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New results on quark helicity distributions and gluon polarization from the COMPASS experiment at CERN

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The new results on quark helicity distributions and on the gluon polarization $\Delta G/G$ from the COMPASS experiment will be presented. COMPASS is a DIS experiment using polarized muons with an energy of 160 GeV scattered off polarized deuteron and proton targets. Quark helicity distributions are obtained from inclusive and semi-inclusive reactions from the 2002-2004 and 2006 deuteron data and from the 2007 proton data. The gluon polarization $\Delta G/G$ is determined from photon-gluon fusion (PGF) events. Two methods based on LO QCD approximation are used to extract PGF events: the selection of open-charm events via the observation of D^* and D^0 mesons or of a pair of high-p_T hadrons. The open-charm result is obtained from the 2002-2004 and 2006 data and it is updated with additional charm channels contributions. For these contributions a new method of the signal strength parameterization based on a neural network classification is used. The high-p_T hadron pair result is obtained from the 2002-2004 data using a new method of accounting for background processes.

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1. Introduction

COMPASS is a DIS at the CERN SPS experiment using polarized muons with an energy of 160 GeV scattered off polarized deuteron and proton targets. The COMPASS spectrometer, the muon beam and the polarized target description can be found in ref. [1]. The data have been collected in 2002-2004 and 2006 years on deuteron target while in 2007 a polarized proton target has been used. Inclusive and semi-inclusive DIS events (virtuality of photon $Q^2 > 1(\mathrm{GeV/c})^2$) allowed us to determine the quark helicity distributions. The spin-dependent structure function $g_1^p(x,Q^2)$ for proton has been measured and combined with the published $g_1^d(x,Q^2)$ structure function, [2] , to evaluate the so-called non-singlet structure function $g_1^{NS}(x,Q^2)$. The new results of this analysis are presented in section 2. One of main goals of the COMPASS spin physics programme is the measurement of the helicity contribution of the gluons, ΔG, to the nucleon spin. It is determined from the longitudinal spin asymmetry obtained from open-charm events (with D^0 and D^* mesons identified) and from high-p_T hadron pairs. The new updated result from open-charm is presented in section 3 while the high-p_T hadron pair analysis is shortly described in section 4.

2. New results on quark helicity distributions

The longitudinal cross-section asymmetry can be decomposed into the virtual photon-proton (deuteron) asymmetries $A_1^{p(d)}$ and $A_2^{p(d)}$ as follows:

$$A_{LL} = D(A_1^{p(d)} + \eta A_2^{p(d)}) \simeq DA_1^{p(d)}, \tag{2.1}$$

where the photon depolarization factor D (as well as η) depends on the event kinematics. All factors in front of A_2 (and A_2 itself) are usually neglected since they are very small in the kinematical range covered by the COMPASS experiment. The spin-dependent structure function $g_1^{p(d)}$ is related to the asymmetry $A_1^{p(d)}$ in the following way:

$$g_1^{p(d)} \simeq \frac{F_2^{p(d)}}{2x(1+R)} A_1^{p(d)}, \tag{2.2}$$

where $F_2^{p(d)}$ and R are the unpolarized (spin independent) structure functions. The new COMPASS result for the proton g_1^p structure function as a function of x are shown in Fig.1 superposed to the results of previous DIS experiments. The good agreement between different experiments is visible. The precise measurement of g_1^p and g_1^d [2] gives the opportunity to evaluate the non-singlet structure function g_1^{NS} defined as follows:

$$g_1^{NS}(x) = g_1^p(x) - g_1^n(x) = 2[g_1^p(x) - \frac{g_1^d(x)}{1-\frac{3}{2}\omega_D}], \tag{2.3}$$

where $\omega_D = 0.05 \pm 0.01$ is the probability of the D state in the deuteron. An evaluation of the first moment of $g_1^{NS}(x)$ provides a new test of the Bjorken sum rule. The Q^2 dependence of $g_1^{NS}(x)$ is decoupled from the QCD evolution of singlet and gluon and a fit to the Q^2 evolution requires only small number of parameters to parameterize the shape of $g_1^{NS}(x)$ at some reference Q^2 point. The

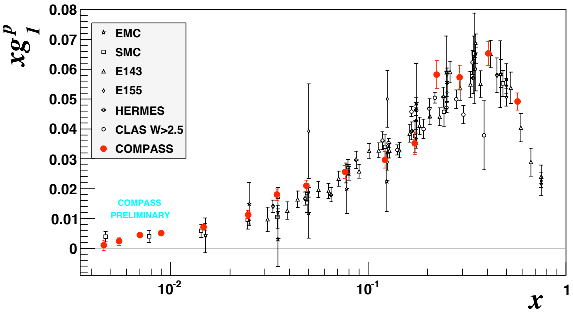

Figure 1: COMPASS result on xg_1^p as a function of x Bjorken . A good agreement between the results from COMPASS and previous experiments is seen. Experimental points are shown in measured Q^2.

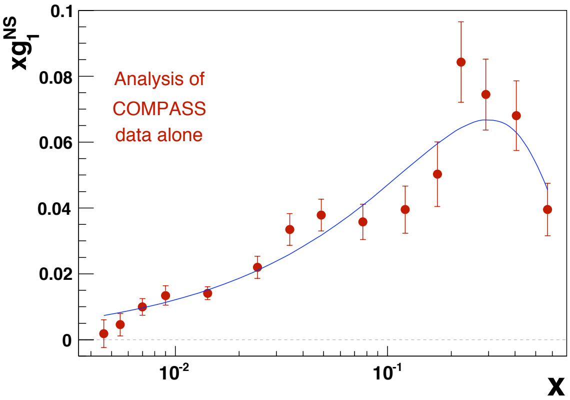

Figure 2: Preliminary vakues of the non-singlet function $g_1^{NS}(x)$ at $Q^2 = 3(\mathrm{GeV/c})^2$. The curve represents the NLO QCD fit to the COMPASS data.

values of $xg_1^{NS}(x)$ as a function of x at the $Q^2 = 3(\mathrm{GeV/c})^2$ together with QCD NLO fit is shown in Fig.2. The first moment of $g_1^{NS}(x)$ which - according to Bjorken sum rule - is equal to:

$$\Gamma_1^{NS}(Q^2) = \frac{1}{6}\frac{g_A}{g_V}C^{NS}(Q^2) \tag{2.4}$$

leads to the following preliminary value for g_A/g_V at $Q^2 = 3(\mathrm{GeV/c})^2$:

$$\frac{g_A}{g_V} = 1.30 \pm 0.007(stat.) \pm 0.10(syst.) \tag{2.5}$$

and it is in a perfect agreement with the one derived from neutron β decay. The presented $g_1^{NS}(x)$ analysis uses COMPASS data only. The dominant systematic error is due to the uncertainty of the beam polarization (5%). The errors related to the fit and QCD evolution are negligible. The combined analysis of inclusive and of semi-inclusive asymmetries for identified hadrons (pions and kaons) measured at COMPASS on proton and deuteron targets allows to evaluate the helicity distributions for different quark flavours: $\Delta u, \Delta\bar{u}, \Delta d, \Delta\bar{d}$ and Δs assumed to be equal to $\Delta\bar{s}$. As in the previous COMPASS LO analysis [3] independent fragmentation is assumed. Unpolarized PDFs were taken from MRST [4] and the DSS parameterization of the fragmentation functions at LO

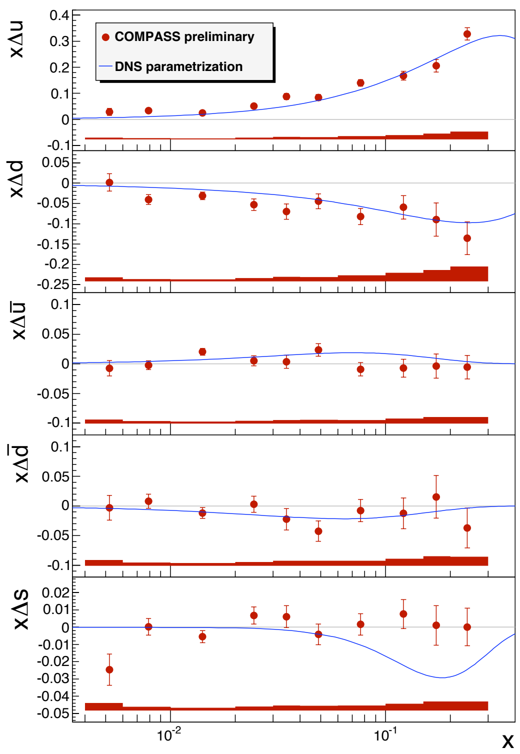

Figure 3: The quark helicity distributions evaluated at common value of $Q^2 = 3(\mathrm{GeV/c})^2$ as a function of x. Systematic errors are shown as a band at the bottom of each plot. For comparison the LO DNS parameterization [5] is shown.

QCD was used [5]. The quark helicity distributions are shown as a function of x at $Q^2 = 3(\mathrm{GeV/c})^2$ with their statistical and systematic errors in Fig.3. More details of the analysis can be found in [3]. The present analysis including 2007 proton data reduces significantly the statistical errors.

3. The determination of the gluon polarization from open-charm events

The open-charm channel is a classical way to access gluons at relatively low energies, when the charm quark can be considered as heavy, not present inside the nucleon and produced only in hard processes. In LO QCD approximation the only subprocess which probes gluons inside nucleon is Photon-Gluon Fusion (PGF). The estimate of the gluon polarization in the open-charm channel is much less Monte-Carlo (MC) dependent than in the two high-p_T hadron method (see section 4.), where the complicated background requires very good MC description of the data. On the other hand the statistical precision in high-p_T hadron method is much higher than in the open charm channel. The details of the open-charm analysis has been recently published in [6]. To increase the statistical precision a weighted method has been used. The most difficult part of the analysis is the estimate of the signal (D^0 events) strength. Two classes of events were used in the gluon polarization determination in the published analysis: D^0 events reconstructed from identified kaons and pions from two-body D^0 decays and so-called D^*-tagged events - events originating from D^* decays into D^0 and slow pions. In the last case three particles in the final state are required

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to be reconstructed and identified but the additional constrain on the D^* mass significantly reduces the combinatorial background. In this presentation a new, updated result obtained by COMPASS is presented. In addition to the two "main" D^0 classes of events two new charm channels were included recently in the analysis: D^0 events reconstructed from the three-body decay of D^0 (charged kaon and pion and π^0) and events where the kaon is not identified by RICH detector (see [1]) due to too low momentum. To estimate the signal strength for these new channels a new, more efficient and simpler method based on a neural network approach has been used. The preliminary result for gluon polarization in LO QCD approximation at average value of $x_g = 0.11^{+0.11}_{-0.05}$ obtained within new analysis is:

$$\frac{\Delta G}{G} = -0.39 \pm 0.24(stat.) \pm 0.11(syst.) \tag{3.1}$$

The scale is $\mu^2 \simeq 13(\mathrm{GeV/c})^2$. An improvement in statistical precision of about 10% between new and published results is obtained.

4. The gluon polarization result from high-p_T hadron pairs

An alternative way to select PGF events is to observe high-p_T hadron pairs in the final state. The analysis is Monte-Carlo dependent (due to physical background from hard sub-processes different from PGF) and requires very good agreement between data and MC. The big advantage is a large gain in statistics compared to the open-charm channel. The new preliminary COMPASS result for the large Q^2 ($Q^2 > 1(\mathrm{GeV/c})^2$) high-$p_T$ analysis is: $\Delta G/G = -0.08 \pm 0.1(stat.) \pm 0.05(syst.)$ at a value of averaged $x_g \simeq 0.082$, with an asymmetric range of $0.06 < x_g < 0.12$, and a scale $\mu^2 \simeq 3(\mathrm{GeV/c})^2$. As in the open-charm analysis a new method of accounting for background processes, based on a neural network approach was used. This analysis has been presented on the conferences (DIS08, SPIN08) and for details the reader is referred to published proceedings (see e.g. [7]). The obtained results from charm channel and from high-p_T hadron pairs point to a rather small value of the gluon polarization. Therefore the contribution from angular orbital momentum of quarks and gluons seems to be important in the understanding of the decomposition of the nucleon spin. Both presented analysis: open-charm and high-p_T hadron pairs are limited to LO QCD approximation so far. The NLO analysis in open-charm channel is now going on. The 2006 data will be soon included in the high-p_T analysis.

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