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COMPASS measurements of the longitudinal spin structure of the nucleon

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Summary. — A short review of the COMPASS measurement of the longitudinal spin structure of the nucleon is given. Two results on the gluon polarisation $\Delta g/g$ are presented. A LO flavour separation analysis is discussed, with special attention to the strange quark polarisation. Finally, new results of the spin dependent asymmetry A_1^p are shown.

PACS 13.60.-r – Photon and charged-lepton interactions with hadrons.
PACS 13.88.+e – Polarization in interactions and scattering.
PACS 14.20.Dh – Protons and neutrons.
PACS 14.70.Dj – Gluons.

1. – Introduction

COMPASS is an experiment at CERN focusing on the spin structure of the nucleon and on hadron spectroscopy. For the analyses presented in this paper, data with a 160 GeV/c and a 200 GeV/c polarised muon beam impinging on a two (three) cell polarised ^{6}LiD or NH_3 targets were used.

The final results of the gluon polarisation, $\Delta g/g$ from the high-p_T hadron pairs events are presented. The updated results of $\Delta g/g$ obtained in LO and NLO analyses of open charm events are shown. The LO flavour separation analysis is discussed with, an emphasis on the ΔS distribution. Finally, new results of the spin dependent asymmetry A_1^p are presented.

2. – Gluon polarisation

The experimental observation by EMC [1] that only a small fraction of the nucleon spin is carried by the quarks spin strongly influenced for several decades the development of spin physics. In order to investigate the origin of the nucleon spin, it is essential to determine the spin fraction carried by gluons. In this paper direct studies of the gluon polarisation based on photon-gluon fusion processes (PGF) are discussed: i) the analysis of hadrons produced with high transverse momenta, ii) open charm studies.

The main advantage of the HipT method is the fact that considerable amount of photon-gluon fusion events are available resulting in a small statistical error of the obtained $\Delta g/g$. On the other hand this analysis is not background free, and in addition requires several inputs from Monte Carlo simulation. In this respect the open charm events in LO provide a background free source of photon-gluon events. Unfortunately in the COMPASS energy range the production cross section for charm mesons is small, as well as the branching ratio for the $D^0 \to K\pi$ channel. Therefore this analysis has limited statistical precision.

2˙1. *High-p_T hadron pairs analysis.* – The final results of the $\Delta g/g$ analysis of high-p_T hadron pairs events with the negative four momentum transfer, Q^2, $Q^2 > 1\,(\mathrm{GeV}/c)^2$ are presented. The analysis has been recently published in [2]. Data were collected during 2002–2006 years when COMPASS used a LiD target. As the Q^2 ensures the perturbative scale, the cut on hadron p_T can be low, here $p_{T_1} = 0.7$ and $p_{T_2} = 0.4\,\mathrm{GeV}/c$, for the first and the second hadron respectively. The total number of events in the selected sample is about 7.3 millions but the sample is strongly contaminated by non–PGF processes. This background is related to the Leading Process (LP) *i.e.* photon-quark absorption, and to the QCD Compton process (QCDC). The observed asymmetry in a two hadron sample can be written as

$$(1)\quad A_{LL}^{2h}(x_{Bj}) = R_{PGF}\, a_{LL}^{PGF} \frac{\Delta g}{g}(x_g) + R_{LP}\, D\, A_1^{LO}(x_{Bj}) + R_{QCDC}\, a_{LL}^{QCDC}\, A_1^{LO}(x_C).$$

The leading-order (LO) inclusive asymmetry A_1^{LO} is given by the ratio of the spin-dependent and the spin-averaged quark distribution functions (PDFs), weighted by the squared quark electric charges; R_i is the fraction of the process i and a_{LL}^i the corresponding analysing power (*i.e.* the asymmetry of the partonic cross-section). The depolarisation factor D depends mainly on y. The variables x_{Bj}, x_g and x_C are the quark (gluon) momentum fractions in the corresponding processes. Unfortunately Rs and a_{LL}s cannot be determined from data. In COMPASS they are estimated using the LEPTO generator with parton shower on, and the MSTW08LO set of parton distribution functions. To improve the data/MC agreement the intrinsic k_T of quarks inside the nucleon and fragmentation parameters had to be adjusted. To reduce the statistical error of $\Delta g/g$ the weighted method of the asymmetry extraction is used. All R's and a_{LL}'s have to be known on an event-by-event basis. We use a Neural Network trained on MC to obtain parametrizations of R's and a_{LL}'s.

The COMPASS final result of $\Delta g/g$ extracted in this analysis is $\Delta g/g = 0.125 \pm 0.060 \pm 0.065$ at average $x_g = 0.09$ and scale $\mu^2 = 3\,(\mathrm{GeV}/c)^2$. The largest contribution to the systematic error (0.045) comes from MC. The COMPASS is the first experiment to obtain results in three bins of x_g. Within statistical errors these three results agree with each other.

2˙2. *Open charm analysis.* – The updated results, with respect to the one shown at the conference, are presented here. They were submitted for publication [3]. The analysis is based on all available data from 2002–2007, taken on both LiD and NH_3 targets. In order to improve the statistical error of $\Delta g/g$ five different D meson decay modes are studied. In total there are about 65000 D^0 candidates and about 29000 D^* candidates out of which 13000 are in the golden channel $D^* \to K\pi\pi_{slow}$.

In the LO open charm analysis the gluon polarisation is directly proportional to the measured double spin asymmetry in $\mu N \to D^0 + X$. The method which is actually used

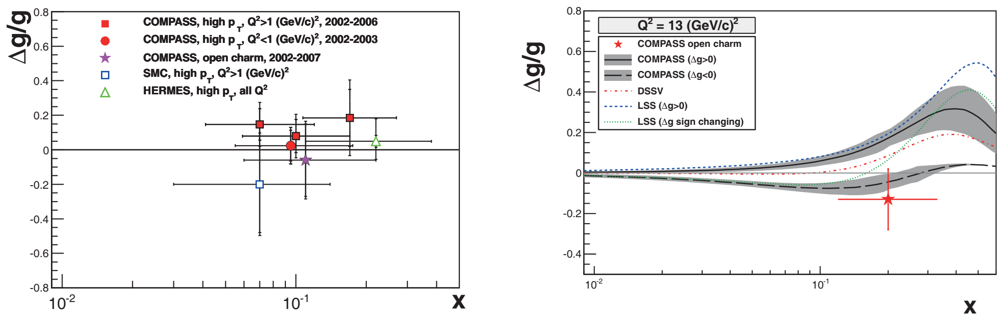

Fig. 1. – Left: The world data on $\Delta G/G$ from LO analyses, right: The COMPASS result of NLO analysis, see text for details.

in the analysis is much more complex, *e.g.* it allows the simultaneous extraction of signal and background asymmetries. To increase the statistical significance of the results events are weighted on an event-by-event basis using a Neural Network approach. The obtained result in LO approximation is $\Delta g/g = -0.06 \pm 0.21 \pm 0.08$ at average $x_g = 0.11$ and scale $\mu^2 = 13\,(\mathrm{GeV}/c)^2$.

The gluon polarisation in NLO approximation was also extracted. The AROMA generator is used with parton shower option on. The parton shower simulates the phase-space for NLO correction, which can be calculated on an event-by-event basis. Large differences are observed between a_{LL} and x_g at LO or at NLO. The result of the NLO analysis is $\Delta g/g_{NLO} = -0.13 \pm 0.15 \pm 0.15$ at average $x_g = 0.20$ and scale $\mu^2 = 13\,(\mathrm{GeV}/c)^2$. The increase of the statistical precision of the NLO with respect to the LO result is related to changes of $(a_{LL})^2$, which is significantly larger in the case of the NLO analysis.

The summary of the COMPASS results on $\Delta g/g$ and comparison with other experiments is shown on fig. 1. In the left panel the LO world results on $\Delta g/g$ are presented. These results include SMC [4], HERMES [5] and COMPASS [6,2,3] analyses. In the right panel the COMPASS NLO result is shown. For comparison results of NLO QCD fits of $\Delta g/g$ from different groups are given: LSS [7], DSSV [8] and COMPASS. A description of the COMPASS NLO fits can be found in [3].

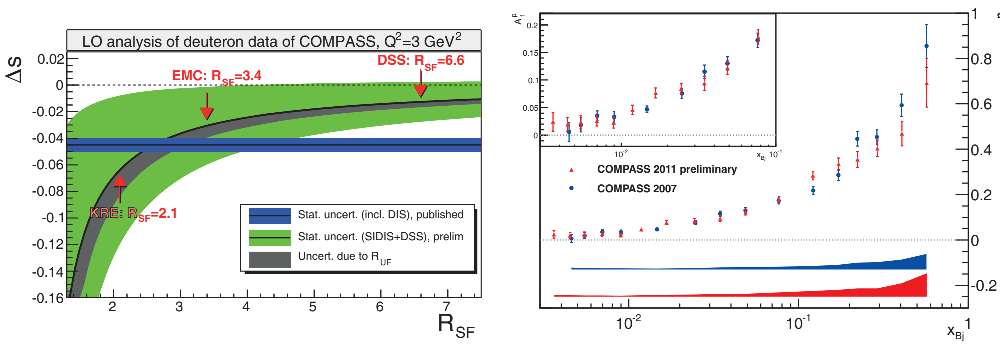

Fig. 2. – The change of the ΔS value and its error as a function of the ratio of the strange to the favoured fragmentation functions (R_{SF}). Right: spin dependent asymmetry A_1^p extracted from COMPASS 2011 data and compared to A_1^p from the previous COMPASS run.

3. – Flavour separation

COMPASS analysed the semi–inclusive asymmetries for kaons and pions produced on both proton and deuteron targets. In the LO approximation the hadron asymmetry can be expressed as

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

where e_q is the quark electric charge, $(\Delta)q$ the (polarised) parton distribution function and D_q^h is the fragmentation function (FF) of quark q into hadron h. With inclusive and semi-inclusive asymmetries one has in total 10 measured asymmetries and 5 unknown parameters $(\Delta u, \Delta d, \Delta\bar{u}, \Delta\bar{d}, \Delta s)$. The flavour separation of the quark helicity distributions is possible using just linear algebra. Some results were already published in [9] using FF from the DSS parametrisation [10]. From the inclusive asymmetries it is known that the strange sea polarisation is negative. This trend is so far not observed in COMPASS and HERMES semi-inclusive analyses where, in the measured range of x, the value of ΔS is consistent with zero. However, as pointed out in [9], the ΔS obtained in the semi-inclusive analysis strongly depends upon the choice of the fragmentation functions used, see fig. 2 left. COMPASS try to extract these FF from the data alone, preliminary results are presented in these proceedings, *cf.* contribution by N. Makke.

The main motivation behind the 2011 COMPASS run was to increase the statistical precision of $\Delta s(x_{Bj})$ as well as the increase the COMPASS acceptance towards lower x. The latter was achieved by the increase in beam energy from 160 GeV/c to 200 GeV/c.

In the first step the spin dependent asymmetry A_1^p and the spin dependent structure function g_1^p were extracted from the new data. The preliminary results of A_1^p are presented in the right panel of fig. 2. The obtained results agree with the previous COMPASS results from an earlier run. The semi-inclusive analysis of the identified hadrons will follow soon.

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