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COMPASS results on transverse spin dependent azimuthal asymmetries in dihadron production in semi-inclusive deep-inelastic scattering

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The parton distribution function h_1^q of a transversely polarized quark q inside a transversely polarized nucleon is chiral odd and therefore not accessible in inclusive deep inelastic scattering. It can be observed however in semi-inclusive deep inelastic scattering (SIDIS) in combination with another chiral odd function like *e.g.* the dihadron interference fragmentation function (IFF) $H_1^{\triangleleft q}$. Using the polarized μ^+ beam of CERN's M2 beamline COMPASS has been investigating the spin structure of the nucleon using polarized solid-state targets since 2002.
In this contribution an overview of COMPASS results for the azimuthal asymmetries in dihadron production is given. This includes the results of all hadron pairs h^+h^- on a polarized deuteron target from the data taken in the years 2002 to 2004, as well as the first data set on a transversely polarized proton target taken in the year 2007 and a data set taken on the same target during the year 2010. The COMPASS spectrometer allows a good particle identification, which can be used to determine the composition of the h^+h^- pairs in terms of pions and kaons. The results for the possible combinations $\pi^+\pi^-$, K^+K^-, π^+K^- and $K^+\pi^-$, obtained very recently from the 2007 and the 2010 data, will be discussed in detail. Moreover the asymmetries for $\pi^+\pi^-$ pairs will be compared to the available model predictions and the corresponding results from HERMES.

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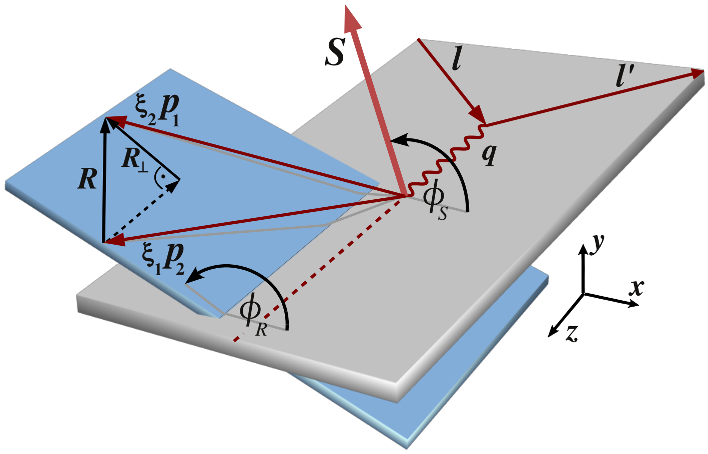

Figure 1: Simplified scheme of the dihadron production process: The incoming lepton and scattered lepton with their 3-momenta $\boldsymbol{l}$ and $\boldsymbol{l}'$ define the scattering plane (gray). The 3-momentum of the virtual photon is denoted by $\boldsymbol{q}$. The angle ϕ_S is the azimuthal angle of the spin $\boldsymbol{S}$ of the fragmenting quark. Each hadron i has its 3-momentum $\boldsymbol{p}_i$, together they define the lepton plane (blue). The corresponding ξ_i values are used for a normalization of the difference vector $\boldsymbol{R}$, *i.e.* $\boldsymbol{R} = (z_2\boldsymbol{p}_1 - z_1\boldsymbol{p}_2)/(z_1+z_2) = \xi_2\boldsymbol{p}_1 - \xi_1\boldsymbol{p}_2$. Hence ϕ_R is the azimuthal angle of $\boldsymbol{R}$ and $\boldsymbol{R}_T$ is its component perpendicular to $\boldsymbol{q}$.

1. Framework & data selection

In the SIDIS process $\mu N \to \mu' h_1 h_2 X$ the incoming lepton is scattered off a transversely polarized quark inside the nucleon via the exchange of a virtual photon. The struck quark hadronizes into at least two unpolarized hadrons. For each oppositely charged hadron pair, the quantity $\boldsymbol{R}$ is defined, *i.e.* their normalized relative momentum. Figure 1 shows a simplified scheme of this process. In the SIDIS cross section the angle ϕ_R between the dihadron plane and the scattering plane and the azimuthal angle of the spin of the initial quark ϕ_S appear in an azimuthal modulation as a function of $\phi_{RS} = \phi_R + \phi_S - \pi$ [1, 2]. To select DIS events in general, kinematic cuts on the squared four momentum transfer $Q^2 > 1\,(\mathrm{GeV}/c)^2$, the fractional energy transfer of the muon $0.1 < y < 0.9$ and the hadronic invariant mass $W > 5\,\mathrm{GeV}/c^2$ were applied. The hadron pair sample requires more selection *w.r.t.* the single hadron asymmetries analysis [3], of which the requirement for a vertex with at least three outgoing tracks (scattered μ^+ and 2 hadrons) is the most fundamental one. All possible combinations of oppositely charged hadron pairs originating from the vertex are taken into account in the analysis. Each of these hadrons has to have a fractional energy $z > 0.1$ and a $x_F > 0.1$, to ensure that the hadron is not produced by target fragmentation. Exclusively produced ρ^0 mesons are rejected by a cut on the missing energy $E_{miss} > 3\,\mathrm{GeV}$ of the pair system. This cut is shown in fig. 2 (left) and its consequence is clearly visible as a removal of the exclusivity peak around 1 in the distribution of $z_1 + z_2$ in fig. 2 (center). Finally a cut of $R_T > 0.07\,\mathrm{GeV}/c$ ensures a well defined azimuthal angle ϕ_R. After all cuts the full statistics on the proton target consists of $45.5 \cdot 10^6$ h^+h^- pairs, of which $28.0 \cdot 10^6$ are identified as pion pairs. The deuteron sample consists of $5.8 \cdot 10^6$ h^+h^- pairs. In the distribution of the invariant mass M_{inv} of the pion pairs, shown in fig. 2 (right) the K^0, ρ^0 and f_1 resonances are clearly visible.

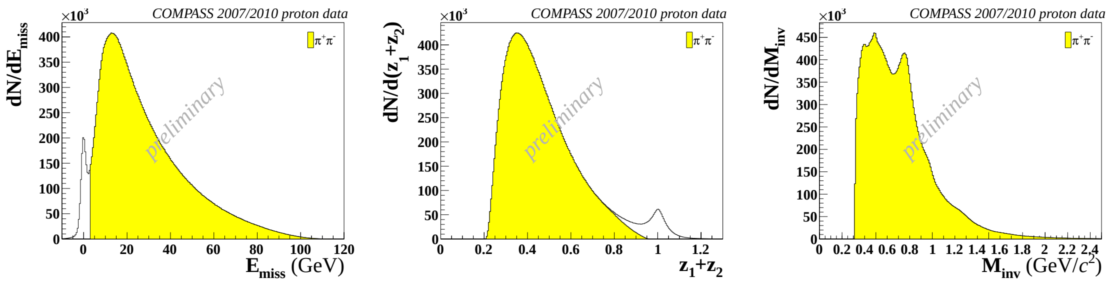

Figure 2: E_{miss} (left), $z_1 + z_2$ (center) and M_{inv} (right) distributions of combined 2007 and 2010 COMPASS proton data for $\pi^+\pi^-$ pairs (other pairs are not shown here for reason of space).

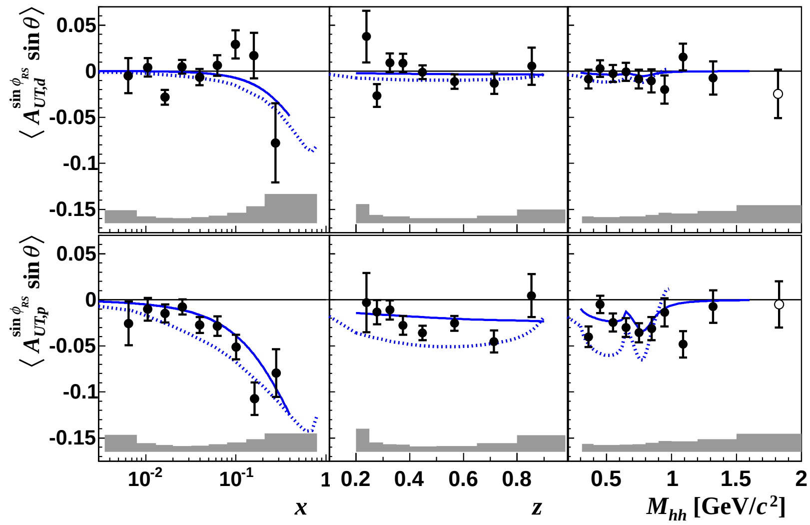

Figure 3: 2002-04 deuteron dihadron asymmetries (top) and 2007 proton dihadron asymmetries (bottom) of h^+h^- pairs in comparison with model predictions from ref. [4] (solid lines) and ref. [5] (dotted lines).

2. Deuteron data 2002-04

The dihadron asymmetry of all hadron pairs h^+h^- for the data collected in 2002-04 on the deuteron target are consistently small and compatible with zero within the uncertainties (fig. 3 top). Furthermore no specific trend is visible for their dependence on x, z and M_{inv}. This result is in line with the COMPASS measurement of the Collins asymmetry on the deuteron, and is interpreted as being due to an almost complete cancellation of the u and d quark transversity on the deuteron target [3], which is also predicted by the available models, see refs. [4, 5].

3. Proton data 2007 and 2010

The first measurement of the dihadron asymmetry of h^+h^- pairs on a proton target at COMPASS was performed using the data collected in the year 2007. The results as a function of x, z and M_{inv} are shown in the bottom part of fig. 3 and ref. [6]. A large asymmetry up to -10% in the valence x-region was measured. A recent extraction of h_1^q including a flavor separation can be found in ref. [7]. As for the z dependence, no specific trend is visible, while for the invariant mass

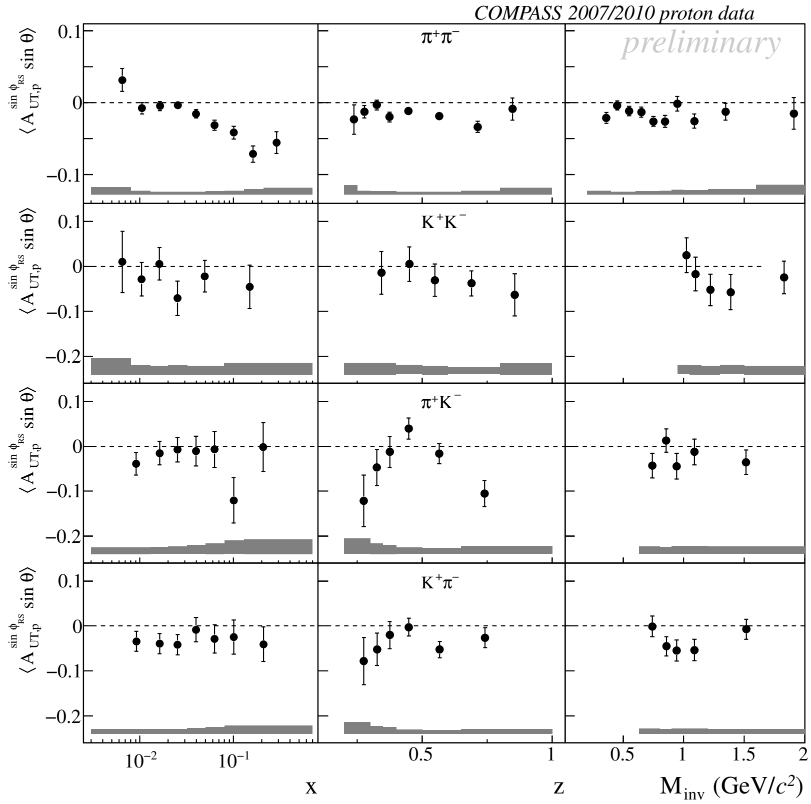

Figure 4: Identified dihadron asymmetries from combined 2007 and 2010 proton data: $\pi^+\pi^-$, K^+K^-, π^+K^- and $K^+\pi^-$ pairs (top to bottom) as a function of x, z and M_{inv} (left to right).

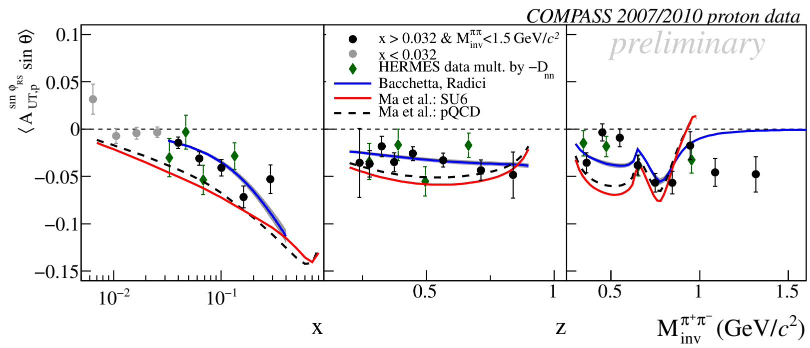

Figure 5: $\pi^+\pi^-$ asymmetries from combined 2007 and 2010 proton data in comparison with HERMES data from ref. [8] and model predictions from refs. [4, 5] in the valence region ($x > 0.032$).

a negative signal around the ρ^0 mass of $0.770\,\mathrm{GeV}/c^2$ is observed and the asymmetry is negative over the whole mass range.

All the COMPASS beam time in the year 2010 was dedicated to collect again data on a transversely polarized proton target. The large amount of data collected not only confirmed and improved the h^+h^- results in terms of statistics, but also allowed to expand the possibilities for further analyses. The COMPASS spectrometer allows a very precise particle identification, which can be used to determine the composition of the h^+h^- in terms of pions and kaons. In particular the signal in the

x valence region ($x > 0.032$) is confirmed, nearly constant with a negative asymmetry in z and the structure in M_{inv} is congruent.
Since the COMPASS spectrometer allows a good charged particle identification, it has been a natural choice to combine these 2 years of data to a final COMPASS result of dihadron asymmetries of identified pairs on a polarized proton target. The results for the possible combinations $\pi^+\pi^-$, K^+K^-, π^+K^- and $K^+\pi^-$ are shown in fig. 4.
The pion pair asymmetry shows a clear signal up to $-6\,\%$ in x, the z dependence is compatible with a constant and for M_{inv} a pronounced peak around the ρ^0 mass is observed. The kaon pairs however with their larger statistical uncertainty show an asymmetry compatible with zero in the x and z dependence, while an indication of a negative value at large M_{inv} is given. The asymmetries of the mixed pairs are mostly compatible with zero, apart from a positive peak around $z = 0.45$ for the π^+K^- and a negative peak around $M_{inv} = 0.9\,\mathrm{GeV}/c^2$ for $K^+\pi^-$.
The $\pi^+\pi^-$ asymmetry was also measured by the HERMES experiment [8]. The overall agreement between these two experiments is good within the uncertainties (fig. 5) bearing in mind the larger kinematic range in x and M_{inv} of COMPASS. This is an important result, also because of the different $\langle Q^2 \rangle$ values in the valence region for the two experiments.
Both available model predictions by Bacchetta *et al.* [4] and Ma *et al.* [5] well reproduce the trend in x, as well as the peak around the ρ^0 mass, while the agreement in other mass regions and z is in general poorer, see fig. 5.
The COMPASS proton and deuteron data give a clear indication of a non-zero transversity h_1 for both u and d quarks, as shown in ref. [7]. With the recent results, of the dihadron asymmetries of identified pairs presented in this proceeding the flavor separation can be further pursued.

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