First Exclusive Measurement of Deeply Virtual Compton Scattering off ^{4}He: Toward the 3D Tomography of Nuclei

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A wealth of information on the structure of matter lies in the correlations between the momentum and spatial distributions of the fundamental constituents of matter: quarks and gluons. These correlations are accessible via the study of Generalized Parton Distributions (GPDs), which we probe with hard exclusive scattering reactions. The deeply-virtual Compton scattering (DVCS) reaction is the preferred probe of GPDs and has been used to study the proton in a number of experiments at HERA, CERN, and Jefferson Lab (JLab), yielding the first 3D partonic images of the proton. New groundbreaking measurements of exclusive DVCS from the ^{4}He nucleus are a critical step towards providing similar 3D pictures of the quark structure of nuclei and a new approach to understanding the modification of protons and neutrons within the dense environment of a nucleus. Studies of ^{4}He are particularly important, as their partonic structure is encoded within a single GPD, simplifying their extraction and interpretation.

Our new measurements provided the first beam-spin asymmetry data on exclusive DVCS from ^{4}He using a highly-polarized electron beam from the Continuous Electron Beam Facility (CEBAF) at JLab. Scattering from a pressurized ^{4}He target was measured in the CEBAF Large Acceptance Spectrometer (CLAS). Isolating exclusive scattering where the nucleus is not broken up in the high-energy collision requires detection of the recoil ^{4}He nucleus. The recoil nucleus was detected using a new radial time projection chamber to ensure that this rare scattering process was cleanly identified. From fitting the azimuthal dependence of the beam-spin asymmetry (A_{LU}), shown in Fig. 1, the real and imaginary parts of the ^{4}He Compton form factor (CFF), which directly sample the nuclear GPD, were extracted in a model-independent way, presented in Fig. 2.

These data, while limited in statistics, proved the experimental feasibility of measuring such nuclear exclusive reactions and lead the way to the approval of next generation nuclear measurements. The future measurements will be carried out using the new CLAS12 spectrometer and the upgraded CEBAF 12 GeV electron beam. In addition to DVCS on ^{4}He, deeply-virtual meson production of φ-meson will be measured, giving us the chance to compare directly the quark and the gluon 3D tomography of the ^{4}He nucleus.

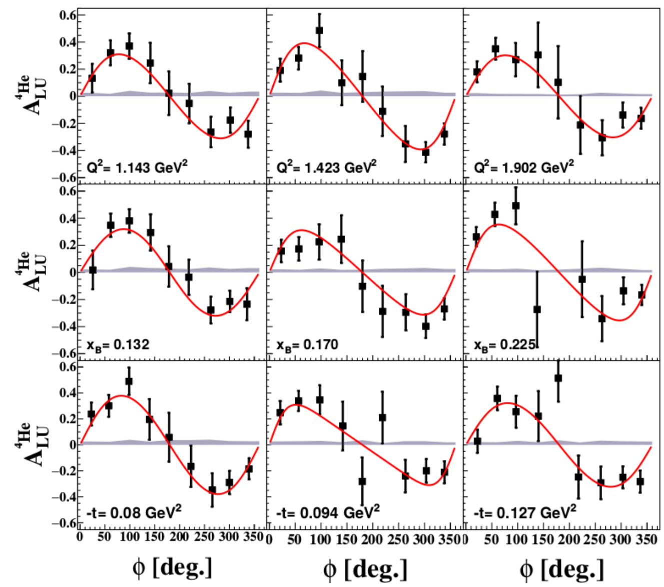

FIG. 1: A_{LU} as a function of azimuthal angle φ. Results are presented for different Q^2 bins (top panel), x_B bins (middle panel), and t bins (bottom panel). The error bars represent the statistical uncertainties. The gray bands represent the systematic uncertainties, including the normalization uncertainties. The red curves are the results of fits with the real and the imaginary parts of the ^{4}He CFF as the free parameters.

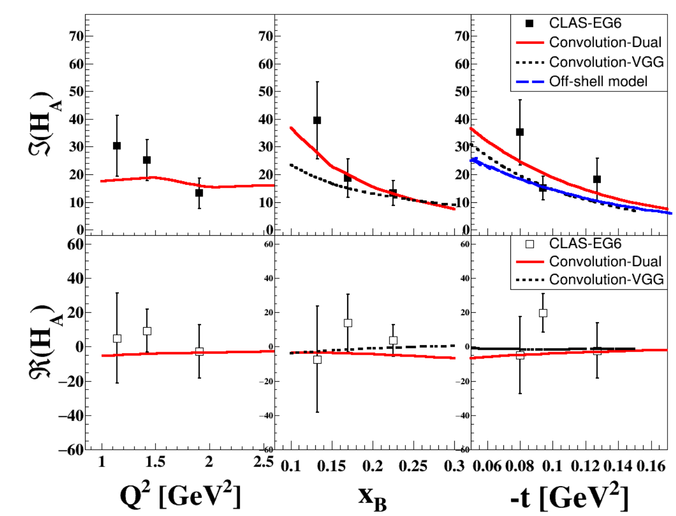

FIG. 2: The leading-twist model-independent extraction of the imaginary (top panel) and real (bottom panel) parts of the ^{4}He CFF (H_A), as a function of Q^2 (left panel), x B (middle panel), and t (right panel). The full red curves are the calculations based on a convolution model. The black-dashed curves are calculations from the same model using different GPDs for the nucleons (VGG model). The blue long-dashed curve on the top-right plot is from an off-shell model.