Coherent DVCS off ^{4}He

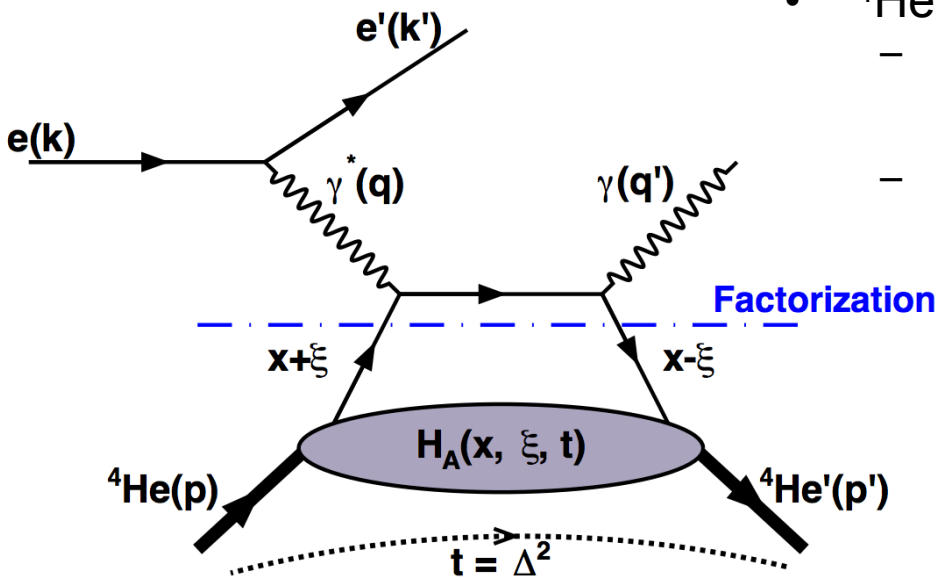
"First Exclusive Measurement of Deep Virtual Compton Scattering off 4He: Toward the 3D tomography of Nuclei"

N. Baltzell
on behalf of EG6 Group

CLAS Collaboration Meeting
June 14, 2017

Motivation

- Generalized Parton Distributions
  - contain information about momentum and spatial degrees of freedom of quarks and gluons
  - in impact parameter space, a tomography of the transverse plane for partons of a given longitdutinal momentum
  - DVCS is widely accepted as the cleanest probe of GPDs, made possible through interference with experimentally indistinguishable Bethe-Heitler process
  - nucleon (free and bound) DVCS is large focus in CLAS12 program



- ^{4}He nucleus
  - light enough to be experimentally feasible to detect, yet dense enough to be sensitive to interesting nuclear effects
  - spinless
    - → only one chiral-even GPD H_A in forward limit, leading-twist
    - → model-independent extraction of Compton Form Factor from Beam Spin Asymmetry

$$A_{LU} = \frac{\alpha_0(\phi) \cdot \mathcal{H}_{Im}}{\alpha_1(\phi) + \alpha_2(\phi) \cdot \mathcal{H}_{Re} + \alpha_3(\phi) \cdot [\mathcal{H}_{Re}^2 + \mathcal{H}_{Im}^2]}$$

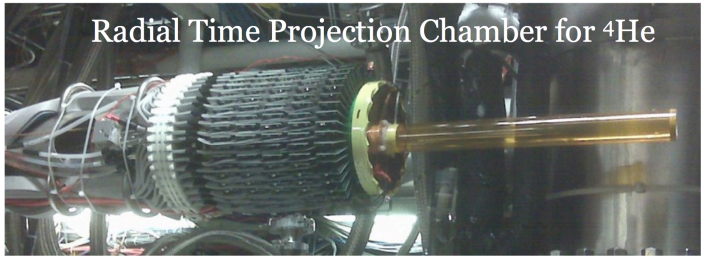
$\mathcal{H}$ – Compton Form-factor

$\alpha_j(\phi)$ – Functions of angle between lepton and hadron scattering planes

$$A_{LU} = \frac{d^4\sigma^+ - d^4\sigma^-}{d^4\sigma^+ + d^4\sigma^-} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$

EG6 Experiment

- PR-08-024, “Deeply Virtual Compton Scattering off 4He”, K. Hafidi et al
  - *Work involved in this presentation is largely the PhD dissertation of M. Hattaway @ IPNO Orsay (currently at ANL)*
  - A first measurement of **exclusive** coherent nuclear DVCS
- PR-07-009, “Meson spectroscopy in Coherent Production on 4He with CLAS”, S. Stepanyan et al



- Detector System
  - CLAS Spectrometer
  - Inner Calorimeter for forward photons
  - 2nd generation RTPC for recoil 4He
    - 20-cm-long, 15-cm-diameter, NeDME drift region from radius of 3 to 6 cm
    - inside 5-T solenoid magnet (for momentum analysis and Moeller background reduction)
  - 4He Target
    - 6 atm, 25-cm long, 6-mm diameter, 27-um-thick Kapton walls

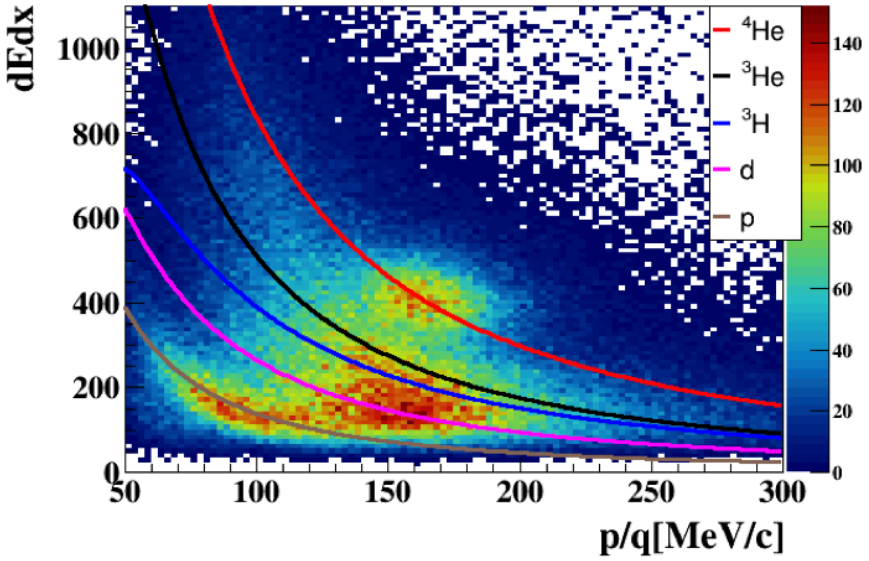
- Production running at 150 nA for ~200 mC of 6.06 GeV polarized electron beam
- Calibration runs with 1.2 GeV beam

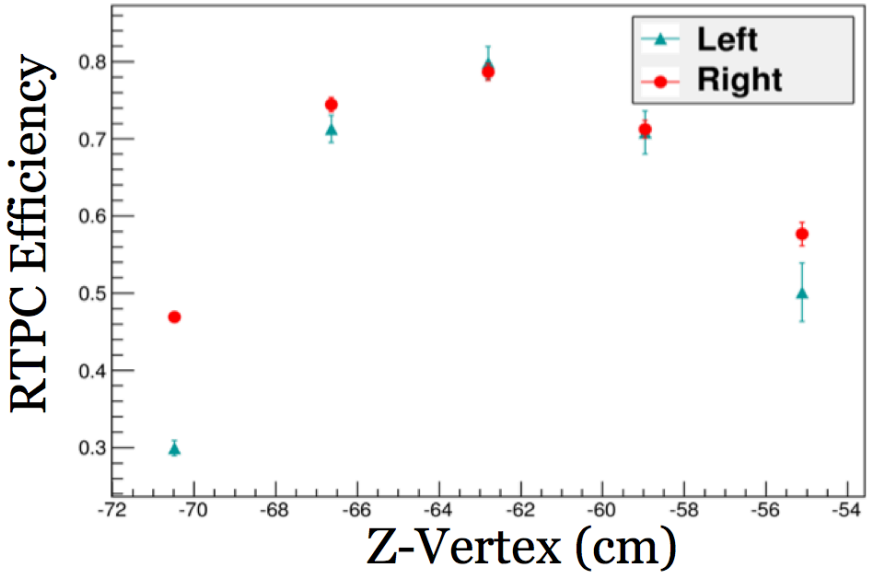
EG6's RTPC

- 2nd generation RTPC. Relative to BoNuS:
  - removed bisecting support for increased acceptance
  - drift gas optimized for ^{4}He detection
  - upgraded electronics for faster readout

- Data with 1.2 GeV electron beam for calibration with elastic scattering off 4He
  - Drift paths and drift speeds, and gains
- Efficiency from exclusive / inclusive
- Offline noise reduction techniques

- Resolutions achieved: z-vertex ~ 7 mm, φ ~ 2°, θ ~ 4°, p ~9%





Coherent DVCS Selection, $\vec{e}A \rightarrow e'A'\gamma$

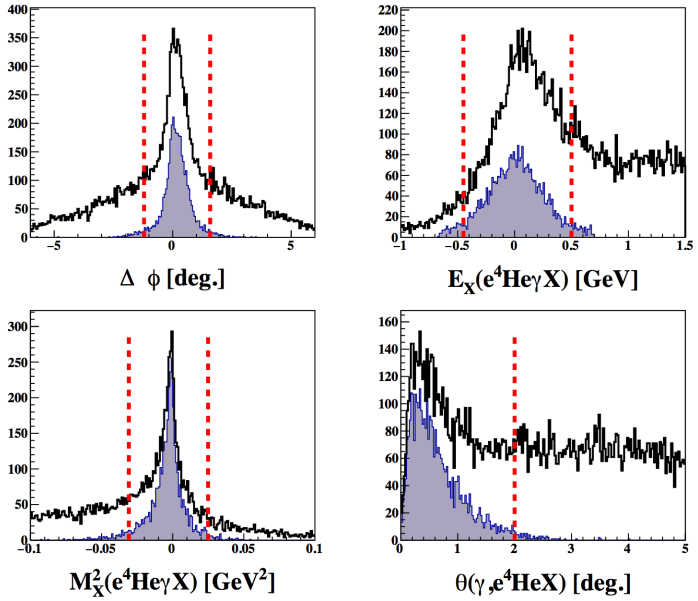
- Electron in CLAS
- High-energy photon in Inner Calorimeter
  - ^{4}He DVCS photons above ~2 GeV
- ^{4}He detected in RTPC
  - momentum ~250-400 MeV

- Exclusivity cuts based on 4-momentum conservation
  - coplanarity between γγ* and γ*^{4}He planes
  - angle between expected and measured photon direction
  - missing mass, energy, and transverse momentum

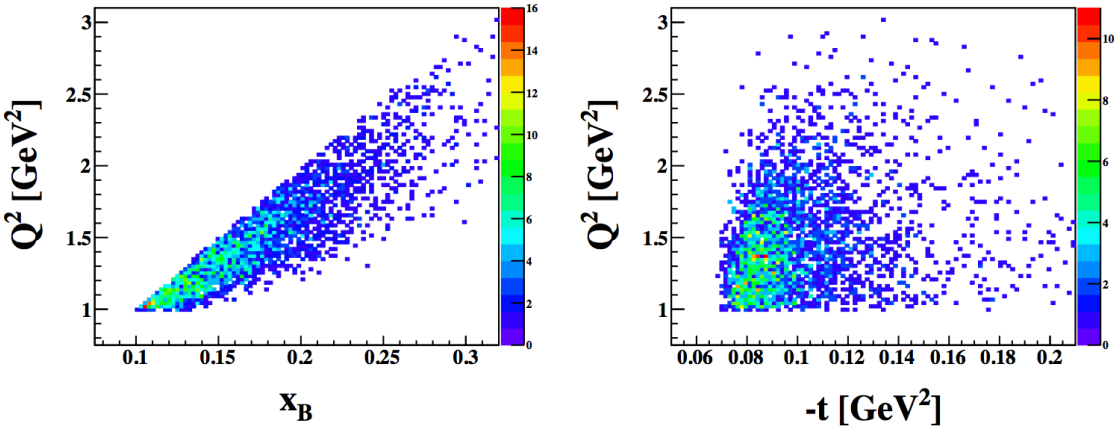
- Kinematics
  - x ~ 0.1-0.25
  - Q^2 ~ 1-2.3 GeV^2
  - -t ~ 0.07 – 0.15 GeV^2

- π^0 background subtraction using "standard" 1-photon-detected π^0 simulations

- Systematic uncertainties overshadowed by statistics
  - systematics dominated by exclusivity cuts ~8% and large binning ~5%



Very good agreement with simulation in exclusivity cut quantities, kinematics



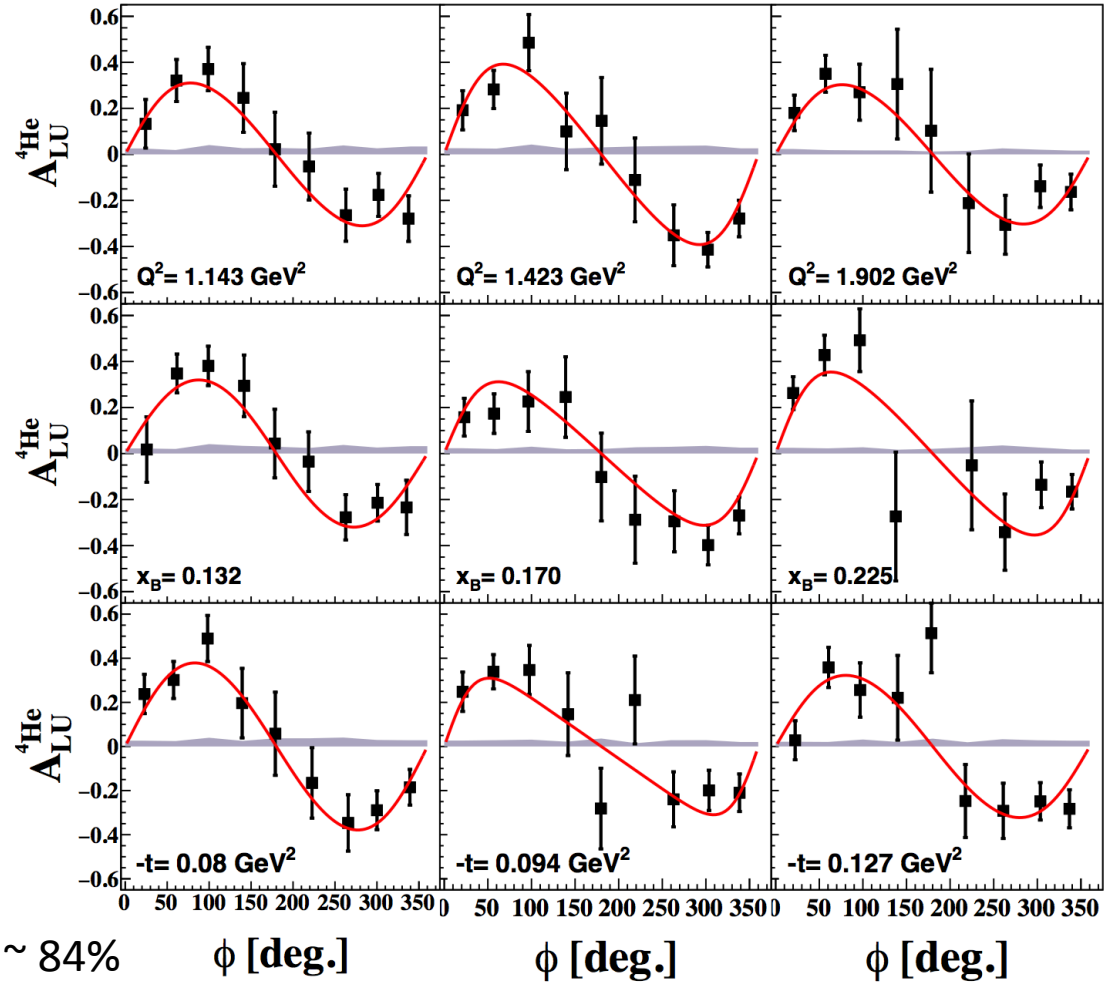
Beam Spin Asymmetry Fits

$$A_{LU} = \frac{d^4\sigma^+ - d^4\sigma^-}{d^4\sigma^+ + d^4\sigma^-} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$

Statistics – limited, binning in only one dimension at a time

Clear asymmetries up to almost 40%, significantly larger than proton

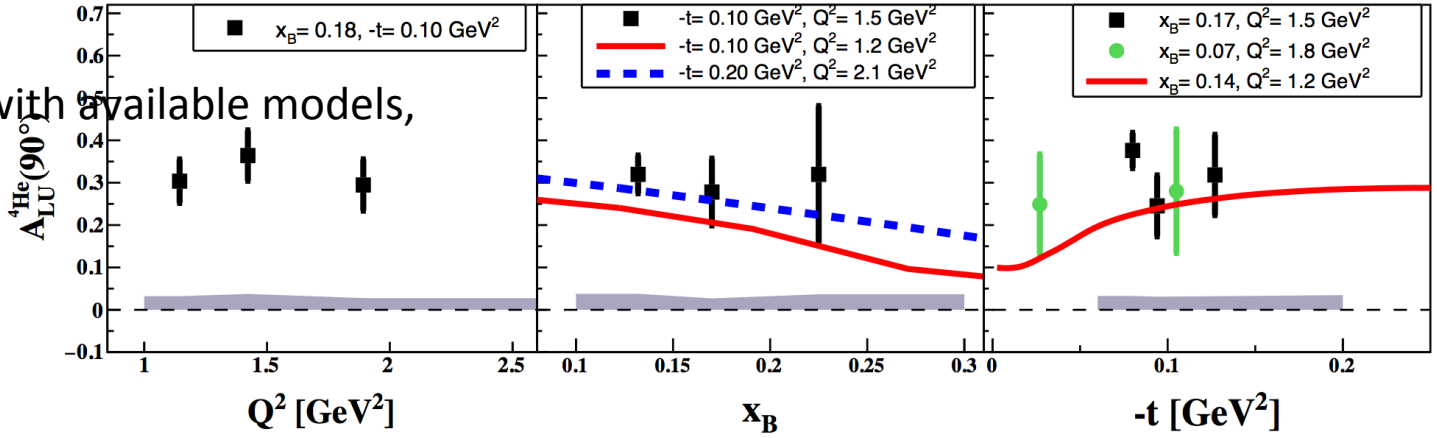
Uncertainties are primarily statistical



Longitudinal Beam Polarization ~ 84%

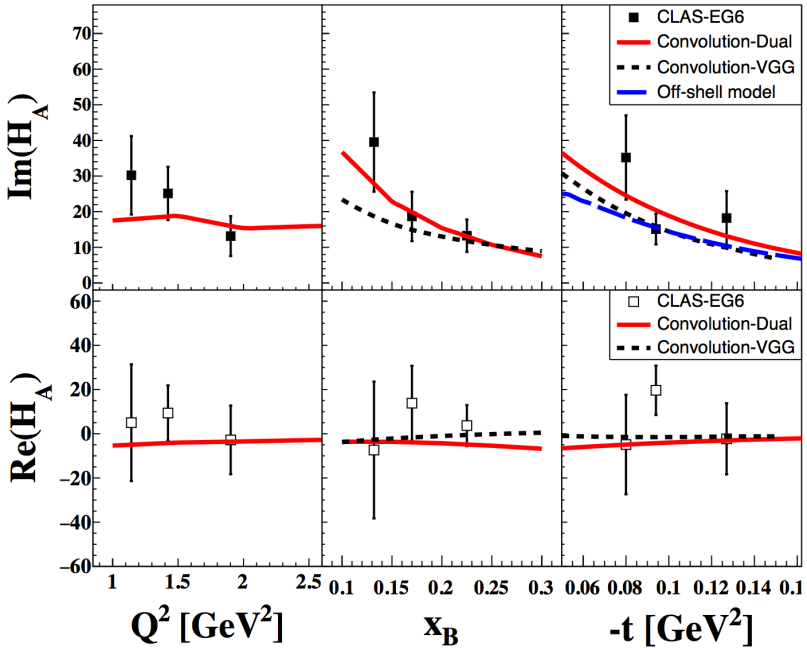
Compton Form Factor

In agreement with available models,



$$A_{LU} = \frac{\alpha_0(\phi) \cdot \mathcal{H}_{Im}}{\alpha_1(\phi) + \alpha_2(\phi) \cdot \mathcal{H}_{Re} + \alpha_3(\phi) \cdot [\mathcal{H}_{Re}^2 + \mathcal{H}_{Im}^2]}$$

Fit directly to Real and Imaginary parts of H



HERMES: A. Airapetian et al, PRL 87, 182001 (2001)
Convolution-Dual: V. Guzey, PRC 78, 025211 (2008)
Convolution-VGG: M. Guidal, M.V. Polyakov, A.V. Radyushkin and M. Vanderhaeghen, PRD 72, 054013 (2005)
Off-Shell: S. Liuiti and K. Taneja, PRC 72, 032201 (2005) J.O. Gonzalez-Hernandez, S.Liuti, G.R. Goldstein and K. Kathuria, PRC 88, 065206 (2013)

Path to CLAS Publication

- EG6 Experiment
  - December 2009
- Calibration, Analysis, repeat …
- M. Hattawy's PhD, IPNO Orsay, 2015
- NPWG Analysis Review
  - Committee: M. Garcon, S. Kuhn, Z. Meziani
  - Nov 2015 – Dec 2016
- Ad Hoc Review
  - Committee: D. Watts, K. Giovanetti, N. Zachariou
  - March 20, 2017 – April 30, 2017
- Collaboration Review
  - finished last week
- *Next: Ad Hoc sign-off, OPT-IN period, and finally submission to PRL*

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

M. Hattawy,[1,22] N.A. Baltzell,[1,37] R. Dupré,[1,22,*] K. Hafidi,[1] S. Stepanyan,[37] S. Bültmann,[31] R. De Vita,[19] A. El Alaoui,[1,38] L. El Fassi,[27] H. Egiyan,[37] F.X. Girod,[37] M. Guidal,[22] D. Jenkins,[43] S. Liuti,[42] Y. Perrin,[26] B. Torayev,[31] E. Voutier,[26,22]

Coherent ^{4}He DVCS @ 12 GeV CLAS

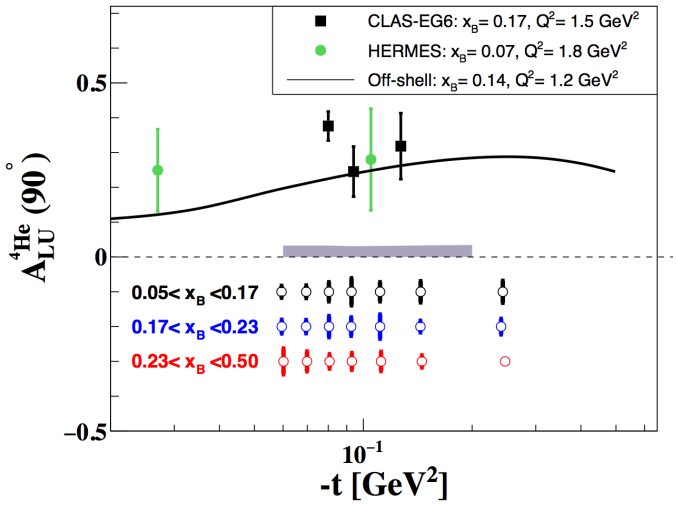
Jefferson Lab PAC 45

Nuclear Exclusive and Semi-inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker

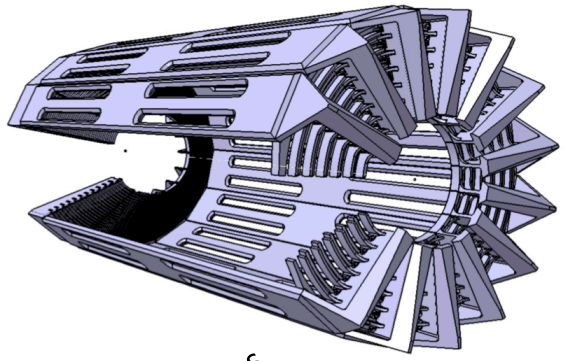
ALERT Run Group[†]

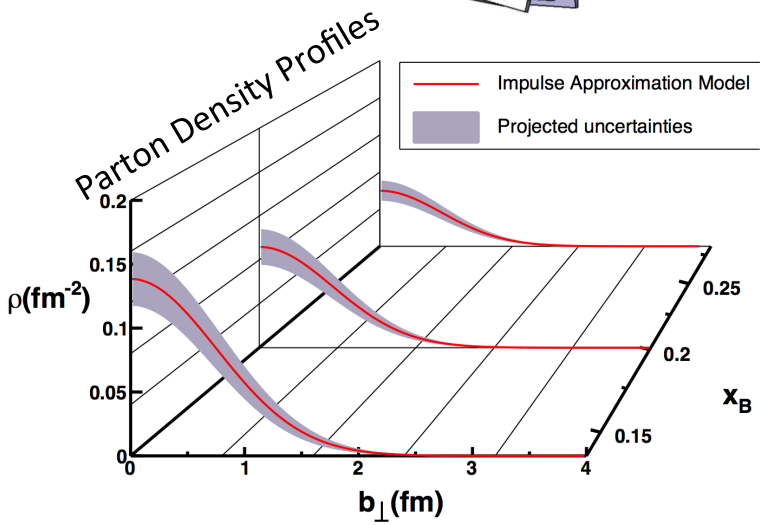
EXECUTIVE SUMMARY

In this run group, we propose a comprehensive physics program to investigate the fundamental structure of the ^{4}He nucleus. An important focus of this program is on the coherent exclusive Deep Virtual Compton Scattering (DVCS) and Deep Virtual Meson Production (DVMP) with emphasis on ϕ meson production. These are particularly powerful tools enabling model-independent nuclear 3D tomography through the access of partons' position in the transverse plane. These exclusive measurements will give the chance to compare directly the quark and gluon radii of the helium nucleus. Another important



A Low Energy Recoil Tracker
stereo drift chamber surrounded by scintillators, for improved particle id and recoil (include ^{4}He) triggering





Summary

- First exclusive measurement of coherent DVCS on ^{4}He, demonstrating model-indepent extraction of ^{4}He Compton Form Factor, opening new avenue for nuclear partonic structure studies with Generalized Parton Distributions
- Letter to be submitted to PRL, soon, in final stages of CLAS publication review process
- Simultaneous measurements of incoherent ^{4}He DVCS also performed (not shown here), separate publication in preparation, investigating EMC-style effects with Generalized Parton Distributions
- ALERT Run Group proposal submitted to PAC 45 with higher luminosity and recoil triggering, more target nuclei, suite of measurements including more coherent ^{4}He DVCS with much higher statistics
- EG6 RTPC NIM paper coming soon also