Results on A_1^p and g_1^p from 2011 COMPASS data

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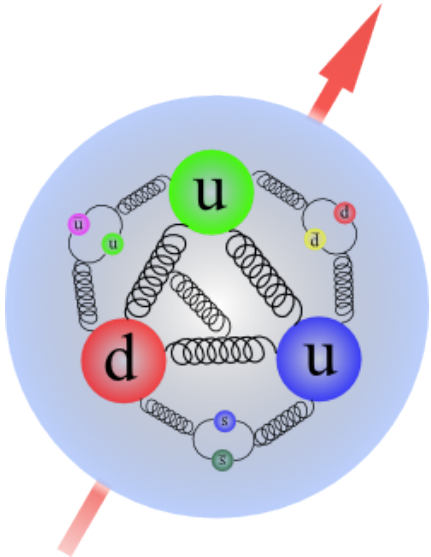
Outline

Motivation

Spin Contribution:

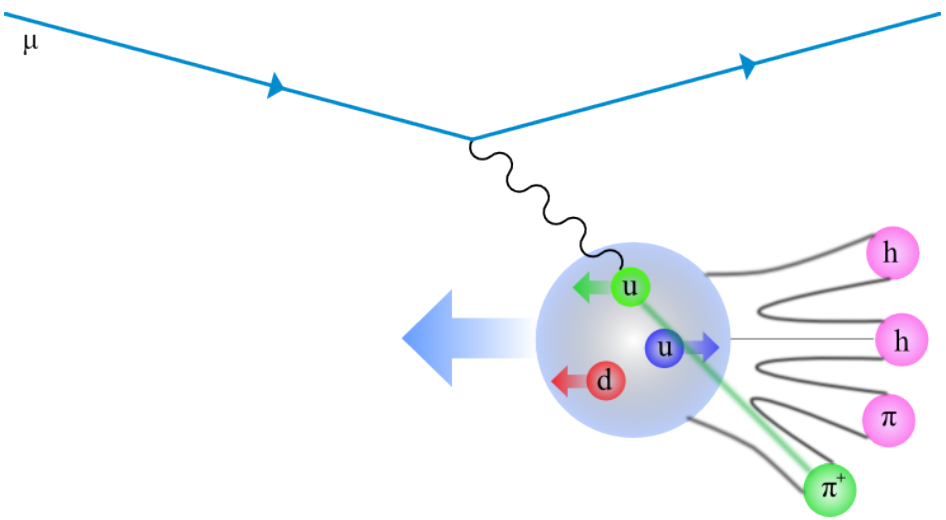
$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

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



- Quarks spin contributes only 30% to the nucleon spin
- Gluon contribution known only for a limited x range
- Hardly any experimental information on orbital angular momentum

Deep Inelastic Scattering

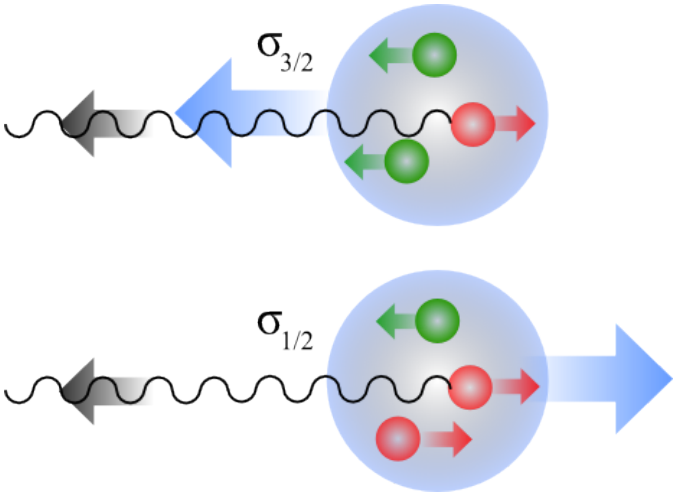


- 4-momentum of the virtual photon: $q = k - k'$
- Energy of the virtual photon: $\nu = \frac{Pq}{M} \overset{\text{lab}}{=} E - E'$
- $Q^2 = -q^2 \overset{\text{lab}}{\approx} 4EE' \sin^2 \frac{\theta}{2}$
- Bjorken scaling variable: $x \overset{\text{lab}}{=} \frac{Q^2}{2M\nu}$
- $y \overset{\text{lab}}{=} \frac{\nu}{E}$

Inclusive cross section:

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\Omega \mathrm{d}E'} \sim \underbrace{c_1 F_1(x, Q^2) + c_2 F_2(x, Q^2)}_{\text{spin independent}} + \underbrace{c_3 g_1(x, Q^2) + c_4 g_2(x, Q^2)}_{\text{spin dependent}}$$

Polarised Deep Inelastic Scattering



- Absorption of polarised photons
  $\sigma_{1/2} \sim q^+$
  $\sigma_{3/2} \sim q^-$
- $q(x) = q(x)^+ + q(x)^-$
  $\Delta q(x) = q(x)^+ - q(x)^-$

- Photon nucleon asymmetry

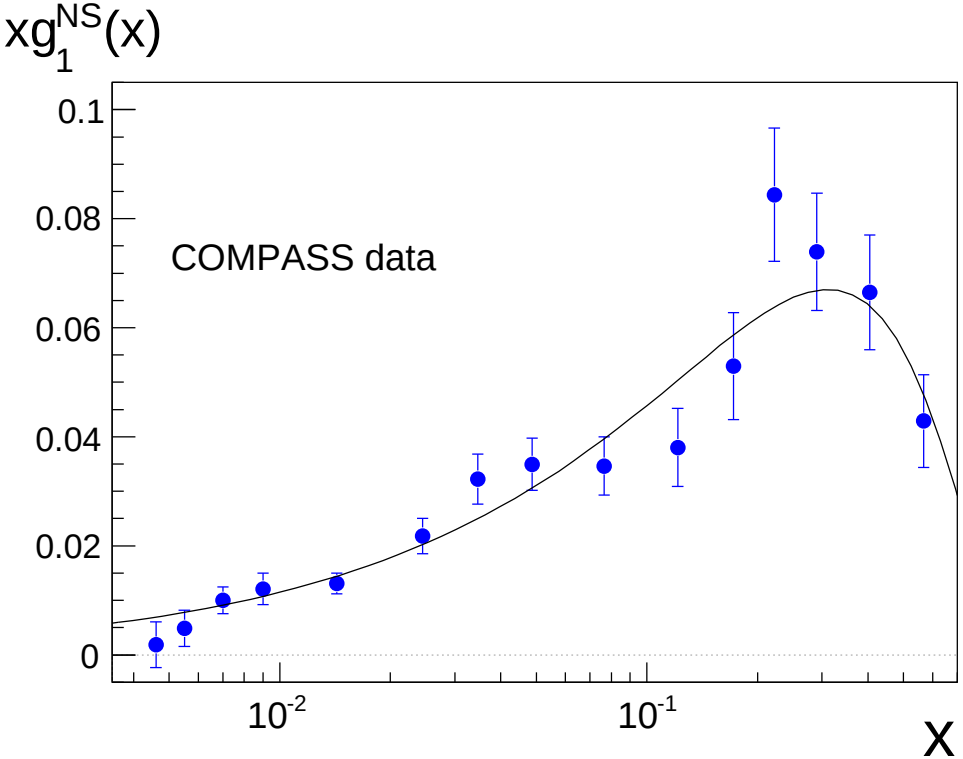
$$A_1(x, Q^2) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{\sum_q e_q^2 (q(x)^+ - q(x)^-)}{\sum_q e_q^2 (q(x)^+ + q(x)^-)} = \frac{g_1(x, Q^2)}{F_1(x, Q^2)}$$

- Spin structure function

$$g_1(x, Q^2) = \frac{1}{2} \sum_q e_q^2 \Delta q(x) = A_1(x, Q^2) \cdot F_1(x, Q^2)$$

Bjorken Sum Rule

$$\int_0^1 g_1^{NS}(x,Q^2)dx = \int_0^1 \left(g_1^p(x,Q^2) - g_1^n(x,Q^2)\right) dx = \frac{1}{6}\left|\frac{g_A}{g_V}\right| C_1^{NS}(Q^2)$$



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Previous results

- g_1^{NS} determined only from COMPASS data @ $Q^2 = 3$ (GeV/c)^2
- $\left|\frac{g_A}{g_V}\right| = 1.2694 \pm 0.0028$ obtained from neutron β-decay.
- COMPASS result: $\left|\frac{g_A}{g_V}\right| = 1.28 \pm 0.07 \pm 0.10$
- Verification of the Bjorken sum rule

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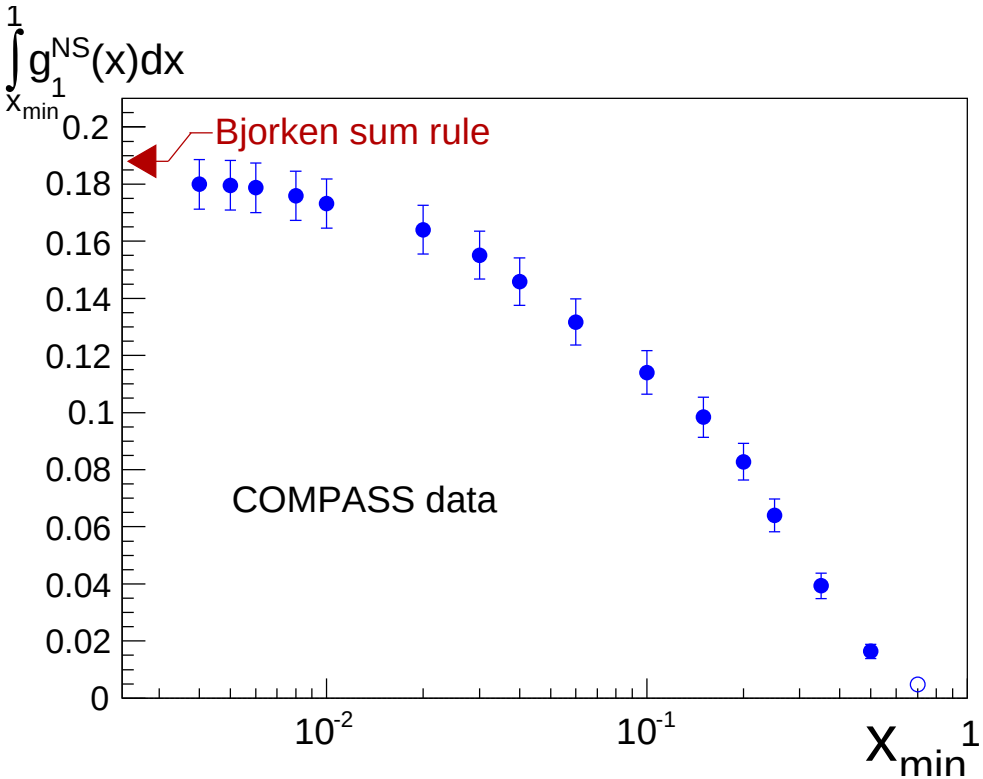

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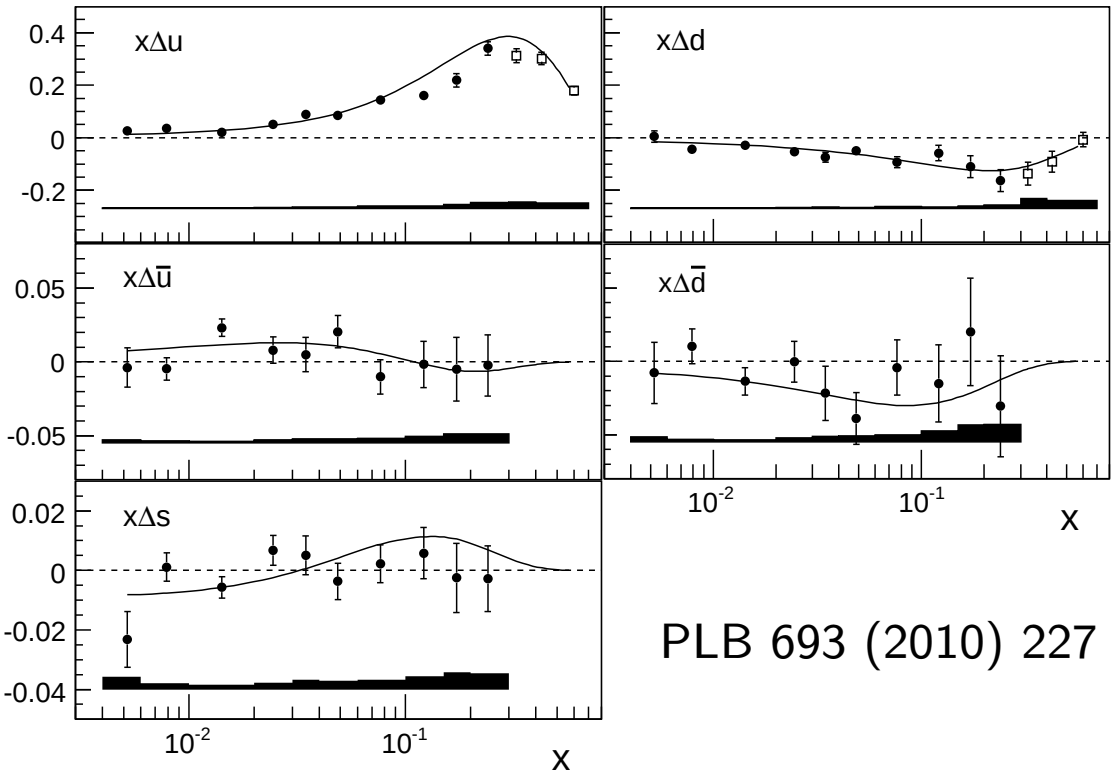
Polarised PDFs from LO fit

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



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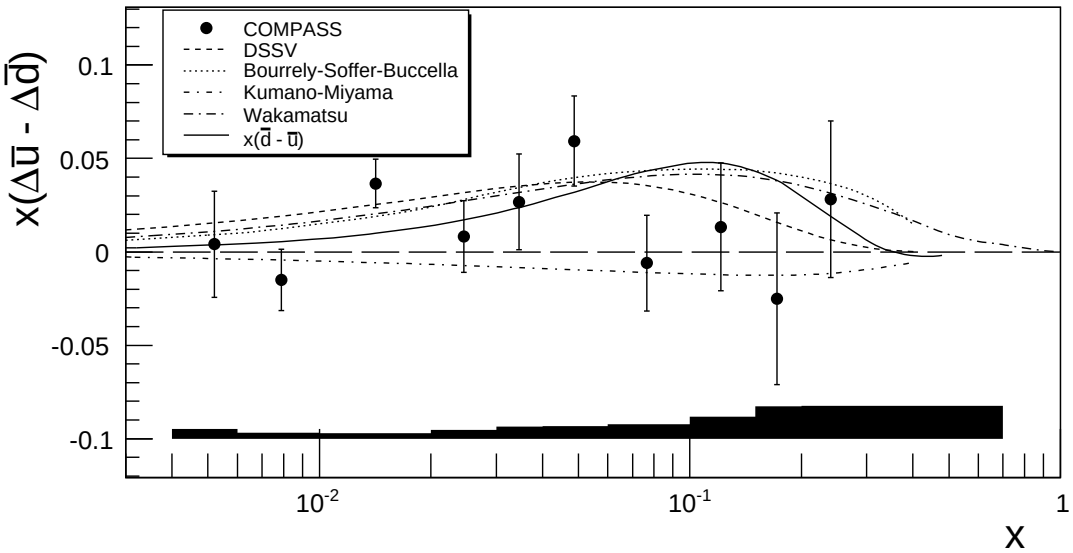
Previous results

- Input:
  - Unpolarised PDF $q(x)$, $\bar{q}(x)$
  - Fragmentation function D_q^h, $D_{\bar{q}}^h$ describing $q \to h$
- Measured:

  A_{1p}, $A_{1p}^{\pi+}$, $A_{1p}^{\pi-}$, A_{1p}^{K+}, A_{1p}^{K-},

  A_{1d}, $A_{1d}^{\pi+}$, $A_{1d}^{\pi-}$, A_{1d}^{K+}, A_{1d}^{K-}
- Flavor asymmetry of the sea

Flavor asymmetry of the sea



- Compatible with zero
- Indication: Slightly positive
- Data compatible with all shown models $\rightarrow$ new data needed
- Data favour models with $\Delta\bar{u} - \Delta\bar{d} \approx \bar{d} - \bar{u}$

$$\int_{0.004}^{0.3} \left(\Delta\bar{u} - \Delta\bar{d}\right) \mathrm{d}x = 0.06 \pm 0.04 \pm 0.02$$

NLO pQCD analyses

- DGLAP equations

$$\frac{\mathrm{d}}{\mathrm{d}\ln Q^2}\Delta q_{NS} = \frac{\alpha_s(Q^2)}{2\pi}\Delta P_{qq}^{NS} \otimes \Delta q_{NS}$$

$$\frac{\mathrm{d}}{\mathrm{d}\ln Q^2}\begin{pmatrix}\Delta q_{Si}\\ \Delta g\end{pmatrix} = \frac{\alpha_s(Q^2)}{2\pi}\begin{pmatrix}\Delta P_{qq}^{S} & 2n_f\Delta P_{qg}\\ \Delta P_{gq} & \Delta P_{gg}\end{pmatrix}\otimes\begin{pmatrix}\Delta q_{Si}\\ \Delta g\end{pmatrix}$$

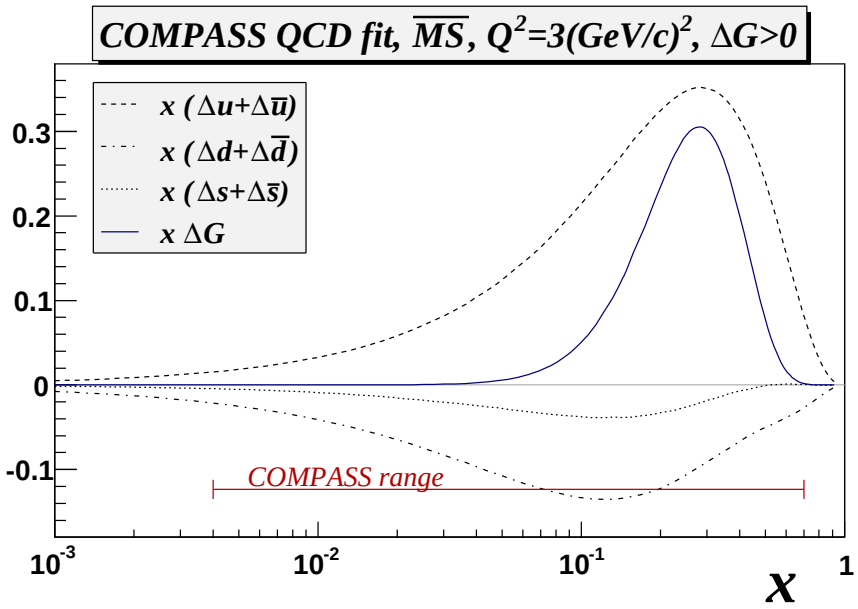
- Input parameterization F of $\Delta q_{Si}, \Delta q_3, \Delta q_8, \Delta g$ at Q_0^2

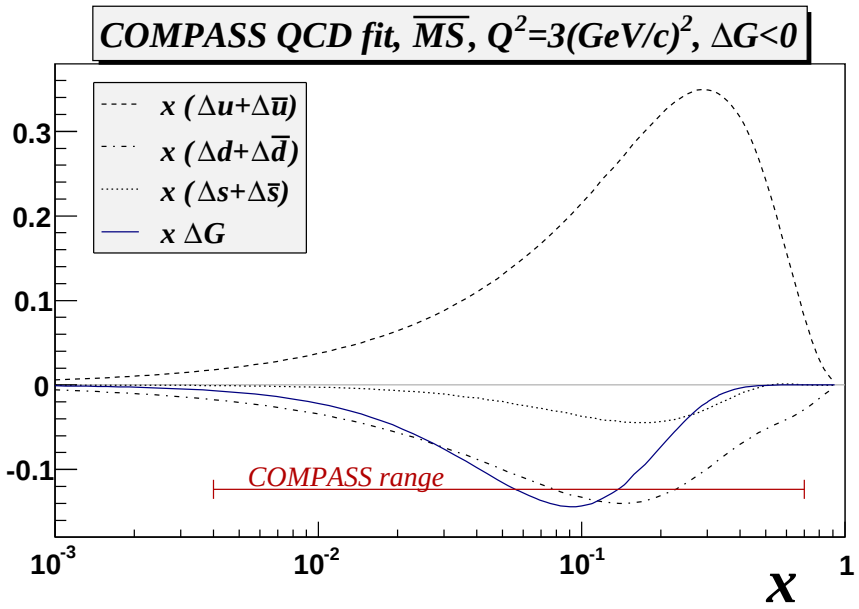
$$F = \eta\frac{x^\alpha(1-x)^\beta(1+\gamma x)}{\int_0^1 x^\alpha(1-x)^\beta(1+\gamma x)\mathrm{d}x}$$

with $\Delta q_{Si} = \Delta u + \Delta d + \Delta s$, $\Delta q_3 = \Delta u - \Delta d$, $\Delta q_8 = \Delta u + 2\Delta d - \Delta s$

- using only inclusive asymmetries quarks and anitquarks cannot be disentangled *e.g.* determination of $\Delta u + \Delta\bar{u}$, $\Delta d + \Delta\bar{d}$, $\Delta s + \Delta\bar{s}$ and Δg
- many analyses from different groups (theor. and exp.)
  e.g. COMPASS, LSS, GRSV, BB, AAC, DSSV.....

Polarised parton distributions





- Small sensitivity to light sea and gluon polarisation
- Quark polarisation $\Delta\Sigma = \int \Delta q_{Si}(x)\mathrm{d}x$

$$\Delta\Sigma = 0.30 \pm 0.01(\textbf{stat}) \pm 0.02(\textbf{evol})$$

- Gluon polarisation $\Delta G = \int \Delta g(x)\mathrm{d}x \qquad |\Delta G| < 0.5$
- Strange quark polarisation

$$\Delta s + \Delta\bar{s} = -0.08 \pm 0.01(\mathrm{stat}) \pm 0.02(\mathrm{syst})$$

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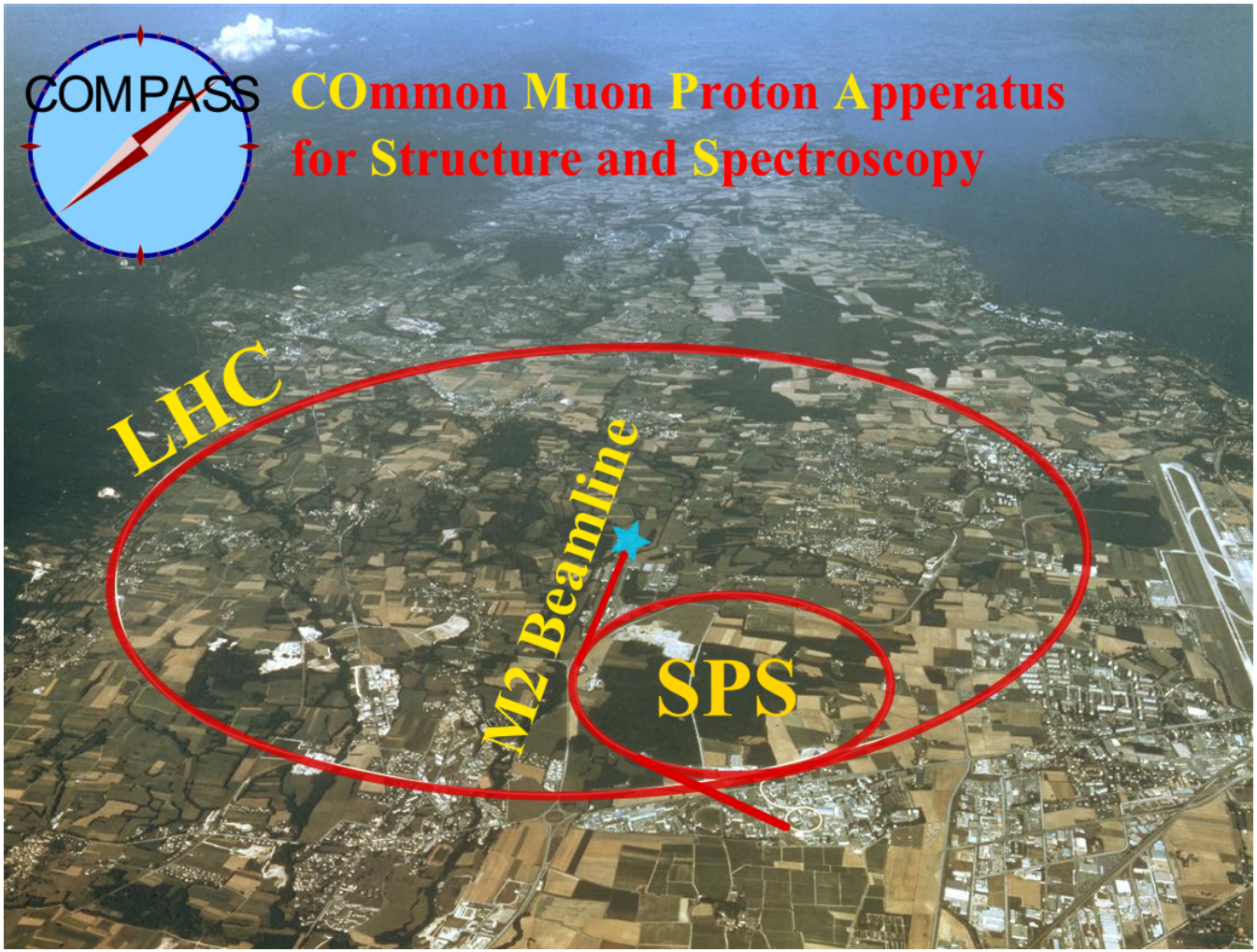
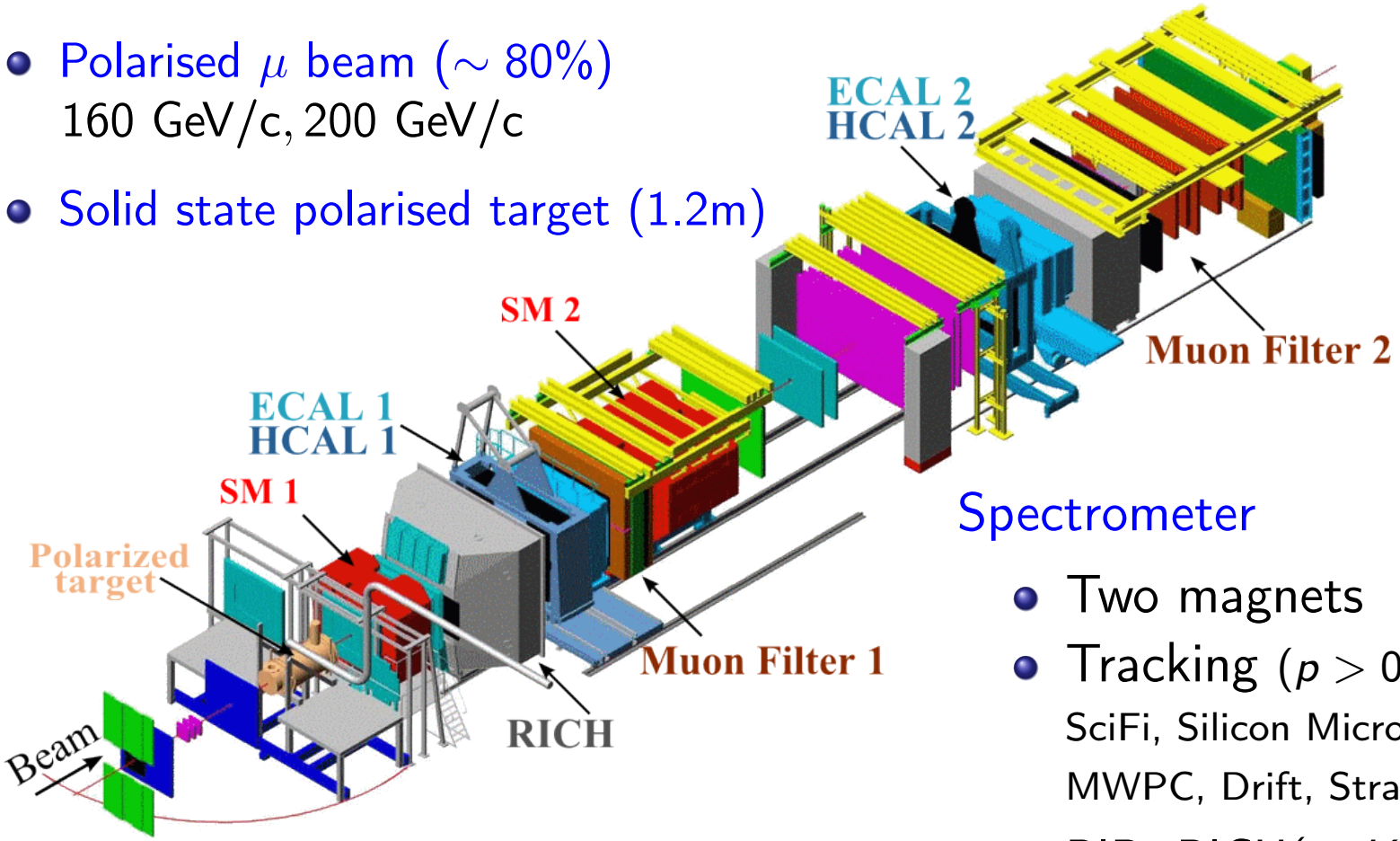
COMPASS



- SPS proton beam: 400 GeV
- Secondary hadron beams (p, K,π) 150 – 270 GeV
- Tertiary muon beam 160 – 200 GeV

COMPASS @ CERN

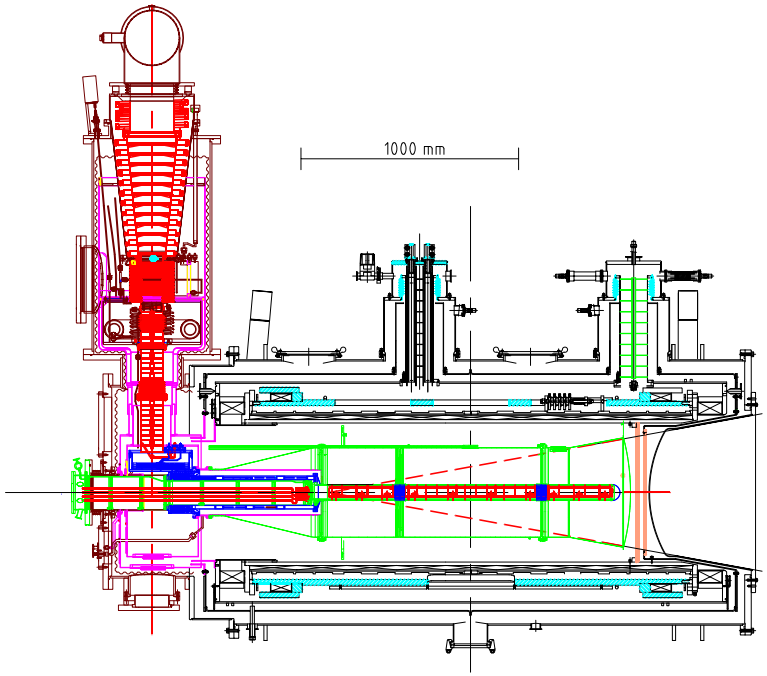
- M2 beamline
- Polarised μ beam ($\sim 80\%$)
  160 GeV/c, 200 GeV/c
- Solid state polarised target (1.2m)

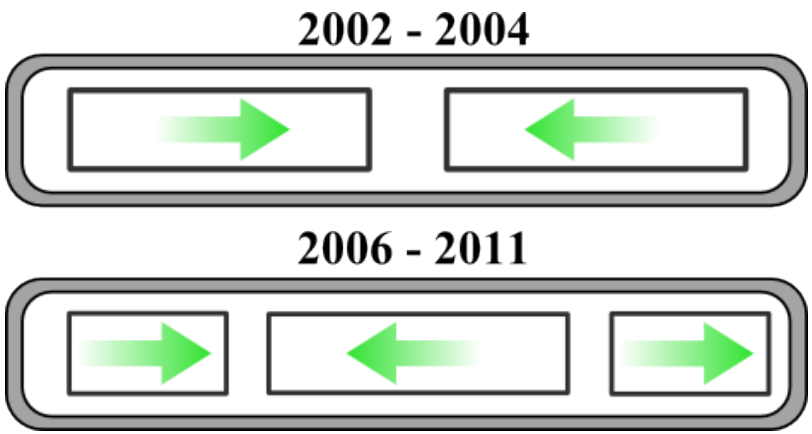


Spectrometer

- Two magnets
- Tracking ($p > 0.5$ GeV/c)
  SciFi, Silicon MicroMega, Gem
  MWPC, Drift, Straws, Driftubes
- PID: RICH(π, K, p)
  ECAL, HCAL, muon filters

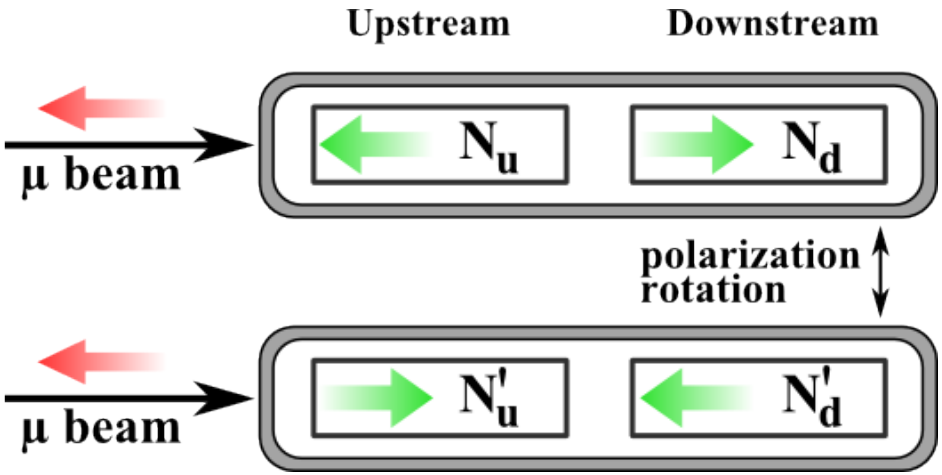
Polarised target





- Upgrade of the target system in 2005
- Three target cells, oppositely polarised
- 180 mrad geometrical acceptance
- Regular polarisation reversals by field rotation
- 2.5 T solenoid field
- Low temperature 50 mK
- NH_3 (Longitudinal proton polarisation: $\sim 90\%$)

Method



- Aim:
  $A = \frac{\sigma^{\Uparrow\downarrow} - \sigma^{\Uparrow\uparrow}}{\sigma^{\Uparrow\downarrow} + \sigma^{\Uparrow\uparrow}}$
- Measured:
  $A_{exp} = \frac{N_u - N_d}{N_u + N_d}$
- Needed:
  - Flux cancellation
  - Acceptance cancellation
    $\rightarrow$ polarisation rotation
    $\rightarrow$ 3 target cells
- $A_{exp} = A \cdot P_B \cdot P_T \cdot f$

- Averaging:

$$A_{exp} = \frac{A + A'}{2} = \frac{1}{2}\left(\frac{N_u - N_d}{N_u + N_d} + \frac{N'_u - N'_d}{N'_u + N'_d}\right)$$

2011 Data

2007 and 2011 data taking

- Target: NH_3
- Increased beam energy
  160 GeV $\rightarrow$ 200 GeV
- Higher Q^2
- Smaller x

Improve results on

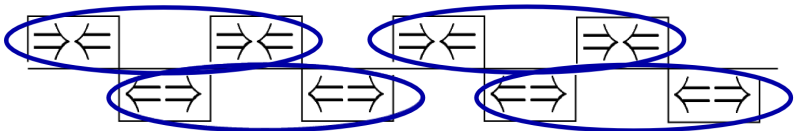
- Bjorken sum rule (systematic error)
- QCD fit
- Flavor asymmetry

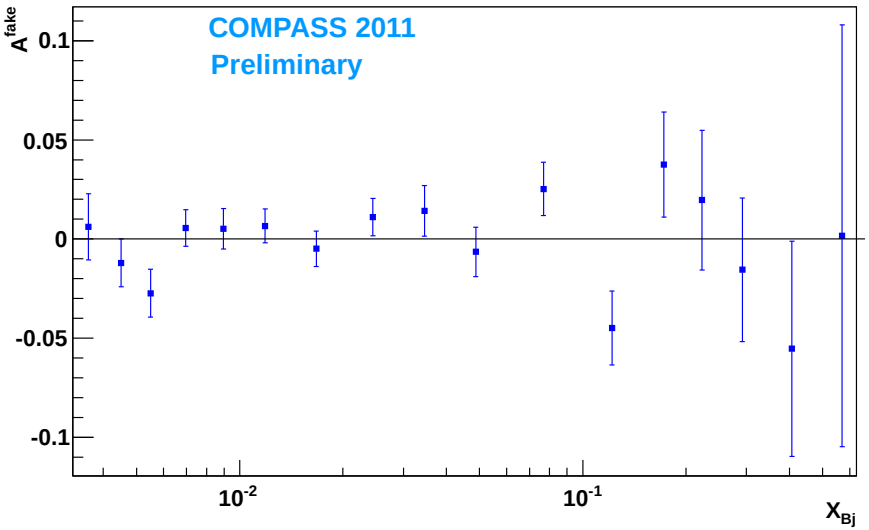
Event selection

- Kinematic cuts:
  - $Q^2 > 1$ (GeV/c)^2
  - $0.1 < y < 0.9$ remove radiative events
- $0.0025(0.0040) < x < 0.7$
- Extrapolated beam track crosses all target cells
  $\rightarrow$ Flux cancellation

Systematic studies

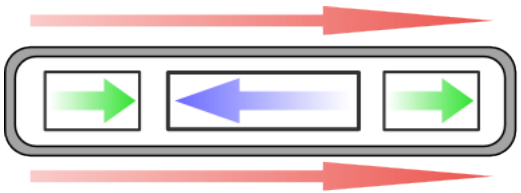
- Determination of the exact target position
- Checking the data quality
  $\rightarrow$ e.g. Influence of small detector movements, detector problems,...
- Most important contribution to the systematic error
  $\rightarrow$ False asymmetries
  - Fake configuration (same spin orientation)





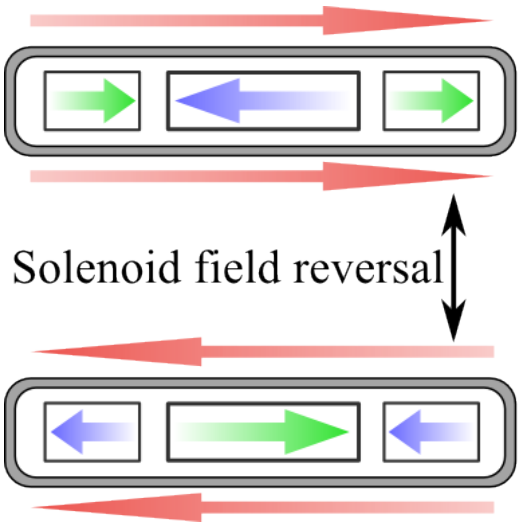
Microwave reversal

- Simultaneous data taking for both spin configurations



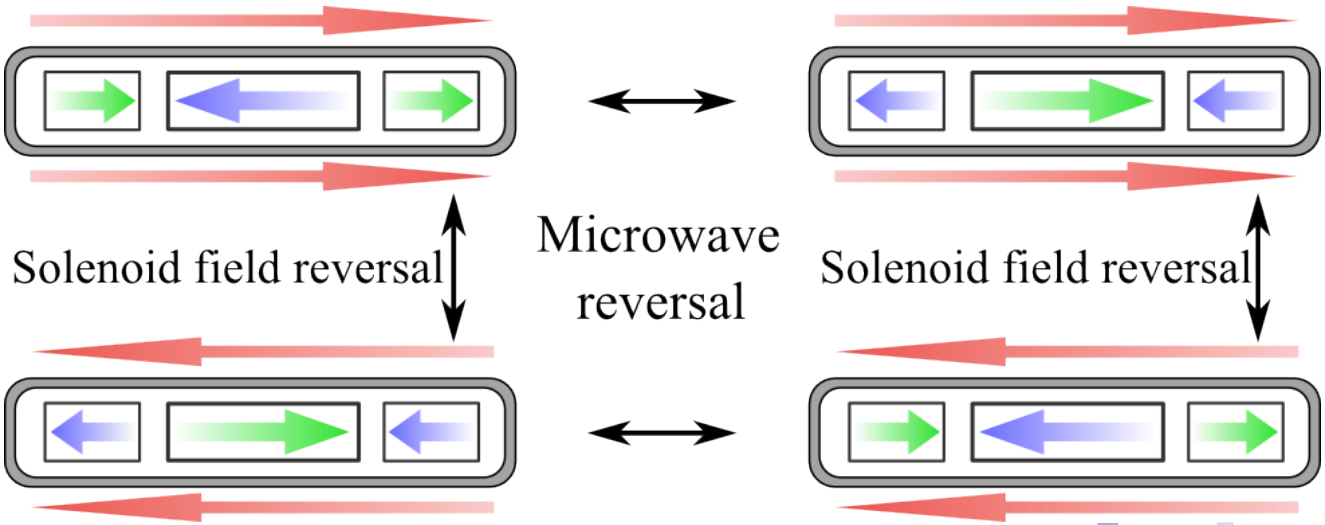
Microwave reversal

- Simultaneous data taking for both spin configurations
- Rotating the solenoid field every 24 h

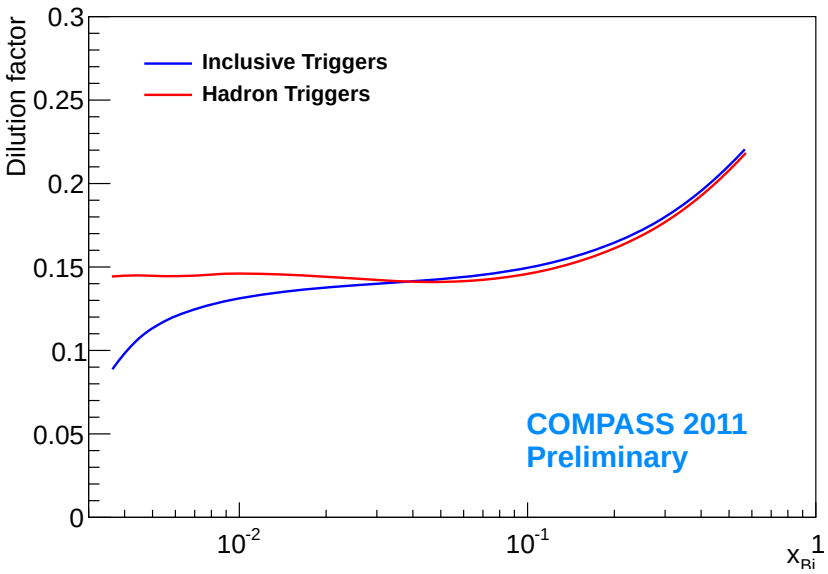


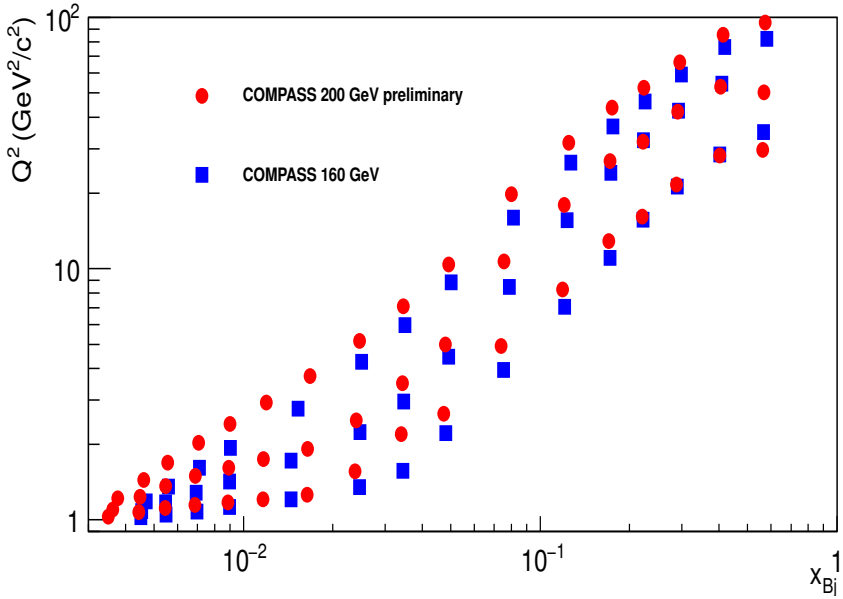
Microwave reversal

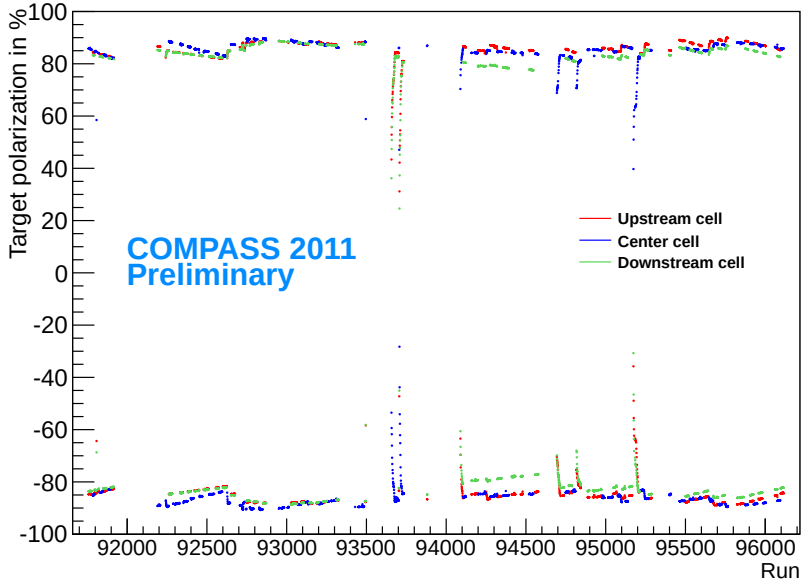
- Simultaneous data taking for both spin configurations
- Rotating the solenoid field every 24 h
- Changing the microwave settings in the middle of 2011
- Reducing the systematic uncertainty due to acceptance / field differences
- Comparing results on A_1 for both microwave settings gives hint on false asymmetries $\Rightarrow$ Negligible effect



Input for A_1^p

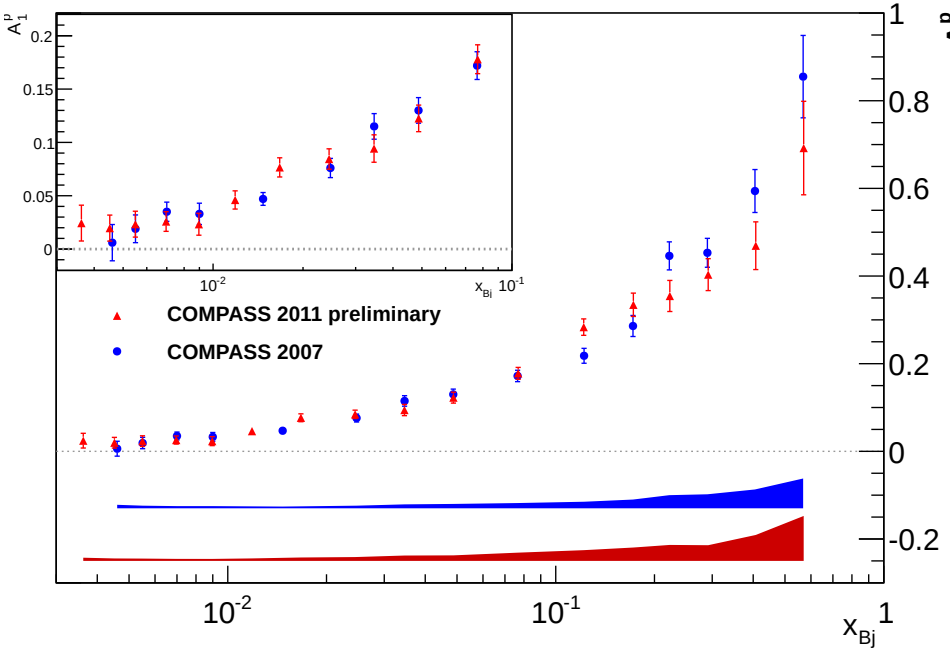


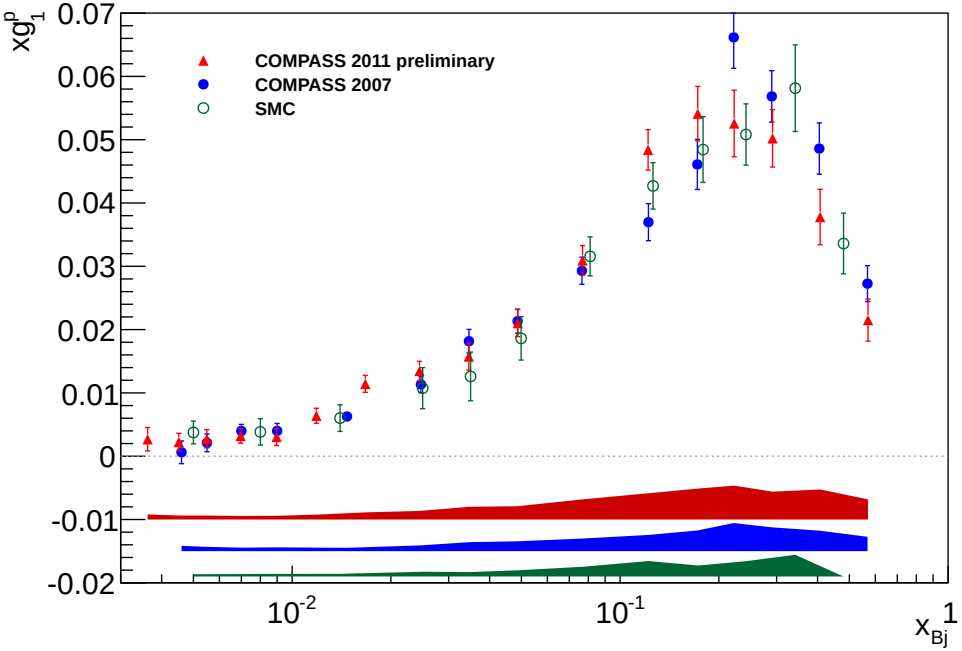




- $78 \cdot 10^6$ Events
- Dilution factor includes radiative corrections
- Higher Q^2 /Smaller x in 2011
- Reach $x \sim 10^{-3}$ in polarised DIS

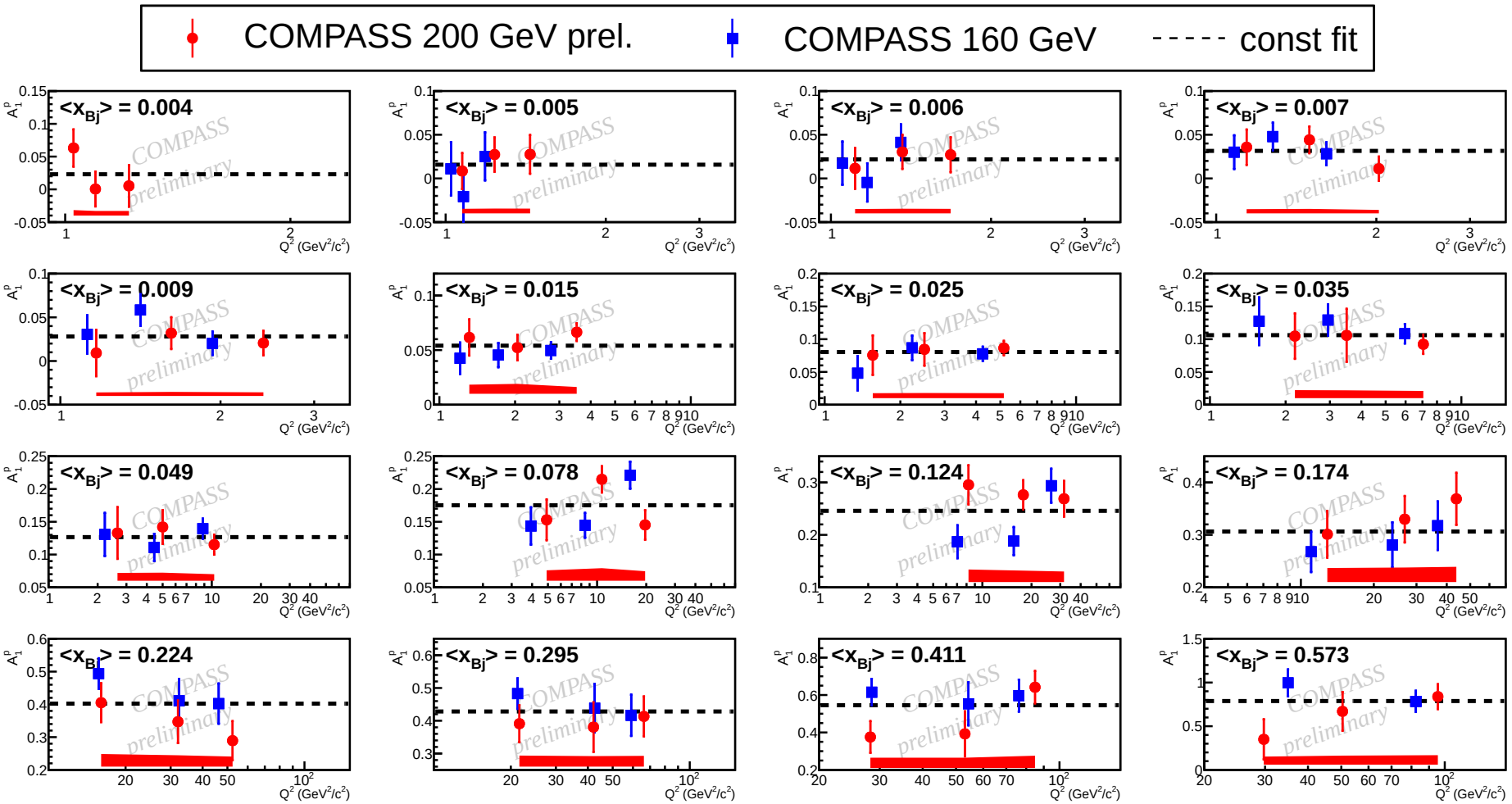
Results for A_1^p in bins of x





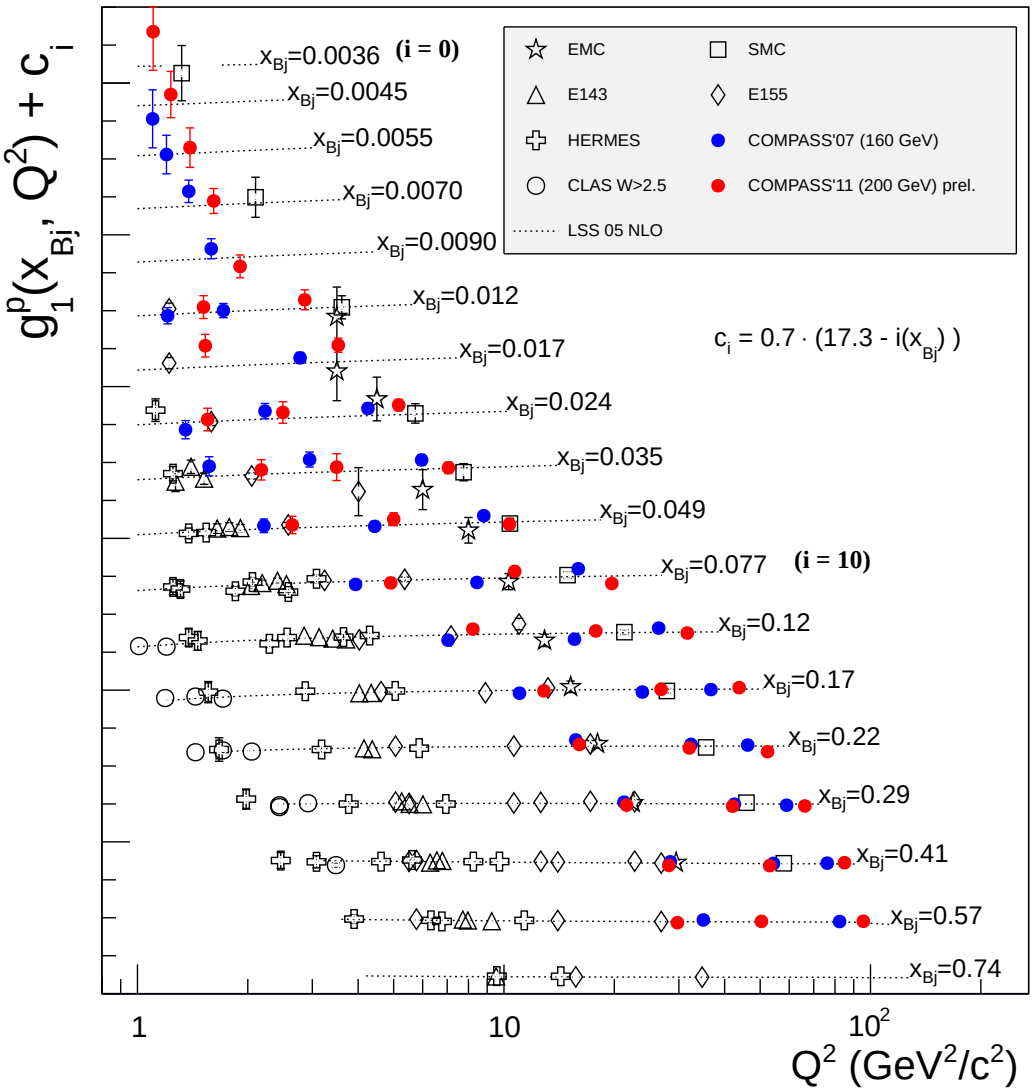
- Good agreement between COMPASS 2011/07 and SMC
- Combined statistical uncertainty (2011 + 2007) smaller than SMC
- $g_1^p(x, Q^2) = A_1^p \cdot F_1^p$

Q^2 dependence of $A_1 p$



- No Q^2 dependence visible
- New data point at very small x

Results in bins of x and Q^2



- COMPASS 2011 (200 GeV)
- COMPASS 2007 (160 GeV)
- LSS'05 fit at NLO
- New data point at very low x
- New input for global QCD fit
- Indirect ΔG extraction

Summary and Outlook

- New measurement at 200 GeV/c
- Measurement of A_1^p and g_1^p
  - New value at small x
  - 2011 data improve the precision of the COMPASS results
- Outlook
  - Improve the results on the test of the Bjorken sum rule
  - Identified hadron asymmetry
  - LO extraction of polarised PDFs
  - Include our results in a NLO pQCD fit