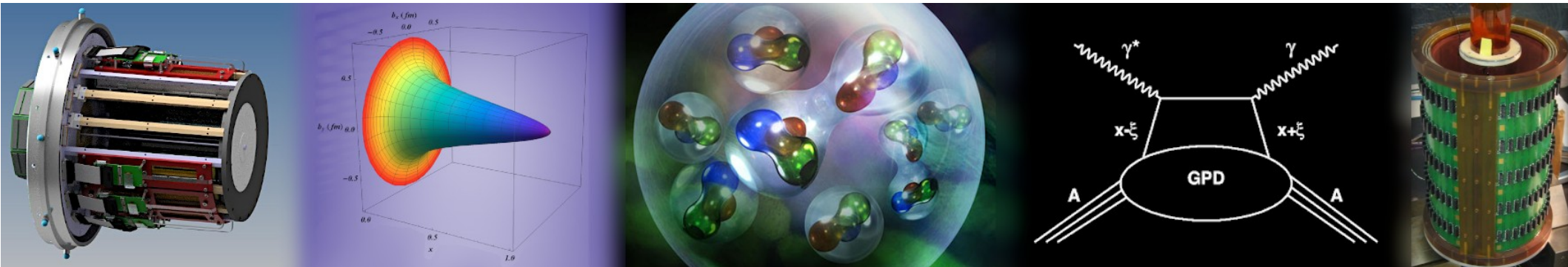


Nuclear GPDs with the ALERT Detector



Raphaël Dupré

For the CLAS Collaboration



European Research Council
Established by the European Commission

Nuclear Effects

Nuclei change nucleons

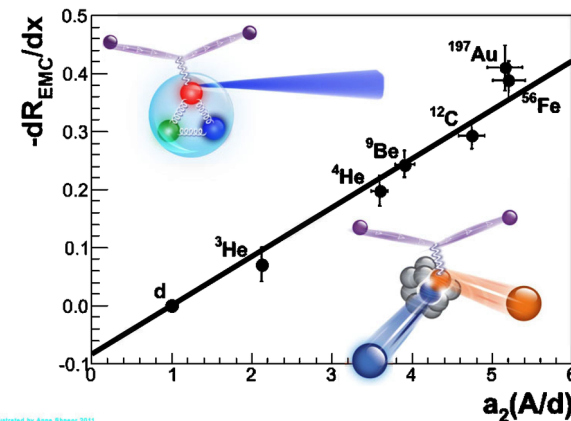
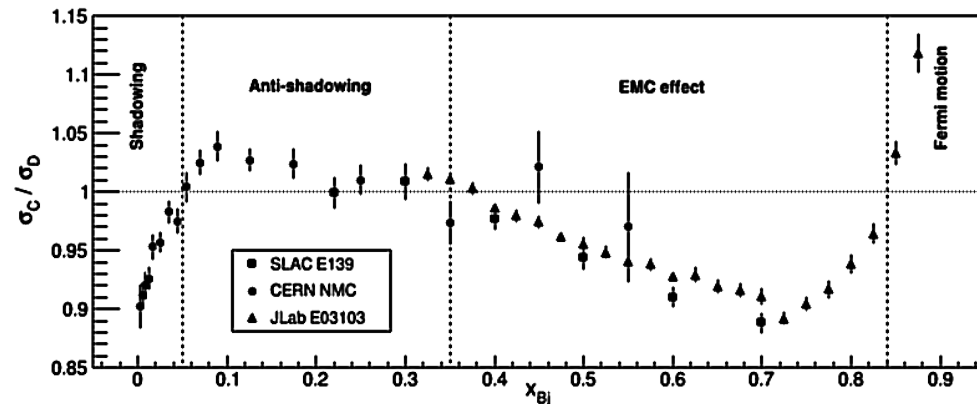
- Several nuclear effects
- The most studies the EMC
 - Reduction of large x quarks

We do not understand why and how

- There are no widely accepted explanation
 - Recent interest with short range nucleon correlations
- Often quantitative statements are off

So, how do we progress from here ?

- More precision or More observables !



Deeply Virtual Compton Scattering

Generalizing the parton distributions

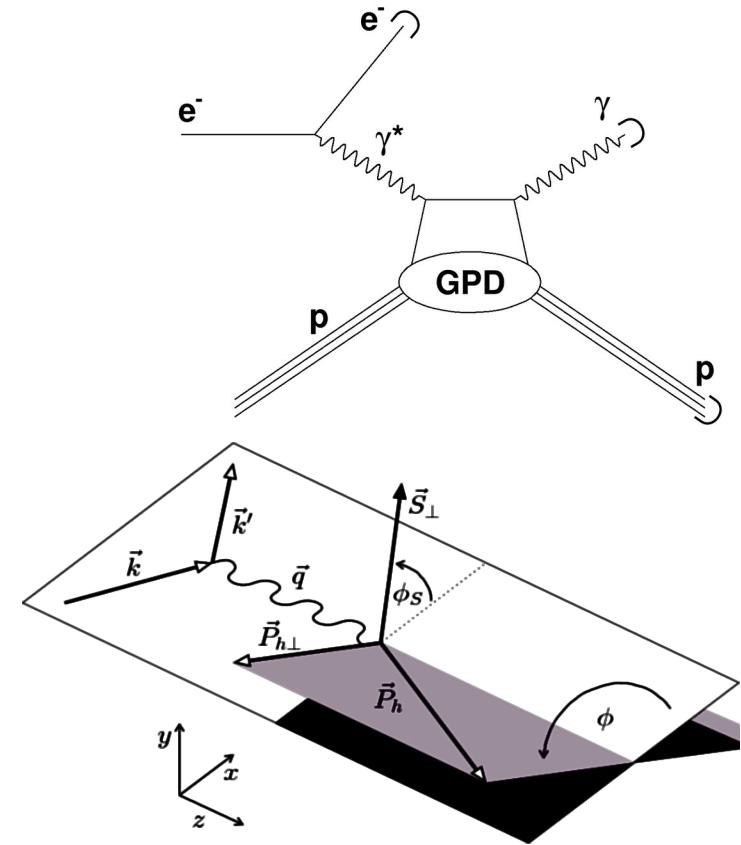
- Three dimensional (x , ξ and t) structure functions
- Accessible through exclusive processes
 - DVCS, DVMP, TCS, DDVCS...

Deeply virtual Compton scattering

- The exclusive electro-production of a photon
- The simplest access to GPDs
- Or more precisely to Compton Form Factors...

Lead to a complex phenomenology

- Many observables (cross section, beam, target and charge asymmetries ...)



Measuring Nuclear DVCS

Nuclei give control over the spin

- Spin-0 \rightarrow 2 GPD ; Spin-1/2 \rightarrow 8 GPDs ; Spin-1 \rightarrow 18 GPDs
- Half of these intervene in DVCS

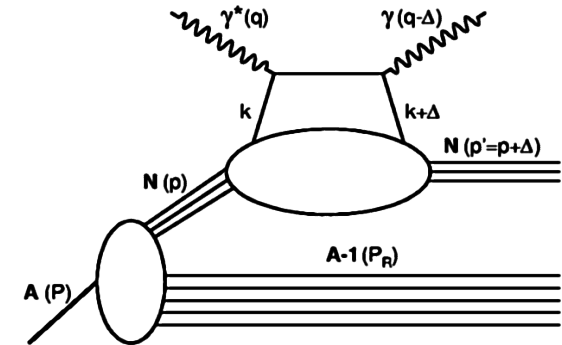
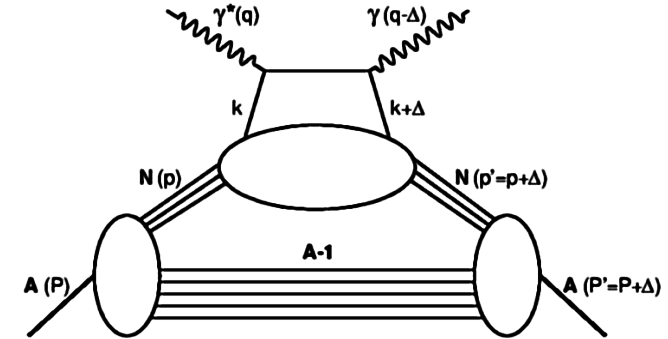
In the nucleus two processes

- Coherent and incoherent channels
 - **Similar to elastic and quasi-elastic**
- Probe the whole nucleus and the bound nucleons

A perfect tool to study the EMC effect

- Offer localization with the t dependence
- Coherent DVCS gives access to non-nucleonic degrees of freedom
- Incoherent DVCS gives access to the modifications of the nucleon

R. Dupré and S. Scopetta. 3D Structure and Nuclear Targets. Eur. Phys. J., A52(6):159, 2016



Jefferson Laboratory and CLAS

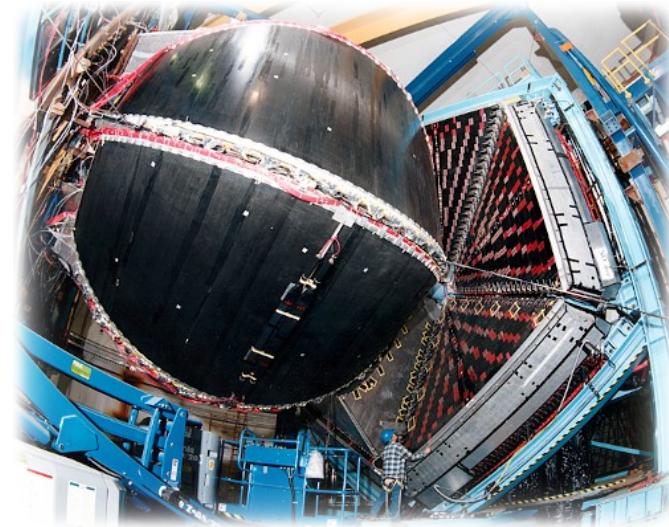


Jefferson Laboratory

- 6 GeV electron beam (now 12 GeV)
- High stability, 100 % duty factor

The CLAS spectrometer

- 2n acceptance
- Luminosity $\sim 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- Upgraded for DVCS measurements
 - A Low angle calorimeter for photons
 - A Solenoid to protect it from secondaries



The Coherent Helium DVCS

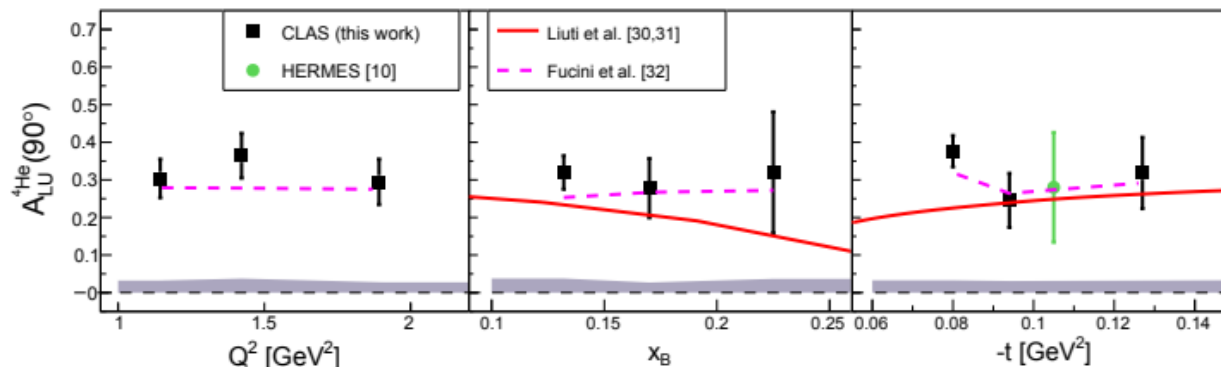
Coherent DVCS on helium

- Measured with CLAS at Jefferson Lab
 - **With the addition of a recoil detector to detect helium nuclei**
- We observed large beam spin asymmetry

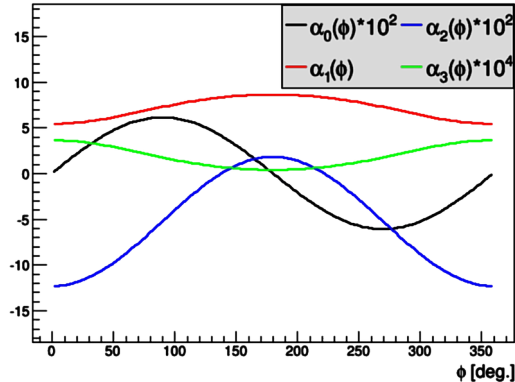
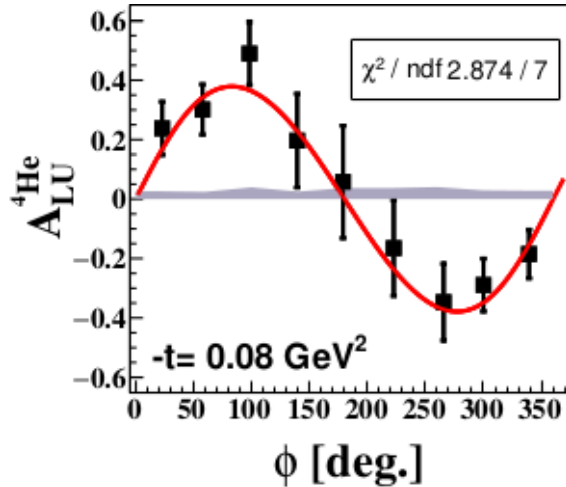
Interpretation

- This strong signal shows we isolated coherent DVCS

M. Hattawy et al. (CLAS Coll.) Phys. Rev. Lett., 119(20):202004, 2017.



Helium CFF extraction



The Helium CFF extraction

- Simplified by the spin-0 (1 GPD/CFF)

Different contributions in phi

- They are calculable within pQCD

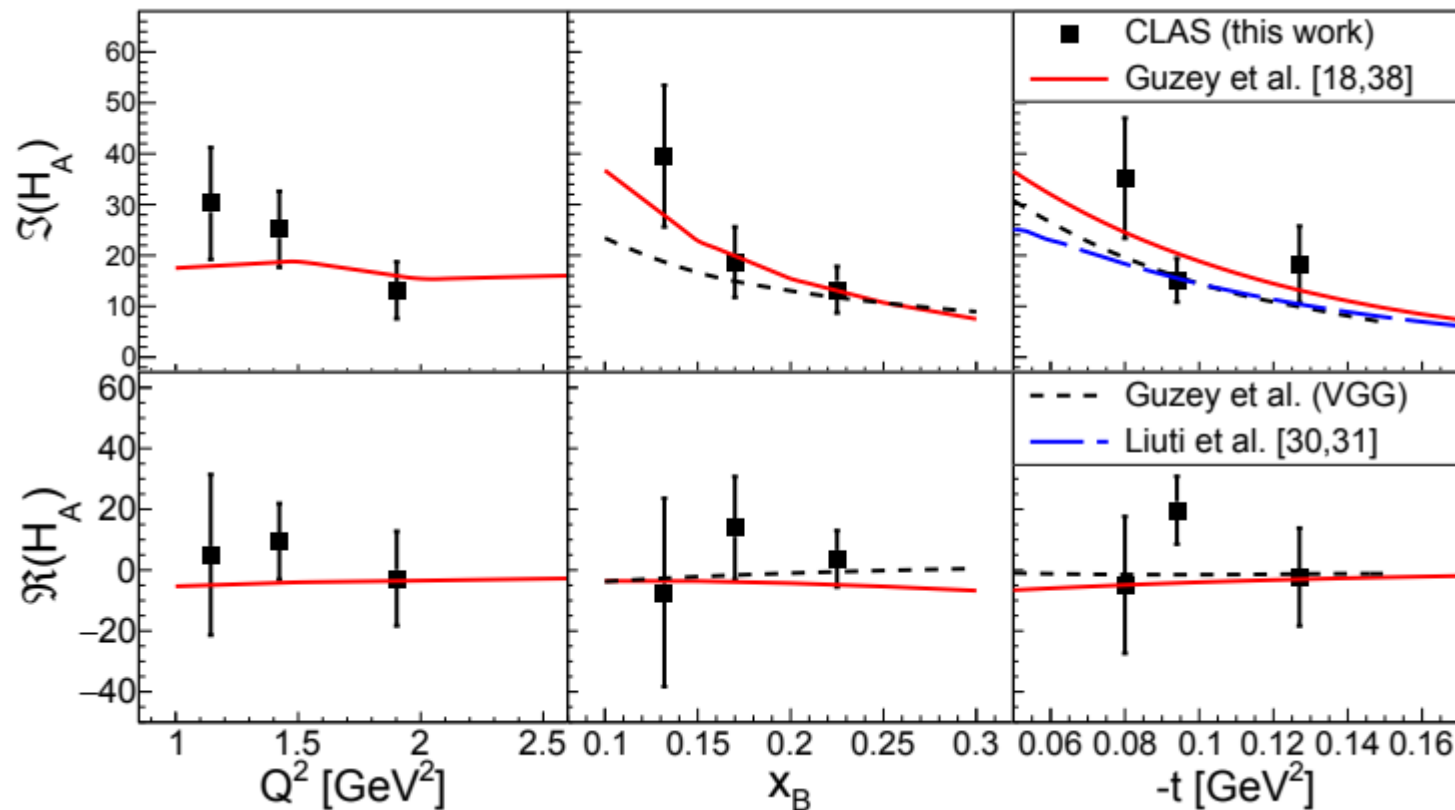
$$A_{LU}(\phi) = \frac{\alpha_0(\phi) \Im m(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi) \Re e(\mathcal{H}_A) + \alpha_3(\phi) (\Re e(\mathcal{H}_A)^2 + \Im m(\mathcal{H}_A)^2)}$$

- The fit converges immediately

M. Hattawy et al. (CLAS Coll.) Phys. Rev. Lett., 119(20):202004, 2017.



Helium Compton Form Factor



Incoherent Helium DVCS

Measurement with CLAS at Jefferson Lab

- Proton bound in helium target

Gives a "generalized" EMC

- Strongly suppressed in particular for anti-shadowing
- Strange behavior compared to the models

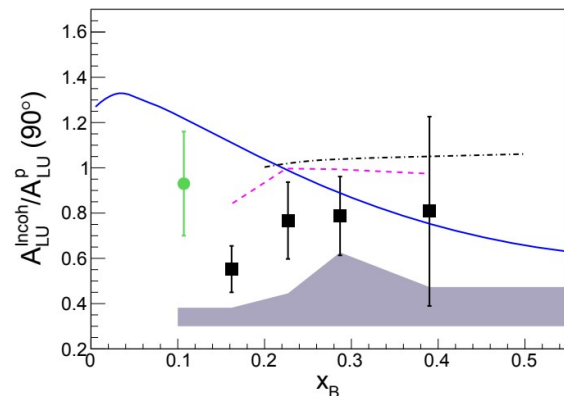
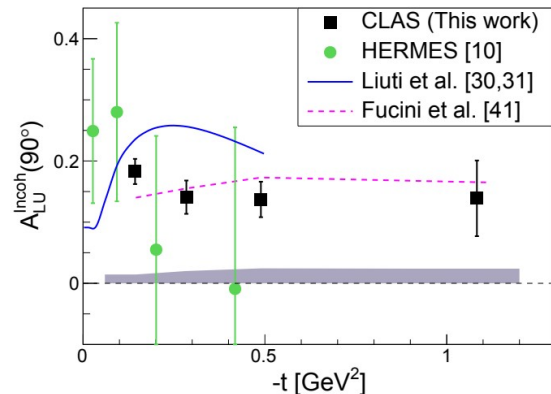
A New kind of EMC effect?

- It could be a nuclear effect
- Or it could be due to final state interactions
 - Can be very complicated in DVCS

M. Hattawy et al. (CLAS Coll.) Phys. Rev. Lett., 123(3):032502, 2019.

More work is ongoing on these questions

- On the theoretical side for a better description
- On the experimental side with nitrogen data



The ALERT Project

Program of measurements at Jefferson Lab with CLAS12

- Measure nuclear DVCS and DVMP on helium-4
- Measure tagged DIS on helium-4 and deuterium
- Measure tagged DVCS on helium-4 and deuterium

Common point of these measurements

- We need to detect nuclear recoils at low energy
- This cannot be done with base CLAS12
- Previously used RTPC is limited in term of PID

We need to use a new detector



The ALERT Detector

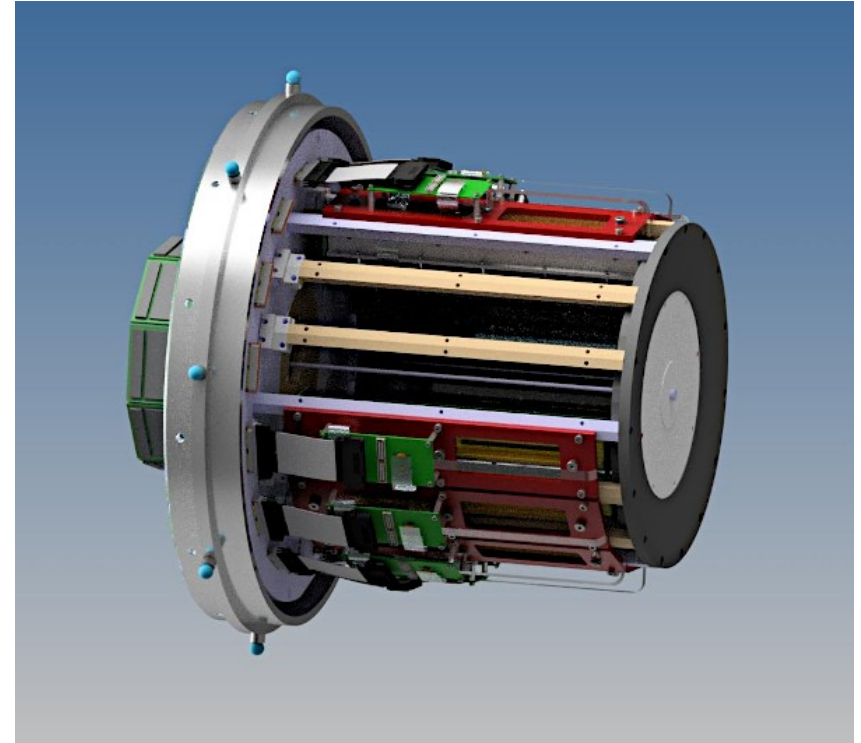
A Low Energy Recoil Tracker

- Hyperbolic drift chamber
- Time-of-Flight array

Collaborative effort within CLAS12

- ANL, IJCLab, JLab, NMSU, and Temple
- We tested a prototype with a nuclear beam in the Fall at the ALTO facility (Orsay, France)

We hope to take data in 2023



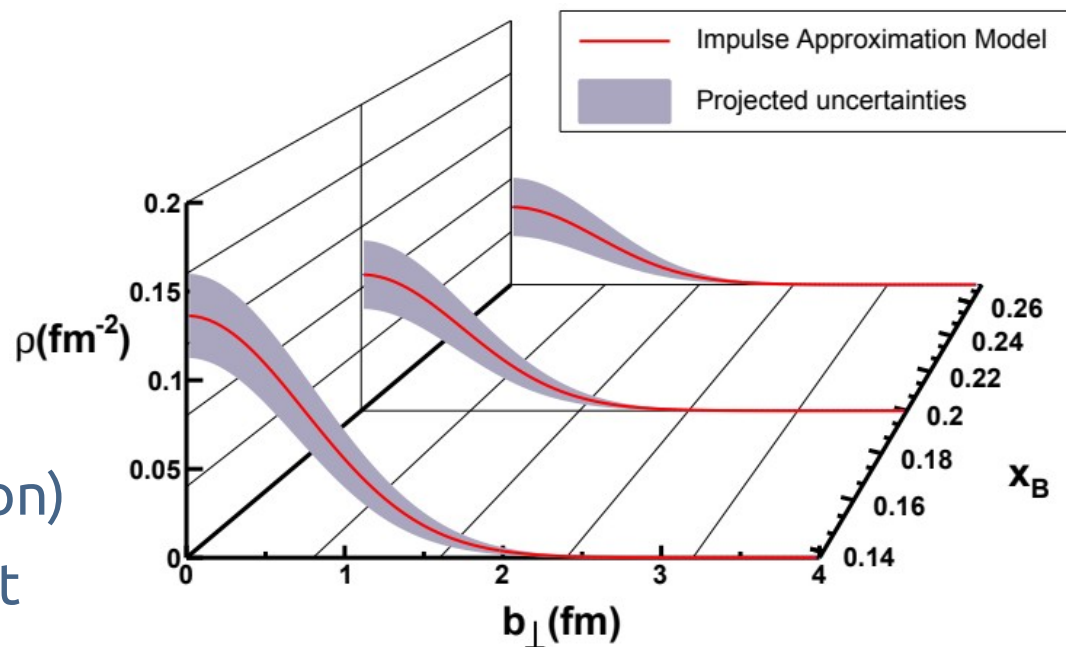
On the side of GPDs

Tomography of a nucleus

- A view into the nucleus in three dimensions
- Using the wider phase space and larger statistics

Extension to the gluons

- We will measure DVMP (Phi meson)
- We hope to obtain a similar result for gluon tomography



Nuclear DVCS at the EIC

We are preparing for nuclear DVCS at the EIC

- Measuring nuclear DVCS at much lower x
- Make a 3D image of the shadowing region

We developed A New Monte-Carlo Event Generator

- ROOT based event generator use the TFoam class to generate a grid and then events
- Use of a recent model tested against data

Sara Fucini, Sergio Scopetta, Michele Viviani Phys.Rev.C 98 (2018) 1, 015203

- We named it TOPEG (The Orsay Perugia Event Generator)

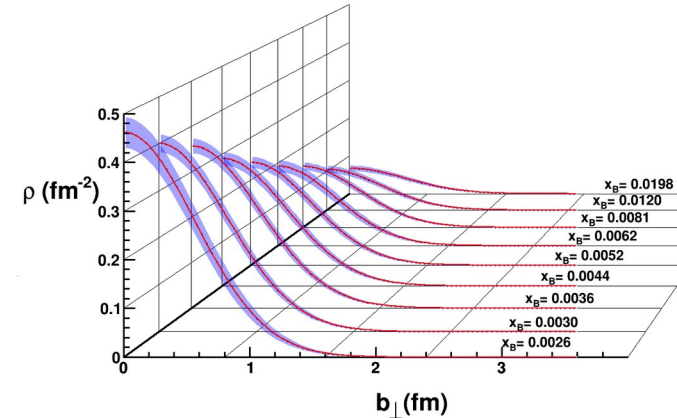
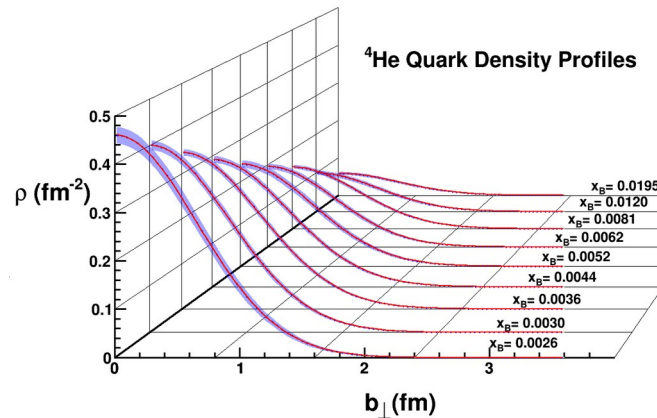
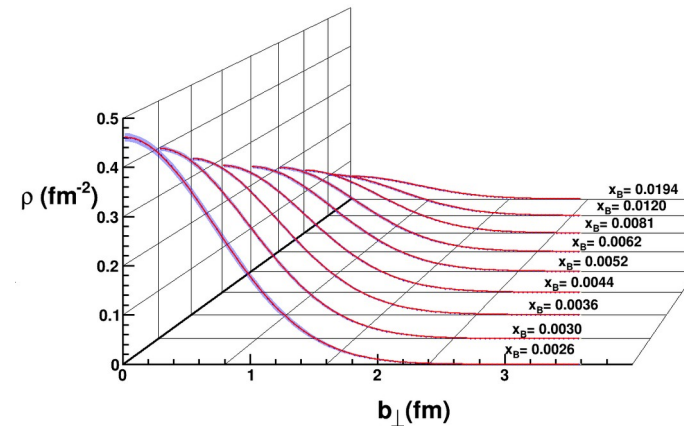
These simulations are part of the EIC Yellow Report (2021)



Nuclear DVCS at the EIC

We expect very nice results from the EIC

- The key detector for this is the Roman pot
- Detecting the nuclear recoil very close to the beam line
- Here we show profile extractions
 - For transverse momentum thresholds of 0.1 (left), 0.2 (center) and 0.3 GeV (right)



Summary

We measured nuclear DVCS with CLAS at JLab

- Large asymmetries are observed in coherent DVCS on helium, as expected by theory
- We made a CFF extraction without model assumptions
- Small asymmetries are observed in incoherent DVCS on helium, not expected by theory

We are preparing for more measurements soon

- Re-analysis of old data for incoherent DVCS on nitrogen
 - **To provide some A dependence for the nuclear effect measured on helium**
- The ALERT program at JLab 12 GeV
 - **Will provide much more statistics, cover a larger phase space and explore new channels**

We are preparing for the EIC

- Nuclear DVCS can be performed at the EIC
- We are developing the phenomenological tools for future studies

