

Recent Results from COMPASS

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1. Introduction

The COMPASS experiment makes use of the CERN SPS high-intensity muon and hadron beams for the investigation of the nucleon spin structure and the spectroscopy of hadrons [1]. Scattering a polarized beam of 160 GeV/c μ^+ off a polarized ${}^6\text{LiD}$ target, results on the deuteron spin-dependent structure function g_1^d [2,3], on transverse spin asymmetries [4,5], and on the gluon polarization in the nucleon [6] have been obtained from the first phase of data taking between 2002 and 2004. In 2004, first data on the polarizabilities of pions and on diffractive meson production were collected with a 190 GeV/c π^- beam.

Here we report on recent results concerning the spin structure of the nucleon and the polarizability of the pion.

2. Spin Structure of the Nucleon

The main goal of COMPASS between 2002 and 2004 was to determine the composition of the nucleon spin, which can have the four components

$$\frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + L_q + L_g \quad ,$$

where $\Delta\Sigma$ and ΔG are the polarizations of quarks and gluons and L_q and L_g their orbital angular momenta, respectively. Using the \overline{MS} renormalization scheme, the contribution of the quarks is given by the observable singlet axial current, $\Delta\Sigma = a_0$. This value is extracted by a QCD fit to the complete set of structure functions. COMPASS has published a new measurement of g_1^d [7], which significantly improves our knowledge in the region of low x_B . Here, a previous SMC measurement [8] had indicated a slightly negative contribution, where we find the data well compatible with zero, as shown in Fig. 1. Therefore, a new fit to the world data on g_1^d , including the aforementioned new COMPASS measurement, and on the unpolarized nucleon structure function yields

$$a_0(Q^2 = 3 \text{ GeV}^2/c^2) = 0.35 \pm 0.03_{\text{stat}} \pm 0.05_{\text{syst}} \quad .$$

The coupling of the gluon distributions to the measured structure functions, which in leading order only contain direct contributions from the quarks, is rather weak and consequently manifests itself only in a weak Q^2 dependence of g_1 . The two curves shown in Fig. 2 correspond to two equally good fits to the data, one with negative gluon polarization, the other one with positive. Thus, from the QCD fit it is concluded that the absolute value of the first moment of ΔG is in the range or 0.2–0.3. The two solutions with their error bands are shown in Fig. 2.

Direct measurements of ΔG are pursued from two independent venues: double spin asymmetries in the production of open charm or hadrons at high transverse momenta. In the former case, the presence of a charm quark selects the photon–gluon fusion process, experimentally realized by reconstructing D^0 mesons, either solely by their decay into charged πK pairs or tagged by $D^* \rightarrow D\pi$.

The result for the gluon polarization, probed at a scale of $\mu = 13 \text{ GeV}^2/c^2$, is

$$\left. \frac{\Delta G}{G} \right|_{x_g \approx 0.15} = -0.57 \pm 0.41_{\text{stat}} \pm 0.17_{\text{syst}} \quad .$$

Another method of enriching the photon–gluon fusion is to select hadron pairs with $\sum p_T^2 > 2.5 \text{ GeV}^2/c^2$; the ratio of processes involving gluons is then determined by means of a Monte Carlo simulation. This analysis has been performed in the photo-production regime ($Q^2 < 1 \text{ GeV}^2/c^2$) as well as in the DIS regime ($Q^2 > 1 \text{ GeV}^2/c^2$), probing the gluon polarization at a scale of $\mu = 3 \text{ GeV}^2/c^2$. The most precise result is obtained in the low Q^2 case,

$$\left. \frac{\Delta G}{G} \right|_{x_g=0.085} = 0.016 \pm 0.058_{\text{stat}} \pm 0.055_{\text{syst}} \quad ,$$

while the result for high Q^2 is

$$\left. \frac{\Delta G}{G} \right|_{x_g=0.13} = 0.06 \pm 0.31_{\text{stat}} \pm 0.06_{\text{syst}} \quad .$$

These results are compared to the QCD fits mentioned above in Fig. 2.

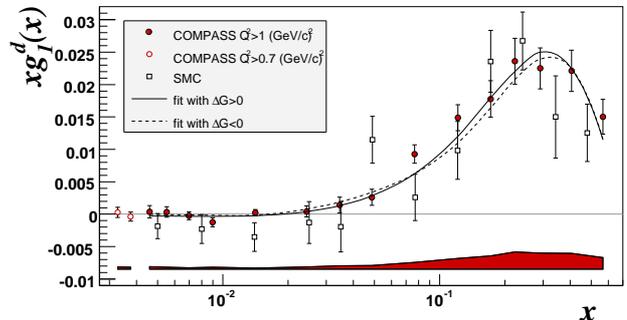


Fig. 1: Measured structure function g_1^d . All data points evolved to scale $Q^2 = 3 \text{ GeV}^2/c^2$. The curves represent QCD fits by the COMPASS collaboration.

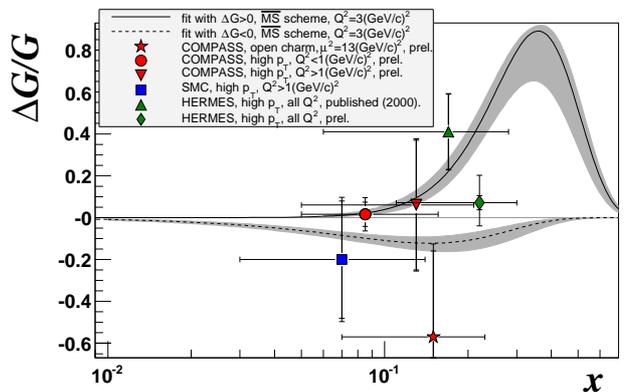


Fig. 2: Measurements of the gluon polarization compared to the QCD fits.

3. Pion Polarizabilities

The response of a composite particle like the pion to external electromagnetic fields is parameterized by two fundamental parameters, the electric ($\bar{\alpha}_\pi$) and magnetic ($\bar{\beta}_\pi$) polarizability. These parameters can be determined experimentally by measuring a deviation of the Compton scattering cross section from the known cross section for a point-like particle. For unstable particles like the pion the t -inverted process can be employed, i.e. the scattering of a beam pion in the Coulomb field of a heavy nucleus, thereby producing a real photon (Primakoff reaction, see Fig. 3):

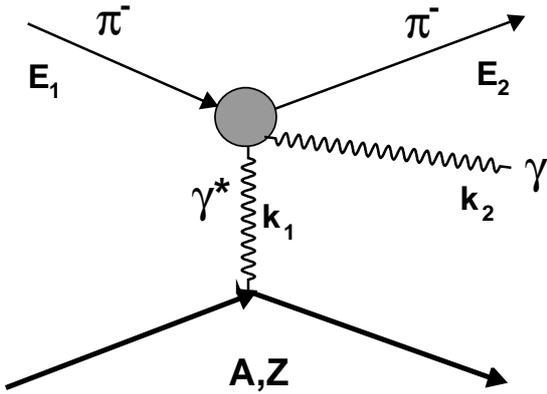
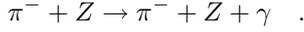


Fig. 3: Primakoff reaction used in COMPASS to measure the polarizabilities of the pion.

In 2004, COMPASS took data with a 190 GeV/c pion beam on a lead target. Events with an outgoing scattered pion, a squared momentum transfer to the target smaller than $0.0075 \text{ GeV}^2/c^2$ and a photon detected in the downstream calorimeter were selected. The polarizability was deduced from the dependence on the energy of the outgoing photon of the ratio of measured over point-like cross section. In the expression for the cross section we assumed $\bar{\alpha}_\pi + \bar{\beta}_\pi = 0$, in accordance with predictions of chiral perturbation theory. Geometrical acceptance and radiative corrections were taken into account and cross-checked with data taken with 190 GeV/c muons. Indeed, performing the equivalent analysis for muons, a value for the polarizability consistent with zero is found, as expected. The preliminary value deduced for the pion magnetic polarizability is

$$\bar{\beta}_\pi = (-2.5 \pm 1.7_{\text{stat}} \pm 0.6_{\text{syst}}) \cdot 10^{-4} \text{ fm}^3 .$$

This value agrees well with the most precise theoretical predictions [9], but is significantly lower than the values deduced in a recent experiment performed at Mainz [10] and earlier at Serpukhov [11]. Figure 4 shows the current world data on $\bar{\alpha}_\pi$ together with the result from chiral perturbation theory.

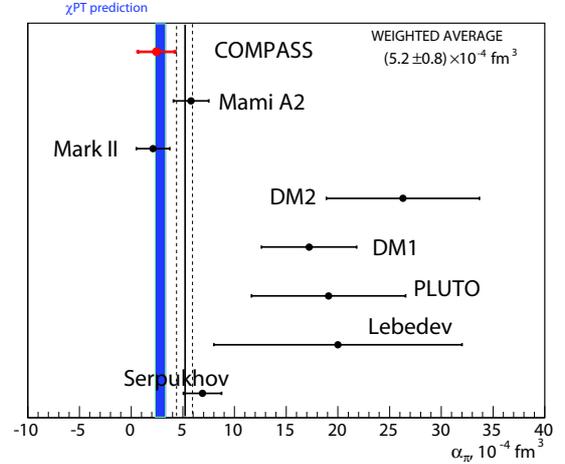


Fig. 4: Overview of all measurements of the pion polarizability, together with the result from chiral perturbation theory. Statistical and systematic errors were added in quadrature.

While the present COMPASS value was extracted from only three days of beam time, a much more precise value is expected in the future after more statistics has been collected with an improved setup of the spectrometer.

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