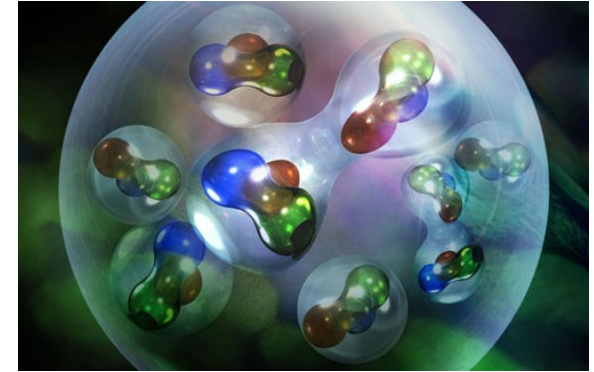
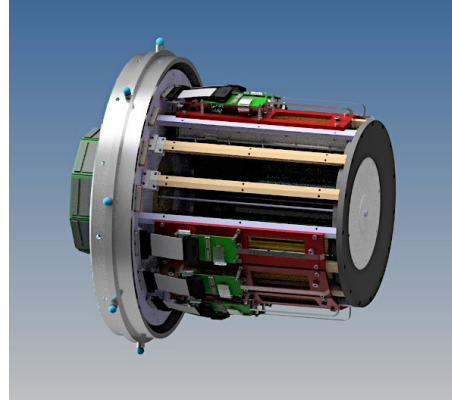
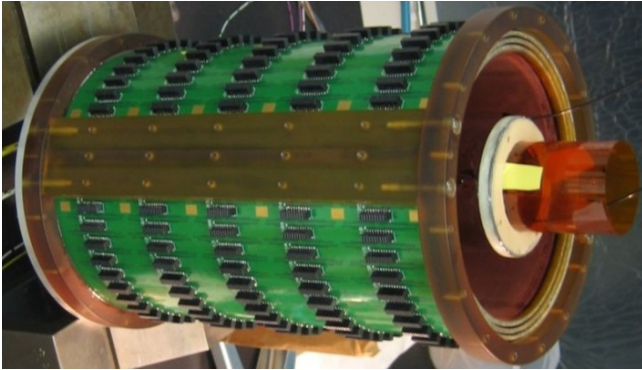


# Nuclear DVCS From CLAS to the EIC



**Raphaël Dupré**

*For the CLAS Collaboration*

# Nuclear Effects

## Nuclei change nucleons

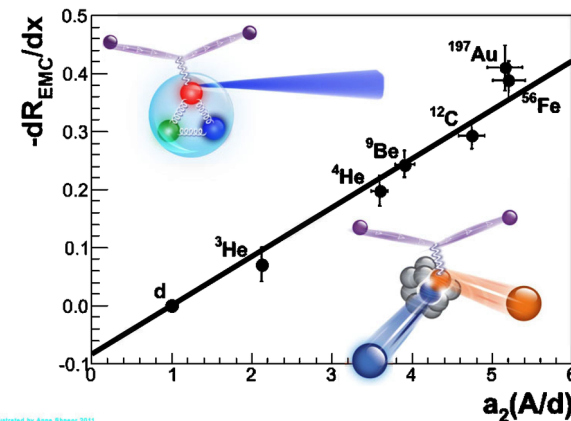
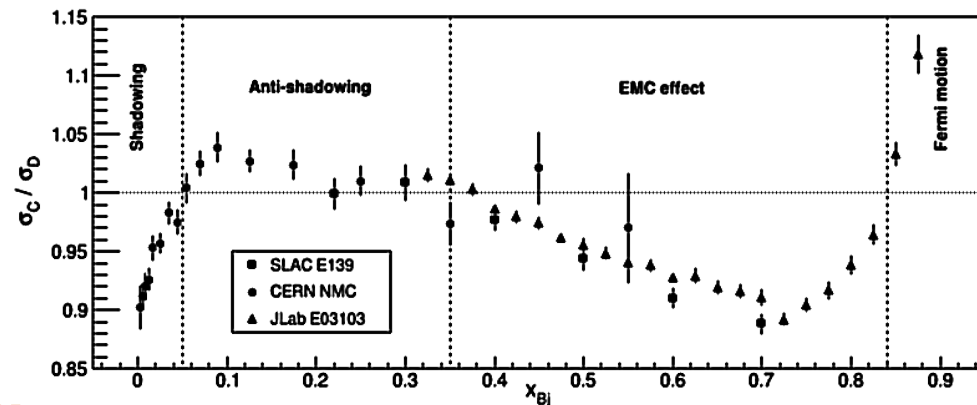
- Several nuclear effects
- The most studies the EMC
  - Reduction of large  $x$  quarks

## We do not understand why and how

- There are no widely accepted explanation
- 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

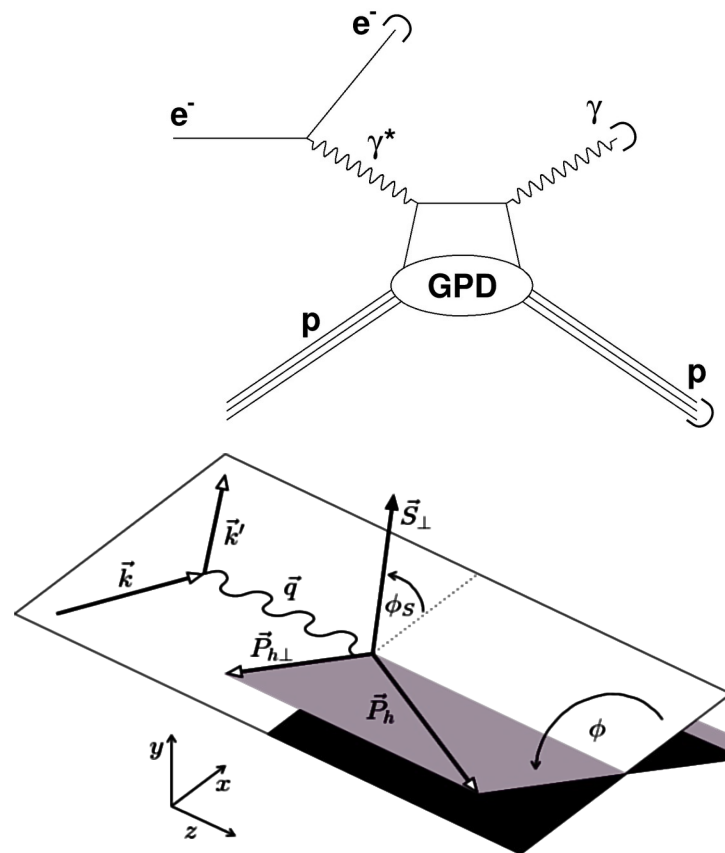
- Three dimensional ( $x$ ,  $\xi$  and  $t$ ) structure functions
- Accessible through exclusive processes
  - DVCS, DVMP, TCS, DDVCS...

## 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

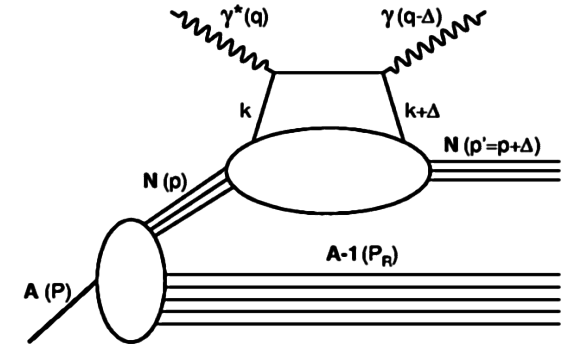
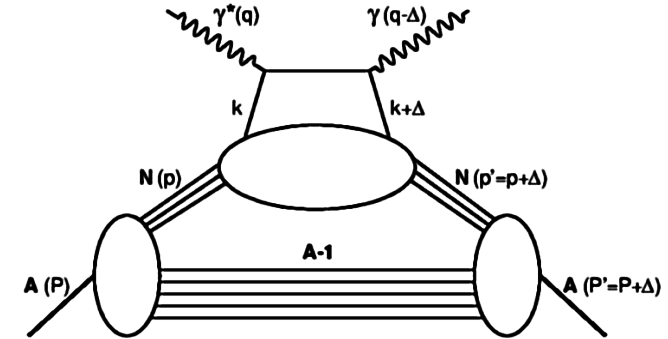
## In the nucleus two processes

- Coherent and incoherent channels
  - Similar to elastic and quasi-elastic
- Give a global view and a probe of the components

## 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*



# The Coherent Helium DVCS

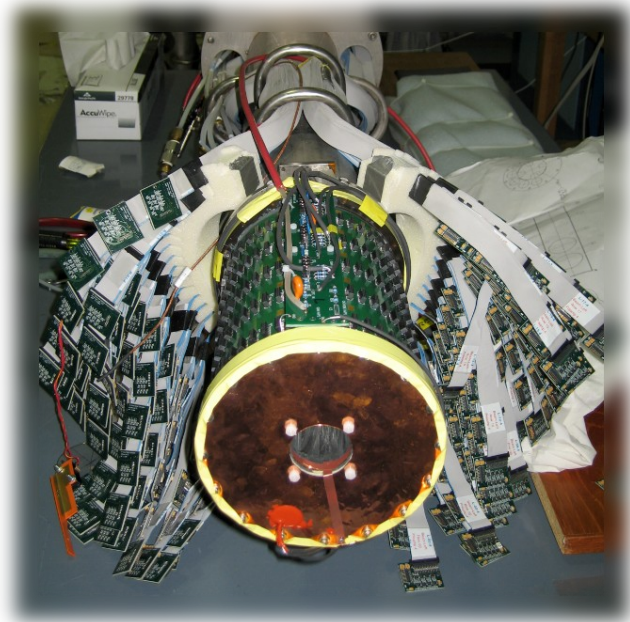
## Coherent DVCS on helium

- Measured with CLAS at Jefferson Lab
  - Use recoil detector to ensure exclusivity
- Shows very strong beam spin asymmetry

## Interpretation

- Very strong signal proves that we have the nuclei as a whole

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



# Helium Compton Form Factors

## Helium CFF extraction

- Spin-0  $\rightarrow$  1 GPD/CFF

## We separate the different contributions in $\phi$

- They are calculable within pQCD
  - Here at leading order
- The fit converges immediately

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



# 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

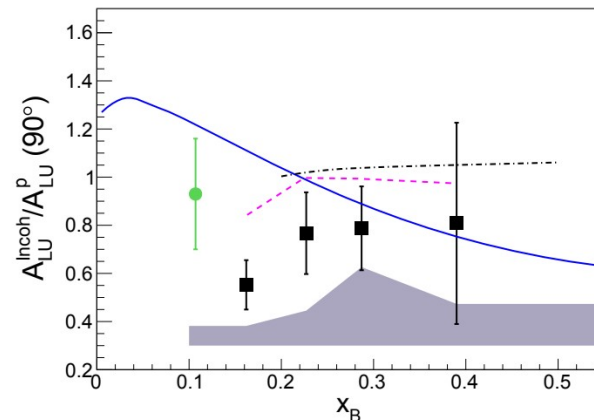
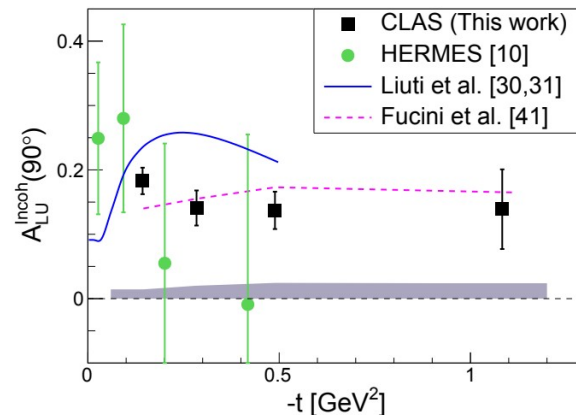
## A New kind of EMC effect?

- 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

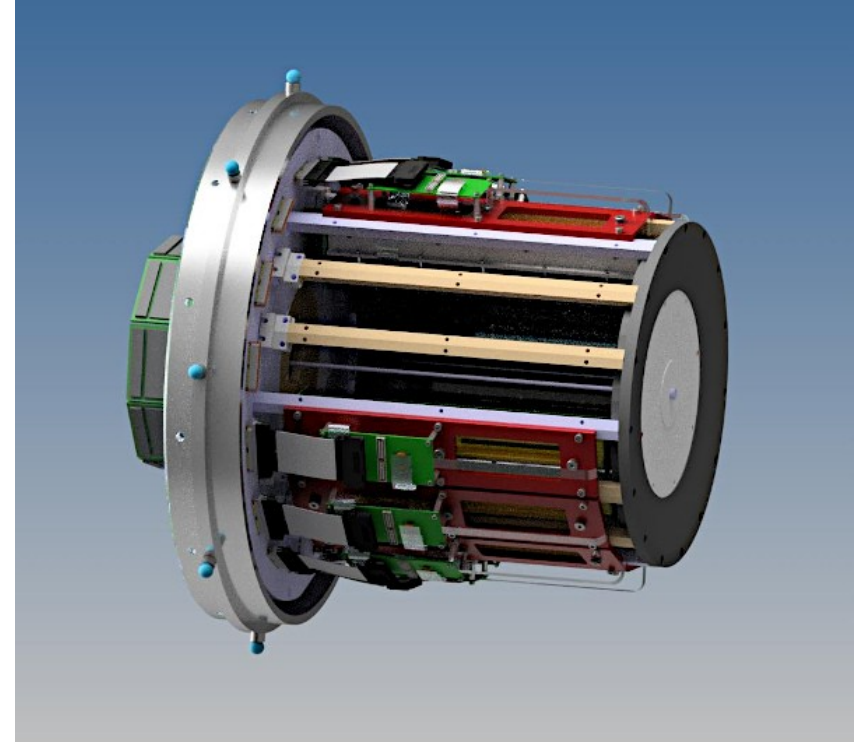
## A Low Energy Recoil Tracker

- 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**



# 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*

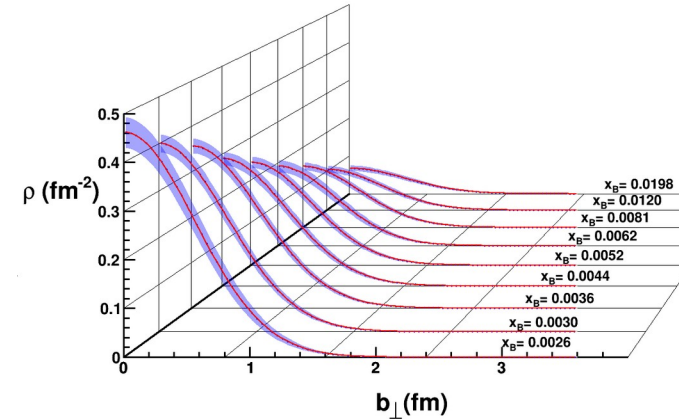
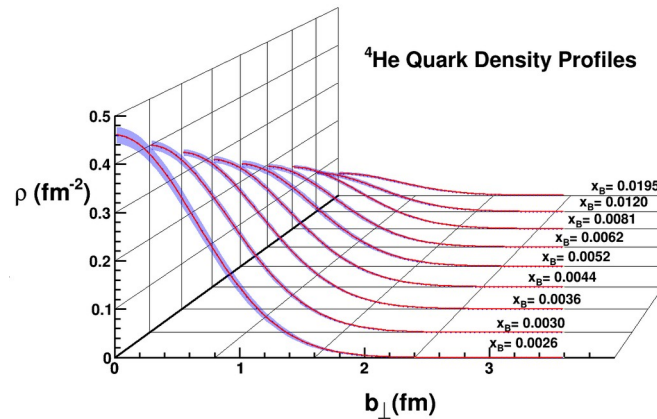
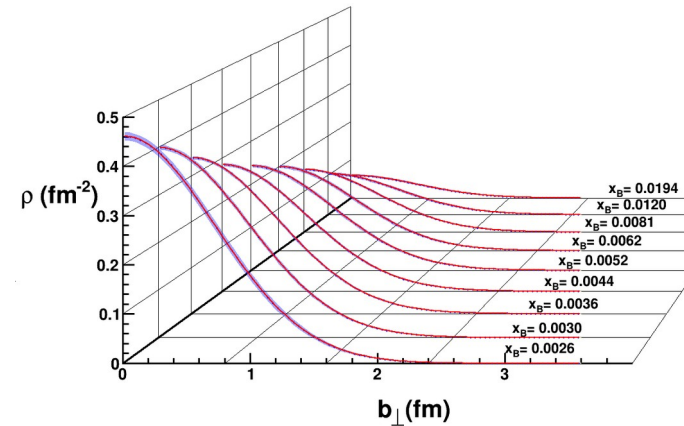
- We named it TOPEG (The Orsay Perugia Event Generator)



# Nuclear DVCS at the EIC

## We expect very nice results

- 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

