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

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ABSTRACT

The physics potential of single spin asymmetry measurements using a polarized internal target in the (unpolarized) 820 GeV HERA proton beam is discussed.

Single spin asymmetries in large p_T inclusive production, both in proton-nucleon and lepton-nucleon interactions, have recently received much attention (for references see [1]). The naive expectation that they should be zero in perturbative QCD has been proven to be false, both experimentally and theoretically. It is now clear that higher twist effects are responsible for these asymmetries, which should be zero only in leading twist-2 perturbative QCD (pQCD). Several models and theoretical analyses suggest possible higher twist effects: there might be twist-3 dynamical contributions or hard scattering higher twists; there might also be intrinsic $k_\perp$ effects, both in the quark fragmentation process and in the quark distribution functions.

To improve the understanding of the pQCD spin sector beyond the twist–2 level it is of great importance to disentangle these different contributions. Measurements of the single spin asymmetry $(d\sigma^{AB^\uparrow \to CX} - d\sigma^{AB^\downarrow \to CX})/(d\sigma^{AB^\uparrow \to CX} + d\sigma^{AB^\downarrow \to CX})$ in several different processes $AB^\uparrow \to CX$ are expected to yield considerable insight into higher twist phenomena:

- $pN^\uparrow \to hX$: all kinds of higher twist contributions may be present.
- $pN^\uparrow \to \gamma X$, $pN^\uparrow \to \mu^+\mu^- X$, $pN^\uparrow \to jets + X$: possible sources of non-zero single spin asymmetries are higher-twist hard scattering effects and $k_\perp$ effects in the quark distribution function.
- $lN^\uparrow \to hX$: a single spin asymmetry can originate either from hard scattering or from $k_\perp$ effects in the fragmentation function.
- $lN^\uparrow \to \gamma X$, $\gamma N^\uparrow \to \gamma X$, $lN^\uparrow \to \mu^+\mu^- X$, $lN^\uparrow \to jets + X$: a single spin asymmetry in any of these processes may be only due to higher-twist hard scattering effects.

This list indicates that a comparative study of single spin asymmetries in different processes might be a unique way of understanding the origin and the importance of higher twist contributions in large p_T inclusive production. An experiment ('HERA–$\vec{N}$' [2]) utilising an internal polarized nucleon target in the (unpolarized) 820 GeV HERA proton beam could contribute significantly here. We note that HERA–$\vec{N}$ physics with a polarized beam is described elsewhere [3].

The integrated luminosity calculation is based upon realistic figures; a target polarisation of $P_T = 0.8$ is assumed, a combined trigger and reconstruction efficiency

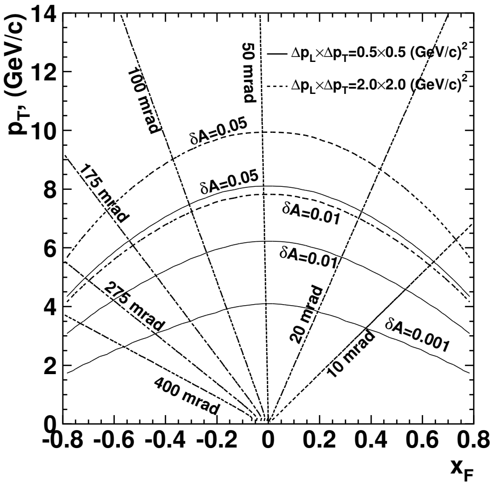

Figure 1: Asymmetry sensitivity levels for π^+ production in the (p_T, x_F) plane. Laboratory angles of the pions are shown.

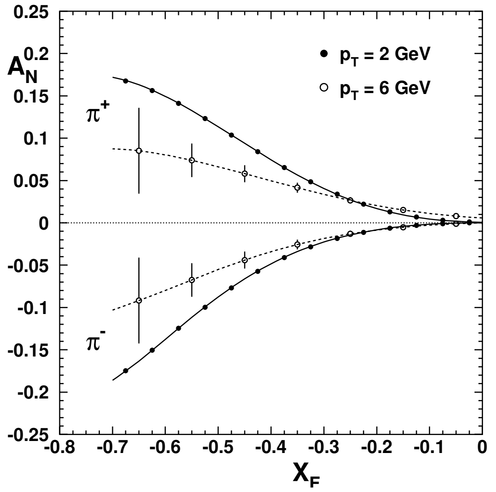

Figure 2: Capability of HERA-$\vec{N}$ to discriminate predictions for different p_T.

of $C \simeq 50\%$ is anticipated. Using $\bar{I}_B = 80$ mA for the average HERA proton beam current (50% of the design value) and a rather conservative polarized target density of $n_T = 3 \cdot 10^{13}$ atoms/cm^2 the projected integrated luminosity becomes $\mathcal{L} \cdot T = 240\ pb^{-1}$. In the following we discuss the capability of HERA-$\vec{N}$ to investigate some of the processes listed above.

Inclusive pion production $p^\uparrow p \to \pi^{0\pm} X$ at 200 GeV exhibits surprisingly large single spin asymmetries, as it was measured by the E704 Collaboration using a transversely polarized beam [4]. For any kind of pions the asymmetry A_N shows a considerable rise above $x_F > 0.3$, i.e. in the fragmentation region of the polarized nucleon. Contours characterizing different HERA-$\vec{N}$ sensitivity levels, δA, for an asymmetry measurements in the reaction $pp^\uparrow \to \pi^+ X$ are shown in Fig. 1. One can conclude that the accessible p_T values are significantly larger than those E704 had; the combined p_T dependence of all involved higher-twist effects can be measured with good accuracy ($\delta A \leq 0.05$) up to transverse momenta of about 10 GeV/c in the central region $|x_F| < 0.2$ and up to 6 GeV/c in the target fragmentation region. This corresponds to an almost one order of magnitude extension in the p_T range in comparison to E704. The capability of HERA-$\vec{N}$ to really prove a predicted p_T dependence is shown in Fig. 2, where the curve was obtained assuming a non–zero quark distribution analysing power according to Ref. [5].

Inclusive direct photon production, $pp^\uparrow \to \gamma X$, proceeds without fragmentation, i.e. the photon carries directly the information from the hard scattering process. Hence this process measures a combination of initial $\boldsymbol{k}_\perp$ effects and hard scattering twist–3 processes. The only results up to now were obtained by the E704 Collaboration [6] showing an asymmetry compatible with zero within large errors for $2.5 < p_T < 3.1$ GeV/c in the central region $|x_F| \lesssim 0.15$.

The statistical sensitivity of HERA-$\vec{N}$ was determined by simultaneous simula-

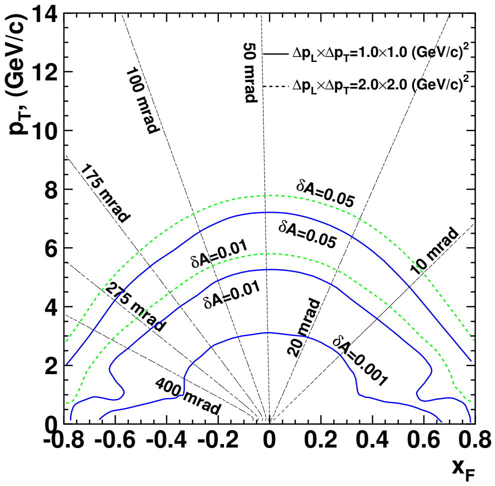

Figure 3: Asymmetry sensitivity levels for photon production in the $(p_T,\ x_F)$ plane. Photon laboratory angles are shown.

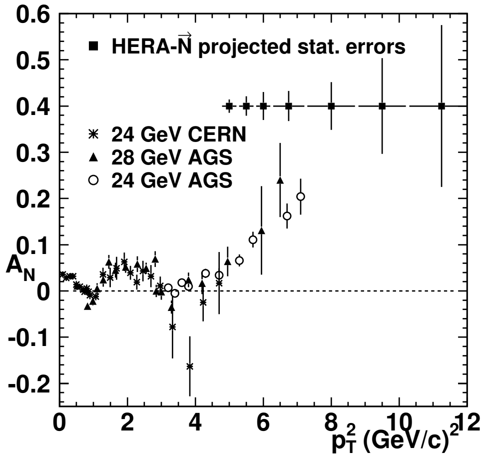

Figure 4: Single spin asymmetry in elastic proton-proton scattering as a function of p_T^2.

tion of the two dominant hard subprocesses contributing to direct photon production, i.e. gluon–Compton scattering ($qg \to \gamma q$) and quark–antiquark annihilation ($q\bar{q} \to \gamma g$), and of background photons that originate mainly from π^0 and η decays. It turns out that a good sensitivity (about 0.05) can be maintained up to $p_T \leq 8$ GeV/c (cf. Fig. 3). For increasing transverse momentum the annihilation subprocess and the background photons are becoming less essential.

Large spin effects in polarized **proton-proton elastic scattering** $p + p^\uparrow \to p + p$ have been discovered many years ago. The single spin asymmetry A_N was found significantly different from zero as it is shown in Fig. 4 in conjunction with the HERA-$\vec{N}$ statistical errors. At HERA-$\vec{N}$ energies the detection of the recoil proton for p_T^2 values in the range $5 \div 12$ (GeV/c)^2 requires a very large angular acceptance (up to 40 degrees) [1]. The forward protons for the same interval in p_T^2 have laboratory angles of the order of a few milliradians and require a dedicated detector very close to the beam pipe.

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