Recent Results from COMPASS Spin Program$^{1,2}$

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Abstract—COMPASS is a fixed target experiment at CERN’s Super-Proton-Synchrotron. Part of its physics program is dedicated to the spin structure of the nucleon, which it studies with a polarized muon beam and polarized targets. An overview of its recent results along this line is given. In particular, the first results of our 2011 longitudinally polarized proton run, a report on our progress towards the extraction of the gluon polarization, $\Delta G$, at NLO and an update on our measurements of transverse spin and $k_T$-dependent processes, from our 2010 transversely polarized proton data, and of hadron multiplicities.

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1. INTRODUCTION

COMPASS represents a continuation of experiments investigating the spin structure of the nucleon via DIS. Its advantage lies in its ability to achieve good precision over a wide $x$ range, down to $\sim 10^{-3}$ for $Q^2 > 1$, and in the fact that it does so not only for inclusive DIS, but also for a variety of semi-inclusive measurements, both in DIS and photoproduction regimes. This is made possible thanks to the concurrence of a unique beamline (CERN SPS M2), that is able to deliver high-energy polarized muons, a thick (~1.2 m), large aperture polarized target and a forward spectrometer equipped, in particular, for particle identification.

The collaboration has taken spin structure data for a total of seven years since 2002, alternating longitudinal and transverse polarization on either deuteron or proton polarized targets. The latest results extracted from these data are reported here. These comprise the first results of our 2011 proton run at 200 GeV, as well as updates on $\Delta G$, transverse spin and $k_T$-dependent processes and multiplicities.

In 2010, the COMPASS II proposal [1] was submitted to investigate further the nucleon structure towards a three dimensional picture. For this a series a new measurements is planned, accessing GPDs and TMDs. Moreover, the studies of semi-inclusive DIS on unpolarized target will be continued. This aspect is the object of separate presentation at this conference [2].

2. EXPERIMENTAL ESSENTIALS

The COMPASS spectrometer is described in details in [3].

Its experimental setup was designed to allow a precise determination of asymmetries. An important point in this respect, is the control of fake asymmetries. We achieve it thanks to the simultaneous measurement of the two spin states in two oppositely polarized target cells ($1/2 \uparrow$, $1/2 \downarrow$) so that fluctuations in incident muon flux cancel out. In order to correct for the difference of acceptance seen by the two cells, the spin orientations are periodically reversed, via target field rotation when possible, i.e. in the longitudinal case, and via re-polarisation, which allows a spin reversal in constant field.

An even better control of the instrumental asymmetries is achieved starting with the 2006 run, where the target is divided in 3 ($1/4 \uparrow$, $1/2 \downarrow$, $1/4 \uparrow$ and vice-versa), so that both spin states have permanently the same average acceptance.

The cross-section asymmetry, $\mathcal{A}$, is related to the counting asymmetry, $A$ by factors describing the polarization of the incoming particles, $P_M$ for the beam, $P_T$ and $f$ for the target polarization and for the, process dependent, dilution factor. It is best expressed as $\mathcal{A}/D$,

$$\mathcal{A}/D = A/(P_M \times P_T \times f \times D), \quad (1)$$

where one takes also into account a kinematical factor, $D$, describing the polarization transfer from the muon to the photon. $D$ is process dependent and typically averages to $\sim 60\%$. Typical values for the LiD, polarized deuteron target are $P_T = 50\%$ and $f = 40\%$, yielding a figure of $\sim 10\%$ for the overall dilution factor relating the physics asymmetry of interest to the experimental asymmetry. For the polarized proton target (NH$_3$), the corresponding numbers are $P_T = 90\%$ and $f = 14\%$, and $\sim 6\%$ overall factor.

The first four years of data taking have been spent on deuterons, to benefit for the larger figure of merit, mainly in the longitudinal mode. Since 2007, the proton target has been used, shared equally between longitudinal and transverse. An estimate of the overall integrated luminosity for the longitudinal mode is $\sim 4$ fb$^{-1}$.

Electromagnetic calorimetry has been progressively installed in both spectrometer stages next to the

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$^1$Talk given on behalf of the COMPASS collaboration.

$^2$The article is published in the original.
already existing hadronic one. It is not yet included in the muon data analysis.

3. 2011 PROTON RUN

An important aspect of our understanding of the polarized structure of the nucleon is the determination of the longitudinally polarized parton densities (pPDFs) in QCD and their first moments, which correspond to the spins carried by the quarks and gluons. DIS has played a crucial role in this determination, with measurements being taken from SLAC, CERN, DESY and JLab experiments. In this context, COMPASS occupies a strategic position, in the small x range. It has undertaken to provide a boost in precision for the inclusive and semi-inclusive $g_1$ data in this range. The 2011 run represents the last building block of this undertaking, bringing the precision on the proton close to that already achieved on the deuteron. This is illustrated in Fig. 1, for the case of inclusive $g_1$.

The analysis of the 2011 SIDIS data, i.e. the semi-inclusive production of hadrons ($\pi$ and $K$) in DIS, is under way. It is projected to shed light on the strange quark polarization puzzle, i.e. the contradiction between the strange quark pPDF obtained from inclusive DIS data and that obtained from SIDIS, described in details in [5].

4. $\Delta G$

Among all pPDFs, the gluon, $\Delta G$, is the least constrained by DIS or SIDIS. Firstly, it does not couple directly to the photon. Secondly, the available level arm in $Q^2$ is too small for it to inferred from the evolution of quark distributions, at least when considering DIS experiments alone, since these are at present restricted to fixed target geometries. COMPASS overcomes the problem by considering direct approaches, viz. open charm and high $p_T$ hadron productions, where the contributions of gluons is enhanced, typically via the second order process called photon-gluon fusion (PGF). This solution has the drawback that the momentum fraction $x$ is not measured in the interaction. In order to access the pPDFs, one has then to devise a way to fold these soft distributions with the partonic level hard processes. Traditionally, COMPASS has relied on Monte-Carlo generators (LEPTO or PYTHIA) to achieve this goal, limiting itself to LO in pQCD. Recently, it has made progress towards NLO.

Firstly, it performed a new analysis of its open charm data [6], still relying on LEPTO but including NLO corrections to hard processes based on [7]. The obtained value is:

$$\Delta G/G = -0.13 \pm 0.15(\text{stat.}) \pm 0.15(\text{syst.})$$

$$x_G = 0.20^{+0.13}_{-0.08} \mu^2 \approx 13\text{GeV}^2.$$

Compared with LO extractions, it is still compatible with zero, with improved precision and at a higher average $x$. Which, combined with what is otherwise conjectured for the functional shape of the distribution as a function of $x$, reinforces the conclusion that $\Delta G$ is small.

Secondly, a new pQCD calculation became available for the unpolarized cross-section of the hadron photoproduction at high $p_T$ [8]. It updates a previous NLO calculation [9] by including higher order corrections, and reproduces much more accurately our data [10]. It therefore gives confidence in our ability to extract valuable information on $\Delta G$ beyond LO from the $\sim 4$ fb$^{-1}$ of photoproduction data accumulated by COMPASS.

5. TRANSVERSE SPIN AND $k_T$-DEPENDENT PROCESSES

COMPASS 2010 run was entirely dedicated to data taking in the transverse polarization mode. Transverse spin effects arise in SIDIS from various $k_T$-dependent parton distributions (TMDs) [11, 12]. E.g. the transversity distribution, $h_1(x, k_T)$, couples to the Collins fragmentation $H_1^c(z, p_T)$ describing the azimuthal hadron distribution correlated with the quark transverse polarization. And the Sivers distribution, $f_1^T(x, kT)$, describing the azimuthal distribution of quarks corre-