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

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on behalf of the COMPASS collaboration

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Dubna, Russia
**COnmon Muon and Proton Apparatus for Structure and Spectroscopy**

NA58 at the CERN SPS

$\sim 250$ physicists

$\sim 30$ institutes

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**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

\[
Q^2 = -q^2 = -(k - k')^2 \quad \text{virtuality of the photon}
\]

\[
x \equiv x_{Bj} = \frac{Q^2}{2M_\nu}
\]

Bjorken scaling variable
Absorption of polarised photons (QPM):

\[ q(x) = q^+(x) + q^-(x) \]
\[ \Delta q(x) = q^+(x) - q^-(x) \]

\[ q^-(x) = \sigma_3/2 \]
\[ q^+(x) = \sigma_1/2 \]

\[ A_1 = \frac{\sigma_1/2 - \sigma_3/2}{\sigma_1/2 + \sigma_3/2} \approx \frac{\sum_q e_q^2 \Delta q}{\sum_q e_q^2 q} = \frac{g_1}{F_1} \]

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:

\[ \frac{d^2\sigma}{dx dQ^2} = c_1 F_1(x, Q^2) + c_2 F_2(x, Q^2) + c_3 g_1(x, Q^2) + c_4 g_2(x, Q^2) \]
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)
  - $P_\mu(E_\mu) = 76\text{--}80\%$

- Spectrometer:
  - Two stages along 60 m
  - Large acceptance 180 mrad

- Target, 1.2 m long:
  - LiD : $f \sim 40 \%$, $P_T \sim 50\%$
  - NH$_3$ : $f \sim 16 \%$, $P_T \sim 85\%$

Fixed polarised target in a 2.5 T solenoid field
New measurement @ 200 GeV

2011 data taking:

- 78 \cdot 10^6 events
- \( E_{beam} = 200 \text{ GeV} \)
- \( Q^2 > 1 \text{ (GeV/c)}^2 \) and \( 0.1 < y < 0.9 \)
- \( 0.025 < x < 0.7 \)
- \( \text{NH}_3: P_T \approx 85\% \)

2007 and 2011 at slightly different \( Q^2 \)
Systematic uncertainties

Two kind of contributions:

\[
A_1^\gamma = \frac{1}{fDP_B P_T} A^{raw} - \left( A_1^{RC} + \mathcal{O}(\frac{x}{Q} A_2) + \mathcal{O}(A_{\text{false}}) \right)
\]

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<th>Multiplicative variables</th>
<th>Error, $\Delta A_1^{\text{mult}}$</th>
<th>Additive variables</th>
<th>Error, $\Delta A_1^{\text{add}}$</th>
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<td>Beam polarisation</td>
<td>$dP_B/P_B$</td>
<td>5%</td>
<td>Transverse asymmetry</td>
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<tr>
<td>Target polarisation</td>
<td>$dP_T/P_T$</td>
<td>5%</td>
<td>Rad. corrections</td>
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<tr>
<td>Depolarisation factor</td>
<td>$dD/D$</td>
<td>2 – 3%</td>
<td>False asymmetry</td>
</tr>
<tr>
<td>Dilution factor</td>
<td>$df/f$</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$\Delta A_1^{\text{mult}} \approx 0.08 \cdot A_1$</td>
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</table>
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

$\langle x_B \rangle = 0.004$

$\langle x_B \rangle = 0.005$

$\langle x_B \rangle = 0.006$

$\langle x_B \rangle = 0.007$

$\langle x_B \rangle = 0.009$

$\langle x_B \rangle = 0.015$

$\langle x_B \rangle = 0.025$

$\langle x_B \rangle = 0.035$

$\langle x_B \rangle = 0.049$

$\langle x_B \rangle = 0.078$

$\langle x_B \rangle = 0.124$

$\langle x_B \rangle = 0.174$

$\langle x_B \rangle = 0.224$

$\langle x_B \rangle = 0.295$

$\langle x_B \rangle = 0.411$

$\langle x_B \rangle = 0.573$

$\rightarrow$ 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 $Q^2$
  - New input and constrains
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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!
E.Zemlyanichkina (JINR, Dubna)