New measurements of transverse spin asymmetries at COMPASS

F. Sozzi on behalf of the COMPASS Collaboration
INFN, Sezione di Trieste
via Valerio 3, 34128, Italy

The study of transverse momentum effects and transverse spin structure of the nucleon is an important part of the scientific program of COMPASS, a fixed target experiment at the CERN SPS. The transverse effects are investigated via semi inclusive DIS reactions with a 160 GeV/c muon beam impinging on transversely polarised targets. The hadrons produced in the reactions are detected in a wide momentum and angular range by a two-stage spectrometer. A deuterium target has been used in the first part of COMPASS data taking from 2002 to 2004, while a proton target has been used in 2007 and 2010. Here we present the recent results obtained from the 2010 data on different channels, involving the azimuthal distribution of single hadrons and the azimuthal dependence of the plane containing hadron pairs. The results confirm the published results of the 2007 data taking with an improved statistical significance; the measured azimuthal asymmetries are clearly non zero, at variance with those measured on a deuterium target.

1 Introduction

To fully specify the quark structure of the nucleon at twist two level, three parton distribution functions (PDF) are needed: the well known momentum and helicity distribution $q(x)$ and $\Delta q(x)$, and the transversity distribution $\Delta_T q(x)$. Transversity describes the probability density of finding transversely polarised quarks in a transversely polarised nucleon. In the past years it has received a lot of attention, both from the experimental and from the theoretical point of view.

Transversity is chiral odd, thus it must be coupled to another chiral-odd function in order to build an observable. It can be measured in semi-inclusive DIS experiments (SIDIS), where at least one hadron in the final state is detected. In particular, two channels investigated by the COMPASS Collaboration are described in this contribution: the azimuthal distribution of single hadrons and the azimuthal dependence of hadron pairs.

2 The COMPASS experiment

COMPASS [1] is a fixed target experiment at the CERN SPS, with a physics program focused on the study of the nucleon spin structure and of hadron spectroscopy. The nucleon spin structure is investigated using a high energy muon beam of 160 GeV/c on targets that are either longitudinally polarised (in order to access gluon polarisation and helicity PDF) or transversely polarised (to access the transversity PDF and transverse momentum dependent PDFs).

The detection and the identification of hadrons for SIDIS measurements is done in a two-stage spectrometer, that allows to cover a large kinematic range in momentum and angular

acceptance. The spectrometer comprises several type of trackers, as well as electromagnetic and hadronic calorimeters, muon walls for the muon identification, and a RICH detector.

Different periods of the COMPASS data taking has been devoted to transversity measurements:

- 20% of the time in the years 2002, 2003 and 2004; the target material was ^{6}LiD, characterised by polarisation values P_t of the order of 50% and dilution factor f around 0.38;
- 50% of the time of year 2007; the material was NH_3 ($P_t \sim 90\%$ and $f \sim 0.15$);
- full 2010 year: a NH_3 target was used again, to improve the precision of the results from the 2007 run.

The most recent results from the 2010 data taking are shown in this contribution.

3 Collins asymmetries

In SIDIS on a transversely polarised target the so called Collins effect [2] gives origin to azimuthal asymmetries in the single hadron production. In this mechanism the Collins fragmentation function, describing the correlation between the fragmenting quark spin and the momentum of the produced hadron, introduces a left-right asymmetry in the distribution of the hadron. The hadron yield can be written as:

$$N = N_0 \cdot (1 + f \cdot P_t \cdot D_{nn} \cdot A_C \cdot \sin(\phi_C)) \tag{1}$$

where f and P_t have been already introduced, and $D_{nn} = (1-y)/(1-y+y^2/2)$ is the transverse spin transfer coefficient from the initial to the struck quark. The Collins angle ϕ_C is defined as $\phi_h - \phi_{s'}$, where ϕ_h is the angle of the transverse momentum of the outgoing hadron and $\phi_{s'} = \pi - \phi_s$ is the azimuthal angle of the struck quark spin (ϕ_s is the azimuthal angle of quark before the hard scattering). A_C is the Collins asymmetry, proportional to the convolution of the Collins fragmentation function and the transversity distribution. Comparing the number of hadrons produced in SIDIS reactions on nucleons polarised transversely in opposite directions, the modulation given by the Collins angle gives access to the asymmetry A_C.

The results obtained from the 2010 data are shown in fig. 1, as a function of x, of the hadron relative energy z, and of the transverse momentum of the hadron p_T; the bands in the picture represent the systematic uncertainties, that are 50% of the statistical errors. The Collins asymmetries confirm the results from 2007 data [3], with an improved statistical precision, around a factor of 2. In the valence region, for x larger than 0.03, there is a large signal of opposite sign for positive and negative hadrons. This result is in agreement with the other existing measurement on a proton target, by the HERMES experiment [4]; since the Q^2 values in the last x bins are higher in COMPASS of a factor 2-3 with respect to HERMES's, the agreement between the two experiments implies a negligible Q^2 dependence for the Collins effect. In the small x region, not covered by the HERMES experiment, the asymmetries are compatible with zero, for both hadron charges.

Transversity has been already extracted performing global fit [5] using Collins asymmetries from COMPASS on deuterium data[8,7,6] and from HERMES on proton data, as well as azimuthal asymmetries in $e^+e^- \to \pi^+\pi^-$ annihilation from Belle [9], that give independent information on the Collins FF. The Collins asymmetries from the 2010 data are of particular importance and interest since they can be used in the global fits, providing precise data, in a large x and Q^2 range.

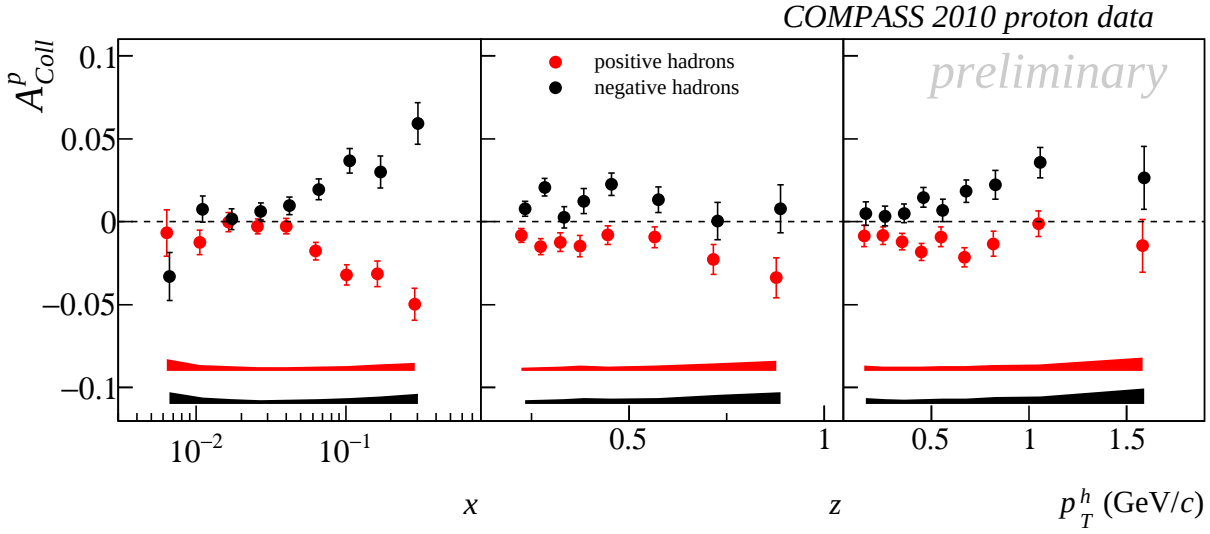

Figure 1: Collins asymmetries for positive and negative hadrons as a function of x, z and p_T.

4 Hadron pair asymmetries

The transversity PDF can be accessed also via the hadron pair asymmetries. In this case, transversity is coupled to another chiral odd function, the di-hadron fragmentation function, describing the correlation between the transverse polarisation of the fragmenting quark and the azimuthal angle of the plane containing the hadron pair.

The hadron pair asymmetries from the 2010 run are shown in fig. 2, as a function of x, the sum of the relative energies of the two hadrons z, and their invariant mass M. The bands represent the systematic uncertainties, equal to 0.8 of the statistical errors. As for the Collins asymmetries, the statistical precision has been improved of a factor 2 with respect to the 2007 results [10]. In the small x region the asymmetry is compatible with zero, while a large signal up to 5-10% in the valence region is visible. Also in this case, in the overlap region there is agreement with the HERMES result [11].

Recently a first extraction of transversity from the hadron-pair asymmetries measured by HERMES or COMPASS has been done. The extraction [12] has been made possible by the first available asymmetries in $e^+e^- \to (\pi^+\pi^-)(\pi^+\pi^-)$ channel by the Belle Collaboration [13]. This way to access transversity is interesting since it provides independent information with respect to the Collins channel. Although with still large error uncertainty, the results extracted from the hadron pair asymmetries are in agreement with the parametrisation obtained in the global fit of the one hadron channel. The new measurement of hadron pair asymmetries from 2010 can be used to improve the significance of the extraction.

5 Conclusions

From 2005 onwards, results on Collins and hadron-pair asymmetries have been produced by COMPASS, using a deuterium target in 2002-2004 and a proton target in 2007 and 2010. The most recent results from the 2010 data confirm the 2007 results with improved statistical uncertainties, and can be used to extract the transversity PDFs in global fits.

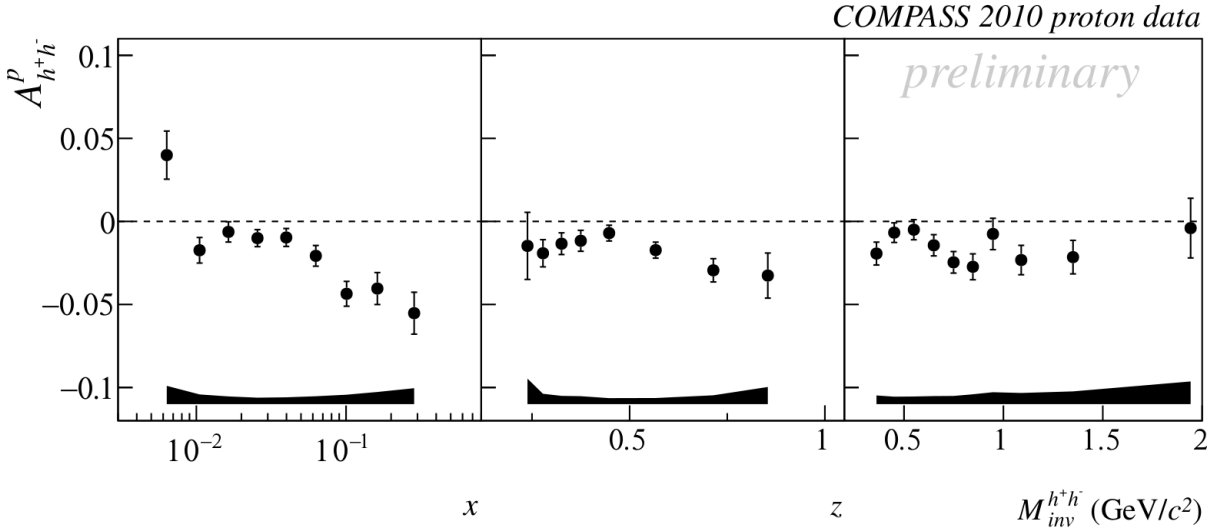

Figure 2: Hadron-pair asymmetries as a function of x, z and M_h.

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