Latest results on longitudinal spin physics at COMPASS

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Abstract.
In this article the main longitudinal spin results of COMPASS are shown: the flavour separation of light quark helicities and the gluon polarisation $\Delta g/g$ in the nucleon. The discussion of the former is focused on Δs and includes the topic of hadron multiplicities. New results of $\Delta g/g$ using an open charm analysis are shown at LO and at NLO in QCD. This analysis combines both deuteron and proton data over the full range of Q^2. A new LO result of $\Delta g/g$ obtained from the analysis of high-p_T hadron pairs for $Q^2 > 1$ (GeV/c)^2 is also presented. This result, obtained from deuteron data alone, is separated in 3 points of x_g. Both methods use the photon-gluon fusion (PGF) process.

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INTRODUCTION

One of the major goals of the COMPASS experiment at CERN is the determination of the longitudinal components of the nucleon spin. To achieve this goal, a naturally polarised muon beam of 160 GeV/c is scattered off a longitudinally polarised deuteron or proton target. COMPASS is taking data since 2002, and until 2006 the target was made of ^{6}LiD material as it is optimal for the $\Delta g/g$ measurements. In 2007 a NH_3 target was used so that the longitudinal spin structure of protons could be studied. The material of the target fills two (2002-2004) or three (2006-2007) consecutive cells. The deuterons (in ^{6}LiD) or the protons (in NH_3) from neighbouring cells are polarised in opposite directions so that the spin asymmetries can be measured.

QUARK HELICITIES

The total contribution of quarks to the nucleon spin is nowadays confirmed to be 30%: $\Delta\Sigma = 0.30 \pm 0.01 \pm 0.01$ [1]. However, the precise determination of the quark helicities per flavour is still ongoing. To accomplish this goal COMPASS uses semi-inclusive asymmetries for kaons and pions on both proton and deuteron targets. In the LO approximation, the hadron asymmetry is defined by

$$A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2 \Delta q(x,Q^2) D_q(z,Q^2)}{\sum_q e_q^2 q(x,Q^2)}. \qquad (1)$$

where e_q is the electric charge of a given quark flavour, Δq (q) the polarised (unpolarised) parton distribution function and D_q the corresponding fragmentation function (FF).

In total COMPASS measures 8 semi-inclusive asymmetries [2]. Adding the inclusive asymmetries for proton and deuteron targets, one is able to separate the following quark helicities: Δu, $\Delta\bar{u}$, Δd, $\Delta\bar{d}$ and Δs. These results were obtained using the DSS parametrisation for D_q and are shown in Fig. 1 (left).

It is known from the NLO pQCD analysis of spin dependent structure function g_1 that the strange quark helicity is negative: $\Delta s(x)+\Delta\bar{s}(x) = -0.08\pm 0.01\pm 0.02$ [1]. However, from Fig. 1 one obtains $\Delta s = -0.01\pm 0.01\pm 0.01$. Since the semi-inclusive result is strongly dependent on the choice of the FF used, COMPASS proposes to extract these FF from data by measuring hadron multiplicities. Preliminary results for charged K and π multiplicities are shown in Fig. 1 (right). The existence of discrepancies between data and the DSS predictions are evident for the K case. These results contain only part of the deuteron data and, therefore, the extraction of multiplicities is still ongoing.

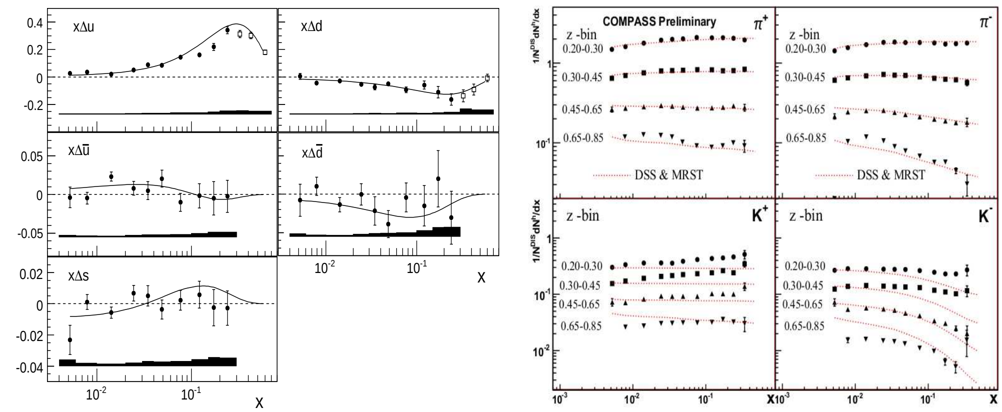

FIGURE 1. Left: COMPASS results on the light quark helicities as a function of x. The curves show the NLO predictions of the DSSV fit. Right: Comparison of the charged π and K multiplicities (number of hadrons per DIS event) measured at COMPASS with the predictions given by the DSS parametrisation.

GLUON POLARISATION

There are two principal ways to study the gluon polarisation in DIS: an indirect method using NLO-pQCD analyses and a more direct one using the PGF process. The QCD analyses of the proton and deuteron g_1 data critically depends on the assumption of the $\Delta g/g$ shape. Thus the systematic error is large. Consequently, the determination of Δg from QCD evolution must be complemented by direct measurements. In COMPASS two main analyses were followed using events with open charm or with high p_T hadron pairs. The first method is free from physical background (at LO). This is justified by the negligible intrinsic charm content of the nucleon in the kinematic domain of COMPASS. The open charm is tagged using D^0 mesons identified via reconstructed invariant mass of their decay products. Since these mesons can only result from interactions with a gluon inside the polarised nucleon (true at LO and also to a very good approximation at NLO), the extraction of $\Delta g/g$ can be performed using the following D^0 asymmetries:

$$A^{D^0} = fP_tP_\mu\langle\hat{a}_{LL}\rangle\frac{\Delta g}{g} \quad \text{with} \quad \hat{a}_{LL}\equiv\frac{\Delta\hat{\sigma}_{\mu g}}{\hat{\sigma}_{\mu g}} = \left(\frac{\hat{\sigma}_{\mu g}^{\leftrightarrows} - \hat{\sigma}_{\mu g}^{\leftleftarrows}}{\hat{\sigma}_{\mu g}^{\leftrightarrows} + \hat{\sigma}_{\mu g}^{\leftleftarrows}}\right). \qquad (2)$$

where f, P_t and P_μ are the fraction of polarisable material inside the target, the target polarisation and the beam polarisation respectively. The partonic asymmetry $\hat{a}_{LL}$ is obtained from a Monte Carlo simulation of the PGF process at COMPASS and, thereafter, it is parametrised by a Neural Network in order to allow for its use on data. In order to overcome the limited charm statistics at COMPASS, a weighted method was developed to minimise the statistical error of $\Delta g/g$ [3]. Since this method implies an event-by-event analysis, a Neural Network is used to distinguish the PGF events from the combinatorial background in the D^0 mass spectra. The open charm analysis is performed at LO and also at NLO in QCD. Both results are shown in Fig. 2 (for details see [3]).

In the second method hadron pairs with high transverse momenta p_T are selected. In this case there are several contributions to the measured asymmetries: LO processes, QCD Compton and PGF processes. For low Q^2 events there are also resolved photon contributions. The analysis is done independently for data with $Q^2 > 1$ (GeV/c)^2 and $Q^2 < 1$ (GeV/c)^2. Despite the large statistics available, this method has to face a more complicated analysis: in order to extract $\Delta g/g$ from the high-p_T asymmetries we need to add to Eq. 2 as many terms as the existing physical processes (with $\Delta g/g$ replaced by A_1^{LO} and $A_1^{Compton}$). The partonic asymmetries, as well as the fractions corresponding to each physical process, are also determined from a Monte Carlo simulation of the COMPASS experiment [4]. The high-p_T results were only obtained at LO and are shown in Fig. 2 (left). They agree with the open charm point from COMPASS and with the high-p_T points from SMC and HERMES. The most fair conclusion than one can draw from such plot is that $\Delta g/g$ is small and compatible with zero within $x_g \in [0.07, 0.2]$.

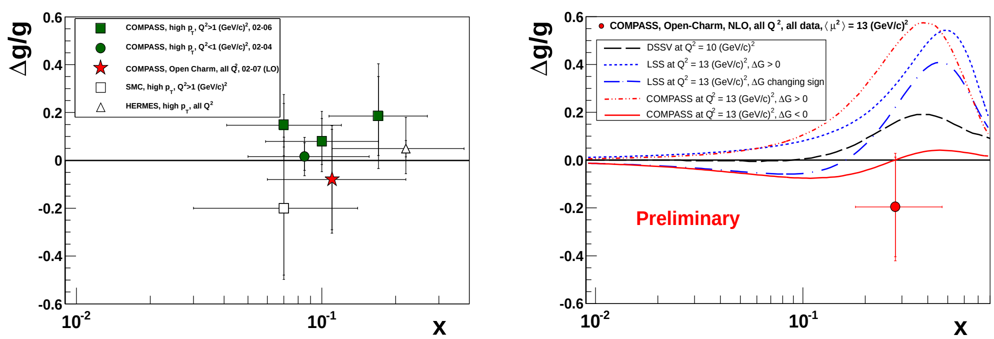

FIGURE 2. COMPASS results of $\Delta g/g$ obtained at LO (left) and at NLO (right) in QCD.

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