Results on the longitudinal double spin asymmetry $A_1^p$ and $g_1^p$ from the 2011 COMPASS data

HK 37.3

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M2 beamline

Polarised $\mu$ beam ($\sim 80\%$)
160 GeV/c, 200 GeV/c

Solid state polarised target (1.2m)
$P_t(NH_3) \sim 90\%$

Two magnets

Tracking ($p > 0.5$ GeV/c)
SciFi, Silicon MicroMega, Gem
MWPC, Drift, Straws, Driftubes

PID: RICH($\pi, K, p$)
ECAL, HCAL, muon filters
Deep Inelastic Scattering

4-momentum of the virtual photon: \( q = k - k' \)

Energy of the virtual photon:
\[
\nu = \frac{pq_{\text{lab}}}{M} \equiv E - E'
\]

\( Q^2 = -q^2 \overset{\text{lab}}{\approx} 4EE' \sin^2 \frac{\theta}{2} \)

Bjorken scaling variable:
\[
x_{\text{lab}} \equiv \frac{Q^2}{2M\nu} \quad y_{\text{lab}} \equiv \frac{\nu}{E}
\]

Inclusive cross section:
\[
\frac{d^2\sigma}{d\Omega dE'} \sim c_1 F_1(x, Q^2) + c_2 F_2(x, Q^2) + c_3 g_1(x, Q^2) + c_4 g_2(x, Q^2)
\]

- spin independent
- spin dependent
Polarised Deep Inelastic Scattering

- Absorption of polarised photons
  \[ \sigma_{1/2} \sim q^+ \]
  \[ \sigma_{3/2} \sim q^- \]

- Photon nucleon asymmetry

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

- Spin structure function

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

Aim:
\[ A = \frac{\sigma_{\uparrow\downarrow} - \sigma_{\uparrow\uparrow}}{\sigma_{\uparrow\downarrow} + \sigma_{\uparrow\uparrow}} \]

Measured:
\[ A_{\text{exp}} = \frac{N_u - N_d}{N_u + N_d} \]

Needed:
- Flux cancellation
- Acceptance cancellation
  \[ \rightarrow \text{polarisation rotation} \]
  \[ \rightarrow 3 \text{ target cells} \]

\[ A_{\text{exp}} = A \cdot P_B \cdot P_T \cdot f \]

- \( f \): Dilution factor
- \( P_T \): Target polarisation
- \( P_B \): Beam polarisation

Averaging:
\[ A_{\text{exp}} = \frac{A + A'}{2} = \frac{1}{2} \left( \frac{N_u - N_d}{N_u + N_d} + \frac{N'_u - N'_d}{N'_u + N'_d} \right) \]
2011 Data

2007 and 2011 data taking
- Target: NH$_3$
- Increased beam energy: 160 GeV → 200 GeV
- Higher $Q^2$
- Smaller $x$

Improve results on
- Bjorken sum rule
- QCD fit
- Flavour 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
  → Flux cancellation
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
\(Q^2\) dependence of \(A_{1p}\)

- No \(Q^2\) dependence visible
- New data point at very small \(x\)
- Good agreement between COMPASS 2011/07
NLO QCD analyses

- **DGLAP equations**

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

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

- **Input parametrization** \( f \) of \( \Delta q_{Si}, \Delta q_3, \Delta q_8, \Delta g \) at \( Q_0^2 \)

\[
f = \eta \frac{x^\alpha (1-x)^\beta (1+\gamma x)}{\int_0^1 x^\alpha (1-x)^\beta (1+\gamma x) dx}
\]

\[
\Delta q_{Si} = \Delta u + \Delta d + \Delta s, \quad \Delta q_3 = \Delta u - \Delta d, \quad \Delta q_8 = \Delta u + 2\Delta d - \Delta s
\]

- using only inclusive asymmetries quarks and anit-quarks cannot be disentangled e.g. determination of \( \Delta u + \Delta \bar{u}, \Delta d + \Delta \bar{d}, \Delta s + \Delta \bar{s} \) and \( \Delta g \)

- many analyses from different groups (theor. and exp.) e.g. COMPASS, LSS, GRSV, BB, AAC, DSSV.......
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 $\Delta G$ extraction**
Small sensitivity to light sea and gluon polarisation

- Quark polarisation $\Delta \Sigma = \int \Delta q_{Si}(x)dx \sim 0.3$
- Gluon polarisation $\Delta G = \int \Delta g(x)dx$ Not constrained
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
  - NLO QCD fit

Outlook

- Improve the test of the Bjorken sum rule
- Identified hadron asymmetries
- LO extraction of polarised PDFs