

# Transverse spin effects in COMPASS

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## Abstract

In the years 2002-2004 COMPASS has collected data with the  $^6\text{LiD}$  target polarization oriented transversely with respect to the muon beam direction for about 20% of the running time, to measure transverse spin effects in semi-inclusive deep inelastic scattering, one of the main objectives of the COMPASS spin program. In 2007, COMPASS has used for the first time a proton  $\text{NH}_3$  target with the data taking time equally shared between longitudinal and transverse polarization of the target. After reviewing the results obtained with the deuteron, the new results for the Collins and Sivers asymmetries of the proton will be presented.

*Key words:* polarized DIS, transversity, SSA

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Since 2002 the COMPASS experiment has performed DIS measurements by impinging 160 GeV/ $c$  positive muons on a solid polarized deuteron or proton target, to get a deeper insight into the structure of the nucleon. Till 2006 a  $^6\text{LiD}$  target has been used, while a  $\text{NH}_3$  target was used in 2007. In 2008 COMPASS has started to measure central production and diffractive processes, from the scattering of 190 GeV/ $c$  pions on a liquid  $\text{H}_2$  target, to search for exotic hadronic states such as hybrids and glue-balls.

The experimental apparatus consists of a two stage magnetic spectrometer able to separate the scattered muon from the produced hadrons. Charged particles are identified by a RICH and by hadronic calorimeters. Since 2006 a new target magnet has been installed increasing the acceptance from 70 mrad scattering angle up to 180 mrad. A complete description of the experiment can be found in [1].

## 1. Collins and Sivers asymmetries

The full description of the spin structure of the nucleon at twist-two level requires the knowledge of the transversity distributions  $\Delta_T q(x)$ , together with the helicity distributions  $\Delta q(x)$  and  $q(x)$ . The transversity distributions  $\Delta_T q(x)$  are difficult to measure since,

being chirally odd, they decouple from inclusive deep inelastic scattering (DIS). However, they can be measured in semi-inclusive DIS (SIDIS) in combination with chiral-odd fragmentation functions, such as the Collins fragmentation function  $\Delta_T^0 D_q^h$  for hadron production, giving rise to an azimuthal single spin asymmetry (SSA) in the final state hadrons [2]. The Collins fragmentation function describes the spin-dependent part of the hadronization of a transversely polarized quark into a hadron with transverse momentum  $p_T^h$ . At leading order, the Collins mechanism leads to a modulation in the azimuthal distribution of the produced hadrons given by:

$$N(\Phi_C) = \alpha(\Phi_C) \cdot N_0 (1 + A_{\text{Col}} \cdot P_T \cdot f \cdot D_{NN} \sin \Phi_C),$$

where  $\alpha$  contains the apparatus efficiency and acceptance,  $P_T$  is the target polarization,  $D_{NN}$  is the spin transfer coefficient and  $f$  is the fraction of polarizable nuclei in the target;  $\Phi_C = \phi_h - \phi_{S'} = \phi_h + \phi_S - \pi$  is the Collins angle, with  $\phi_h$  the hadron azimuthal angle and  $\phi_{S'}$  the final azimuthal angle of the quark spin and  $\phi_S$  the azimuthal angle of the nucleon spin in the  $\gamma - N$  system. Finally

$$A_{\text{Col}} = \frac{\sum_q e_q^2 \cdot \Delta_T q(x) \cdot \Delta_T^0 D_q^h(z, p_T^h)}{\sum_q e_q^2 \cdot q(x) \cdot D_q^h(z, p_T^h)}$$

is the Collins asymmetry, arising from the product of the transversity distribution  $\Delta_T q$  and the Collins fragmentation function  $\Delta_T^0 D_q^h$ .

A different mechanism [3] has also been suggested in the past as possible source of single spin asymmetries in the cross-section of unpolarized leptons impinging on transversely polarized nucleons. Allowing for an intrinsic  $\vec{k}_T$  dependence of the quark distribution in the nucleon, a transverse spin polarization may induce a left-right asymmetry in such a distribution, giving rise to a measurable ‘Sivers asymmetry’:

$$A_{\text{Siv}} = \frac{\sum_q e_q^2 \cdot \Delta_0^T q(x, p_T^h) \cdot D_q^h(z)}{\sum_q e_q^2 \cdot q(x) \cdot D_q^h(z)}$$

with a modulation expressed in terms of the Sivers angle  $\Phi_S = \phi_h - \phi_S$ . Since in this case the unpolarized fragmentation functions are known, the measurement of the Sivers asymmetry for both positive and negative produced hadrons allows directly to extract the Sivers functions, if the measured asymmetry are different from zero, while a zero result for an isoscalar target like the  ${}^6\text{LiD}$  used in COMPASS can come both from a vanishing Sivers function or from a cancellation between  $u$  and  $d$  quark contributions.

## 2. Results

The event selection requires standard DIS cuts, i.e.  $Q^2 > 1 \text{ (GeV}/c)^2$ , mass of the final hadronic state  $W > 5 \text{ GeV}/c^2$ ,  $0.1 < y < 0.9$ , and the detection of at least one hadron in the final state. For the detected hadrons it is also required that:

- the fraction of the virtual photon energy carried is  $z = E_h/E_\gamma > 0.2$  to select hadrons from the current fragmentation region;
- $p_T > 0.1 \text{ GeV}/c$  (where  $p_T$  is the hadron transverse momentum with respect to the virtual photon direction) for a better determination of the azimuthal angle  $\phi_h$ .

The asymmetries have been calculated as a function of  $x$ ,  $z$  and  $p_T$  for positive and negative hadrons respectively. Both the resulting Collins and Sivers asymmetries from

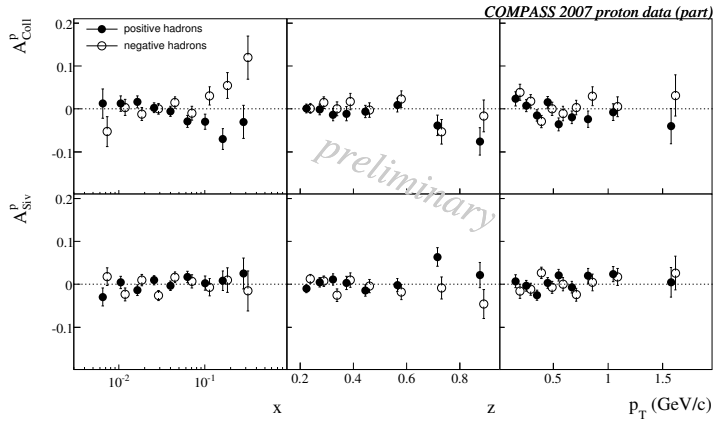


Fig. 1. Collins and Sivers asymmetry for positive (full points) and negative (open points) hadrons as a function of  $x$ ,  $z$  and  $p_T$  for the proton 2007 data.

the whole deuteron data for all hadrons turned out to be small and compatible with zero [4], a trend that is also shown by the identified hadron results [5], a result which was interpreted as a cancellation between the contribution of the  $u$  and  $d$  quarks, for the isoscalar deuteron target. The new results for the proton  $\text{NH}_3$  target are shown in fig. 1 both for the Collins (upper row) and for the Sivers (lower row) asymmetries. The Collins asymmetries as a function of  $x$  are small, compatible with 0, up to  $x \sim 0.05$ , while in the last points a signal appears, and the asymmetries increases up to 10% with opposite sign for the positive (closed points) and negative (open points) hadrons. The trend is in good agreement with what observed by HERMES [6]. At variance the Sivers asymmetries are small and compatible with zero over the full  $x$  range and for both positive and negative hadrons; in this case the compatibility with HERMES results is fine for negative hadrons but is marginal, if any, for positive hadrons. The origin of the disagreement, needs to be understood [7] and will be an interesting issue for the near future.

## References

- [1] The COMPASS Collaboration, P. Abbon *et al.*, Nucl. Instrum. Meth. **A577** (2007) 455.
- [2] J. C. Collins, Nucl. Phys. B **396** (1993) 161.
- [3] D.W. Sivers, Phys. Rev. **D41** (1991) 83.
- [4] The COMPASS Collaboration, E.S. Ageev *et al.*, Nucl. Phys. **B 765** (2007) 31.
- [5] The COMPASS Collaboration, CERN-PH-EP/2008-002 and hep-ex/0802.2160, submitted to Phys. Lett. B.
- [6] M. Dieffenthaler *et al.*, arXiv:0706.2242 (2007), published in ‘Munich 2007, Deep-inelastic scattering’ 579-582.
- [7] W. Vogelsang, these proceedings.