Double Spin Asymmetry Measurements with HERA-$\vec{N}$

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ABSTRACT

The physics potential of double spin asymmetry measurements using a polarized internal target in a polarized 820 GeV HERA proton beam is discussed. It appears possible to measure the polarized gluon distribution in the range $0.1 \leq x_{gluon} \leq 0.4$ with a good statistical accuracy.

Perturbative QCD (pQCD) allows sizeable double spin asymmetries for various 2→2 partonic subprocesses. Relying on the factorization theorem a rich spectrum of asymmetries at the hadronic level can be predicted. The measurement of double spin asymmetries A_{LL} in certain final states seems to be one of the most valuable tools to measure the polarized gluon distribution function in the nucleon. The presently most accurate way to do so is the study of those processes which can be calculated in the framework of pQCD. Both *direct photon (plus jet)* and *J/ψ (plus jet)* production are most suited because there are only small uncertainties due to fragmentation. In the following we discuss the capabilities of HERA–$\vec{N}$ [1] to perform such measurements for an integrated luminosity of 240 pb^{-1} (see Ref. [2]).

Inclusive photon production with HERA–$\vec{N}$ was the subject of a very recent study [3]. Basing on a NLO calculation rather firm predictions were obtained including an assessment of their theoretical uncertainties; the latter turned out to be of rather moderate size. In Fig.'s 1a and 1b three different predictions for the asymmetry are shown in dependence on p_T and pseudorapidity η, in conjunction with the attainable statistical uncertainty of HERA–$\vec{N}$. As can be seen, there is sufficient statistical accuracy in a wide kinematical region to discriminate between different polarized gluon distribution functions.

Compared to direct photon production the production of $c\bar{c}$ quarkonium states is a similarly clean tool to measure the polarized gluon distribution. Because of the relatively large quark mass the $c\bar{c}$ production cross section and the expected asymmetry are supposed to be calculable perturbatively. **For inclusive J/ψ production** we calculated the double spin asymmetry within the framework of the color-octet model [4]. As have been shown recently, the color-octet mechanism gives the main contribution in J/ψ production at HERA-$\vec{N}$ energies [5]. In Fig.'s 1c and 1d we present the expected asymmetry versus p_T and η for two different polarized gluon distributions; one observes that a very good discrimination between different sets is possible over the HERA-$\vec{N}$ kinematical range.

The complete kinematics of the 2→2 subprocess can be reconstructed if the away-side jet in the production of photon or J/ψ is measured as well. In this case the

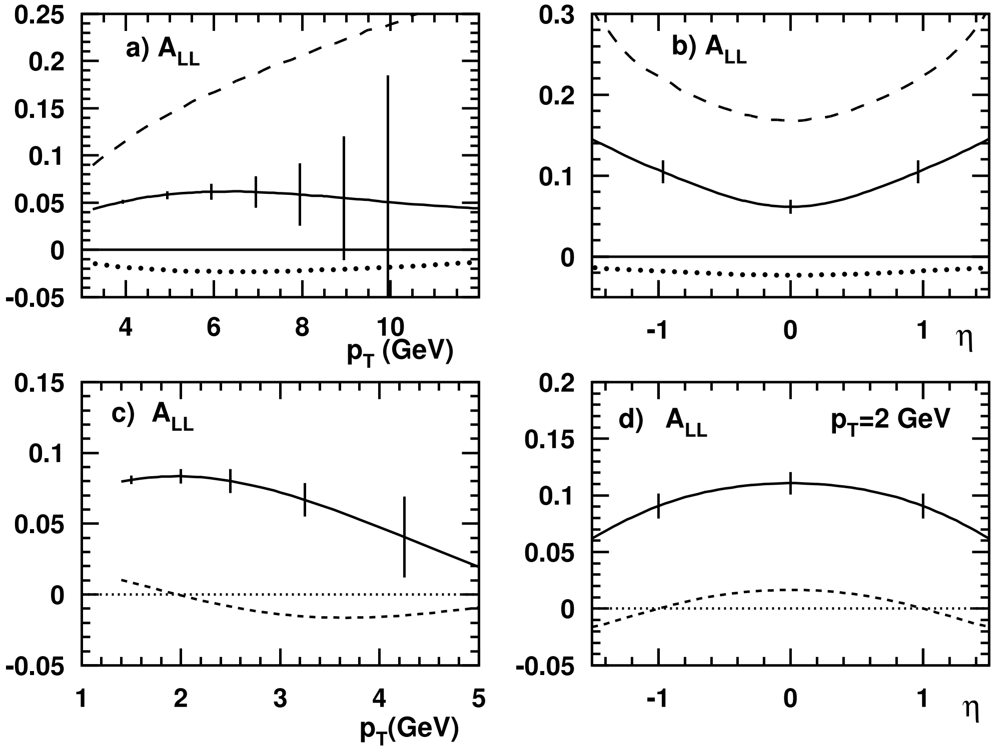

Figure 1: Double spin asymmetry in inclusive a,b) photon and c,d) J/ψ production vs. p_T and η for different polarized gluon distribution functions (see Ref.'s [3,5]), shown in conjunction with the HERA–$\vec{N}$ statistical sensitivity.

asymmetry A_{LL} can be directly related to the polarized gluon distribution if a certain subprocess can be selected. Using this approach **photon plus jet production** was discussed in Ref. [6] as a tool to directly measure ΔG/G. The quark–antiquark annihilation subprocess is suppressed relatively to quark-gluon Compton scattering because of the lower density of antiquarks (of the polarized sea) compared to gluons (polarized gluons).

In **J/ψ plus jet production** the quark-gluon subprocess contributes only about 10% to the asymmetry compared to the gluon-gluon fusion subprocess. In Fig. 2 the calculated HERA–$\vec{N}$ statistical sensitivity for the $\Delta G(x)/G(x)$ measurement, on the present level of understanding, is shown vs. x_{gluon} in conjunction with predicted errors for *STAR* running at RHIC at 200 GeV c.m. energy [7]. The errors demonstrate clearly that in the region $0.1 \le x_g \le 0.4$ a significant result from *photon plus jet production* can be expected with an accuracy being about competitive to that predicted for RHIC. At this point we note that the HERA–$\vec{N}$ fixed target kinematics causes additional problems for the jet reconstruction when compared to a collider experiment. The number of photon events accompanied by a successfully reconstructed jet decreases considerably when approaching lower values of p_T and, correspondingly, of x_{gluon}. Preliminary jet reconstruction efficiencies were calculated and taken into acoount for the results in Fig. 2. The measurement of $\Delta G(x)/G(x)$ in

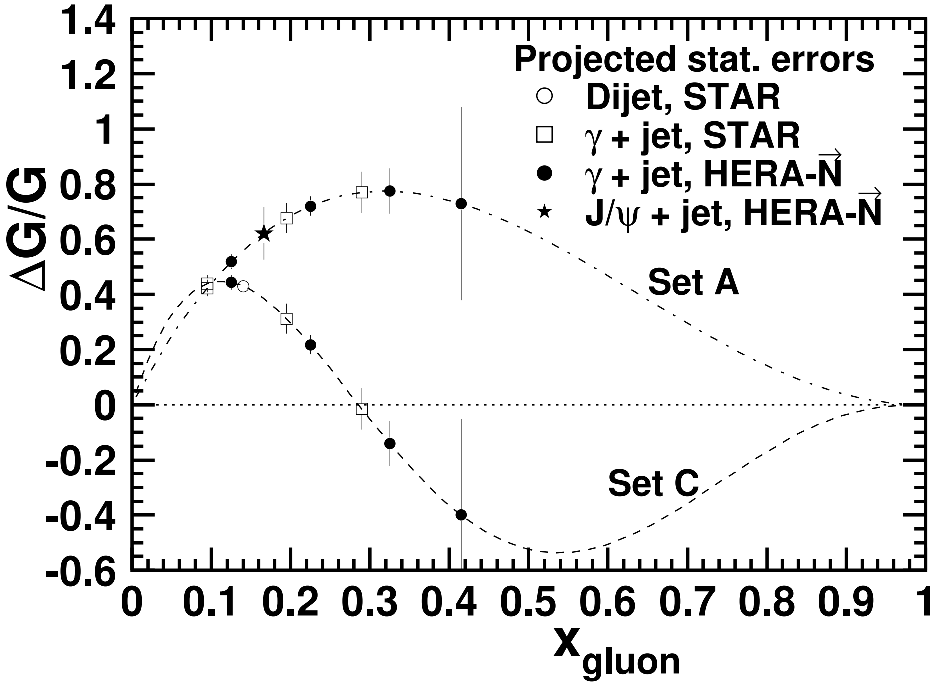

Figure 2: Typical predictions for the polarized gluon distribution confronted with the projected statistical errors expected for HERA-$\vec{N}$ and RHIC experiments.

J/ψ plus jet production is feasible only for $x_g = 0.1 \div 0.2$, i.e. for J/ψ transverse momenta of about 2.5 GeV/c being a perturbatively save value in quarkonium production. This prediction is shown as an additional entry in Fig. 2. Although being one point only, this is an important measurement because the lowest lying point from *photon plus jet* production is obtained for rather small values of p_T where pQCD is not expected to give reliable predictions in this channel. We note that the nature of the gluon-gluon subprocess has similar consequences for *jet plus jet* production at RHIC; there is [7] one point at a similar value of x_g, as well (cf. Fig. 2).

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