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Tagging at JLab and beyond

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-4

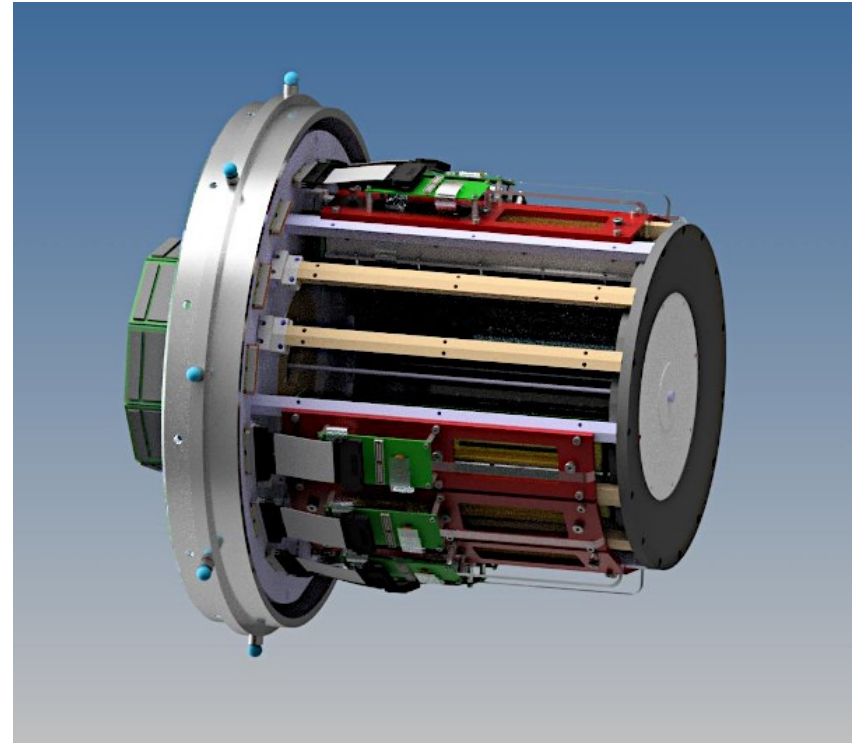
- Study bound nucleons (ALERT @ JLab)
- Study of EMC and SRC (ALERT @ JLab)

Heavy targets

- Centrality tagging, SRCs...

Important part of the EIC program !

- Based on very little actual experience



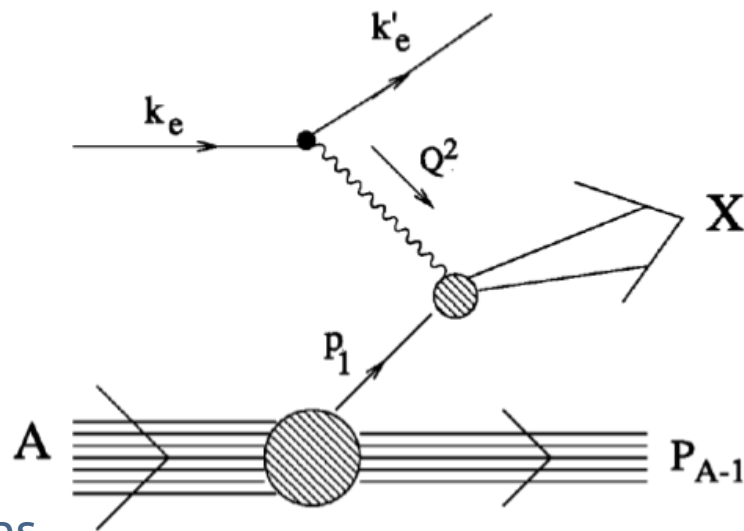
More About Tagging

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 ?

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



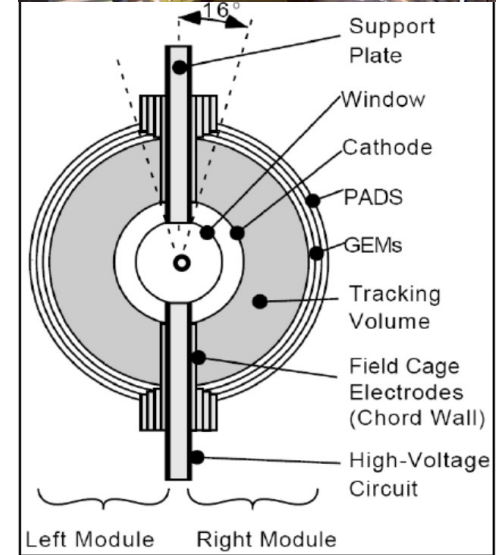
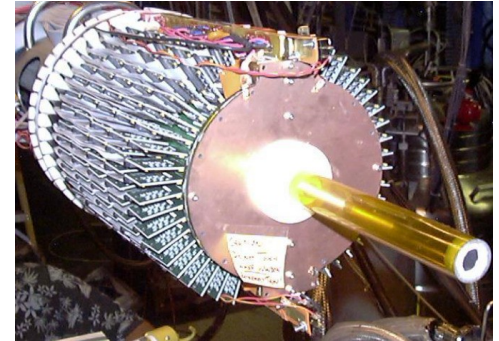
The Original Bonus Experiment

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

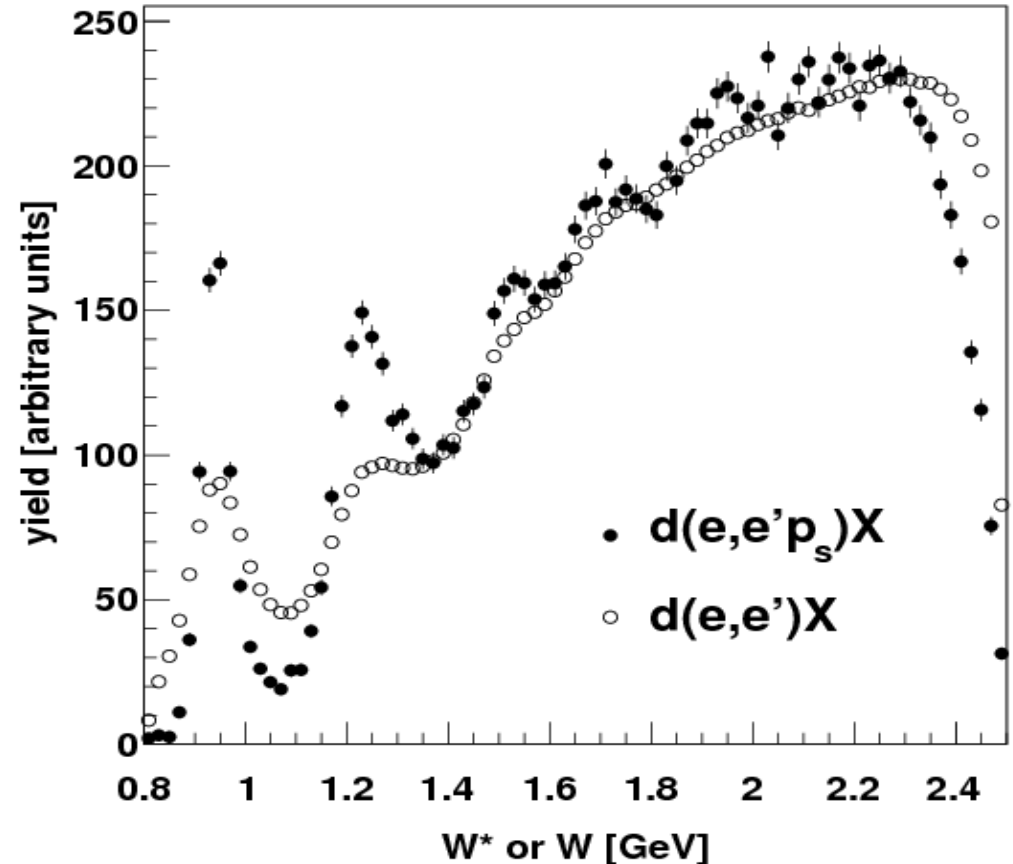


Tagging Nuclear Reactions

Does tagging actually work ?

- 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 F_2

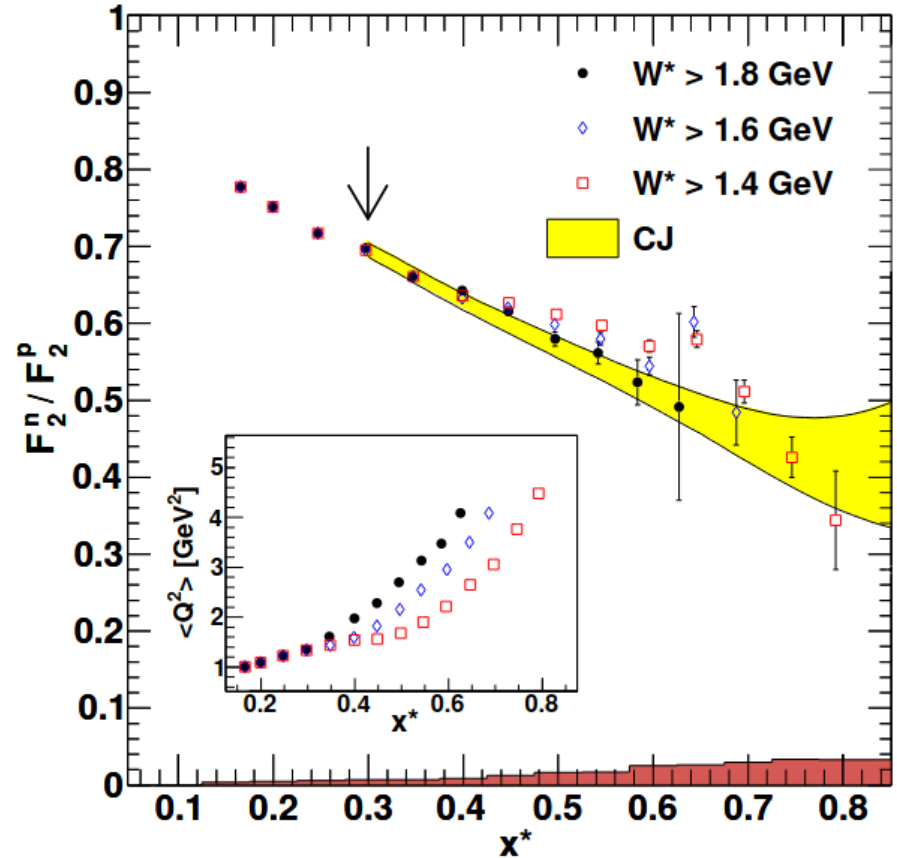
- As a function of x^*
 - Corrected for the proton kinematic
- With pretty loose W^* cut
 - Due to a lack of data

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

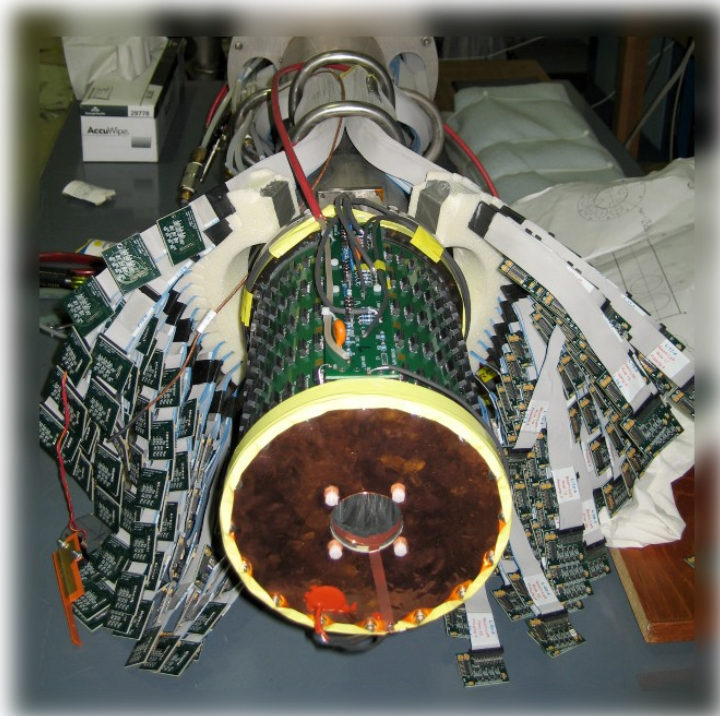
Contribution to PDF fits

- Unique data for PDF fits
 - Free of nuclear effects

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



A New RTPC for CLAS



RTPC can also be used for light nuclei

- They usually do not event make it out of the target...

How to handle that ?

- Use a light nuclei : Helium-4 for instance
- 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

Another CLAS +RTPC experiment ran in 2009

- Most of the scientific program was outside the topics of this workshop, but...



Incoherent Helium DVCS

Measurement with CLAS at Jefferson Lab

- Proton bound in helium target

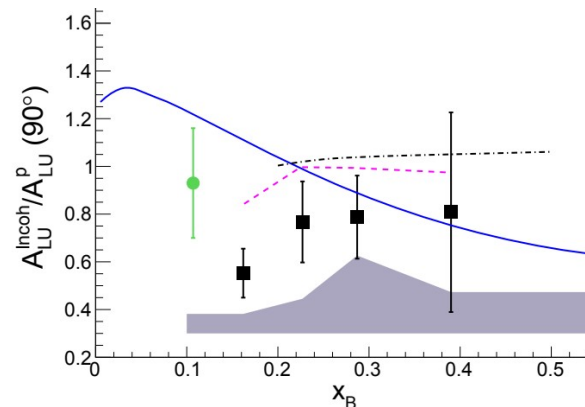
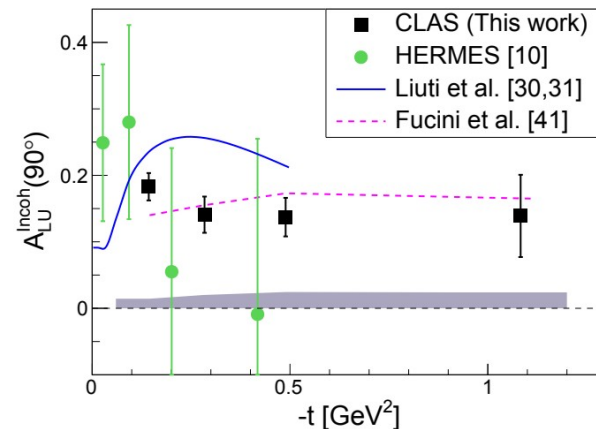
Gives a "generalized" EMC

- 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



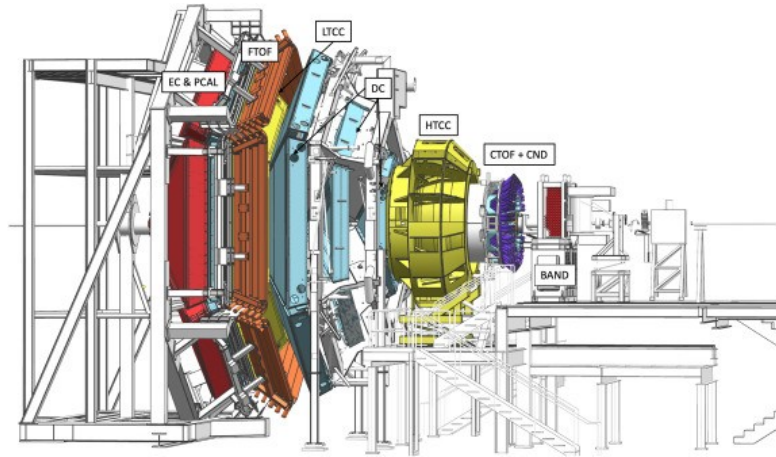
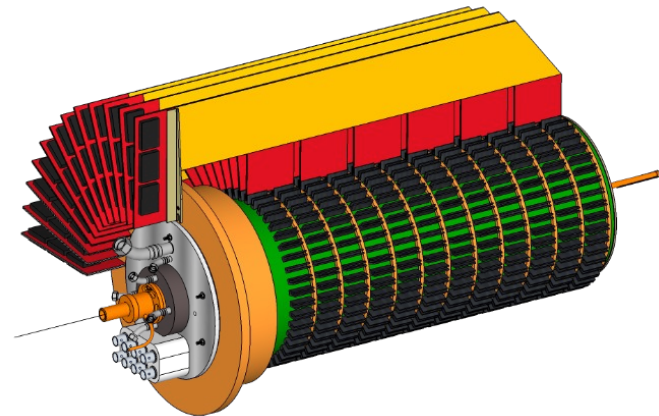
Going to Bonus12

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 upgraded JLab and CLAS12



Running the Bonus12 experiment

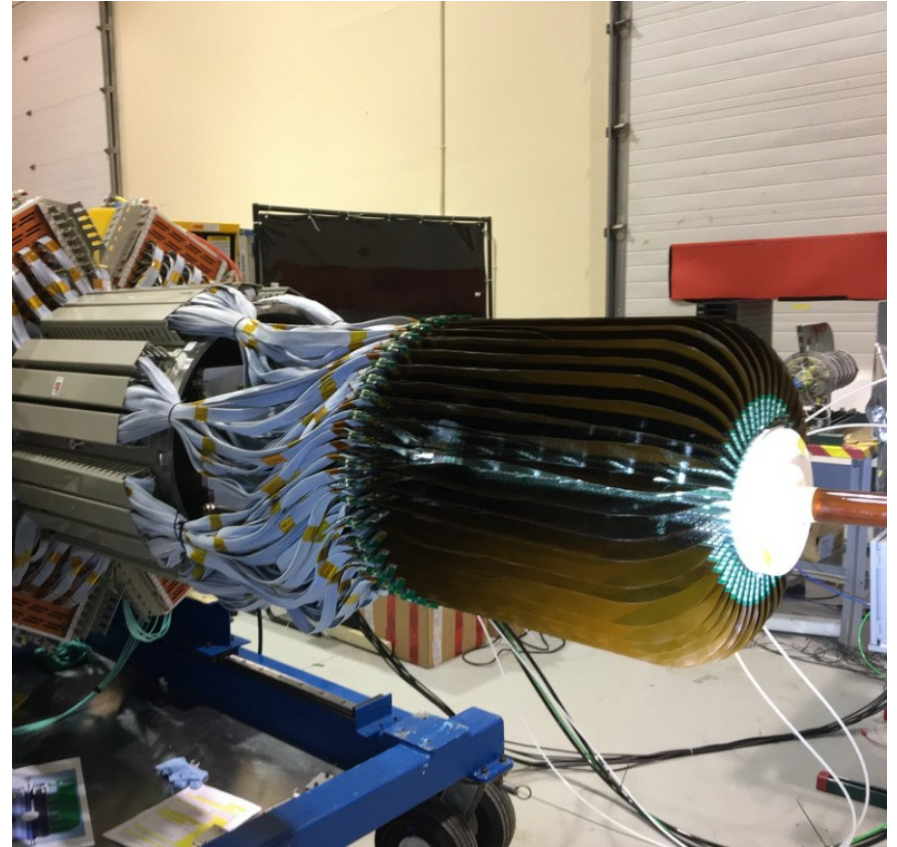
The experiment ran in 2020

- 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



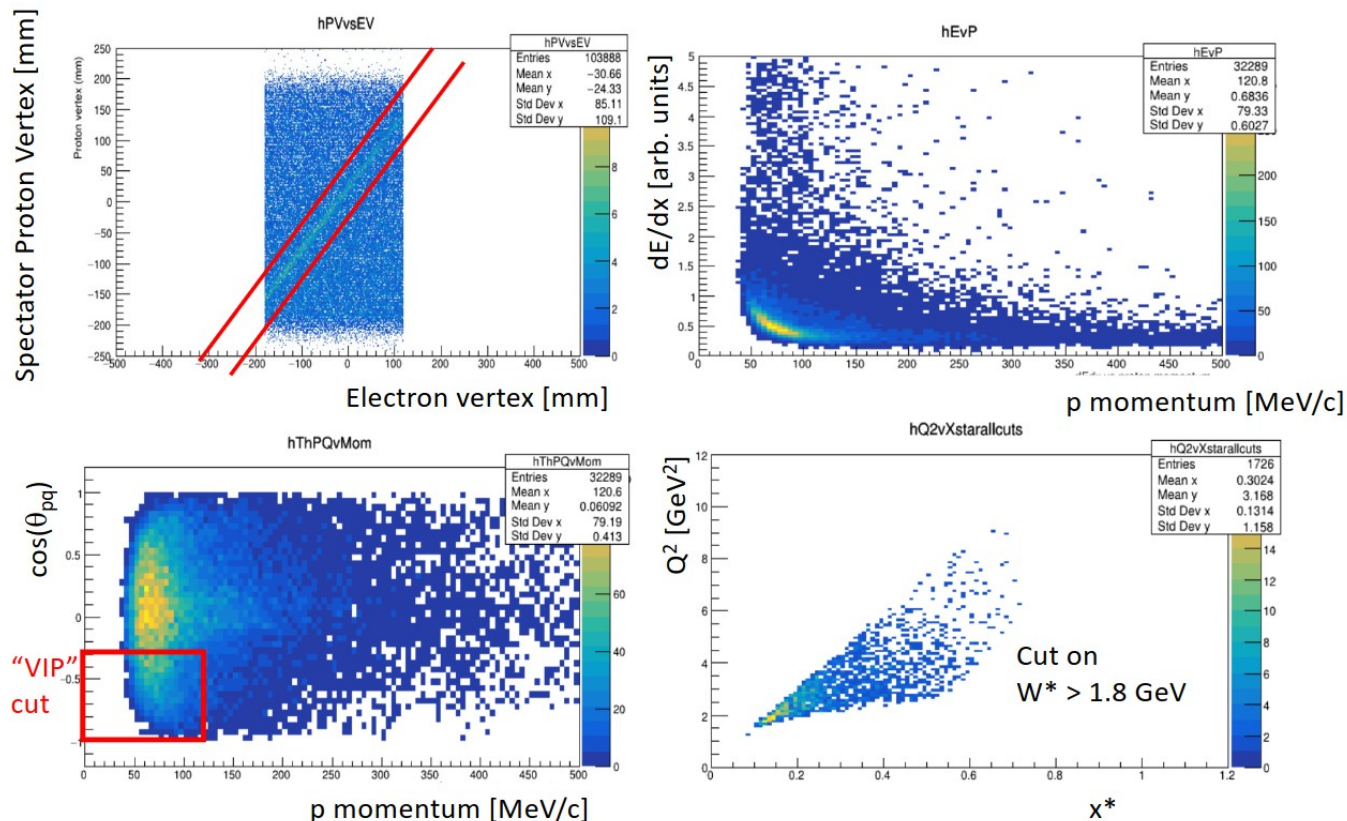
Running the Bonus12 experiment

The experiment ran in 2020

- In difficult conditions
- We accumulated $\sim 5\text{B}$ triggers

Data analysis is in progress

- See here a sample of the data at 10.4 GeV
- Illustrates the coverage we have



Can we tag other processes ?

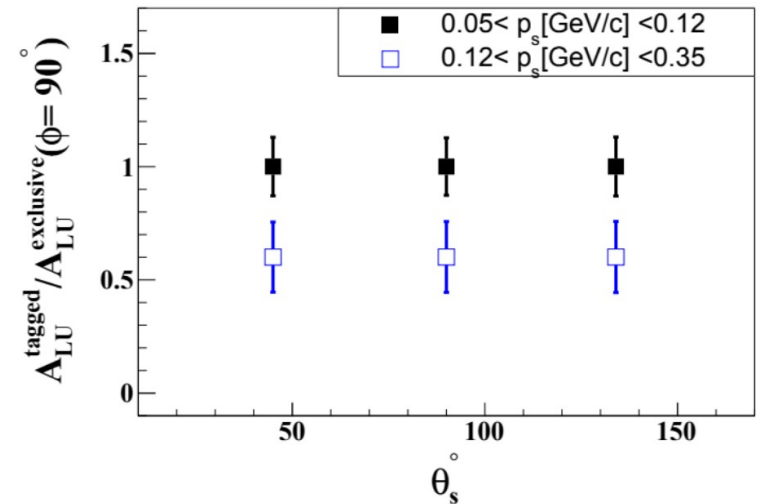
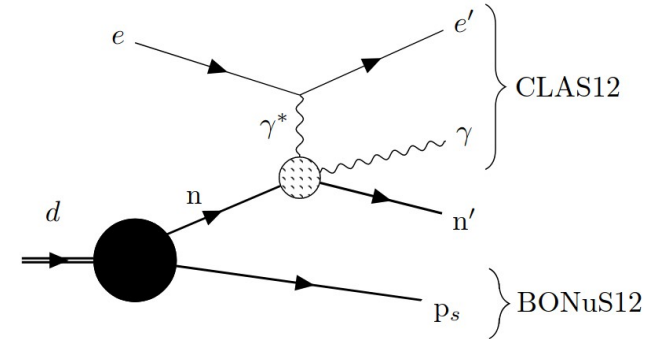
We can and we will !

- 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 ?

Talk from Mathieu yesterday



The ALERT Detector

Going beyond the RTPC !

- Capability to differentiate various light nuclei
- Handle higher luminosity

A Low Energy Recoil Tracker

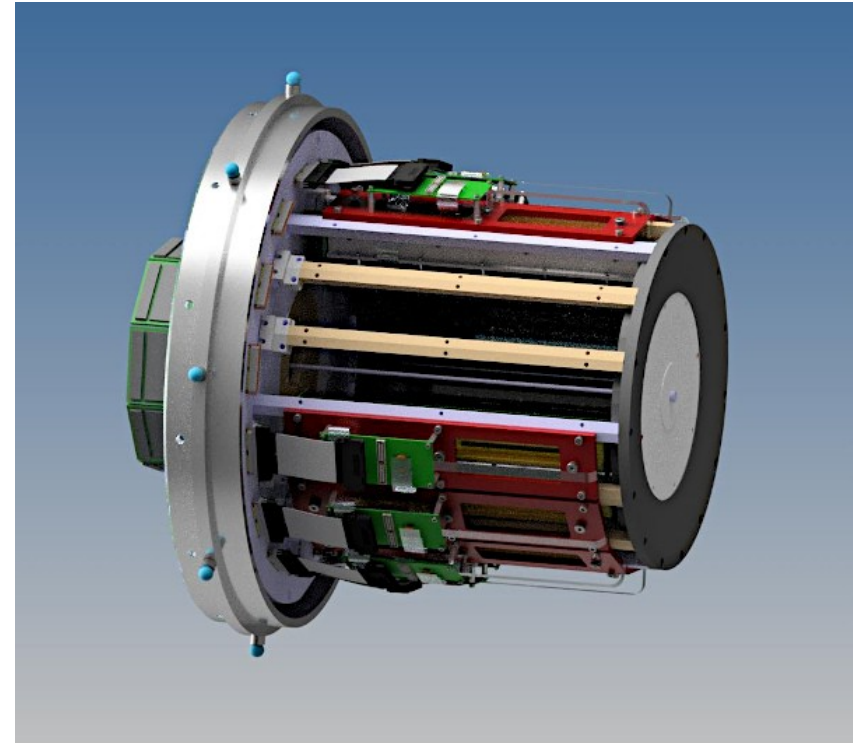
- Hyperbolic drift chamber
- Time-of-Flight array

Collaborative effort within CLAS12

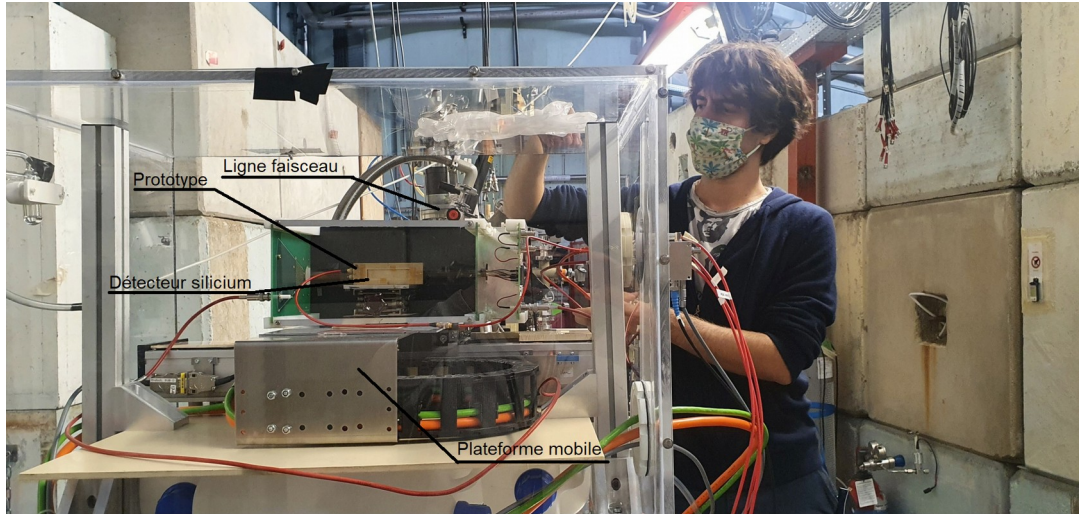
- ANL, IJCLab, JLab, NMSU, Mississippi SU, ODU and Temple
- We tested a prototype with a nuclear beam in the Fall at the ALTO facility (Orsay, France)

We are scheduled to take data in July 2024

- R&D and administrative approval were long processes
- Detector construction started, stringing starts in September !
- Plan to deliver to Jlab in Jan/Feb



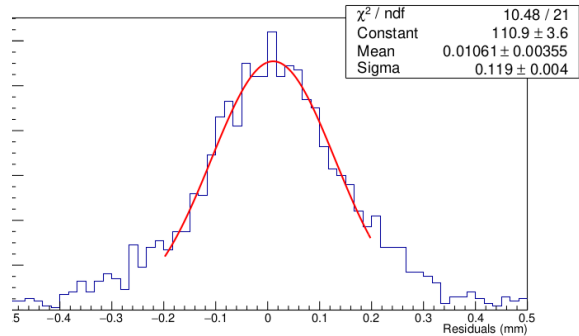
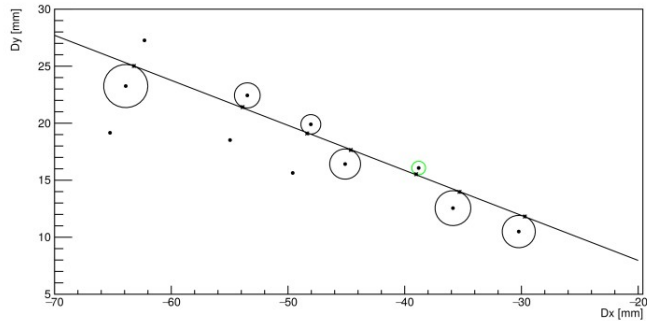
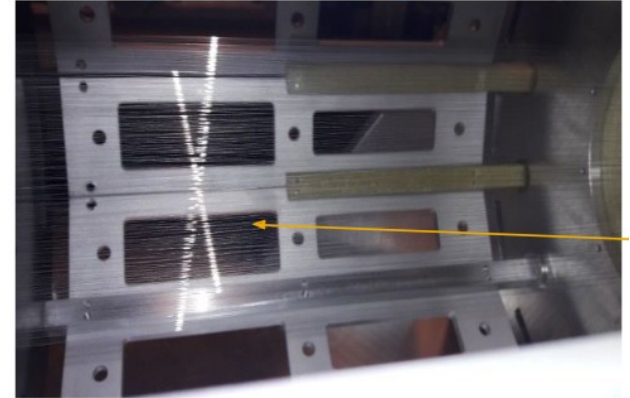
Many Prototypes of ALERT



2020



2023



July 20, 2023

R. Dupré – Tagged DIS Experiments

14/17

Tagging to Access Offshellness

Tagging connects EMC to nucleon kinematics

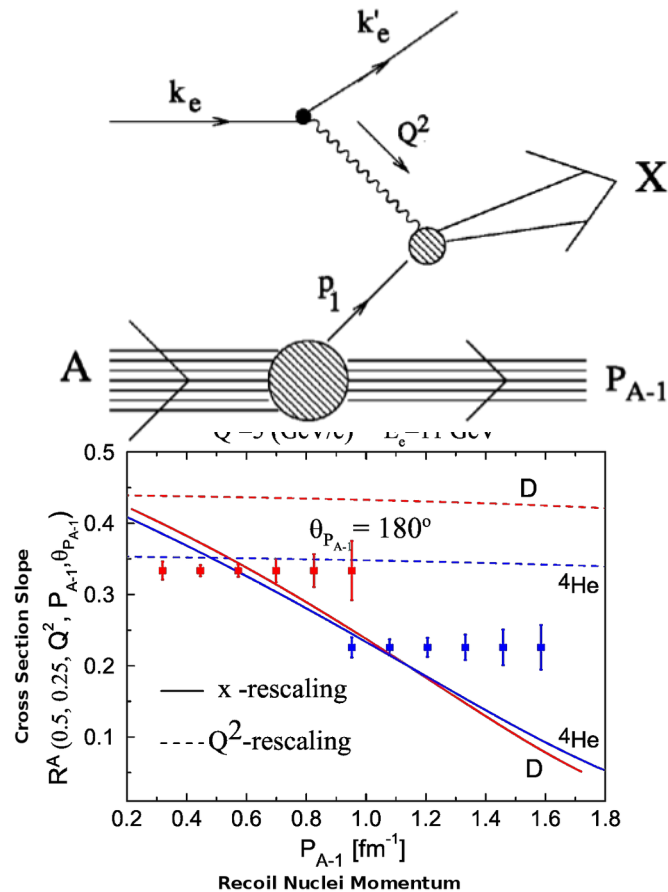
- Linked through virtuality of the nucleon
- Can differentiate mean field from SRC nucleons

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



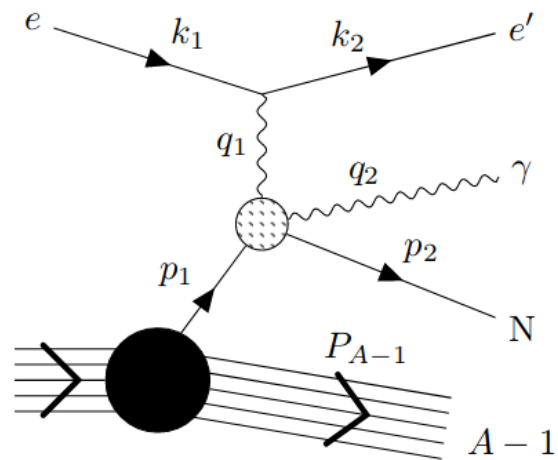
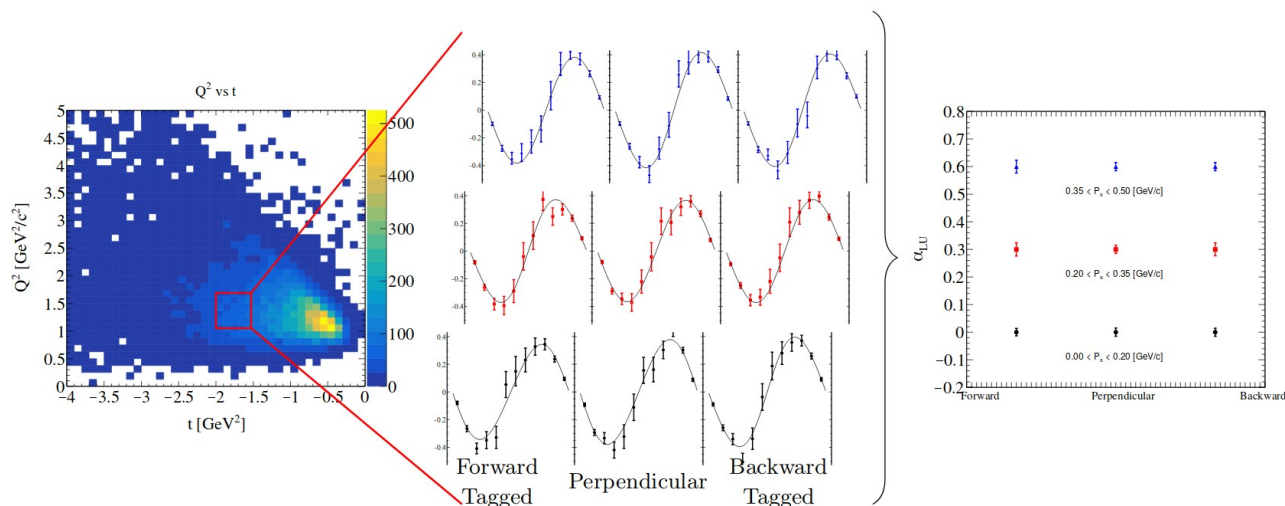
Understanding the Incoherent DVCS

Tagging the incoherent DVCS

- A tagged measurement can pin down the origin of the strong BSA suppression in incoherent DVCS
- By better controlling 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

- ALERT detector will be the next major experiment of tagging
 - New results for low and intermediate momentum of protons out of D
 - Expand the tagging program to helium-4
- Construction is in progress at Orsay and Argonne
 - Scheduled to start running the (whole?) second half of 2024

Farther in the future... EIC

- The importance of tagging in the EIC program is impressive

