In a recent paper [1], we reported measurements of the beam-target double-spin asymmetries and target single-spin asymmetries for the exclusive $\pi^+$ electroproduction reaction $\gamma^*p \rightarrow n\pi^+$. The results were obtained from scattering of 6 GeV longitudinally polarized electrons off longitudinally polarized protons using the CLAS detector at Jefferson Lab. The kinematic range covered spans invariant energies $1.1 < W < 3$ GeV and squared four-momentum transferred $1 < Q^2 < 6$ GeV$^2$, significantly extending the kinematic range of previous data in both $W$ and $Q^2$. Results were obtained for about 6000 bins in $W$, $Q^2$, and the pion-nucleon decay angles $\cos \theta^*$ and $\phi^*$.

The beam-target asymmetries are in reasonable agreement with empirical fits to world data in the framework of unitary isobar models only for $W < 1.6$ GeV. Our new data will help to constrain the relative importance of a myriad of nucleon excited states with masses above 1.6 GeV at relatively high values of $Q^2$, where the transition form factors are poorly known.

Except at forward angles, very large target-spin asymmetries are observed over the entire $W$ region. Sample results are shown in Fig. 1. As for the beam-target asymmetries, reasonable agreement is found with phenomenological fits to previous data for $W < 1.6$ GeV, but large differences are observed at $W > 1.6$ GeV. From the theoretical viewpoint of models based on generalized parton distributions, our results indicate that strong higher-twist contributions are needed to describe the target-spin asymmetries.

Figure 1: Target single-spin asymmetry $A_{UL}$ for the reaction $ep \rightarrow e\pi^+n$ as a function of $\phi^*$ in seven bins in $W$ (columns) and in six bins in $\cos \theta^*$ (rows). The results are from the two lower $Q^2$ bins of this analysis. The solid red curves are from the MAID 2007 unitary isobar fit, the blue long-dashed curves are from a JANR fit, and the green short-dashed curves are for the GPD-inspired model from Goloskokov and Kroll.