Recent COMPASS results on the polarized structure function g_1^d of the deuteron

C. Quintans, LIP-Lisbon

on behalf of the COMPASS Collaboration

3^{rd} October 2006

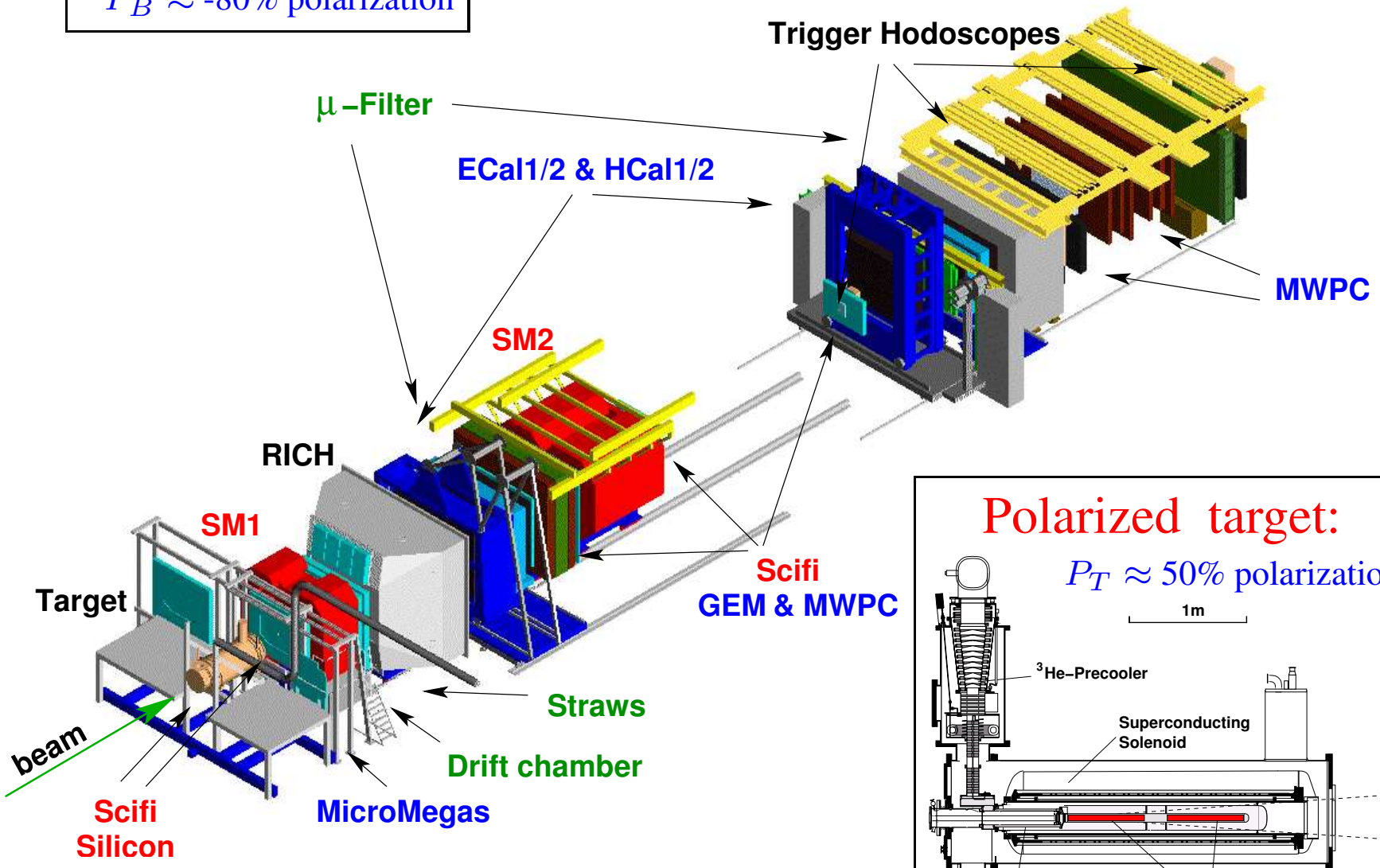
Overview

- The COMPASS experiment
- Inclusive asymmetries A_1^d ($Q^2 \lesssim 1$ (GeV/c)^2)
- Spin-dependent structure function g_1^d results: $Q^2 \lesssim 1$ (GeV/c)^2
- First moment of g_1 ($Q^2 > 1$ (GeV/c)^2)
- Summary

The COMPASS Experiment at CERN

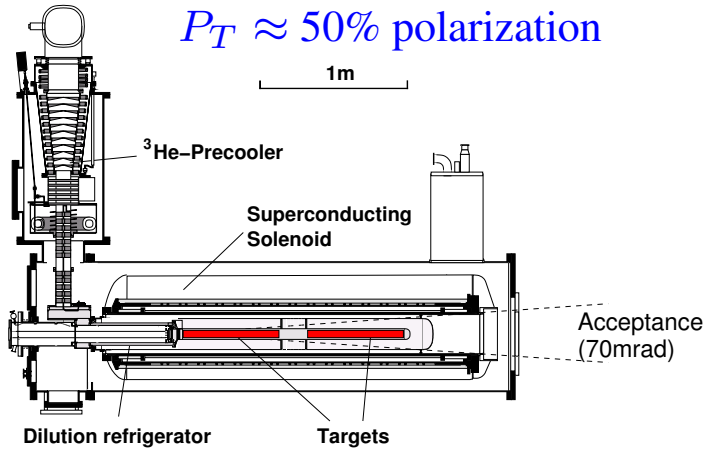
μ-beam @160 GeV

$P_B \approx$ -80% polarization

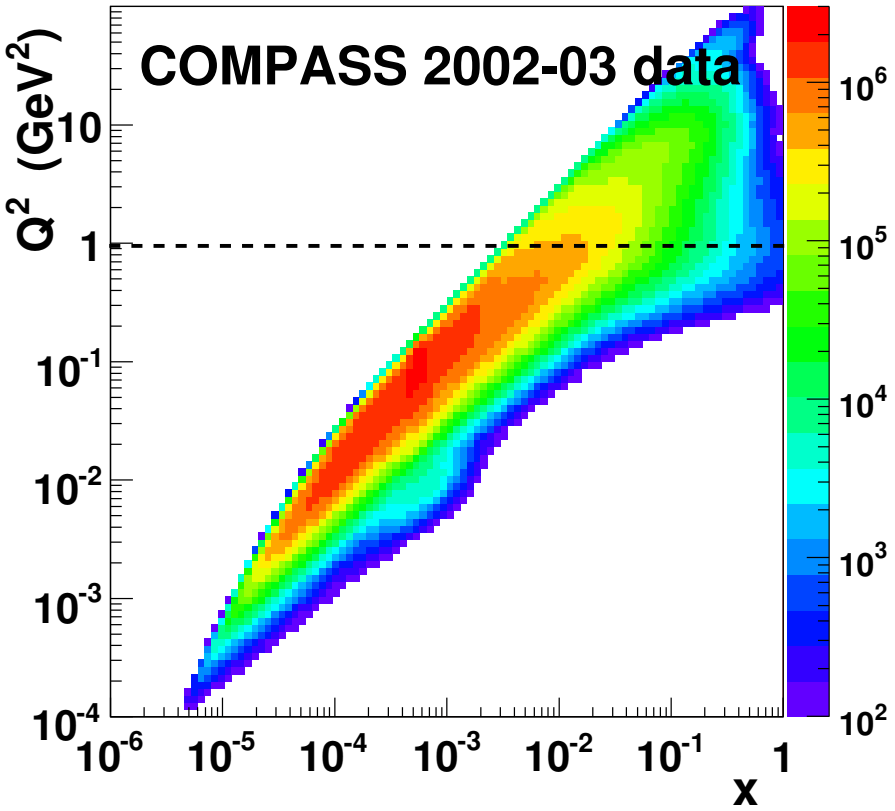


Polarized target: ^6LiD

$P_T \approx$ 50% polarization



Kinematic domain and trigger conditions



- Inclusive triggers (μ')
- Hadronic triggers
  - ⋆ Semi-inclusive triggers ($\mu' + 2$ MIPs cluster in HCALs)
  - ⋆ Calorimetric trigger (9 MIPs cluster in HCALs)

The A_1^d asymmetry

The μ-deuteron asymmetry is measured from the difference between cross-sections from 2 oppositely polarized target cells:

$$A^{\mu d} = \frac{1}{f P_T P_B} \left(\frac{N^{\Rightarrow} - N^{\Leftarrow}}{N^{\Rightarrow} + N^{\Leftarrow}} \right)$$

f: target dilution factor

This measured asymmetry relates to the longitudinal and transverse γ^*-deuteron asymmetries:

$$\frac{A^{\mu d}}{D} = A_1^d + \eta A_2^d$$

D: γ^* depolarization factor

For the COMPASS kinematic region η is small, as well as A_2 measured at SLAC and SMC:

$$|\eta A_2^d| \ll |A_1^d| \quad \Rightarrow \quad \frac{A^{\mu d}}{D} \approx A_1^d$$

Inclusive Asymmeries at COMPASS

A_1 results from 2 independent analyses, that probe different physics:

- $Q^2 > 1$ (GeV/c)^2: DIS interactions
  2002, **2003** and **2004** data – $88 \cdot 10^6$ events [hep-ex/0609038, subm. PLB]

- $Q^2 < 1$ (GeV/c)^2: quasi-real photon interactions
  2002 and**2003** data – $300 \cdot 10^6$ events

To ensure flux and acceptance cancelation in A_1 calculation:

– 2 oppositely polarized target cells used simultaneously;

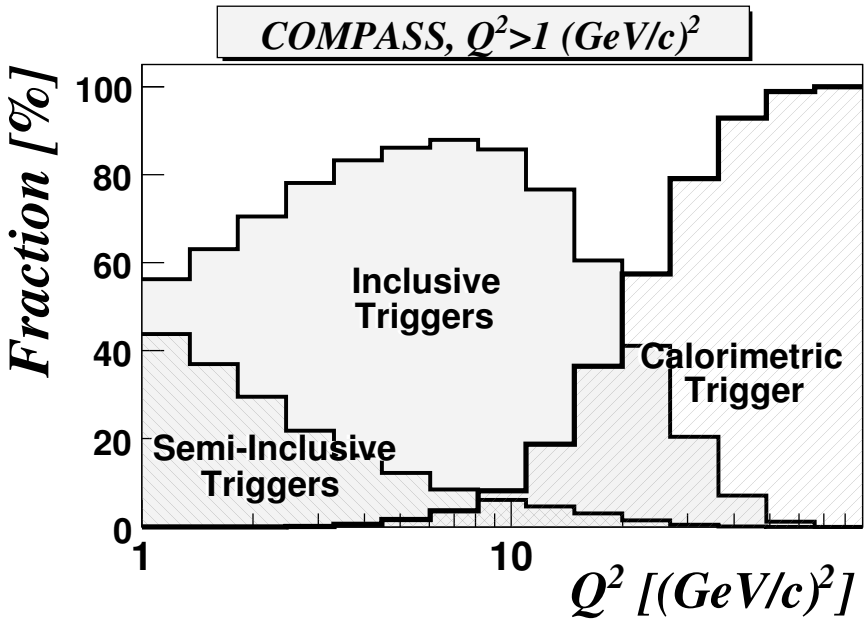
– a field reversal every 8 hours;

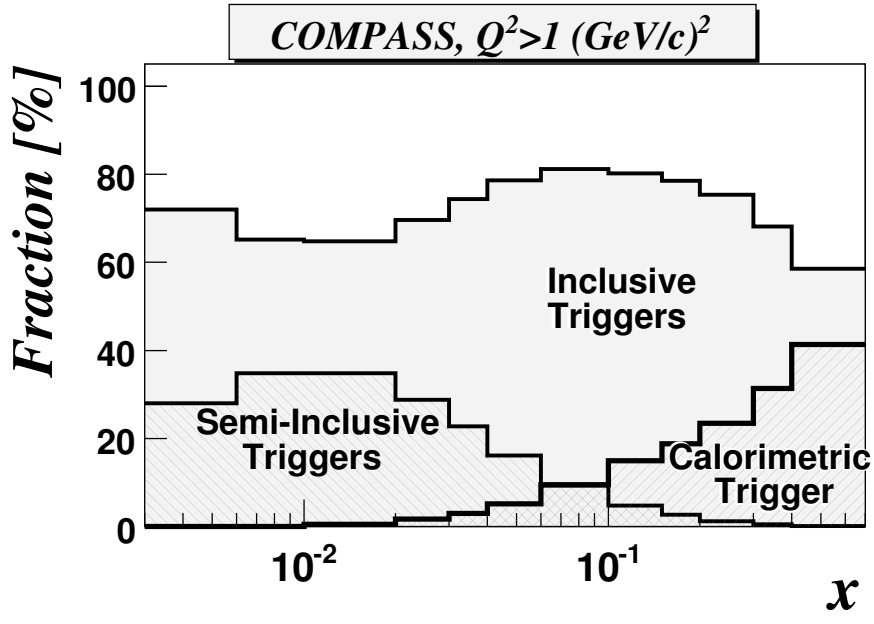
– polarization reversal at least once per year;

– target cuts to ensure the beam crosses the 2 cells.

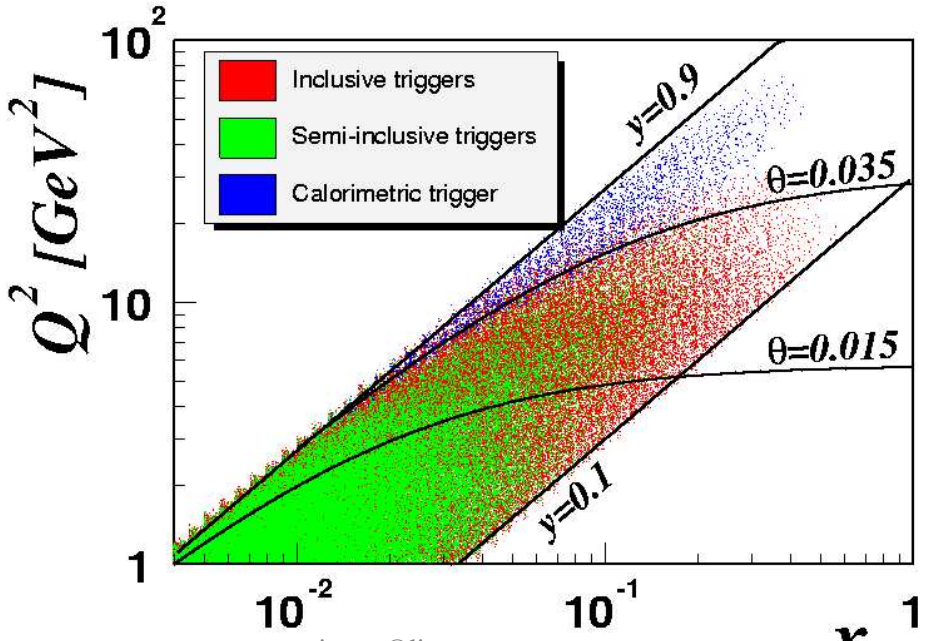
Triggers distribution

($Q^2 > 1$ (GeV/c)^2)



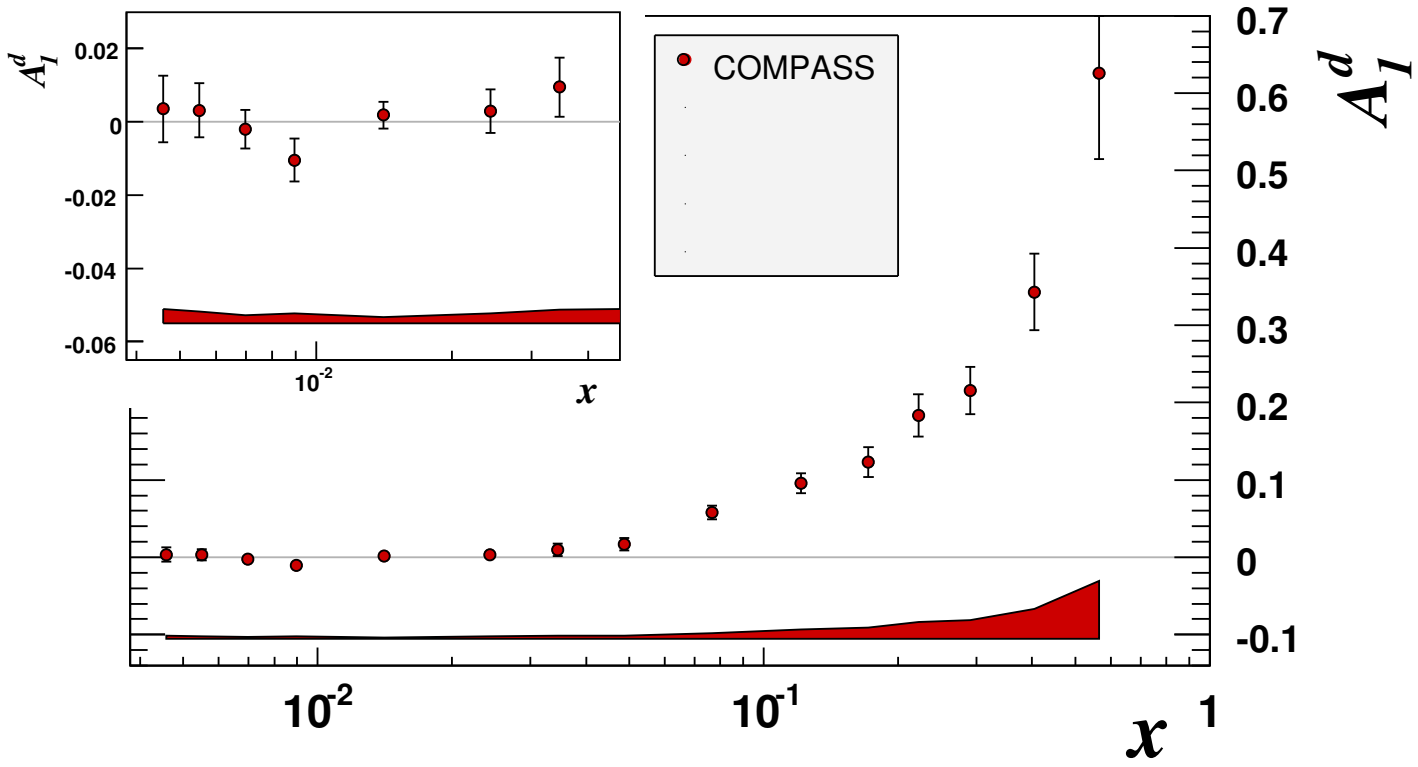


- $Q^2 > 1$ (GeV/c)^2
- $0.004 < x < 0.7$
- $0.1 < y < 0.9$



Inclusive asymmetry A_1^d: COMPASS results

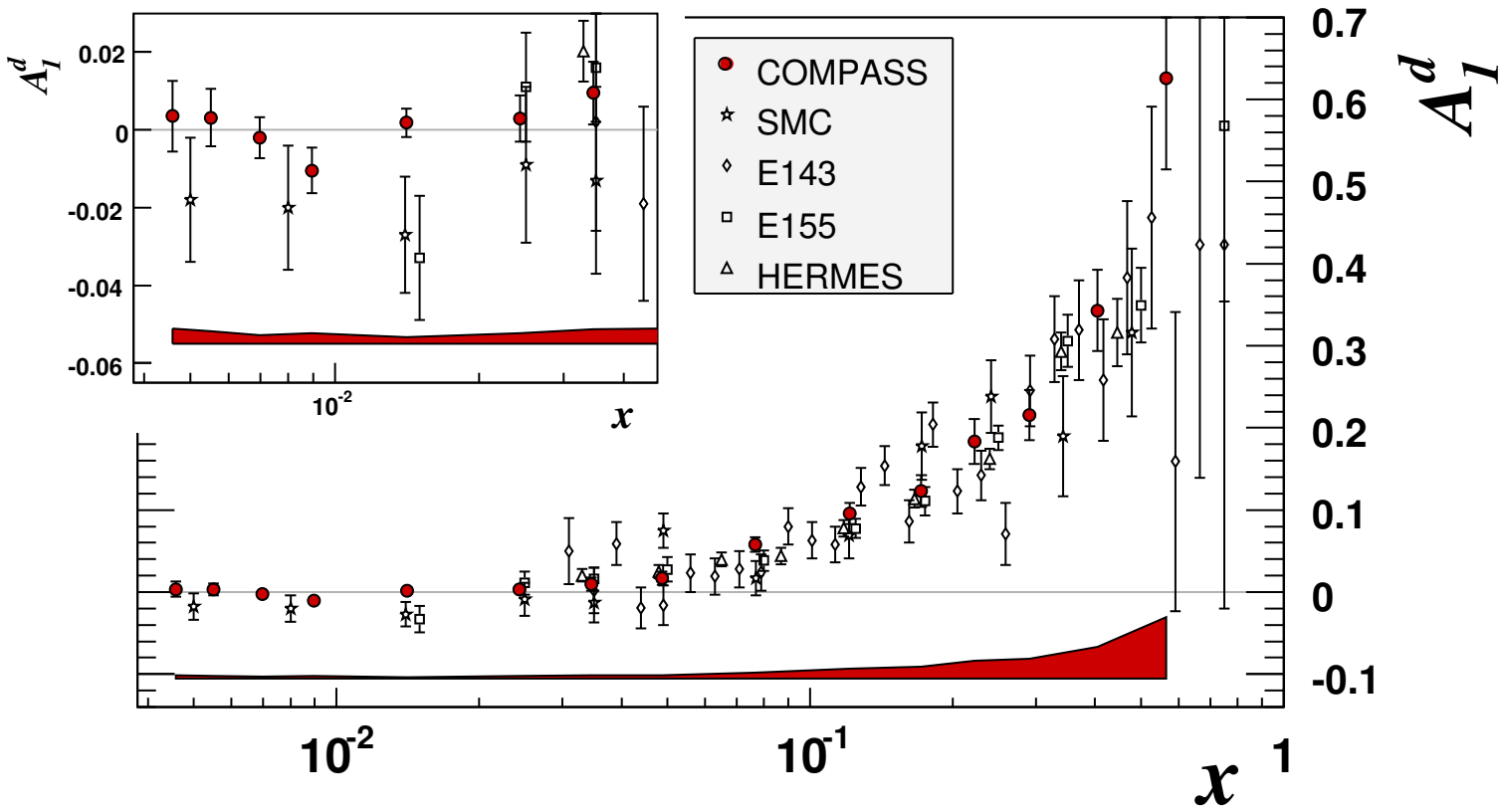
$(Q^2 > 1\ (\mathrm{GeV/c})^2)$



- Result compatible with 0 at $x < 0.03$; large asymmetry at large x
- Systematic errors from: P_B, P_T, D and f ($\approx 10\%$ in total); radiative corrections (small effect); and false asymmetries (from instabilities of the apparatus over time. Estimation: $< 0.4\sigma_{stat}$).

Inclusive asymmetry A_1^d: world results

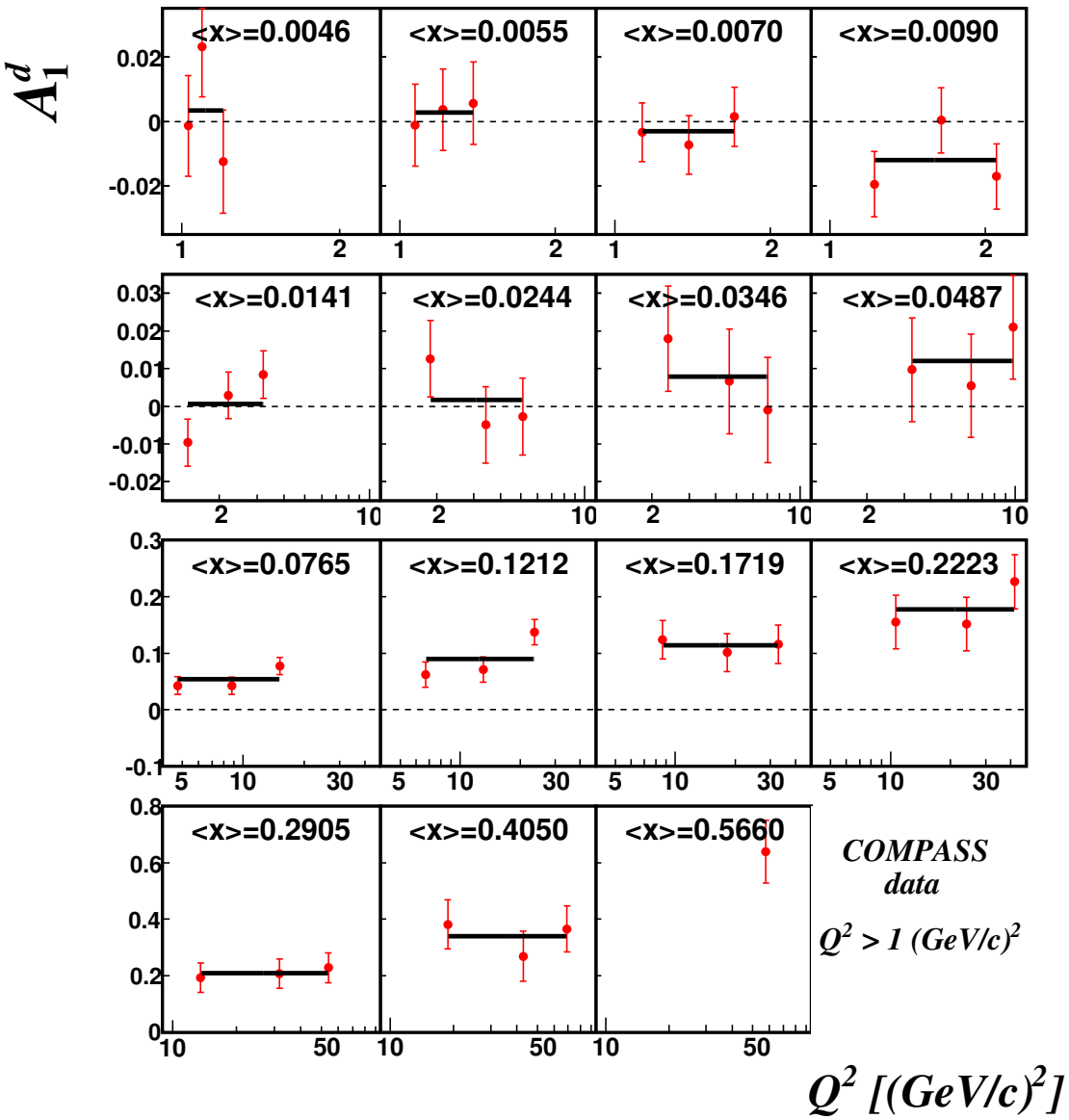
$(Q^2 > 1\ (\mathrm{GeV/c})^2)$



- Good agreement with the results from other experiments
- Improved measurement in the low x region
- Tendency towards negative values at low x not confirmed

Inclusive asymmetry A_1^d: COMPASS results

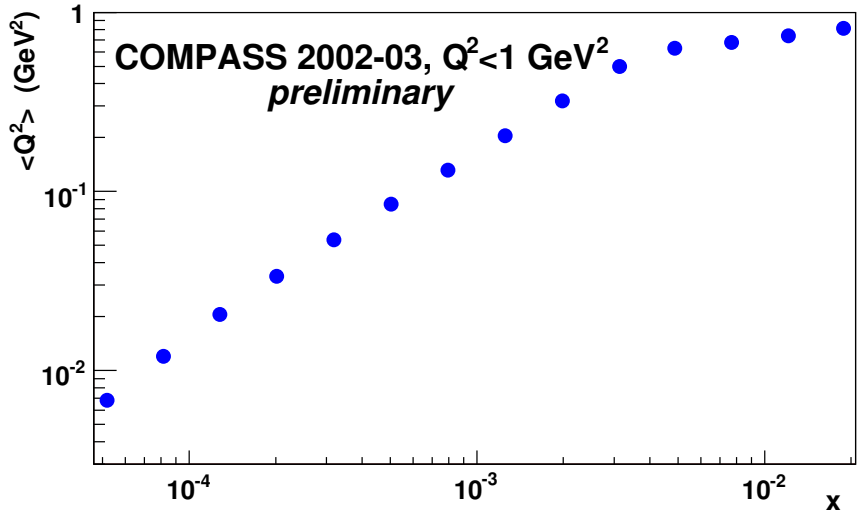
($Q^2 > 1$ (GeV/c)^2)



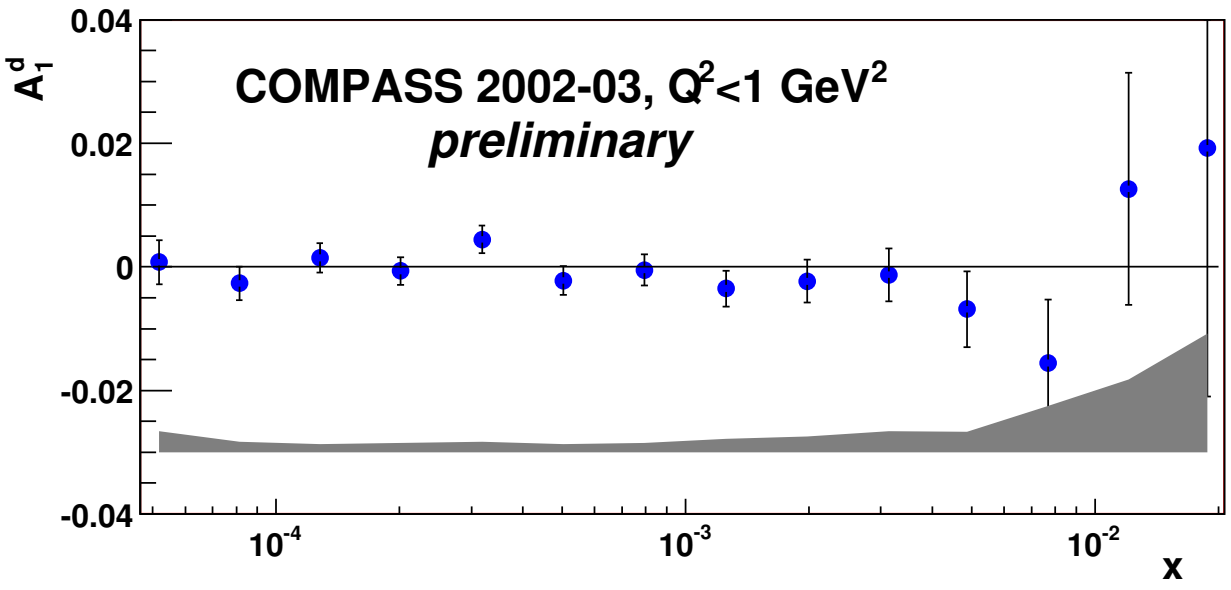
- No significant dependence of $A_1^d(x, Q^2)$ on Q^2

Asymmetry A_1^d: COMPASS results

$(Q^2 < 1\ (\mathrm{GeV/c})^2)$

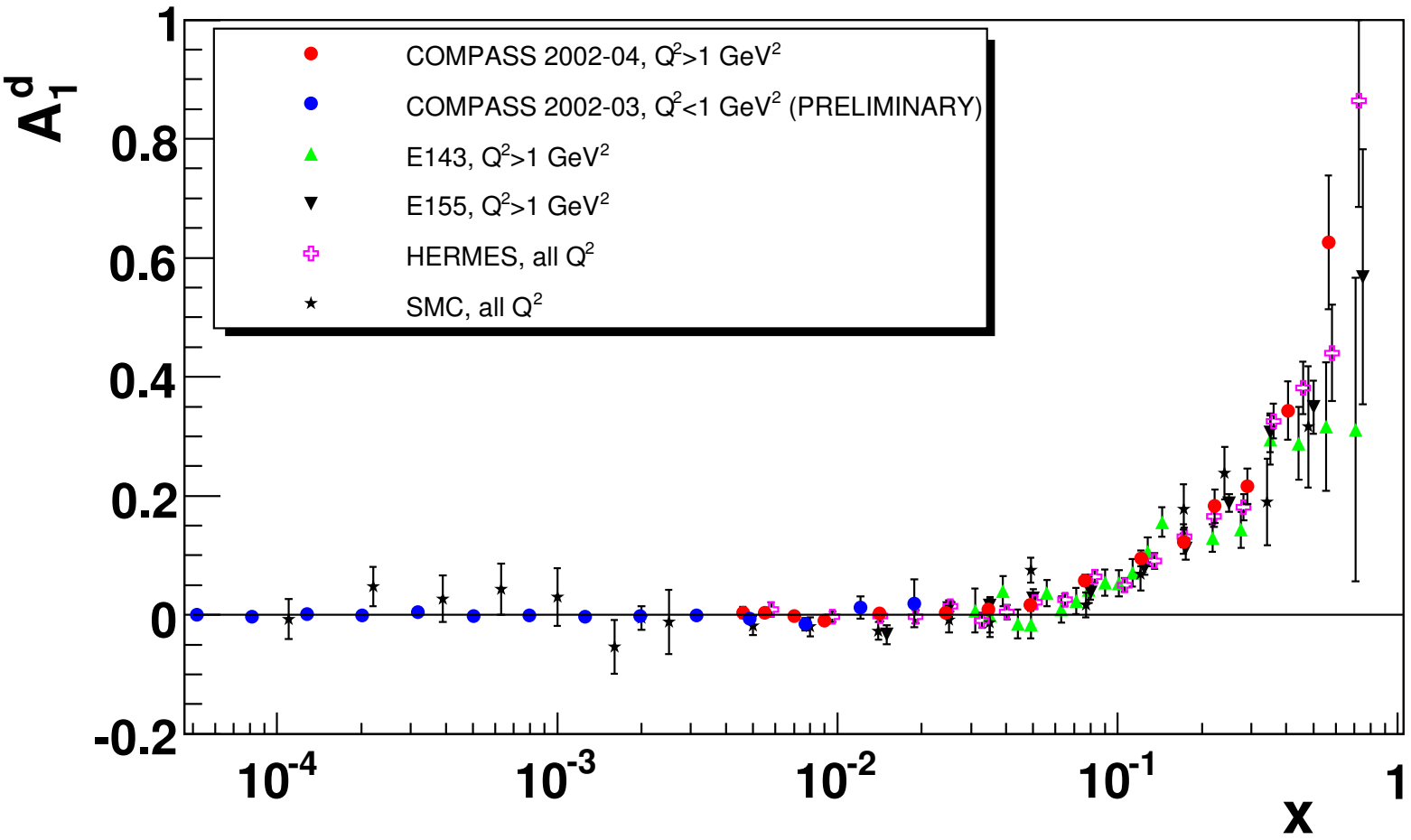


$x > 4 \cdot 10^{-5}$



- Asymmetry compatible with 0
- Estimation that false asymmetries are the dominant systematics $(A_{false} \approx \sigma_{stat})$

Asymmetry A_1^d: world results



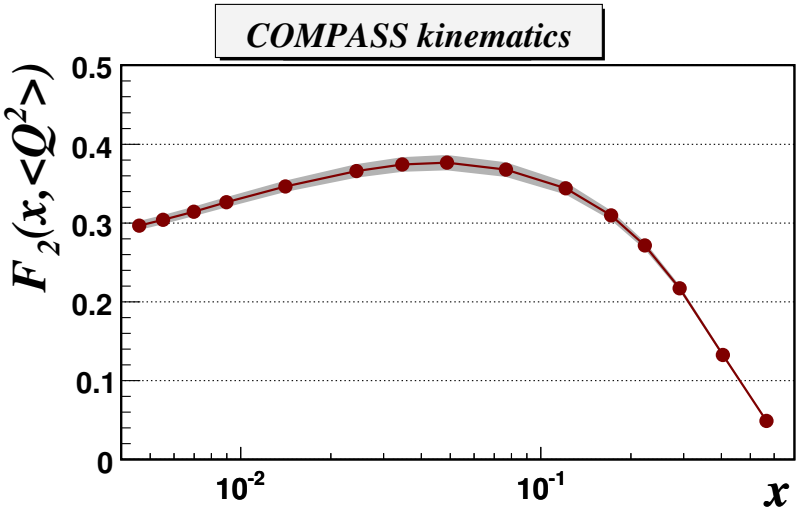
- COMPASS results extend the knowledge of the asymmetry to very low x values, with improved accuracy.

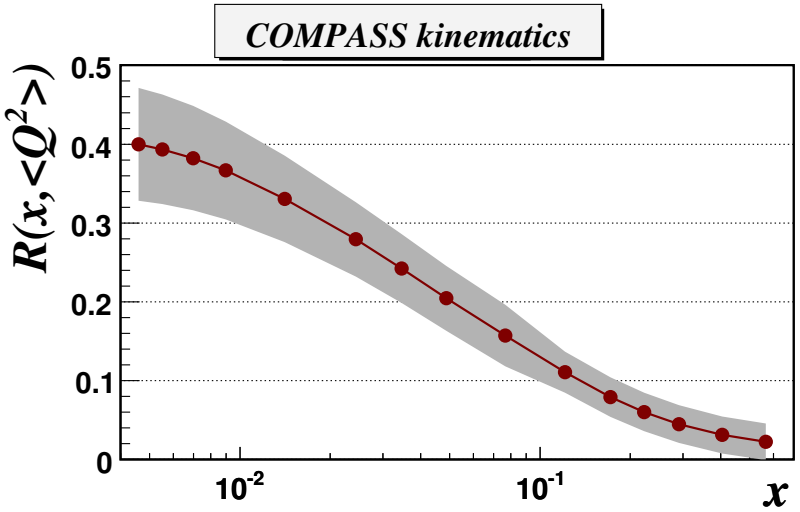
Structure function g_1^d $(Q^2 > 1\ \mathbf{(GeV/c)^2})$

The longitudinal spin-dependent structure function g_1^d is obtained from A_1^d:

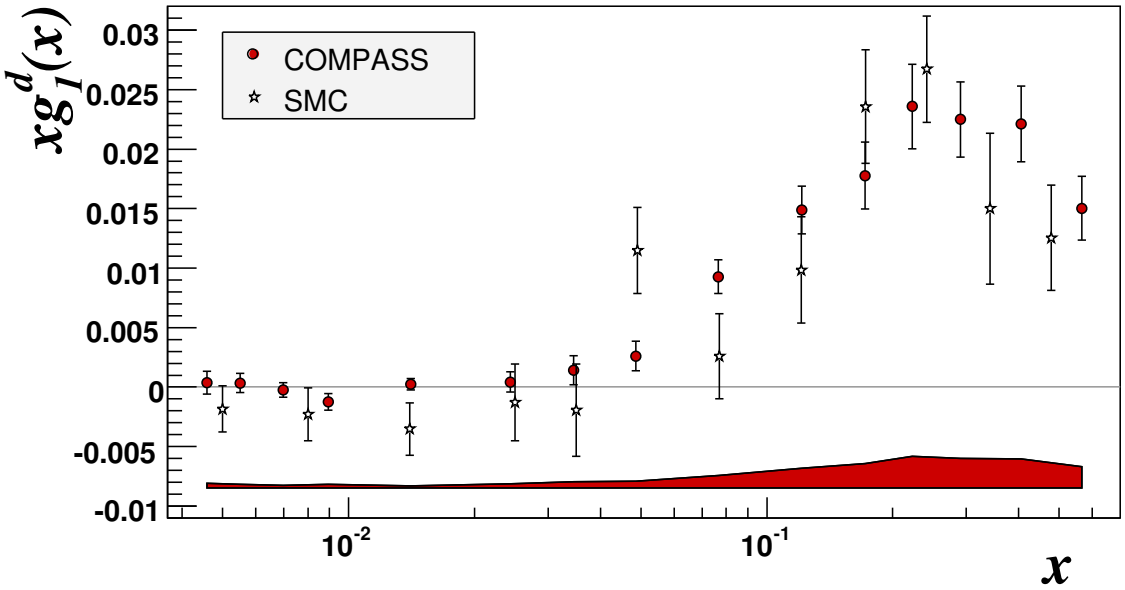
$$g_1^d(x,Q^2) \approx A_1^d(x,Q^2)\frac{F_2^d(x,Q^2)}{2x(1+R(x,Q^2))}$$

- Spin-independent structure function F_2^d: from SMC parameterization
- Ratio $R = \sigma^L/\sigma^T$: from updated SLAC parameterization





From g_1^d $(Q^2 > 1\ \mathbf{(GeV/c)^2})$ to g_1^N $(Q^2 = 3\ \mathbf{(GeV/c)^2})$

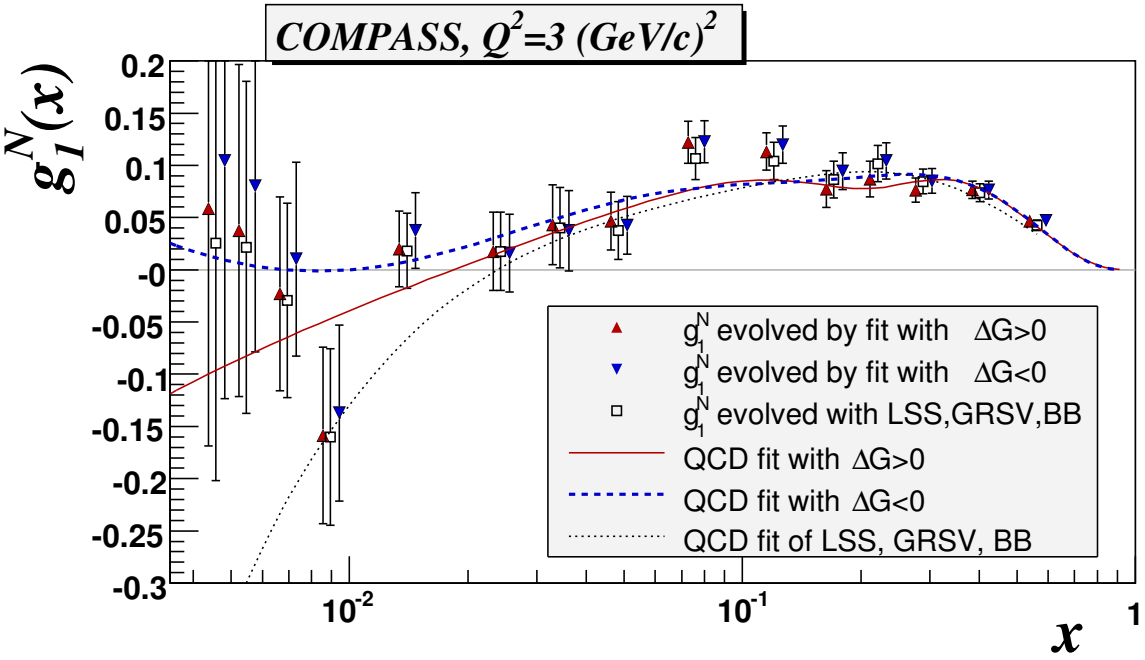


$$g_1^d = g_1^N\,(1 - \frac{3}{2}\omega_D)$$
$$= \frac{g_1^p + g_1^n}{2}(1 - \frac{3}{2}\omega_D)$$

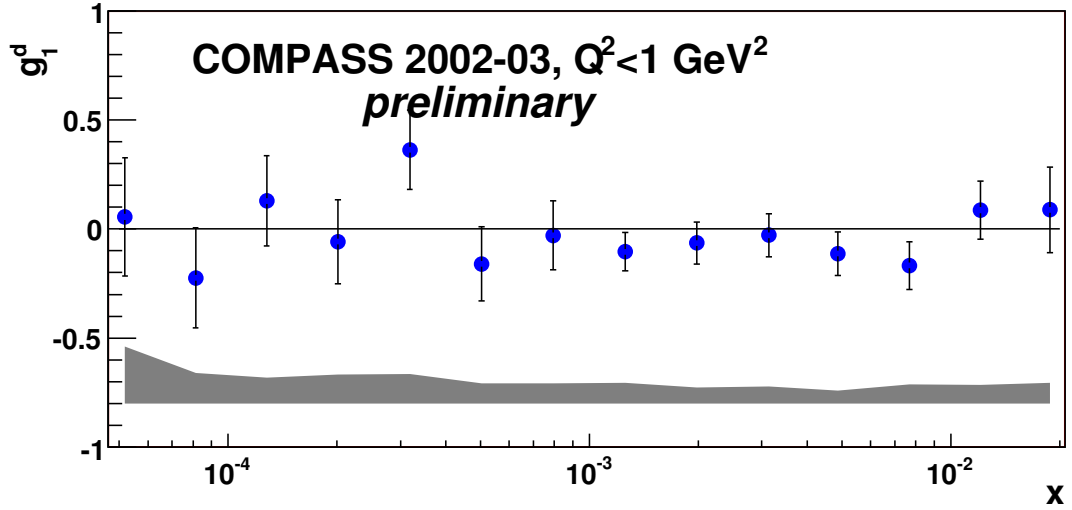
with $\omega_D = 0.05 \pm 0.01$

g_1^N datapoints evolved to $Q^2 = 3\ \mathrm{GeV}^2$ using QCD fit

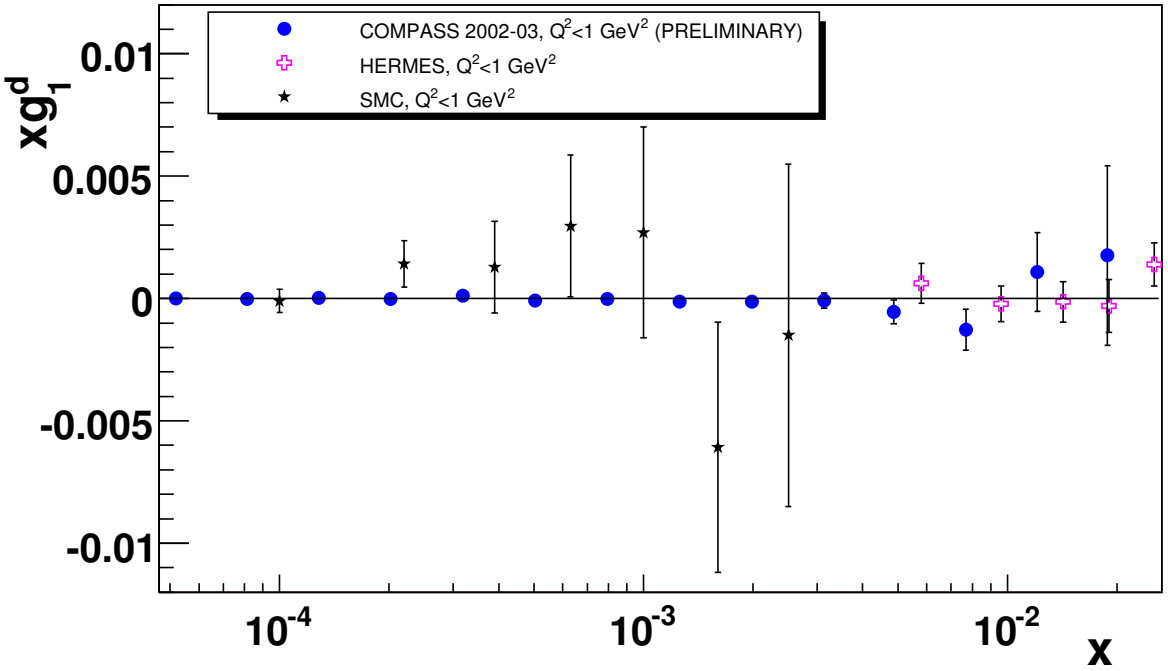
↪ see next talk, by I. Savin.



Structure function g_1^d $(Q^2 < 1\ \mathbf{(GeV/c)^2})$



- With F_2 from standard SMC parameterization (SMC fit + JKBB model)



COMPASS result is 1 order of magnitude more precise than SMC one.

The first moment of g_1 ($Q^2 > 1$ (GeV/c)^2)

The first moment of g_1^N:

$$\Gamma_1^N(Q^2) = \int_0^1 g_1^N(x, Q^2)dx$$

relates to the flavor-singlet axial current a_0, that can be interpreted as the quarks spin contribution to the nucleon spin.

- g_1^N is evolved to a fixed Q^2 using a QCD fit
- COMPASS data do not confirm tendency for fast decrease of g_1 at low x, suggested by SMC results. Therefore the integral of g_1 in the extrapolated range ($x < 0.004$ & $x > 0.7$) is estimated to be only 2% of Γ_1^N, while for SMC it was about 50%.

The first moment of g_1 $(Q^2 > 1$ **(GeV/c)**$^2)$

- First moment of g_1^N, from COMPASS data alone:

$$\Gamma_1^N(Q_0^2 = 3\ GeV^2) = \int_0^1 g_1^N(x)dx = \\ = 0.050 \pm 0.003(stat) \pm 0.002(evol) \pm 0.005(syst)$$

- At NLO, $\Gamma_1^N(Q^2) = \frac{1}{9}\left(1 - \frac{\alpha_s(Q^2)}{\pi} + \mathcal{O}(\alpha_s^2)\right)\left(a_0(Q^2) + \frac{1}{4}a_8\right)$.
  Using a_8 from hyperon-β decay assuming SU(3)$_f$
  ($a_8 = 0.585 \pm 0.025$):

$$a_0(Q_0^2 = 3\ GeV^2) = 0.35 \pm 0.03(stat) \pm 0.05(syst)$$

Summary

- COMPASS results on inclusive longitudinal γ^*-deuteron asymmetry A_1^d with
  – $Q^2 > 1$ (GeV/c)^2 (final, 2002 - 2004 data) [hep-ex/0609038],
  – $Q^2 < 1$ (GeV/c)^2 (preliminary, 2002-2003), were presented.

  - ★ Practically no dependence of the asymmetry on Q^2 is observed at $Q^2 > 1$ (GeV/c)^2.
  - ★ The asymmetry in the low x region, obtained with unprecedented precision, is compatible with zero.
  - ★ The asymmetry is large in the high x region.
  - ★ The A_1^d results from COMPASS show good agreement with previous experiments.

Summary (cont.)

- Results on the polarized structure function g_1^d were shown. The first moment of g_1, from COMPASS data alone, is:

  $\Gamma_1^N(Q_0^2 = 3(GeV/c)^2) = 0.050 \pm 0.003(stat) \pm 0.002(evol) \pm 0.005(syst)$.

- The singlet axial coupling value obtained is

  $a_0(Q_0^2 = 3(GeV/c)^2) = 0.35 \pm 0.03(stat) \pm 0.05(syst)$.

- New QCD fits have been performed to estimate the impact of present COMPASS data $\rightarrow$ see next talk:
  "The QCD Analysis of the World Data on Structure Functions $g_1^{p,d,n}$ for Proton, Deuteron, and Neutron", by I. Savin.

- More data from the COMPASS Run 2006, now ongoing, will increase the measurements precision.

Thank you!