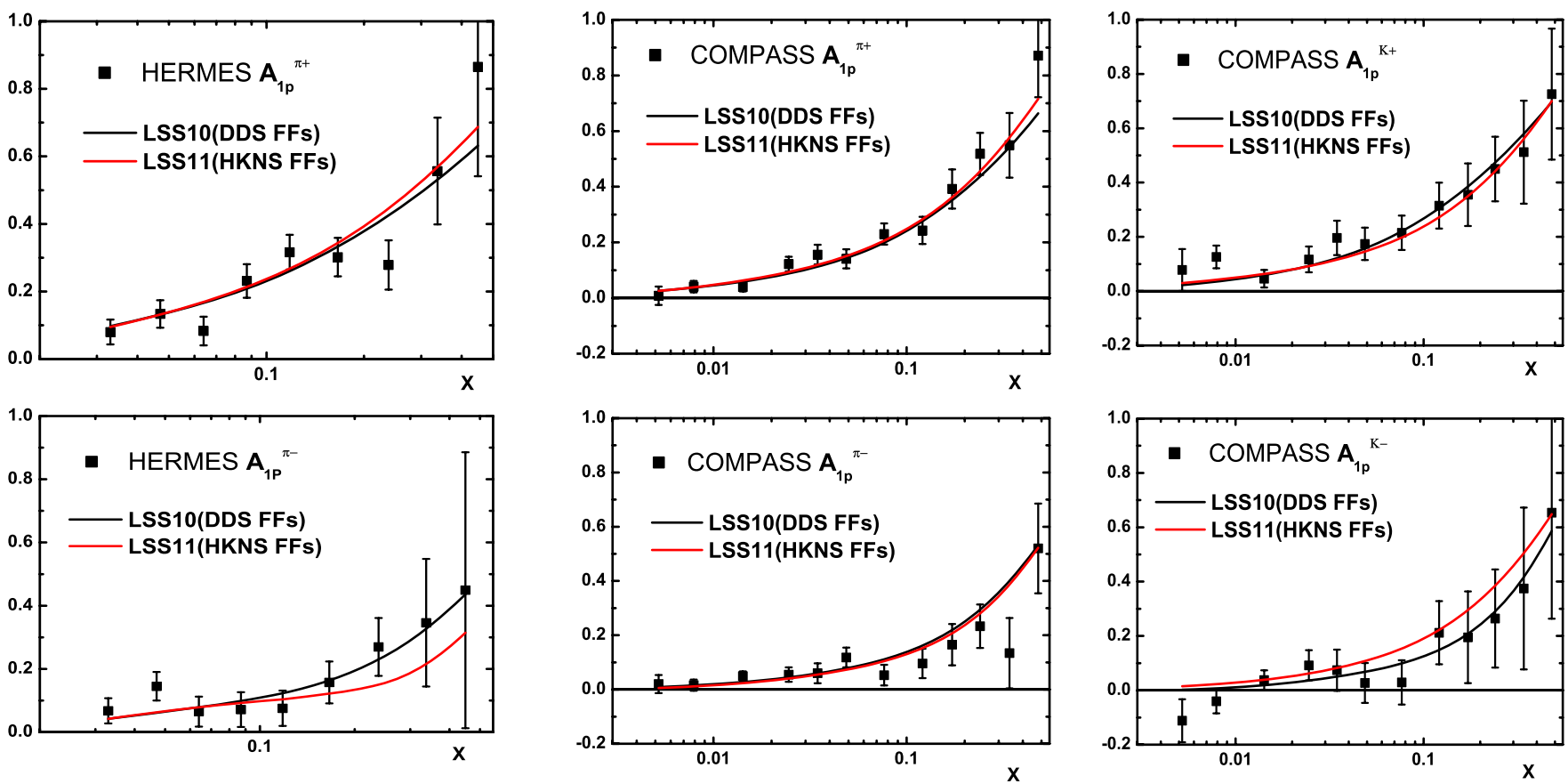


$err^2 = stat^2 + sys^2 \Rightarrow$ the wide corridors overestimated

Fit to the world DIS and SIDIS data using HKNS FFs

A good description of the SIDIS data

$$\chi^2_{NrP}(DSS) = 0.87 \quad \Rightarrow \quad \chi^2_{NrP}(HKNS) = 0.92$$



Impact of the HKNS FFs on polarized sea quark densities

- **Negligible** changes of $\Delta\bar{d}(x)$ and $\Delta G(x)$ densities

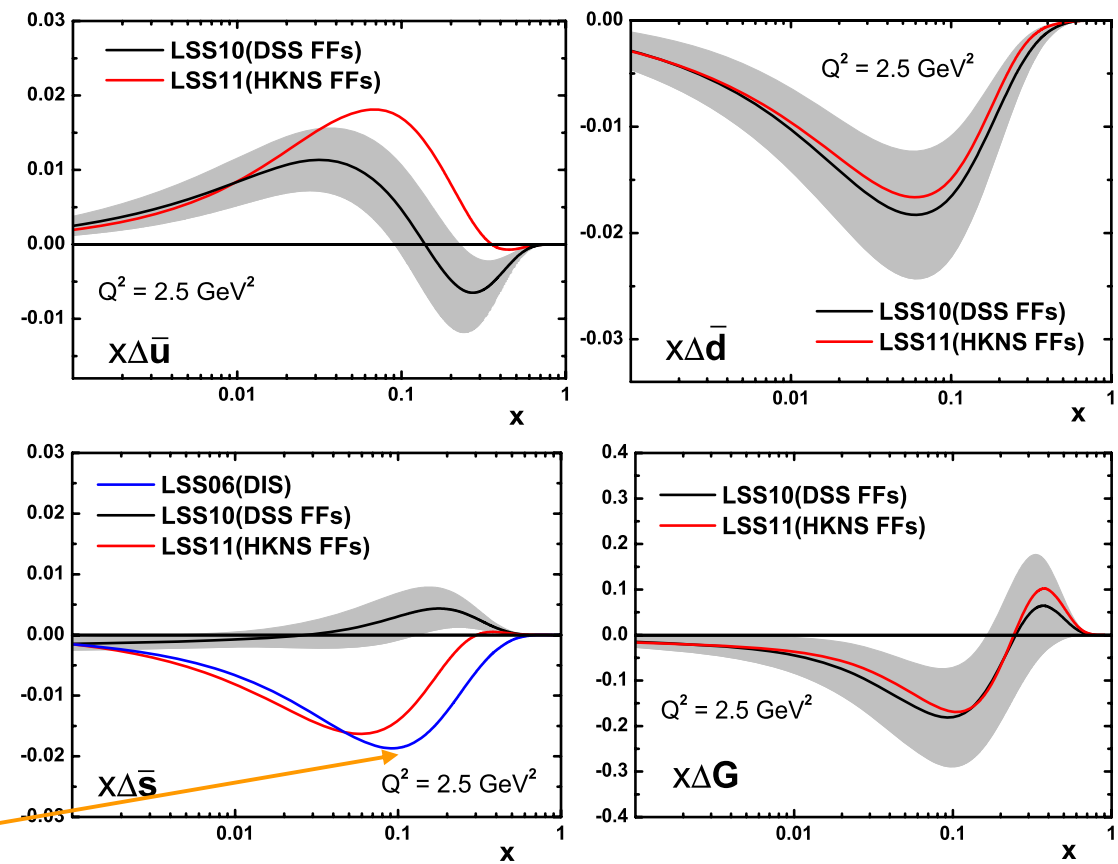
- **Visible** change of $\Delta\bar{u}(x)$ for x > 0.03

- **Dramatic** change of $\Delta\bar{s}(x)$ due to a **significant** difference in the transition

$$\bar{s} \rightarrow K^{+}$$

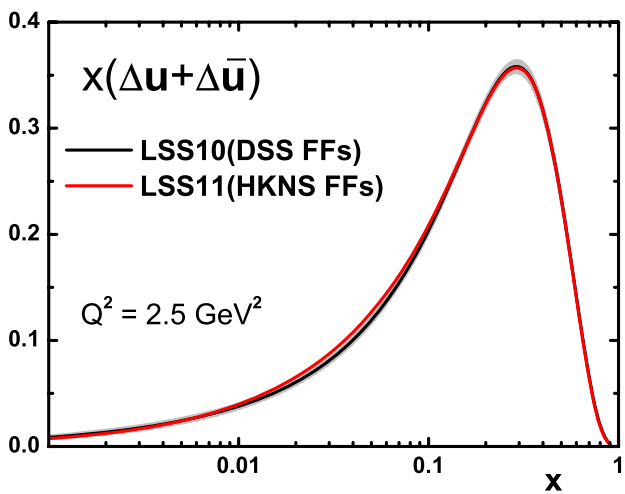
It is **negative** for any *x* in the measured region and consistent with $(\Delta s+\Delta\bar{s})(x)/2(DIS)$

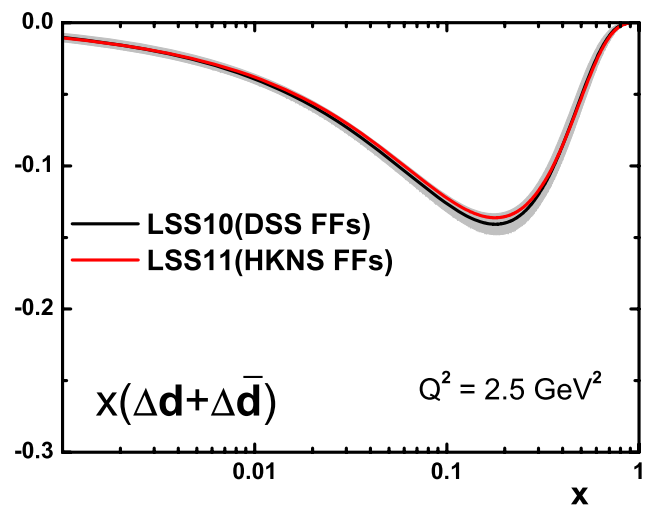
Error bands → $\Delta\chi^2 = 1$



$$err^2 = stat^2 + sys^2$$

As expected, the sums $(\Delta u + \Delta\bar{u})$ and $(\Delta d + \Delta\bar{d})$ corresponding to DSS and HKNS FFs are well consistent. This confirm once more the fact that they are fixed mainly from the inclusive DIS data





SUMMARY

- The impact of the fragmentation functions on the polarized sea quark densities, and especially on $\Delta\bar{s}(x)$, is studied

- To this end a new NLO QCD analysis of the world inclusive and *semi* inclusive DIS data using the Hirai et al. FFs is performed

→ It was found that the kaon DSS FFs are the source of the conflict between negative $\Delta\bar{s}(x)_{DIS}$ and sign-changing $\Delta\bar{s}(x)_{DIS+SIDIS}$

→ If the Hirai et al. FFs are used, $\Delta\bar{s}(x)_{DIS+SIDIS}$ is negative and consistent with $\Delta\bar{s}(x)_{DIS}$ obtained from DIS analysis

A more reliable determination of FFs is badly needed (precise UNpolarized SIDIS data are very important) in order to extract correctly the polarized sea quark densities !