Transverse single-spin asymmetries in proton-proton collisions and the role of twist-3 fragmentation†

D. Pitonyak,*1 K. Kanazawa,*2 Y. Koike,*3 and A. Metz*2

The field of transverse single-spin asymmetries (SSAs) in hard semi-inclusive processes began close to 40 years ago at FermiLab. People noticed early on that the collinear parton model cannot generate the large effects that were found. It was then pointed out that SSAs for single-particle production in hadronic collisions are genuine twist-3 observables for which, in particular, collinear 3-parton correlations have to be taken into account. This formalism later on was worked out in more detail and applied to SSAs in processes like light hadron production in proton-proton collisions, $p^{\uparrow}p \to hX$. Here we focus on SSAs in such reactions, which have been complemented by many experiments, including those at RHIC.

For quite some time it was believed that effects inside the transversely polarized proton dominate the transverse SSA in $p^{\uparrow}p \to hX$ (typically denoted by A_N)[1–4]. In particular, the so-called Qiu-Sterman function T_F was thought to be the main non-perturbative object that generates this observable. T_F can be related to the transverse-momentum dependent (TMD) Sivers parton density $f_{1T}^{\perp}$. Because of this relation, one can extract T_F from data on either A_N or on the Sivers transverse SSA in semi-inclusive deep-inelastic scattering (SIDIS) A_{SIDIS}^{Siv}. It therefore came as a major surprise when an attempt failed to simultaneously explain both A_N and A_{SIDIS}^{Siv} — the two extractions for T_F actually differ in sign[5], a puzzle that has become known as the "sign mismatch".

At this point one may start to question the dominance of T_F. In fact, data on the neutron target transverse SSA in inclusive DIS[6] seem to support this point of view[7]. Therefore, we study here the potential role of fragmentation effects, whose analytical result in the twist-3 formalism was first worked out in [8]. It involves the non-perturbative functions $\hat{H}$, $\hat{H}_{FU}^{\Im}$, and H, where the first is related to the TMD Collins function and the third can be written in terms of the other two.

In Fig. 1 we show our results from fitting the collinear 3-parton fragmentation correlator $\hat{H}_{FU}^{\Im}$ to data for $A_N^{\pi^0}$ from STAR[9–11] and $A_N^{\pi^{\pm}}$ from BRAHMS[12]. Our fit describes the data very well; moreover, one can see without $\hat{H}_{FU}^{\Im}$, one cannot obtain the rise in A_N at large x_F that is characteristic of the data. Therefore, we have demonstrated for the first time that twist-3 factorization actually can describe high-energy RHIC data for A_N^{π} if one takes the fragmentation contribution into account. This work also allows us to potentially resolve the sign-mismatch crisis since one does not need T_F to describe the data. Since in the twist-3 approach part of A_N can be fixed by spin/azimuthal asymmetries in SIDIS and in $e^+e^- \to h_1h_2X$, we have shown that at present a simultaneous description of all those observables is possible.

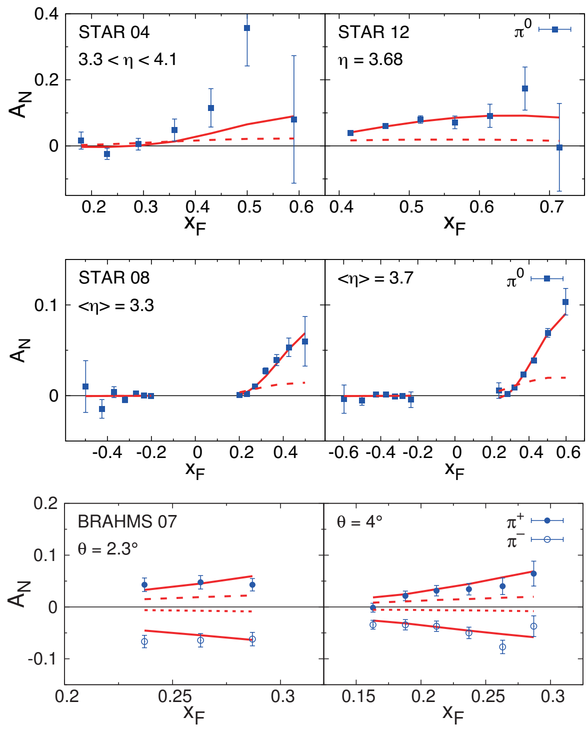

Fig. 1. Fit results for $A_N^{\pi^0}$ and $A_N^{\pi^{\pm}}$. The dashed line (dotted line in the case of π^-) means $\hat{H}_{FU}^{\Im}$ switched off.

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*1 RIKEN Nishina Center
*2 Department of Physics, Temple University
*3 Department of Physics, Niigata University

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