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Abstract. We give a brief overview of the physics related to the spin-dependent gluon distribution of the nucleon.

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INTRODUCTION

There are now several experiments aiming at measuring the spin-dependent gluon distribution in the nucleon. The latter is defined by [1, 2]

$$\Delta g\left(x,Q^2\right) = \frac{i}{4\pi x P^+}\int d\lambda\, \mathrm{e}^{i\lambda x P^+}\, \langle P,S|G^{+\nu}(0)\,\tilde{G}^{+}_{\nu}(\lambda n)|P,S\rangle\Big|_{Q^2}\,, \qquad (1)$$

written in $A^+ = 0$ gauge, where x is the gluon's light-cone momentum fraction of the proton momentum P, and Q the factorization scale appearing in a hard process to which the gluon contributes. $G^{\mu\nu}$ is the field strength tensor, and $\tilde{G}^{\mu\nu}$ its dual. In more simple terms, $\Delta g(x,Q^2)$ describes the difference in probabilities for finding a gluon with positive or negative helicity in a proton with positive helicity, at a "resolution" scale Q:

$$\Delta g(x,Q^2) \equiv g_+^+(x,Q^2) - g_-^+(x,Q^2)\,, \qquad (2)$$

where superscripts (subscripts) denote the proton (gluon) helicity.

There are good reasons to be interested in Δg. First of all, its integral could well be an important contributor to the proton spin. It is a remarkable feature that the integral $\Delta\Gamma(Q^2) \equiv \int_0^1 dx \Delta g(x,Q^2)$ evolves as $1/\alpha_s(Q^2)$, that is, rises logarithmically with Q. This peculiar evolution pattern is a very deep prediction of QCD, related to its so-called axial anomaly. It has inspired ideas [3] that a reason for the experimentally found small size of the proton's axial charge should be sought in a "shielding" of the quark spins due to a particular perturbative part of the DIS process $\gamma^* g \to q\bar{q}$. The associated cross section is of order $\alpha_s(Q^2)$, but the peculiar Q^2-evolution of $\Delta\Gamma(Q^2)$ would compensate this suppression. We note that this interpretation of the axial charge, however, corresponds to a particular choice of factorization scheme. To be of any phenomenological relevance, such models would require a very large positive gluon spin contribution, $\Delta\Gamma > 1.5$, even at a low "hadronic" scale of 1 GeV or so. Such a large polarization of the confining fields inside a nucleon, even though suggested by some models of nucleon structure [4], would be a very puzzling phenomenon and would once again challenge our picture of the nucleon. Initial results from RHIC, presented at this conference [5, 6], now suggest that $\Delta\Gamma$ is not of such a large size. To obtain detailed information on $\Delta g(x,Q^2)$ and its integral will be an outstanding task for experiments in the field. The COMPASS collaboration at CERN [7] and HERMES at DESY [8] are attempting to constrain Δg by selecting particular heavy-flavor and hadron-pair final states in fixed-target lepton-nucleon scattering. Two features make RHIC the by far superior facility for studying gluon polarization [9]: (1) a variety of probes of Δg is available. Over the next few years, a succession of channels, beginning with the more copious pion and jet productions and continuing with prompt-photon, photon-plus-jet, and heavy-flavor production, will serve to pin down $\Delta g(x,Q^2)$ in ever more detail. (2) thanks to RHIC's high energy, the underlying theoretical calculations based on asymptotic freedom of QCD are generally better understood and more successful than in the fixed-target regime. In addition, at least two different energies are available at RHIC, offering large kinematical coverage and allowing tests of the underlying calculations. In any case, information from lepton-proton and proton-proton scattering is complementary.

PHENOMENOLOGY OF Δg IN POLARIZED pp SCATTERING

The basic concept that underlies most of spin physics at RHIC is the factorization theorem. It states that large momentum-transfer reactions may be factorized into long-distance pieces that contain the desired information on the spin structure of the nucleon in terms of its *universal* parton densities, and parts that are short-distance and describe the hard interactions of the partons. The latter can be evaluated using perturbative QCD.

As an example, we consider in the following the spin asymmetry for the reaction $pp \to \pi X$, where the pion is at high transverse momentum p_T, ensuring large momentum transfer. The statement of the factorization theorem is then

$$d\Delta\sigma = \sum_{a,b,c} \Delta f_a \otimes \Delta f_b \otimes d\Delta\hat{\sigma}_{ab}^{c} \otimes D_c^{\pi} \qquad (3)$$

for the polarized cross section, where $\otimes$ denotes a convolution and where the sum is over all contributing partonic channels $a+b \to c+X$, with $d\Delta\hat{\sigma}_{ab}^{c}$ the associated partonic cross section. In general, a leading-order estimate of (3) merely captures the main features, but does not usually provide a quantitative understanding. Only with knowledge of the next-to-leading order (NLO) QCD corrections to the $d\Delta\hat{\sigma}_{ab}^{c}$ can one reliably extract information on the parton distribution functions from the reaction. For the case of high-p_T pions, these NLO corrections have been computed recently [10]. The Δf_i in Eq. (3) are the polarized parton distributions, and D_c^{π} are pion fragmentation functions.

In the left part of Fig. 1 we show the Δg distributions of several current NLO analyses [11, 12, 13] of polarized deeply-inelastic lepton-nucleon scattering (DIS), along with crude estimates of the associated uncertainties. One can see that very little is known about Δg from DIS. The right part of Fig. 1 shows how this translates into an "uncertainty band" for the double-spin asymmetry in pion production, $A_{LL}^{\pi^0}$, at $\sqrt{s} = 200$ GeV, along with expected sensitivities for the PHENIX experiment to be achieved for integrated luminosity of 65/pb and polarization 70%. It is evident that there is a great potential for discriminating between the various currently proposed polarized gluon distributions.

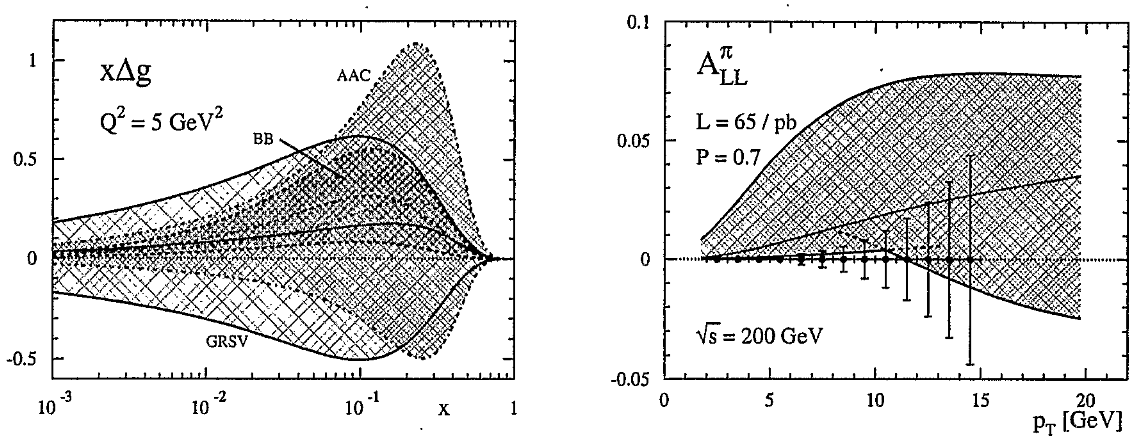

FIGURE 1. Left: $x\Delta g(x, Q^2 = 5\ \mathrm{GeV}^2)$ from NLO analyses [11, 12, 13] of polarized DIS. The various bands indicate ranges in Δg that were deemed consistent with the scaling violations in the data. Right: estimates of the current uncertainty in $A_{LL}^{\pi^0}$ due to Δg, and projected sensitivities for measurements by PHENIX at mid rapidities and $\sqrt{s} = 200$ GeV for integrated luminosity of 65/pb and polarization 70%. Plot taken from [9].

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