Valence quarks polarization from COMPASS

A.Korzenev[a], Mainz University

On behalf of the COMPASS collaboration

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \langle L_z \rangle$$

$$\Delta\Sigma = (\Delta u_v + \Delta d_v) + \text{sea}$$

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and Related Subjects

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[a]on leave from JINR, Dubna

Hadron asymmetries

Semi-inclusive asymmetries

$$A^+ = \frac{\sigma^{h+}_{\uparrow\downarrow} - \sigma^{h+}_{\uparrow\uparrow}}{\sigma^{h+}_{\uparrow\downarrow} + \sigma^{h+}_{\uparrow\uparrow}} \quad A^- = \frac{\sigma^{h-}_{\uparrow\downarrow} - \sigma^{h-}_{\uparrow\uparrow}}{\sigma^{h-}_{\uparrow\downarrow} + \sigma^{h-}_{\uparrow\uparrow}}$$

$$A_1^h(x) = \frac{\sum_q e_q^2(\Delta q(x) D_q^h + \Delta\bar{q}(x) D_{\bar{q}}^h)}{\sum_q e_q^2(q(x) D_q^h + \bar{q}(x) D_{\bar{q}}^h)}$$

Difference asymmetry

$$A^{+-} = \frac{(\sigma^{h+}_{\uparrow\downarrow} - \sigma^{h-}_{\uparrow\downarrow}) - (\sigma^{h+}_{\uparrow\uparrow} - \sigma^{h-}_{\uparrow\uparrow})}{(\sigma^{h+}_{\uparrow\downarrow} - \sigma^{h-}_{\uparrow\downarrow}) + (\sigma^{h+}_{\uparrow\uparrow} - \sigma^{h-}_{\uparrow\uparrow})}$$

$$A_d^{\pi^+-\pi^-}(x) = A_d^{K^+-K^-}(x) = \frac{\Delta u_v(x) + \Delta d_v(x)}{u_v(x) + d_v(x)}$$

- Fragmentation functions $D_q^h = \int D_q^h(z)dz$ are poorly known
- Difference asymmetry originally was proposed in:
  L.Frankfurt *et al.*, Phys. Lett. B230 (1989) 141
- First was used in SMC: B. Adeva *et al.*, Phys. Lett. B369 (1996) 93.
- Meaningful physics results for the deuteron target in LO QCD even without hadron identification

Requirement for the precision (LO QCD)

- The first moment of g_1^d at $Q^2 = 10\,\mathrm{GeV}^2$ (PLB 647 (2007) 8):

$$\Gamma_1^N = \int_0^1 g_1^N dx = \frac{1}{9}\left(a_0 + \frac{1}{4}a_8\right) = 0.051 \pm 0.003(stat) \pm 0.003(evol) \pm 0.005(syst)$$

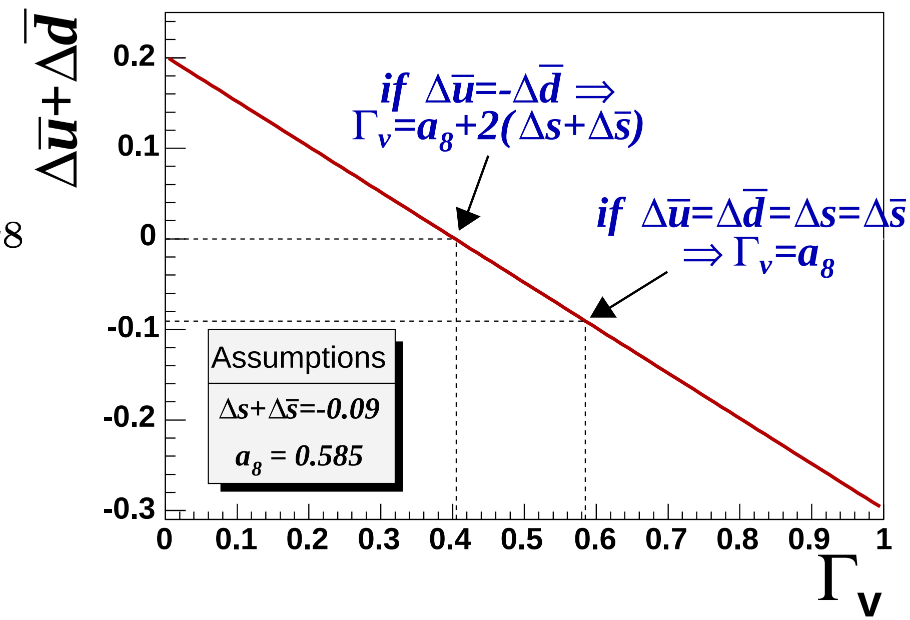
- The goal of the measurement:

$$\Gamma_v \equiv \int_0^1 (\Delta u_v(x) + \Delta d_v(x))dx$$

- Combining with axial charges a_0 and a_8

$$\Delta\bar{u} + \Delta\bar{d} = 3\,\Gamma_1^N - \frac{1}{2}\Gamma_v + \frac{1}{12}a_8$$

$$= (\Delta s + \Delta\bar{s}) + \frac{1}{2}(a_8 - \Gamma_v)$$



- To distinguish between light flavor "symmetric" ($\Delta\bar{u}=\Delta\bar{d}=\Delta s=\Delta\bar{s}$) and "asymmetric" ($\Delta\bar{u}=-\Delta\bar{d}$) scenarios the precision $\delta\Gamma_v < |\Delta s + \Delta\bar{s}|$ is needed

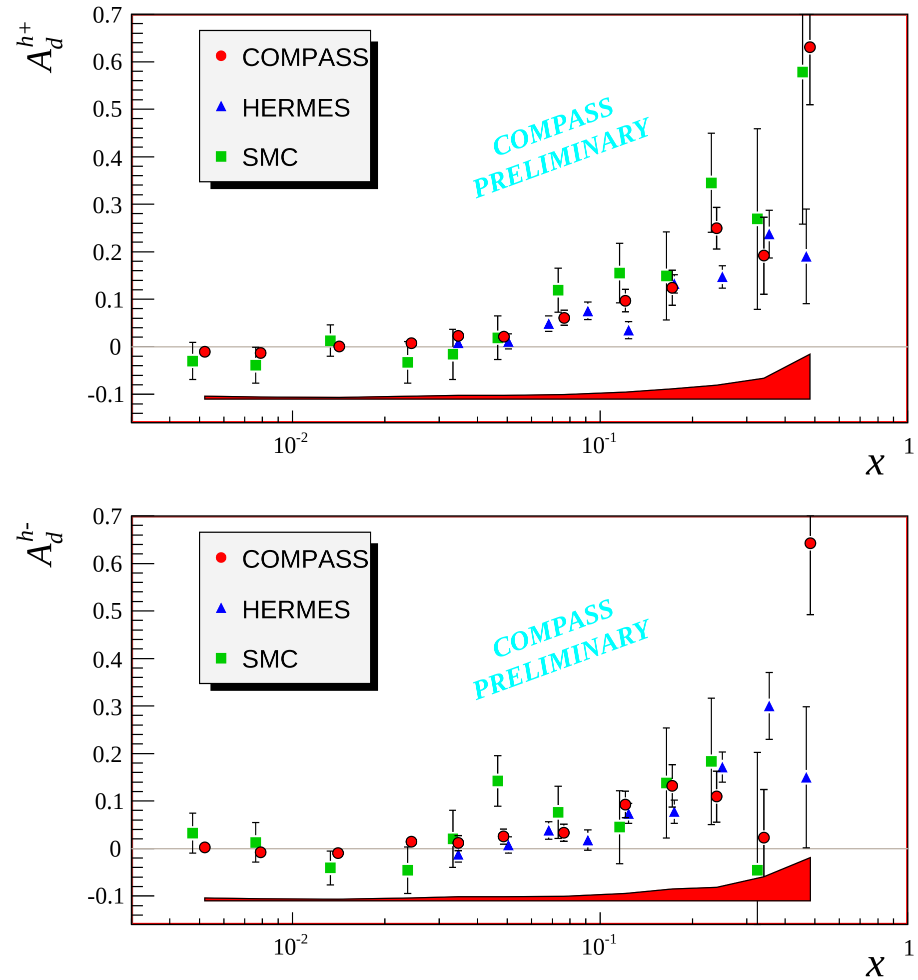
Single hadron asymmetries A^+ and A^-

- Deuteron data 2002-2004 are used
- Kinematic cuts (DIS region):

$$Q^2 > 1\,\text{GeV}^2, \qquad 0.1 < y < 0.9$$

- No hadron identification
- Current fragmentation region: $z > 0.2$
- To avoid ambiguity between secondary μ and the scattered μ, and suppress contribution from diffractive events:

$$z < 0.85$$



- Final statistics:

$$N^+ = 30{\cdot}10^6, \quad N^- = 25{\cdot}10^6, \quad cor(N^+, N^-) \approx 20\%$$

Difference asymmetry approach

- A^{+} and A^{-} asymmetries are used to obtain A^{+-}

$$A^{+-} = \frac{1}{1-r}(A^{+} - rA^{-})\,, \quad \text{with} \quad r = \frac{\sigma^{h-}_{\uparrow\downarrow} + \sigma^{h-}_{\uparrow\uparrow}}{\sigma^{h+}_{\uparrow\downarrow} + \sigma^{h+}_{\uparrow\uparrow}} = \frac{\sigma^{h-}}{\sigma^{h+}}$$

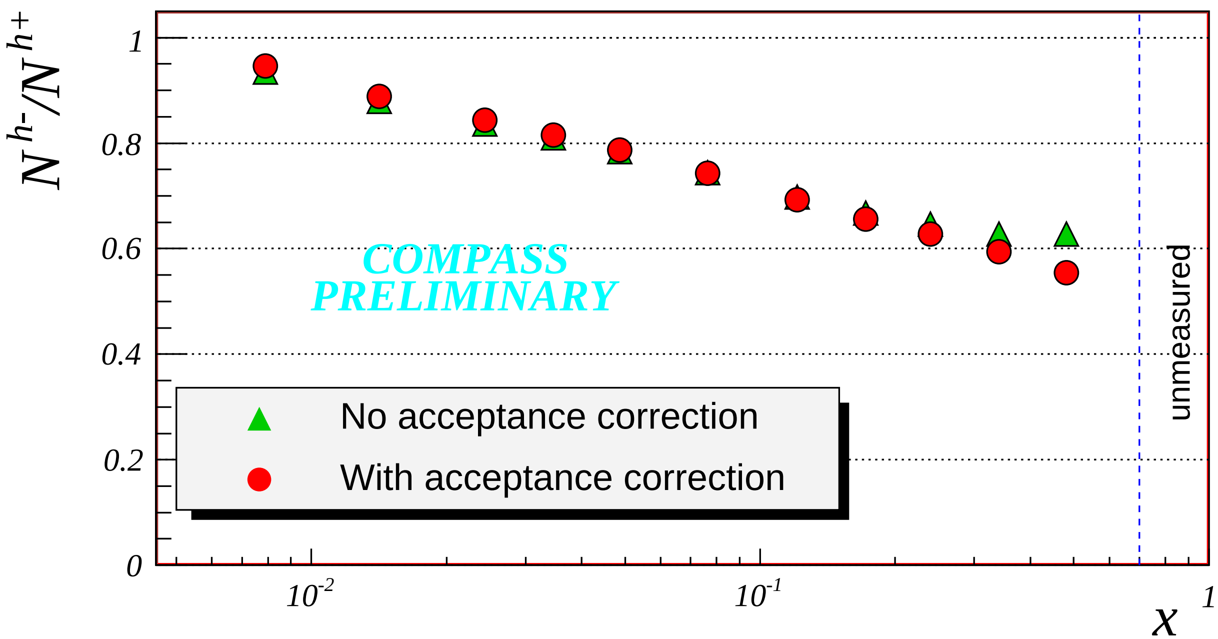
- In principle, r can be measured in unpolarized experiment. In practice, it is obtained from the ratio N^{-}/N^{+} corrected by the ratio of acceptances:

$$r = \frac{\sigma^{h-}}{\sigma^{h+}} = \frac{N^{-}/a^{-}}{N^{+}/a^{+}}\,.$$

- The error is inversely proportional to $(N^{+} - N^{-})$. Thus no precision at small x where $N^{+} \approx N^{-}$. The x-interval: $0.006 < x < 0.7$.

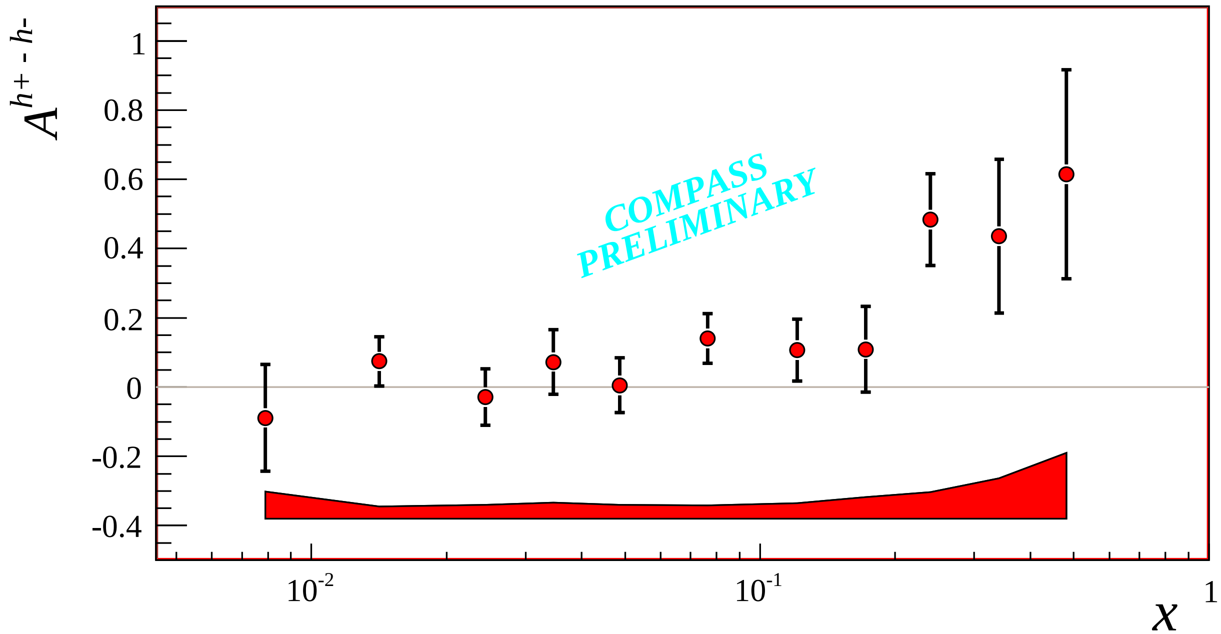
$$(\delta A^{+-})^2 \sim \frac{N^{+} + N^{-}}{(N^{+} - N^{-})^2}$$

The ratio of cross sections



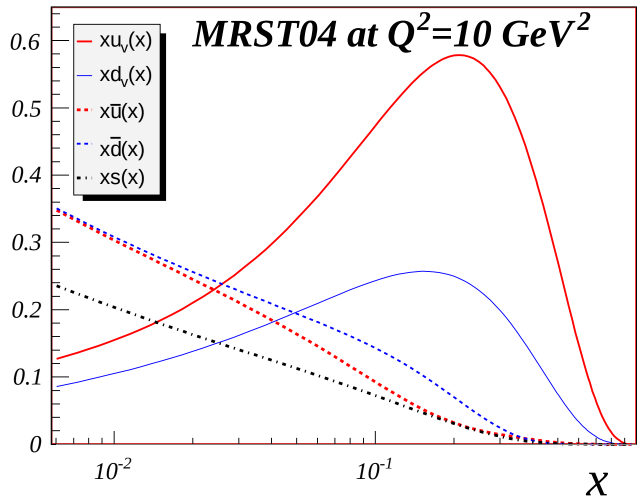
- For the acceptance ratio the full chain of MC simulation (spectrometer + the same cuts as for data) with default LEPTO settings was done
- The effect at high x due to the the solenoid acceptance (weaker effect with the new COMPASS solenoid)

Difference asymmetry



- Dominant contributions to the systematic error:
  - ◇ Contributions from beam polarization P_b, target polarization P_t, dilution factor f, depolarization factor D give in total $0.08 \cdot A$
  - ◇ Upper limit for the false asymmetry: $< 0.5 \cdot \delta A(stat)$

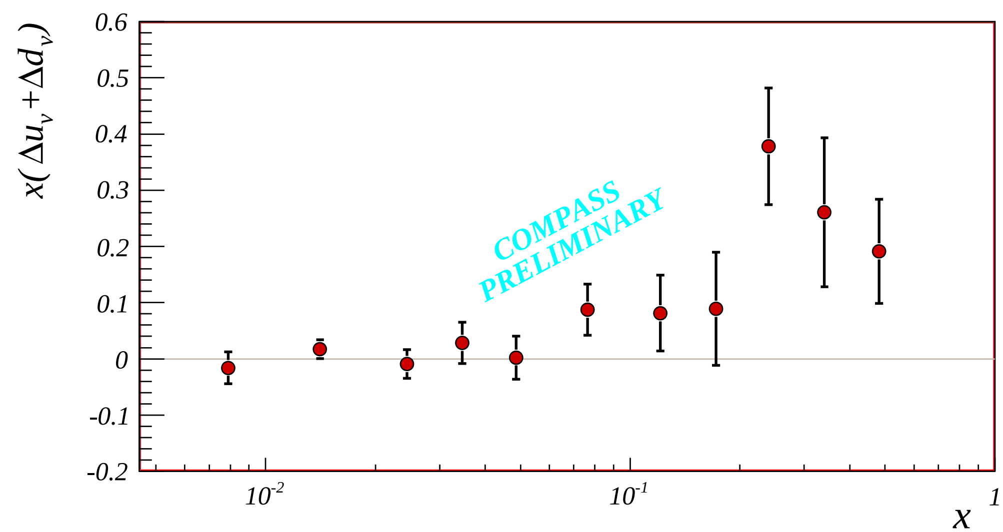
Valence quark distribution (LO)



- For unpolarized PDF LO MRST04 was chosen (=MRST02)
- $Q^2 = 10\,\mathrm{GeV}^2$

$$\Delta u_v(x) + \Delta d_v(x) = A^{+-}(x) \cdot \left[u_v(x) + d_v(x)\right]$$

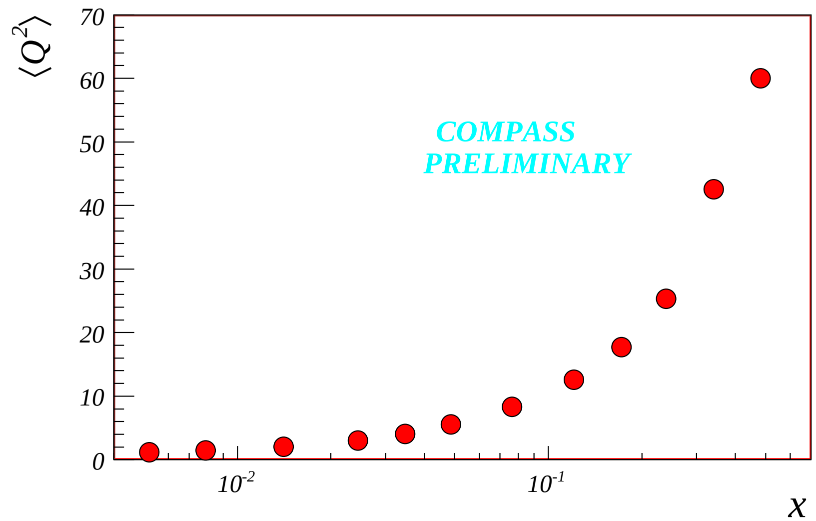
Problem: all points have different Q^2

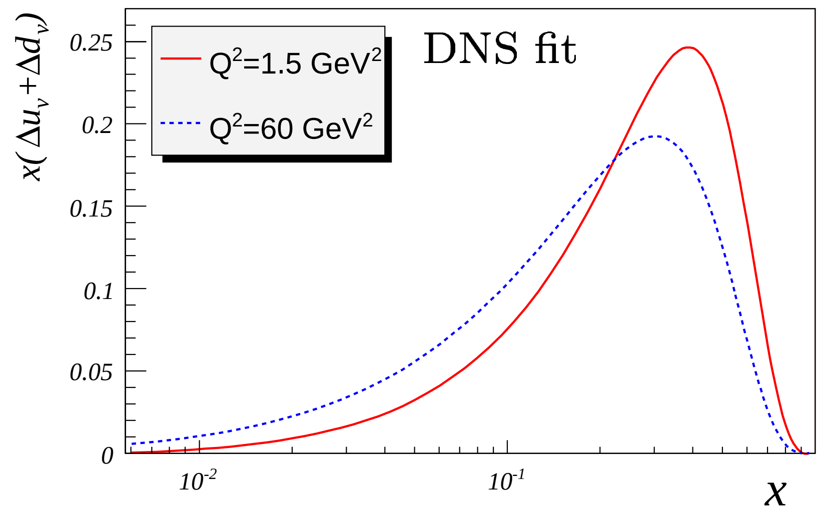


Extrapolation to $Q^2 = 10\,\text{GeV}^2$

- Values of COMPASS Q^2 vary in the range $1 - 70$ GeV^2
- Analogously to g_1^d analysis:

$$\Delta q(x, Q_0^2) \;=\; \Delta q(x, Q^2) + \left[\Delta q^{par}(x, Q_0^2) - \Delta q^{par}(x, Q^2)\right]$$





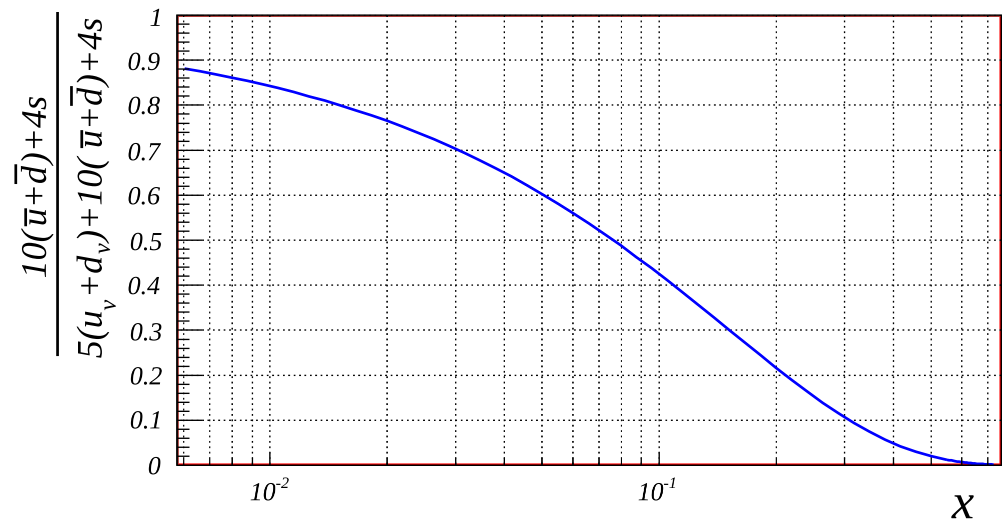
- The used parametrization: **(DNS)** D. de Florian, G.A.Navarro and R.Sassot, Phys. Rev. D **71** (2005) 094018. (based on KKP param. of FF)

Constraint on $\Delta\bar{q}$ at high x region

- Unpolarized sea contribution to F_2 at high x vanishes
- Positivity conditions:

$$|\Delta q| < q, \qquad |\Delta\bar{q}| < \bar{q}$$

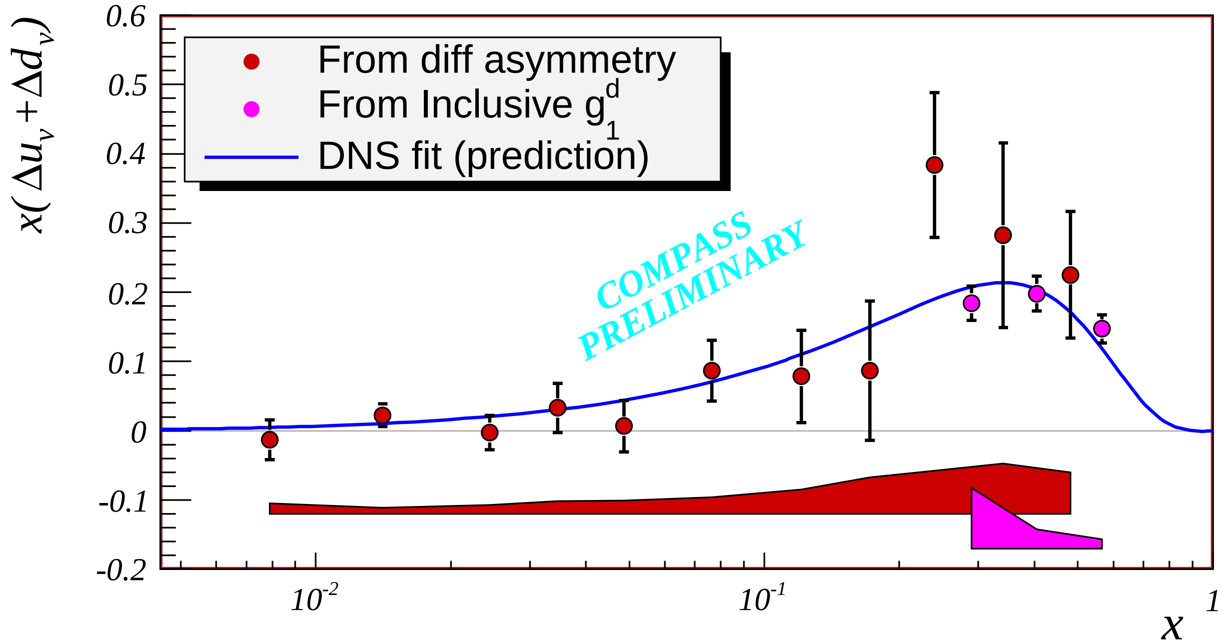
- Constrain in SMC & HERMES analyses: $\Delta\bar{u} = \Delta\bar{d} = \Delta s = 0$ at $x > 0.3$



- Statistical error δA_1 is factor ~6 smaller as compared to $\delta A^{h^+-h^-}$ $\Rightarrow$ constraint $\Delta\bar{q} = 0$ is equivalent to usage of g_1^d results:

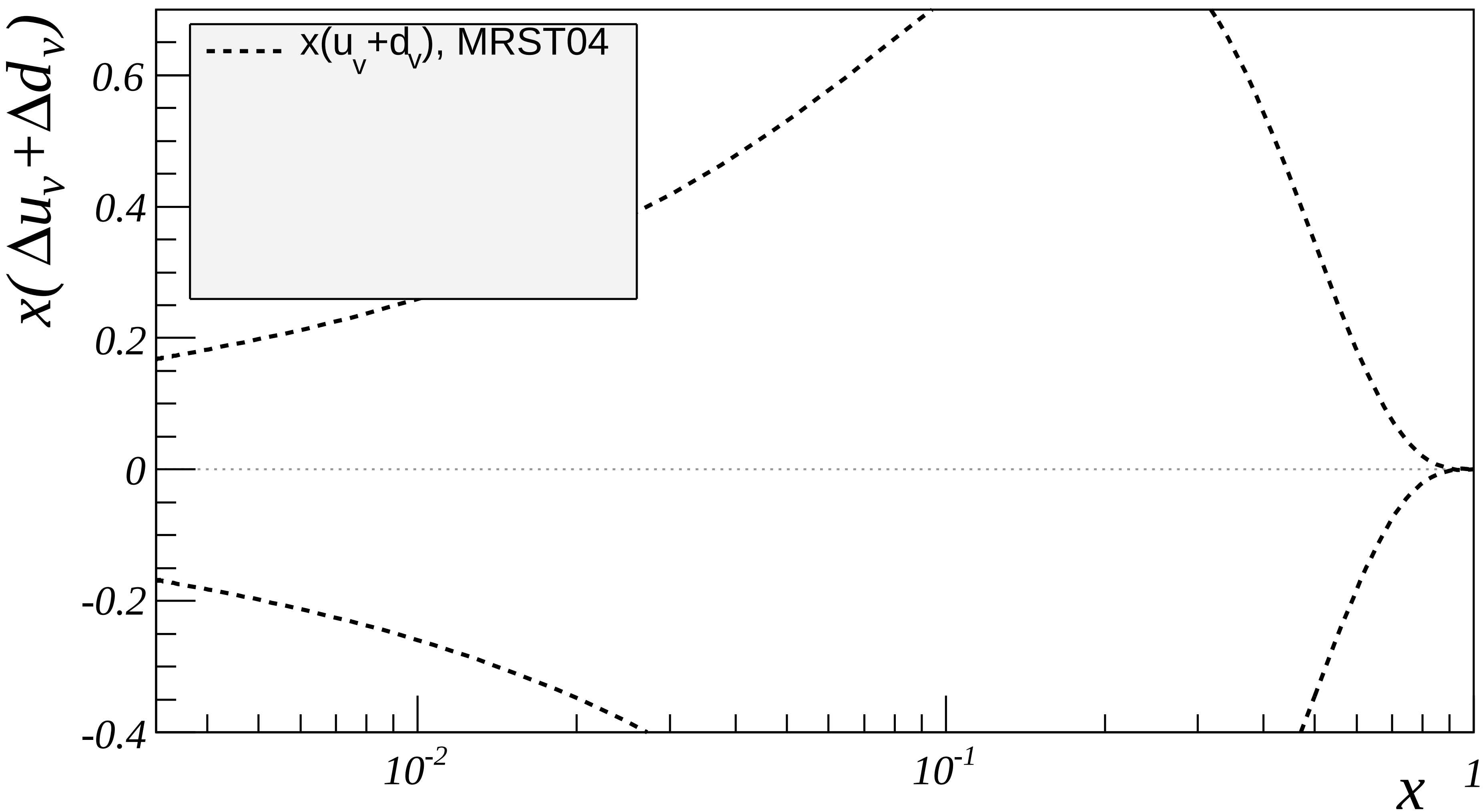
$$\Delta u_v + \Delta d_v \;=\; \frac{36}{5}\frac{g_1^d(x,Q^2)}{(1-1.5\omega_D)} - \left[2(\Delta\bar{u}+\Delta\bar{d}) + \frac{2}{5}(\Delta\bar{s}+\Delta\bar{s})\right]$$

Valence quark distribution at Q^2=10 GeV^2 (LO)



- Dominant contributions to the systematic error:
  - ◇ Error due to diluting factors $(P_b P_t f D)$ is in total 8%
  - ◇ Upper limit for the false asymmetry: $< 0.5 \cdot \sigma^{stat}$
  - ◇ Error due to inclusive data: MRST is used for the upper limit on $2(\Delta\bar{u} + \Delta\bar{d}) + \frac{2}{5}(\Delta s + \Delta\bar{s})$

Comparison with other experiments



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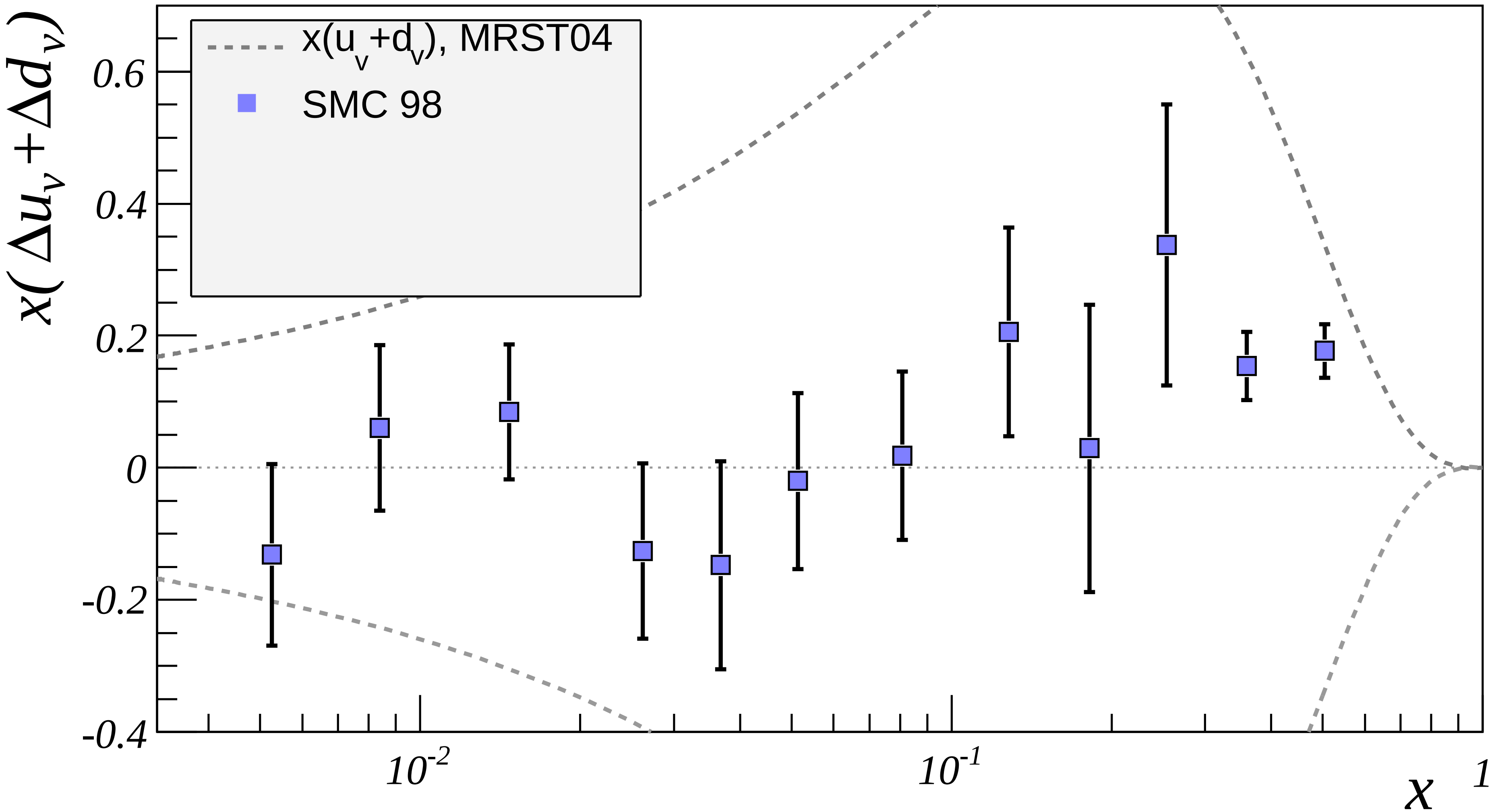

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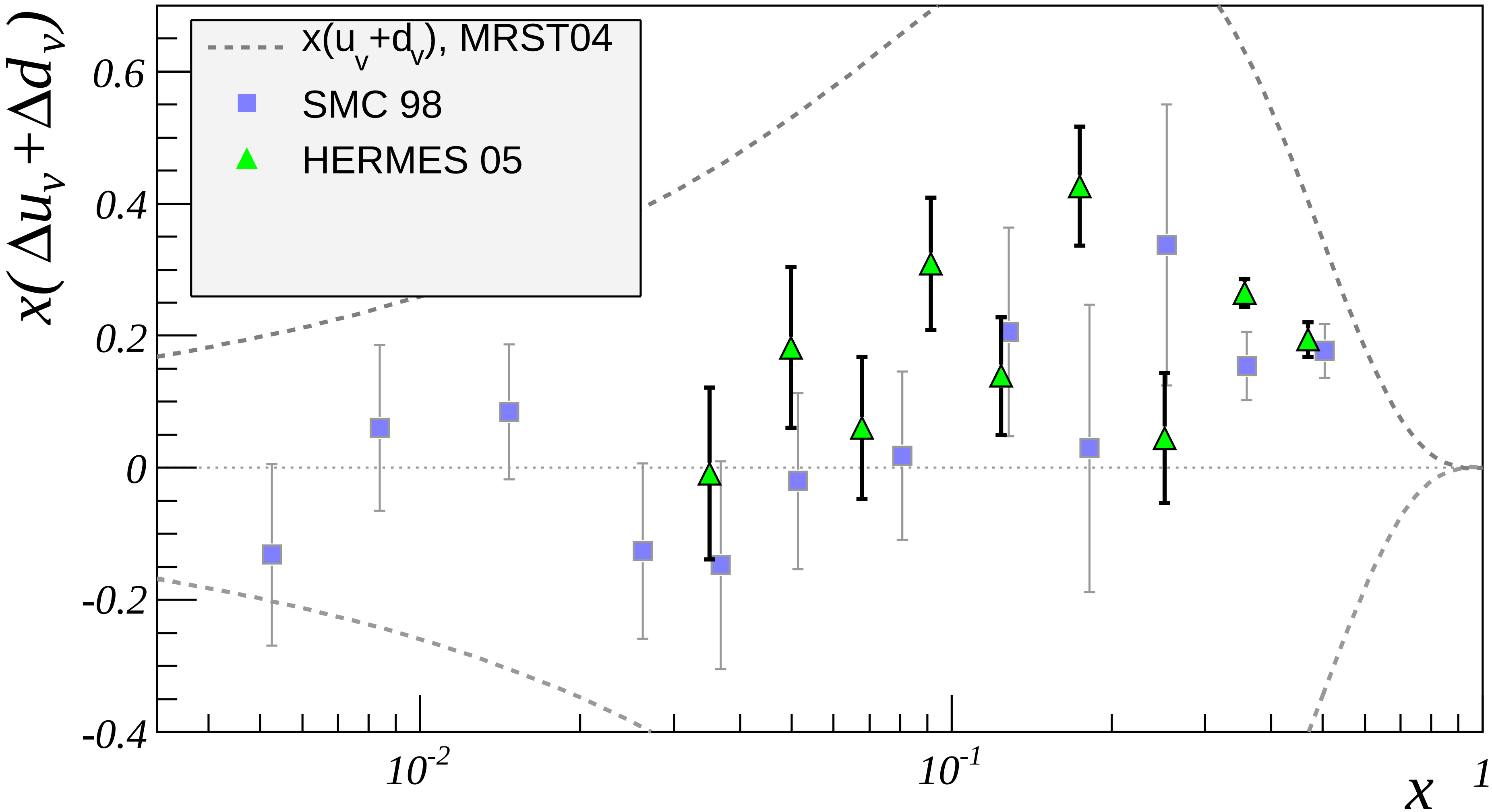

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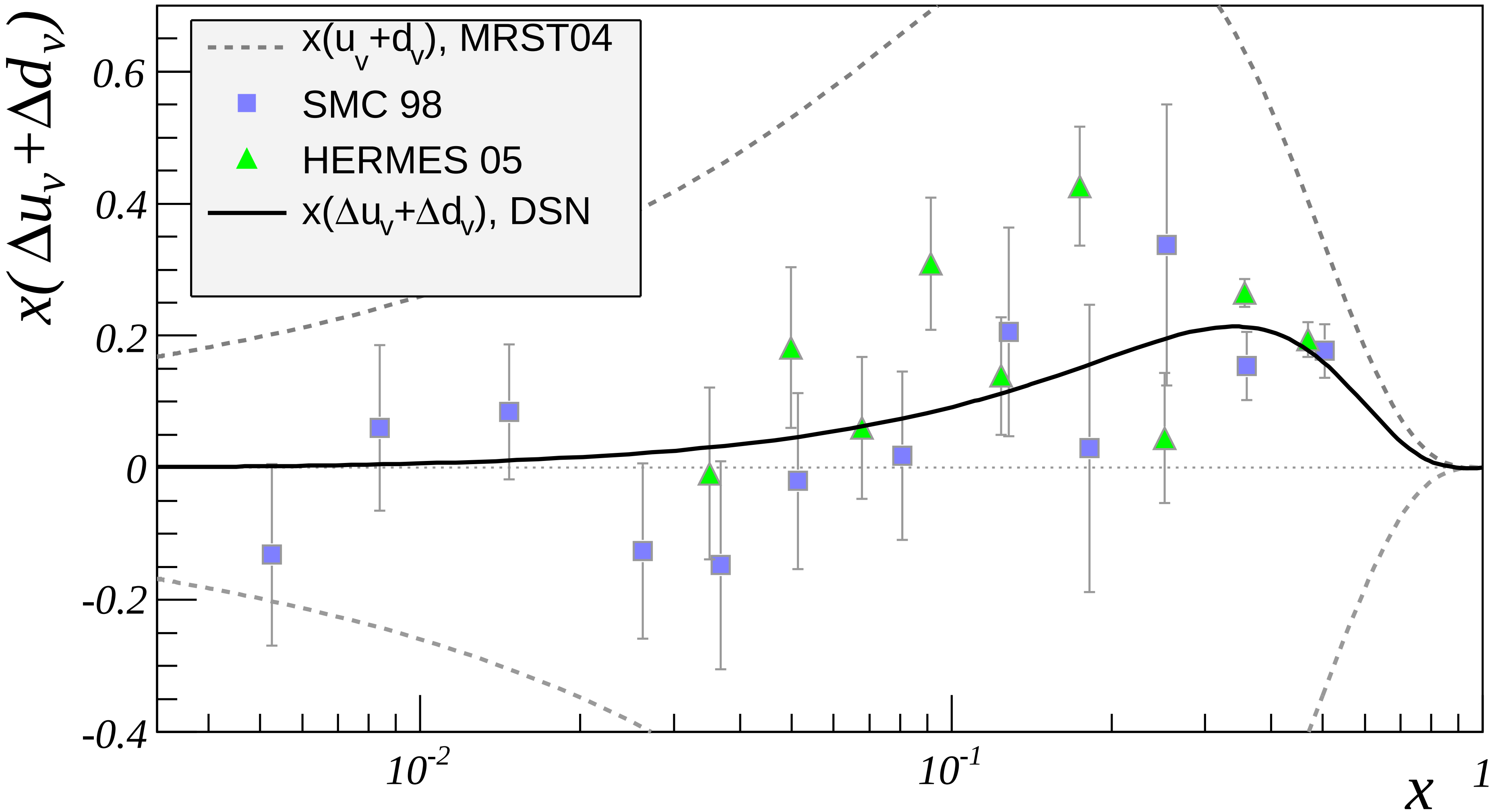

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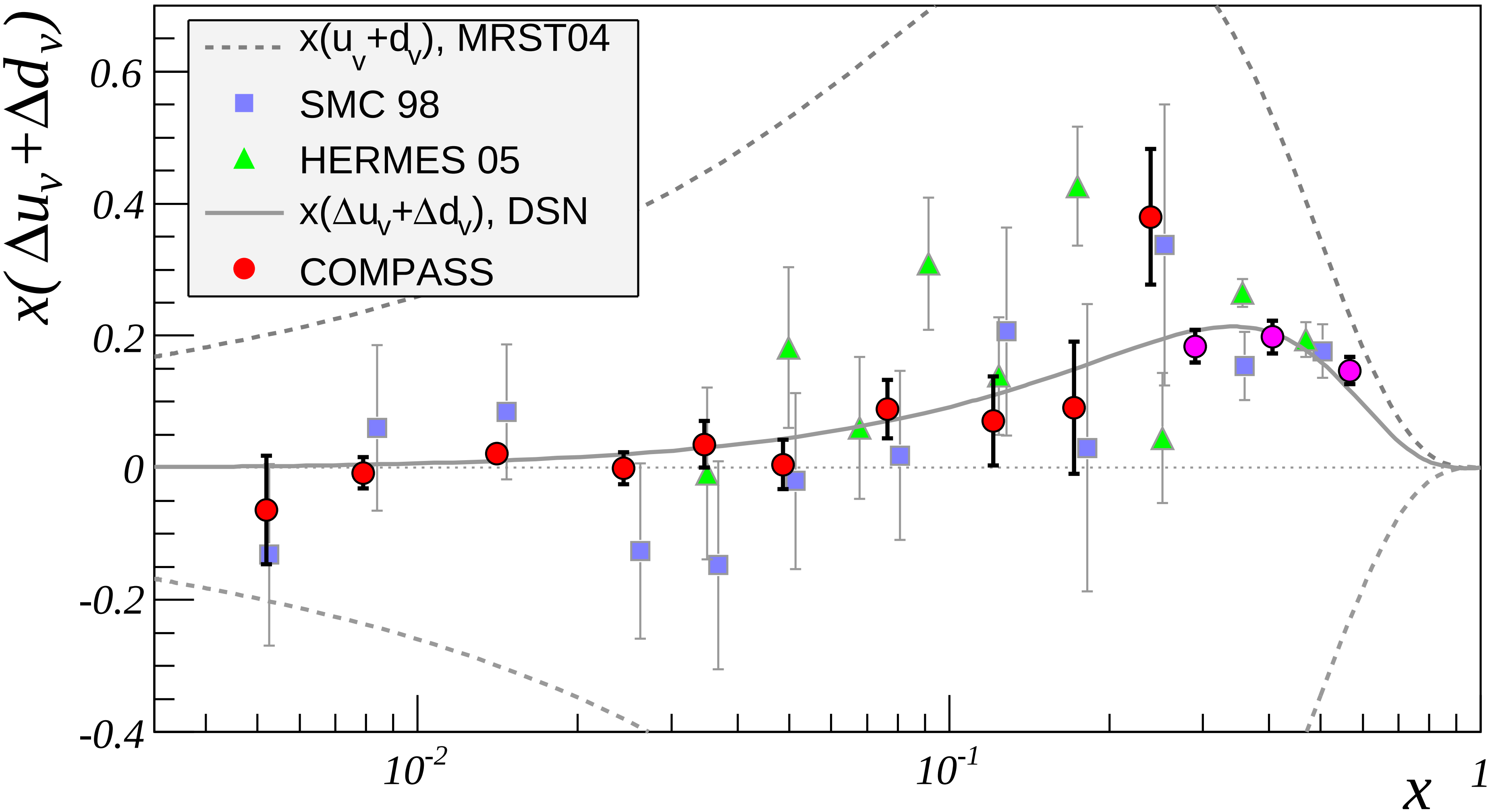
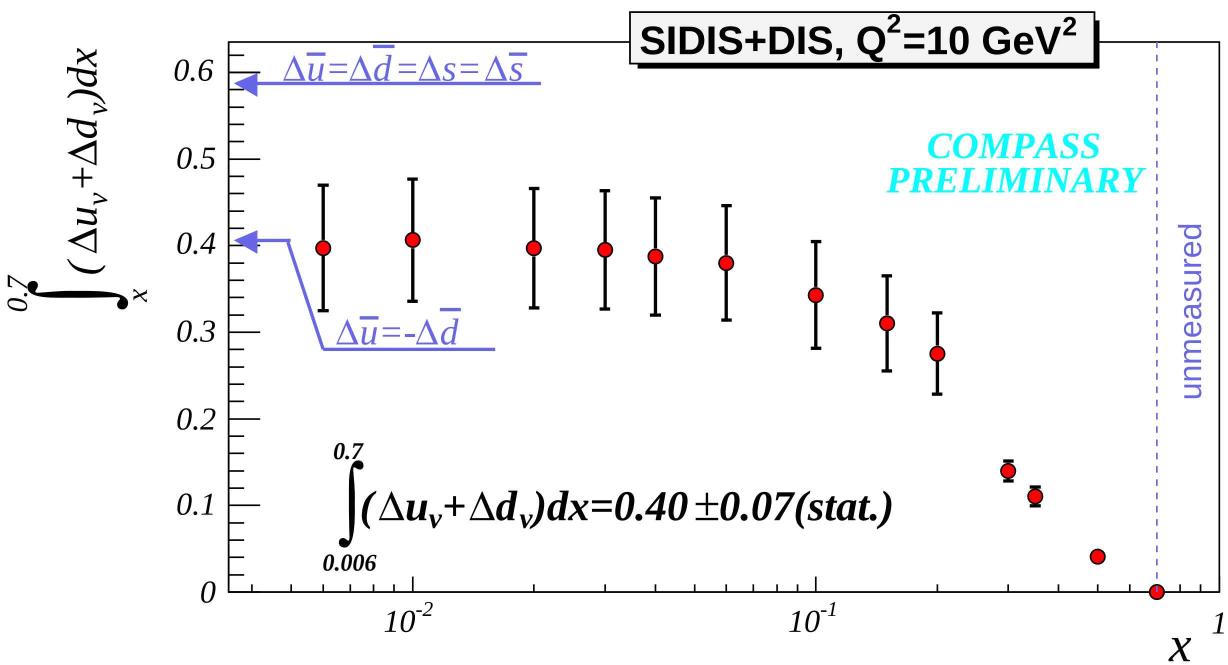
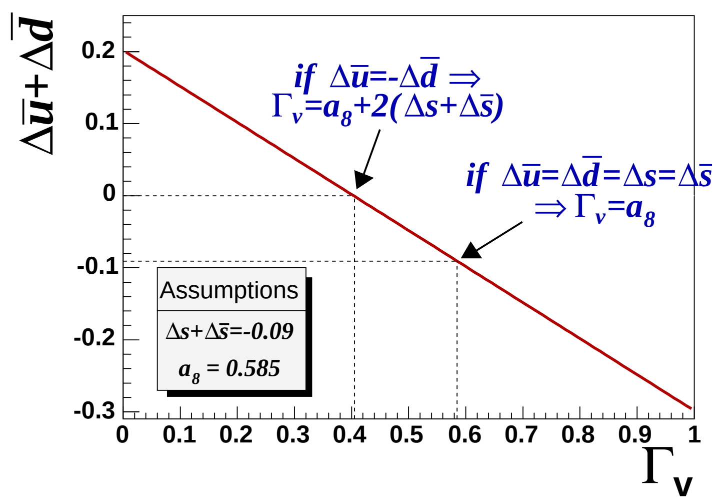


Estimate for the first moments (LO)





- Contribution from unmeasured high x region (DNS fit):

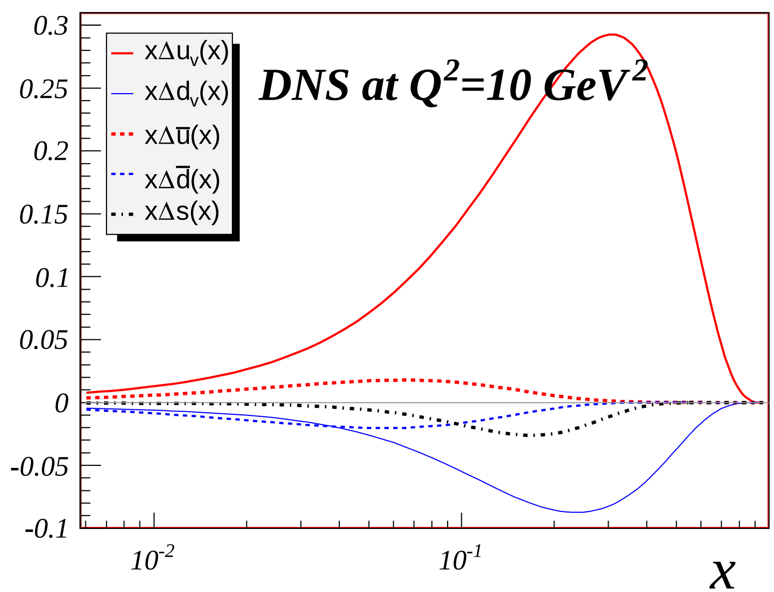
$$\int_{0.7}^{1}(\Delta u_v + \Delta d_v)dx = 0.004$$

- The estimate of Γ_v (SIDIS+DIS) is $2.5\sigma_{stat}$ away from the flavor symmetric sea scenario

Estimates for the first moments (LO)

	x-range	Q^2 GeV^2	$\Delta u_v + \Delta d_v$ measurem.	$\Delta u_v + \Delta d_v$ DNS	$\Delta\bar{u} + \Delta\bar{d}$ measurem.	$\Delta\bar{u} + \Delta\bar{d}$ DNS
SMC 98	0.003–0.7	10	$0.26 \pm 0.21 \pm 0.11$	0.386	$0.02 \pm 0.08 \pm 0.06$	-0.009
HERMES 05	0.023–0.6	2.5	$0.43 \pm 0.07 \pm 0.06$	0.363	$-0.06 \pm 0.04 \pm 0.03$	-0.005
COMPASS	0.006–0.7	10	$0.40 \pm 0.07 \pm 0.05$	0.385	$0.0 \pm 0.04 \pm 0.03$	-0.007

- The SMC results were obtained with the assumption of $SU(3)_f$ symmetric sea: $\Delta\bar{u} = \Delta\bar{d} = \Delta s = \Delta\bar{s}$
- The COMPASS data (inclusive or semi-inclusive) were not used in the DNS fit.
- For the COMPASS value of $\Delta\bar{u}+\Delta\bar{d}$ g_1^d data were used + 10% error on a_8



Summary

- A first evaluation of the polarized valence quark distribution $\Delta u_v + \Delta d_v$ from COMPASS was presented
- The deuteron data 2002-2004 were used. The analysis of 2006 data is in progress
- The difference asymmetry approach for unidentified hadrons of opposite changes was used to extract $\Delta u_v + \Delta d_v$
- Strong increase in the precision at small values x as compared to SMC results (by factor $\sim$6)
- DNS parametrization gives successful prediction for our data. $SU(3)_f$ symmetric sea scenario is disfavored