1-HADRON TRANSVERSE TARGET SPIN ASYMMERTIES AT COMPASS

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Abstract

COMPASS is a fixed target experiment at CERN where the nucleon spin structure is investigated using a 160 GeV/c polarized μ^+ beam and polarized solid state targets. After taking data in the years 2002–2004 using a transversely polarized ^{6}LiD (deuteron) target, in 2007 and 2010 data were collected on a transversely polarized NH_3 (proton) target. The measurements of single spin asymmetries in semi-inclusive deep inelastic scattering (SIDIS) on a transversely polarized target are an important part of the COMPASS physics program. They allow to investigate the transversity distribution functions, *e.g.* coupled to the Collins fragmentation function, as well as transverse momentum dependent distribution functions, like the Sivers distribution function, by measuring azimuthal asymmetries in hadron production. In this contribution we present the results from the 2010 data for the Collins and Sivers asymmetries.

1 Introduction

The spin structure of the nucleon at twist-two level in the collinear case can be fully characterized by three independent parton distribution functions (PDF) for each quark flavour: the unpolarized distribution function $f_1(x)$, the helicity distribution function $g_1(x)$ and the transverse spin distribution function $h_1(x)$. The latter, also called transversity, is chiral odd and decouples from inclusive deep inelastic scattering (DIS). In combination with another chirally odd function like the Collins fragmentation function (FF) $H_1^h(z, p_T^2)$ [1] it is possible to measure transversity in semi inclusive DIS (SIDIS) in single hadron production. At the COMPASS experiment transversity can also be measured in Λ hyperon polarization and in two-hadron inclusive production [2], where it is coupled to the interference fragmentation function $H_1^{\sphericalangle}$.

When the intrinsic transverse momentum of the quarks $\vec{k_T}$ is taken into account, the nucleon structure at leading twist can be described by eight PDFs, which are all measured at COMPASS. This contribution will concentrate on the Collins function as well as on the Sivers function [3], which is correlated to the Sivers distribution function $f_{1T}^{\perp}(x, \vec{k_T})$.

COMPASS is a fixed target experiment at the CERN M2 beamline 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 6LiD (deuterium) target (years 2002–2004) [4] and a transversely polarized NH_3 (proton) target (years 2007 and 2010) [5] were used. The proton target consists of three target cells, where the outer ones are polarised oppositely to the inner one. The achieved polarisation is up to 95% with a dilution factor of 0.15.

2 The Collins asymmetry

The Collins mechanism leads to an azimuthal modulation in the distribution of the unpolarized hadrons produced in the fragmentation of a transversely polarized quark. The number of produced hadrons is then given by $N_h(\phi_C) = N_h^0[1 + f\ P_T\ D_{NN}\ A_{Coll}\ \sin(\phi_C)]$, where 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 coeffizient from the initial to the struck quark. The Collins angle $\phi_C = \phi_h + \phi_s - \pi$ is the sum of the azimuthal angle of the produced hadron and the azimuthal angle of the nucleon spin with respect to the scattering plane. The Collins asymmetry A_{Coll} is given by

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

with the convolution of the transversity distribution $h_1(x)$ and the Collins fragmentation function $H_1^h(z, p_T^2))$ in the nominator. Here $z = E_h/(E_\mu - E_{\mu'})$ is the fraction of the virtual photon energy energy carried by the hadron and p_T^h is the transverse momentum of the hadron with respect to the photon direction.
To select events in the DIS region, 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 hadronic mass $W > 5\,\mathrm{GeV}/c^2$ are applied. Furthermore $z > 0.2$ and $p_T^h > 0.1\,\mathrm{GeV}/c$ are required for the selection of the hadrons. In the following this selection will be referred to as the standard sample.
The preliminary results for the Collins asymmetry from the 2010 measurement on the proton target are shown in Fig. 1 as a function of x, z and p_T^h for positive and negative hadrons. For $x > 0.1$ the asymmetries are clearly different from zero and of opposite sign for positive and negative hadrons. At lower values of x the asymmetries are compatible with zero. In bins of z and p_T, the asymmetries show no clear trend but are different from zero in average. The 2010 results are in perfect agreement with the measurements on the Collins asymmetries of 2007, but with smaller error bars due to the higher statistics gained in 2010. The HERMES experiment [6] at DESY has also measured the Collins asymmetries on a proton target using a polarized electron beam at a lower Q^2. In comparison the results from both experiments are in very good agreement. This indicates a weak Q^2 dependence of the Collins FF.
With the higher statistics achieved during the 2010 measurment it is now possible to explore kinematical regions different from the standard sample described above. In one of the new analyses y was restricted to the region of $0.05 < y < 0.1$. The cut on W was dropped and the remaining cuts on z and p_T were kept the same as for the standard sample. Since there is no data for $x < 0.032$ at this low-y selection, for comparison an additional cut $x > 0.032$ was applied on the standard sample. Fig. 2 shows the results of the $0.05 < y < 0.1$ analysis in comparison with the standard sample. The upper row shows the asymmetries for positve hadrons and the lower row for negative hadrons. For positive hadrons the trend of the asymmetries stays the same but the absolute value increases in all bins of x, z and p_T. For negative hadrons no effect is visible. In a third analysis the sample corresponding to $0.1 < z < 0.2$ (low-z sample) was choosen while all other cuts were like the ones for the standard sample. The results are shown in Fig. 3 for the standard sample and the $0.1 < z < 0.2$ sample. The upper row shows the asymmetries

for positve hadrons and the lower row for negative hadrons. In bins of x the low-z sample follows the standard sample but with slightly decreased values for large x values, both for positive and negative hadrons. In bins of p_T no difference can be seen.

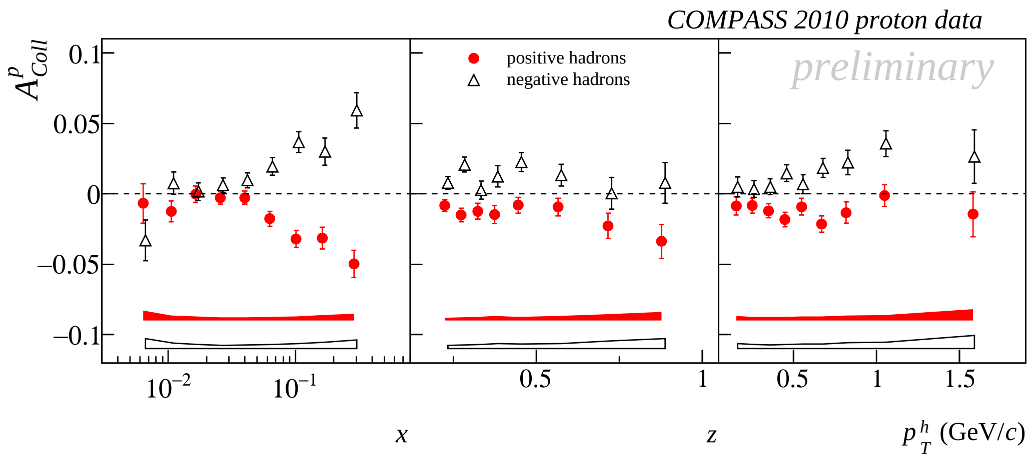

Figure 1: Collins asymmetries of 2010 proton data as a function of x, z and p_T^h for positive and negative hadrons. The bands correspond to the systematical error.

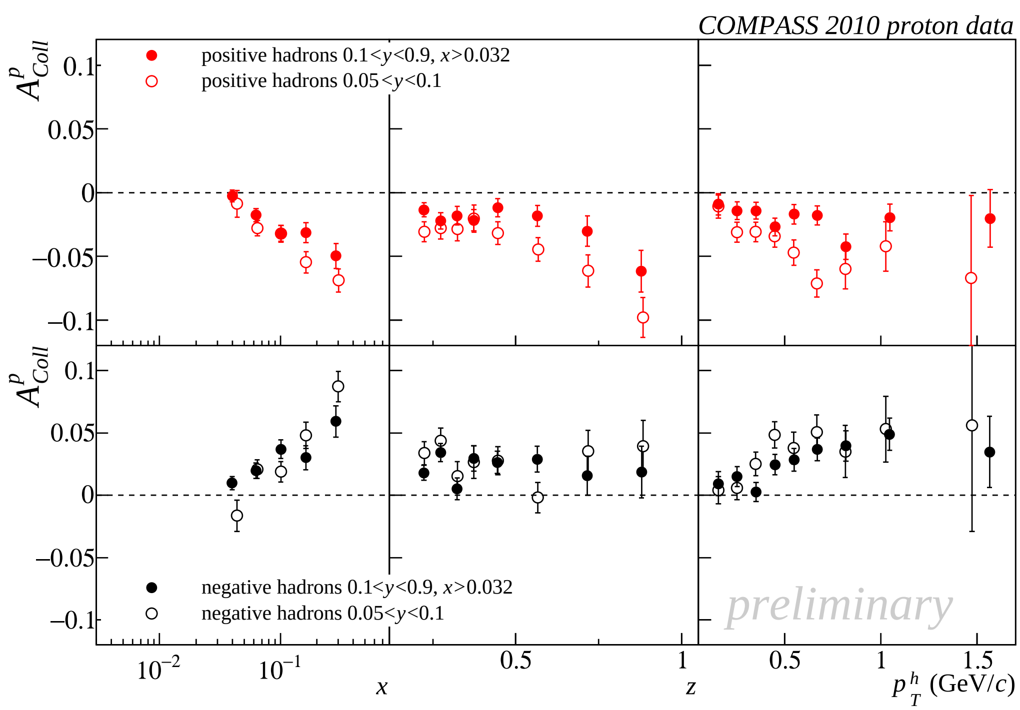

Figure 2: Collins asymmetries of 2010 proton data as a function of x, z and p_T^h for $0.1 < y < 0.9$ and $0.05 < y < 0.1$ with $x > 0.032$. Upper row shows positive hadrons, lower row negative hadrons.

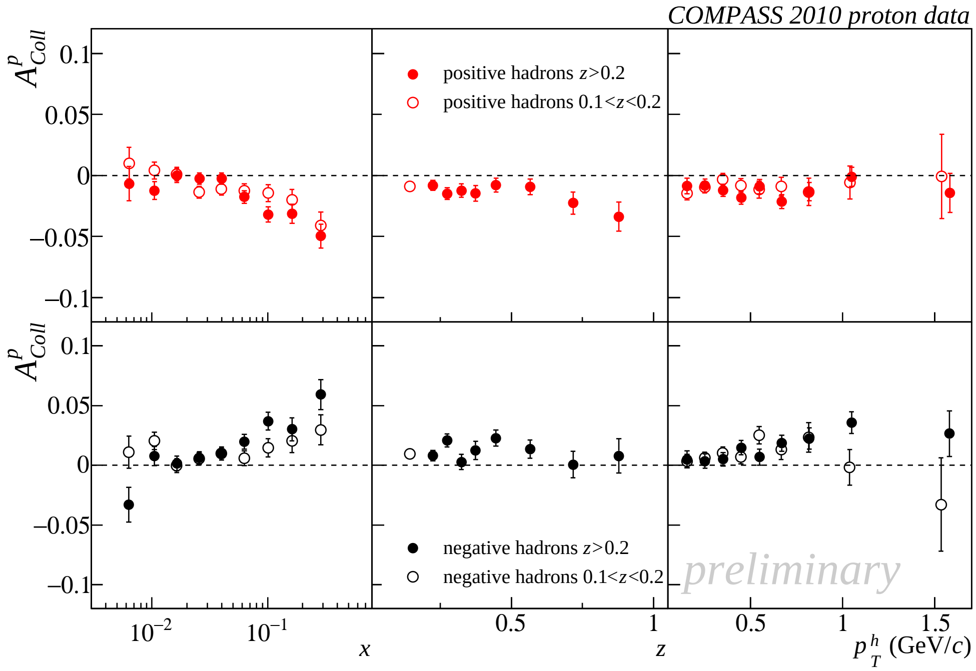

Figure 3: Collins asymmetries of 2010 proton data as a function of x, z and p_T^h for $z > 0.2$ and $0.1 < z < 0.2$. Upper row shows positive hadrons, lower row negative hadrons.

3 The Sivers asymmtery

The Sivers function $f_{1T}^{\perp}(x, \vec{k_T})$ gives the correlation between the transverse spin of a nucleon and the intrinsic transverse momentum of unpolarized quarks. 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 difference of the azimuthal angle of the produced hadron and the azimuthal angle of the nucleon spin in the gamma-nucleon system. The Sivers asymmetry A_S is given by the convolution of the Sivers function and the unpolaried 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 Sivers asymmetries of the 2010 measurement on the proton target at COMPASS are shown in Fig. 4 in bins of x, z and p_T. For positive hadrons the asymmetries show a positive signal in all three kinematic variables, even at small values of x, whereas for negative hadrons (triangles) the asymmetries are compatible with zero within the error bars. There is again a very good agreement with the published results from the 2007 data taken at COMPASS. Compared to the HERMES results [7] on the proton target the asymmetries measured at COMPASS show the same trend but are smaller in absolute value.
Fig. 5 shows the Sivers asymmetries for the low-y ($0.05 < y < 0.1$) selection in bins of x, z and p_T for positive hadrons in comparison to the standard sample ($0.1 < y < 0.9$). Here a clear increase of the Sivers asymmetries is visible for the low-y sample, which could be explained by the smaller values of Q^2 and W in this selection. A Q^2 dependance is expected and has been calculated [8], but no dependece on W is foreseen. The asymmetries for negative hadrons (not shown) are again compatible with zero.

In Fig. 6 the measured Sivers asymmetries from the low-z sample and the standard sample are shown for positive hadrons. As it can be seen from the plot, the Sivers asymmetries become much smaller in size for low-z. The asymmetries for negative hadrons (not shown) stay compatible with zero also for the low-z sample.

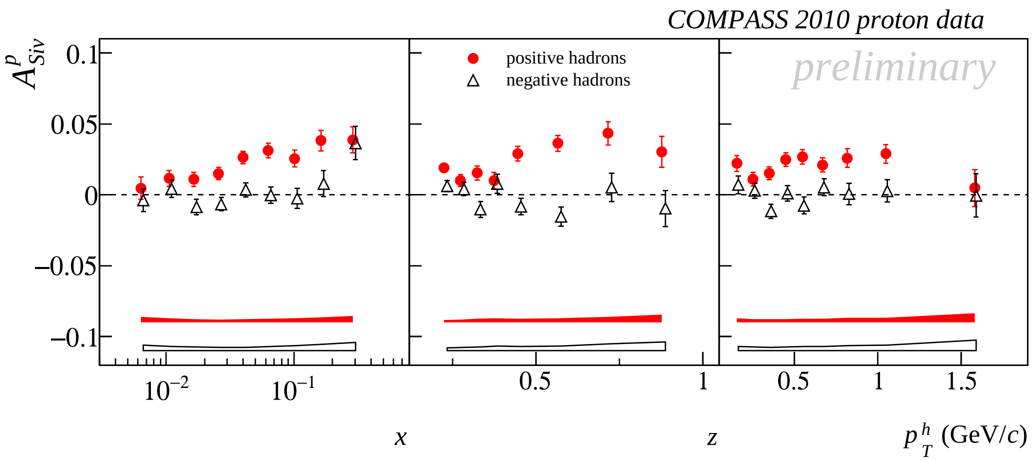

Figure 4: Sivers asymmetries of 2010 proton data as a function of x, z and p_T^h for positive and negative hadrons. The bands correspond to the systematical error.

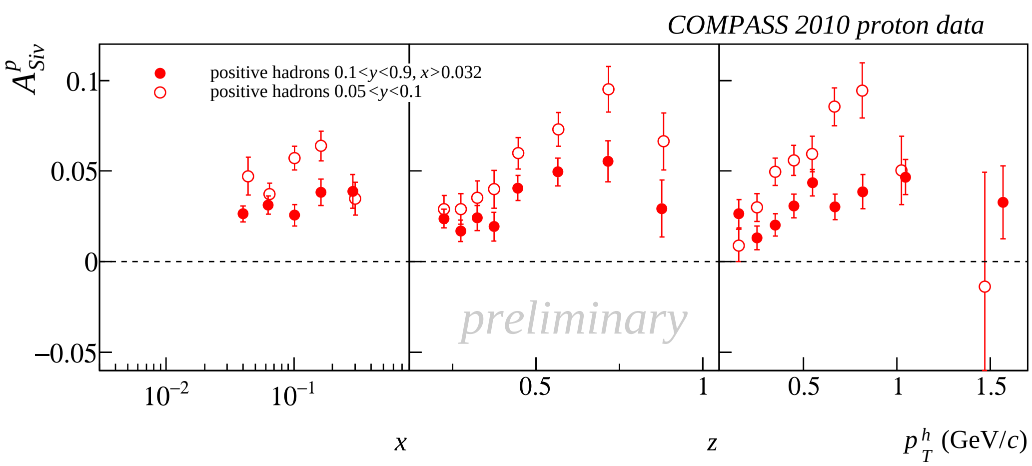

Figure 5: Sivers asymmetries of 2010 proton data as a function of x, z and p_T^h for $0.1 < y < 0.9$ and $0.05 < y < 0.1$ with $x > 0.032$, positve hadrons only.

4 Conclusion

The present results from the 2010 measurement on the proton target at COMPASS show non-zero asymmetries for Collins and Sivers which are in very good agreement with the published results from the 2007 run. In contrast in the measurement on a deuterium target 2002–2004 the asymmetries were compatible with zero [4]. Dedicating the whole data taking period 2010 to measure on a transversely polarized proton target led to a

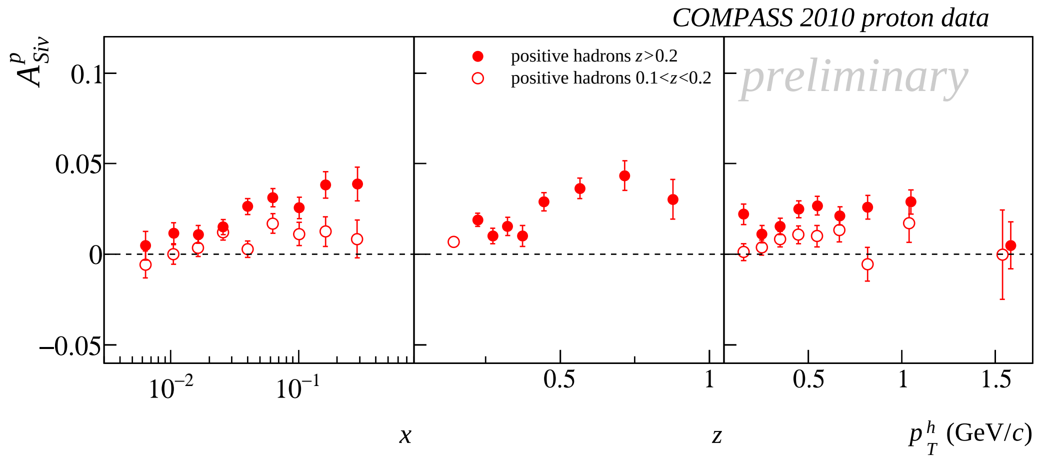

Figure 6: Sivers asymmetries of 2010 proton data as a function of x, z and p_T^h for $z > 0.2$ and $0.1 < z < 0.2$, positve hadrons only.

decrease of the statistical error by a factor of about 1.7 compared to the 2007 measurement. This also allows the investigation of different kinematical regions which show very interesting results, expecially for the Sivers asymmetries. Work is ongoing to extract the asymmetries for identified hadrons as well as the other six transverse spin dependent asymmetries which are present in the expression of the SIDIS cross-section.

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