Nucleon longitudinal spin structure at COMPASS

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The nucleon spin structure is studied at COMPASS via the measurement of the spin dependent properties of deep inelastic muon-deuteron scattering. Both inclusive and semi-inclusive observables are investigated, with the emphasis put on the latter. This allows to access, in particular, the gluon polarization ($\Delta G/G$) and the flavor decomposition of the quark helicity distributions.

Results from measurements with longitudinal target polarization are presented, as well as uncertainties expected from the first 3 years of data taking.

1. INTRODUCTION

COMPASS [1] is a fixed-target experiment installed on the CERN SPS M2 beam line. One of its goals is the unraveling of the spin structure of the nucleon. In this respect, it attempts to answer questions left open by the measurements of the double spin asymmetry in inclusive deep inelastic lepton-nucleon scattering A_1.

First, the gluon distribution ΔG remains largely undetermined. QCD fits of present world data can only but poorly constrain it from the Q^2 dependence of A_1, for lack of lever arm in Q^2.

Secondly, inclusive data alone do not allow to separate quark and anti-quark distributions.

In COMPASS, additional information is brought by semi-inclusive measurements. These are performed with transverse as well as longitudinal target spin orientations, which allows to investigate also the transversity distribution, *cf.* [2].

Finally, in the inclusive measurement of A_1, COMPASS reaches unprecedented precision in the low Bjorken x domain, which will bring improvement in the knowledge of the integral of the g_1 structure function.

2. EXPERIMENTAL ESSENTIALS

The COMPASS spectrometer is described in [1]. Its experimental setup was designed to allow a precise determination of asymmetries. Thanks to its simultaneous measurement of both orientations of target spin in 2 oppositely polarized target cells, u and d, and to a frequent reversal of spin orientations, the acceptance and incident muon flux cancel out in the formula for the cross-section asymmetry $A_{\mu N}$:

$$A_{\mu N} = \frac{1}{2} \quad \frac{1}{P_b \times P_t f} \left(\frac{N_u^{\Uparrow\uparrow} - N_d^{\Uparrow\downarrow}}{N_u^{\Uparrow\uparrow} + N_d^{\Uparrow\downarrow}} + \frac{N_d^{\Uparrow\uparrow} - N_u^{\Uparrow\downarrow}}{N_d^{\Uparrow\uparrow} + N_u^{\Uparrow\downarrow}} \right) \tag{1}$$

where N is the counting rate, $\Uparrow\uparrow$ and $\Uparrow\downarrow$ denote the 2 spin configurations, P_b is the beam polarization ($\sim$76%), P_t and f are the ^6LiD target polarization ($\sim$50%) and, process dependent, dilution factor ($\sim$40%).

The experiment has accumulated $\sim 3\ fb^{-1}$ of data in its 3 years of running from 2002 to 2004. About half of these data has been analyzed so far.

3. $\Delta G/G$

In COMPASS, we access the gluon distribution via the photon-gluon fusion PGF process, whereby a virtual photon couples to a gluon via a $q\bar{q}$ pair. We consider two different selections of the PGF: open charm and high p_T hadron production. Both have been successfully used to directly measure the unpolarized gluon distribution at the HERA collider experiments (with the difference that high p_T refers to the production of jets there). For both, hard interactions are selected irrespective of Q^2, by, respectively, the charm mass and the p_T cut. But the 2 selections differ largely in terms of statistics (higher for high p_T) and background. In the high p_T case, not only do physics background processes contribute significantly but their impact can only be evaluated by a Monte Carlo modelization of the experiment. The intricacy of the problem becomes larger at low Q^2, where processes involving resolved photons dominate. Therefore, two sub-cases are further considered, *viz.* $Q^2 > 1$ and all Q^2. A determination of $\Delta G/G$ has been obtained for the sub-sample with $Q^2 > 1$ and for the much bigger sample with all Q^2 only the projection for the precision expected from the 2002-2004 data is so far available. The 2 values are plotted on Fig. 1 and discussed in [3].

For events with open charm production, PGF enters alone at leading order (in the limit where the nucleon's intrinsic charm is neglected). The main difficulty lies in the combinatorial background associated with their selection by the identification of a D^o meson from its $K\pi$ decay. This is a major concern in COMPASS where the vertex resolution is not sufficient to reconstruct the decay vertex, because of the thickness of the target. Special care is therefore taken to optimize the use of the data. First, the favorable cases when the D^o comes from a $D^* \to D^o\pi$ decay are counted separately, *cf.* Fig. 1. Secondly, a weighting procedure is applied for the derivation of $\Delta G/G$:

$$\Delta G/G = \frac{1}{P_T P_b f} \; \frac{\sum_i^{\Uparrow\uparrow} w_i - \sum_i^{\Uparrow\downarrow} w_i}{\sum_i^{\Uparrow\uparrow} w_i^2 + \sum_i^{\Uparrow\downarrow} w_i^2} \qquad\qquad w_i = \frac{\langle a_{LL} \rangle_i}{(1 + B/S)_i}$$

where a_{LL} is PGF's analysing power and S and B are the signal and background counting rates. In these conditions, the precision is expected to be $\delta\Delta G/G \simeq 0.24$, with direct and D^*-tagged D^o's contributing about equally. This projection is plotted on Fig. 1.

4. INCLUSIVE A_1

The inclusive A_1 is derived from (1) through $DA_1 \simeq A_{\mu N}$, where D is the depolarization factor from the muon to the virtual photon. The data selection is actually not literally

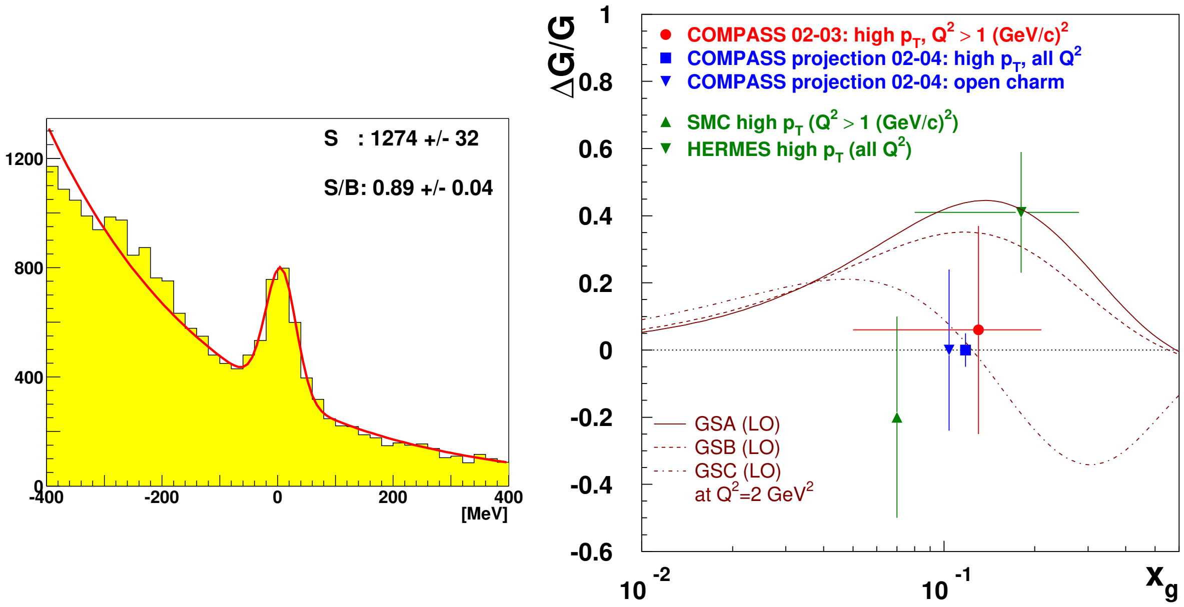

Figure 1. Left: D^o peak in the $K\pi$ invariant mass distribution of D^*-tagged events for 2003 (*i.e.* ~1/4 of total) data. Right: $\Delta G/G$: Results from COMPASS high p_T $Q^2 > 1$ (2002-2003 data, *i.e.* ~1/2 of total) [3], compared with results from HERMES (all Q^2) [4] and SMC ($Q^2 > 1$) [5], and projected error for COMPASS high p_T all Q^2 and open charm channels from all of 2002-2004 data. The curves show the parameterizations of $\Delta G/G$ *vs.* the momentum fraction carried by the gluon, x_g, from [6].

inclusive: at low x a charged hadron is required in the final state, as was done by the SMC experiment [7]. This removes the background from elastic and quasi-elastic scattering and allows for the interaction vertex to be unambiguously located in either of the target cells. The kinematical domain is restricted to $Q^2 > 1$ and $0.1 < y < 0.9$, which makes the measurement cover nearly the same x domain as SMC.

The results for the 2002-2003 data [8] are shown in Fig. 2, together with results from SMC [7], HERMES [9] and E155 [10]. They significantly improve the accuracy in the region $x < 0.03$.

5. SEMI-INCLUSIVE A_1

At the difference with the inclusive case, semi-inclusive measurements allow to separate quark and anti-quark contributions. This is possible when two conditions are met. First, the hard scattering and soft fragmentation processes must be proved to factorize. Secondly, the current fragmentation (arising from the struck quark) must be clearly separated from the target one. One also needs a large enough set of independent measurements in order to get a meaningful flavor separation. COMPASS intends to compute the following asymmetries: $A_1, A_1^{h^+}, A_1^{h^-}, A_1^{K^+}, A_1^{K^-}, A_1^{K_s^o}$, which, on its deuterium (isoscalar) target, gives access to the following combinations: $\Delta u + \Delta d, \Delta\bar{u} + \Delta\bar{d}, \Delta s + \Delta\bar{s}$.

The analysis is under way. Preliminary results have been obtained for the asymmetries $A_1^{h^+}$ and $A_1^{h^-}$ and are shown on Fig. 2, together with results from SMC [11].

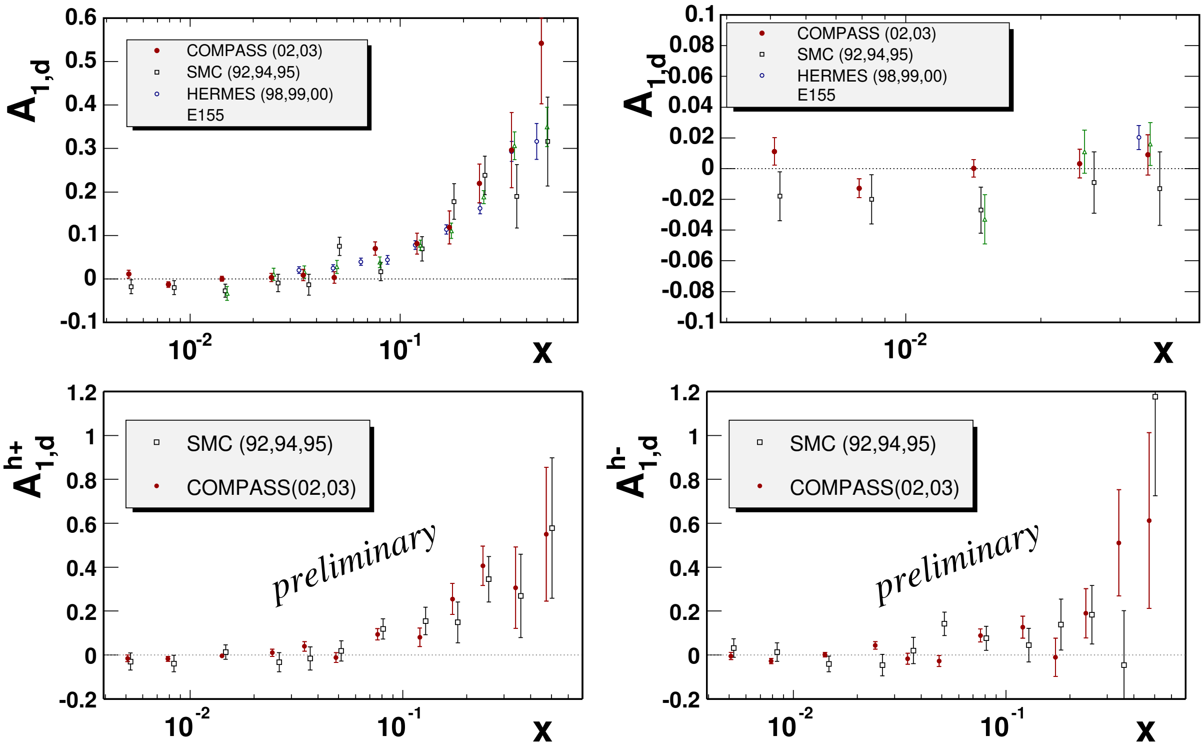

Figure 2. $A_{1,d}$ *vs.* x from COMPASS 2002-2003 data compared with the results from other experiments (*see text for the references*). Top: Inclusive (with a zoom on the low x region). Bottom: Semi-inclusive ($z = E_h/E_{\gamma^*} > 0.2$ to select current fragmentation).

6. OUTLOOK

COMPASS has demonstrated its ability to significantly contribute to the understanding of the nucleon's spin. It is to complete the analysis of its first 3 years of data by the end of 2005, yielding 2 measurements of $\Delta G/G$, via the high p_T and open charm channels, with respective precisions of $\sim$0.05 and $\sim$0.24. While less precise, the open charm channel will provide a model-free determination. The experiment will resume data taking in 2006.

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