Semi-Inclusive Spin Asymmetries from COMPASS

A. Korzenev
On behalf of the COMPASS collaboration
Mainz University,
on leave from JINR, LPP

\[ \frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + <L_z> \]

\[ \Delta \Sigma = \Delta u + \Delta \bar{u} + \Delta d + \Delta \bar{d} + \Delta s + \Delta \bar{s} \]

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Outline of the talk

- Introduction
  - polarized $\mu$ beam
  - Spectrometer
- Inclusive & semi-inclusive DIS asymmetries
  - Inclusive asymmetry measurement
  - Prospect for semi-inclusive analysis
- Summary
INTRODUCTION
More than 220 physicists from 30 institutes
The CERN $\mu$-beam

- Energy 160 GeV
- 5s spill every 14.4s
- Intensity $2 \cdot 10^8 \mu$/spill
- Natural polarization due to parity violation in the week decay of parent hadrons $P_\mu = -76\%$
**Semi-Inclusive Spin Asymmetries from COMPASS**

- **Beam**
  - Energy: 160 GeV
  - Intensity: $2 \times 10^6 \mu$ per spill
  - Polarization: $\sim -76\%$

- **Target**
  - Two 60 cm long target cells with opposite polarization
  - Target material $^6$LiD
    - Polarization: $\sim 50\%$
    - Dilution factor: $\sim 50\%$
  - Target material: $^{6}$LiD
  - Two 60 cm long target cells with opposite polarization

- **Spectrometer**
  - With 2 stages (SM1: 1Tm, SM2: 4.4 Tm)
  - Electromagnetic & hadron calorimeters
  - Particle identification: RICH & $\mu F$

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Inclusive & semi-inclusive DIS asymmetries
Polarized DIS

- the goal of measurement is

\[ A_1 \equiv A^{\gamma N} = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \equiv \frac{\sum_q e_q^2 (q^{\uparrow \uparrow} - q^{\downarrow \uparrow} + \bar{q}^{\uparrow \uparrow} - \bar{q}^{\downarrow \uparrow})}{\sum_q e_q^2 (q^{\uparrow \uparrow} + q^{\downarrow \uparrow} + \bar{q}^{\uparrow \uparrow} + \bar{q}^{\downarrow \uparrow})} = \frac{\sum_q e_q^2 (\Delta q + \Delta \bar{q})}{\sum_q e_q^2 (q + \bar{q})} \]

- In terms of structure functions

\[ A_1 = \frac{g_1 - \gamma^2 g_2}{F_1} \]

- the muon-nucleon asymmetry \( A^{\mu N} \) is measured

\[ A_1 = \frac{1}{D} A^{\mu N} = \frac{1}{D f P_t P_b} \cdot \frac{N^{\uparrow \downarrow} - N^{\uparrow \uparrow}}{N^{\uparrow \downarrow} + N^{\uparrow \uparrow}} \]
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What is detected in final state?

Inclusive DIS

- Detected particle: $\mu$, $\mu'$
- $A_1 = \frac{\sum_q e_q^2 (\Delta q(x) + \Delta \bar{q}(x))}{\sum_q e_q^2 (q(x) + \bar{q}(x))}$
- only $\Delta q + \Delta \bar{q}$ can be measured

Semi-Inclusive DIS

- Detected particle: $\mu$, $\mu'$, $h$, ...
- $A_1^h = \frac{\sum_q e_q^2 (\Delta q(x) \int D_q^h dz + \Delta \bar{q}(x) \int D_{\bar{q}}^h dz)}{\sum_q e_q^2 (q(x) \int D_q^h dz + \bar{q}(x) \int D_{\bar{q}}^h dz)}$
- $D_q^h \neq D_{\bar{q}}^h \Rightarrow$ quarks and anti-quarks separation

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Measurement of asymmetry

- Polarization reversal every 8 hours to cancel systematics due to day-night effects.
- To get rid of the influence of geometrical acceptance data with opposite polarization are combined

\[ A_{\mu N} = \frac{1}{2} \left( \frac{N_U - N_D}{N_U + N_D} - \frac{N'_U - N'_D}{N'_U + N'_D} \right) \frac{1}{P_t P_b f} \]
- To account for the detector instability groups of runs which are close in time are combined together
- Events are weighted with \( w = f D P_b \) what gives decrease of statistical error \( \sim 10\% \).
Parameterization of beam polarization

- MC simulation of the beam line
- systematics uncertainty is 3%
- Average polarization is 76%

Depolarization Factor

- it accounts for polarization transfer from $\mu$ to virtual photon

$$D \simeq \frac{y(2-y)}{2 - 2y + y^2}$$
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Target polarization

\[ P_t = \frac{\sum_{\text{runs}} |P_u|N_u + \sum_{\text{runs}} |P_d|N_d}{\sum_{\text{runs}} N_u + \sum_{\text{runs}} N_d} \]

Target Polarization 2003

Dilution Factor \( f \)

- it gives the fraction of polarized material in the target

\[ f = \frac{n_d \sigma_d}{n_d \sigma_d + \sum_A n_A \sigma_A} \]

- Naive: \(^6\text{LiD} \approx 2D + \alpha \Rightarrow f \approx 0.5\]
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**Inclusive Asymmetry \( A_1 \)**

- No hadron tagging

\[
A_1 = \frac{\sum_q e_q^2 (\Delta q(x) + \Delta \bar{q}(x))}{\sum_q e_q^2 (q(x) + \bar{q}(x))}
\]

- Data of 2002 are shown
- 6.5 \( \cdot \) 10^6 DIS events
- COMPASS/SMC beam time is \( \sim 1/7 \)

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**Kinematics cuts:**

- \( 0.1 < y < 0.9 \)
- \( Q^2 > 1 \text{ GeV}^2/c^2 \)

**Kinematics range:** \( 0.003 < x_{Bj} < 0.4 \)
Semi-inclusive asymmetries
Asymmetries which we measure

\[ \vec{A}_1 = \{ A_1, A_1^{h+}, A_1^{h-}, A_1^{K+}, A_1^{K-}, A_1^{K_0} \} \]

Inclusive Asymmetry

90% of hadrons are pions

Secondary vertices produced by track coming from interaction point

RICH PID
Threshold: \( p_K > 9 \) GeV

Mass Spectrum

Zoom

90% of hadrons are pions

Invariant mass. \( Z > 450 \) mm.
Extraction of parton densities $\Delta q$

- Asymmetries which we measure:
  $$\vec{A}_1 = \{ A_1, A_1^{h+}, A_1^{h-}, A_1^K, A_1^{K-}, A_1^{K^0} \}$$

- $A_1^h = \frac{\sum_q e_q^2 (\Delta q(x) \int D_q^h dz + \Delta \bar{q}(x) \int D_{\bar{q}}^h dz)}{\sum_q e_q^2 (q(x) \int D_q^h dz + \bar{q}(x) \int D_{\bar{q}}^h dz)}$ can be rewritten in matrix form as:
  $$\vec{A}_1 = \mathcal{B}(q(x), D_q^h(z)) \cdot \vec{\Delta q}$$

- Deuteron is isoscalar ($u^p = d^n, d^p = u^n$) ⇒ limited flavor separation:
  $$\vec{\Delta q} = \{ \Delta u + \Delta d, \Delta \bar{u} + \Delta \bar{d}, \Delta s \}$$
  assuming $\Delta s = \Delta \bar{s}$

- If combined with data from proton target full flavor separation is possible:
  $$\vec{\Delta q} = \{ \Delta u, \Delta \bar{u}, \Delta d, \Delta \bar{d}, \Delta s, \Delta \bar{s} \}$$
Summary

- The first results on inclusive asymmetry $A_1$ with statistics of 2002 have been shown.
- Release of asymmetries $A_1$, $A_1^{h+}$, $A_1^{h-}$ for statistics of 2002+2003 at the beginning of October.
- $A_1^{K+}$, $A_1^{K-}$, $A_1^{K_S^0}$ in progress.
- A lot of data to be analyzed
  - DST is produced for 2002, 2003
  - Data taking of 2004 is about finished
- Good perspective and upgrade of spectrometer after 2005.