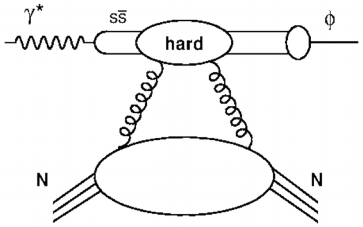
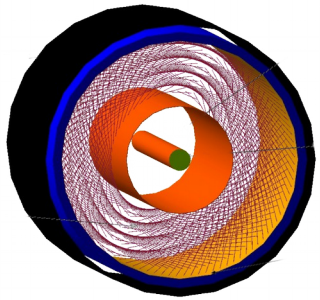
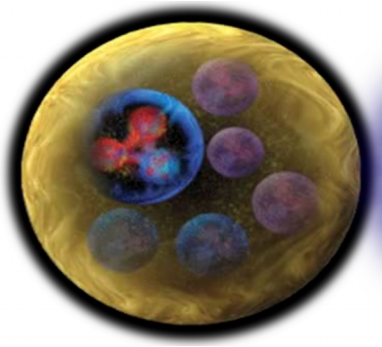
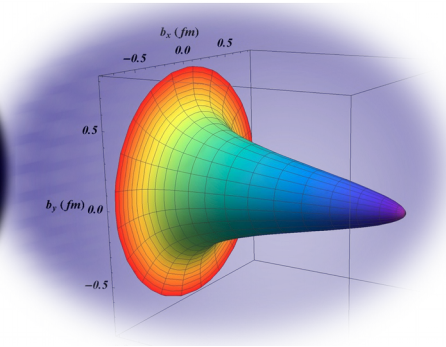
Nuclear partonic structure from breakup measurements A >= 2









Exploring nuclear effects and neutron structure

Raphaël Dupré

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

université PARIS-SACLAY

erc European Research Council Established by the European Commission

Tagging 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**
  - *Understudy for JLab and EIC*

Helium-4

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

Heavy targets

- **Centrality tagging**

Tagging Nuclear Reactions

Tagged processes

- When we detect nuclear fragments in coincidence
- Mix classic nuclear physics with quark level observables

Why tagging?

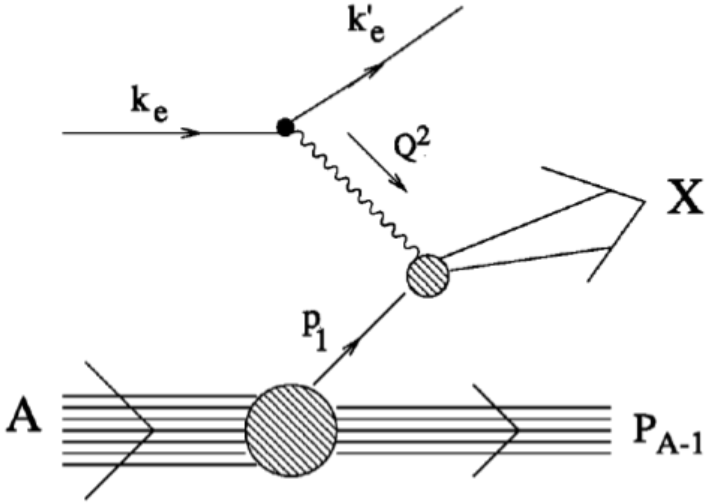
- To control final state interaction
- To control the initial state
  - *Access to the nucleon's virtuality*

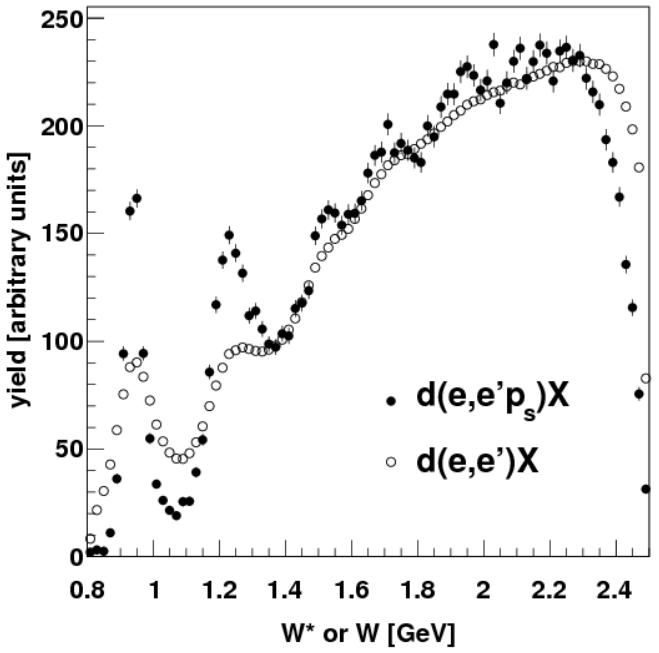
Can we do tagging?

- Done only for deuterium
  - *Bonus measurement from CLAS*
- Need a recoil detector (fixed target)

  → ALERT
- Or a forward detector (collider)

  → EIC





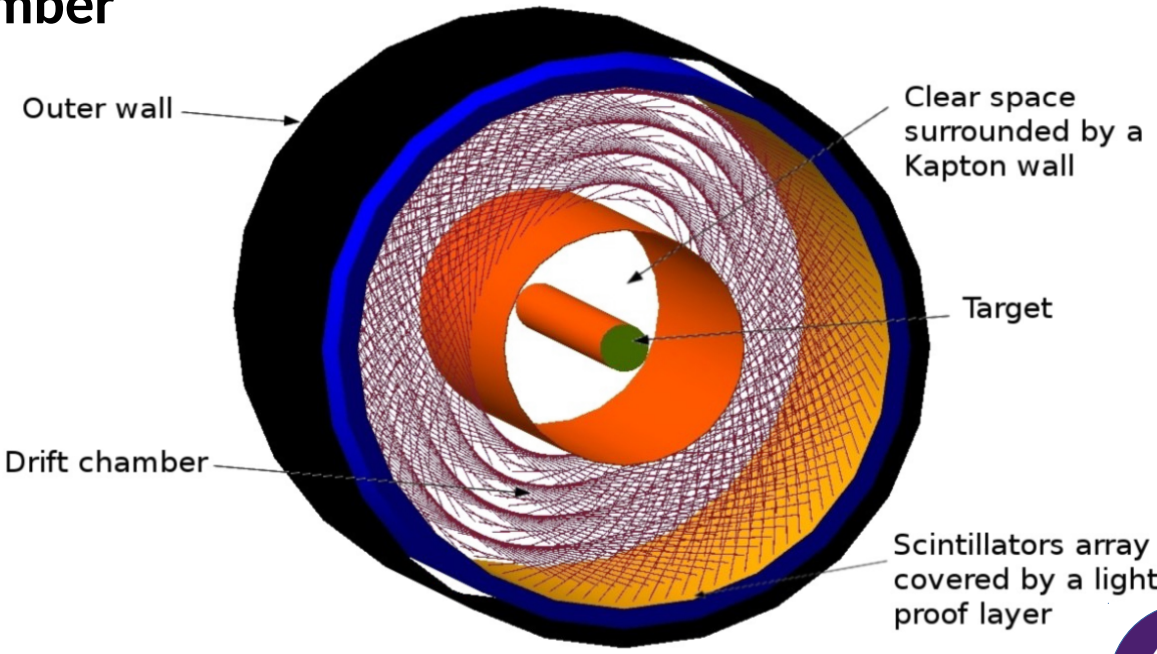
Tagging at JLab with ALERT

A Low Energy Recoil Tracker

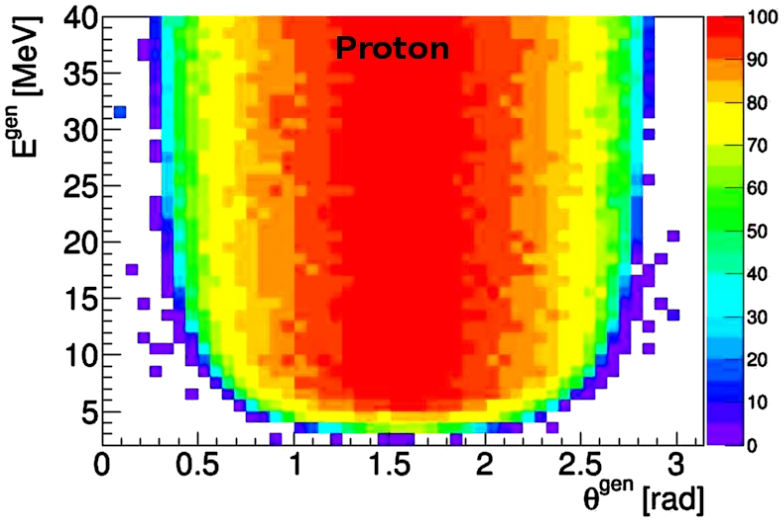
- **Optimized for low momentum measurement**
- **Placed in the center of CLAS12 (Hall-B)**
- **Around a thin gaseous target**

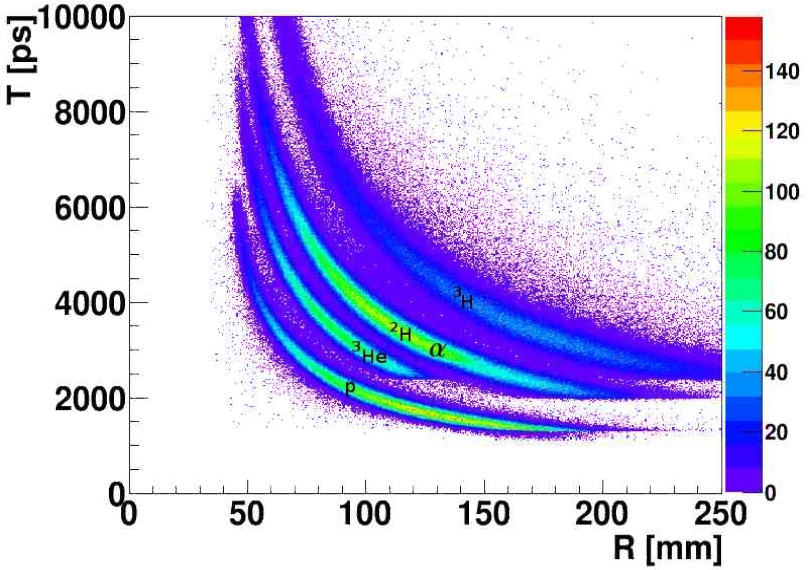
Composed of

- **An hyperbolic drift chamber**
  - *Stereo angles give the z-axis resolution*
- **Scintillators**
  - *For Time-of-Flight measurement*
  - *Energy measurement for good PID*



ALERT specifications





Capabilities for very low momentum detection

- As low as 70 MeV/c for protons and 240 MeV/c for 4He
- Detection at large angles in forward and backward directions (25° from the beam)

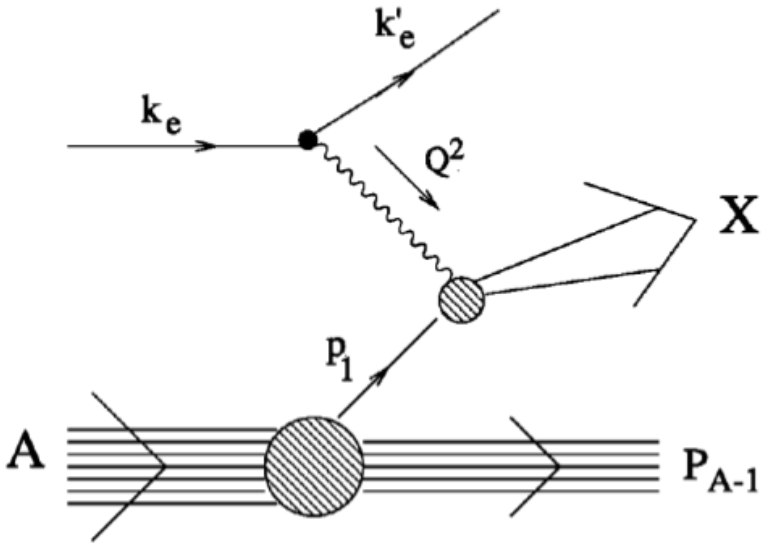
Capabilities to handle high rates

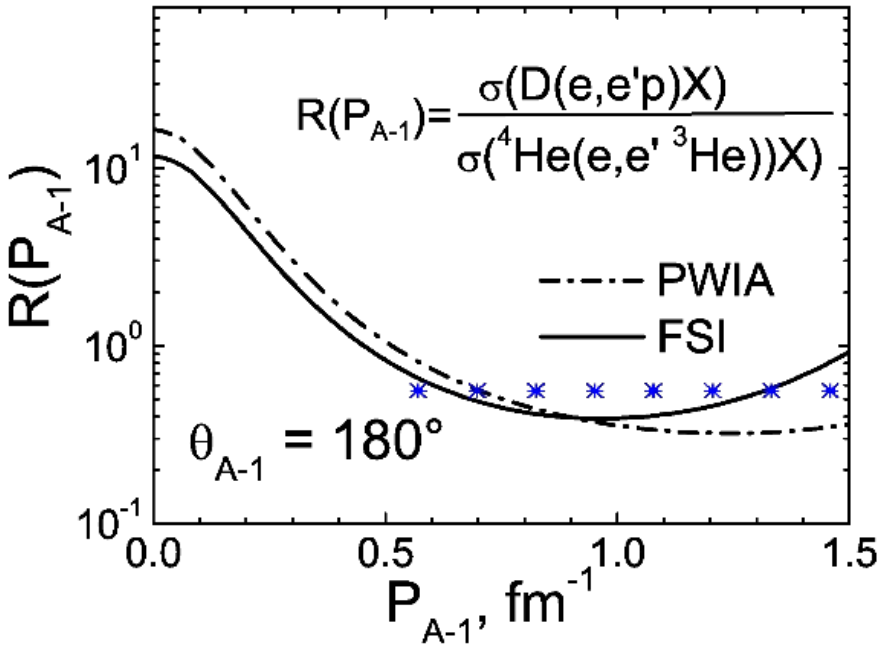
- Luminosity up to 10^{35} $cm^{-2}s^{-1}$

Excellent PID and resolution

- Can identify isotopes of light nuclei precisely
- The only way to go beyond A = 2

Testing tagging models





Not sexy, but necessary

- First, test that the theory is under control
- CLAS12 + ALERT give a large momentum and angle range to test

First test of the process for A>2

- It is key to generalize the method beyond deuterium
- Allows to access higher Fermi momentum and to generalize any finding

Link EMC effect to nucleon momentum

Tagging links EMC to nucleon kinematics

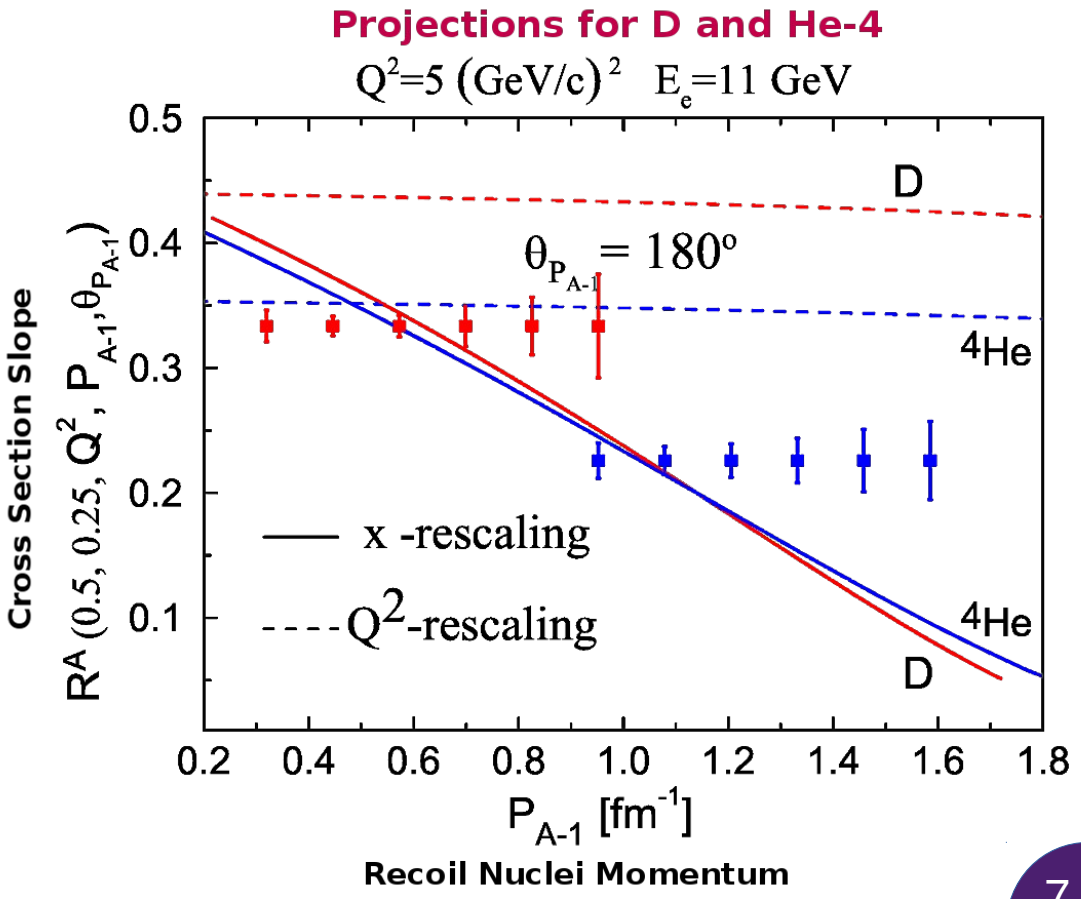
- Linked to virtuality
- Differentiate mean field from SRC

Test models and more

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

Different nuclei

- Cover different momentum ranges
- Mean field vs SRC



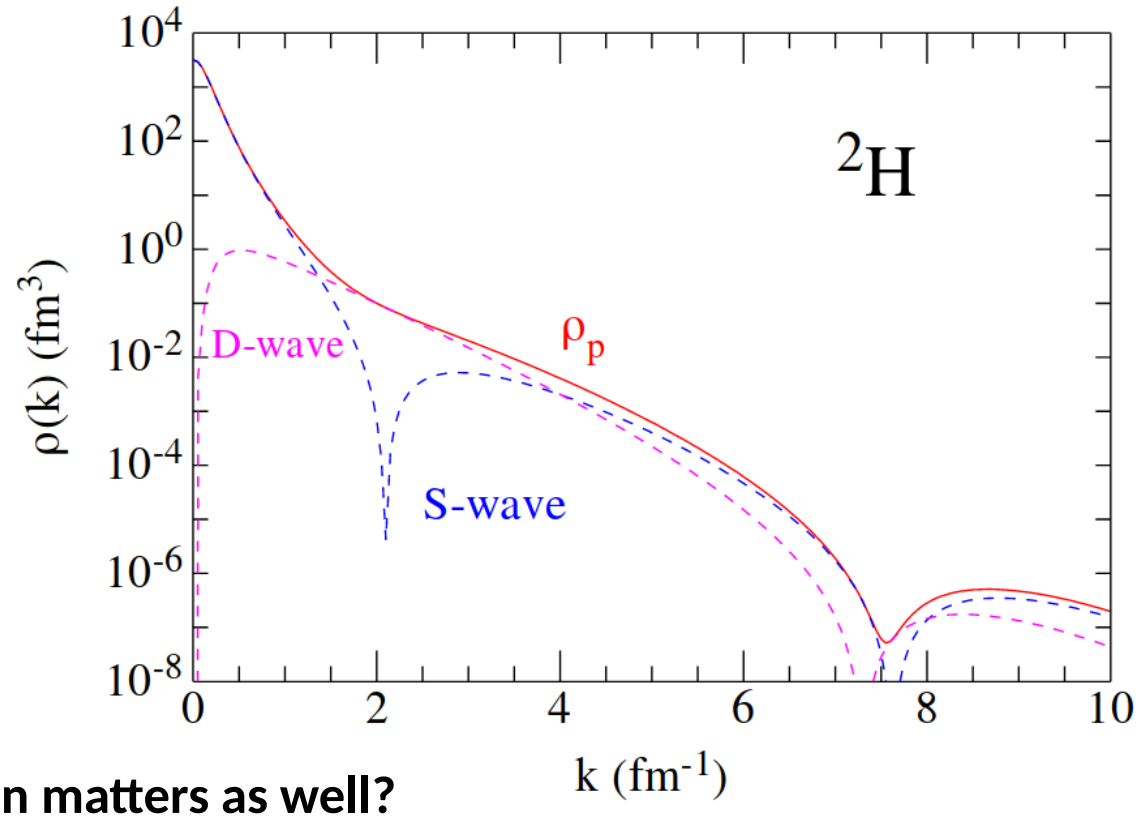
Mean field nucleon vs SRC nucleons

How to set a limit?

- Different arguments can be made
- It will be nuclei dependent

How relevant is this limit?

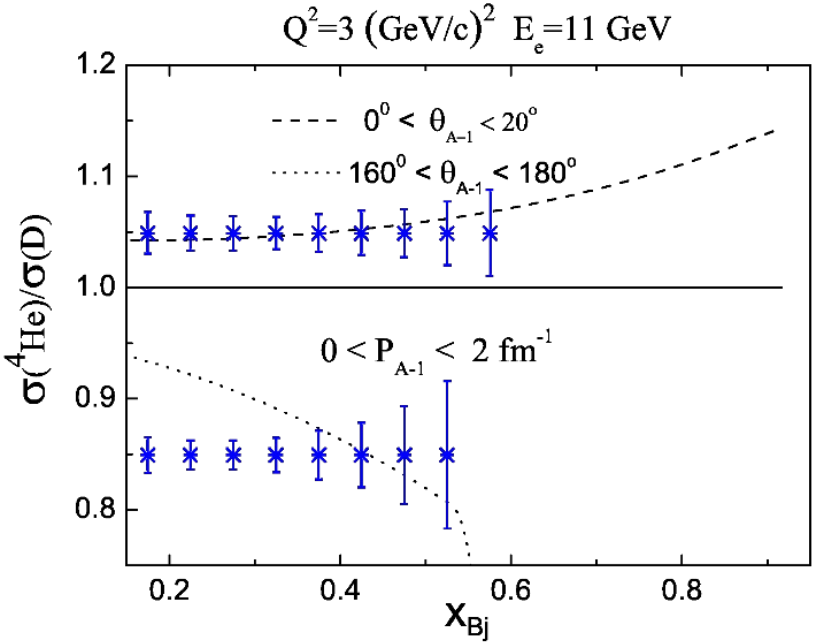
- Does only momentum or virtuality matters?
- Or the nucleon correlation matters as well?
  - *If yes in what direction?*

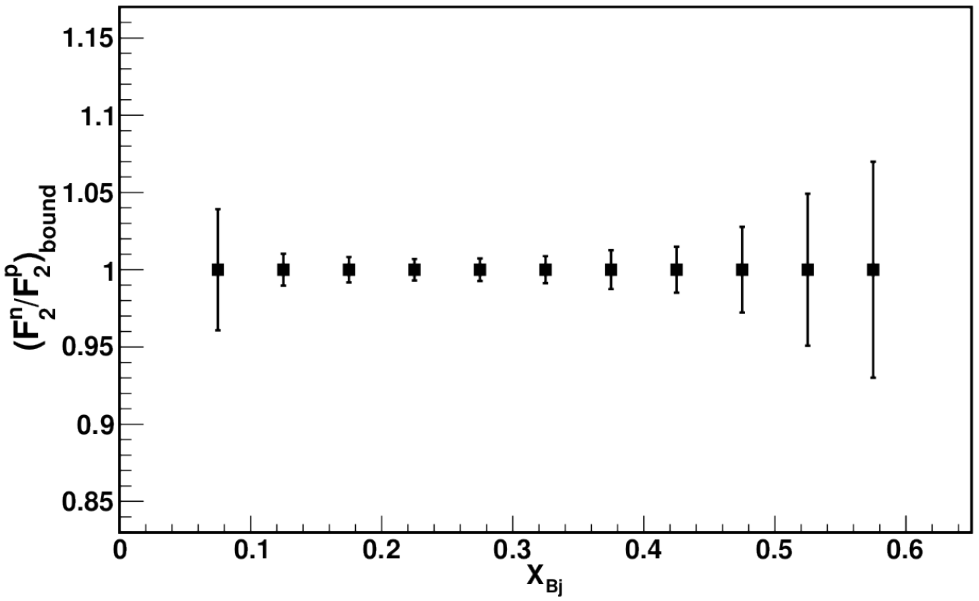


How can we resolve these questions?

- Tagged processes (A-1 tagging mainly here)
- Generalized parton distributions

Other opportunities with tagging





Tagged DIS gives many other opportunities to test specific EMC models

- In some binding models, the EMC effect is due to the cancellation of much larger effects
- These can be tested with spectator detection

Tagged DIS can also be used for flavor selection

- We can test how the d/u ratio changes in the nuclear medium

GPDs & Nuclei

Generalizing the parton distributions

- Three dimensions: x, ξ and t
- Spin-0 → 1 GPD // Spin-1/2 → 4 GPDs

Deep virtual Compton scattering

- The simplest access to GPDs
- Allows the tomography of the target

In the nucleus

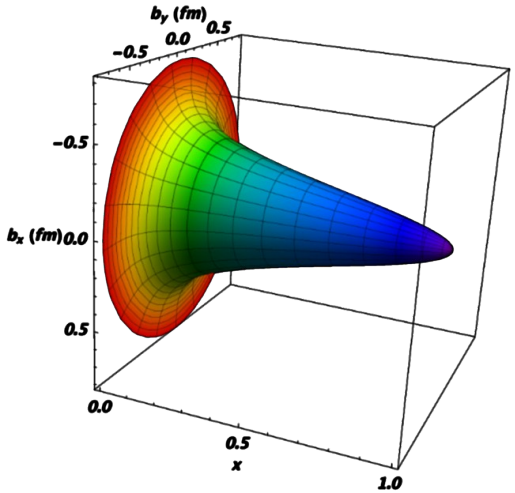
- Coherent and incoherent channels
  - *Similar to elastic and quasi-elastic*

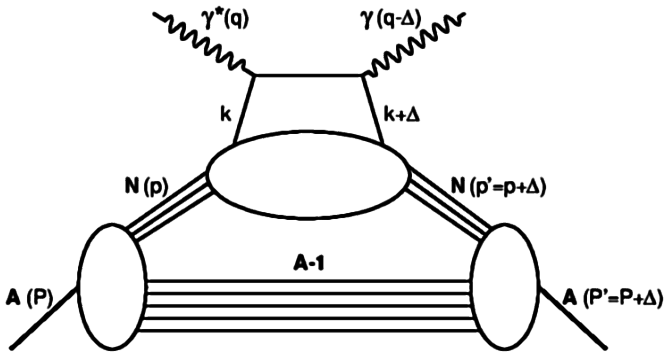
Perfect probe into the EMC effect

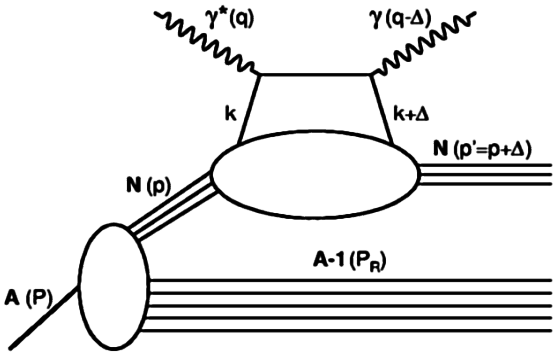
- Offer localization with the t dependence

Goes much beyond

- Can look at the nuclei without the nucleons







CLAS Incoherent DVCS

Measurement of CLAS

- Proton bound in helium target

Gives a generalized EMC

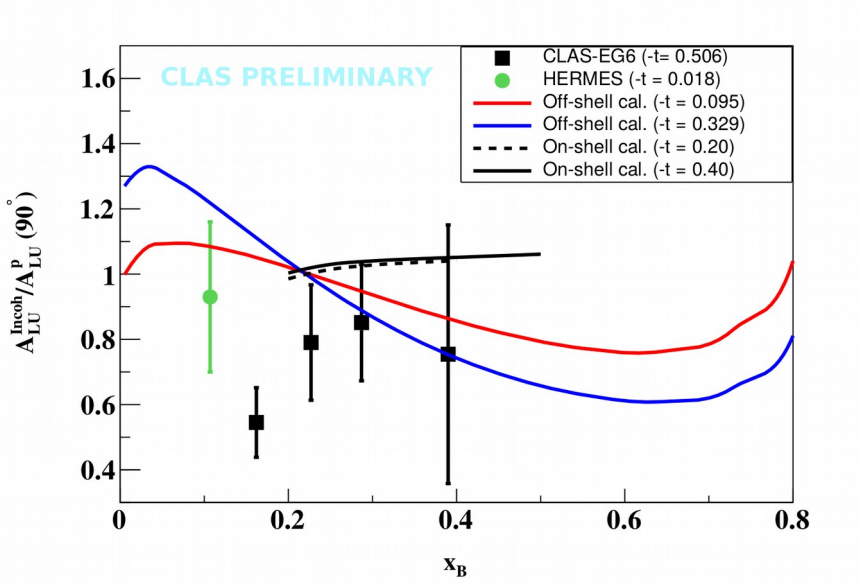
- Strongly suppressed in particular in the anti-shadowing region
- Strange behavior compared to the models

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*

Can we resolve this with tagging?

- We will try using ALERT



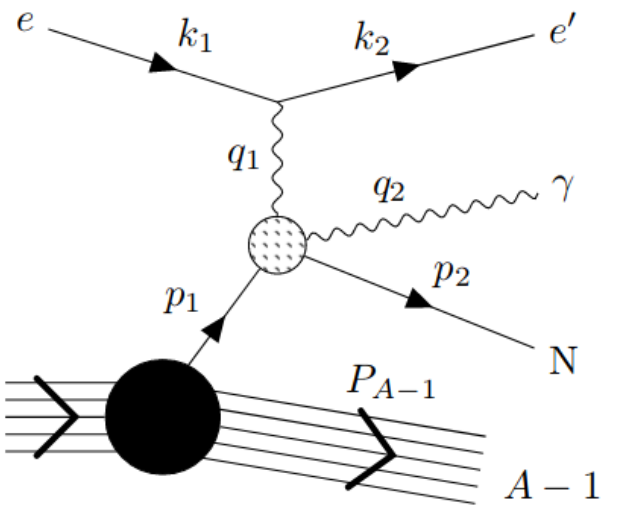
Tagged DVCS

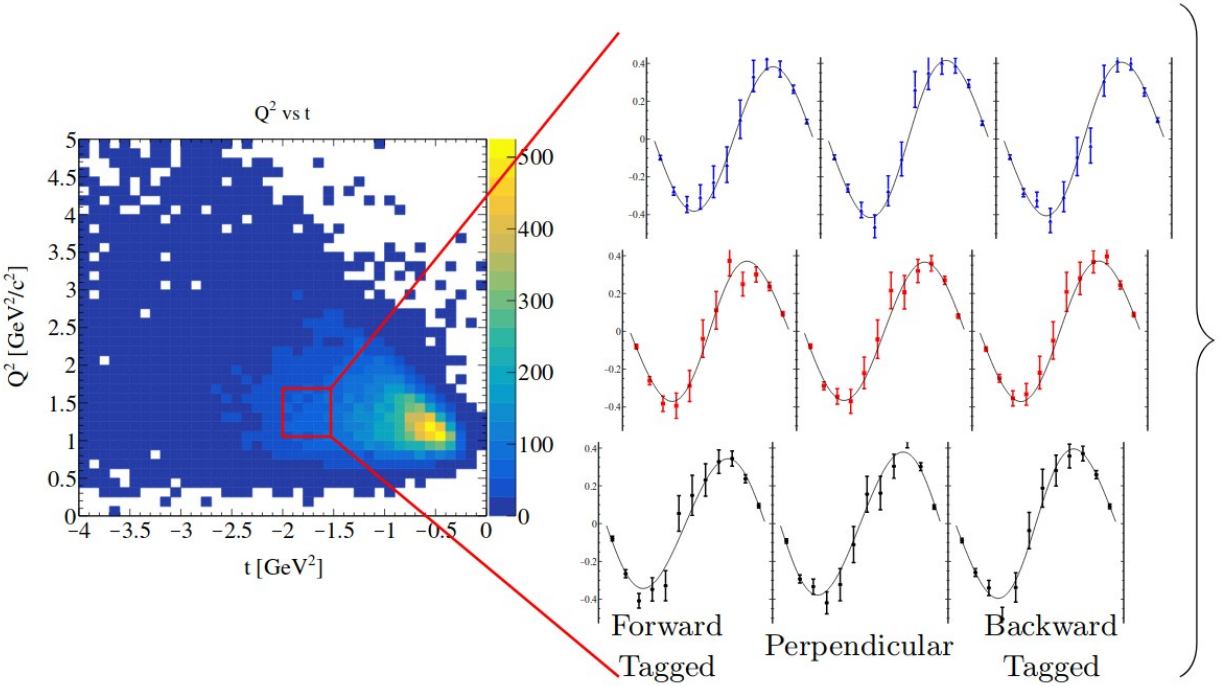
Tagging DVCS

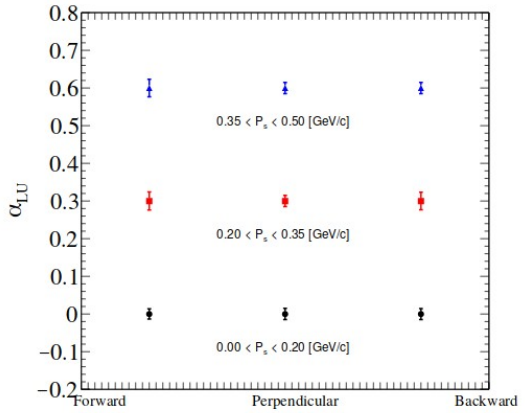
- To better control the reaction
- Both initial and final state are better under control

Proposed for JLab 12 GeV

- Similar method can be used for all sort of processes, quasi-elastic etc.







Tagged Neutron DVCS

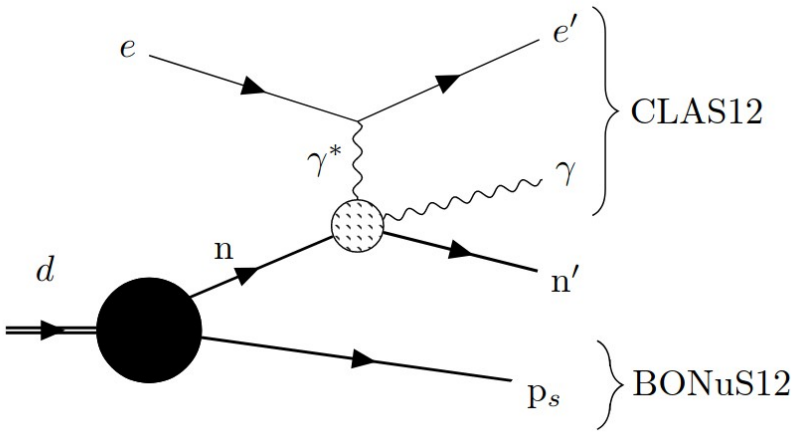
In parallel to Bonus 12

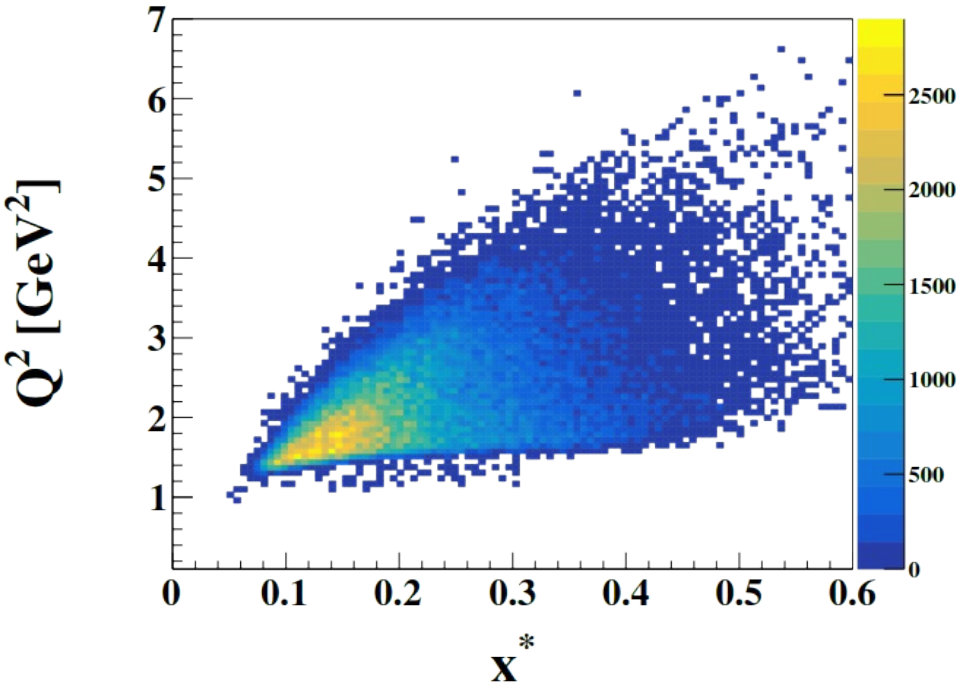
- Start running in two weeks

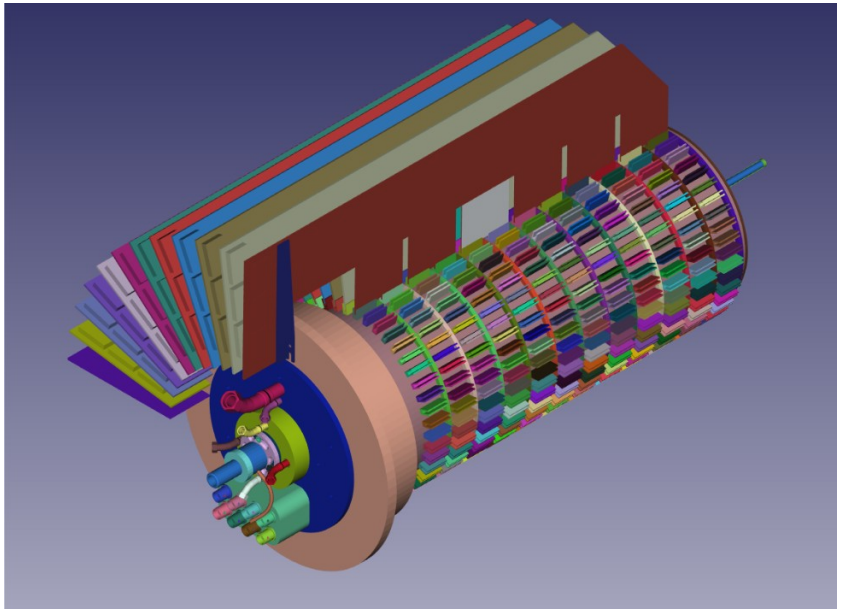
Large statistics

- As efficient as direct neutron detection

Unique insight on FSI







Tagging at the EIC

Kinematics of colliders makes it much simpler

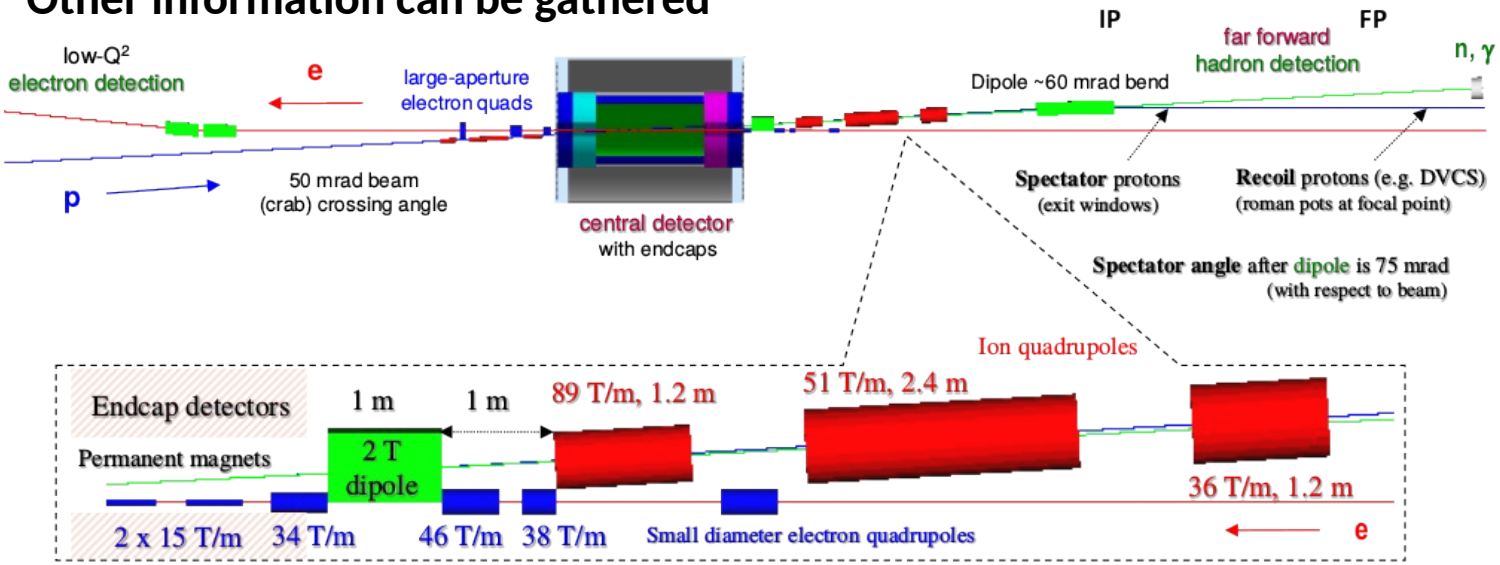
- Allows detection of both proton and neutrons
- As any nucleus with a magnetic rigidity different from the beam
  - *Raises questions for A-2 tagging in view of the pn dominance in SRC pairs*

Allows tagging and polarized target at the same time

- Access to effective target of polarized neutrons

Gives access to many body tagging

- For large nuclei, the A-1 contribution becomes small
- Other information can be gathered



Tagging in Many Body Systems

Centrality measurements are now standard in A-A

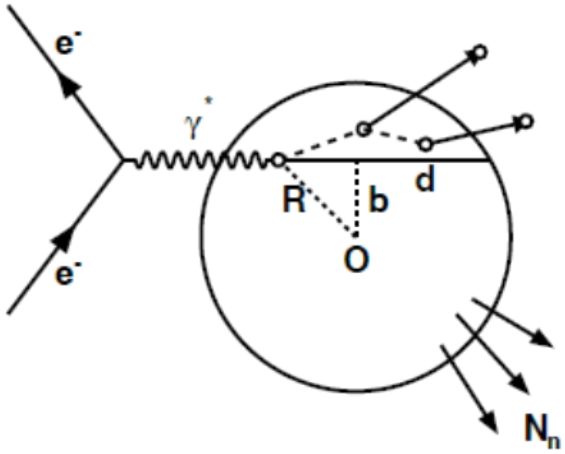
- They get more and more evolved
- Also applied in p-A
  - *With some caveats*

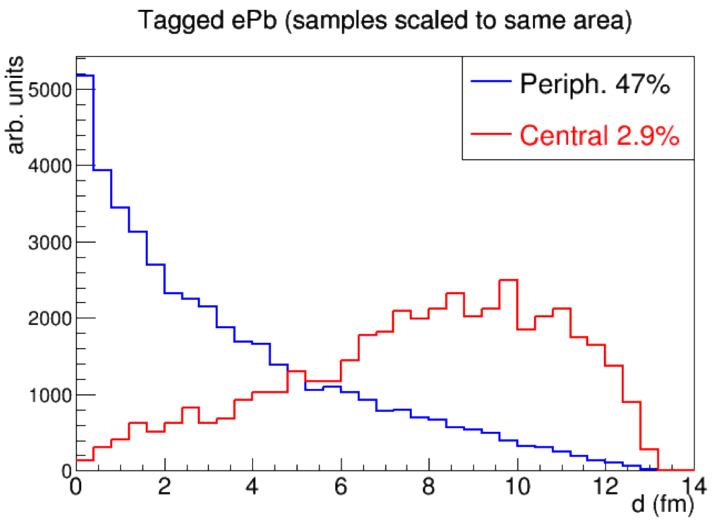
We need such measurements at EIC

- Else we are dominated by surface events
- Effort to create proper Monte-Carlo tools with Beagle
- Plans to use E665 data from Fermi Lab to calibrate

Impacts the beam line design

- This is a good time to worry about this





Workshop in Paris-Saclay (14th of Sept. to 23rd of Oct.)

Six weeks focused on tagging (INT style long workshop)

- Exploring QCD with Tagged Processes

Different focus each week

- Many body tagging, hadronization and measuring centrality in AA, pA and eA
- Experimental progress on tagged processes, in fixed target and collider settings
- Tagging light nuclei to understand nuclear effects
- Tagging light nuclei to access pion, kaon and neutron structure
- The future of tagging in fixed and collider kinematics
- Treating final state interactions in tagged processes

Each week starts with long review talk from an expert of the field

- Aimed at students, postdocs and people new to the domain

Support available

- Local expenses for attendees, including PhD students
- Contact us: W. Cosyn, R. Dupre, C. Keppel, M. Sargsian

https://www.universite-paris-saclay.fr/fr/exploring-qcd-with-tagged-processes

Summary

We do not understand the link between the nucleon and quark structure of nuclei

- We need new observables to resolve this issue

Tagged process offer clean new observables

- To help understand the EMC effect
- And many other features of the nucleus

EIC will extend these studies much more

- Simplify tagging with proper instrumentation
- Tagging will be the tool of choice for centrality estimation

Come in the Fall discuss all these at Univ. Paris-Saclay

- 14th of Sept. to 23rd of Oct