

Nuclear Exclusive and Semi-inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker: ALERT Run Group

We propose a comprehensive physics program to investigate the quark and gluon structure of light nuclei, namely deuterium and ^4He , through coherent exclusive Deep Virtual Compton Scattering (DVCS) and Deep Virtual Meson Production (DVMP) important focus of this program is the study of the effect of the nuclear matter on the structure of nucleons. We propose a next generation nuclear physics measurements in which low energy recoil nuclei are detected. The tagging of recoiling nuclei especially in semi-inclusive reactions will be realized for the first time in these measurements. This powerful measurement will provide unique information about the nature of medium modification including the EMC effect through its dependence of the nucleon virtuality.

At the heart of all these measurements is the Low Energy Recoil Tracker (ALERT) in addition to the CLAS12 detector. The ALERT detector will be composed of a stereo drift chamber for track reconstruction and an array of scintillators for particle identification. Coupling these two types of fast detectors will ensure that it can be included in the trigger to reject background efficiently, while keeping the quantity of material as low as possible to detect low energy particles. ALERT will be installed inside the solenoid magnet instead of the CLAS12 Silicon Vertex Tracker.

The ALERT run group will need 11 GeV longitudinally polarized electron beam. The two main gaseous targets are ^4He and deuterium. We will also need to run hydrogen and ^4He targets at different beam energies for detector calibration.

Proposal 1: Partonic Structure of ^4He and deuterium nuclei

We propose to study the partonic structure of ^4He and deuterium by measuring both the Beam Spin Asymmetry (BSA) in DVCS, and the coherent production of neutral pions and phi mesons in DVMP. Due to the ^4He nucleus having spin-0, only one chiral-even Generalized Parton Distribution (GPD), $H^A(x, \xi, t)$, and one chiral-odd GPD, $H_T^A(x, \xi, t)$, parameterize its partonic structure at twist-2 while two GPDs, $H_A^{\text{twist-3}}(x, \xi, t)$ and $\tilde{H}_A^{\text{twist-3}}(x, \xi, t)$ arise at twist-3. The latter describes partonic spin-orbit correlations in the nucleus. One major goal of this proposal is to obtain a wide range in kinematics and better statistics after the success obtained, for the first time, in measuring the exclusive DVCS off ^4He during the experiment CLAS-08-024 in the eg6 run period. The real and imaginary parts of the ^4He Compton Form factors (CFFs) will be extracted in a model independent way from the experimental asymmetries, allowing us to access the nuclear transverse spatial distributions of partons and their spin correlations. The proposed measurements will use the upgraded CEBAF 11 GeV longitudinally polarized electron beam. In order to ensure the exclusivity of our reactions, the basic CLAS12 detector will be upgraded with ALERT.

The other focus of this proposal is to measure exclusive coherent phi meson electroproduction off a ^4He target. The kinematic regime to be explored includes very low $|t|$ up to the first diffractive minimum as found in ^4He elastic scattering ($|t'| \approx 0.6 \text{ GeV}^2$), Q^2 up to 12 GeV^2 , and x_B up to 0.4. The phi meson will be detected primarily through the charged K^+K^- channel, with the neutral $K_S^0 K_L^0$ KS0KL0 channel also available through $K_S^0 \rightarrow \pi^+ \pi^-$. Differential cross-sections for phi electroproduction off ^4He will be measured for the first time.

The ALERT recoil detector provides a unique opportunity to study the gluonic structure of a dense light nucleus. The average transverse gluonic density of the ^4He nucleus can be extracted within a GPD framework using the measured longitudinal cross-section of coherent phi production. Additionally, threshold effects of phi production can be explored by exploiting the ALERT detector's large transverse acceptance of low $|t|$ events. This experiment will complement a previously approved experiment (PR-12-007) that will study the gluonic distribution of the proton using a very similar framework.

Proposal 2: Tagged EMC measurements of light nuclei

We propose to measure semi-inclusive deep inelastic scattering from light nuclei (deuterium and ^4He). The detection of the low energy recoil (p , ^3H and ^3He), in addition to the scattered electron, will provide unique information about the nature of the EMC effect and its dependence on the bound nucleon virtuality. In particular, the proposed experiment will provide stringent tests leading to clear differentiation between the many models describing the EMC effect. The proposed measurements will use the 11 GeV electron beam on thin gaseous targets. The scattered electrons will be detected in CLAS12, while the fragments of the nuclear target will be detected in ALERT.

Proposal 3: Tagged DVCS

Deeply Virtual Compton Scattering on the proton is set to reveal a 3 dimensional picture of how quarks and gluons are distributed inside of the nucleon. For light nuclei, the Fermi motion of the bound nucleon complicates the picture. The case of large Fermi momenta corresponds to configuration where two nucleons are separated by a small distance. The interaction in this region (i.e. the short-range part of the N-N potential) originates with short-range gluon exchange that is not well understood. We propose investigating these configurations with DVCS using ^4He and deuterium targets, where the final state includes a recoiling nucleus (less one nucleon) and the nucleon, which participated in the hard process. ALERT detector with a very low density that can provide a trigger signal is ideal for detecting recoiling ions (p , ^2H , ^3H , ^3He , and ^4He) in coincidence with the forward CLAS12 spectrometer. The ability to trigger in coincidence with CLAS12 rejects the significant background associated with a CLAS12-only trigger. Furthermore, the low mass density of a gas target and drift chamber tracking system will allow the recoils to be detected at momenta starting near the Fermi momentum.