Transversity signals in two hadron correlation at COMPASS

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Abstract.
Measurement of two hadron production introducing the chiral odd interference fragmentation function $H_1^{\triangleleft}$ is considered a new probe of the transverse spin distribution $\Delta_T q(x)$. 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. First results of the analysis of two hadron production will be reported.

Keywords: Transverse Spin Physics, Interference Fragmentation Functions, Transversity
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THEORETICAL BACKGROUND

The cross-section for deep inelastic scattering off spin 1/2 hadrons can be parametrised, in leading order, in terms of three quark distribution functions: the helicity averaged distribution $q(x)$, the longitudinal helicity distribution $\Delta q(x)$, and the transverse spin distribution $\Delta_T q(x)$. This last distribution function, referred to as transversity, is chiral-odd and can only be measured in combination with another chiral-odd function. So far, attempts were made to measure $\Delta_T q(x)$ in combination with the Collins fragmentation-function $\Delta D_a^h(z, p_T^h)$, requiring the partial detection of the hadronic products (semi-inclusive measurement) [1][2]. Another suggested and very promising probe is the measurement of two hadron production introducing the chiral odd interference fragmentation function $H_1^{\triangleleft}(z, M_h^2)$. The properties of interference fragmentation functions are described in Refs. [3][4][5][6][7][8].

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:

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

with $\phi_{RS} = \phi_R - \phi_{S'} = \phi_R + \phi_S - \pi$, where $\phi_{S'}$ is the azimuthal angle of the struck quark spin, ϕ_S is the azimuthal angle of the initial quark spin and $\phi_{S'} = \pi - \phi_S$.

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 $\mathbf{R} = \frac{1}{2}(\mathbf{P}_1 - \mathbf{P}_2)$ which is perpendicular to the summed hadron momentum $\mathbf{P}_h = \mathbf{P}_1 + \mathbf{P}_2$.

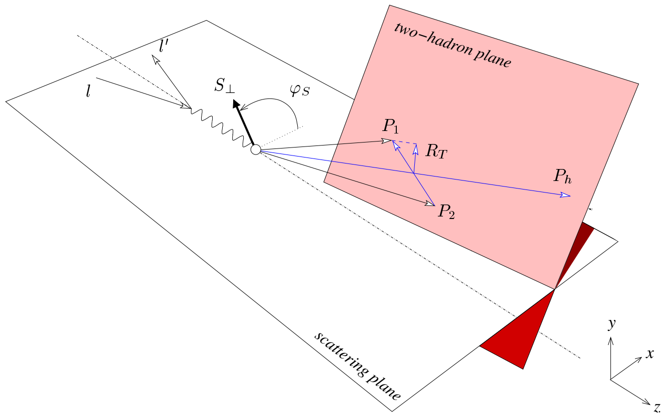

FIGURE 1. Description of the angles involved in the measurement of single spin asymmetries in deep-inelastic production of two hadrons (from Ref. [7])

The angles are defined according to Ref. [9] (see Fig. 1), which follows the so-called *Trento conventions* by:

$$\cos\phi_R = \frac{(\hat{\mathbf{q}}\times\mathbf{l})}{|\hat{\mathbf{q}}\times\mathbf{l}|}\cdot\frac{(\hat{\mathbf{q}}\times\mathbf{R_T})}{|\hat{\mathbf{q}}\times\mathbf{R_T}|}, \qquad \sin\phi_R = \frac{(\mathbf{l}\times\mathbf{R_T})\cdot\hat{\mathbf{q}}}{|\hat{\mathbf{q}}\times\mathbf{l}|\,|\hat{\mathbf{q}}\times\mathbf{R_T}|}, \tag{2}$$

Additionally, $z = z_1 + z_2 = (E(h_1)+E(h_2))/(E_l - E_{l'})$, E_l being the incoming and $E_{l'}$ the scattered lepton energy, is the fraction of the transfered energy carried by the two hadrons, and M_h^2 is their invariant mass squared.

As a result, an asymmetry is expected in the azimuthal angle of the hadron plane which depends on ϕ_{RS}. This asymmetry, which gives information on the transversity distribution, has not been measured so far on a transversely polarised target. One model even predicts a strong dependance of the fragmentation function $H_1^{\sphericalangle}(z,M_h^2)$ on the invariant mass of the two-hadron system in the region of the ρ-mass (Ref. [5]) due to an interference term in two pion production. Another model [6] does not see this strong dependance.

The measured raw asymmetry $A_{UT}^{sin\phi_{RS}}$ is connected to the physically relevant asymmetry $A_{\phi_{RS}}$ by

$$\frac{A_{UT}^{sin\phi_{RS}}}{D_{NN}fP} = A_{\phi_{RS}} = \frac{\Sigma_i e_i \Delta_T q_i(x) H_1^{\sphericalangle h}(z,M_h^2)}{\Sigma_i e_i q_i(x) D_i^h(z,M_h^2)} \tag{3}$$

where $f(\approx 0.4)$ is the dilution factor, $P(\approx 0.45)$ the target polarisation and $D_{NN} = (1-y)/(1-y+y^2/2)$ the depolarisation factor. Here, $y = (E_l - E_{l'})/E_l$ is the fraction of the incoming lepton energy transfered to the hadronic system.

RESULTS FROM THE COMPASS 2002 AND 2003 RUNS

The COMPASS experiment [10][11] 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 ≈-76%.

The polarised target consists of two subsequent target cells filled with ^{6}LiD, each 60 cm long, which can be individually polarised using separate RF-cavities. This allows to take data simultaneously on two target cells of opposite polarisation. The target can be polarised longitudinally or transversely with respect to the beam axis.

The data discussed here was taken in 2002 and 2003 with a transversely polarised target. The sample consists of three 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]. The primary vertex, with identified incoming and scattered muon, is required to be in either of the two target cells. At least two hadrons are required to origin from the same vertex. The separation of muons and hadrons is primarily done by cutting on the amount of traversed material in the spectrometer and on the energy loss in the two hadronic calorimeters. Moreover, the 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 within the COMPASS trigger acceptance. 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 are selected by choosing all combinations of positive (h_1) and negative (h_2) hadrons fulfilling the requirements $z_1 = E(h_1)/(E_l - E_{l'}) > 0.1$ and $z_2 = E(h_2)/(E_l - E_{l'}) > 0.1$ as well as $z = z_1 + z_2 < 0.9$. The first two conditions reject the target fragmentation region while the later suppresses the contamination with exclusively produced ρ-mesons. The resulting sample contains $2.8 10^6$ hadron combinations.

From the data, for each target cell and polarisation, the property

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

can be derived, where $F_{acc}(\phi_{RS})$ is the (unknown) angle dependant acceptance function of the detector. However, by comparing the subperiods with opposite target spin, this acceptance function cancels, resulting in

$$A_{UT}^{sin\phi_{RS}} \cdot sin\phi_{RS} = \frac{N^{\Uparrow}(\phi_{RS}) - RN^{\Downarrow}(\phi_{RS} + \pi)}{N^{\Uparrow}(\phi_{RS}) + RN^{\Downarrow}(\phi_{RS} + \pi)} \tag{5}$$

where $R = N_{tot}^{\Uparrow}/N_{tot}^{\Downarrow}$ is the ratio of the events with opposite target polarisation. (For a more detailed description please refer to [2]). This procedure is repeated for both target cells and all periods. Finally, the weighted mean of the results is calculated.

Figure 2 shows the preliminary results from the COMPASS 2002 and 2003 data. The upper plot shows the asymmetries vs. the invariant mass M_h of the hadron pair, while the two lower plots show the asymmetries vs. x and z respectively.

The observed asymmetries are very small and no significant signal can be observed. Especially the asymmetry vs. M_h does not at all show a strong dependance on the hadron invariant mass. The fluctuations for the signal vs. x and z are very small and still compatible with zero. Including the data of the COMPASS 2004 run on a ^{6}LiD target will double the total statistics and improve the sensitivity by a factor 1.4.

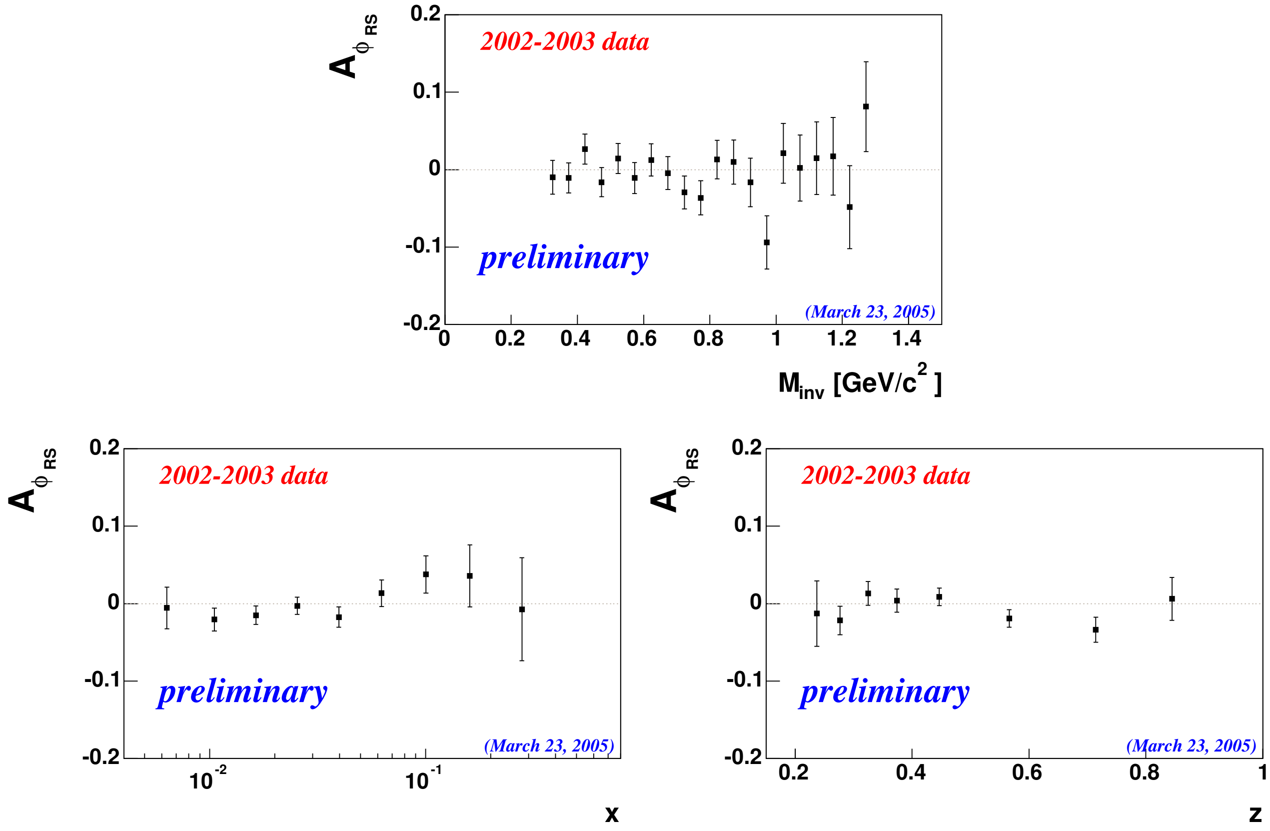

FIGURE 2. Asymmetries $A_{\phi_{RS}}$ for the 2002 and 2003 data vs. invariant mass of the hadron pair (top) and x (bottom left) and $z = z_1 + z_2$ (bottom right).

Furthermore, including hadron identification using the RICH information will clean the hadron sample. Additionally, a complementary measurement on a proton target is planned for the COMPASS 2006 run.

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