The spin structure function of the proton g_1^p measured at COMPASS

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Outline

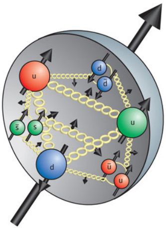
What is the nucleon spin made up of?

Spin contribution

Spin sum rule :

$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z^g + L_z^q$$

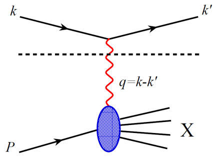
where $\Delta\Sigma = \Delta u + \Delta d + \Delta s$



This talk focuses on the COMPASS polarised DIS campaigns on a proton target (2007 & 2011)

Polarised deep inelastic scattering: Access to g_1

DIS process



Kinematic variables

$Q^2 = -q^2 = -(k-k')^2$	virtuality of the photon
$x_{Bj} = \frac{Q^2}{2M_p\nu}$	Bjorken variable

Inclusive cross section

$$\frac{d^2\sigma}{dx_{Bj}dQ^2} = \underbrace{c_1\, F_1(x_{Bj}, Q^2) + c_2\, F_2(x_{Bj}, Q^2)}_{\textit{unpolarised structure functions}} + \underbrace{c_3^{s,S}\, g_1(x_{Bj}, Q^2) + c_4^{s,S}\, g_2(x_{Bj}, Q^2)}_{\textit{polarised structure functions}}$$

Beam and target polarised $\rightarrow$ Access to g_1

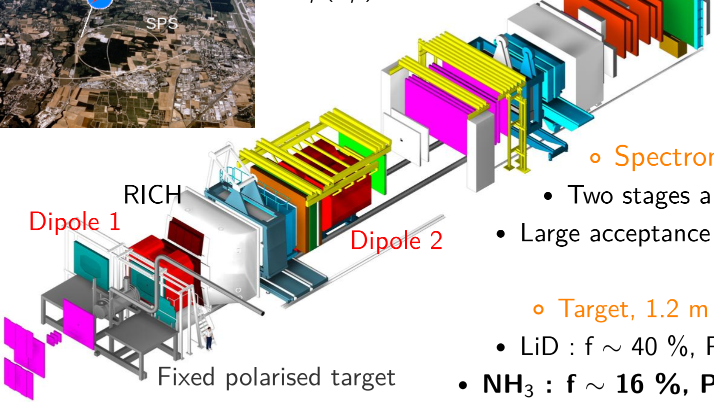
COMPASS spectrometer

- Polarised μ^+ beam from SPS

  $2 \cdot 10^8$ $(1 \cdot 10^8)$ μ per spill of $\sim$ 10 s

  160 GeV (200 GeV)

  $P_\mu(E_\mu)$=76–80%



- Spectrometer :
  - Two stages along 60 m
  - Large acceptance 180 mrad
- Target, 1.2 m long:
  - LiD : f $\sim$ 40 %, P_T $\sim$50%
  - **NH_3 : f $\sim$ 16 %, P_T $\sim$85%**

DIS campaigns

Years	Target	Beam Energy	No. of DIS events ($\times 10^6$)
2002-2006	^{6}LiD	160 GeV	135.1
2007	NH_3	160 GeV	85.3
2011	NH_3	200 GeV	78

- Get statistics at low x_{Bj} for longitudinally polarised protons
- Balance measurements between proton and deuteron data for analyses using both
  - → Flavour separation: Δq poorly known at low x_{Bj}
  - → Bjorken sum rule: projected precision : $\int_{0.003}^{0.7} g_1^{NS} dx$: $\pm 0.006(stat.) \pm 0.011(syst.)$
- Extend the kinematic domain for ΔG extraction via global fits

g_1 extraction from double spin asymmetry

Double spin asymmetry

$$A_{\parallel} = \frac{d\sigma^{\rightleftarrows} - d\sigma^{\rightrightarrows}}{d\sigma^{\rightleftarrows} + d\sigma^{\rightrightarrows}} = D(A_1 + \eta A_2)$$

where D and η are kinematic variables.

COMPASS case : $\eta \propto \frac{x_{Bj}}{Q} \sim 0$

Virtual photon-nucleon asymmetry

$$A_1 = \frac{g_1 - \gamma^2 g_2}{F_1} \sim \frac{g_1}{F_1} \qquad A_2 = \gamma \frac{g_1 + g_2}{F_1} \sim 0$$

where $\gamma \propto \frac{x_{Bj}}{Q}$ is a kinematic variable (small at COMPASS)

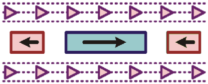
$$\Rightarrow A_{\parallel} \approx D \cdot \frac{g_1}{F_1}$$

COMPASS target

$$\frac{A_{\parallel}}{D} = \frac{1}{|P_B \, P_T| \; f \; D} \left(\frac{N^{\rightleftarrows} - N^{\rightrightarrows}}{N^{\rightleftarrows} + N^{\rightrightarrows}} \right)$$

Simultaneous recording of the two spin states in oppositely polarised target cells

COMPASS target

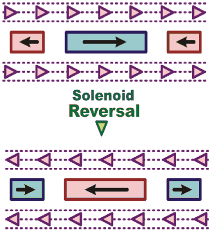


COMPASS target

$$\frac{A_{\parallel}}{D} = \frac{1}{|P_B\, P_T|\; f\; D} \left(\frac{N^{\rightleftarrows} - N^{\rightrightarrows}}{N^{\rightleftarrows} + N^{\rightrightarrows}} \right)$$

Simultaneous recording of the two spin states in oppositely polarised target cells

COMPASS target



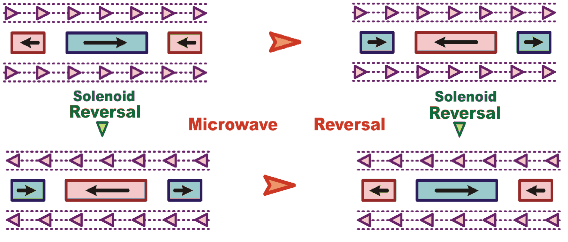
$\rightarrow$ Reversal by field rotation every 24h to cancel out acceptance difference

COMPASS target

$$\frac{A_{\parallel}}{D} = \frac{1}{|P_B\, P_T|\; f\; D} \left(\frac{N^{\rightleftarrows} - N^{\rightrightarrows}}{N^{\rightleftarrows} + N^{\rightrightarrows}} \right)$$

Simultaneous recording of the two spin states in oppositely polarised target cells

COMPASS target

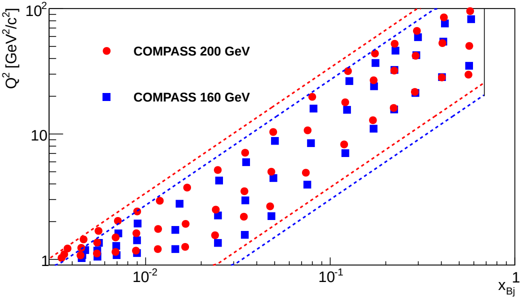


→ Reversal by field rotation every 24h to cancel out acceptance difference
→ Reversal by micro-wave once in a while to cancel out acceptance/field correlation

Kinematic domain

COMPASS :

- $0.0025 \leq x_{Bj} \leq 0.7$
- $1\ \mathrm{GeV}^2 \leq Q^2 \leq 120\ \mathrm{GeV}^2$



→ COMPASS is the only experiment to reach $x_{Bj} \sim 10^{-3}$ in polarised DIS

Systematic error

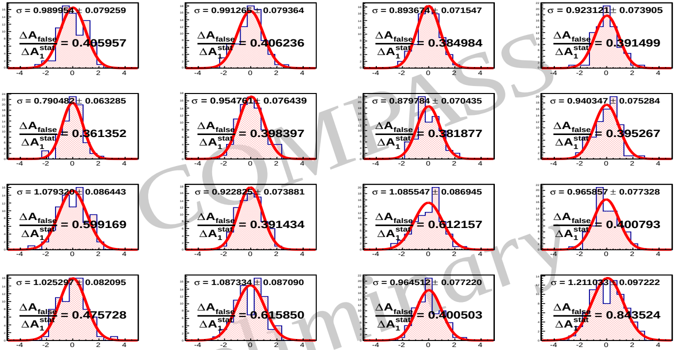
- Two kinds of contributions:
  - Multiplicative
  - Additive

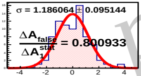
$$A_1^{1\gamma} = \frac{1}{fDP_BP_T}A^{raw} - \left(A_1^{RC} + \mathcal{O}(\frac{x}{Q}A_2) + \mathcal{O}(A_{False})\right)$$

Multiplicative variables error, ΔA_1^{mult}	Beam polarisation	dP_B/P_B	5%
	Target polarisation	dP_T/P_T	5%
	Depolarisation factor	dD/D	2 – 3 %
	Dilution factor	df/f	2 %
	Total		$\Delta A_1^{mult} \simeq 0.08A_1$
Additive variables error, ΔA_1^{add}	Transverse asymmetry	$\mathcal{O}(x/Q)\cdot\Delta A_2$	$10^{-3} - 10^{-2}$
	Rad. corrections	ΔA_1^{RC}	$0.1\cdot Max(\lvert A_{1,\ incl}^{RC}\rvert, \lvert A_{1,\ hadr}^{RC}\rvert) = 10^{-5} - 10^{-3}$
	False asymmetry	ΔA_{false}	$< 0.34 : 0.84 \cdot \Delta A_1^{stat}$ **(Dominant)**

False asymmetry estimation: Stability over time

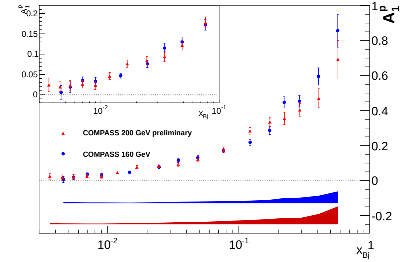
- 1 pull distribution per x-bin
- 1 entry ∼ 48h of data with 1 field rotation

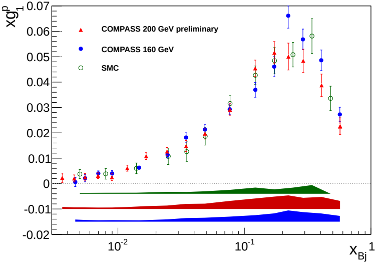




- Instability impact: smaller than 0.34 to 0.84 x the statistical error

COMPASS Proton results at 200 GeV and 160 GeV





$$g_1(x_{Bj}) = \frac{F_2}{2\,x_{Bj}\,(1+R)} A_1$$

- SMC parametrisation of F_2

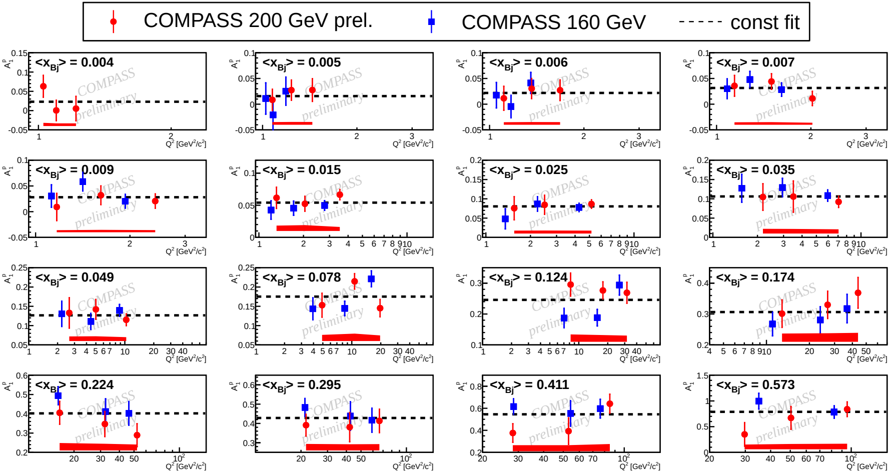
  SMC PRD **55** (1998) 112001

- $\mathrm{R} = \frac{\sigma^L}{\sigma^T}$

  COMPASS PLB **647** (2007) 330

- Statistical errors (2007 and 2011) 2-3 times smaller than 2 years of SMC.
- Lower x_{Bj} value reached

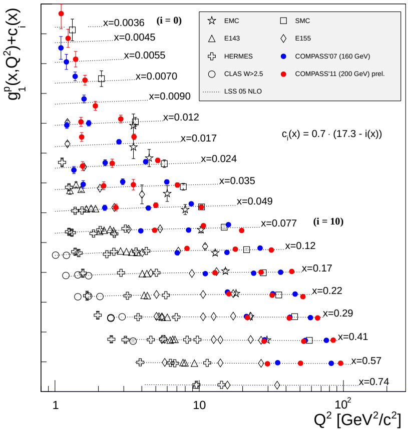
Asymmetry A_1^p : Q^2 evolution



$\Rightarrow$ No significant dependence on Q^2 observed

Indirect measurement of ΔG, g_1^p: Q^2 evolution

World data $g_1^p(x)$
as a function of Q^2 in bins of x



- COMPASS 160 GeV
- COMPASS 200 GeV
- NEW data point at very low x

New inputs for global fits and indirect ΔG extraction

LSS'05 fit at next-to-leading order

PRD **73** (2006) 034023

Conclusions

→ Improvement of statistics with the new results of g_1^p at 200 GeV

→ Extension of the measured region to lower x_{Bj} and larger Q^2

→ New inputs and constraints for global fits

Outlook

- Update of the Bjorken Sum Rule
- Indirect measurement of ΔG via g_1 COMPASS global fit
- Extraction of $A_{1,p}^{\pi^+}$, $A_{1,p}^{\pi^-}$,$A_{1,p}^{K^+}$ and $A_{1,p}^{K^-}$
- Extraction of Δq per flavour

BACKUP

Triggers contribution

- Inclusive sample: largest contribution
- Large x_{Bj}: Equal contribution from semi-inclusive & inclusive sample
- Large Q^2: Largest contribution from the semi-inclusive sample