# Transverse single-spin asymmetries in prompt photon production from proton-proton collisions†

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Collinear twist-3 factorization has been used since the 1980s in order to describe transverse single-spin asymmetries $A_N$. For a general process $A^\uparrow B \to C\,X$, the cross section can be written as the sum of three terms depending on which non-perturbative function is kept at twist-3. For hadron production, which has been intensely studied for close to 40 years, the distribution and fragmentation contributions to the cross section cannot be disentangled, i.e., all of them are summed together in the cross section. For many years it was often assumed that the piece involving the so-called Qiu-Sterman (QS) function $G_F(x,x)$ was the main cause of $A_N^\pi$. However, this led to a so-called "sign mismatch" between the QS function and the transverse momentum dependent (TMD) Sivers function extracted from semi-inclusive deep-inelastic scattering (SIDIS)[1]. Recently we showed in [2] for the first time that the fragmentation contribution in collinear twist-3 factorization actually can describe $A_N^\pi$ very well. By using a Sivers function fully consistent with SIDIS, we demonstrated that this mechanism could also resolve the sign-mismatch puzzle. Nevertheless, an independent extraction of $G_F(x,x)$, through observables like $A_N^{jet}$ and $A_N^\gamma$, is crucial to confirm this assertion. However, one must keep in mind that for $A_N^{jet}$ and $A_N^\gamma$ other twist-3 distribution effects can enter besides the QS function. Thus, in order to have a "clean" extraction of $G_F(x,x)$, it would be ideal if these other terms were small.

Therefore, we return to the SSA in $p^\uparrow p \to \gamma X$ to see if this reaction could provide such an observable. In twist-3 collinear factorization, $A_N^\gamma$ has contributions from multiparton correlators inside either the transversely polarized proton or the unpolarized proton. For this process the former has been widely discussed in the literature for both (twist-3) quark-gluon-quark[3–10] and tri-gluon[11] non-perturbative functions, which are chiral-even objects evaluated at either soft-gluon or soft-fermion poles (SGPs/SFPs). The full result for twist-3 effects on the side of the unpolarized proton is a new piece from this work and, although we refrain from showing the explicit formula for brevity, will be included in our numerical analysis. This term involves a chiral-odd quark-gluon-quark correlator $E_F(x,x)$, which is related to the TMD Boer-Mulders function.

We now focus on the phenomenology. For the SGP correlators $E_F(x,x)$ and $G_F(x,x)$ we make use of iden-

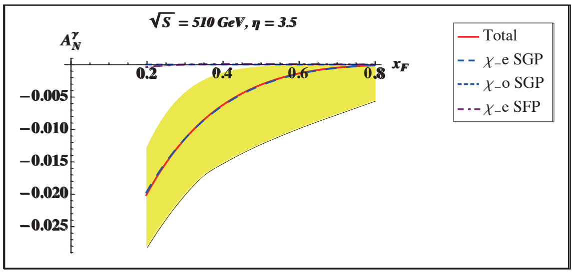


Fig. 1. $A_N^\gamma$ vs. $x_F$ at fixed $\eta = 3.5$ and $\sqrt{S} = 510\,\mathrm{GeV}$.

tities that relate the first to the Boer-Mulders function and the second to the Sivers function. Since at this point no information on the SFP functions is available, we assume the relation $G_F(0,x)+\widetilde{G}_F(0,x) = G_F(x,x)$. Model calculations of quark-gluon-quark correlators show that chiral-even SFP functions are much smaller as compared to the SGP one and might even vanish. Therefore, we believe that this ansatz is reasonable.

In Fig.1 we show an estimate of $A_N^\gamma$ (along with an uncertainty band) from all these pole contributions for a set of kinematics relevant for the measurement of this observable at PHENIX and STAR. One sees that the entire effect is due to the "Sivers-type" QS mechanism. Using the Sivers function extracted from SIDIS, our results show that $A_N^\gamma$ could be on the order of several (negative) percent in the forward region, providing a "clean" observable to extract of the QS function $G_F(x,x)$. In light of the "sign-mismatch" crisis involving $G_F(x,x)$ and the Sivers function[1], and the recently proposed solution to this issue that relies on the twist-3 fragmentation mechanism[2], such an extraction is of vital importance. In addition, one can obtain important information on the process dependence of the Sivers function as well as help discriminate between the Generalized Parton Model and twist-3 formalisms since the former predicts a *positive* asymmetry. Thus, measurements of this process by PHENIX and STAR are crucial.

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