Transversity signals in two hadron correlation at COMPASS

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Abstract. Over the last couple of years, transverse spin physics has gained increasing attention as well from theoretical as from experimental side. To fully specify the quark structure of the nucleon at the twist-two level, the transverse spin distribution function $\Delta_T q(x)$ has to be taken into account. The measurement of two hadron production introducing the chiral odd interference fragmentation function $H_1^{\sphericalangle}$ is considered a new probe of the transverse spin distribution function.
COMPASS is a fixed target experiment on the SPS M2 beamline at CERN. Its target can be polarised both longitudinally and transversally with respect to the polarised 160 GeV/c μ^+ beam. In 2002, 2003, and 2004, 20% of the beam-time was spent in the transverse configuration on a ^{6}LiD target, allowing the measurement of transversity effects on a deuterium target. The results of the analysis of two hadron production based on the full statistics on the deuterium target are reported.

Keywords: Transverse Spin Physics, Interference Fragmentation Functions, Transversity
PACS: 14.20.Dh, 13.60.Hb

To fully specify the quark structure of the nucleon at the twist-two level, three quark distribution functions have to be taken into account: the spin averaged distribution q(x), the helicity distribution Δq(x) and the transverse spin distribution Δ_Tq(x). This last distribution function, referred to as transversity, is chiral-odd and can only be measured in combination with another chiral-odd function. At COMPASS, Δ_Tq(x) can be measured in semi-inclusive deep-inelastic scattering (SIDIS), requiring the detection of hadronic products, thus introducing fragmentation functions as additional chiral-odd functions.
So far, attempts were made to access transversity in convolution with the Collins fragmentation-function $\Delta_T^0 D_q^h(z, p_T^h)$ in single hadron production [1, 2, 3].
An alternative approach to transversity is the measurement of two hadron production, introducing the chiral odd interference fragmentation function $H_1^{\sphericalangle}$ where an asymmetry is expected in the azimuthal angle of the hadron plane with respect to the lepton scattering plane. The properties of interference fragmentation functions are described in detail in Refs. [4, 5, 6, 7, 8, 9, 10, 11].

At leading twist, the fragmentation function of a quark q into a pair h of two hadrons h_1 and h_2 can be written as:

$$D_q^h(z, M_h^2) + H_1^{\sphericalangle}(z, M_h^2) \sin\theta \sin\phi_{RS} \tag{1}$$

The angles (see Fig. 1) are defined according to Ref. [12]. Here, θ is the polar angle of the first hadron in the two–hadron center-of-mass frame with respect to the direction

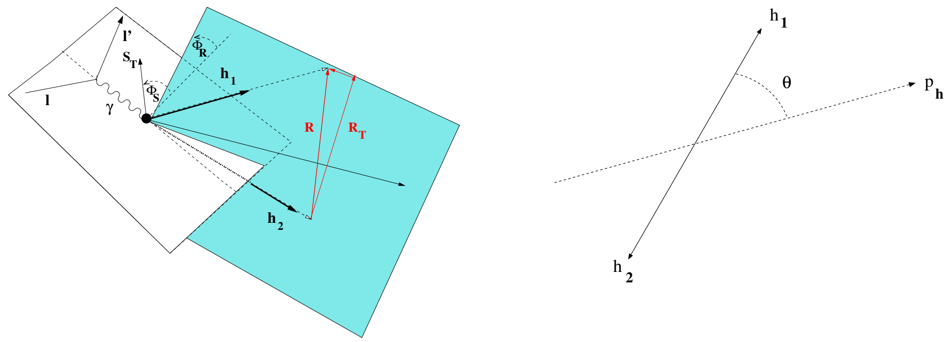

FIGURE 1. Description of the angles involved in the measurement of single spin asymmetries in deep-inelastic production of two hadrons

of the the summed hadron momentum $\mathbf{P}_h = \mathbf{P}_1 + \mathbf{P}_2$. We define $\phi_{RS} = \phi_R - \phi_{S'} = \phi_R + \phi_S - \pi$, where $\phi_{S'}$ is the azimuthal angle of the fragmenting quark, ϕ_S is the azimuthal angle of the initial quark spin and $\phi_{S'} = \pi - \phi_S$.

Here, ϕ_R is the angle between the lepton scattering plane and the plane spanned by the virtual photon momentum $\mathbf{q}$ and the component $\mathbf{R}_T$ of the relative hadron momentum $\mathbf{R} = \frac{z_2\mathbf{P}_1 - z_1\mathbf{P}_2}{z_1+z_2}$ which is perpendicular to $\mathbf{P}_h$. With E_l being the incoming and $E_{l'}$ the scattered lepton energy, $z_1 = E(h_1)/(E_l - E_{l'})$ and $z_2 = E(h_2)/(E_l - E_{l'})$ are the fractions of the transfered energy carried by the two hadrons and $z = z_1 + z_2$.

Due to the contribution of different production channels, $H_1^{\sphericalangle}(z, M_h^2)$ can be decomposed into two components [10],

$$H_1^{\sphericalangle}(z, M_h^2) = H_1^{\sphericalangle,sp}(z, M_h^2) + \cos\theta H_1^{\sphericalangle,pp}(z, M_h^2) \tag{2}$$

$H_1^{\sphericalangle,sp}$ is related to the interference between s- and p-wave states, while $H_1^{\sphericalangle,pp}$ describes the interference between two p-wave states. At COMPASS kinematics, however, θ peaks close to $\pi/2$ with $\langle\sin\theta\rangle \approx 0.94$. Therefore, the contribution of $H_1^{\sphericalangle,pp}$ is rather small. The quoted results are derived by integration over sin θ. In order to evaluate the contribution of $H_1^{\sphericalangle,pp}$, a two–dimensional fit covering the θ–ϕ_{RS} plane is required.

The cross section to produce a hadron pair h on a transversely polarized target is described by coupling the interference fragmentation function to the transverse spin distribution Δ_Tq(x). As a result, an asymmetry $A_{\phi_{RS}}$ is expected in the azimuthal angle ϕ_{RS}.

$$\frac{\Sigma_q e_q \Delta_T q(x) H_{1,q}^{\sphericalangle h}(z, M_h^2)}{\Sigma_q e_q q(x) D_q^h(z, M_h^2)} \propto A_{\phi_{RS}} = \frac{A_{UT}^{\sin\phi_{RS}}}{D_{NN} f P} \tag{3}$$

Where $A_{UT}^{\sin\phi_{RS}}$ is the measured raw asymmetry, $f\,(\approx 0.4)$ the dilution factor, $P\,(\approx 0.50)$ the target polarisation and $D_{NN} = (1-y)/(1-y+y^2/2)$ the depolarisation factor. $y = (E_l - E_{l'})/E_l$ is the fraction of the lepton energy transfered to the hadronic system.

This asymmetry has not been measured so far on a transversely polarised deuterium target and only few predictions exist for both proton and deuterium targets [6, 7, 8].

The COMPASS experiment [13] uses the high intensity 160 GeV secondary μ^+-beam from π-decay in the CERN SPS M2 beamline. This beam is naturally longitudinally polarised with a polarisation of $\approx$-76%. The polarised target consists of two target cells, each 60 cm long, which can be individually polarised using separate RF-cavities. This allows to simultaneously take data of opposite target polarisation. The target can be polarised longitudinally or transversely with respect to the beam axis.

The data discussed here were taken in 2002–2004 with a transversely polarised ^{6}LiD target during five independent data taking periods, where each period was split in two subperiods with opposite spin orientation in the individual target cells.

The event selection is analogous to the analysis of the Collins and Sivers asymmetries [1, 2, 3]. Kinematic cuts $Q^2 > 1\,(GeV/c)^2$, $W > 5\,GeV/c^2$ and $0.1 < y < 0.9$ were applied to ensure a deep-inelastic scattering sample above nuclear resonances and to avoid effects due to radiative corrections and smearing. The final data sample had average values for $x = 0.035$, $y = 0.33$, and $Q^2 = 2.4\,(GeV/c)^2$. The mean hadron multiplicity of the events selected by these kinematic cuts is 1.9 hadrons/event.

Based on this sample, hadron pairs coming from the primary vertex are selected by either choosing all combinations of positive (h_1) and negative (h_2) hadrons or by selecting the leading (i.e. the most energetic) and next to leading hadrons. The later method gives rise to four different asymmetries depending on the charge combinations of the hadrons. The selected hadrons have to fulfil the requirements $z_1 > 0.1$ and $z_2 > 0.1$ as well as $z = z_1 + z_2 < 0.9$ to reject the target fragmentation region and suppresses contamination with exclusively produced ρ-mesons. The resulting sample contains 6.1 10^6 combinations for all '+ -'–pairs and 6.4 10^6 leading-subleading hadron pairs ('+ +': 19 %,'+ -': 34 % ,'- +': 32 % ,'- -': 14 %).

From the data, for each target cell (u,d) and polarisation ($\Uparrow, \Downarrow$), the distribution

$$N(\phi_{RS}) = N_0 \cdot (1 \pm A_{UT}^{\sin\phi_{RS}} \cdot \sin\phi_{RS}) \cdot F_{acc}(\phi_{RS}) \tag{4}$$

can be derived, where $F_{acc}(\phi_{RS})$ is the (unknown) angle dependant acceptance function of the detector. However, by combining both subperiods with opposite target spin as well as both target cells, using the ratio product $A_{RS}(\phi_{RS})$ described in detail in [3]

$$A_{RP}(\phi_{RS}) = \frac{N_u^{\Uparrow}(\phi_{RS}) N_d^{\Uparrow}(\phi_{RS})}{N_u^{\Downarrow}(\phi_{RS}) N_d^{\Downarrow}(\phi_{RS})} \tag{5}$$

these acceptance functions cancel and the asymmetry can be fitted by

$$A_{RP}(\phi_{RS}) = 1 + 4A_{UT}^{\sin\phi_{RS}} \sin\phi_{RS} \tag{6}$$

Figure 2 shows the preliminary results from the COMPASS 2002– 2004 data. While the top plot shows the asymmetries for all positive–negative hadron combinations, the bottom plot shows the same for the selected leading–subleading pairs. Shown are the asymmetries vs. x (left), invariant mass M_h (middle) and z (right).

The observed asymmetries are very small and no significant signal can be observed in either of them. The asymmetry vs. M_h does not show a dependance on the hadron invariant mass. The fluctuations for the signal vs. x and z are very small and still compatible with zero. This is in good agreement with the predictions of [8] for the

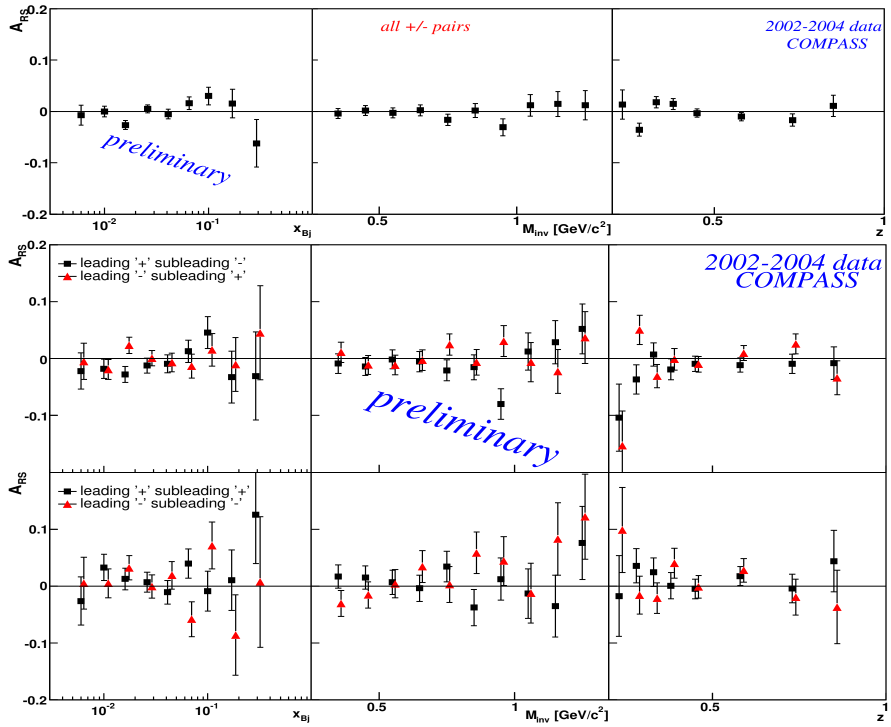

FIGURE 2. Asymmetries $A_{\phi_{RS}}$ for the 2002 to 2004 data for all hadron pairs with unlike charge (top) and for leading and subleading pairs (bottom) with charges +/- (squares) and -/+ (triangles) (middle row) and +/+ (squares) and -/- (triangles) (bottom row). Asymmetries are shown vs. x (left), invariant mass of the hadron pair (middle) and $z = z_1 + z_2$ (right).

deuteron target, where generally the values are below 1 % , except for $x > 0.2$ with $\approx$ 5 %, where, however, our statistics is limited.

Currently, work is going on to implement hadron identification using the RICH information, giving seperate asymmetries for kaons and pions. Additionally, a complementary measurement on a proton target is now foreseen for the COMPASS 2007 run.

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