TWO HADRON ASYMMETRIES AT THE COMPASS EXPERIMENT.

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The COMPASS experiment covers a broad physics program with muon and hadrons beams. The muon beam can be scattered on a longitudinally or transversely polarised target. In this article the production of hadron pairs in deep inelastic scattering of muons on transversely polarised ^{6}LiD target is described. Data selection cuts and results on the spin asymmetries are presented. The results are based on the data collected by the experiment in the years 2002 and 2003. Plans and prospects for the future are discussed, in particular in connection with hadron identification.

1. Two hadron production and transversity

The transverse spin distribution function $\Delta_T q(x)$, called “transversity”, is a chiral-odd object. It is not accessible in inclusive DIS, but it can be measured together with another chiral-odd function. First attempts to adress transversity have been made by measuring single spin asymmetries of hadrons produced in DIS processes on transversely polarised nucleons, where the asymmetry is expected to be the product of transversity and a spin-dependent fragmentation function, the “Collins function”[1]. Our results obtained for the 2002 data are already published[2].

Another process is semi-inclusive DIS where at least two hadrons are observed in the final state. Here the cross section at leading twist can be parametrised in terms of the convolution of transversity with an interference fragmentation function $H_1^{\triangleleft}(z, M_{inv}^2)$. If a pair of hadrons is the result of the fragmentation of transversely polarised quark, an asymmetry $A_{\phi_{RS}}$ depending on the angle between the scattering plane and the 2 hadron plane is expected:

$$A_{\phi_{RS}} \propto \frac{\Sigma_i e_i^2 \Delta_T q_i(x) H_1^{\sphericalangle}(z, M_{inv}^2)}{\Sigma_i e_i^2 q_i(x) D_i^h(z, M_{inv}^2)}. \tag{1}$$

Here D_i^h is the spin independent fragmentation function, z is the sum of scaled hadron energies ($z = z_{h1} + z_{h2}$), M_{inv}^2 is the invariant mass of two hadrons and $q_i(x)$ is the unpolarised distribution function. The sum is over the quark flavours i. The expected properties of the interference fragmentation function and suggested experimental access to it are described in several publications[1−8]:

The angle ϕ_{RS} is defined as $\phi_{RS} = \phi_R + \phi_S - \pi$, where ϕ_R is the azimuthal angle of the $\mathbf{R_T}$ vector, $\mathbf{R_T}$ is the component of the vector of the difference of the two hadron momenta ($\mathbf{P_{h1}} - \mathbf{P_{h2}}$) perpendicular to their sum ($\mathbf{P_{h1}} + \mathbf{P_{h2}}$), ϕ_S is the azimuthal angle of initial quark spin.

The reference system for the measurement is defined by the scattering plane of the lepton beam ($\mathbf{l}, \mathbf{l}'$) and the virtual photon ($\mathbf{q}$) direction as shown in figure 1.

The asymmetry (1) is related to the experimentally measured counting rate asymmetry, which is defined in the following way:

$$A_m(\phi_{RS}) = \frac{N^{\uparrow}(\phi_{RS}) - rN^{\downarrow}(\phi_{RS})}{N^{\uparrow}(\phi_{RS}) - rN^{\downarrow}(\phi_{RS})} = A_{UT}^{\sin\phi_{RS}} \sin\phi_{RS} = DPfA_{\phi_{RS}} \sin\phi_{RS}, \tag{2}$$

where $N^{\uparrow(\downarrow)}$ is the number of events for the target with the up (down) polarization orientation in the laboratory system, $r = \frac{N_{tot}^{\uparrow}}{N_{tot}^{\downarrow}}$ is the ratio of the total number of events (i.e. integrated over the angle ϕ_{RS}) for the two polarization orientations, $D = \frac{(1-y)}{(1-y+y^2/2)}$ is the depolarization factor, P is the target polarization, f is the dilution factor of the polarised target.

The asymmetries $A_{UT}^{\sin\phi_{RS}}$ are obtained from the fit to the $A_m(\phi_{RS})$ distributions.

2. COMPASS experiment

The COMPASS experiment[9,10] covers a broad physics program with muon and hadrons beams.

The experimental setup of COMPASS for the muon program consists of the transversely (or longitudinally) polarised target and of a two-stage magnetic spectrometer with particle identification and hadron calorimeters.

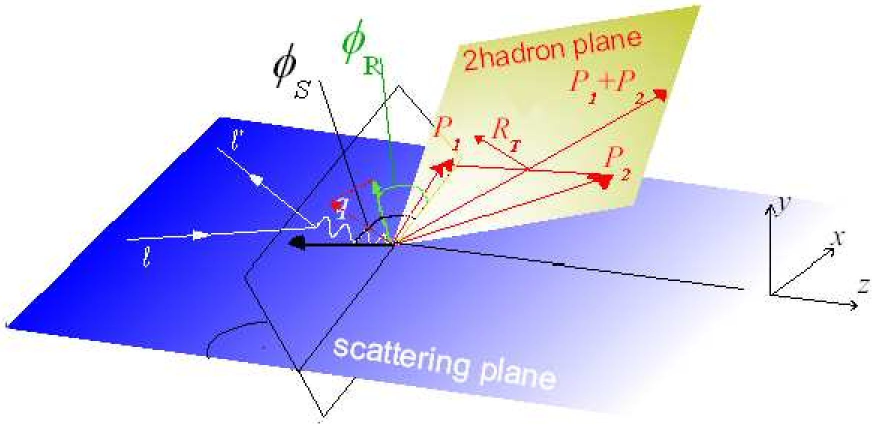

Figure 1. Reference system and angles definitions.

The muon beam has the energy of 160 GeV. The target consists of two 60 cm long cells filled with ^{6}LiD which has a dilution factor of 40%. The target material is polarised to about 50%. The polarization of the material in the first cell is opposite to the one in the second cell, and periodically (once a week) reversed in both cells. This configuration allows cancellation of the acceptance effects in the measured asymmetry.

The first stage of the COMPASS spectrometer is used for the low momenta and large angle tracks reconstruction. High momentum tracks are reconstructed in the second stage. The tracking system consists of various type and size detectors and include small ($50 \times 70\,\mathrm{mm}^2$) silicon and scintillating fiber planes in the beam region, medium size drift, proportional and novel micromesh chambers and large ($3.2 \times 2.8\,\mathrm{m}^2$) straw tube trackers. A set of hodoscopes allows to trigger on events satisfying a suitable correlation between the scattering angle and the momenum loss of the scattered muon. Large angle events are triggered on the basis of the energy deposited in the hadron calorimeter.

Particle identification (not used for the presented results on asymmetry), is provided by a RICH detector, which allows to identify pion, kaon and proton tracks of momenta above 3, 10 and 17 GeV respectively.

3. Data selection

3.1. *Event selection*

In this article the data collected on the transversely polarised ^{6}LiD target during the years 2002 and 2003 are presented. The following event selections are applied: Properly reconstructed events have an incident and a scattered muon and a primary vertex inside the target cells.

DIS events are defined by selection $Q^2 > 1\,GeV^2$. Further cuts are performed on the scaled photon energy: $0.1 < y < 0.9$. The final requirement is that the events contain at least one reconstructed hadron pair with oppositely charged hadrons.

3.2. *Muon and hadron selection*

There is a necessity to distinguish muons and hadrons among the tracks outgoing from the primary vertex. The muon identification procedure uses muon filter detectors and the hadron calorimeter signal. Moreover, the condition that tracks should have more than 30 radiation length in the spectrometer is imposed.

Hadrons are all particles not identified as muons. Current fragmentation region is assured by cuts on $z_h > 0.1$ and $x_F > 0.1$ for each hadron. In order to remove exclusive mesons a cut on $z < 0.9$ is applied. An additional selection on the $\mathbf{R_T > 0.05}$ GeV is performed in order to have well defined angles.

4. Results

The resulting asymmetries are presented in fig. 2 as functions of the three variables: x, z, and M_{inv}. For the invariant mass calculation, all hadrons are assumed to be pions.

The results are compatible with zero. The indicated errors are statistical. The size of the systematics errors were estimated by evaluating "false asymmetries" of the data. They were obtained by scrambling the data with opposite polarisations into fake configurations. The extracted false asymmetries are comptible with zero and their statistical errors are of the same size as the statistical uncertainties of the physics result.

5. Future prospects - hadron identification.

In the nearest future we plan to investigate other two-hadron asymmetries, mainly for identified charged hadron pairs: $\pi\pi$, $K\pi$ and KK. So far some investigations were performed, concerning the possibility separating different hadron flavors using the COMPASS RICH[11], which has been fully operational for the COMPASS transversal data taking starting from the year 2003.

The effect of the RICH identification of hadrons is illustrated on fig.3, which refers to the data collected in the year 2003: the left plot shows the invariant mass distribution comparison for all reconstructed hadron combinations and for the combinations where both particles have an identification answer of RICH. The fraction of the combinations with such answer is 74% of all reconstructed pairs. In the plot to the right one can see the effect of hadron identification: in the three histograms the invariant mass is evaluated following the mass assignments as given by the RICH.

References

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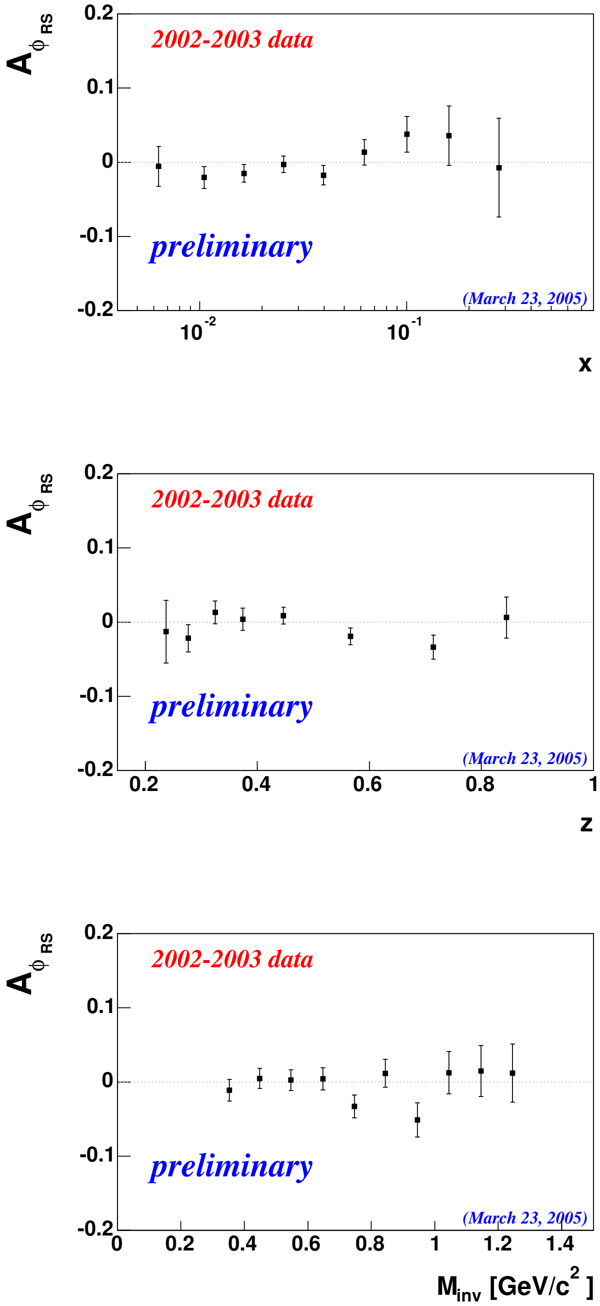

Figure 2. Asymmetry as a function of $x_{Bjorken}$ (upper plot), $z = z_1 + z_2$ (middle plot), and two-hadron invariant mass m_{inv} (lower plot).

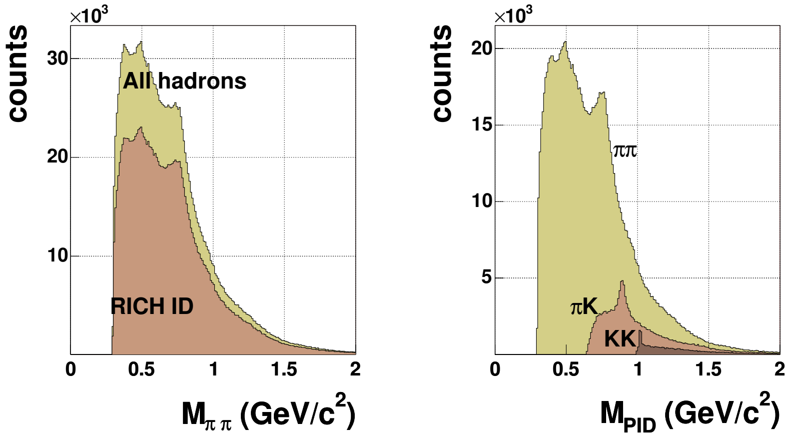

Figure 3. Invariant mass distribution of two hadrons for the COMPASS 2003 data with transverse target polarization. The light histogram on the left plot shows the invariant mass of all reconstructed hadron pairs. The dark histogram on the left plot shows only combinations where both hadrons are identified by RICH. In both cases for both hadrons π mass is assumed. On the right plot: histograms of the invariant masses of hadron pairs with mass hypothesis for each hadron as given by the RICH.