One-Hadron transverse target spin asymmetries at COMPASS

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The measurements of single spin asymmetries in semi-inclusive deep inelastic scattering on a transversely polarized target are an important part of the COMPASS physics program. By measuring the spin dependent azimuthal asymmetries in hadron production one can access both transversity - using the Collins fragmentation function - and the Sivers distribution function. The COMPASS collaboration has measured these asymmetries in the scattering of a 160 GeV/c polarized μ^+ beam off a transversely polarized ^{6}LiD (deuteron) target in the years 2002–2004 and off a transversely polarized NH_3 (proton) target in 2007 and 2010. In this contribution we present the results from the 2010 data for the Collins and Sivers asymmetries.

1 Introduction

The quark content of the nucleon at twist-two level in the collinear case can be fully characterized by three independent parton distribution functions (PDF), namely the unpolarized distribution function $f_1(x)$, the helicity distribution function $g_1(x)$ and the transverse spin distribution function $h_1(x)$, also called transversity. Due to its chiral-odd nature, transversity cannot be accessed directly via deep inelastic lepton-nucleon scattering (DIS), but can be measured in semi inclusive DIS in combination with another chirally odd function like the Collins fragmentation function (FF) $H_1^h(z, p_T^2)$ [1] in single hadron production. Other possibilities to access transversity, which are also investigated at COMPASS, are the Λ hyperon polarization and the coupling to the interference FF $H_1^{\triangleleft}$ for the production of hadron pairs [2, 3]. Taking the intrinsic transverse momentum of the quarks k_T into account, the nucleon structure at leading twist can be described by eight transverse momentum dependent distribution functions, which are all measured at COMPASS. One of these is the Sivers function [4], which gives the correlation between the transverse spin of a nucleon and the intrinsic transverse momentum of unpolarized quarks.

COMPASS is a fixed target experiment at the CERN M2 beam line where the nucleon spin structure is investigated using a 160 GeV/c polarized μ^+ beam and polarized solid state targets. For measuring transverse spin effects a transversely polarized ^{6}LiD (deuterium) target (years 2002–2004) [5] and a transversely polarized NH_3 (proton) target (years 2007 and 2010) [6] were used. The proton target consists of three target cells, where a polarization of the free protons of up to 95% can be achieved.

2 Collins asymmetry

The Collins mechanism leads to a modulation in the azimuthal distribution of the hadrons produced in the fragmentation of a transversely polarized quark, which is given by $N_h(\phi_C) = N_h^0[1 + f\ P_T\ D_{NN}\ A_{Coll}\ \sin(\phi_C)]$. Here f is the target dilution factor, P_T is the target polarization and $D_{NN} = \frac{(1-y)}{(1-y+y^2/2)}$ is the spin transfer coefficient. The Collins angle ϕ_C is defined as $\phi_C = \phi_h + \phi_s - \pi$, where ϕ_h is the azimuthal angle of the hadron transverse momentum p_T and ϕ_S is the azimuthal angle of the nucleon spin with respect to the scattering plane. The Collins asymmetry A_{Coll} is given by

$$A_{Coll} = \frac{\sum_q e_q^2 \cdot h_1(x) \otimes H_1^h(z, p_T^2)}{\sum_q e_q^2 \cdot f_1(x) \otimes D_q^h(z, p_T^h)},$$

where D_q^h is the unpolarized FF and $\otimes$ indicates the convolutions over transverse momenta. Here $z = E_h/(E_\mu - E_{\mu'})$ is the fraction of the virtual photon energy carried by the hadron and p_T^h is the transverse momentum of the hadron with respect to the photon direction. In order to select only events from the DIS regime, kinematic cuts on the photon virtuality $Q^2 > 1\,(\mathrm{GeV}/c)^2$, on the fractional energy transfer of the muon $0.1 < y < 0.9$ and on the invariant mass of the hadronic final state $W > 5\,\mathrm{GeV}/c^2$ are applied. Furthermore for the selection of the hadrons $z > 0.2$ and $p_T^h > 0.1\,\mathrm{GeV}/c$ are required.
Figure 1 shows the preliminary results for the Collins asymmetry from the 2010 measurement as function of x, z and p_T^h for both positive and negative hadrons. The asymmetries are compatible with zero for small values of x but they show a clear signal in the valence region ($x > 0.1$) of opposite sign for positive and negative hadrons. The results are in a very good agreement with the measurement of 2007 at COMPASS and the results from HERMES [7]. The good agreement with the HERMES experiment, where transversity was measured using an electron beam at lower energies compared to COMPASS, indicates a weak Q^2 dependence of the Collins asymmetry.

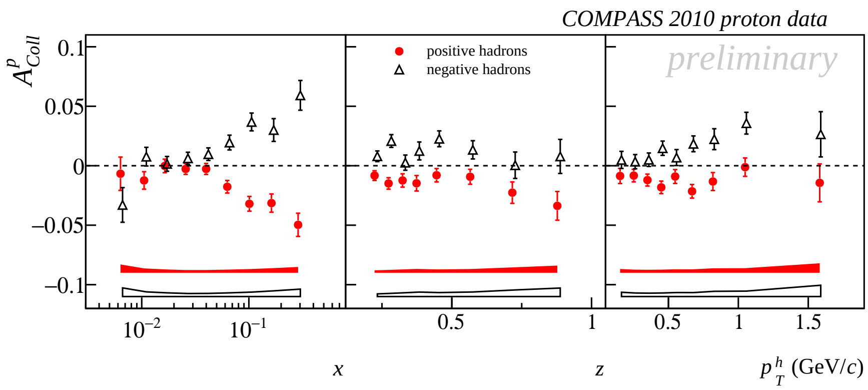

Figure 1: Collins asymmetries of 2010 proton data as a function of x, z and p_T^h for positive and negative hadrons. The bands correspond to the systematical error.

3 Sivers asymmetry

The Sivers effect is sensitive to the correlation of the transverse momentum of an unpolarized quark inside a transversely polarized nucleon and the transverse polarization of this nucleon. This effect is described by the Sivers function $f_{1T}^{\perp}(x, \vec{k_T})$. The number of produced hadrons $N_h(\phi_S) = N_h^0[1 + f\ P_T\ A_S\ \sin(\phi_S)]$ depends on the Sivers angle $\phi_S = \phi_h - \phi_s$. The Sivers asymmetry A_S is given by the convolution of the Sivers function and the unpolarized fragmentation function:

$$A_S = \frac{\sum_q e_q^2 \cdot f_{1T}^{\perp}(x, \vec{k_T}) \otimes D_q^h(z, p_T^h)}{\sum_q e_q^2 \cdot f_1(x) \otimes D_q^h(z, p_T^h)}$$

The preliminary results for the Sivers asymmetry from the 2010 run on a transversely polarized proton target are shown in Fig. 2 as a function of x, z and p_T. In contrast to the Collins asymmetry, for positive hadrons the Sivers asymmetry is clearly different from zero also for low values of x but it is small and compatible with zero for negative hadrons. The agreement with the previous COMPASS measurement from 2007 is again very good. In comparison with the results from the HERMES experiment [8] the Sivers asymmetries measured at COMPASS show the same trend but are smaller in absolute value, which indicates - in contrary to the Collins case - a possible Q^2 dependence.
For further investigation the asymmetries were also extracted for a y range of $0.05 < y < 0.1$. Since there is no data for $x < 0.032$ at this low-y selection, an additional cut $x > 0.032$ was applied on the standard sample for better comparison. Figure 3 shows the preliminary results for the low-y sample for the Sivers asymmetry together with the results from the standard sample for positive hadrons. A clear increase of the Sivers asymmetry is visible for the low-y data, which could be again explained by the smaller average Q^2 in this sample. Also latest extractions of the Sivers function with TMD evolution [9] indicate a large Q^2 dependence. For negative hadrons (not shown) no effect is visible for all three variables x, z and p_T^h.

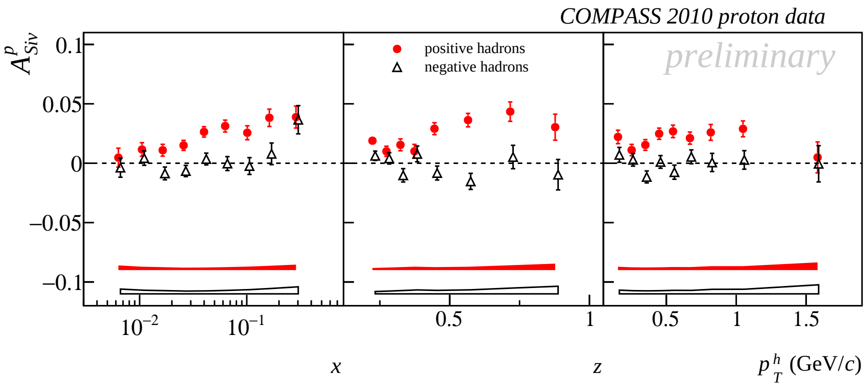

Figure 2: Sivers asymmetries of 2010 proton data as a function of x, z and p_T^h for positive and negative hadrons. The bands correspond to the systematical error.

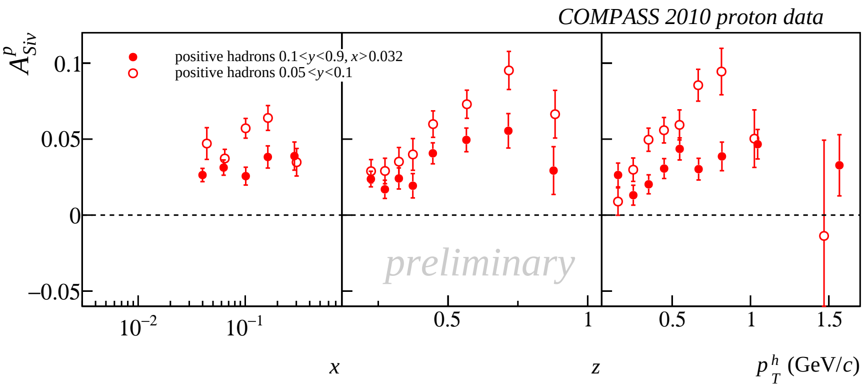

Figure 3: Sivers asymmetries of 2010 proton data as a function of x, z and p_T^h for $0.1 < y < 0.9$ and $0.05 < y < 0.1$ with $x > 0.032$, positive hadrons only.

4 Conclusion

The measurements on a transversely polarized proton target at COMPASS in 2010 show non-zero asymmetries for Collins and Sivers which are in very good agreement with the published results from the 2007 run. The higher statistics achieved in 2010 allows the investigation of different kinematical regions which show interesting results, especially for the Sivers asymmetries. The next steps will be the extraction of the asymmetries for identified hadrons making use of the COMPASS RICH detector as well as the other six transverse spin dependent asymmetries which are expected to be present in the expression of the SIDIS cross-section.

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