Collins and Sivers asymmetries on the deuteron from COMPASS

Andrea Bressan
(on behalf of the COMPASS collaboration)

Università degli Studi di Trieste and INFN - Sezione di Trieste
via Valerio, 2 - 34127 Trieste (I)

Abstract. The COMPASS Experiment at the CERN SPS has a broad physics program focused on the nucleon spin structure and on hadron spectroscopy, using muon and hadron beams. One of the main objectives for the spin program with the muon beam is the measurement of the transversity distribution $\Delta_T q(x)$ in semi inclusive deep inelastic scattering (SIDIS). In the years 2002, 2003, and 2004 data were collected using a 160 GeV polarized muon beam and a ^{6}LiD target transversely polarized with respect to the muon beam for about 20% of the running time. Here the results for the Collins and the Sivers asymmetries extracted from the 2002 data are presented together with the projected statistical error for the whole 2002-2004 period and for the proton run foreseen in 2006. Results for Λ polarization from 2002-2003 data are also presented.

Keywords: polarized DIS, transversity, SSA
PACS: 13.60.-r, 13.88.+e, 14.20.Dh, 14.65.-q

At leading twist, three independent quark distribution functions, the unpolarized distribution $q(x)$, the helicity distribution $\Delta q(x)$ and the transversity distribution $\Delta_T q(x)$, are needed to describe the quark spin content of the nucleon. At variance with q and Δq, $\Delta_T q$ is chiral-odd and cannot be measured in inclusive DIS, which is the main source of information on the nucleon partonic structure [1]. It can, however, be measured in SIDIS in combination with chiral-odd fragmentation functions, which are, f.i., the Collins fragmentation function, ΔD_a^h for single hadron production, an analogous fragmentation function $\Delta D^0_{\Lambda/q}$ for the Λ polarization and the interference fragmentation function $H_1^{\sphericalangle}$ for hadron pair production. The result is an azimuthal single spin asymmetry (SSA) in the final state hadrons [2]. For single hadrons, SSA can also arise from correlation between the nucleon spin and the intrinsic quark transverse momentum k_T [3]; such an effect is described by the so called Sivers distribution function, $\Delta_0^T q(x,k_T)$. The Collins and Sivers effects can be easily disentangled in SIDIS since they are related to asymmetries which depend on two independent azimuthal angles.

Here we concentrate on the SSA arising from the Collins and Sivers mechanisms, and on the measurement of the Λ polarization, while two hadron asymmetries from the COMPASS data are described in [4].

The Collins mechanism leads to an azimuthal modulation of the event rate given by:

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

where the function α contains the apparatus efficiency and acceptance, P_T is the target polarization ($\sim 50\%$), D_{NN} is the spin transfer coefficient and f is the target dilution

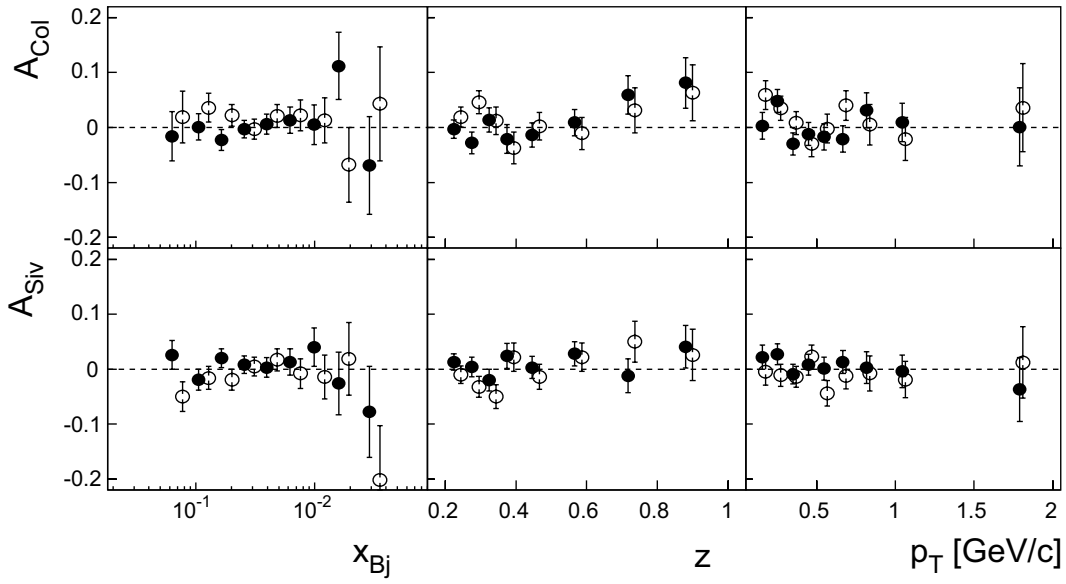

FIGURE 1. Collins and Sivers asymmetry for positive (full points) and negative (open points) hadrons as a function of $x_{\rm Bj}$, z and p_T^h.

factor, i. e. the fraction of polarizable nuclei in the target ($\sim 40\%$); $\Phi_C = \phi_h - \phi_{S'} = \phi_h + \phi_S - \pi$ is the Collins angle, with ϕ_h the hadron azimuthal angle and $\phi_{S'}$ (ϕ_S) the final (initial) azimuthal angle of the quark spin. Finally $A_{\rm Col} \sim \sum_q e_q^2 \cdot \Delta_T q \otimes \Delta D_q^h$ is the Collins asymmetry, arising from the product of the transversity distribution and the Collins fragmentation function, which is being measured by the Belle Collaboration [5]. A similar expression can be written for the Sivers mechanism, with a modulation expressed in terms of the Sivers angle $\Phi_S = \phi_h - \phi_S$.

The resulting Collins and Sivers asymmetries from the 2002 data for events with $Q^2 > 1$ and for all hadrons with $z > 0.2$ are shown in figure 1 [6], with the error bars accounting only for the statistical uncertainty. Different sources of systematic effects have been checked, showing that systematic errors are smaller than the plotted statistical uncertainty. Within the accuracy, both the Collins and Sivers asymmetries turned out to be small and compatible with zero; the same behavior is observed when only leading (in z) hadrons are considered [6].

The phenomenological work of Anselmino and coworkers [7] on the Sivers effect have shown that HERMES results for protons and COMPASS results on deuteron may be described within the same theoretical frame, at least at this level of accuracy.

Vogelsang and Yuan [8] have extracted the Collins fragmentation functions by fitting the proton Collins asymmetry measured by HERMES, assuming a saturated Soffer bound. The favored and unfavored fragmentation functions turn out to have opposite sign and about the same size. Using these distributions and fragmentation functions, the Collins asymmetry on deuteron in the COMPASS kinematics turns out to be small, as an effect of the isoscalar target, and in good agreement with our data. They have also fitted the Sivers asymmetries from HERMES with a simple parametrization of the Sivers function for u and d quarks and calculated on deuteron for COMPASS; again the

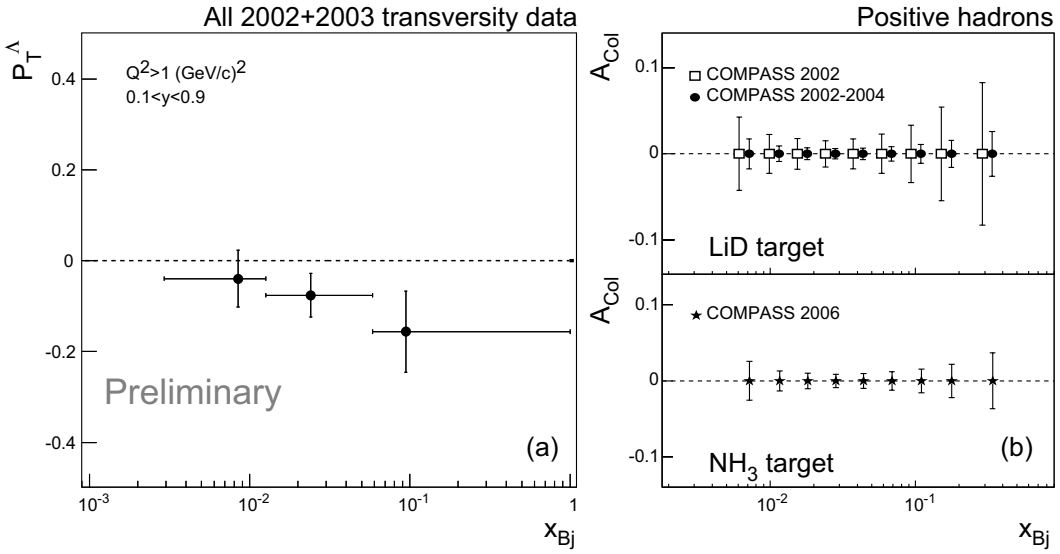

FIGURE 2. (a) P_T^Λ as a function of $x_{\rm Bj}$ for DIS events of 2002-2003 runs. (b) Estimation of statistical errors for $A_{\rm Col}$ as a function of $x_{\rm Bj}$ for deuterium (top) and proton (bottom) targets.

resulting asymmetry is small (except in the large-x valence region) and compatible with the data.

The measurement of the Λ transverse polarization P_T^Λ from a transversely polarized target also allows to access the transversity distribution since $P_T^\Lambda \sim \sum_q \Delta_T q \otimes \Delta D^0_{\Lambda/q}$. The transverse Λ polarization measured for the COMPASS 2002-2003 data is presented in fig. 2, showing a negative trend with large statistical uncertainties; see [9] for details.

The analysis of the full deuterium data (2002-2004) is well progressing and soon we will have the statistical accuracy shown in figure 2(b); also the measurement of P_T^Λ will benefit by factor ~ 2 in statistics by including the 2004 data. In 2006 the COMPASS collaboration plans to take data on a transversely polarized proton target (NH_3). The statistical accuracy for the measurement of $A_{\rm Col}$ on the proton target is also shown in figure 2(b), assuming 30 days of data taking. The COMPASS proton data will permit a first look to the flavor decomposition of $\Delta_T q(x)$ achieving new important information on the "transverse" spin structure of the nucleon.

REFERENCES

1. V. Barone, A. Drago and P. G. Ratcliffe, Phys. Rept. **359** (2002) 1.
2. J. C. Collins, Nucl. Phys. B **396** (1993) 161.
3. D. W. Sivers, Phys. Rev. D **41** (1990) 83.
4. R. Joosten [for the COMPASS Collaboration], these proceedings.
5. A. Ogawa *et al.*, "Collins function measurements at BELLE", these proceedings.
6. V. Yu. Alexakhin *et al.* [the COMPASS Collaboration], Phys. Rev. Lett. **94** (2005) 202002.
7. M. Anselmino *et al.*, Phys. Rev. D **71**, 074006 (2005) [arXiv:hep-ph/0501196].
8. W. Vogelsang and F. Yuan, Phys. Rev. D **72**, 054028 (2005) [arXiv:hep-ph/0507266].
9. A. Ferrero [for the COMPASS Collaboration], talk presented at "Tranversity 2005", Como, Italy, September 7-10, 2005.