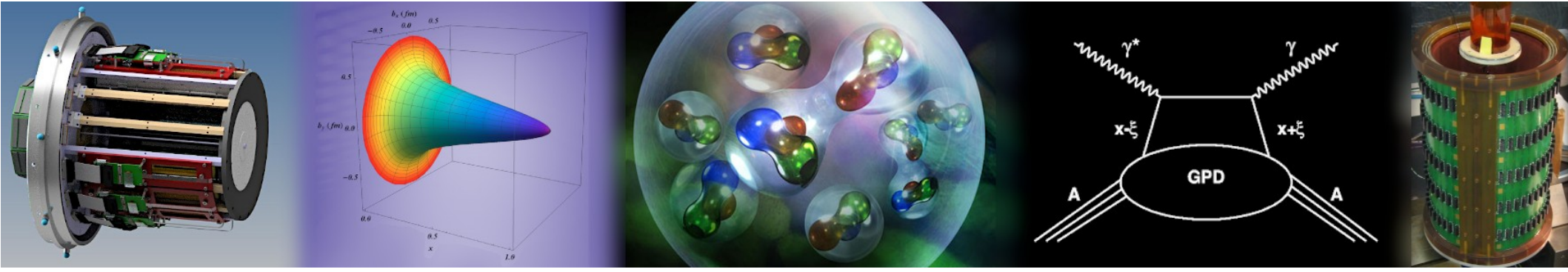
Nuclear DVCS with ALERT

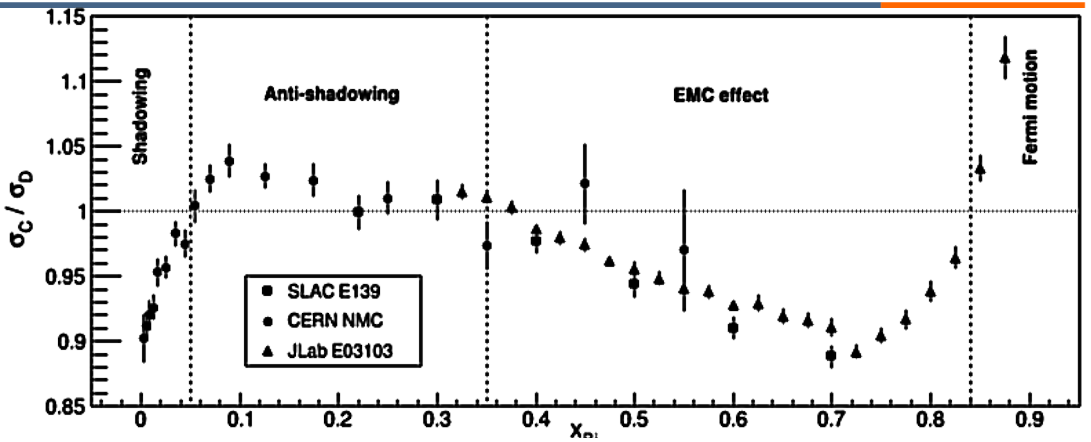


Raphaël Dupré
CNRS/IN2P3
Univ. Paris-Saclay

The Nucleus Quark Structure

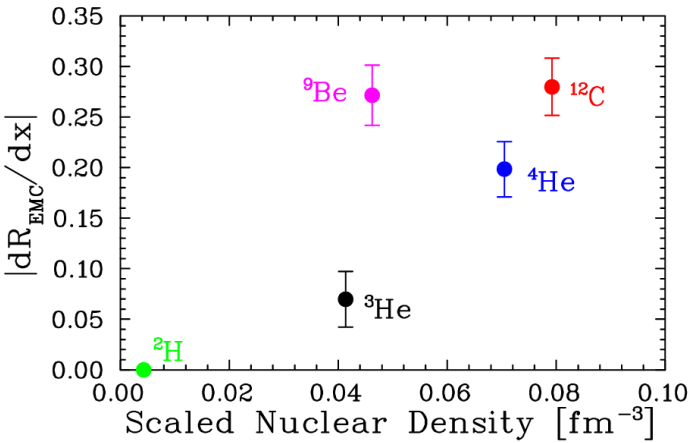
The nuclear PDFs show many suprises

- Quarks are affected by the nuclear medium
- The EMC effect at large x, the shadowing effect at lower x
- The dependence of this effect appears to have complexe dependence to nuclear density



Studied for decades by both theorists and experimentalists

- Still a very controversial topic, with many theories and very few certainties
- Drell Yan measurements have brought unique progress
- Can the DVCS and GPD framework do the same ?



Measuring Nuclear DVCS

Nuclei give control over the spin

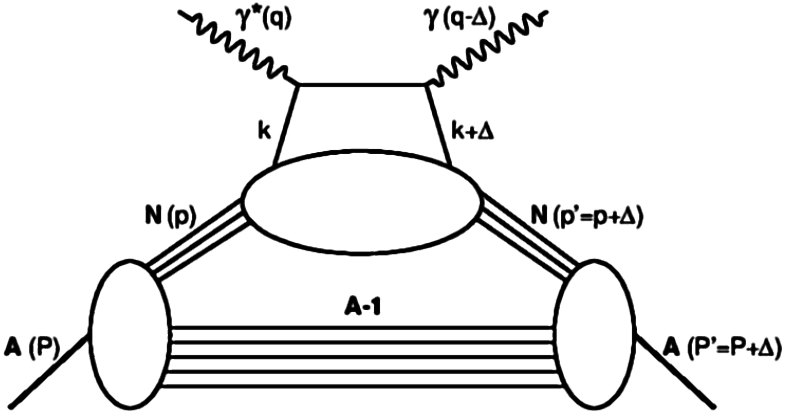
- Spin-0 → 2 GPD ; Spin-1/2 → 8 GPDs ; Spin-1 → 18 GPDs
- Half of these intervene in DVCS

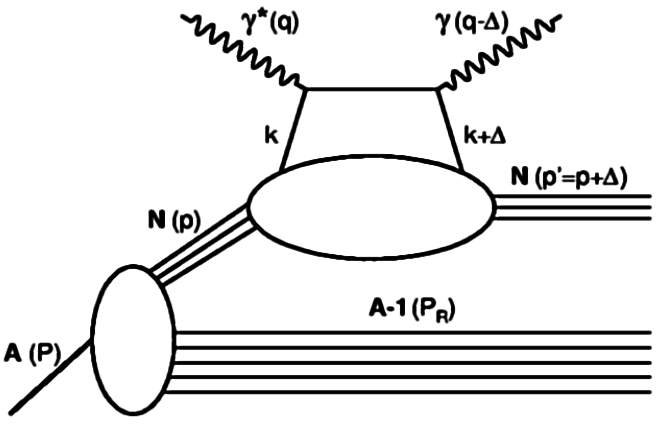
In the nucleus two processes

- 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

- Coherent DVCS gives access to the full nucleus
  - **Including non-nucleonic degrees of freedom**
- Incoherent DVCS gives access to the bound nucleon
  - **To test modifications of the bound nucleon structure**





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

HERMES Results

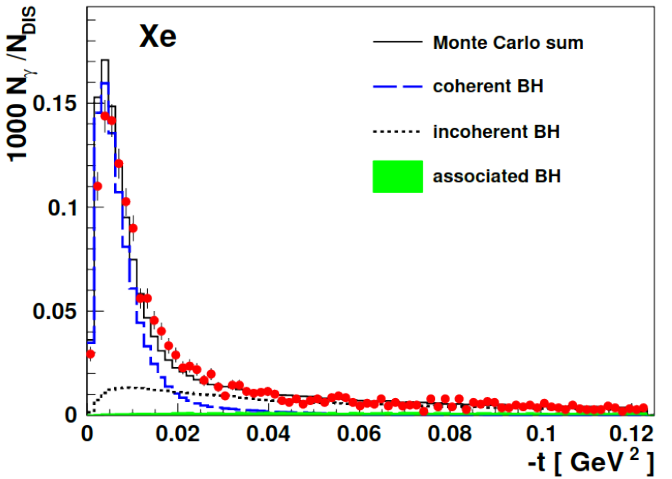
Nuclear DVCS measurement by HERMES

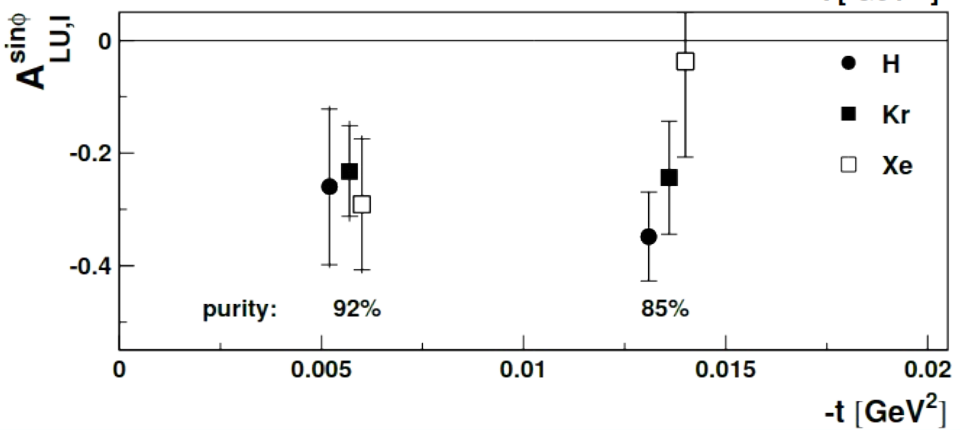
- Charge and beam-spin asymmetries
- No clear nuclear dependence
- In a rather pure coherent sample

This is a problem…

- In the coherent process we expect a significant increase
- Argument about the way coherent and incoherent are separated

Can we measure the recoil nuclei ?





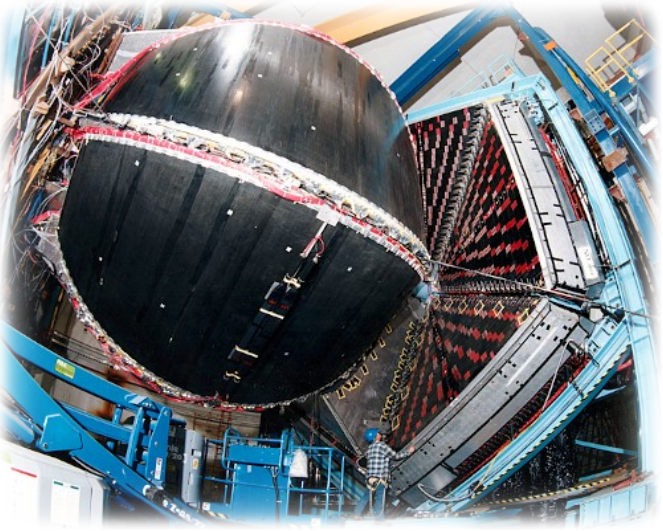
The CLAS experiment at JLab

Jefferson Laboratory

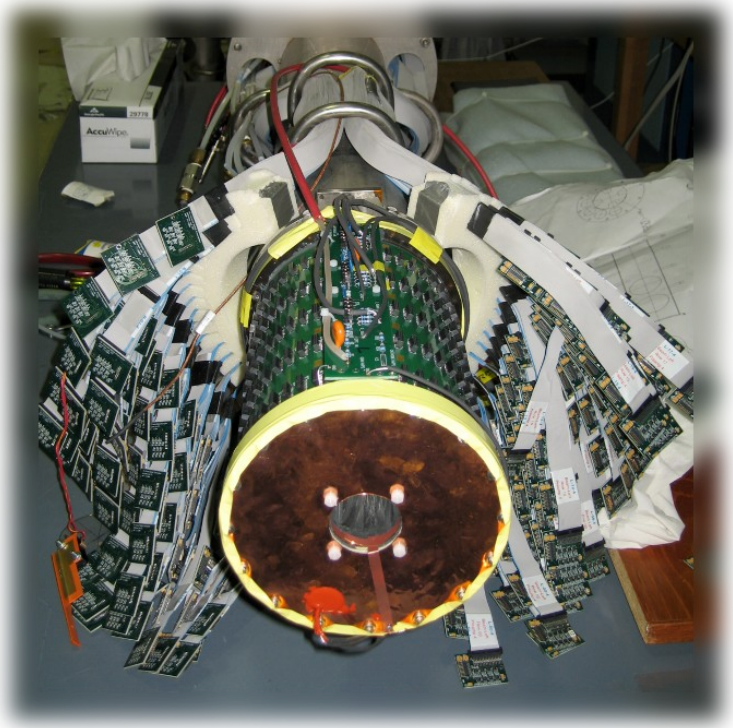
- 6 GeV electron beam (at the time)
- High stability, 100 % duty factor

The CLAS spectrometer

- 2π acceptance
- Luminosity ~10^{34} $cm^{-2}s^{-1}$
- Upgraded for DVCS measurements
  - **Low angle calorimeter for photons**
  - **Solenoid to protect from low angle electrons**



Detecting Recoil Nuclei



Recoil nuclei are evasive

- They usually do not make it out of the target…

How to handle that ?

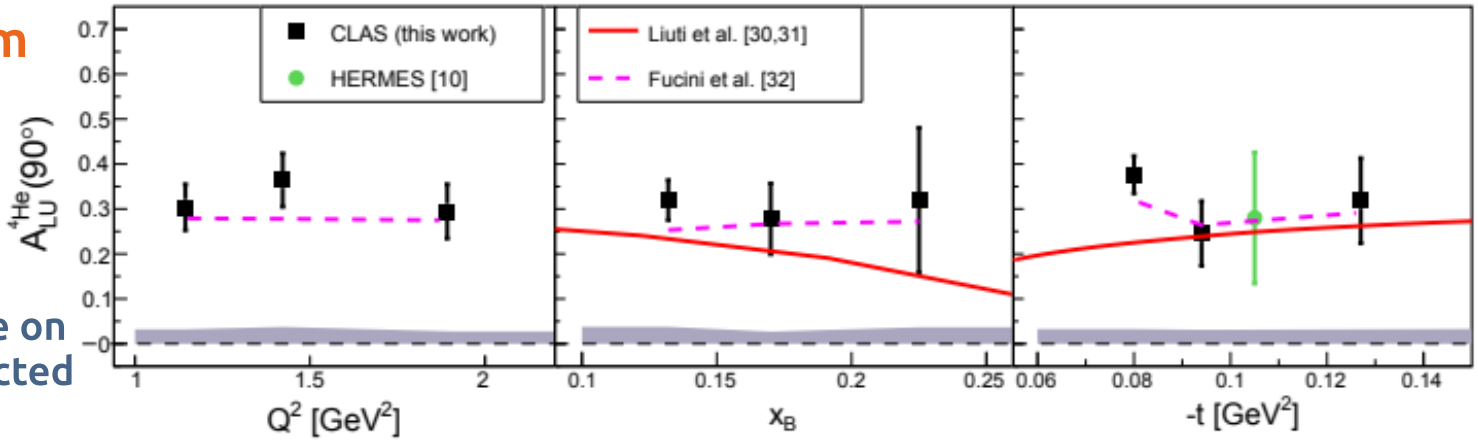
- Use a light nuclei : Helium
  - **It is also spin-0 which is nice for simplicity**
- Use a very light target : a straw
  - **Filled at 5 Atm with 50 µm thick walls**
- Get very close to it : Radial TPC
  - **3 cm away from the target**

The experiment ran in 2009

The Coherent Helium DVCS

Coherent DVCS on helium

- Fully exclusive
- We observed large beam spin asymmetry
  - **About twice the one on the proton, as expected from theory**



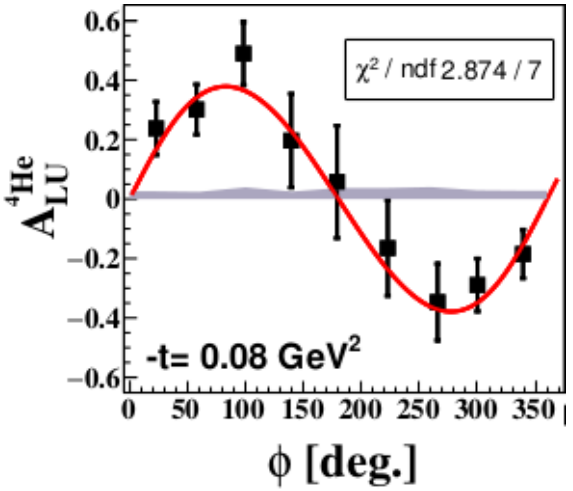
Interpretation of the results

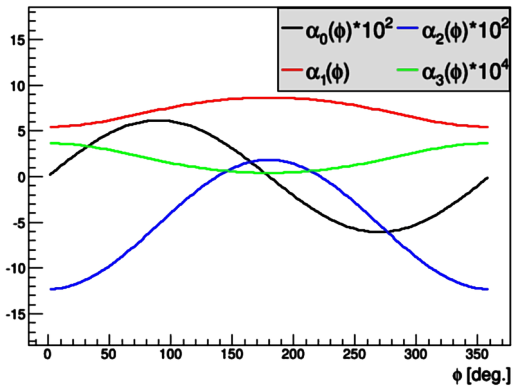
- This strong signal shows we fully isolated coherent DVCS
- The amount of data is too little for advanced interpretation
- But enough to check if we can extract the CFF !

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

R. Dupré et al. (CLAS Coll.) Phys.Rev.C 104 (2) 025203, 2021

Nuclear CFF Extraction





We extract the Compton form factors

- Phenomenology simplified by the spin-0
  - **Single complex CFF to be extracted**

Results are obtained using the different contributions in phi

- Calculable within pQCD (here LO, LT)

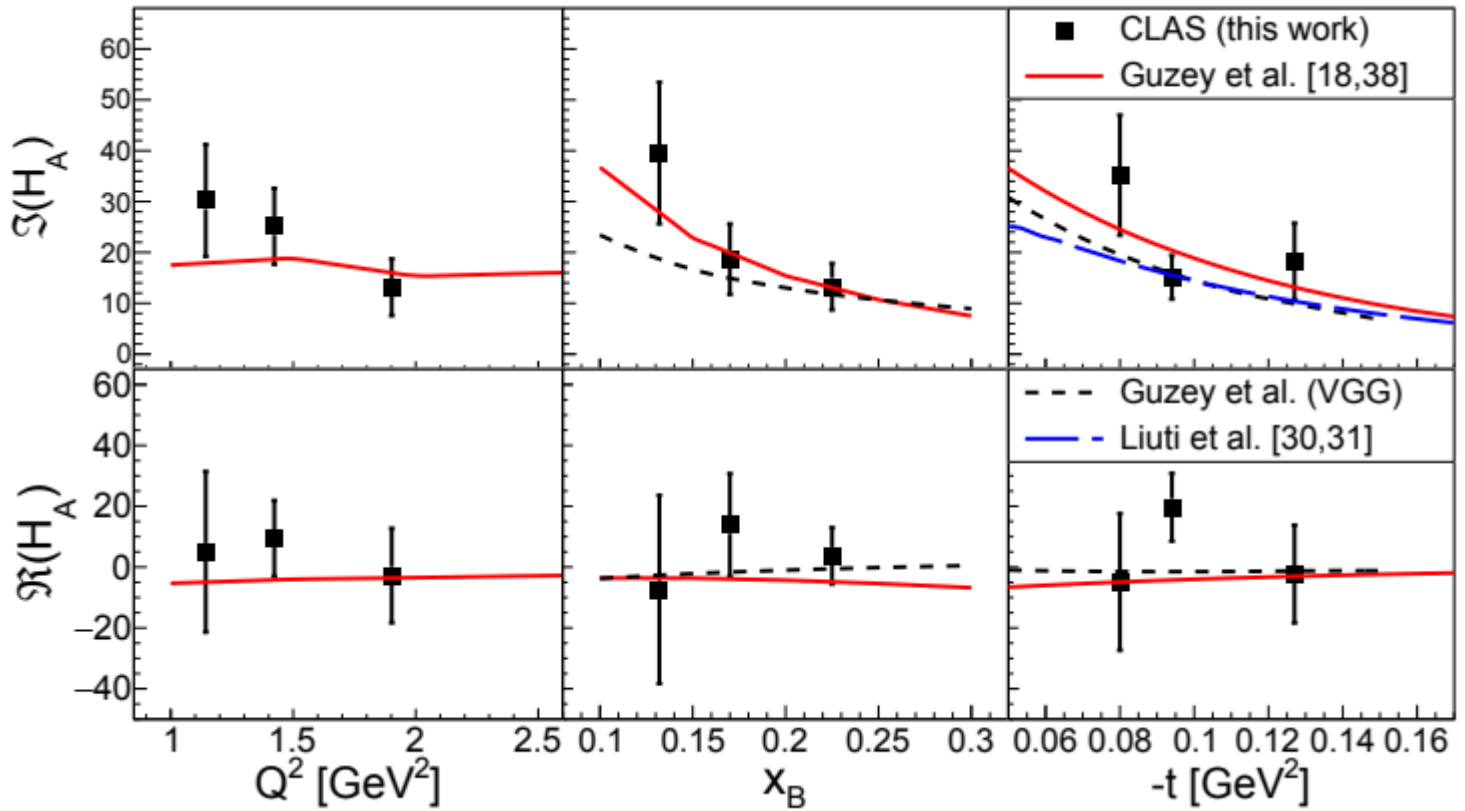
$$A_{LU}(\phi) = \frac{\alpha_0(\phi)\,\Im m(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi)\,\Re e(\mathcal{H}_A) + \alpha_3(\phi)\left(\Re e(\mathcal{H}_A)^2 + \Im m(\mathcal{H}_A)^2\right)}$$

- The fit converges immediately

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

R. Dupré et al. (CLAS Coll.) Phys.Rev.C 104 (2) 025203, 2021

(First) Model independent CFF extraction



Incoherent Helium DVCS

Gives a "generalized" EMC

- Strongly suppressed in particular for anti-shadowing
- Behavior not predicted by the models

A New kind of EMC effect?

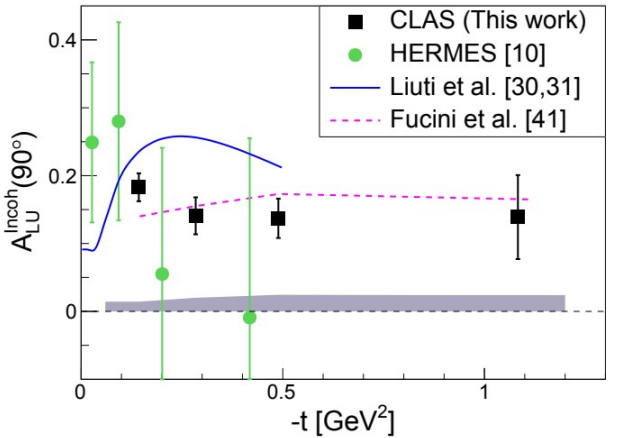
- It could be an initial state nuclear effect
- Or it could be due to final state interactions
  - **Can be very complicated in DVCS**

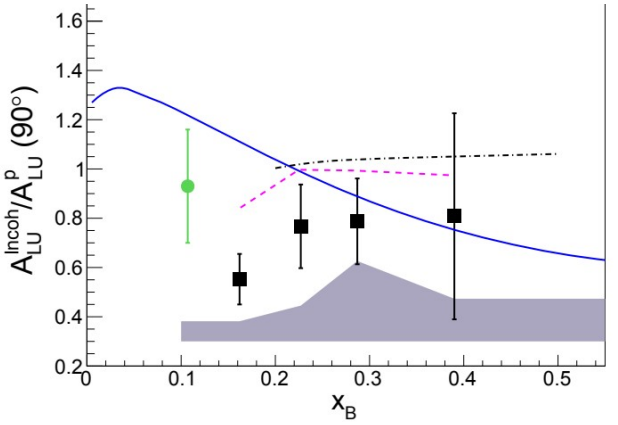
M. Hattawy et al. (CLAS Coll.) Phys. Rev. Lett., 123(3):032502, 2019.

R. Dupré et al. (CLAS Coll.) Phys.Rev.C 104 (2) 025203, 2021

More work is ongoing on these questions

- Larger nuclei show larger suppression (unpublished)





Moving Forward with JLab 12 GeV

What do we want to improve ?

- Larger luminosity, we want finer binning and better precision
- We want to tag the nuclear fragments in the incoherent
  - **Gives control over the final state interactions**

How can we do that experiment ?

- Higher energy, lowers t minimum and increase the cross section
- A completely new detector for the detection of nuclear fragments
  - **Faster to limit pile-up at large luminosities**
  - **With a better particle identification to separate isotopes**

The ALERT Detector

A Low Energy Recoil Tracker

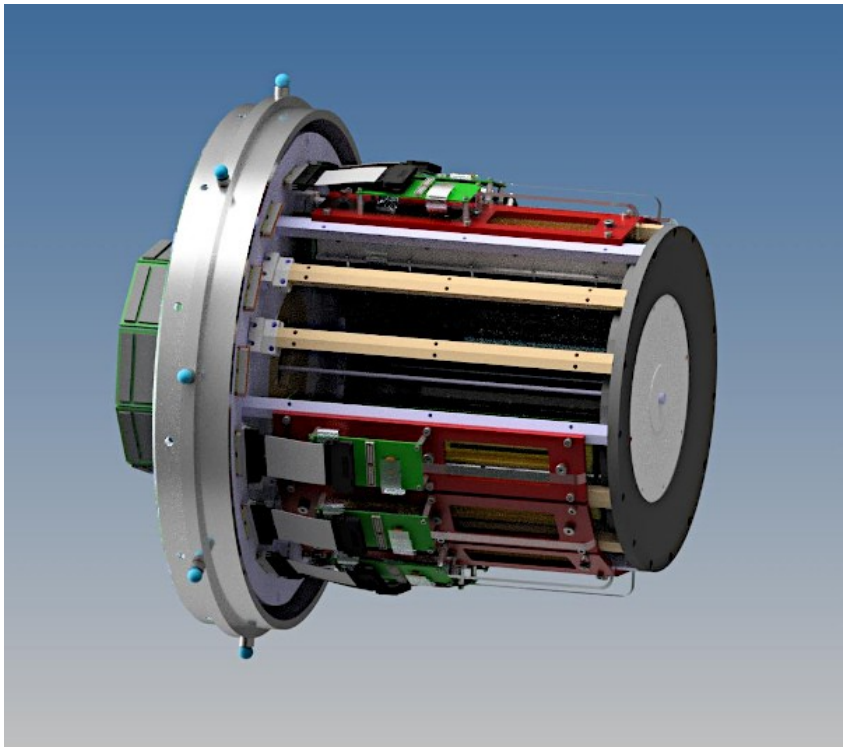
- Hyperbolic drift chamber
- Time-of-Flight array

It will be used for a large array of experiments

- Nuclear DVCS, DVMP...
- Tagged processes (DIS & DVCS)

Collaborative effort within CLAS12

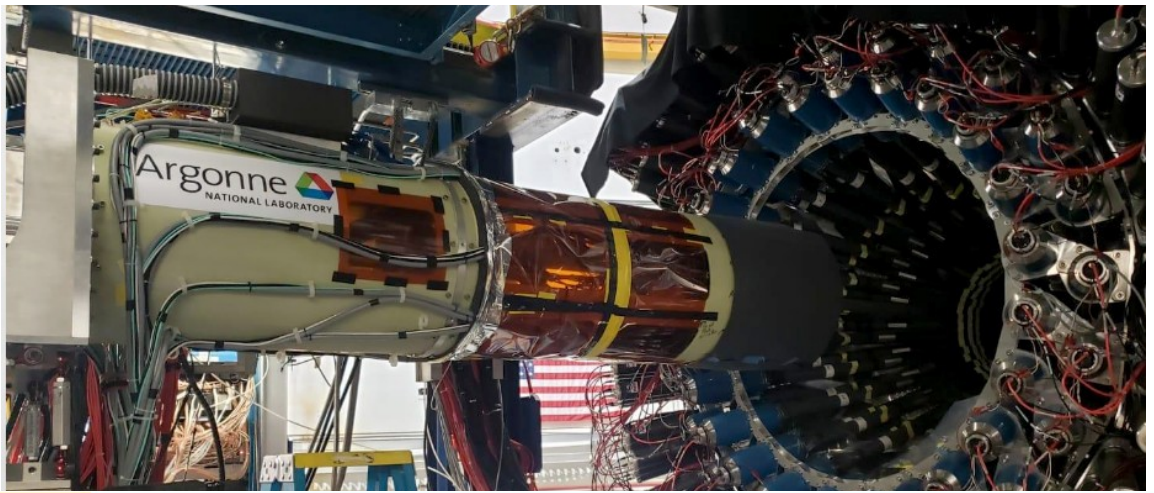
- ANL, GW, IJCLab, JLab, Mississippi SU, NMSU, ODU, Temple, W&M ...



ALERT Construction

After extensive R&D, we built ALERT

- The drift chamber in IJCLab and the time-of-flight in ANL (2023-24)
- Assembly, commissioning and installation on the beam line of Hall-B in JLab (2024-25)

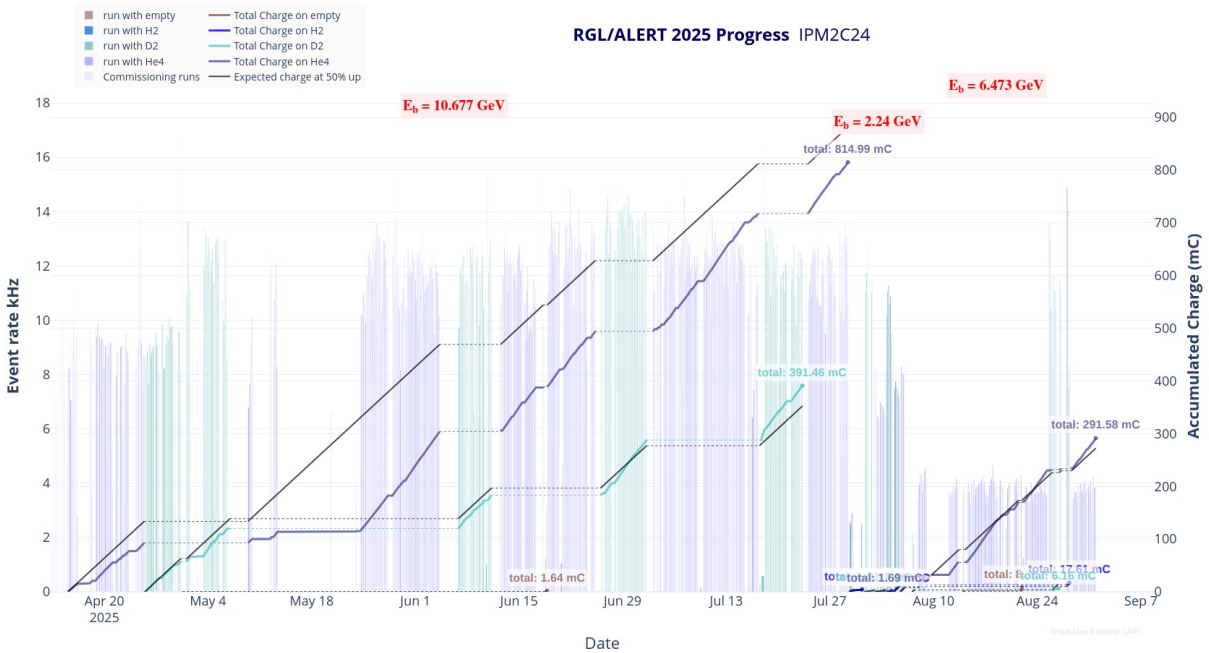


ALERT Run

Finally we got beam on target

- Issues with beam quality, burning electronics, a broken wire…
- All problems found some resolution
- Data looked good
- The accelerator sorted itself

We got the amount of data we requested !



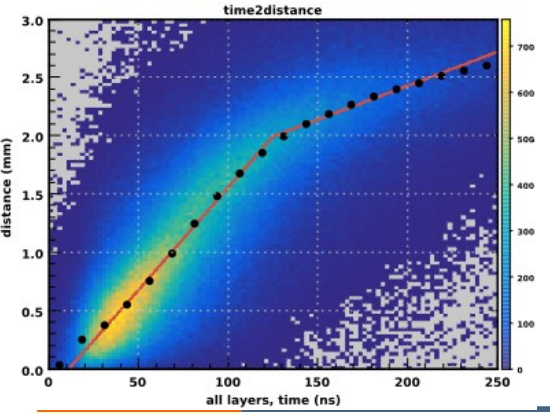
ALERT Performance & Calibration

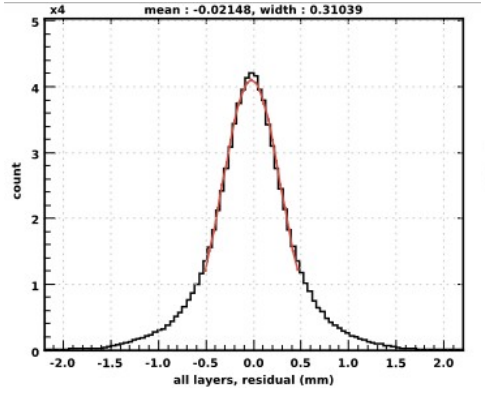
Calibration still on going

- Much progress made already
- But still more work needed

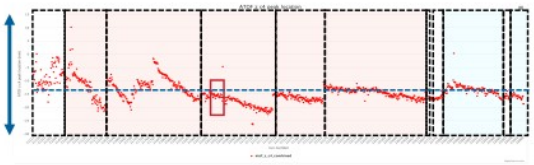
We work to complete calibration

- Toward the end of Summer

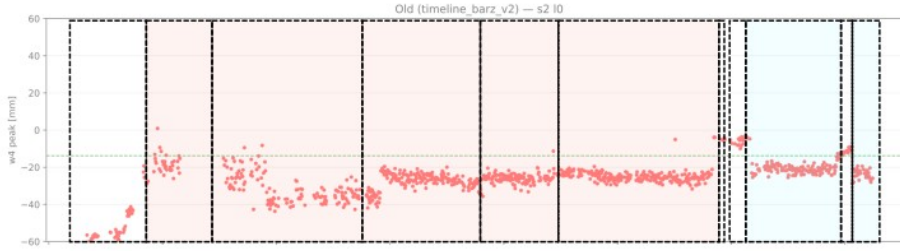




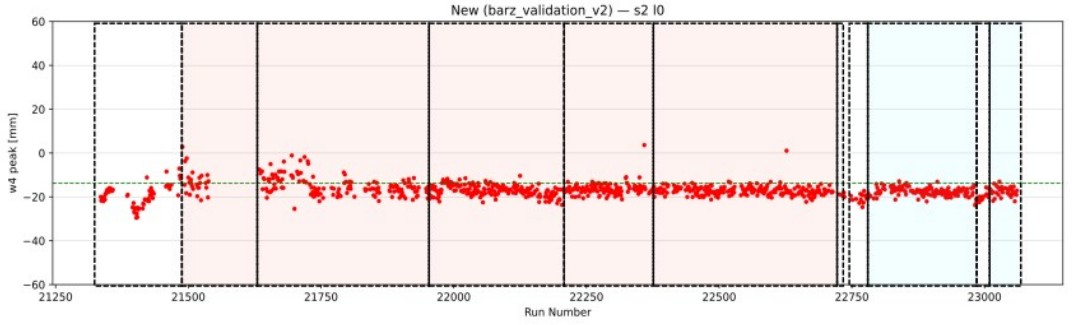
Original



Before



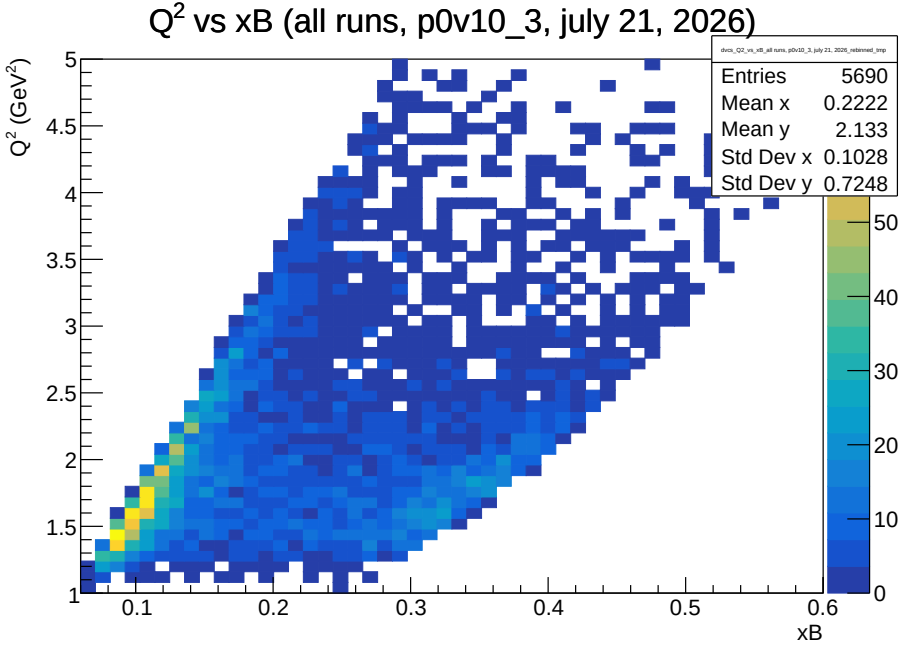
After

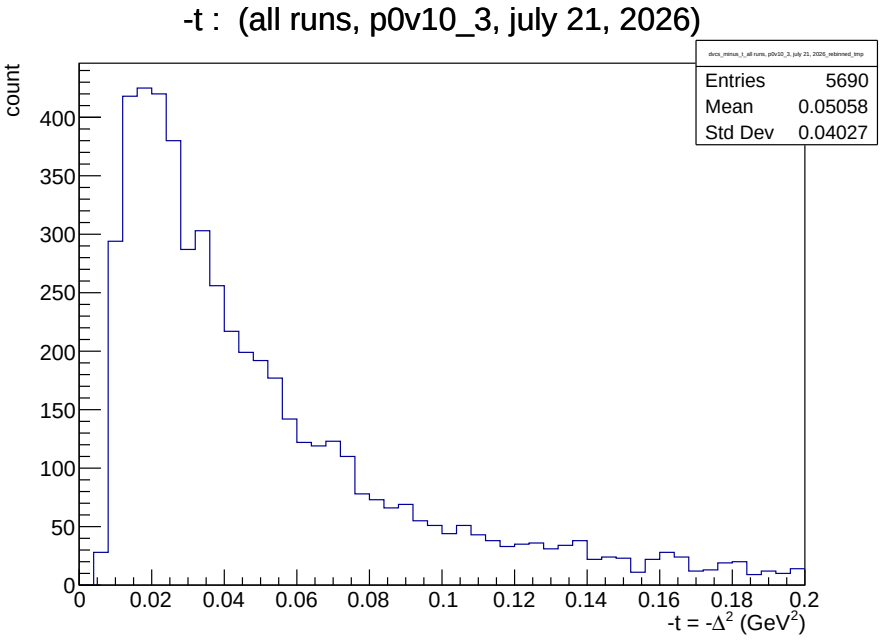


First peak at the data

The data presented here is still very much uncalibrated

- The version used here does not have most recent calibration/reconstruction and only a fraction of the dataset (1-2%)
- Felix Touchte-Codjo is working on this analysis, we hope to see some preliminary assymetries soon





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 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)

https://gitlab.in2p3.fr/dupre/nopeg

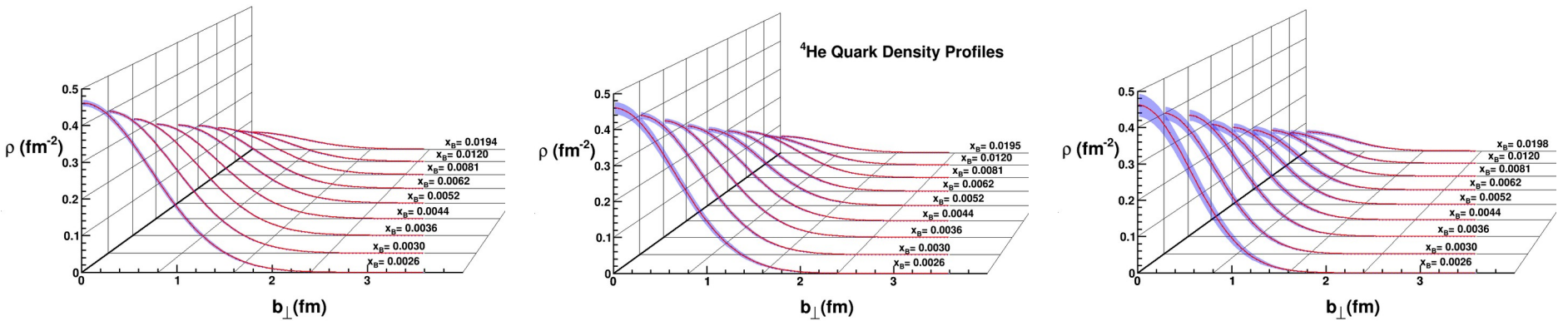
These simulations were produced for the EIC Yellow Report (2021)

- Studies prolonged for the ECCE proposal
- New models are in the work for this event generator (tagged DVCS in particular)

EIC Projections

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)**



Much more GPD physics with exclusive meson productions

- Particularly sensitive to the gluon component

Summary

We still need to learn much about the nucleus in QCD

- Either we do not understand the mechanisms at play
- Or we lack a quantitative demonstration

There are many avenues, I focused here on nuclear GPDs

- We measured coherent and incoherent nuclear DVCS
  - **Confirming some of our understanding and raising new questions**
- We just finished the new generation measurement with CLAS12
  - **We expect new results very soon and publication in a couple of years**

This topic will very much continue with EIC

- Roman pots will allow to measure DVCS on light nuclei
- The high energy gives access to completely new kinematics