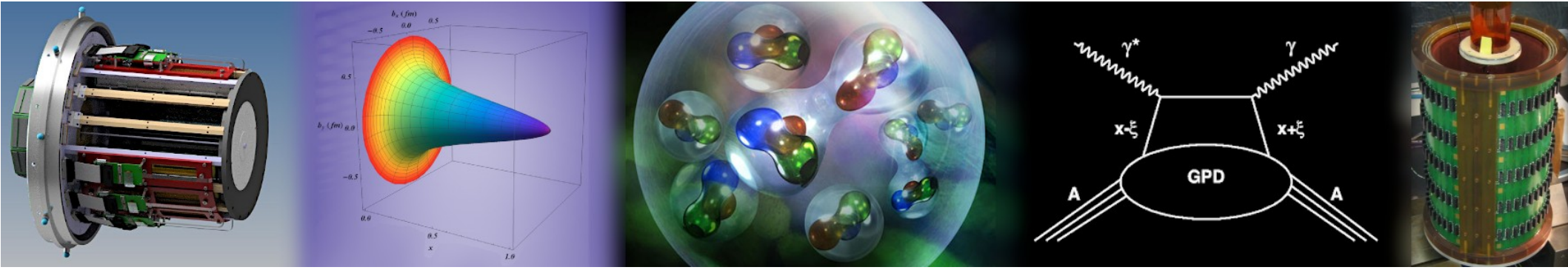
Tagged DIS Experiments Current and Future



Raphaël Dupré

Univ. Paris-Saclay

European Research Council
Established by the European Commission

Tagging in JLab Overview

Deuterium (polarized or not)

- Study pion and kaon content (TDIS @ JLab)
- Study the unpolarized neutron (Bonus @ JLab)
- Study nuclear effects and SRC (BAND @ JLab)

Helium-3 (polarized)

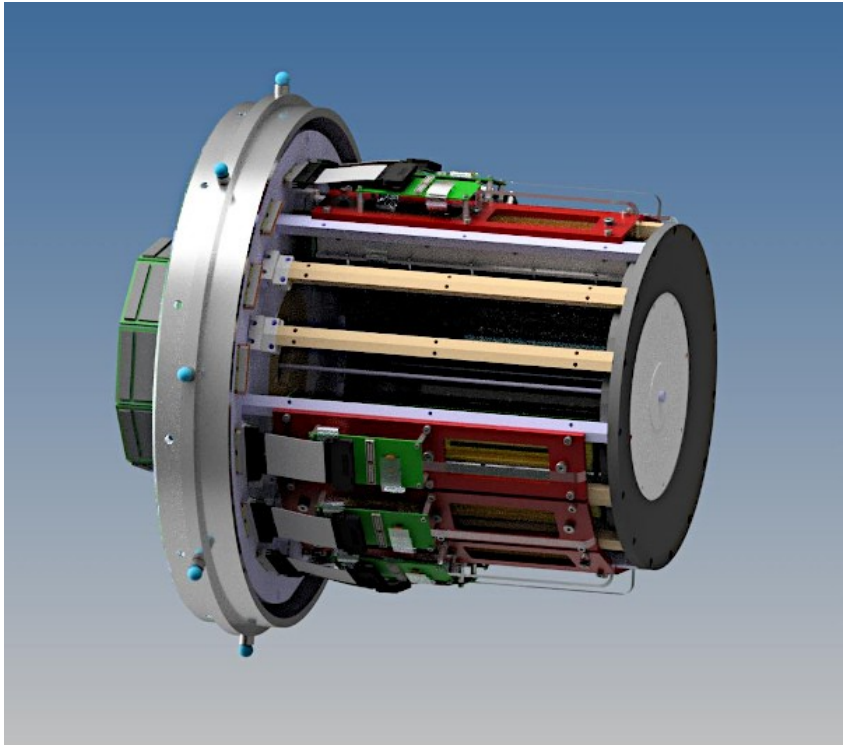
- Effective polarized neutron, 3N SRC...

Helium-4

- Study bound nucleons (ALERT @ JLab)
- Study of EMC and SRC (ALERT @ JLab)

Heavy targets

- Centrality tagging, SRCs...



Strategies to Target Neutrons

How to approach the problem ?

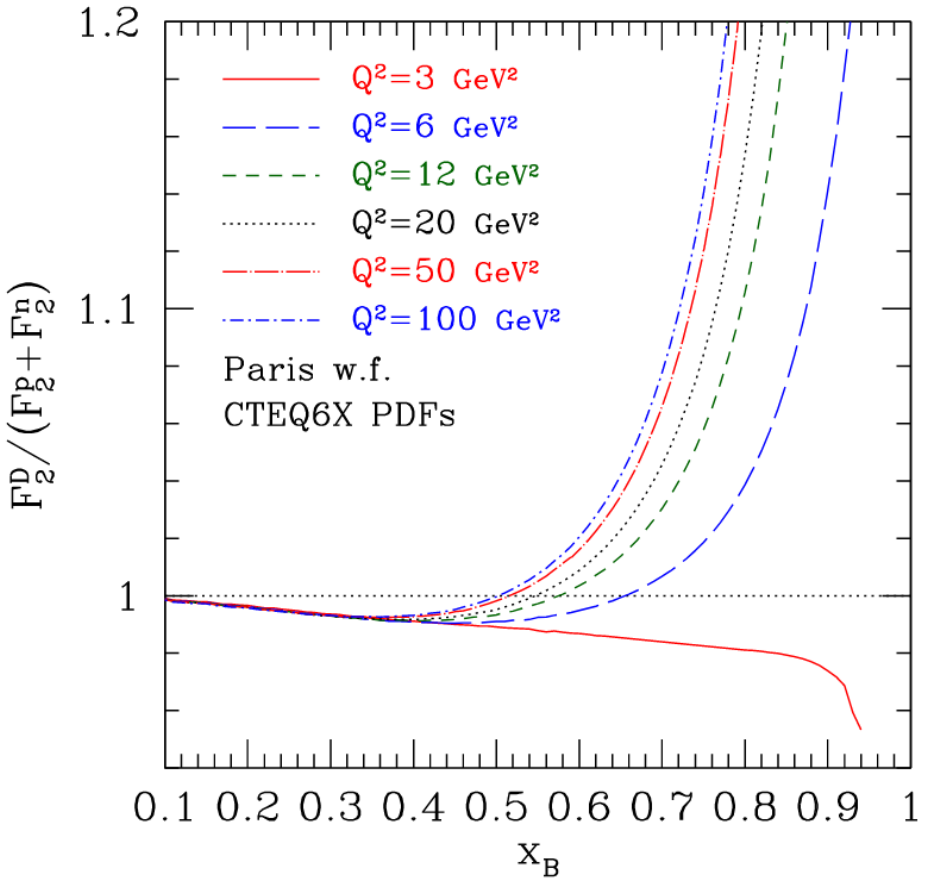
- Use of nuclei to get stable neutrons
- The lightest the better to simplify things
  - **Deuterium in most cases, helium-3 if we want polarization**

Can we just substract the protons ?

- Yes ! This is mostly what has been done in the past
- But, high x is where nuclear effects are large even in deuterium

Some alternative strategies

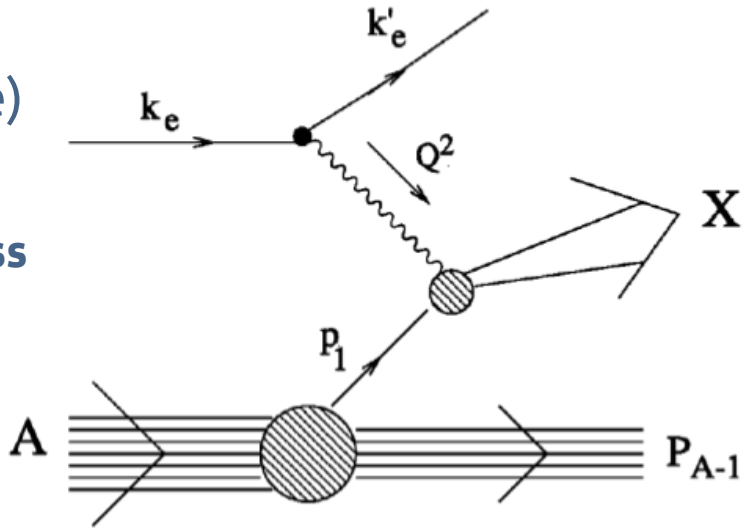
- Tagging where you make sure it was a neutron interacting
- Comparing symmetric nuclei (tritium and helium-3)



More About Tagging

Why are the tagged processes special ?

- They are semi-inclusive hard processes (>GeV scale)
- In which we detect nuclear fragments (MeV scale)
  - **Selecting the optimal kinematics to isolate our process**
- They give unique information on the state of the nucleus right at the hard interaction



What do we use it for ?

- Select special configuration of the nucleus
- Can be very useful to understand nuclear effects
- Also to avoid nuclear effects and get quasi-free neutrons
  - **We want to tag a backward proton at the lowest possible energy**

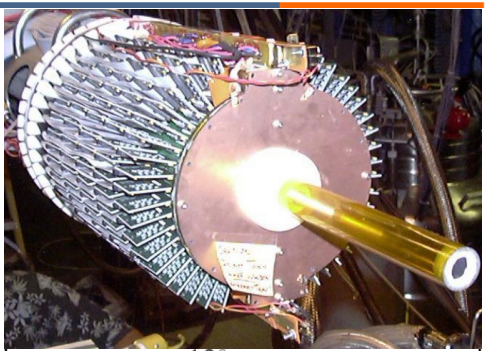
The Original Bonus Experiment

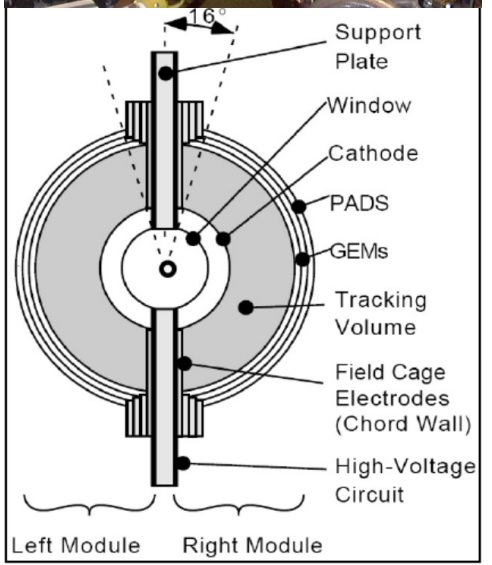
At JLab with the CLAS spectrometer

- Electron beam at 5.3 GeV and a large acceptance spectrometer
  - **But no way to measure protons below 200 MeV/c**

The BONUS detector

- A small radial TPC placed right around a gaseous deuterium target
- All materials kept to a minimum
- Capable to detect as low as 60 MeV/c protons





Tagging Nuclear Reactions

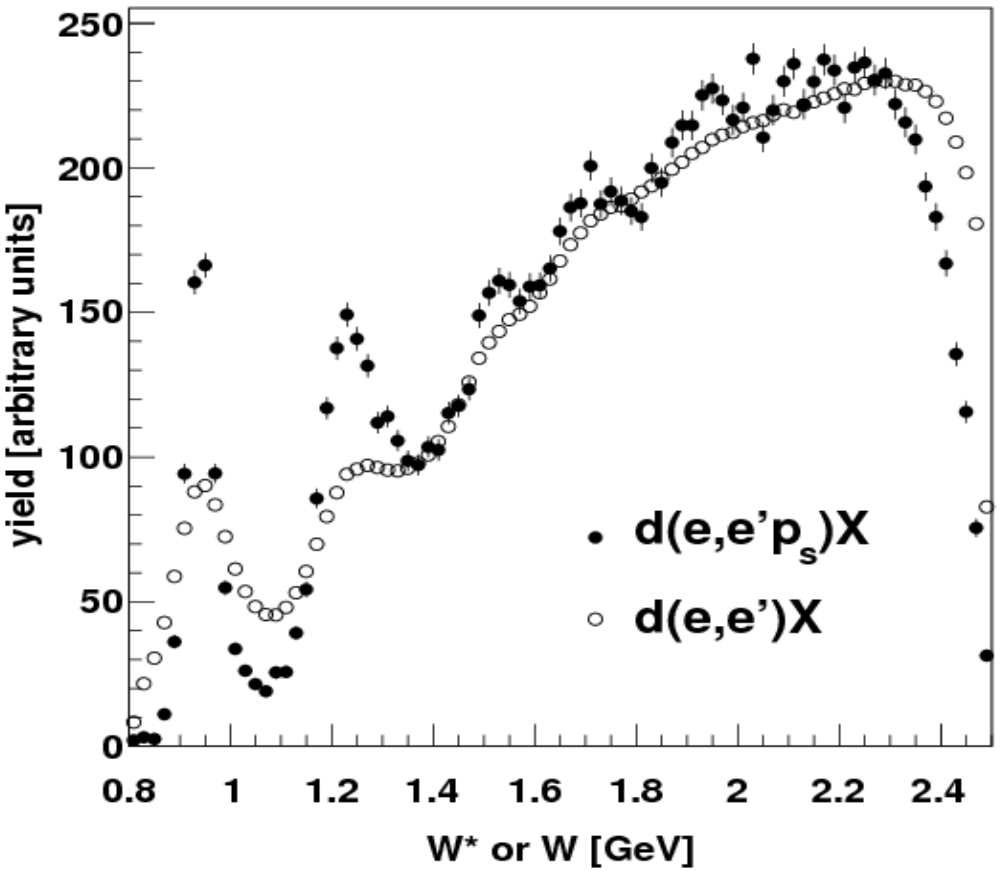
Does tagging actually works ?

- To control final state interaction
  - **To validate our calculations**
  - **Then to select ideal kinematics**

W. Cosyn and M. Sargsian, Phys. Rev. C84 (2011) 014601

- To control the initial state
  - **Access to the nucleon's kinematic**
  - **Access to the nucleon's virtuality**
  - **And correct for it !**

Yes !



Bonus Results

Measure of the neutron F2

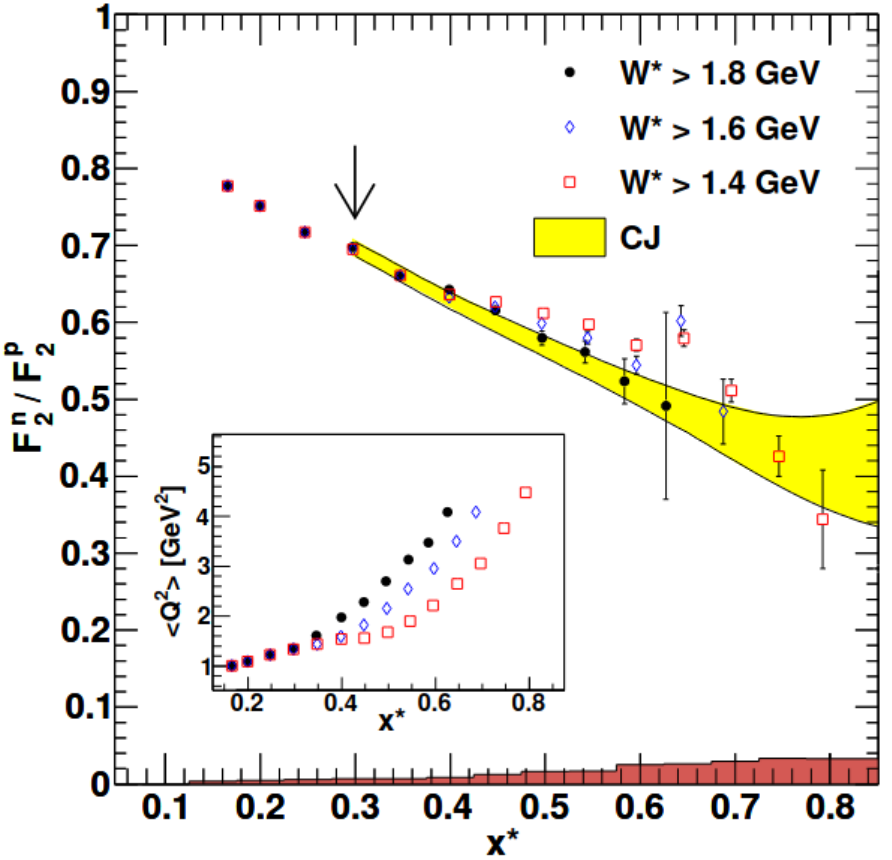
- As a fonction of x*
  - **Corrected for the proton kinematic**
- With pretty loose W* cut
  - **Due to a lack of data**

N. Baillie et al. CLAS Coll. Phys.Rev.Lett. 108 (2012) 142001

Contribution to PDF fits

- Unique data for PDF fits
  - **Free of nuclear effects**

A. Accardi et al. Phys.Rev.D 93 (2016) 11, 114017



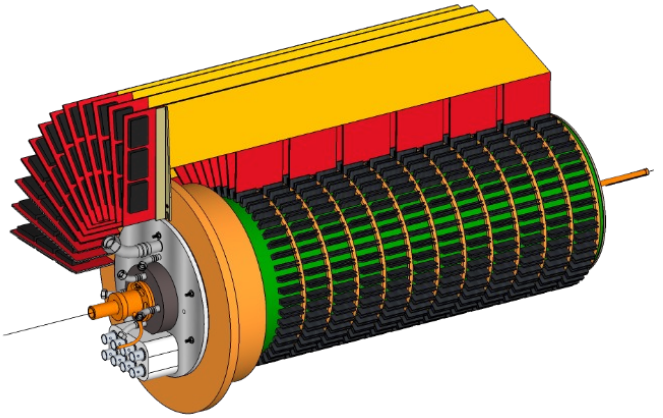
Going to Bonus12

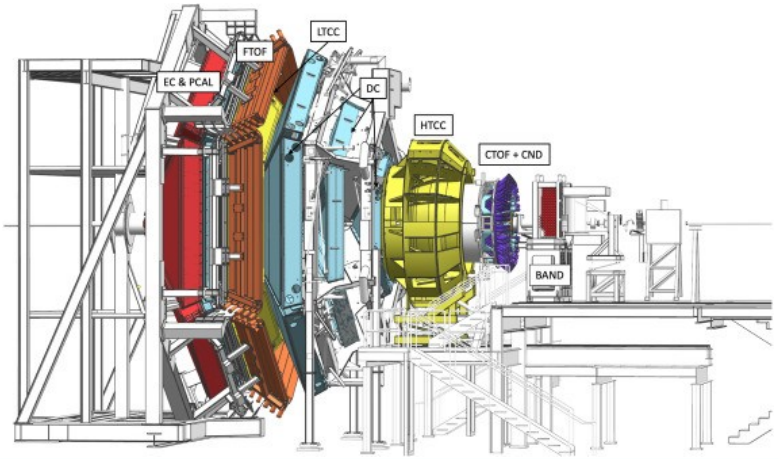
The same detector but better

- No more structure inside
  - **GEMs are self supported**
- Longer target and detector
- Faster electronics
  - **To get more statistics**

The same JLab but better

- A newly ugraded JLab and CLAS12





Running the Bonus12 experiment

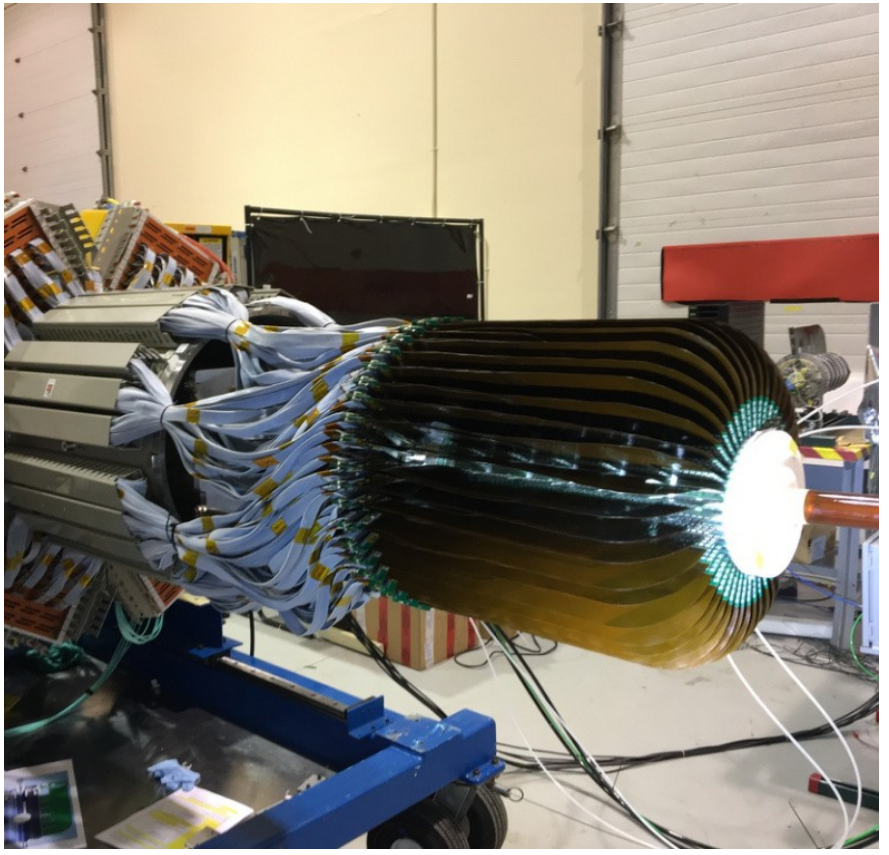
The experiment ran in 2020

- With a short pause in the middle
- Accumulated ~5B triggers

Data analysis is in progress

- Detector calibration is done
- Bonus specific reconstruction is now in place
- We are starting the extraction of the final observables

Sadly, no early pick at the data is available yet



Running the Bonus12 experiment

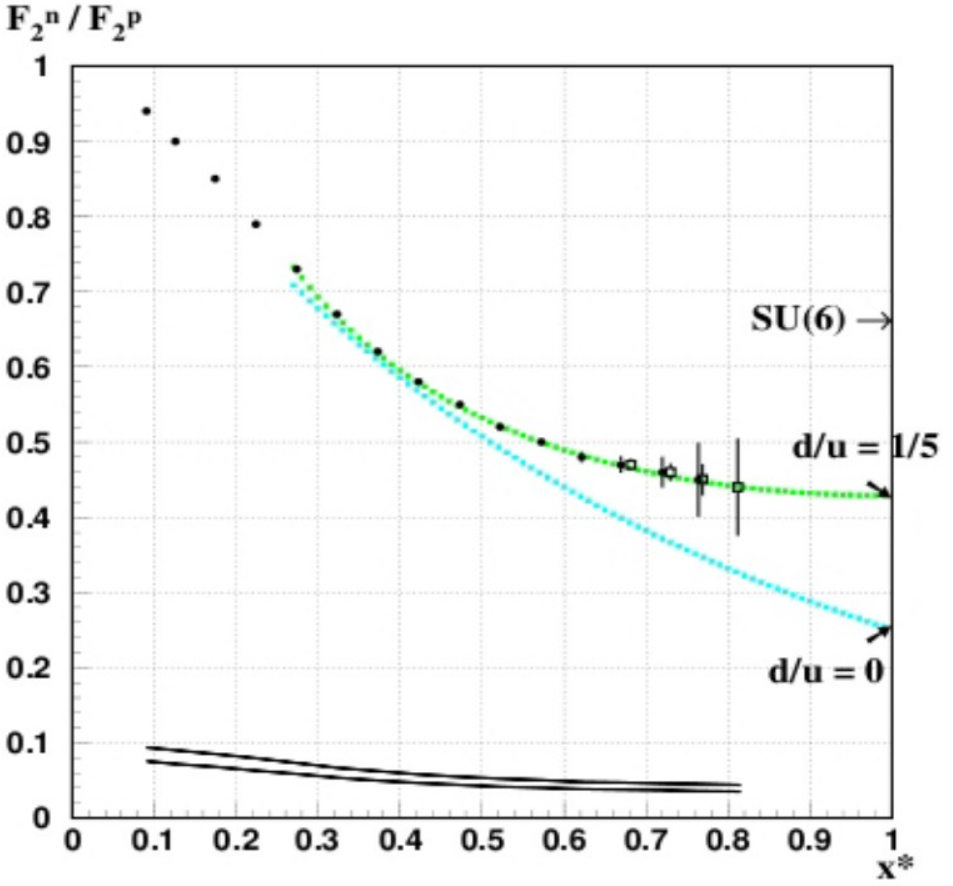
The experiment ran in 2020

- With a short pause in the middle
- Accumulated ~5B triggers

Data analysis is in progress

- Detector calibration is done
- Bonus specific reconstruction is now in place
- We are starting the extraction of the final observables

Sadly, no early pick at the data is available yet, only a projection



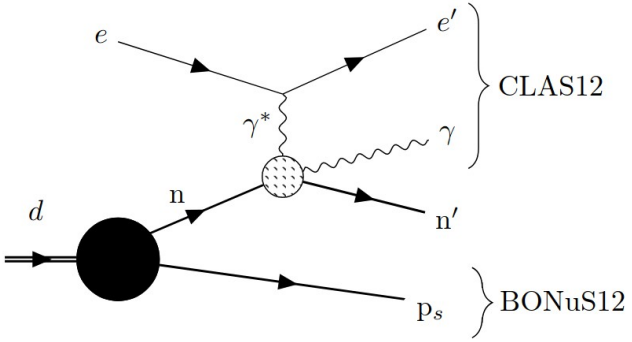
Can we tag other processes ?

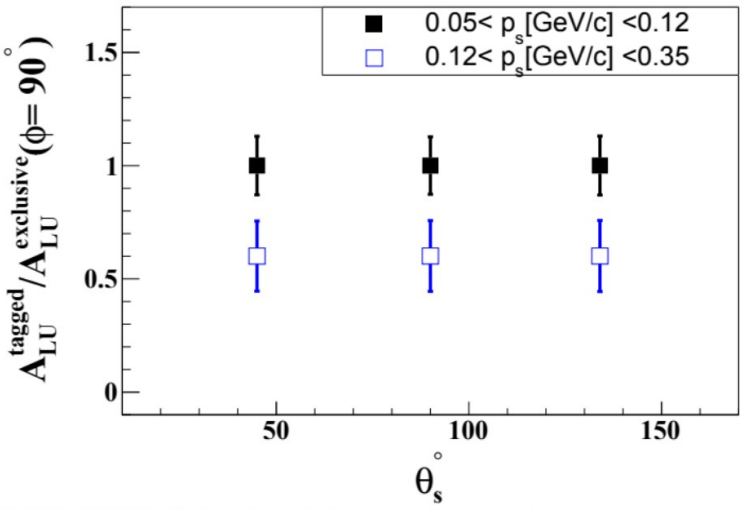
We can and we will !

- DVCS on neutron is also of interest
- It has been measured through D minus p
- It can also be detected in the final state
  - **Experiment with CLAS12**

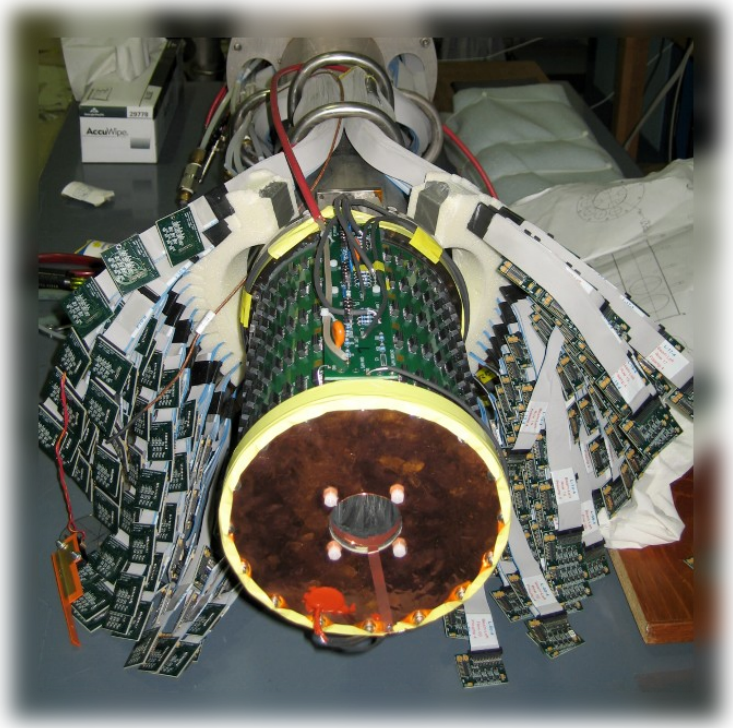
But tagging is the cleanest

- Accounts for all missing energies and momenta to check exclusivity
- Controls the nuclear effects
  - **Can those be large ?**





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 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

Incoherent Helium DVCS

Measurement with CLAS at Jefferson Lab

- Proton bound in helium target

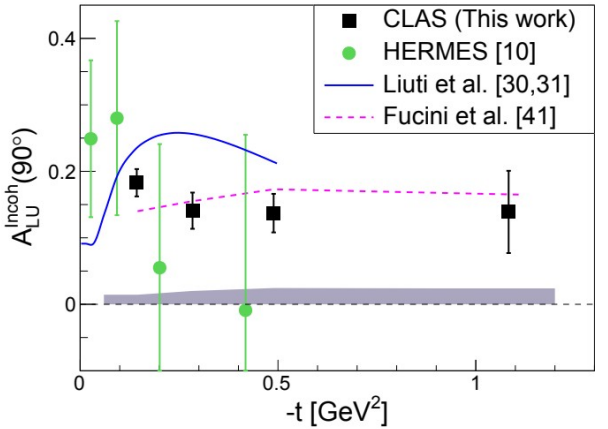
Gives a "generalized" EMC

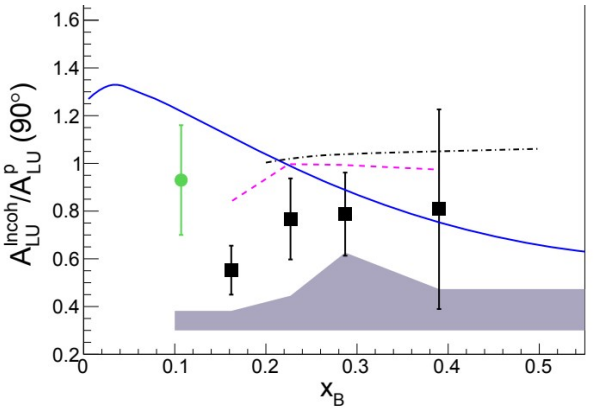
- Strongly suppressed
- Strange behavior compared to the models

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 tagging





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

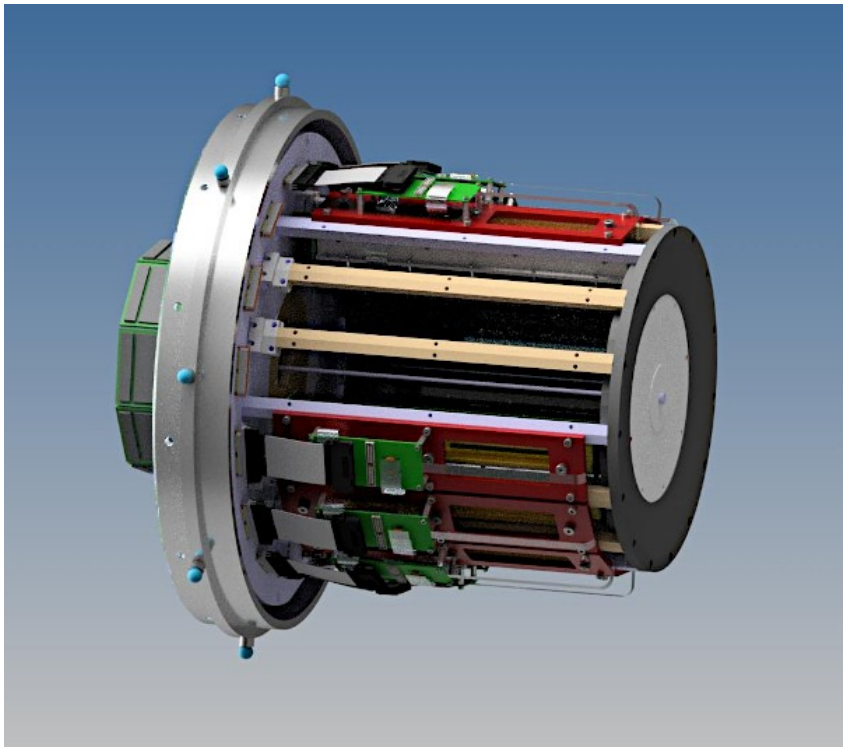
- Nuclear DVCS, DVMP...
- Tagged processes (detailed later)

Collaborative effort within CLAS12

- ANL, IJCLab, JLab, NMSU, Mississippi SU 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 July 2024

- Official soon I was told



Tagging to Access Offshellness

Tagging connects EMC to nucleon kinematics

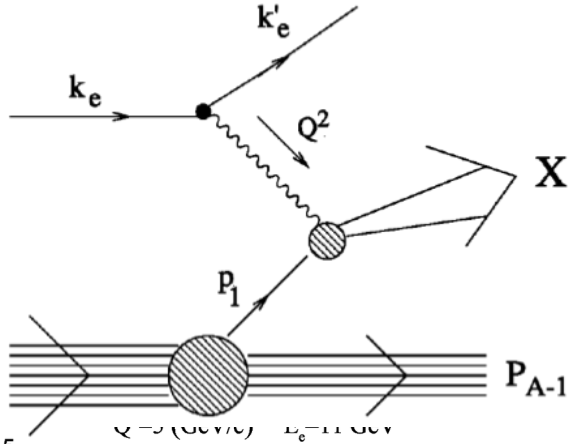
- Linked through virtuality of the nucleon
- Can differentiate mean field from SRC nucleons

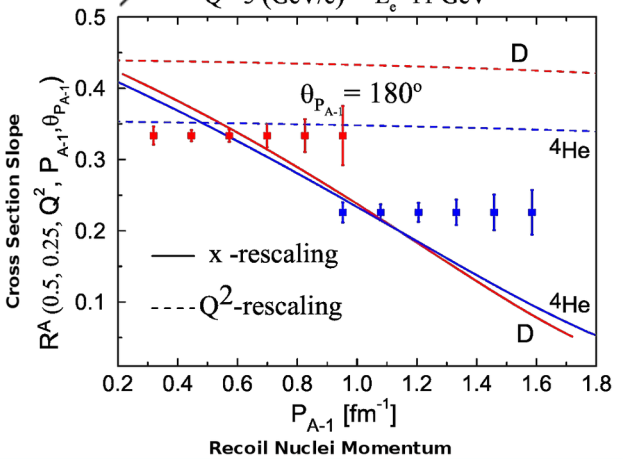
This will test models and more

- Comparison between deuterium and helium
- It unequivocally resolve the link between the EMC effect and nucleon momentum

Different nuclei

- Cover different momentum ranges
- Mean field vs SRC





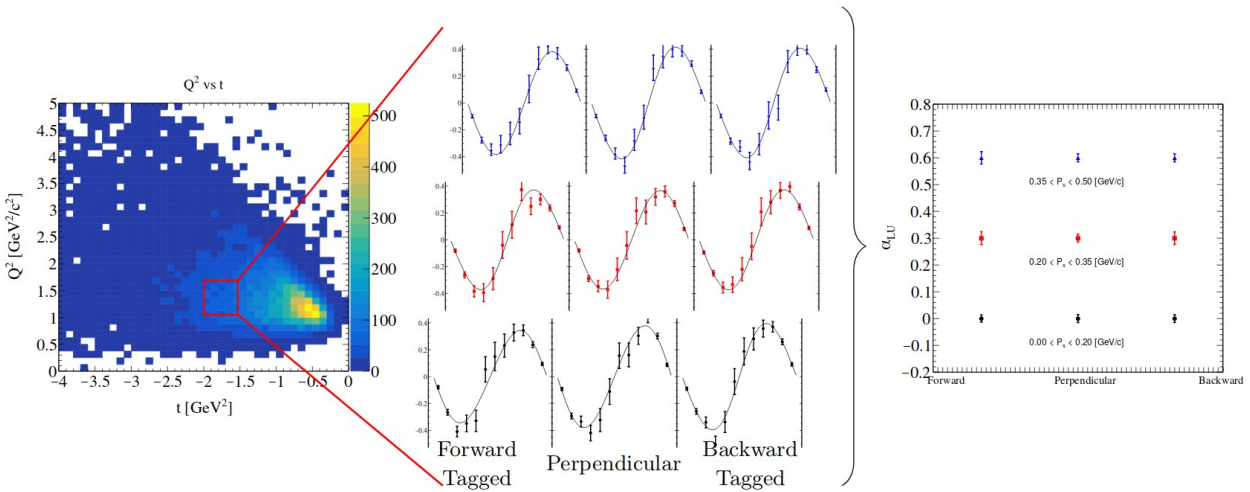
Understanding the Incoherent DVCS

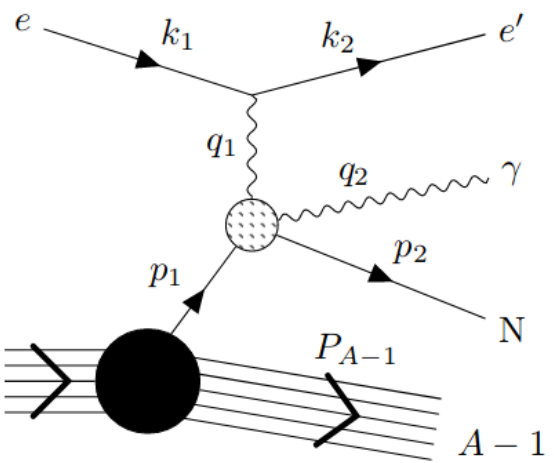
Tagging the incoherent DVCS

- A tagged measurement can pin down the origin of the strong BSA suppression in incoherent DVCS
- By better controling the initial and final states independently

Proposed for JLab 12 GeV

- This is probably an important addition for all incoherent processes in the future





Summary

Bonus experiments used tagging as an effective neutron target

- Demonstration that the process works well
- Bonus paved the way for many more tagging experiments
  - **The Bonus12 experiment is completed (including tagging DVCS on neutrons)**

Tagging can be used to understand nuclear effects

- BAND experiment presented earlier
- ALERT detector will be the next major experiment of tagging
  - **New results for low and intermediate momentum of protons out of D**
  - **Expend the tagging program to helium-4**

Farther in the future… EIC

- The importance of tagging in the EIC program is impressive