The polarized Valence Quark Distribution from COMPASS

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SPIN-Praha-2007

Outline

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- Cuts and statistics
- Asymmetries
- $\Delta u_v + \Delta d_v$ results
- Estimation for the first moment (LO)
- Summary

Introduction

Static SU(6) quark model:

$\Delta\Sigma = \Delta u + \Delta d + \Delta s = 1$

EMC (1988):

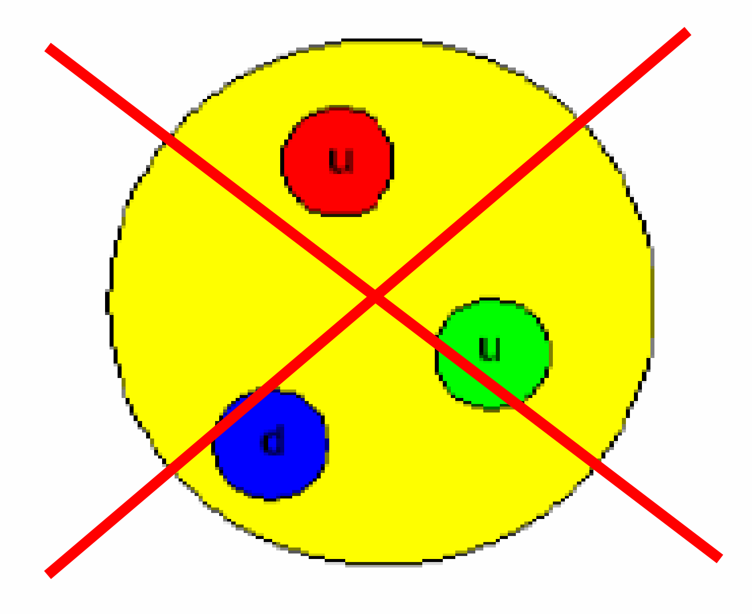
$\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14$

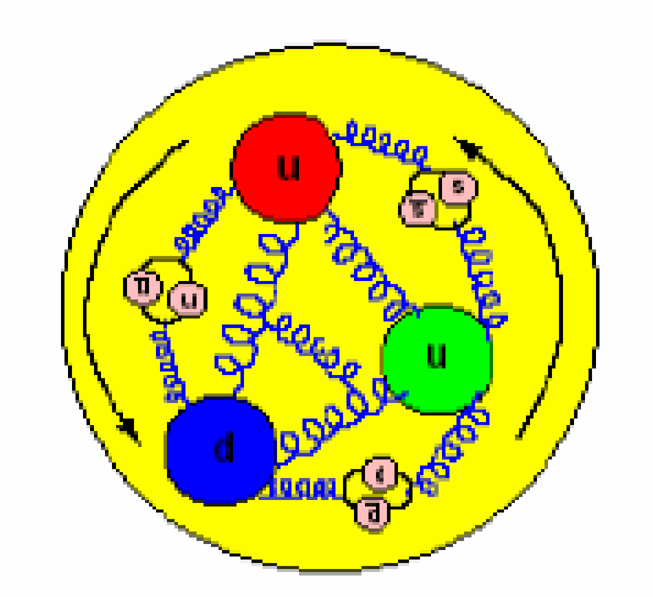
($\pm$stat $\pm$syst)

$\Delta s + \Delta\bar{s} = -0.14 \pm 0.03$

COMPASS:

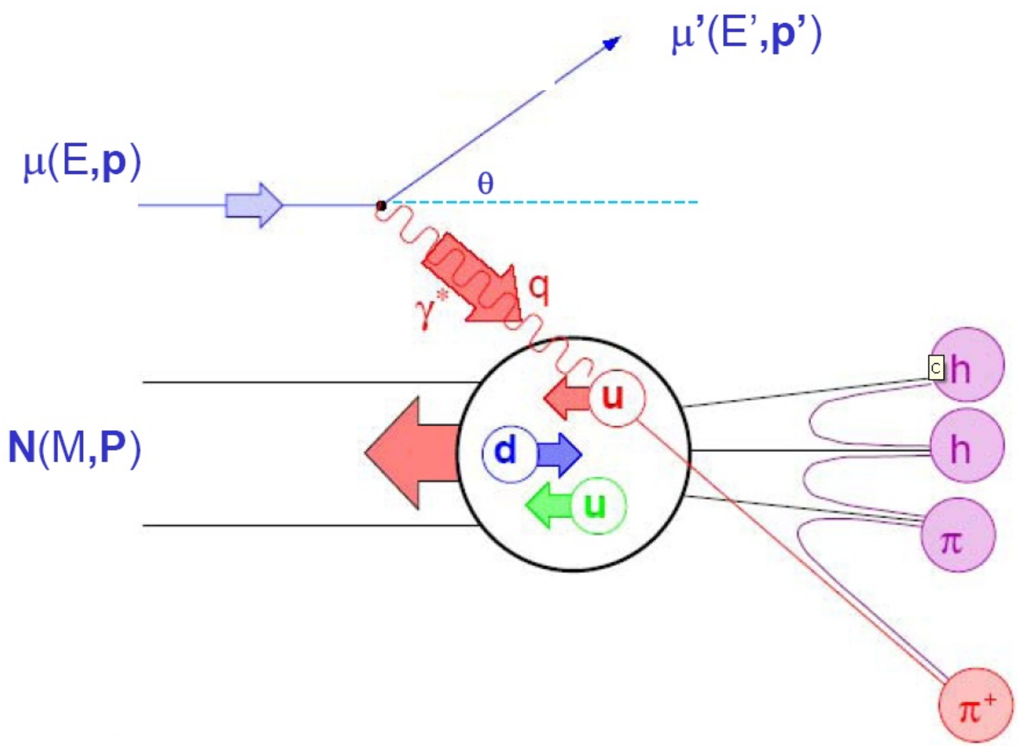
$\Delta\Sigma = 0.35 \pm 0.03 \pm 0.05$





$$\boxed{S_N = \tfrac{1}{2} = \tfrac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g \quad (\hbar = 1)}$$

Introduction

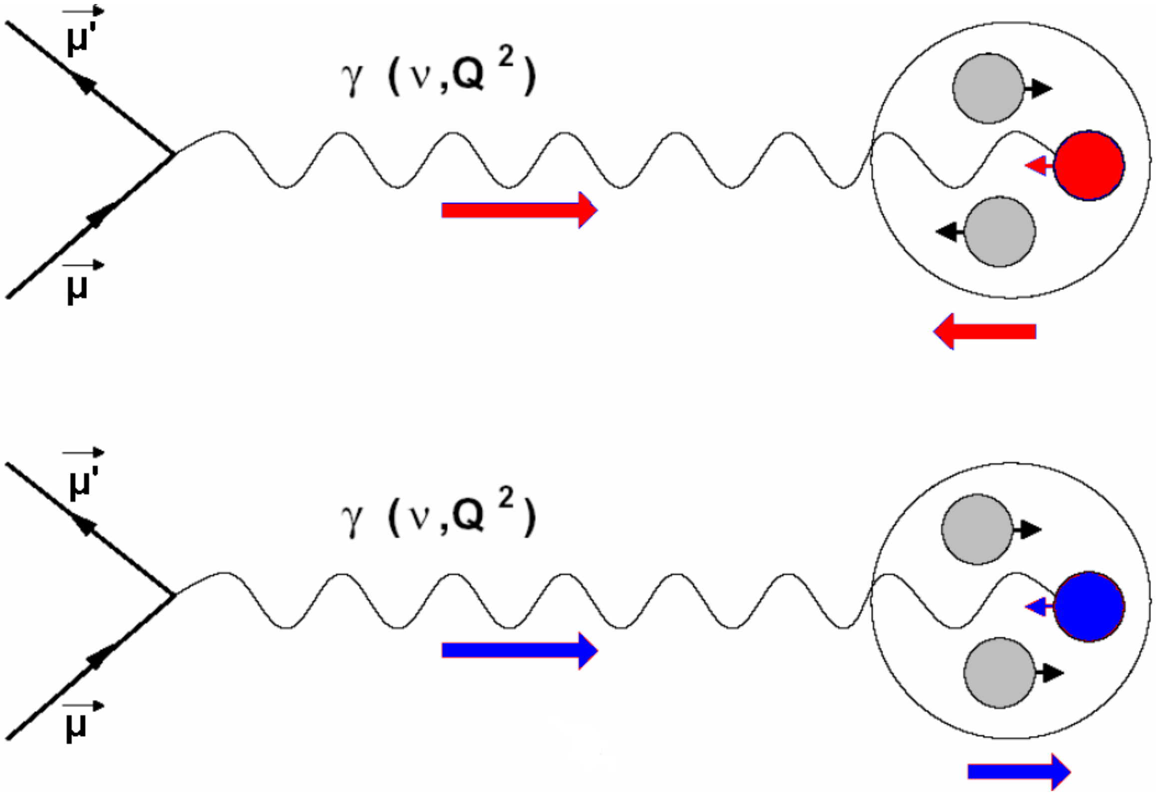


Main kinematical variables

- $Q^2 = -q^2 = (p-p')^2$
- $\nu = E - E'$
- $x = Q^2/2M\nu$
- $y = \nu/E$
- $z = E_h/\nu$

$$\frac{d^2\sigma}{d\Omega dE'} \approx \underbrace{c_1F_1\left(x,Q^2\right)+c_2F_2\left(x,Q^2\right)}_{\text{spin independent}}+\underbrace{c_3g_1\left(x,Q^2\right)+c_4g_2\left(x,Q^2\right)}_{\text{spin dependent}}$$

Introduction



QPM

+: quark ↑↑ nucleon

$\sigma_{\frac{1}{2}} \sim q^{+}$

–: quark ↑↓ nucleon

$\sigma_{\frac{3}{2}} \sim q^{-}$

$q^{+}(x)$ and $q^{-}(x)$ - the probability density function of finding a quark with a spin ↑↑ or ↑↓ to the nucleon spin.

$q(x) = q^{+}(x) + q^{-}(x)$
$\Delta q(x) = q^{+}(x) - q^{-}(x)$

$q_v(x) = q(x) - \bar{q}(x)$
$\Delta q_v(x) = \Delta q(x) - \Delta\bar{q}(x)$

Introduction

From experiments it is known, unpolarized sea is not symmetric:

$$\int_0^1 dx[\bar{d}(x) - \bar{u}(x)] \begin{array}{l} = 0.148 \pm 0.039 \ (NMC) \\ = 0.118 \pm 0.012 \ (E866) \\ = 0.16 \pm 0.03 \ (HERMES) \end{array} \neq 0$$

What we can say about polarized sea ?

Introduction

$$SU_f(3) \qquad m_u \simeq m_d \simeq m_s \simeq 0$$

$$\begin{aligned}
a_0 &= \Delta u + \Delta\bar{u} + \Delta d + \Delta d + \Delta s + \Delta\bar{s} \\
a_3 &= \Delta u + \Delta\bar{u} - (\Delta d + \Delta\bar{d}) \\
a_8 &= \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} - 2(\Delta s + \Delta\bar{s})
\end{aligned}
\qquad \Delta q = \int_0^1 \Delta q(x)dx$$

$$\boxed{\Delta\bar{u} + \Delta\bar{d} = (\Delta s + \Delta\bar{s}) + \frac{1}{2}(a_8 - (\Delta u_v + \Delta d_v))}$$

Since: $a_0 = 0.35 \pm 0.03 \pm 0.05$ (from COMPASS DIS data)

$a_8 = 0.59 \pm 0.03$ (from weak decay Hyperons)

Then: $\Delta s + \Delta\bar{s} = \frac{1}{3}(a_0 - a_8) = -0.09 \pm 0.01 \pm 0.02$

It is possible to find $\Delta\bar{u} + \Delta\bar{d}$ from valence quark distribution

Introduction

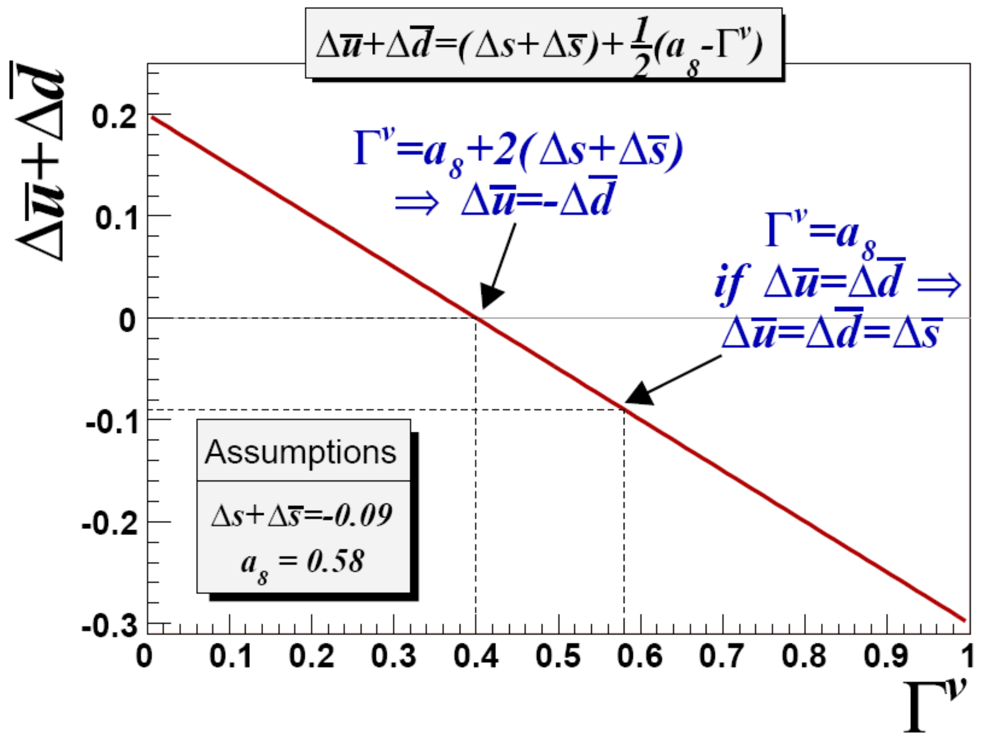
Two scenarios:

1. Flavor symmetric:

$$(\Delta\bar{u}=\Delta\bar{d}=\Delta\bar{s})$$

2. Flavor asymmetric:

$$(\Delta\bar{u}=-\Delta\bar{d})$$



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

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

The goal of the measurement is: Γ_v

With the precision: $\delta\Gamma_v < |\Delta s+\Delta\bar{s}|$

Introduction

The hadrons asymmetry contains the fragmentation functions

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

The fragmentation functions $D_q^h = \int D_q^h(z)dz$ aren't well know

Using *SU$_f$(2)* and *charge conjugation* symmetries →
3 functions of fragmentation of pion:

$$D_1 = D_u^{\pi^+} \stackrel{SU(2)}{=} D_d^{\pi^-} \stackrel{C}{=} D_{\bar{d}}^{\pi^+} \stackrel{SU(2)}{=} D_{\bar{u}}^{\pi^-}$$

$$D_2 = D_{\bar{u}}^{\pi^+} \stackrel{SU(2)}{=} D_{\bar{d}}^{\pi^-} \stackrel{C}{=} D_d^{\pi^+} \stackrel{SU(2)}{=} D_u^{\pi^-}$$

$$D_3 = D_s^{\pi^+} = D_s^{\pi^-} = D_{\bar{s}}^{\pi^+} = D_{\bar{s}}^{\pi^-}$$

Introduction

The difference asymmetry was proposed in Phys. Lett. [B230 (1989) 141]

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

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

in LO QCD for deuteron target:

No hadron identification is needed

No fragmentation functions is needed

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

Introduction

To obtain A^{+-}, A^{+} and A^{-} asymmetries are used

$$A^{+-} = \frac{1}{1-r}(A^{+} - rA^{-})$$

Where:

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

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

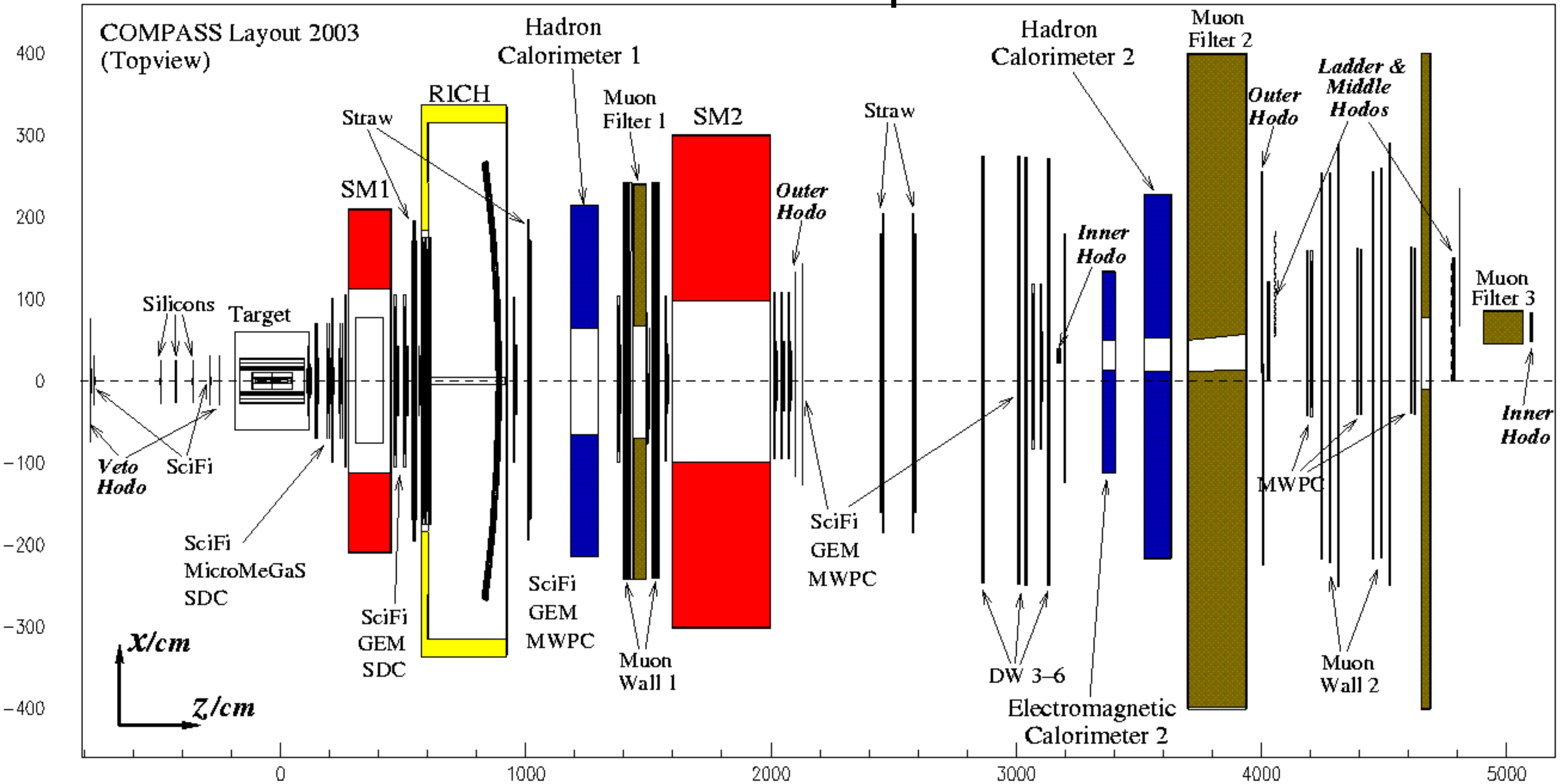
$$r = \frac{\sigma^{h-}_{\uparrow\downarrow} + \sigma^{h-}_{\uparrow\uparrow}}{\sigma^{h+}_{\uparrow\downarrow} + \sigma^{h+}_{\uparrow\uparrow}} = \frac{\sigma^{h-}}{\sigma^{h+}}$$

r can be obtained from the ratio of N^{-}/N^{+} corrected with the ratio of acceptances:

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

Introduction

COMPASS experiment



- Luminosity: **5 .10^{32} cm^{-2}s^{-1}**
- Beam intensity: **2.10^{8} μ^{+}/spill**
- Energy μ beam: **160 GeV**
- Polarised beam: **80%**
- Target material: **^{6}LiD**
- Two target cells: ↑↑, ↑↓
- Polarised target: **50%**

Cuts and statistics

Data from the years 2002 + 2003 + 2004

Kinematics cuts
$Q^2 > 1$ GeV^2
$0.1 < y < 0.9$
$0.2 < Z_h < 0.85$

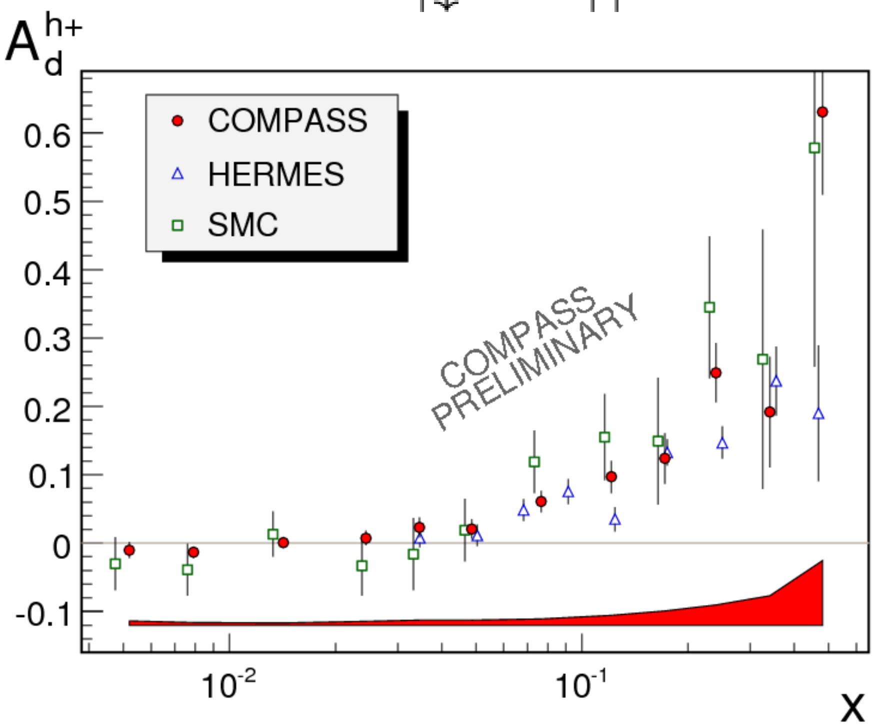
Pos. hadrons	30×10^6
Neg. hadrons	25×10^6
Cor. (N^+, N^-)	20%

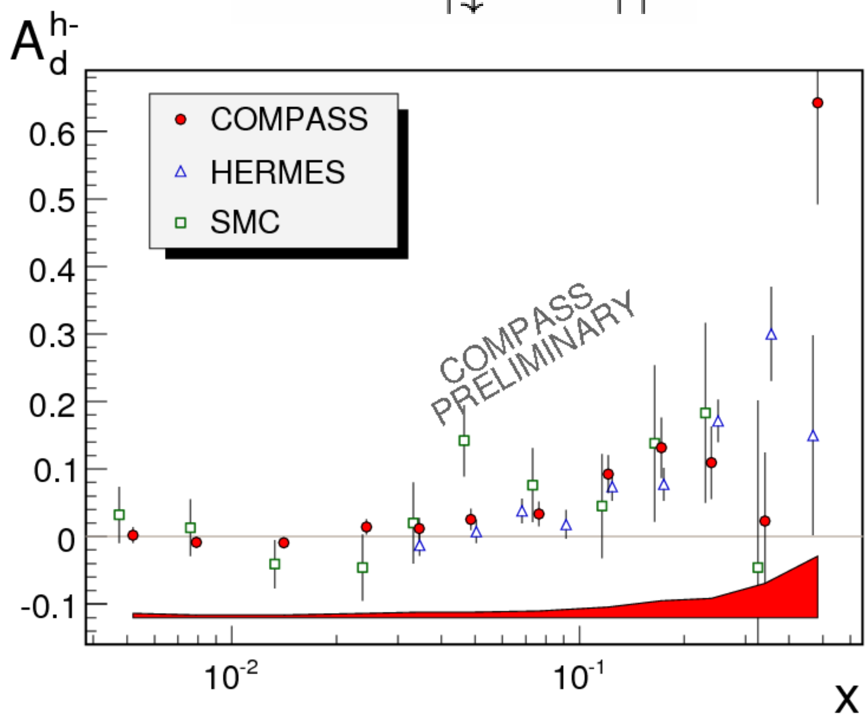
Asymmetries

Semi-Inclusive asymmetries

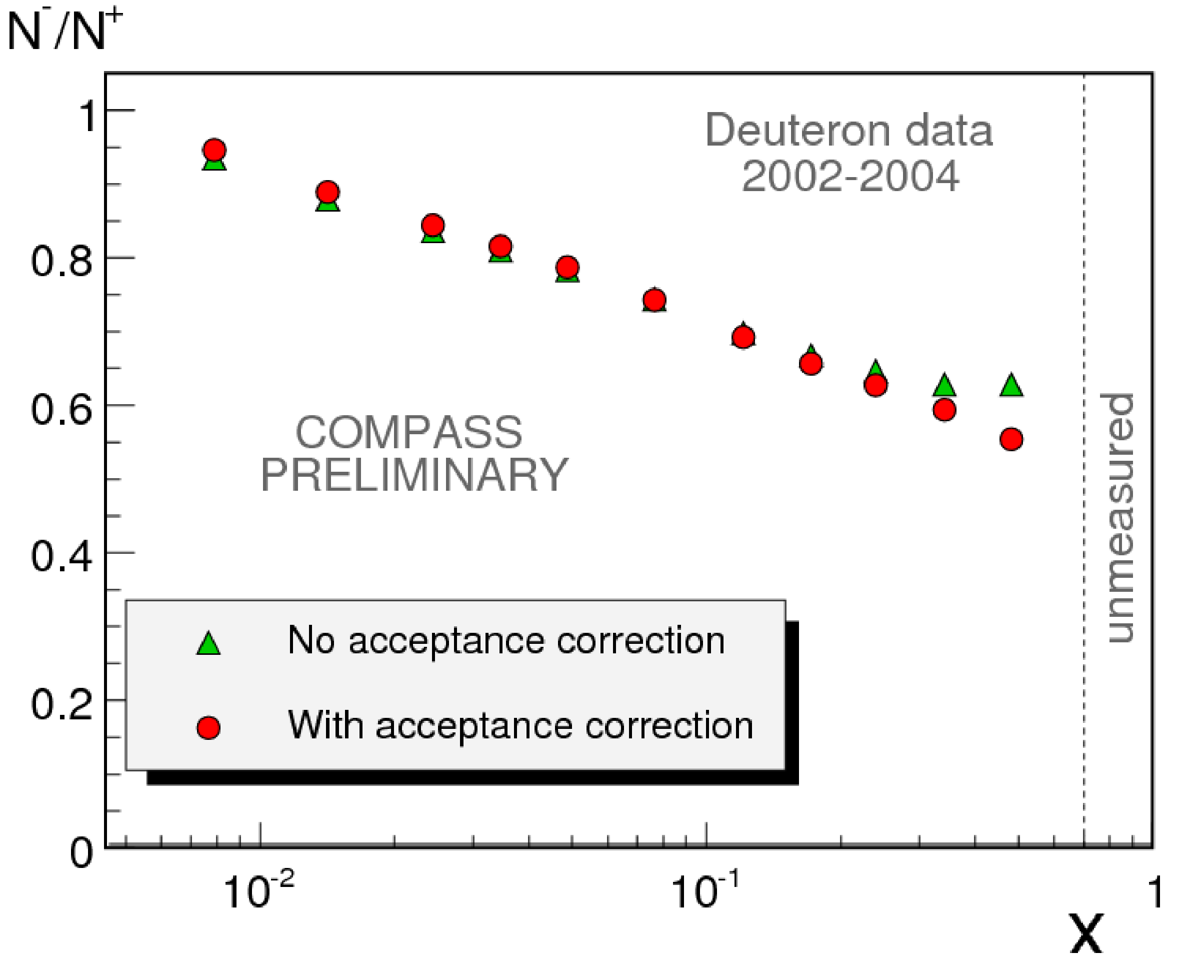
$$A^+ = \frac{\sigma^{h+}_{\uparrow\downarrow} - \sigma^{h+}_{\uparrow\uparrow}}{\sigma^{h+}_{\uparrow\downarrow} + \sigma^{h+}_{\uparrow\uparrow}}$$

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





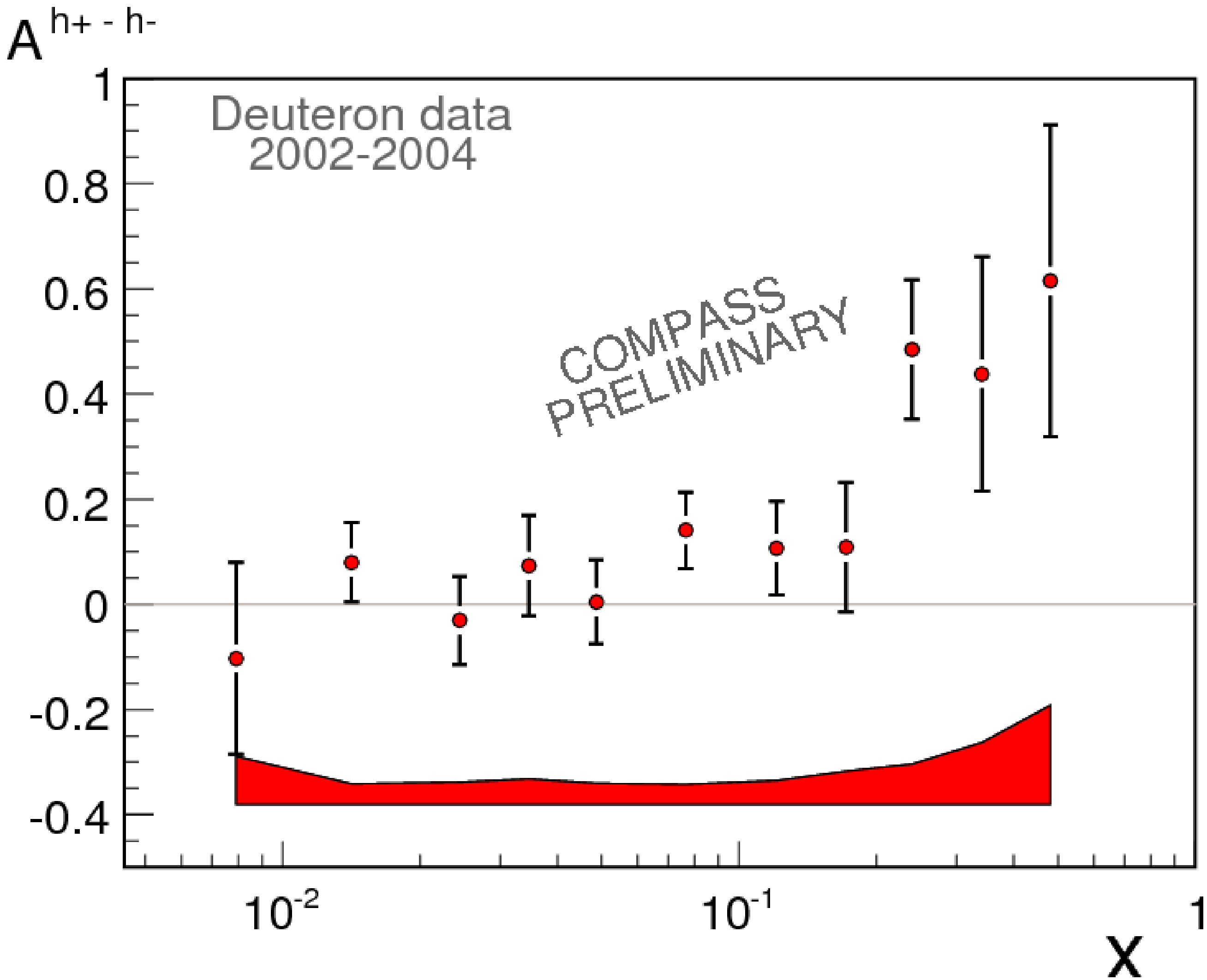
Asymmetries



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

Asymmetries

$$A^{+-} = \frac{1}{1-r}(A^{+} - rA^{-})$$

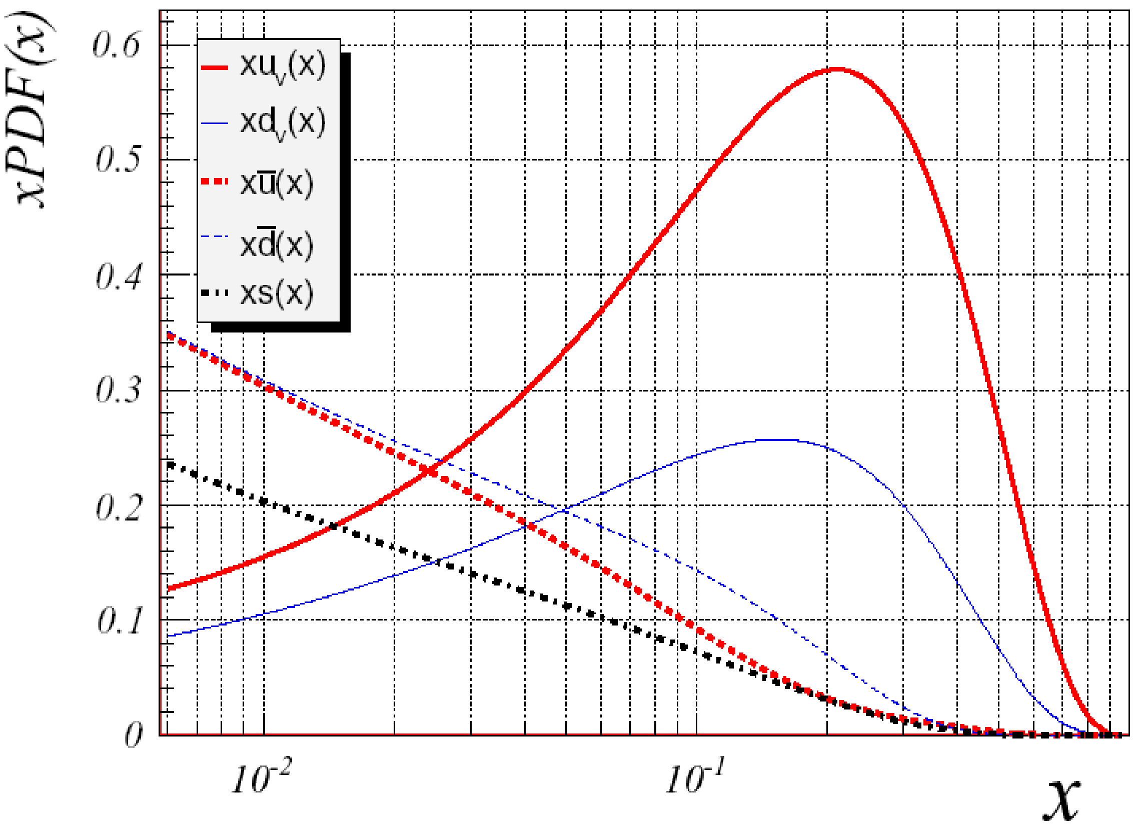


$\Delta u_v + \Delta d_v$ results

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

Unpolarized PDFs:

- LO MRST2004 was used
- with Q^2=10 GeV^2



$\Delta u_v + \Delta d_v$ results

Since all points have different Q^2 (1-70 GeV^2) an evolution to common Q^2 is needed

To evolve Δq to $Q^2 = 10$ GeV^2 :

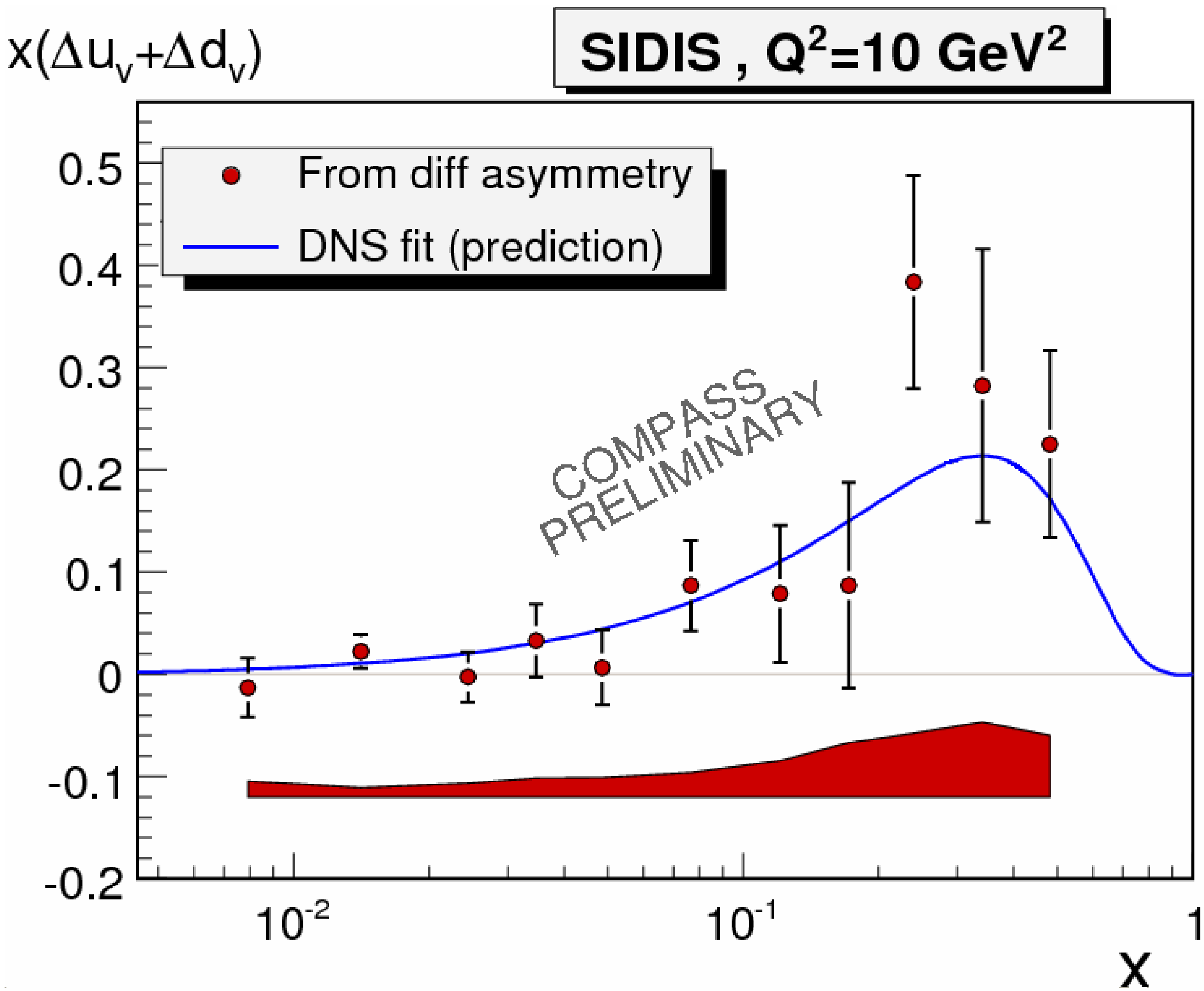
$$\Delta q(x, Q^2{=}10) \; = \; \Delta q(x, Q^2) + \left[\Delta q^{par}(x, Q^2{=}10) - \Delta q^{par}(x, Q^2)\right]$$

The following parameterization was used:

- LO DNS – D. de Florian, G.A. Navarro, R. Sassot, Phys. Rev. D 71 (2005) 094018 (based on KPP parameterization of FF)

$\Delta u_v + \Delta d_v$ results

Valence quark distribution (LO):



$\Delta u_v + \Delta d_v$ results

For large *x* the unpolarized sea contribution << unpolarized valence contribution. Due to positivity conditions |Δq|<q the polarized sea contribution to the spin the nucleon can be neglected.

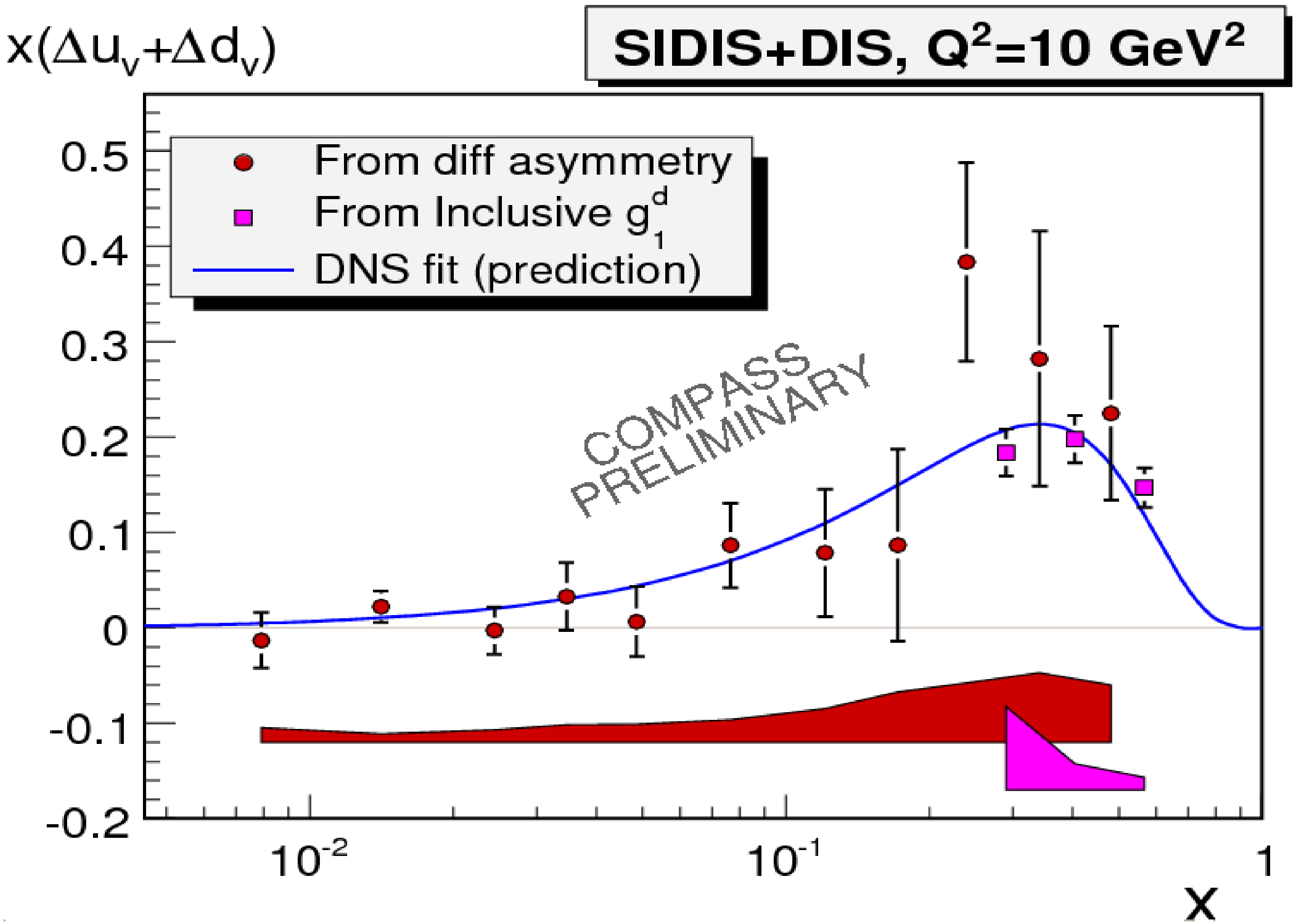
$$\Delta u_v + \Delta d_v = \frac{36}{5}\frac{g_1^d(x,Q^2)}{(1-1.5\omega_D)} - \cancel{\left[2(\Delta\bar{u}+\Delta\bar{d})+\frac{2}{5}(\Delta\bar{s}+\Delta\bar{s})\right]}$$

- Constraint in SMC & HERMES analyses at $x>0.3$

$$\Delta\bar{u} = \Delta\bar{d} = \Delta s = 0$$

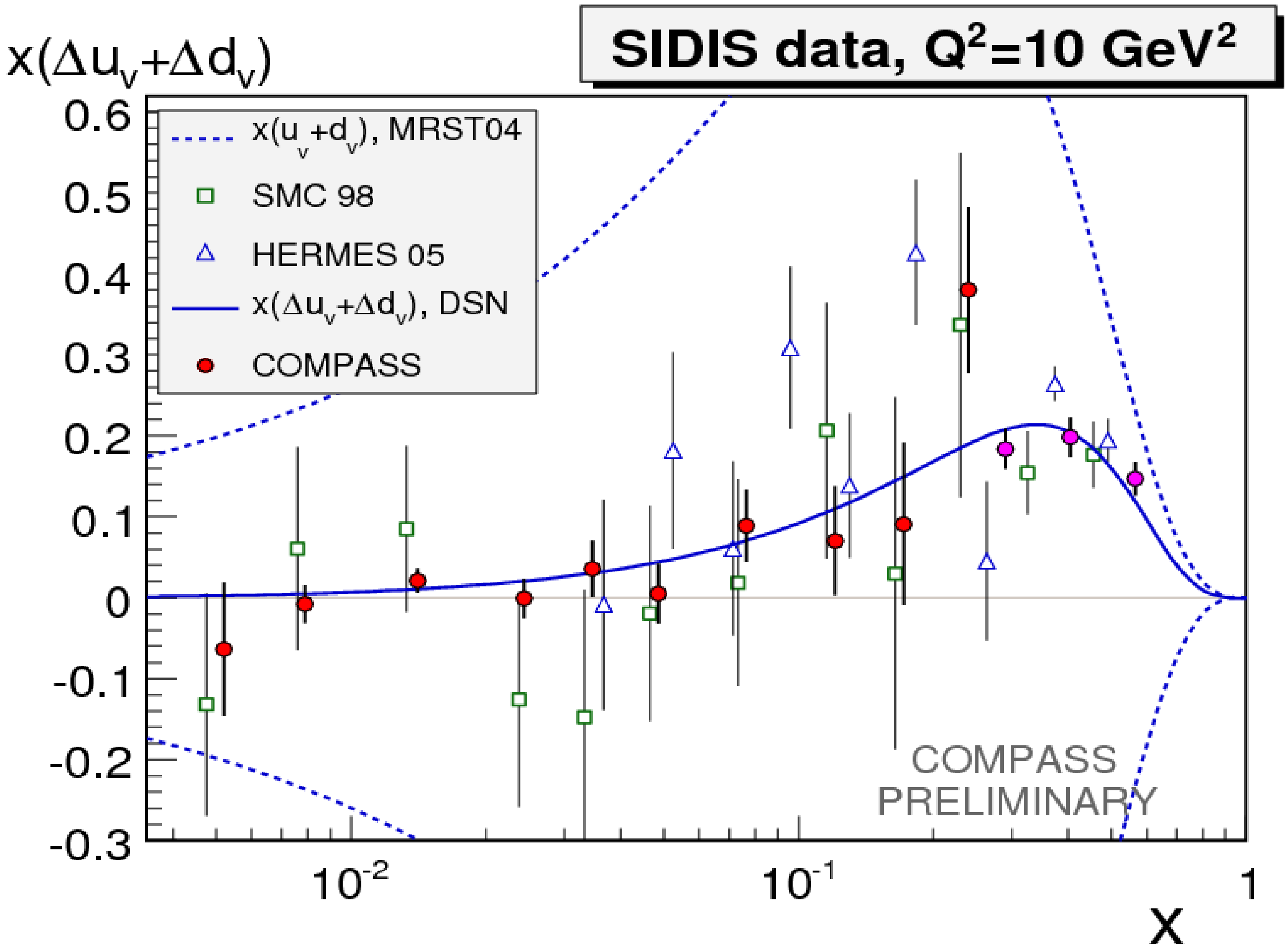
- Use of g_1^d results decreases the statistical error on Δ by a factor 6

$\Delta u_v + \Delta d_v$ results



Constraint the Δq at high x region

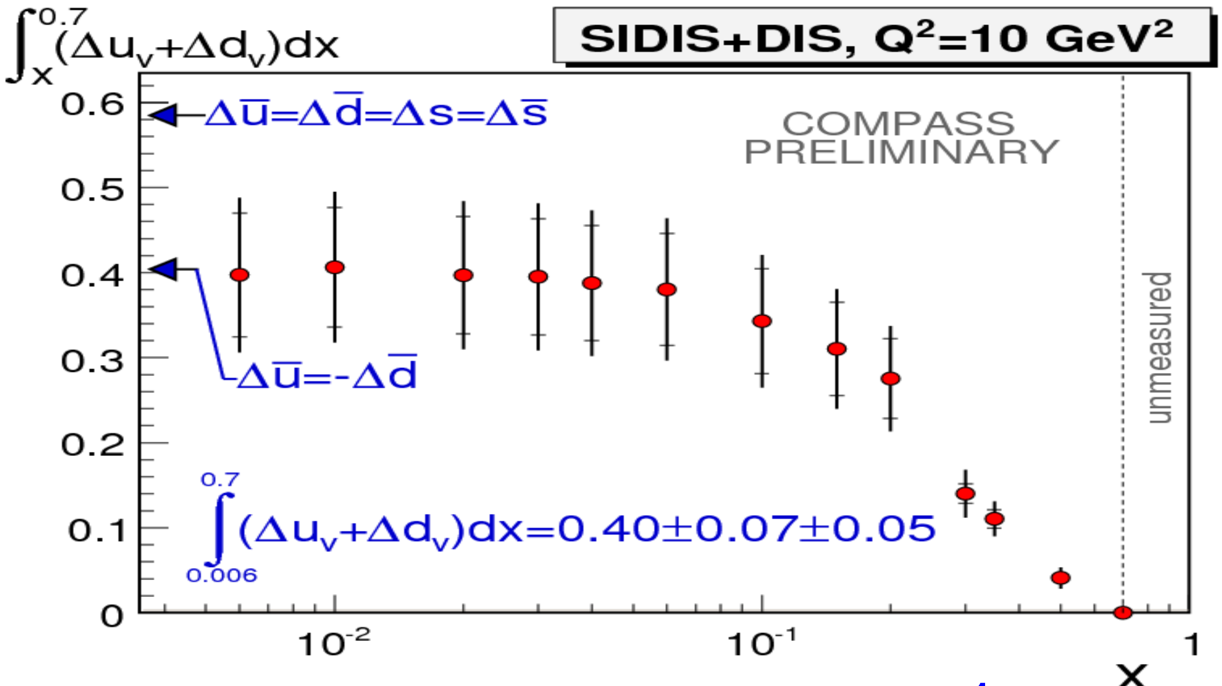
$\Delta u_v + \Delta d_v$ results



The comparison with other experiments

SMC 98, HERMES 05

Estimation for the first moment (LO)



- Contribution from unmeasured region (DNS fit): $\int_{0.7}^{1}(\Delta u_v+\Delta d_v)dx = 0.004$
- In small *x* region the integral is flat.
- The value of Γ_v differs by $2.5\sigma_{stat}$ from symmetric sea scenario:

$$(\Delta\bar{u}+\Delta\bar{d})\Big|_{Q^2=10\,\mathrm{GeV}^2}^{SIDIS+DIS} = (\Delta s+\Delta\bar{s})+\frac{1}{2}(a_8-\Gamma_v) = 0.0 \pm 0.04$$

This doesn't mean $\Delta\bar{u} = 0,\ \Delta\bar{d} = 0$

Estimation for the first moments (LO)

	x-range	Q^2 GeV^2	$\Delta u_v + \Delta d_v$		$\Delta\bar{u} + \Delta\bar{d}$	
			Exp. value	DNS	Exp. value	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 x ranges for SMC98 and COMPASS are like
- The SMC results were obtained with the assumption: $\Delta\bar{u} = \Delta\bar{d} = \Delta s = \Delta\bar{s}$ ($SU(3)_f$ symmetric sea)
- The COMPASS data were not used in the DNS fit.

Summary

- Hadron asymmetries $\mathbf{A^{h^+}}$, $\mathbf{A^{h^-}}$ and $\mathbf{A^{h^+-h^-}}$ are obtained with deuteron COMPASS data (2002 - 2004).
- Use of $\mathbf{A^{h^+-h^-}}$ and $\mathbf{A_1}$ asymmetries on deuteron target allows to extract $\Delta u_v + \Delta d_v$.
- DNS prediction is in agreement with obtained result.
- *SU(3)*$_f$ symmetric sea scenario is disfavored with a significance ~2σ.
- To separate $\Delta\bar{u}$ & $\Delta\bar{d}$. we will use the proton data of year 2007.