Measurement of the strange quark helicity distribution from semi-inclusive DIS on the deuteron

Markus Ehrenfried
for the HERMES Collaboration

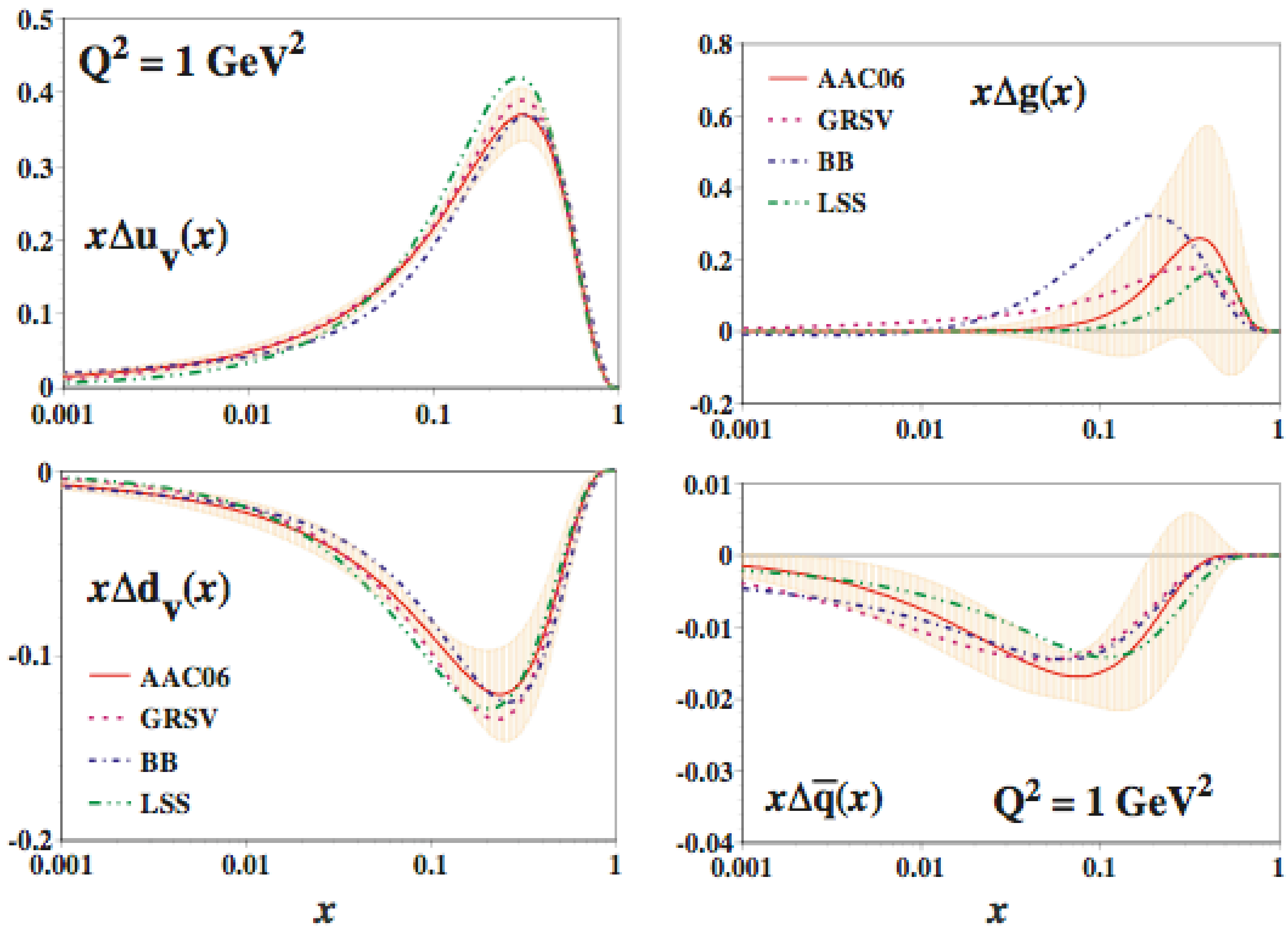
JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

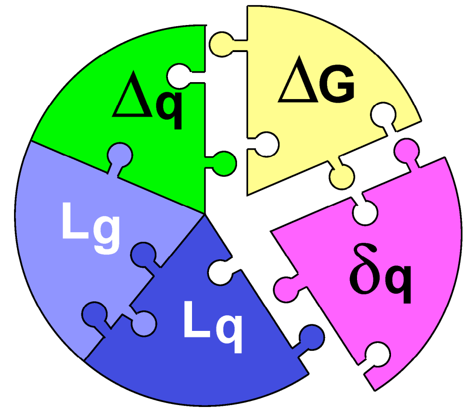
hermes

DESY

Disentangling the contributions to the nucleon's spin

$$\langle s_z^N \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_z^q + \Delta G + L_z^G$$



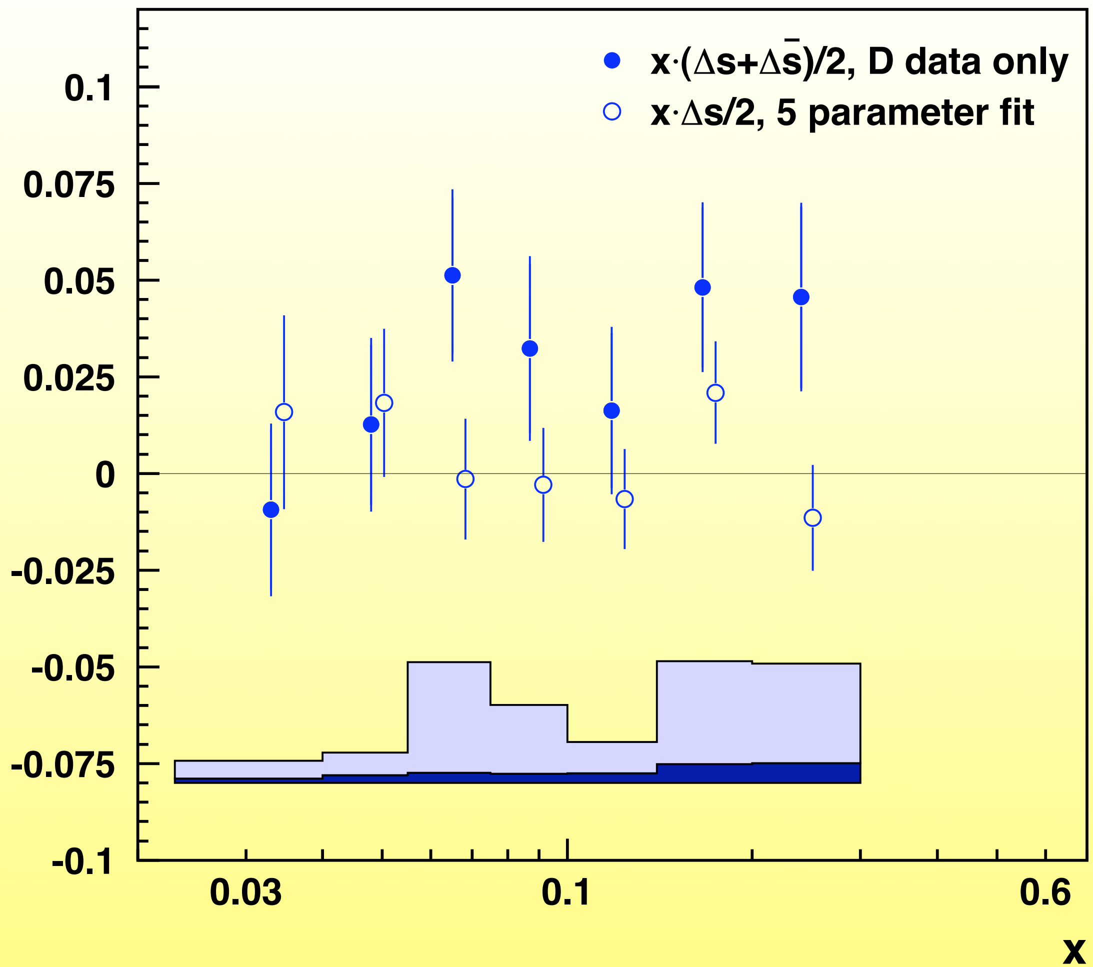


- $\Delta\Sigma \approx 0.21 - 0.35$
- strange quark helicity distributions are a clean way to get information about the quark sea polarization in DIS.

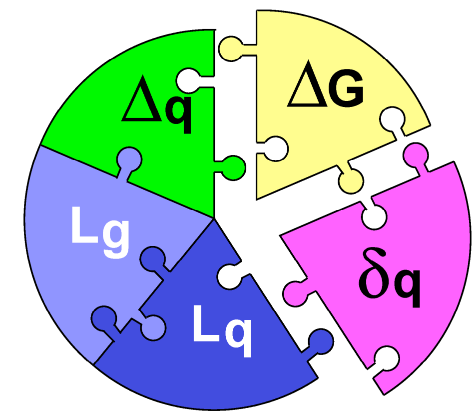
AAC: M. Hirai et al., hep-ph/0603213 (2006)

Disentangling the contributions to the nucleon's spin

$$\langle s_z^N \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_z^q + \Delta G + L_z^G$$

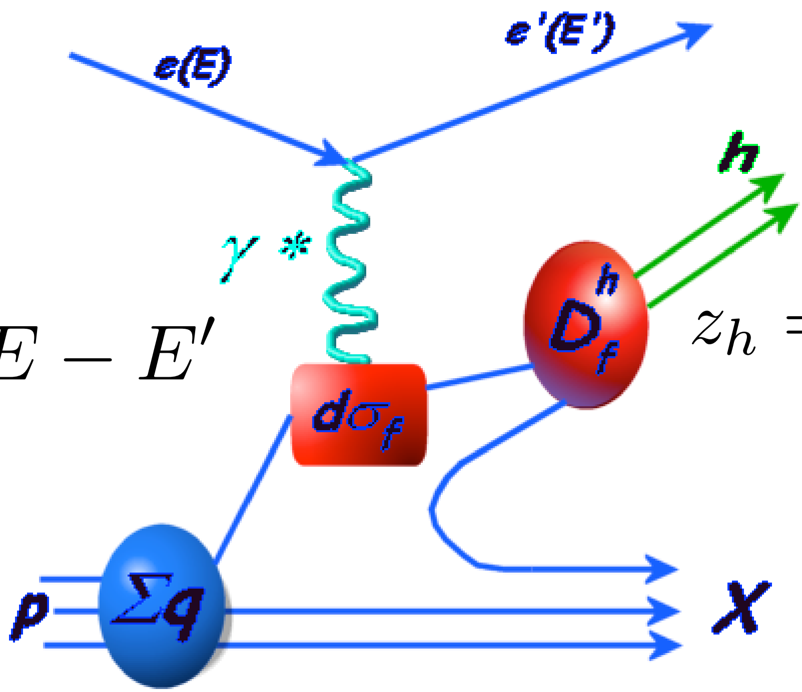


A. Airpetian et al. (HERMES), Phys. Rev. D 71, 012003 (2005)



- $\Delta\Sigma \approx 0.21 - 0.35$
- strange quark helicity distributions are a clean way to get information about the quark sea polarization in DIS.

Semi-inclusive DIS



$$\nu = E - E'$$

$$z_h = \frac{E_h}{\nu}$$

$$x = \frac{Q^2}{2M\nu}$$

$$Q^2 = -q^2 \overset{lab.}{\simeq} 4EE' \sin^2 \frac{\theta}{2}$$

- observation of a coincindent hadron in the final state
- flavour structure of the hadron is correlated to the quark which was struck inside the nucleon
- this analysis:
  $K^{\pm}$ double spin asymmetry on an deuteron target are used to probe the strange quark sea.

“Isoscalar” measurement of $\Delta s + \Delta \bar{s}$

- strange quarks carry no isospin
  ➠ the strange seas in the proton and the neutron are identical

- the deuteron is an isoscalar target
  ➠ fragmentation process in DIS can be described without assumptions regarding isospin dependent fragmentation

- “fragmentation functions” needed in this analysis are obtained from multiplicities directly at HERMES kinematics with the same data

- symmetry assumptions:
  (i) isospin symmetry between proton and neutron
  (ii) charge-conjugation invariance in fragmentation

- spin asymmetries used: $A_{1,d}^{K^\pm}(x, Q^2, z)$ and $A_{1,d}(x, Q^2)$

Semi-inclusive virtual photo-absorption cross section for kaon production (in LO):

$$\sigma^K(x,z) \propto \sum_q e_q^2\, q(x)\, D_q^K(z)$$

$$q = u, \overline{u}, d, \overline{d}, s, \overline{s}$$

fragmentation function: number density that a quark of flavour *q* will fragment into a kaon

Double-spin asymmetry:

$$A_1^K(x,z) = \frac{\sigma_{1/2}^K - \sigma_{3/2}^K}{\sigma_{1/2}^K + \sigma_{3/2}^K} = \frac{\sum_q e_q^2\, \Delta q(x)\, D_q^K(z)}{\sum_q e_q^2\, q(x)\, D_q^K(z)}$$

Asymmetry expressed with purities: $A_1^{K^\pm}(x,z) = \sum_q \mathcal{P}_q^{K^\pm}(x,z) \frac{\Delta q(x)}{q(x)}$

with $\mathcal{P}_q^{K^\pm}(x,z) = \frac{e_q^2\, q(x)\, D_q^{K^\pm}(z)}{\sum_{q'} e_{q'}^2\, q'(x)\, D_{q'}^{K^\pm}(z)}$

"Probability that the virtual photon struck a quark of flavour *q* in the nucleon when a $K^\pm$ is detected."

Simple linear relationship between the two measured asymmetries and the total non-strange quark distribution $Q(x) \equiv u(x) + \overline{u}(x) + d(x) + \overline{d}(x)$ and total strange quark distribution $S(x) \equiv s(x) + \overline{s}(x)$:

$$\begin{pmatrix} A_{1,d}(x) \\ A_{1,d}^{K^\pm}(x) \end{pmatrix} \propto \begin{pmatrix} \mathcal{P}_Q(x) & \mathcal{P}_S(x) \\ \mathcal{P}_Q^{K^\pm}(x) & \mathcal{P}_S^{K^\pm}(x) \end{pmatrix} \begin{pmatrix} \Delta Q(x)/Q(x) \\ \Delta S(x)/S(x) \end{pmatrix}$$

$$\begin{pmatrix} A_{1,d}(x) \\ A_{1,d}^{K^\pm}(x) \end{pmatrix} \propto \begin{pmatrix} \mathcal{P}_Q(x) & \mathcal{P}_S(x) \\ \mathcal{P}_Q^{K^\pm}(x) & \mathcal{P}_S^{K^\pm}(x) \end{pmatrix} \begin{pmatrix} \Delta Q(x)/Q(x) \\ \Delta S(x)/S(x) \end{pmatrix}$$

Purities in terms of PDFs and fragmentation functions:

$$\mathcal{P}_Q(x) = \frac{5\,Q(x)}{5\,Q(x) + 2\,S(x)} \qquad \mathcal{P}_S(x) = \frac{2\,S(x)}{5\,Q(x) + 2\,S(x)}$$

$$\mathcal{P}_Q^{K^\pm}(x) = \frac{Q(x) \int \mathcal{D}_{\mathrm{non-strange}}^{K^\pm}(z)\,\mathrm{d}z}{Q(x) \int \mathcal{D}_{\mathrm{non-strange}}^{K^\pm}(z)\,\mathrm{d}z + S(x) \int \mathcal{D}_{\mathrm{strange}}^{K^\pm}(z)\,\mathrm{d}z}$$

$$\mathcal{P}_S^{K^\pm}(x) = \frac{S(x) \int \mathcal{D}_{\mathrm{strange}}^{K^\pm}(z)\,\mathrm{d}z}{Q(x) \int \mathcal{D}_{\mathrm{non-strange}}^{K^\pm}(z)\,\mathrm{d}z + S(x) \int \mathcal{D}_{\mathrm{strange}}^{K^\pm}(z)\,\mathrm{d}z}$$

with

$$\int \mathcal{D}_{\mathrm{non-strange}}^{K^\pm}(z)\,\mathrm{d}z = 4 \int D_{\mathrm{u}}^{K^\pm}(z)\,\mathrm{d}z + \int D_{\mathrm{d}}^{K^\pm}(z)\,\mathrm{d}z$$

$$\int \mathcal{D}_{\mathrm{strange}}^{K^\pm}(z)\,\mathrm{d}z = 2 \int D_{\mathrm{s}}^{K^\pm}(z)\,\mathrm{d}z$$

These fragmentation functions

$$\int \mathcal{D}^{K^\pm}_{\mathrm{non-strange}}(z)\,\mathrm{d}z = 4\int D^{K^\pm}_{\mathrm{u}}(z)\,\mathrm{d}z + \int D^{K^\pm}_{\mathrm{d}}(z)\,\mathrm{d}z$$

$$\int \mathcal{D}^{K^\pm}_{\mathrm{strange}}(z)\,\mathrm{d}z = 2\int D^{K^\pm}_{\mathrm{s}}(z)\,\mathrm{d}z$$

can be obtained from unpolarized SIDIS data taken at HERMES kinematics, assuming only charge-conjugation invariance in the fragmentation process:

$$D^{K^\pm}_{u} = D^{K^\mp}_{\bar{u}}, \qquad D^{K^\pm}_{d} = D^{K^\mp}_{\bar{d}}, \qquad D^{K^\pm}_{s} = D^{K^\mp}_{\bar{s}}$$

The strange and non-strange fragmentation functions are then extracted by fitting the *x* dependence of this ratio:

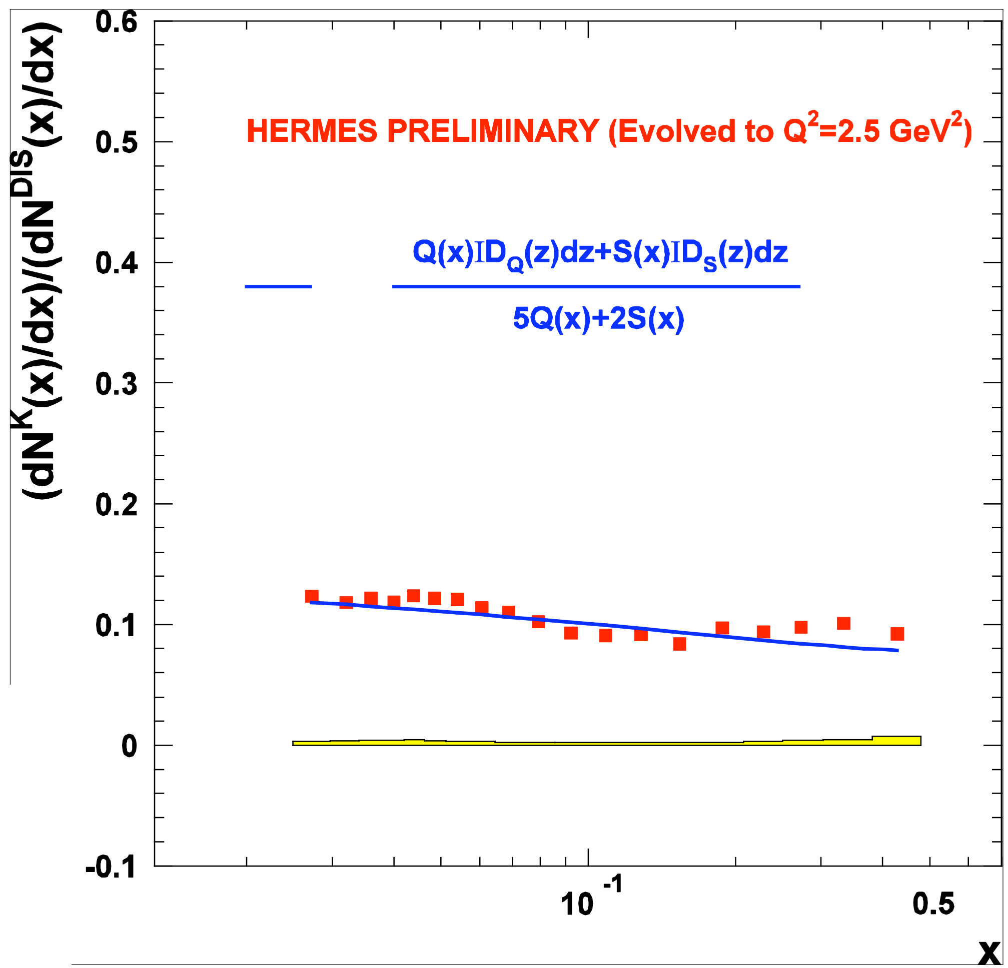
$$\frac{\mathrm{d}N^{K^\pm}(x)/\mathrm{d}x}{\mathrm{d}N^{\mathrm{DIS}}(x)/\mathrm{d}x} = \frac{Q(x)\int \mathcal{D}^{K^\pm}_{\mathrm{non-strange}}(z)\,\mathrm{d}z + S(x)\int \mathcal{D}^{K^\pm}_{\mathrm{strange}}(z)\,\mathrm{d}z}{5\,Q(x) + 2\,S(x)}$$

(parton distributions from CTEQ6 used)

$$\frac{\mathrm{d}N^{K^\pm}(x)/\mathrm{d}x}{\mathrm{d}N^{\mathrm{DIS}}(x)/\mathrm{d}x} = \frac{Q(x)\int \mathcal{D}^{K^\pm}_{\mathrm{non-strange}}(z)\,\mathrm{d}z + S(x)\int \mathcal{D}^{K^\pm}_{\mathrm{strange}}(z)\,\mathrm{d}z}{5\,Q(x)+2\,S(x)}$$

	This Work	***Kretzer***	***KKP***
$\int D^K_{nstrg}(z)dz$	*0.379±0.002±0.009*	*1.103*	*1.111*
$\int D^K_{strg}(z)dz$	*1.722±0.024±0.108*	*0.783*	*0.296*

Strangeness suppression factor for $s\bar{s}$ production is important for $\mathcal{D}^{K^\pm}_{\mathrm{non-strange}}(z)$



Event selection

$$Q^2 > 1\ \mathrm{GeV}^2$$

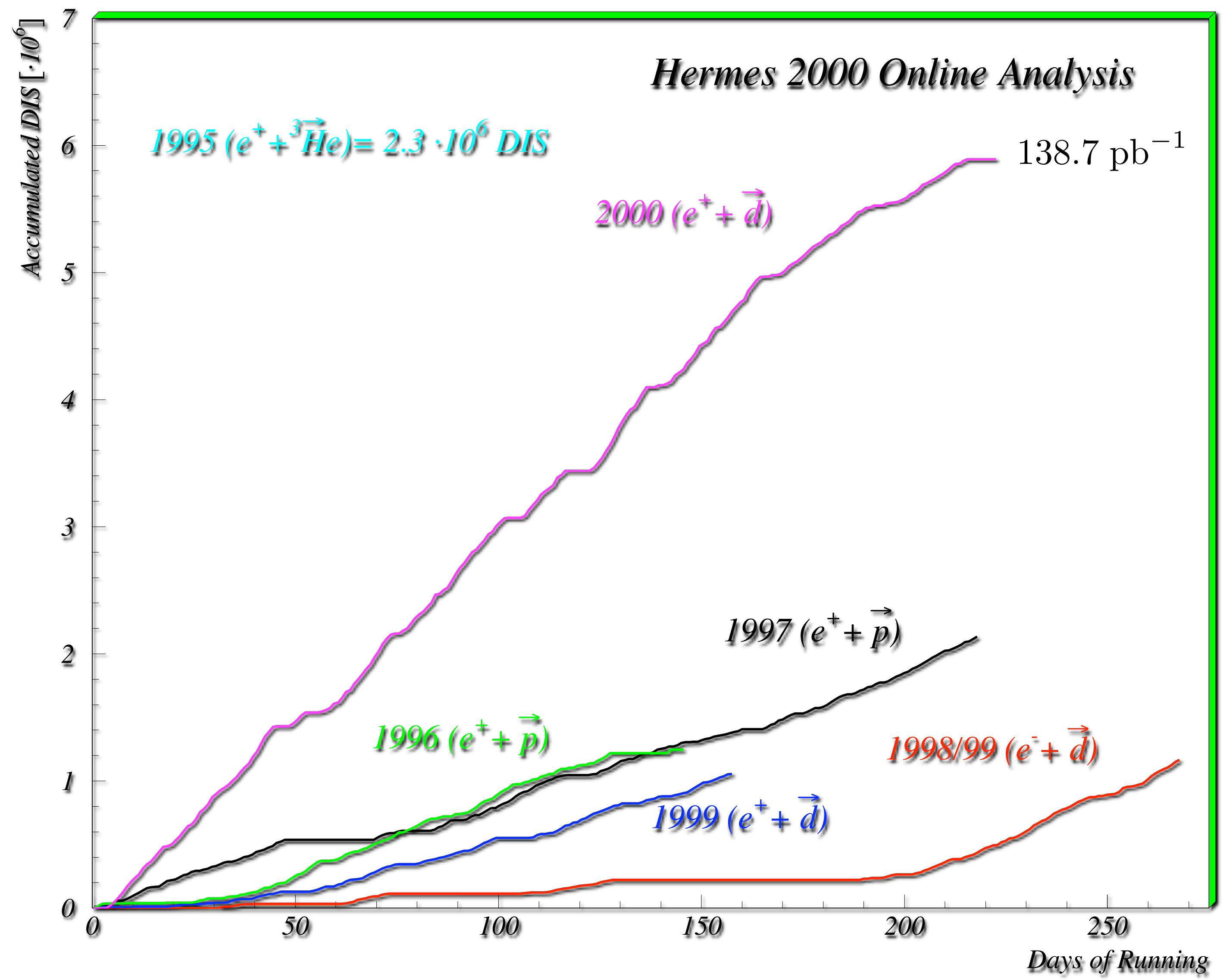
$$W^2 > 10\ \mathrm{GeV}^2$$

$$y = \frac{\nu}{E} < 0.85$$

coincident hadrons:

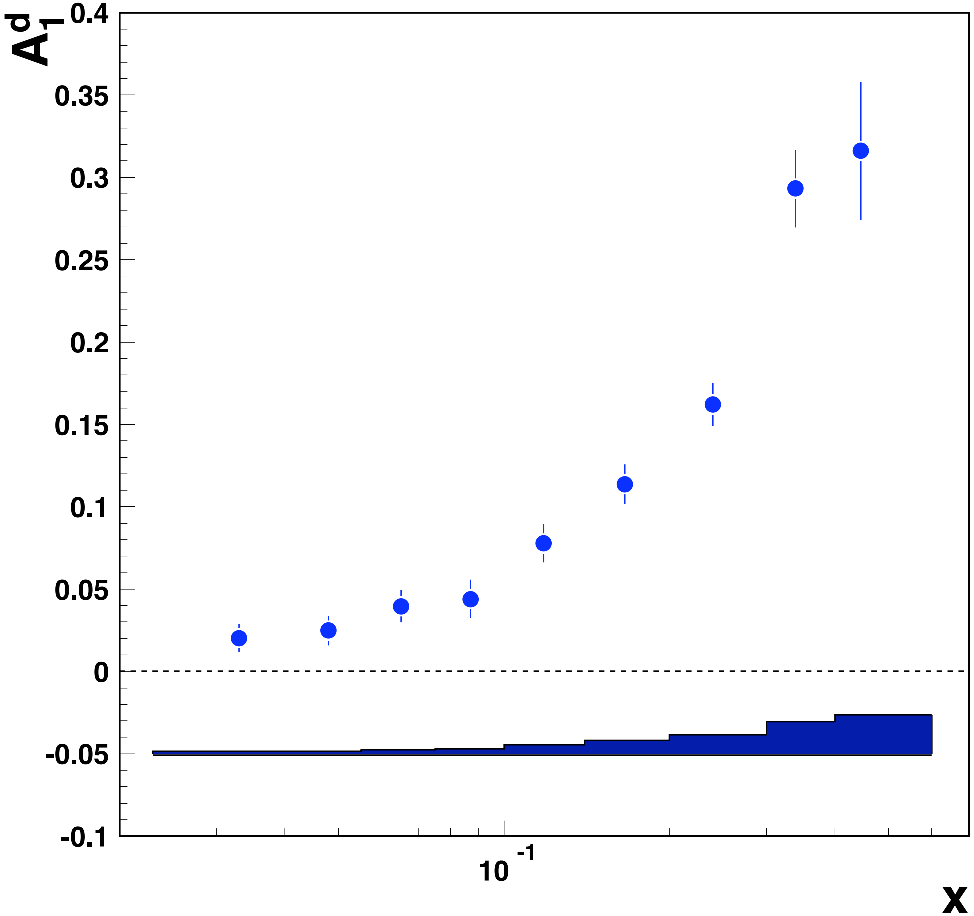
$$0.2 < z_h < 0.8$$

$$x_F \approx \frac{2p_L}{W} > 0.1$$

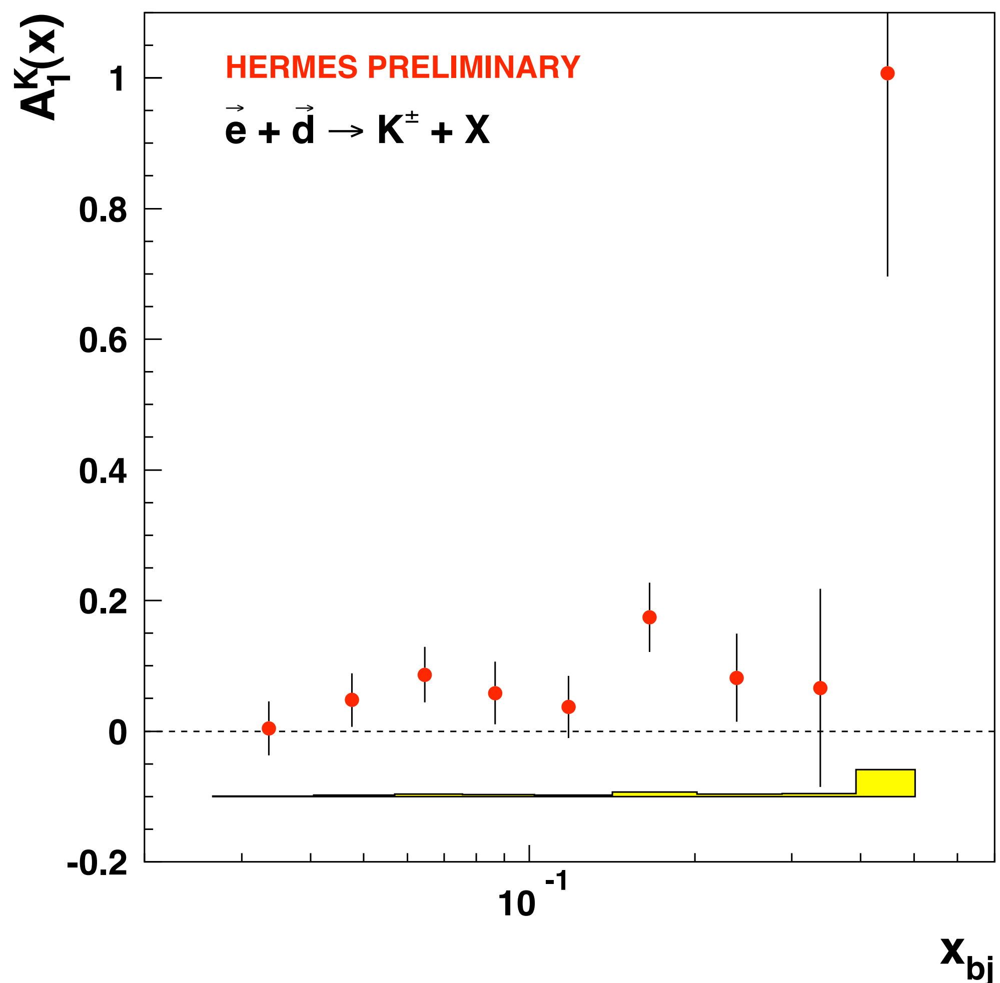


p_L = longitudinal momentum of hadron w.r.t. the $\gamma^\star$

$$\begin{pmatrix} A_{1,d}(x) \\ A_{1,d}^{K^\pm}(x) \end{pmatrix} \propto \begin{pmatrix} \mathcal{P}_Q(x) & \mathcal{P}_S(x) \\ \mathcal{P}_Q^{K^\pm}(x) & \mathcal{P}_S^{K^\pm}(x) \end{pmatrix} \begin{pmatrix} \Delta Q(x)/Q(x) \\ \Delta S(x)/S(x) \end{pmatrix}$$

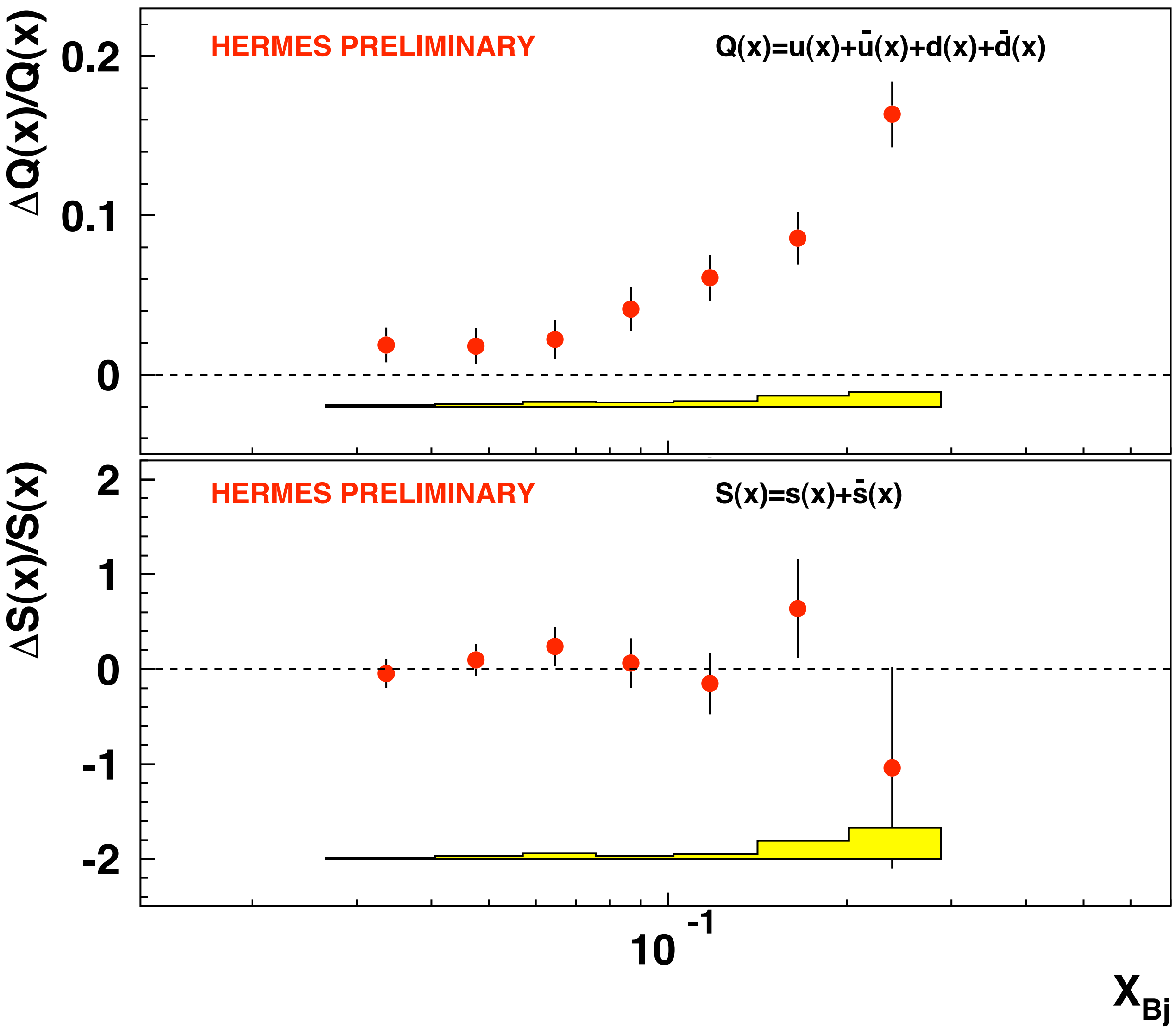


inclusive asymmetry



Kaon asymmetry

$$\begin{pmatrix} A_{1,d}(x) \\ A_{1,d}^{K^\pm}(x) \end{pmatrix} \propto \begin{pmatrix} \mathcal{P}_Q(x) & \mathcal{P}_S(x) \\ \mathcal{P}_Q^{K^\pm}(x) & \mathcal{P}_S^{K^\pm}(x) \end{pmatrix} \begin{pmatrix} \Delta Q(x)/Q(x) \\ \Delta S(x)/S(x) \end{pmatrix}$$



non-strange quark polarization

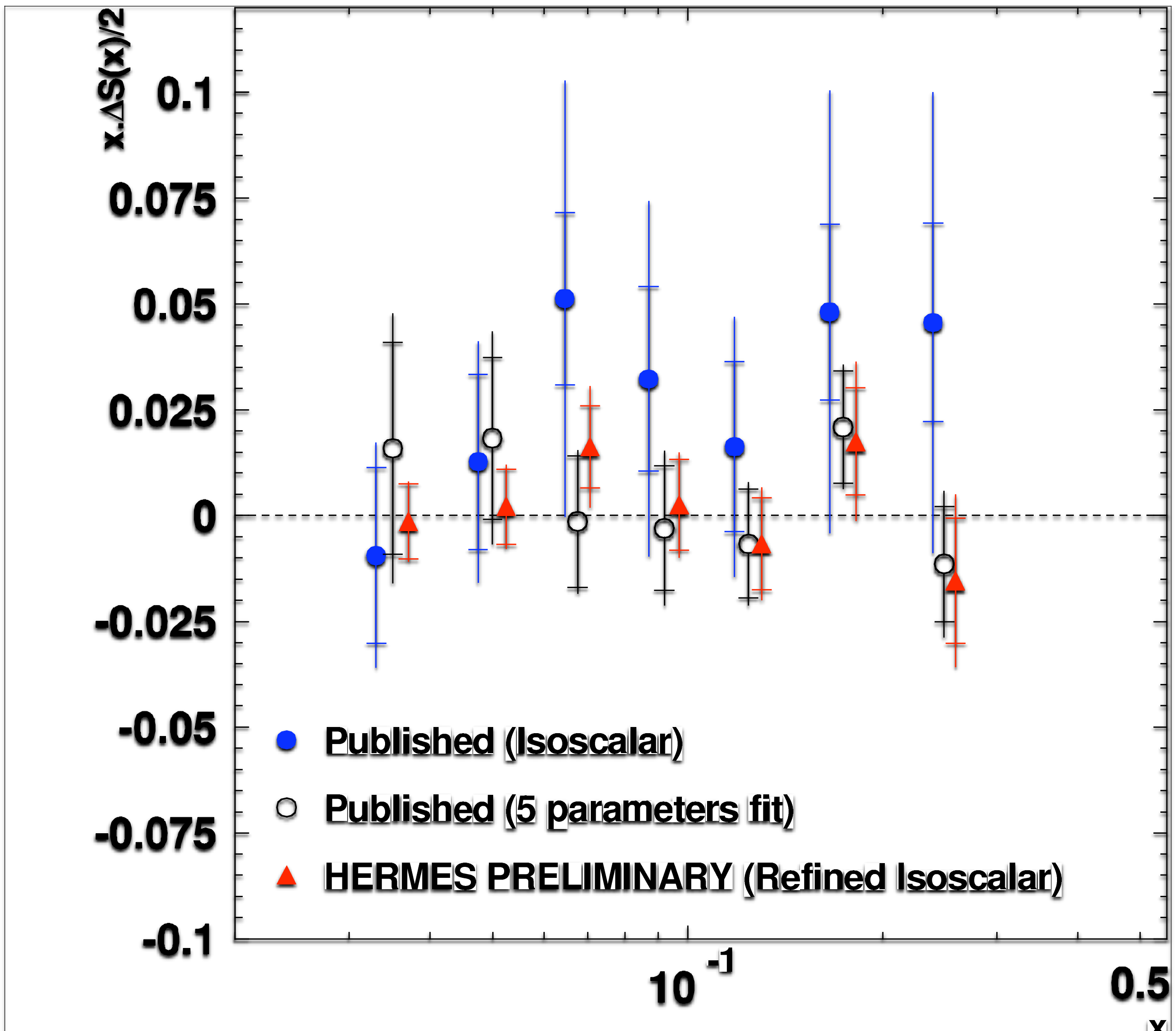
$$\int_{0.02}^{1} \Delta Q = 0.286 \pm 0.026 \pm 0.011$$

strange quark polarization

$$\int_{0.02}^{1} \Delta S = 0.006 \pm 0.029 \pm 0.007$$

Summary

$$\int_{0.02}^{1} \Delta S = 0.006 \pm 0.029 \pm 0.007$$



- ΔS is consistent with zero within the measured range

  $0.02 < x < 0.60$
  $0.2 < z < 0.8$

- First moment of ΔS is zero within uncertainties.