# New results on the proton spin-dependent structure function $g_1^p$ at COMPASS with $E = 200$ GeV

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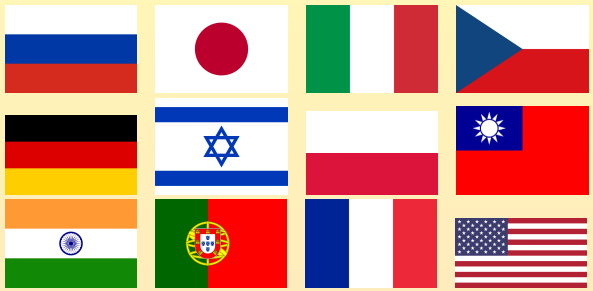
# COmmon Muon and Proton Apparatus for Structure and Spectroscopy



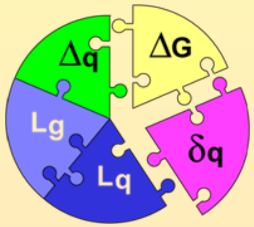
NA58 at the CERN SPS
$\sim$ 250 physicists
$\sim$ 30 institutes

| Muon programm | Hadron programm |
|---|---|
| Spin dependent structure function $g_1$ | |
| Gluon polarisation in the nucleon | Primakoff effect, $\pi$ and $K$ polarisabilities |
| Quark polarisation distributions | Exotic states, glueballs |
| Transversity | (Double) charmed barions |
| Vector meson production | Multiquark states |
| $\Lambda$ polarisation | |

Future: Drell-Yan on a polarised target and DVCS

# How is the nucleon spin distributed among its constituents?

Nucleon spin

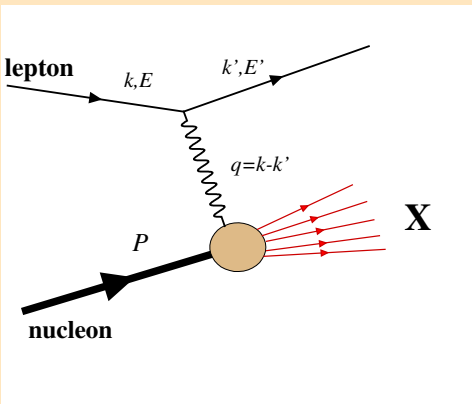



$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{q,g}$$

quark gluon orbital momentum

The direct evidence for existence of quarks inside the nucleon is provided by DIS. The idea is to accelerate leptons to very high energies, then allow them to interact with a stationary nucleon, and investigate what happens.

## Inclusive Deep Inelastic Scattering

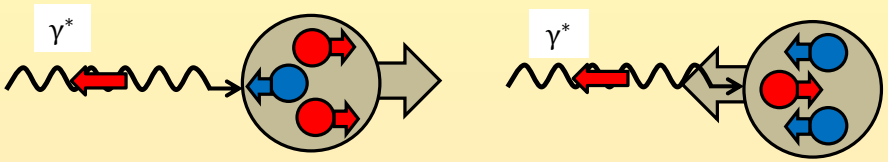



$Q^2 = -q^2 = -(k - k')^2$ virtuality of the photon

$x \equiv x_{Bj} = \frac{Q^2}{2M_p\nu}$ Bjorken scaling variable

# Polarised Deep Inelastic Scattering: access to $g_1$

Absorption of polarised photons (QPM):




$\sigma_{3/2} \sim q^-(x)$ $\sigma_{1/2} \sim q^+(x)$

$$q(x) = q^+(x) + q^-(x)$$
$$\Delta q(x) = q^+(x) - q^-(x)$$
$+$ quark $\uparrow\uparrow$ nucleon
$-$ quark $\downarrow\uparrow$ nucleon

Photon-Nucleon asymmetry:

$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} - \sigma_{3/2}} \approx \frac{\sum_q e_q^2 \Delta q}{\sum_q e_q^2 q} = \frac{g_1}{F_1}$$

Double spin asymmetry:

$$A_{||} = \frac{\sigma^{\leftrightarrows} - \sigma^{\rightleftarrows}}{\sigma^{\leftrightarrows} + \sigma^{\rightleftarrows}} = D(A_1 + \eta A_2)$$

Spin-dependent structure function:

$$g_1 = \frac{1}{2} \sum_q e_q^2 \Delta q = A_1 \frac{F_2}{2x(1+R)} \approx \frac{A_{||}}{D} \frac{F_2}{2x(1+R)}$$

Inclusive cross-section:

$$\frac{d^2\sigma}{dxdQ^2} = \underbrace{c_1 F_1(x, Q^2) + c_2 F_2(x, Q^2)}_{\text{unpolarised structure function}} + \underbrace{c_3 g_1(x, Q^2) + c_4 g_2(x, Q^2)}_{\text{polarised structure function}}$$

# COMPASS spectrometer


- Polarised $\mu^+$ beam from SPS

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

160 GeV (200 GeV)

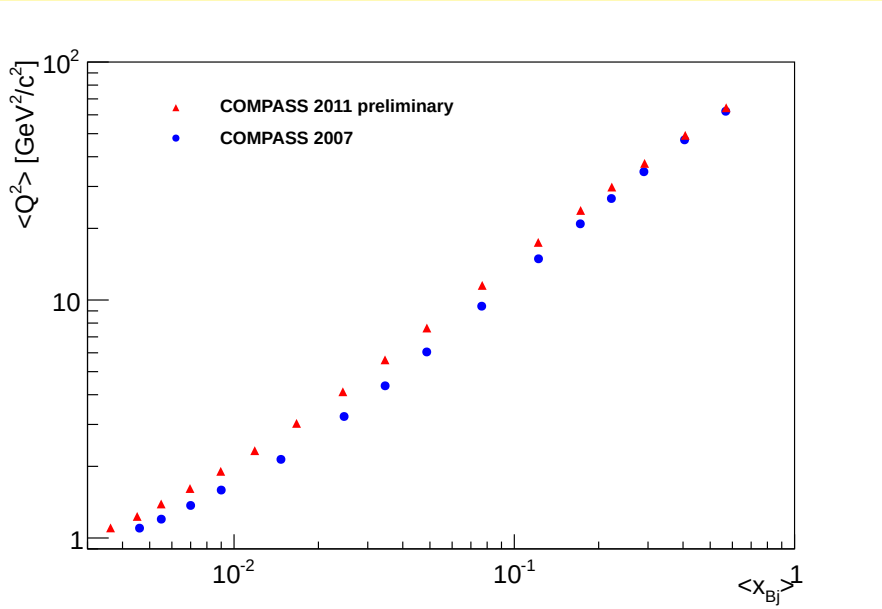
$P_\mu(E_\mu)$=76–80%

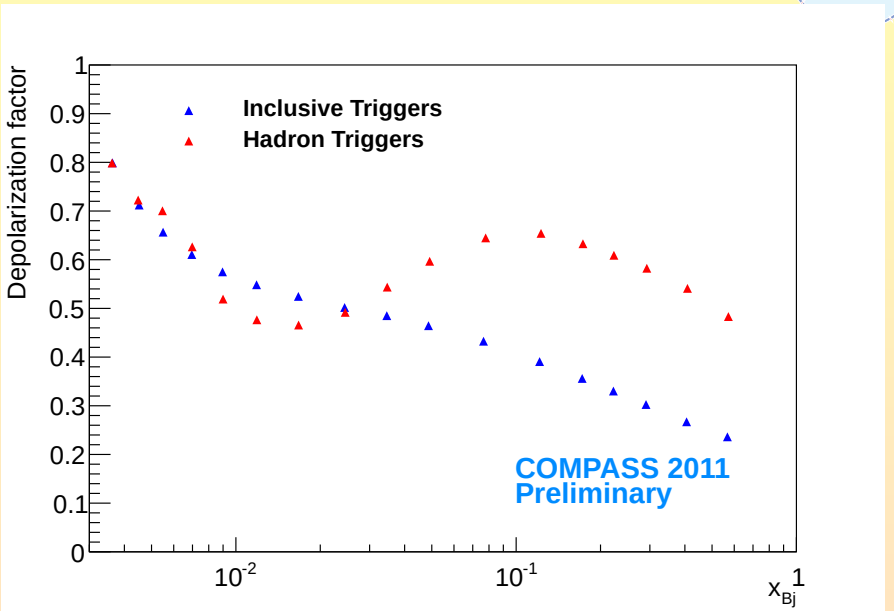



Fixed polarised target
in a 2.5 T solenoid field

- 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%**

# New measurement @ 200 GeV

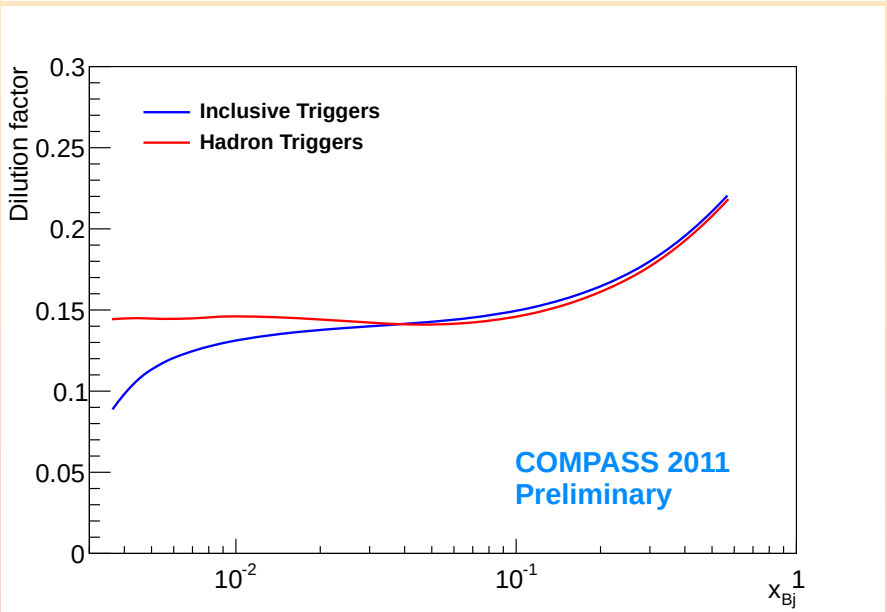



## 2011 data taking:

- $78 \cdot 10^6$ events
- $E_{beam} = 200$ GeV
- $Q^2 > 1$ (GeV/$c$)$^2$ and $0.1 < y < 0.9$
- $0.025 < x < 0.7$
- $NH_3$: $P_T \approx 85\%$

2007 and 2011 at slightly different $Q^2$



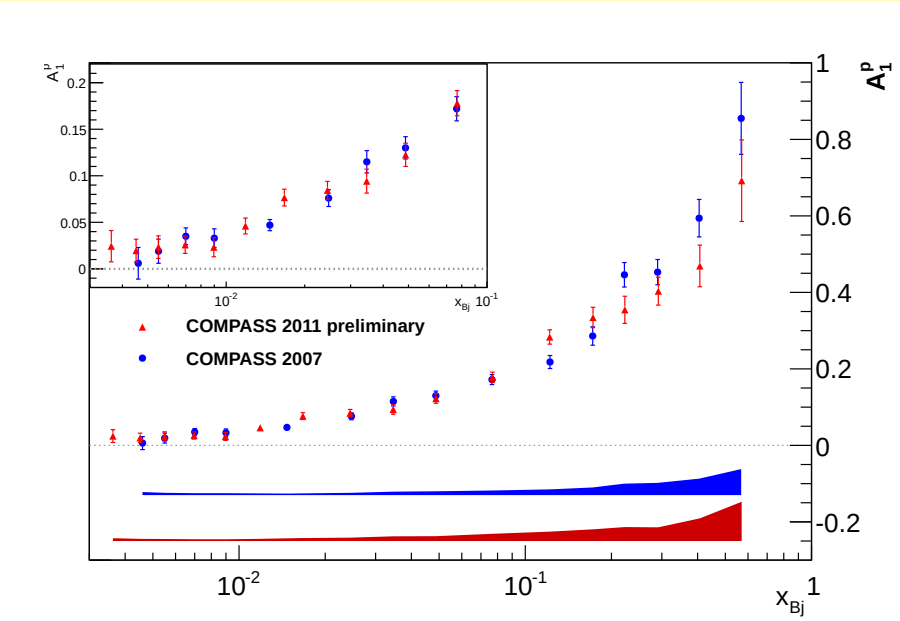
# Systematic uncertainties

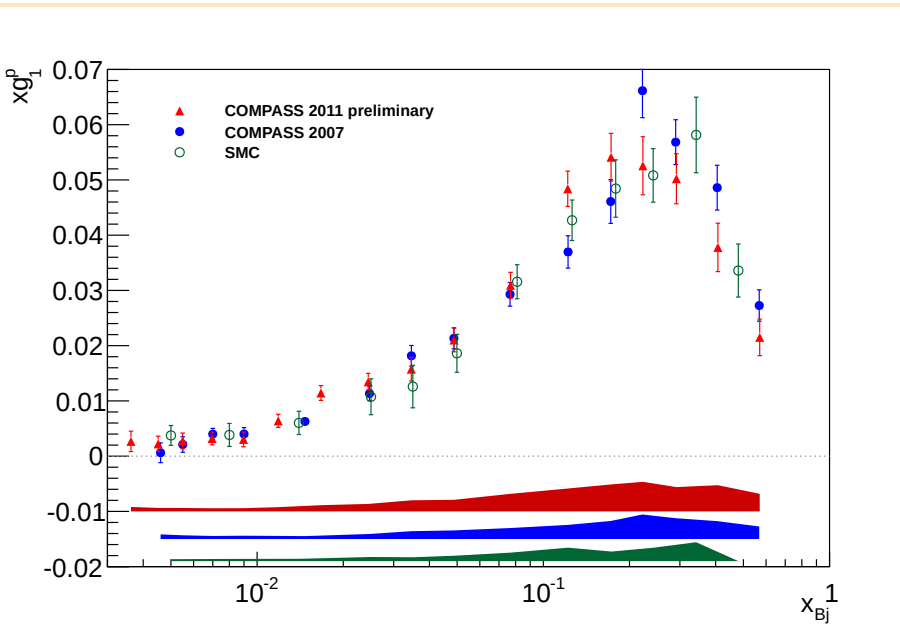
Two kind of contributions:

$$A_1^{\gamma} = \overbrace{\frac{1}{fDP_B P_T}}^{\text{Multiplicative}} A^{raw} - \overbrace{(A_1^{RC} + \mathcal{O}(\frac{x}{Q}A_2) + \mathcal{O}(A_{false}))}^{\text{Additive}}$$

| | | | |
|---|---|---|---|
| Multiplicative variables error, $\Delta A_1^{mult}$ | 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 | | $\Delta A_1^{mult} \approx 0.08 \cdot A_1$ |
| Additive variables error, $\Delta A_1^{add}$ | Transverse asymmetry | $\mathcal{O}(x/Q) \cdot \Delta A_2$ | $10^{-3}$–$10^{-2}$ |
| | Rad. corrections | $\Delta A_1^{RC}$ | $10^{-5}$–$10^{-3}$ |
| | False asymmetry | $\Delta A_{false}$ | $< 0.34 : 0.84 \cdot \Delta A_1^{stat}$ (Dominant) |

# COMPASS proton results at 200 GeV and 160 GeV

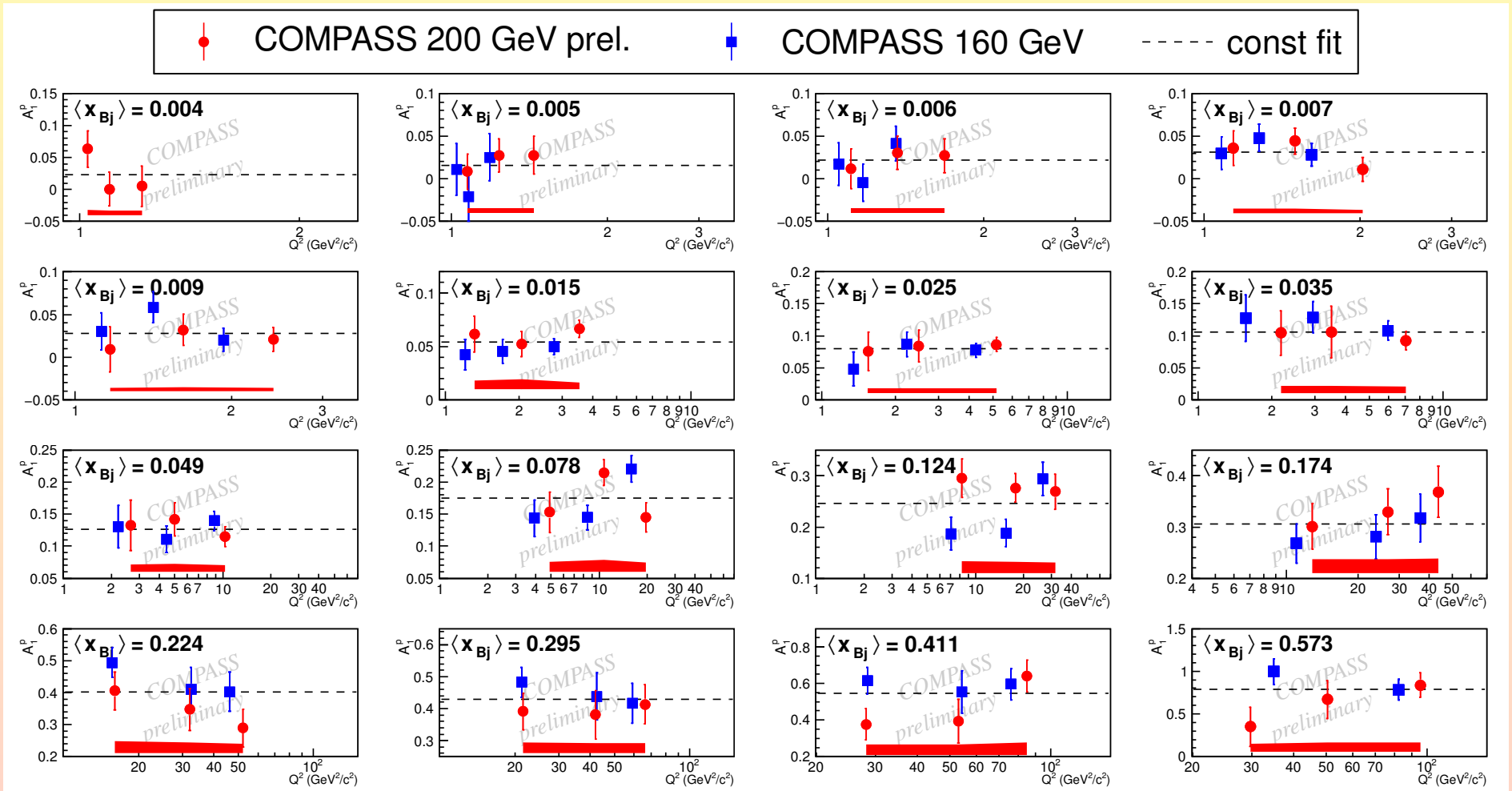



$$g_1(x) = \frac{F_2}{2x(1+R)} A_1$$

- SMC parametrisation of $F_2$
  SMC [PRD 58 (1998) 112001]
- $R = \frac{\sigma_L}{\sigma_T}$
  E143 [PLB 452 (1999) 194]
- Statistical errors (2007 and 2011) 2-3 times smaller than 2 years of SMC
- Lower $x$ value reached

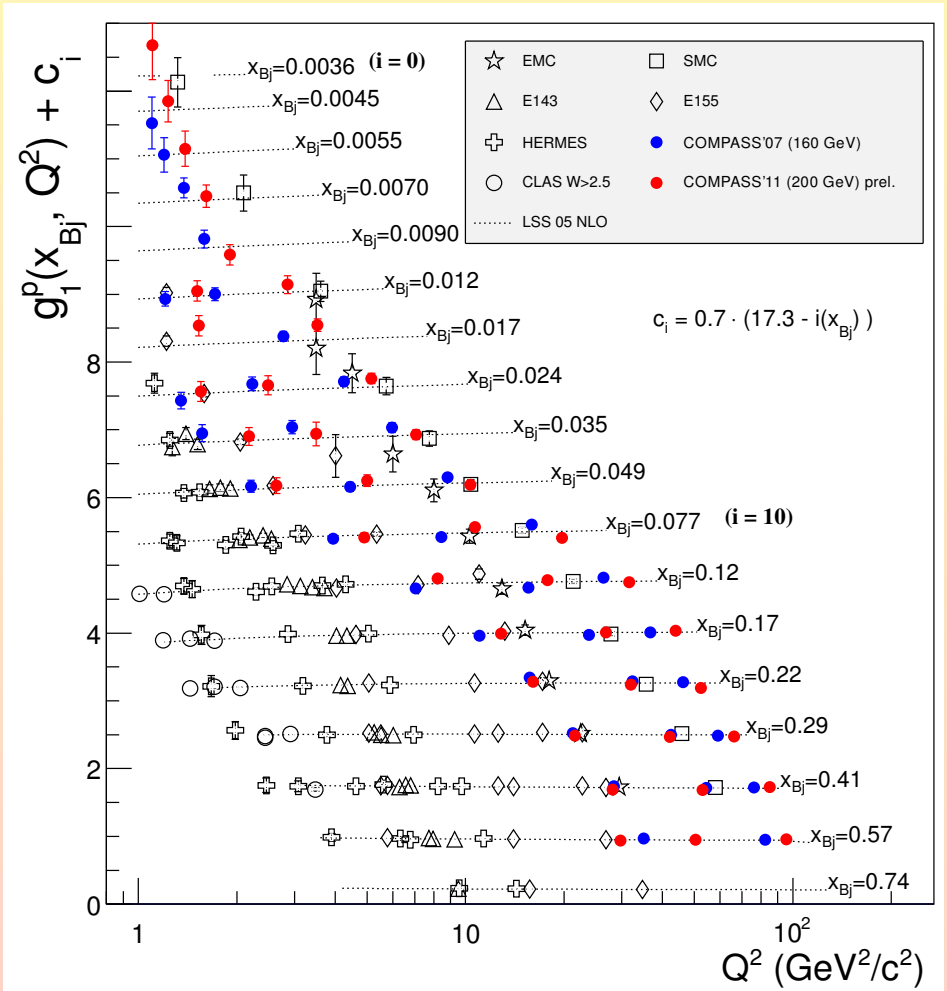
# Asymmetry $A_1^p$: $Q^2$ evolution




↪ No significant dependence on $Q^2$ observed

# Indirect measurement of $\Delta G$, $g_1^p$: $Q^2$ 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 $\Delta G$ extraction

LSS'05 fit at next-to leading order

## Conclusion

- New measurement of $g_1^p$@200 GeV (2011 data)
  - Extension of the measured region to lower $x$ and larger $Q^2$
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## Outlook

- Update of the Bjorken Sum Rules
- Indirect measurement of $\Delta G$ via $g_1$ COMPASS global fit
- Extraction of $A_{1,p}^{\pi+}$, $A_{1,p}^{\pi-}$, $A_{1,p}^{K+}$, $A_{1,p}^{K-}$
- Extraction of $\Delta q$ per flavour

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Thank You For Attention!

# Backup slides