Hard exclusive pion electroproduction at backward angles with CLAS

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We report on the first measurement of cross sections for exclusive deeply virtual pion electroproduction off the proton, $e p \rightarrow e' n \pi^+$, above the resonance region at backward pion center-of-mass angles. The $\phi_{\pi}$-dependent cross sections were measured, from which we extracted three combinations of structure functions of the proton. Our results are compatible with calculations based on nucleon-to-pion transition distribution amplitudes (TDAs).

We have measured for the first time the cross section of $e p \rightarrow e' n \pi^+$ at large photon virtuality, above the resonance region, for pions at backward angles, using the CLAS detector at Jefferson Lab [1]. The motivation to address such a kinematic regime was provided by the potentially applicable collinear factorized description in terms of nucleon-to-pion TDAs that encode valuable nucleon structural information. The final goal was an experimental validation of the factorized description and the extraction of nucleon-to-pion TDAs from the observed quantities. Our analysis represents a first encouraging step towards this goal.

The QCD collinear factorization theorems state that for special kinematic conditions a broad class of hard exclusive reactions can be described in terms of universal nucleon structure functions. The universal structure functions accessible in “nearly-backward” kinematics are nucleon-to-meson TDAs. On the right panel of Fig. 1 we illustrate the corresponding factorization mechanism involving TDAs for $e p \rightarrow e' n \pi^+$. Since momentum conservation imposes the constraint $\sum_i x_i = 2\xi$, TDAs depend effectively on only 4 variables.

FIG. 1: Left: QCD factorization mechanism for the exclusive electroproduction of a meson ($\pi^+$) on the nucleon (proton) in the “nearly-forward” kinematic regime at large $Q^2$ and small $|t|$ (GPDs: bottom blob of the diagram) and of the meson (the pion DA upper blob of the diagram). Right: factorization mechanism for the same reaction in the complementary “nearly-backward”, where $Q^2 \gg W^2 \gg$ fixed $x_{ Bj} \gg$, and small $|u|$, the non-perturbative nucleon-to-pion transitions (TDAs) (bottom blob of the diagram) and the nucleon DA (upper blob of the diagram).

In Fig. 2, we compare our data for $\sigma_U$ ($= \sigma_T + \epsilon \sigma_L$) to the theoretical predictions of $\sigma_T$ from the nucleon pole exchange $\pi N$ TDA model suggested in the TDA model.

The curves show the results of three theoretical calculations using different input phenomenological solutions for the nucleon DAs with their uncertainties represented by the bands. Black band: BLW NNLO, dark blue band: COZ, and light blue band: KS. The black dashed curve, inspired by the higher twist nature of $\sigma_{LT}$ and $\sigma_{TT}$ in the TDA picture, shows $(-\Delta^2_{LT}/Q^2)\sigma_U$ parameterized from the experimental data. The red curves are the predictions of Regge model for bold solid: $\sigma_U$, dashed: $\sigma_{LT}$, dot-dashed: $\sigma_{TT}$. We see a very reasonable agreement between the TDA model-dependent calculation and our data. However, this is not incontrovertible evidence for the validity of the factorized description, and the Regge-based description yields a similar result for the last $Q^2$ point but a very different $Q^2$ dependence.