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The COMPASS results on longitudinal spin effects and future measurements

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Abstract

A short review of the COMPASS results obtained in inelastic polarized muon scattering off the longitudinally polarized proton and deuteron targets is given. The measured gluon polarization inside the nucleon is presented including the final value of $\Delta G/G$ from the open charm LO analysis. New results on A_1^p and the Bjorken Sum Rule test are shown. Finally the plans and goals of the future COMPASS measurements are presented.

Keywords: Delta G/G, gluon polarization, nucleon structure, Bjorken sum rule

1. Introduction

COMPASS is an experiment at CERN focusing on the spin structure of the nucleon and hadron spectroscopy. Between 2002 and 2004, a 160 GeV/c polarized muon beam and a two cell polarized ^{6}LiD target were used for spin studies. For the 2006 data taking major upgrades of the spectrometer were made. This included of the RICH improvement for particle ID, a new COMPASS solenoid around the target with an angular acceptance increased from 70 mrad to 180 mrad, and a new three cell target. In 2006 the ^{6}LiD target was used as it is optimal for $\Delta G/G$ measurement. In 2007 an ammonia NH_3 target was used so that spin effects on polarized protons could be studied.

COMPASS has a rich physics program. Two more COMPASS talks were given in this conference: transverse spin effects were presented by C. Schill and for hadron spectroscopy please refer to work by J. Bernhard. In this paper selected results for longitudinal spin effects will be presented. This includes measurement of the gluon polarization inside the nucleon, spin dependent structure functions, quark helicity distribution and finally ideas for further COMPASS measurements.

2. Gluon polarization

The EMC results [1] in the late 80s suggested that the quarks may be responsible for only a small fraction of the nucleon spin contrary to the naive expectation that the spin of the nucleon may be built from valence quarks only. Several other experiments in world leading laboratories of particles physics (at CERN, DESY, JLAB and SLAC) confirmed the EMC observation with improved precision. The contribution of quarks to the nucleon spin is now believed to be about 30%. More generally the spin of the nucleon can be decomposed as:

$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g, \qquad (1)$$

where $\Delta\Sigma$ and ΔG are the polarized quark and gluon contributions to the nucleon spin and $L_{q,g}$ are their angular momenta. In COMPASS so far the gluon polarization is measured by studying photon-gluon fusion processes (PGF). This can be done in *i*) open charm studies and *ii*) in the analysis of hadrons produced with high transverse momenta (HipT). In the former case the analysis is free from any physical background. It is believed that the charm quarks are not constituents of the nucleon and so the appearance of the charm mesons in the final state suggest that a PGF process took place. Unfortunately due to the large charm mass, in the COMPASS energy range the production cross section for charm mesons is small also branching ratio for the $D^0 \to K\pi$ is below 4%. Therefore the analysis has limited statistical precision. The latter method has an advantage over open charm that the production cross-section is larger therefore the statistical error of $\Delta G/G$ will be reduced. On the other hand the HipT analysis is not background free. Even at the highest $p_T s$ there are contributions from leading order and QCD Compton processes. In

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addition for low Q^2 events the resolved photon contribution has to be included, which may reach 50% of the cross section. Almost all the crucial ingredients for this analysis have to be obtained from MC simulation using generators like LEPTO or PYTHIA. Therefore in this analysis the systematic error plays a very important role. In this paper the older results will be only mentioned while the new open charm analysis will be discussed in detail.

In the current open charm analysis all available data from 2002-2007 were used. In order to improve the statistical error of $\Delta G/G$ five different D mesons 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 a simplified approach the gluon polarization $\Delta G/G$ can be obtained from:

$$\frac{\Delta G}{G} = \frac{1}{P_T P_b f a_{LL} \frac{S}{S+B}} A^{\mu N \to D^0 + X} \quad (2)$$

where $P_{T,b}$ are the target and beam polarization, respectively, f is the dilution factor of the material which takes into account the fraction of polarizable nucleons in the target, including radiative corrections. a_{LL} is the so called analysing power which represents the polarization transfer from muon to photon and from gluon to charm quarks. The $\frac{S}{S+B}$ is the ratio between signal and signal plus combinatorial background, and finally the $A^{\mu N \to D^0 + X}$ is the measured asymmetry. The method which is actually used in the analysis is much more complex *e.g.* it allows the simultaneous extraction of signal and background asymmetries, details can be found in [2]. The typical spectra for all five discussed channels are shown in the Fig. 1.

To increase the statistical significance of the results the events are weighted on an event by event basis. The weight for each event is $\frac{1}{P_T P_b f a_{LL}} \frac{S}{S+B}$. In the current analysis $S/(S+B)$ is parametrized using a Neural Network approach. As a model of background the wrong charge combinations (*wcc*) are used *e.g.* $K^+\pi^+$, while the D^0 decays into $K^+\pi^-$ a good charge combination (*gcc*). The NN is trying to find the differences between *wcc* and *gcc* in the phase space of the input parameters which can be attributed to the D^0 mesons present in the good charge combination sample. The input parameters for NN are *e.g.* E_{D^0}, z_{D^0}, particle PID quality. An example of NN parametrization is shown in Fig. 2. As a function of $S/(S+B)$ as obtained from NN the D^* spectrum is plotted. As one observes the higher $S/(S+B)$ from NN the larger the observed peak in real physics data.

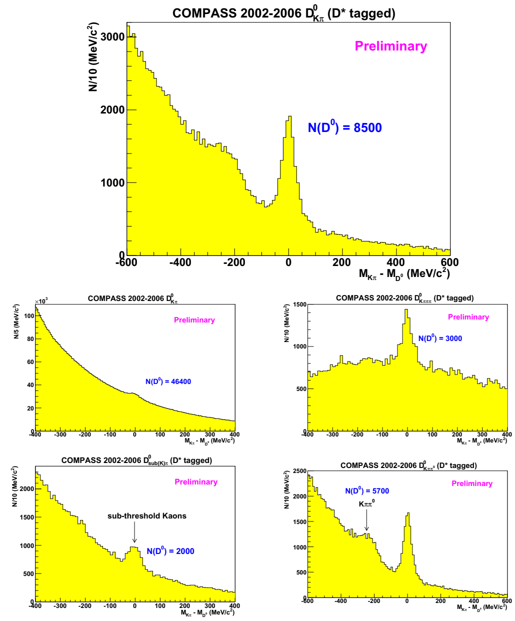

Figure 1: The mass spectra for D^0 mesons in five analyzed channels. Data from 2002-2006 are presented.

The final result $\Delta G/G = -0.08 \pm 0.21 \pm 0.11$ is compatible with zero and the error bar is reduced by a factor of 1.3 w.r.t. the previously published value [2]. The current value is about 0.4 higher than previously published. With the additional years and new channels included in the analysis, and taking into account the correlation between the two analyses, the resulting change corresponds to a bit more than two sigma. We treat it as a statistical fluctuation. The results from five channels are summarized in Table 1.

Table 1: The $\Delta G/G$ results from COMPASS open charm analysis.

channel	$\Delta G/G$
$D^* \to K\pi\pi_{slow}$	-0.19 ± 0.30
$D^0 \to K\pi$	$+0.02 \pm 0.42$
$D^* \to K\pi\pi^0\pi_{slow}$	-0.41 ± 0.58
$D^* \to K3\pi\pi_{slow}$	$+0.63 \pm 0.83$
$D^* \to K_{subth}\pi\pi_{slow}$	$+0.5 \pm 1.0$
TOTAL	$-0.08 \pm 0.21(stat.) \pm 0.11(sys.)$

The COMPASS results on $\Delta G/G$ from HipT analysis are the following. The preliminary result for $Q^2 > 1$ (GeV/c)^2 2002-2004 is $\Delta G/G = 0.08 \pm 0.10 \pm 0.05$. The hard scale of the process is ensured by $Q^2 > 1$ (GeV/c)^2 cut, therefore one can be less strict about hadrons transverse momenta cuts. The analysis is still in progress. The improved method of analysis allows an error reduction by about 30%. In addition the 2006 data are being