SINGLE HADRON MULTIPLICITIES IN SIDIS AT COMPASS

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Abstract

Single hadron fragmentation functions, FFs, play an important role in several aspects of hadronic spin physics. In particular, they are crucial for the determination of flavour separated polarized parton distribution functions (polarized $PDFs$) from Semi-Inclusive DIS data.

The COMPASS collaboration at CERN is undertaking a programme of measurements of pion and kaon multiplicities in $SIDIS$ for the purpose of extracting these FFs. Preliminary results, derived from muon-nucleon scattering data collected on an LiD target, are presented.

The dependence of the multiplicities upon transverse momentum, p_T, is also investigated, having in view, this time, the dependence of the $PDFs$ and FFs upon the parton intrinsic motion. Preliminary findings, obtained for unidentified charged hadrons, are reported.

1 Introduction

FFs are universal non perturbative objects appearing in the observables of many hard reactions. In the presence of the hard scale, and within the collinear factorization framework, the cross-section can be written as a convolution of the hard partonic cross-section, $PDFs$ and FFs. In the frame of hadronic spin physics, the FFs are needed for *e.g.*, the analysis of the production of hadrons with high p_T, in high energy proton-proton collisions at RHIC or in photoproduction at COMPASS [1], and in $SIDIS$.

The latter plays an important role in the spin sector, because in inclusive polarized DIS, only electromagnetic currents can be used (neutrino scattering from polarized targets being impractical) and therefore quarks and anti-quarks enter symmetrically and cannot be disentangled. $SIDIS$ breaks this symmetry: at LO in pQCD, *e.g.*, the cross-section for the production of hadron h reads:

$$\sigma^h(x,z) = \sum e_q^2 \, q(x) \, D_q^h(z) \, ,$$

where the summation runs on all quark flavours, x and z are the momentum fractions of quark q and hadron h and D_q^h is the FF of q into h. It is therefore able to achieve a complete flavour separation of the polarized $PDFs$, in the fixed target realm.

Such an exercise was performed by HERMES [2]. It yielded the surprising result that the strange polarized PDF, Δs, is compatible with zero (in the measured x range) contrary to expectations based on QCD fits of inclusive data. COMPASS has confirmed this result [3], over an extended x range and with improved precision, *cf.* Fig. 1, which makes it now challenging for global fits to reconcile inclusive and semi-inclusive data. COMPASS showed, though, that the magnitude of the discrepancy is very sensitive to the choice of FFs, in particular to the magnitude of the kaon fragmentation, $D_s^{K-} = D_{\bar{s}}^{K+}$ [3].

$SIDIS$ can also be analyzed, in the low p_T domain, in terms of unintegrated $PDFs$ and FFs where the transverse distributions are modeled by a Gaussian ansatz [5]. Such models can then be used to extract transverse momentum dependent distributions $TMDs$ [6].

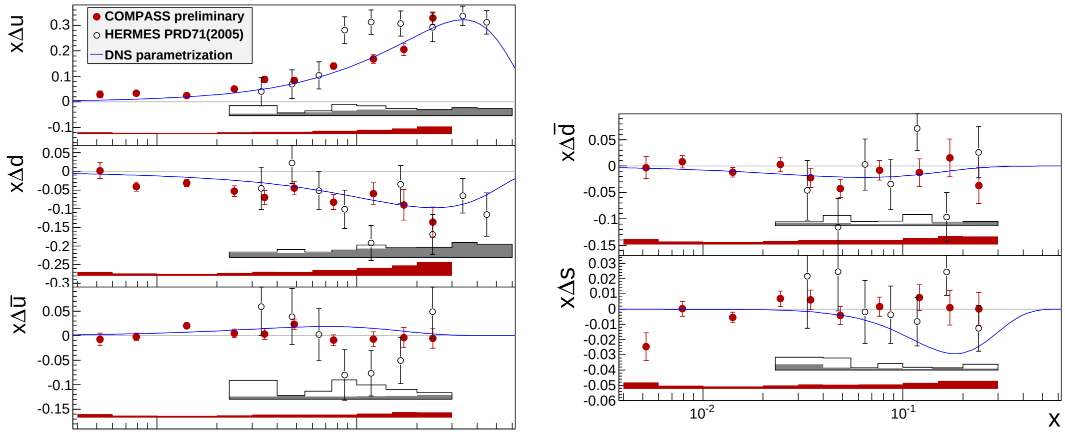

Figure 1: The quark $PDFs$ at $Q^2 = 3\,\mathrm{GeV}^2$ as a function of x. The values are derived from LO analyses of $SIDIS$ asymmetries. The curves are from the DNS fit [4], *i.e.* an NLO QCD fit of both DIS and $SIDIS$ data, using FFs from [7].

2 Multiplicity measurement

FF have been initially extracted from mostly high energy e^+e^- collider data [7] [8]. Such extractions suffer from two limitations. They can only separate quarks from anti-quarks based on model assumptions. Their evolution to the Q^2 accessible to fixed target $SIDIS$, $\sqrt{s} \simeq 17$ GeV in our case, relies heavily on the poorly constrained gluon distributions, D_g^h. More reliable and versatile FFs can be obtained form a global fit of data comprising, in addition to e^+e^-, pp and $SIDIS$ data, such as the DSS fit [9].

In $SIDIS$, one studies the fragmentation process by determining multiplicity distributions for the detected hadrons. At COMPASS, we identify the hadrons with a RICH detector which places strict constraints on the measured momenta. The range retained for the kaon momenta in the present analysis, is [10,50] GeV/c. In order for the acceptance of our spectrometer to remain sizable over the measured domain, we impose a cut on the mass of the hadronic system, $W > 7$ GeV. For the other kinematic variables, we follow a standard DIS selection scheme, *viz.*: $Q^2 >1$ GeV^2, $0.1< y <0.9$. The measured multiplicities are shown on Fig. 2. They agree with DSS for the pions at low z, but significantly depart from it at high z and for the kaons.

Our intent is now to repeat the analysis on 2006 data, which were acquired with an experimental apparatus differing in several aspects from that of 2004 ones, in order to better understand our systematics.

The analysis of K_S^0 along similar lines is under way. An interesting application of this work is that, combined with the $K^{\pm}$, it gives access to the non-singlet combination $(D_u - D_d)^{K^+ + K^-}$ in a model independent way, following the approach described in [10].

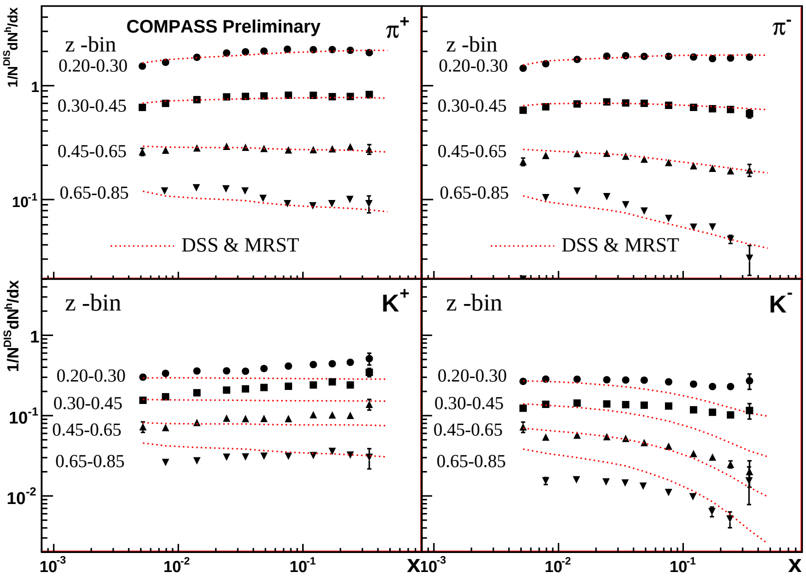

Figure 2: Multiplicities of pions and kaons at COMPASS as a function of x for various bins in z compared to a LO pQCD calculation based on MRST04 $PDFs$ and DSS FFs

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The presently discussed data were acquired on our polarized deuterium target, which is a mixture of LiD and He, *i.e.* an isoscalar target for which nuclear medium effects are expected to be small. We plan to take $SIDIS$ data on a liquid H_2 target in 2012.

3 p_T dependent hadron multiplicities

We also analyze our LiD data as a function of the transverse momentum with respect to the virtual photon, p_T, following the model approach described in [5]. The multiplicities distributions along p_T lend themselves to a good Gaussian fit, provided the fitted domain is restricted to low p_T in order to avoid the region where pQCD effects become dominant. We perform such a fit for p_T <0.85 GeV/c, in z intervals, for a series of two-dimensional (x, Q^2) bins.

The z dependence of the resulting Gaussian widths, $\langle p_T^2 \rangle$, is of particular interest because of its relation to the intrinsic transverse momenta $k_\perp$ and $p_\perp$; $p_\perp$ representing the motion of the detected hadron with respect to the fragmenting parton and $k_\perp$, the motion of the parton inside the initial nucleon. The authors of [5] approximate this dependence by a simple $\langle p_\perp^2 \rangle + z^2 \langle k_\perp^2 \rangle$ expression. Such a linear relation fails to describe our data over the wide z range (0.2< z <0.8) they cover. Instead, inspired by a similar ansatz for the FFs in [7], we assume a z dependence for the fragmentation such that:

$$\langle p_T^2 \rangle \;=\; z^\alpha (1-z)^\beta \, \langle p_\perp^2 \rangle \;+\; z^2 \, \langle k_\perp^2 \rangle \tag{1}$$

where α and β are constants which best-fit values are $\alpha = 0.5$, $\beta = 1.5$. It must be noted that this non-linear behavior is reproduced qualitatively by an update of the model of [5] published recently [11].

Using equation (1), the intrinsic average square momenta $\langle k_\perp^2 \rangle$ and $\langle p_\perp^2 \rangle$ are extracted for each of our (x, Q^2) bins. As an example, the extracted $\langle k_\perp^2 \rangle$ are plotted *vs.* Q^2 in

Fig. 3. They clearly exhibit a strong Q^2 dependence. When plotted *vs.* x instead (figure not shown), they display only a weak trend at low Q^2, which vanishes as Q^2 increases.

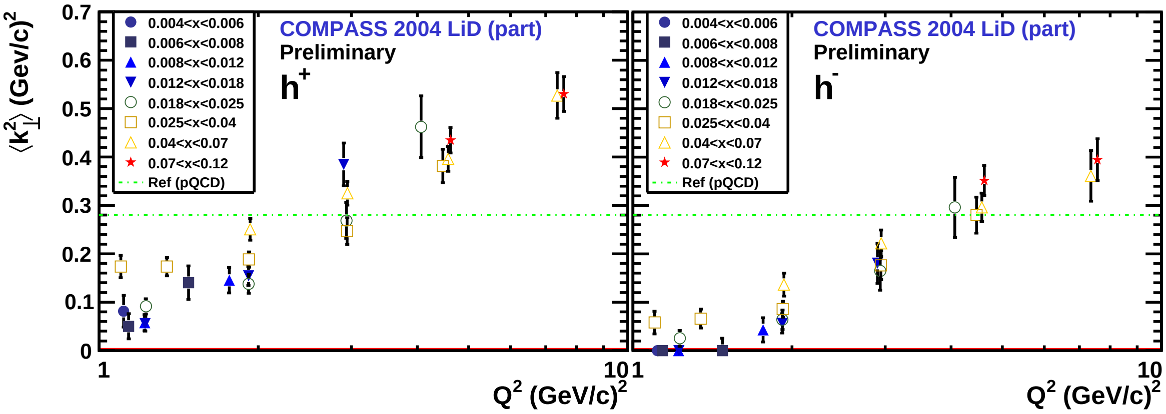

Figure 3: $\langle k_\perp^2 \rangle$ *vs.* Q^2 for positive and negative hadrons. Each data point corresponds to a two-dimensional (x, Q^2) bin. The dotted line is the result of a global fit to data from many experiments [5].

Also, $\langle k_\perp^2 \rangle$ is systematically higher for positive hadrons than for negative ones, suggesting a flavour dependence. We plan to further investigate this hypothesis by extending the present p_T analysis to identified hadrons. Kaon identification could provide access to characteristics of the strange quark $TMDs$.

References

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