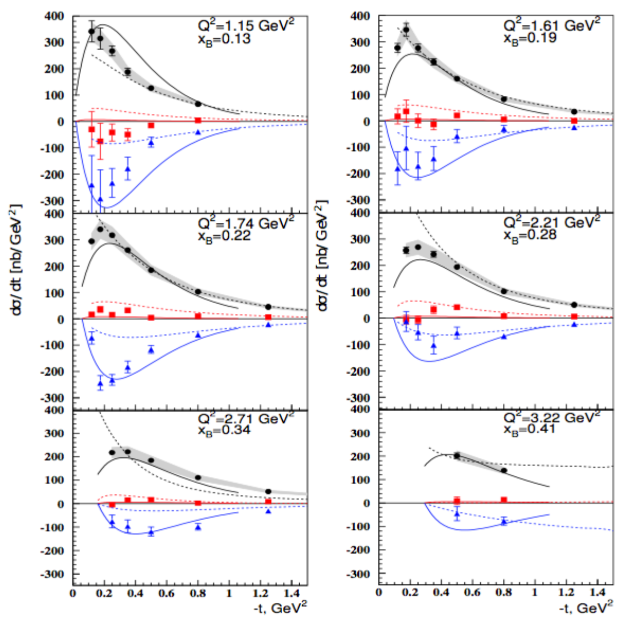
Measurement of Exclusive π^0 Electroproduction Structure Functions and their Relationship to Transversity GPDs

The proton lies at the heart of every atom that builds our visible universe, yet scientists are still struggling to obtain a detailed, 3D picture of its primary building blocks: quarks and gluons. A recent measurement at Jefferson Lab tested a method that holds promise for obtaining this 3D picture of proton structure. In the experiment, electrons were slammed into a number of quarks inside protons just hard enough for the quarks to absorb energy from the electrons and then give it away again as neutral pions (particles built of a quark and antiquark), without ever breaking up the protons. The measurement provided information on the particles' transverse momenta, which can be used to reveal how far the quarks are away from the proton's center. The result confirmed that protons are complicated particles with sophisticated dynamics, and proved that this method can be used toward obtaining a 3D view of the proton.

A major goal of hadronic physics is to describe the three-dimensional structure of the nucleon in terms of its quark and gluon fields. During the past decade, the handbag mechanism has become the leading theoretical approach for extracting nucleon quark and gluon structure from exclusive reactions, such as deeply virtual Compton scattering (DVCS) and deeply virtual meson electroproduction (DVMP). In this approach, the quark distributions are parameterized in terms of generalized parton distributions (GPDs), which contain information about the distributions of both the longitudinal momentum and the transverse position of partons in the nucleon.

There are eight GPDs. Four correspond to parton helicity conserving (chiral-even) processes, denoted by H^q, $\tilde{H}^q$, E^q and $\tilde{E}^q$, and four correspond to parton helicity-flip (chiral-odd) processes, H_T^q , $\tilde{H}_T^q$, E_T^q and $\tilde{E}_T^q$, the latter initiated via transversely polarized virtual photons. The GPDs depend on the three kinematic variables: x, t and the *skewness* ξ.



Most of the reactions studied, such as DVCS or vector meson production, are, at leading order, primarily sensitive to the chiral-even GPDs. The chiral- odd GPDs are difficult to access, since subprocesses with a quark helicity-flip are suppressed. However, a complete description of nucleon structure requires the knowledge of the chiral-odd GPDs as well as chiral-even GPDs. Pseudoscalar meson electroproduction, and in particular π^0 electroproduction in the reaction $ep \rightarrow e'p'\pi^0$, is especially sensitive to the quark helicity-flip subprocesses.

The π^0 electroproduction cross section has been measured with the CLAS spectrometer over a large kinematic range of t, Q^2 and φ, where φ is the azimuthal angle of the hadron reaction plane. The primary focus is its interpretation within the framework of the handbag model, and its sensitivity for accessing the quark helicity-flip GPDs. The differential cross sections contain the structure functions $\sigma_T + \varepsilon\sigma_L$, σ_{TT} and σ_{LT}, which were extracted from the data. Typical results for a few of the kinematic intervals are shown in the figure. Also, the results of two GPD-based models by Kroll and Goloskokov (GK) and Goldstein and Liuti (GL) are superimposed. The structure functions in both cases are primarily from the quark helicity-flip (chiral odd) GPDs H_T and $\bar{E}_T$, while the contribution from the quark non-helicity-flip (chiral even) GPDs is very small. In the model of GL, the GPD H is dominant, so that the quark helicity flip manifests itself in the helicity flip of the final state nucleon while in the model of GK, the dominant GPD is $\bar{E}_T$ in which there is no nucleon helicity flip, so that the meson must carry away one unit of angular momentum.

Within the handbag interpretation, the data appear to confirm the expectation that pseudoscalar, and in particular π^0, electroproduction is a uniquely sensitive process to access the transversity GPDs $\bar{E}_T$ and H_T.

[1] I. Bedlinskiy, V. Kubarovsky, S. Niccolai, P.Stoler et al. (*CLAS Collaboration*), Phys. Rev. Lett. 109, 112001 (2012).