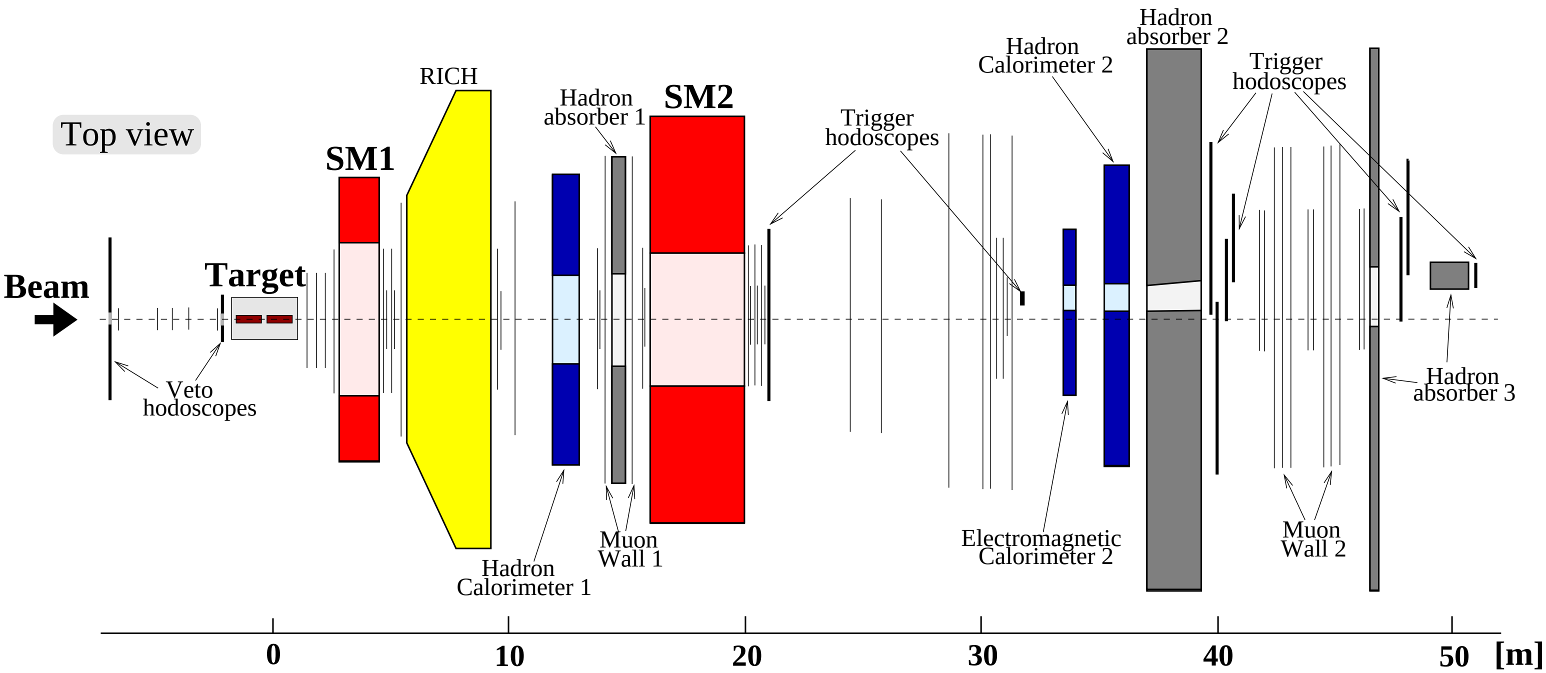
Measurement of the spin structure of the deuteron at COMPASS

Jürgen Hannappel on behalf of the COMPASS collaboration

Overview

- The COMPASS experiment
- The Asymmetry A_1
  and the spin structure function g_1
- Results from the 2002 and 2003 beam time
- The results in a wider view: QCD fit to world data
- Summary and outlook

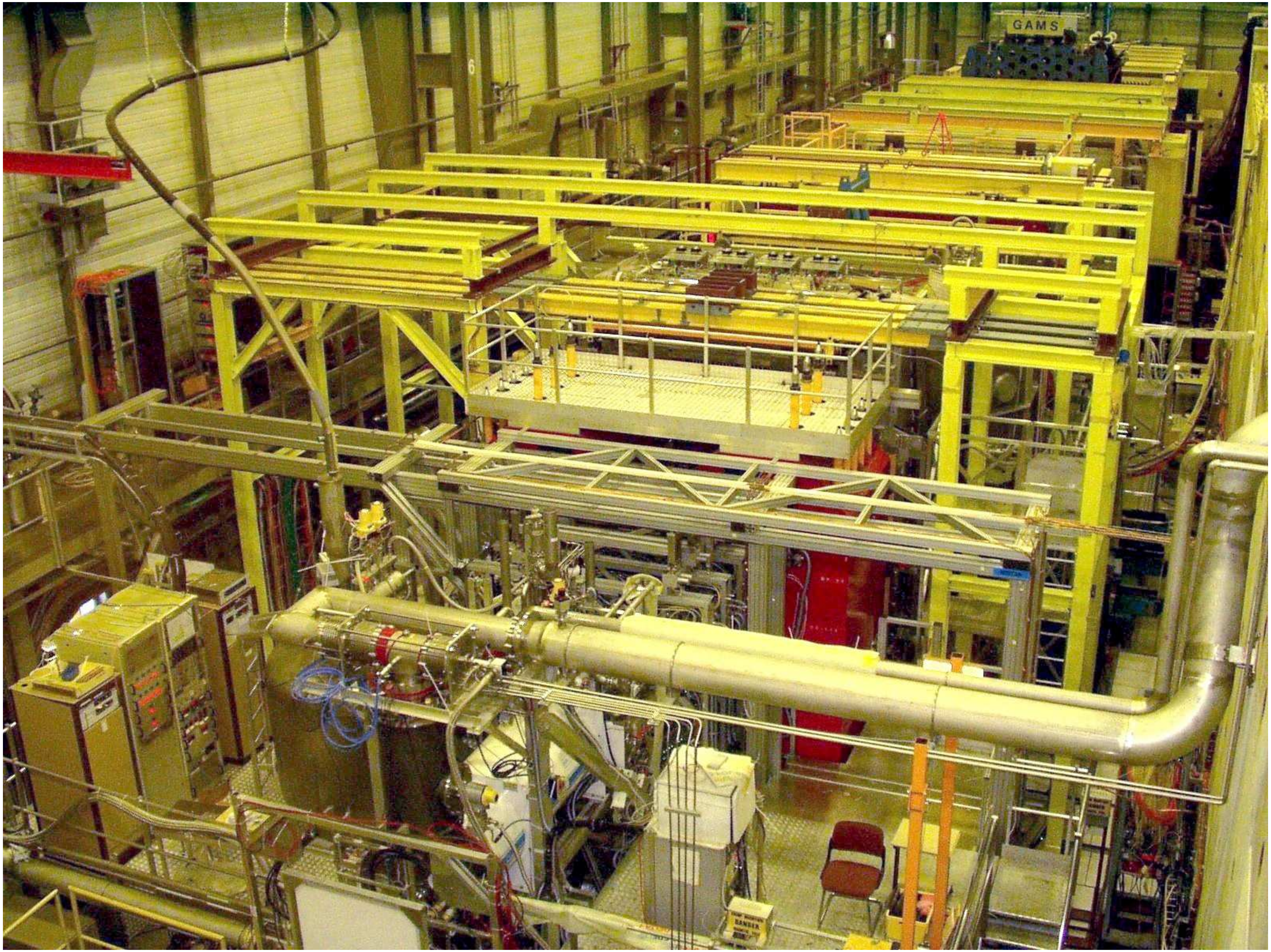
COMPASS experiment (2002–2003)



160 GeV/c μ^+ beam, $\approx$-75% polarisation

^{6}LiD target, polarisations: +54%, -50%

Target spin rotated every 8 hours


GAMS

Virtual photon asymmetry $A_1^{\gamma d}$

- We want:

$$A_1^{\gamma d} = \frac{\frac{1}{2}(\sigma_0 - \sigma_2)}{\frac{1}{3}(\sigma_0 + \sigma_1 + \sigma_2)}$$

- We measure μ-asymmetry:

$$A^{\mu d} = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$$

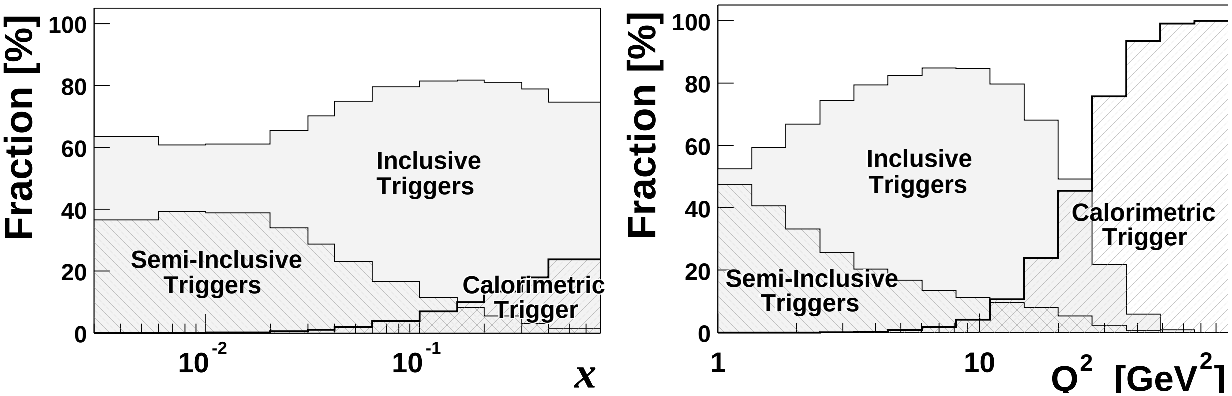
- We use:

$$A^{\mu d} = D\left(A_1^{\gamma d} + \eta A_2^d\right)$$

- A_2^d is known (E155) and small (< 0.01)
- $\eta = \frac{2(1-y)}{y(2-y)}\sqrt{Q^2}/E_\mu$ is also small (< 0.01)

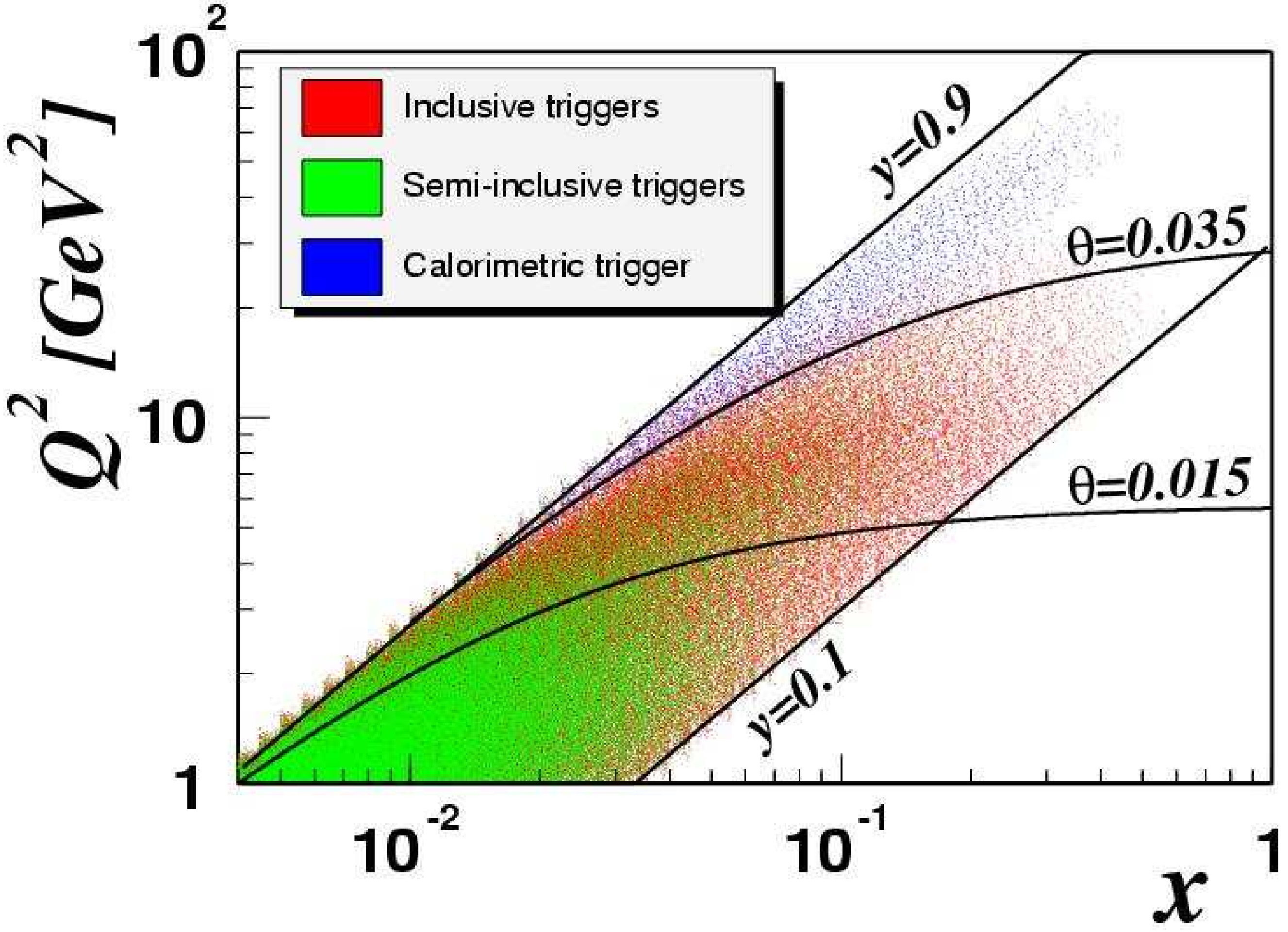
$$\hookrightarrow A_1^{\gamma d} \simeq \frac{A^{\mu d}}{D}$$

Triggers used



- inclusive and semi-inclusive data are compatible
- possible due to good hadron acceptance
- Monte Carlo studies confirm that
- SMC's “hadron method”

Kinematics


Inclusive triggers
Semi-inclusive triggers
Calorimetric trigger
y=0.9
θ=0.035
θ=0.015
y=0.1
Q^2 [GeV^2]
10^2
10
1
10^-2
10^-1
1
x

The polarized structure function g_1^d

- We want:

$$g_1^d$$

- We use:

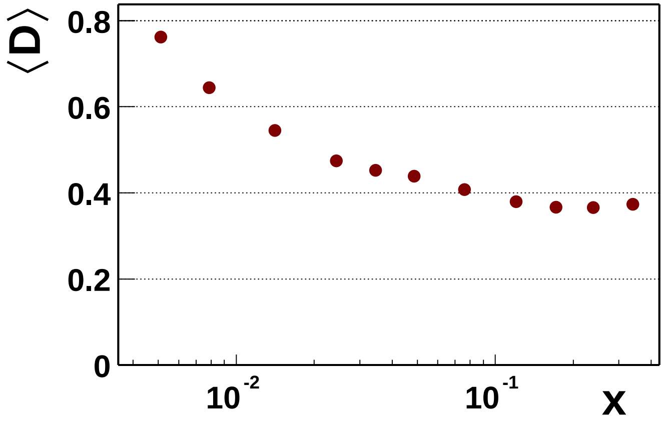
$$g_1^d = \frac{F_2^d}{2x(1+R)} A_1^{\gamma d}$$

- F_2^d is known from fixed target experiments

- $R = \sigma_L/\sigma_T$ known from measurements (NMC, E143)

Depolarisation factor D

$$D \simeq \frac{y(2-y)}{y^2 + 2(1+R)(1-y)}$$

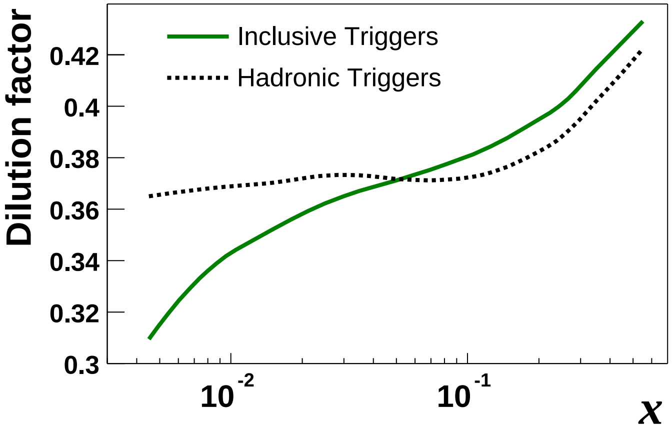


- $y = E_\gamma / E_{\mathrm{beam}}$ known from kinematics

- $R = \sigma_L / \sigma_T$ known from measurements (NMC, E143)

Dilution factor f

$$f = \frac{n_d \sigma^d_{1\gamma}}{\Sigma_A n_A \sigma^A_{\mathrm{tot}}}$$



- Dilution factor contains
  - Fraction of D
  - Cross sections for all nuclei
  - Radiative corrections
    $\hookrightarrow$ dependence on x
    $\hookrightarrow$ different for DIS/SIDIS triggers

Weighting Method to extract A_1^d

- Measure numbers of events:

$$N_i = a_i \phi_i n_i \bar{\sigma} (1 + P_T P_B f D A_1^d)$$

for different combinations of beam and target spin

- We weight each event with $P_B f D$

$\hookrightarrow$ improvement of statistical error by 10%

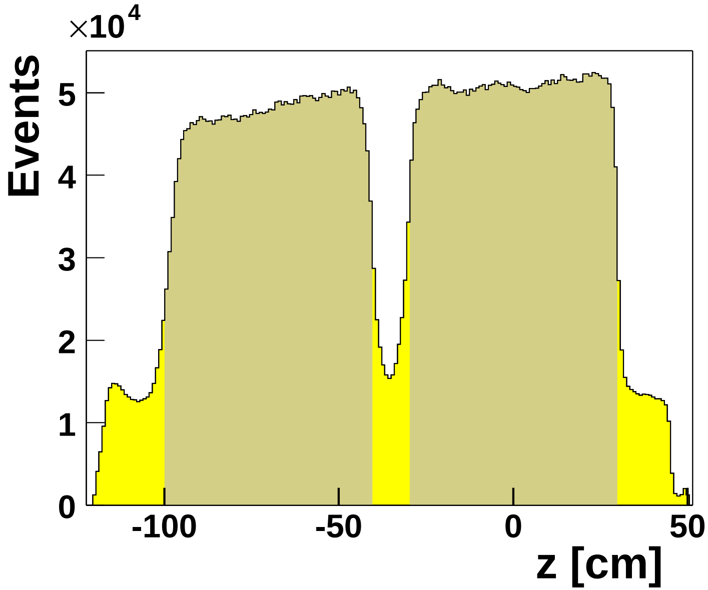
- f,D from event kinematics

- P_B from μ-Energy

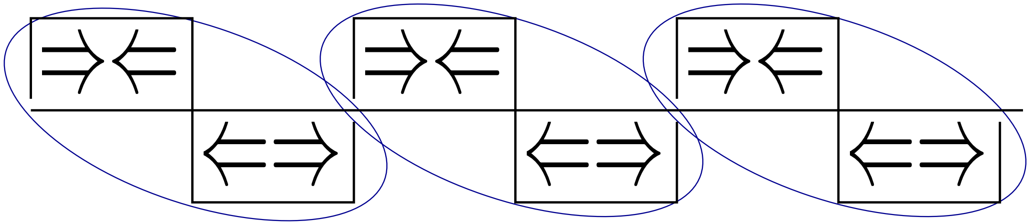
Asymmetry calculation

Different acceptance for target cells

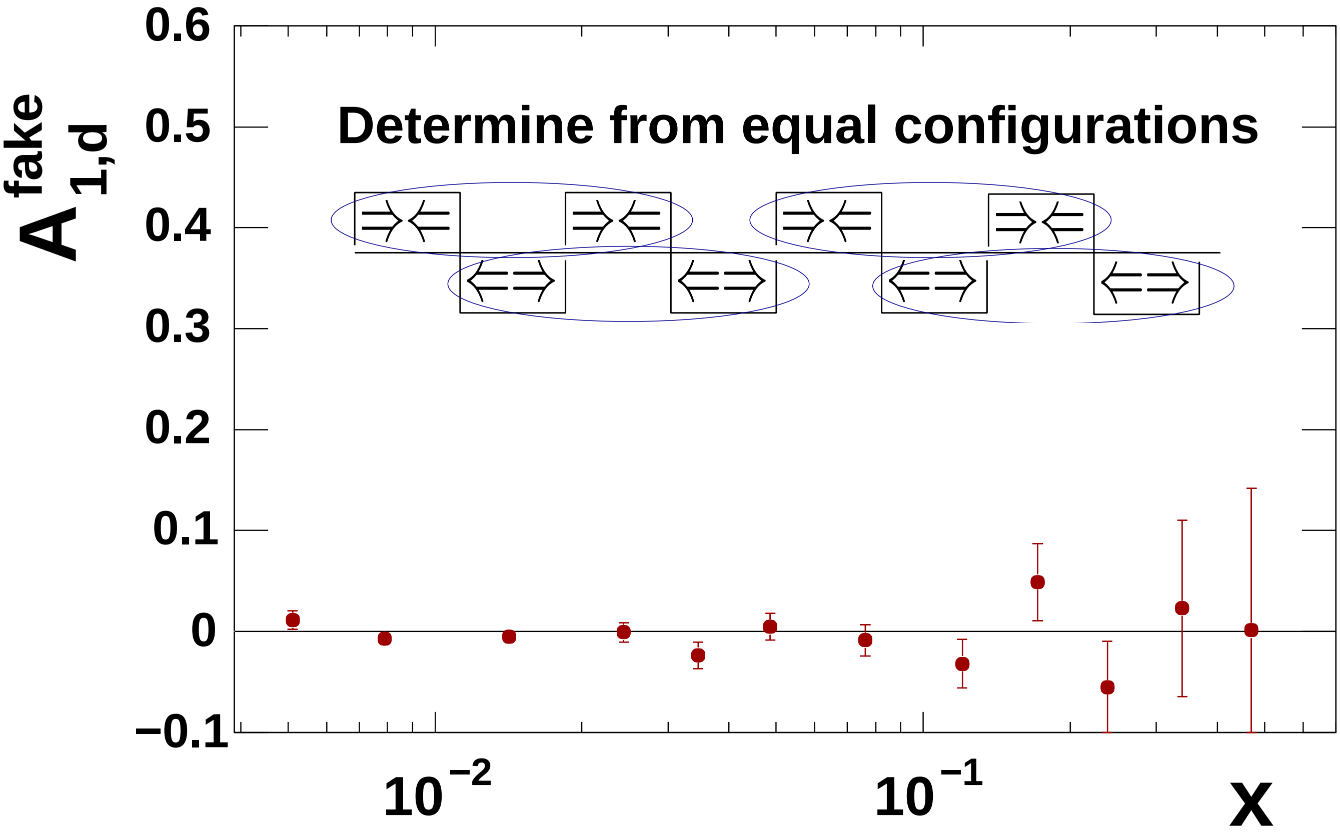
$\hookrightarrow$ use spin reversal to cancel acceptance effects



Compute asymmetries from opposite polarizations:

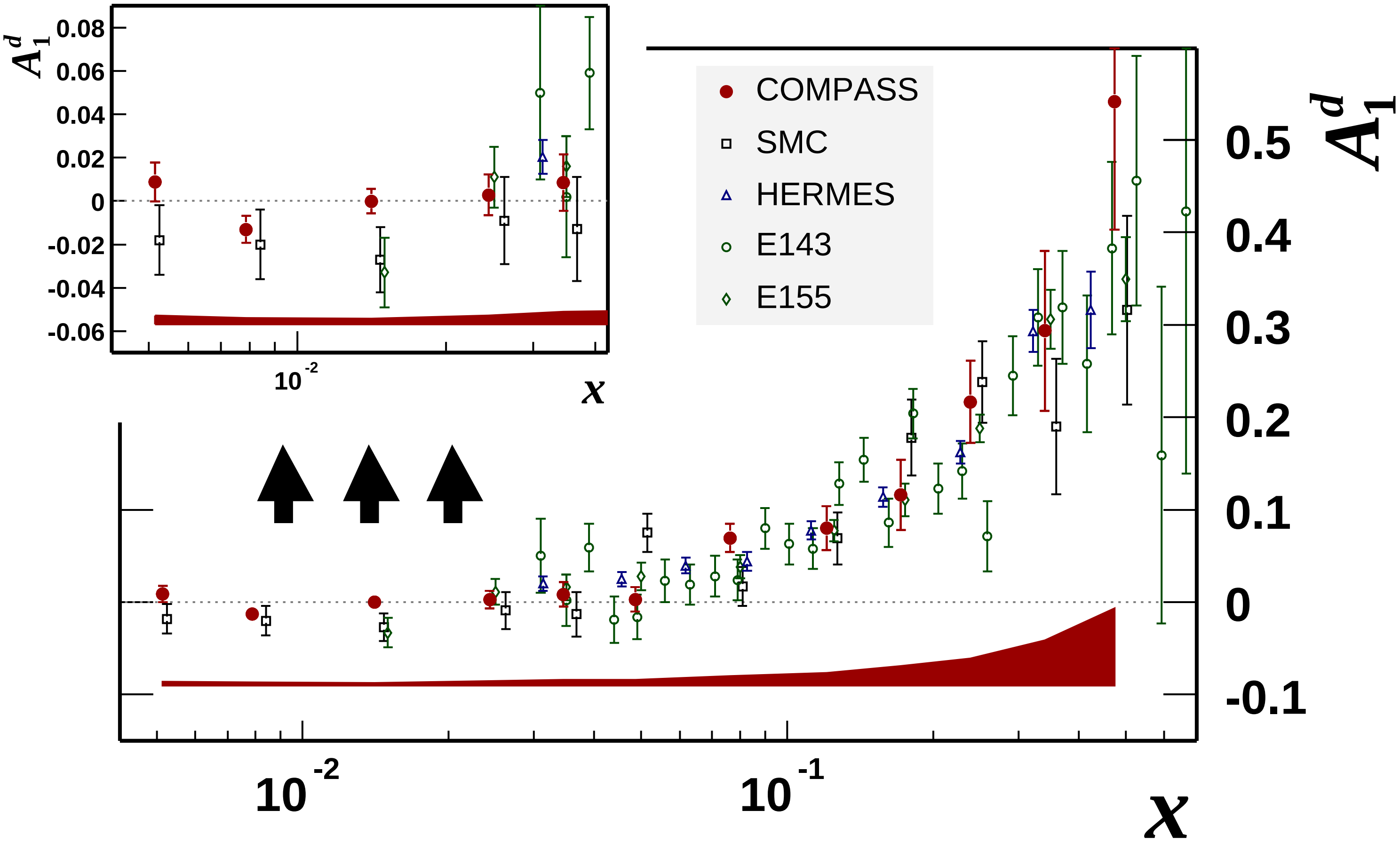


False asymmetries



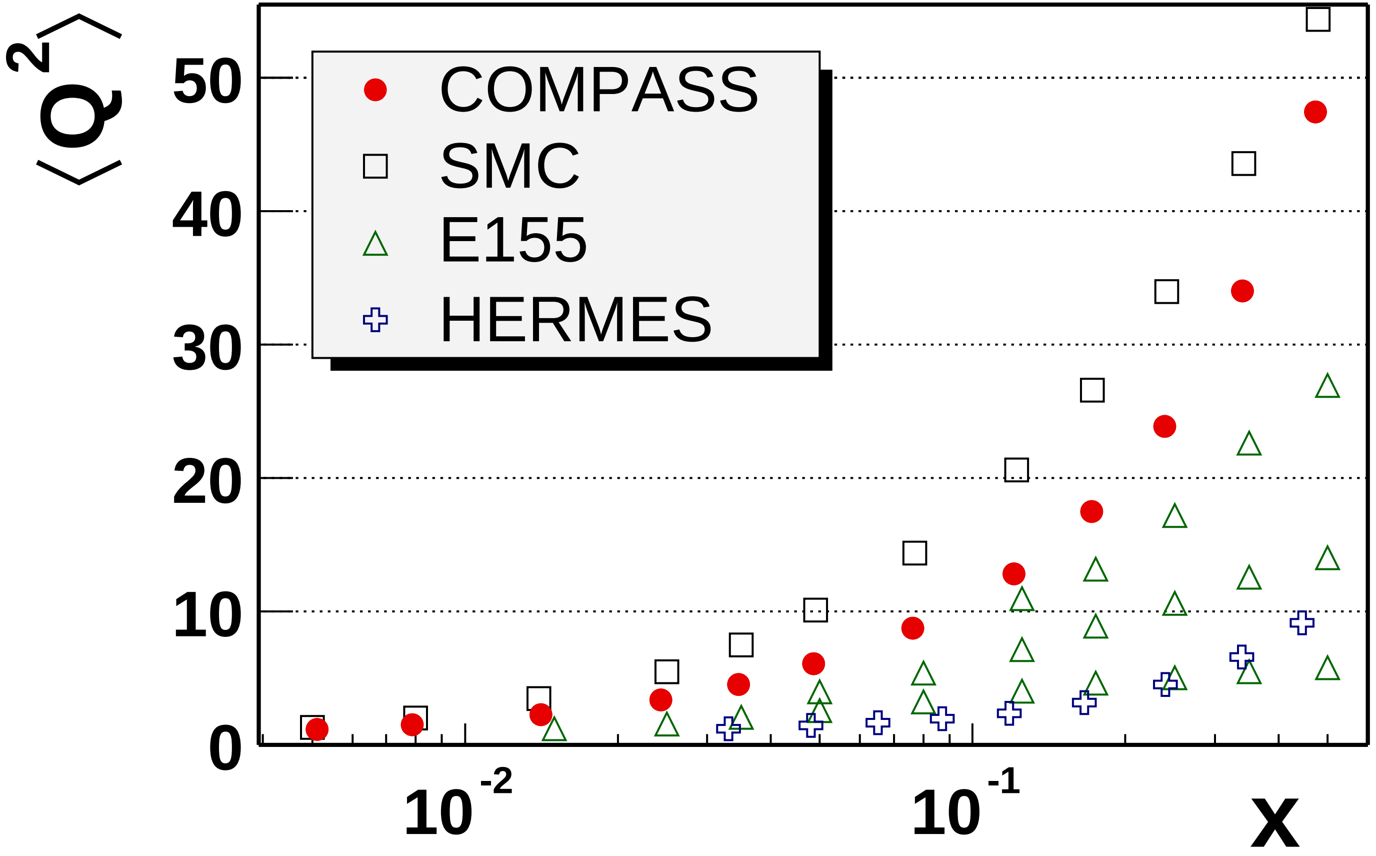
Compatible with 0

Results: A_1^d (PLB 612 (2005) 154)

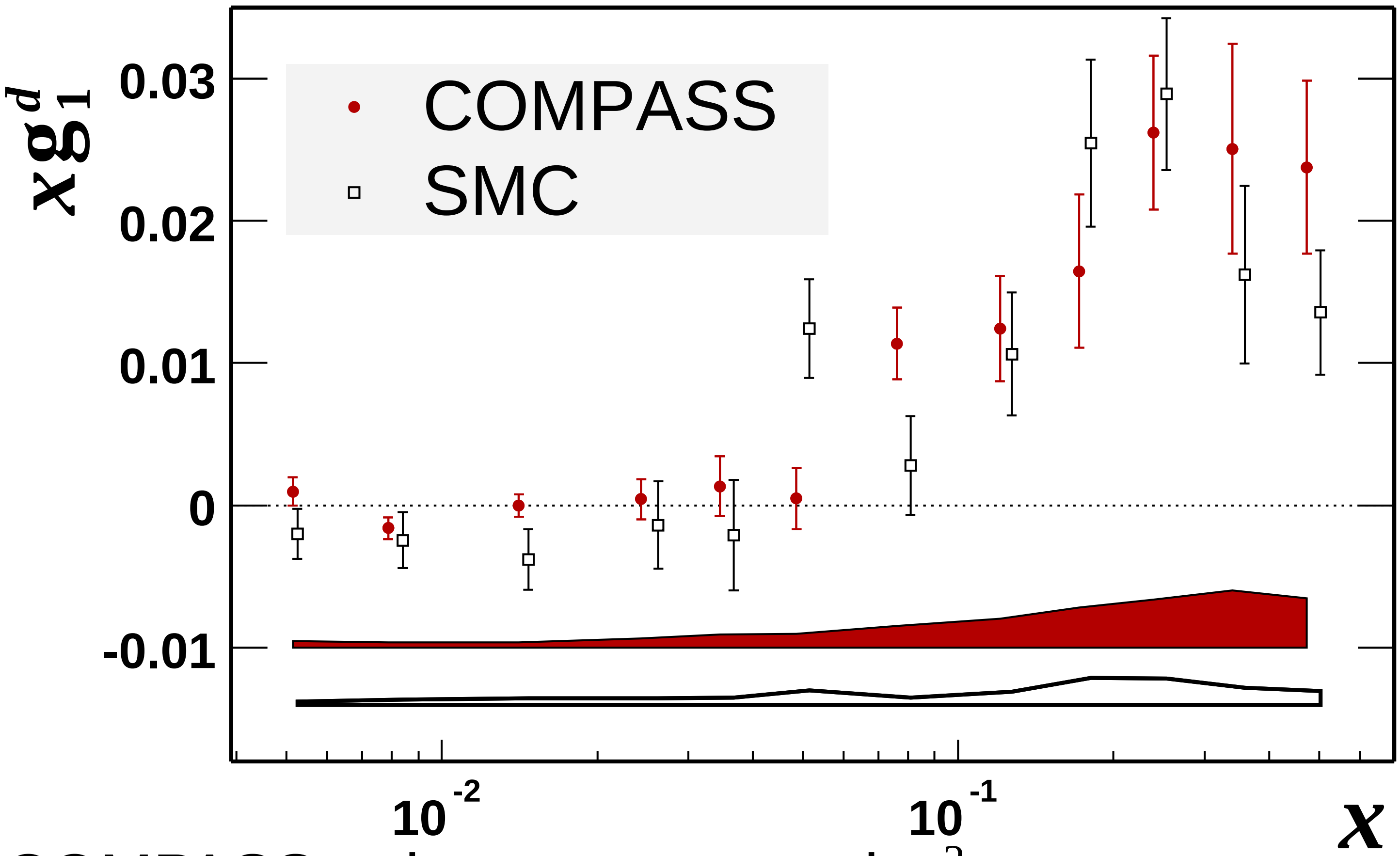


Precision at low x better by factor 2-3

Kinematics



Results: g_1^d



COMPASS points at measured Q^2,
SMC points at COMPASS Q^2

Results: A QCD fit to world data

- Program by D. Fasching, hep-ph/9610261 (program “2” in SMC notation)
- Solution of DGLAP evolution equations via numerical integration
- NLO calculation in $\overline{\mathrm{MS}}$ scheme

Results: A QCD fit to world data

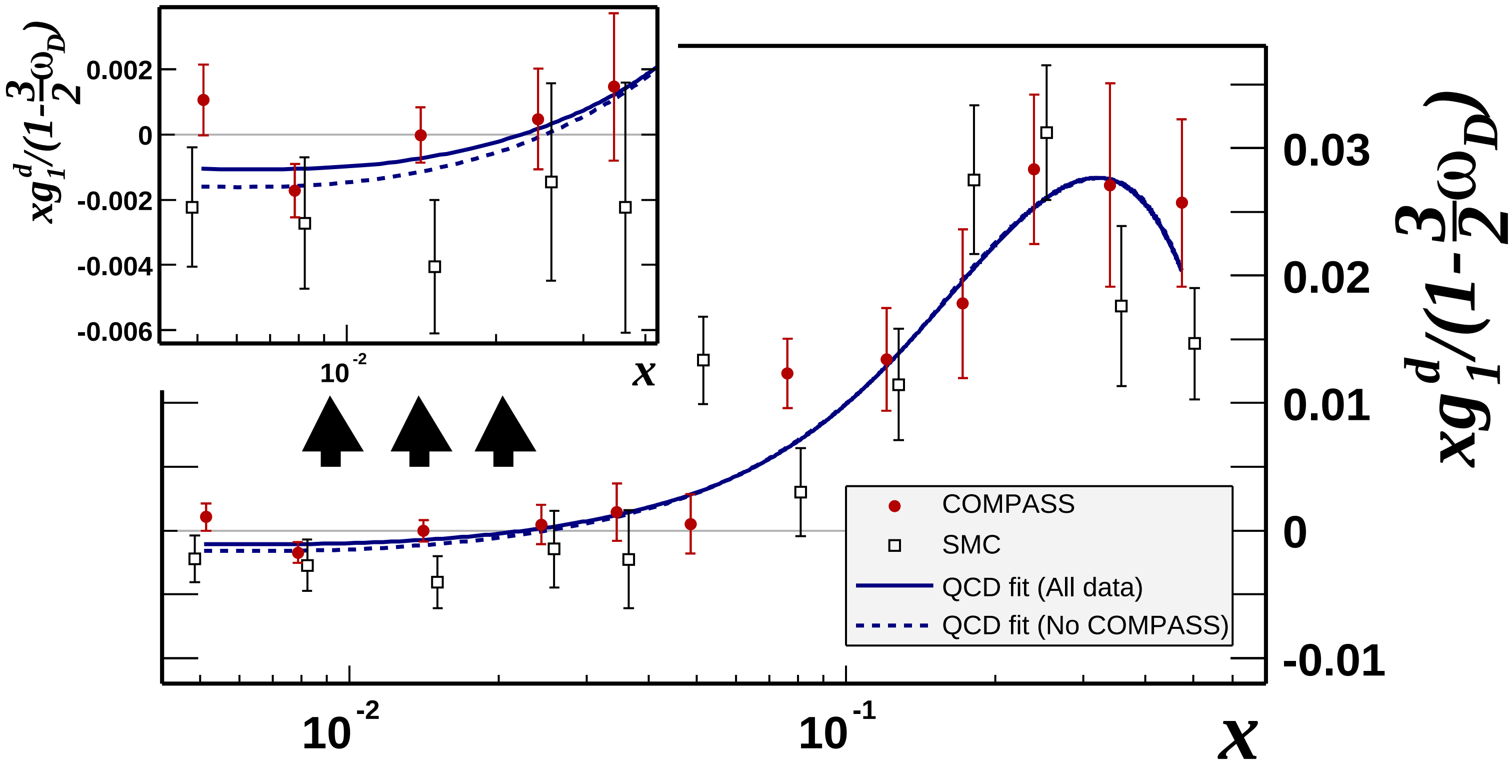
- Parametrisation of $\Delta\Sigma$, Δq_3, Δq_8 and ΔG:

$$\Delta f = \frac{\eta}{\int_0^1 x^\alpha (1-x)^\beta (1+\gamma x) \mathrm{d}x} x^\alpha (1-x)^\beta (1+\gamma x)$$

- Minimization by MINUIT $\chi^2 = \sum_{i=1}^{N} \frac{\left[g_1^{\mathrm{calc}}(x,Q^2) - g_1^{\mathrm{exp}}(x,Q^2)\right]^2}{\left(\sigma_{\mathrm{stat}}^{\mathrm{exp}}(x,Q^2)\right)^2}$

- 11 free parameters fitted

Results: A QCD fit to world data



Shown at measured Q^2

Results: A QCD fit to world data

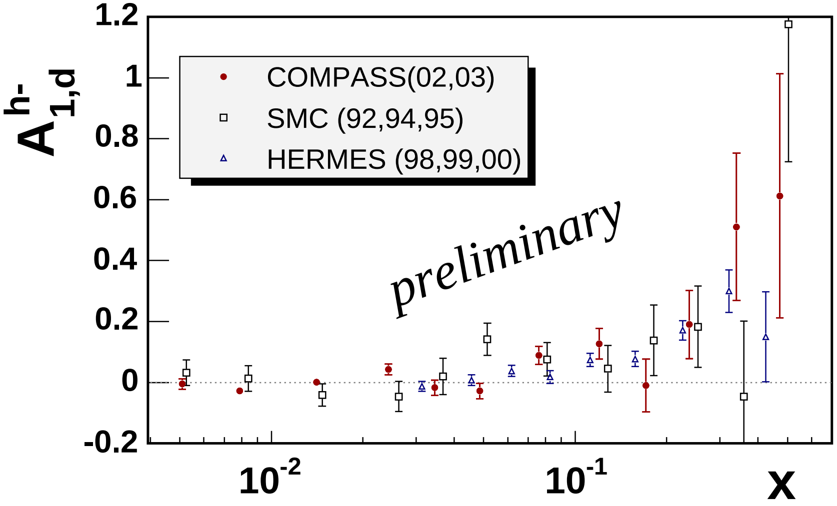
The COMPASS data change the $\int_0^1 \Delta\Sigma(x)\mathrm{d}x$ Integral:

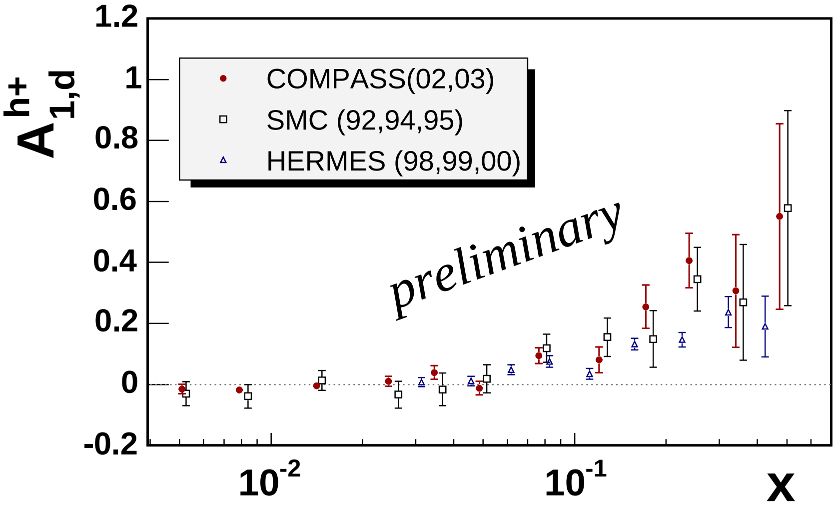
$$\begin{aligned} \int_0^1 \Delta\Sigma(x)\mathrm{d}x &= 0.237^{+0.024}_{-0.029} && \text{all data} \\ &= 0.202^{+0.042}_{-0.077} && \text{w/o COMPASS} \end{aligned}$$

Taken at $Q^2 = 4\mathrm{GeV}^2/c^2$.

Precision improved by a factor of 2

Semi-inclusive asymmetries





Summary and Outlook

- New data for A_1^d and g_1^d were shown
  $\hookrightarrow$ significant improvement at low x

- Asymmetries for low Q^2 will come soon

- COMPASS has a lot more interesting topics:
  - N. d'Hose: Diffractive ρ^0 production at COMPASS
  - P. Pagano: Collins and Sivers asymmetries on the deuteron from the COMPASS data
  - R. Joosten: Transversity signals in two hadron correlation at COMPASS
  - C. Bernet: Recent measurement of $\Delta G/G$ at COMPASS
  - ...and more to be shown elsewhere