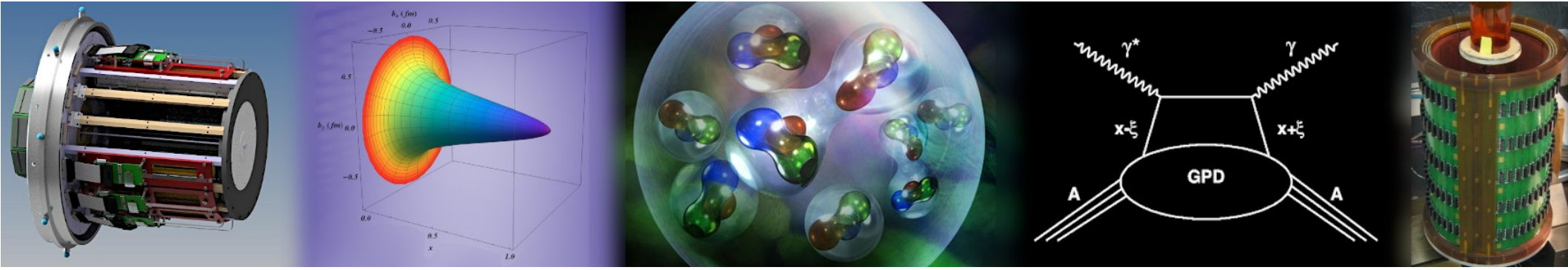
Exclusive and tagged processes Nuclei at CLAS 22 GeV



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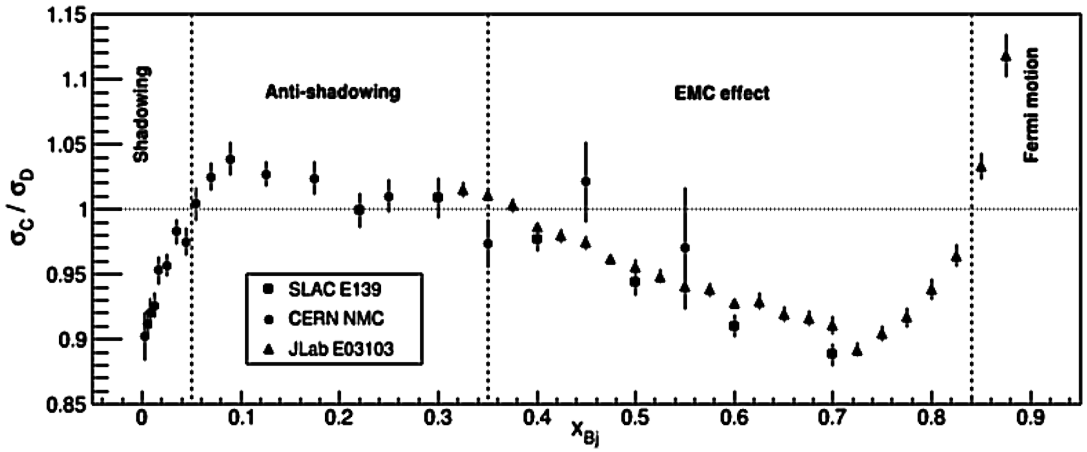
European Research Council
Established by the European Commission

Nuclear Structure in QCD

The QCD structure of the nucleus remains a mystery

- Despite our efforts in this collaboration and many others
- The EMC effect remains unexplained (or over exlained?)



We can explore with CLAS the nuclear structure

- Through traditional functions (PDFs, GPDs, TMDs...)
- Through other measurements (x>1, direct SRC detection, tagging, hadronization...)

Nuclear PDFs

Much progress this past years

- Higher orders, higher twist effects, target mass corrections...
- Better handeling of error bars
  - **Increased their size significantly**

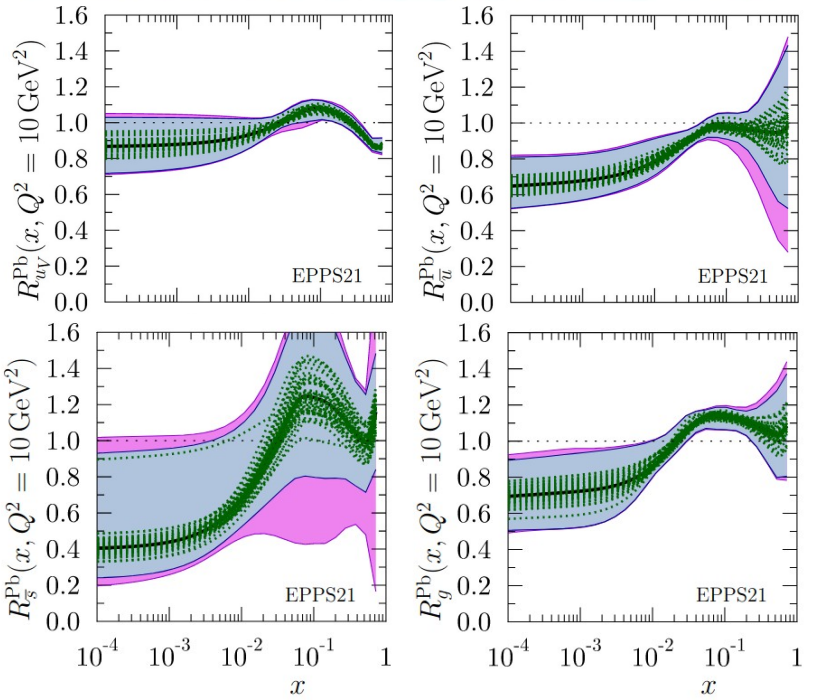
The amount of data did not grow much in the past couple of decades

- Mostly by lowering Q and W cuts
- Including some d-Au and p-Pb
- DIS data is the most crucial
  - **We can play a role here !**

Towards EPPS21 nuclear PDFs

K. J. Eskola[1,2], P. Paakkinen[3*], H. Paukkunen[1,2] C. A. Salgado[3]

2106.13661v2 [hep-ph] 21 Sep 2021



Measuring Nuclear DVCS

Nuclei give control over the spin

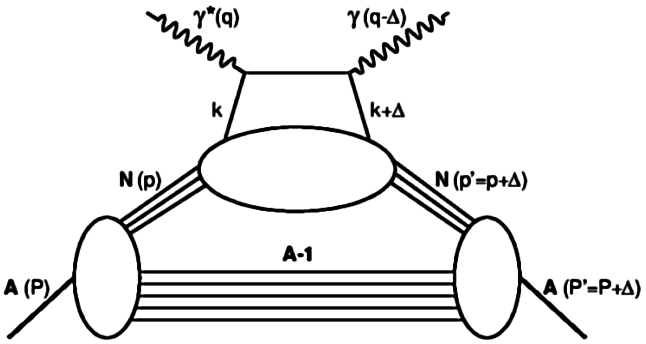
- Spin-0 → 2 GPD ; Spin-1/2 → 8 GPDs ; Spin-1 → 18 GPDs
- Half of these intervene in DVCS

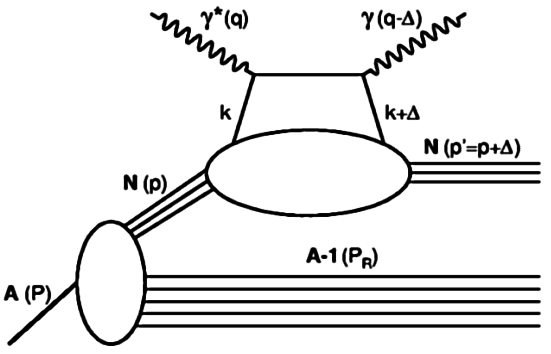
In the nucleus two processes

- 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

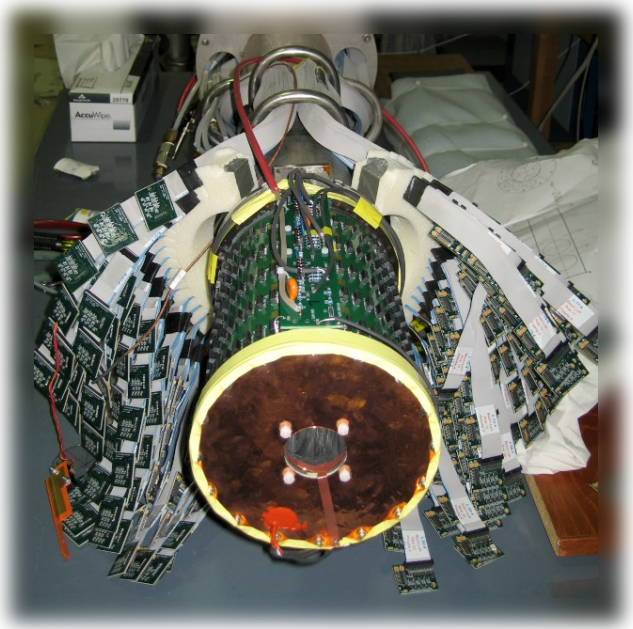
- Coherent DVCS gives access to the full nucleus
  - **Including non-nucleonic degrees of freedom**
- Incoherent DVCS gives access to the bound nucleon
  - **To test modifications of the bound nucleon structure**





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

The Coherent Helium DVCS



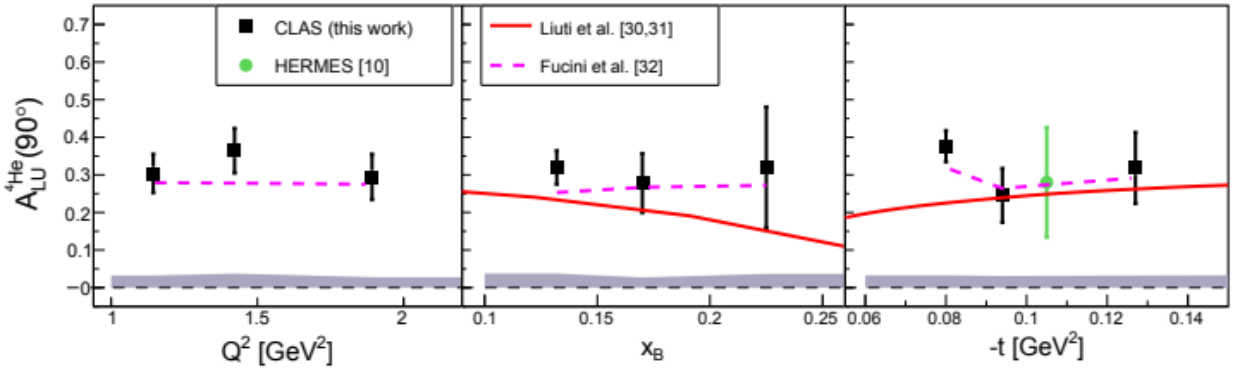
Coherent DVCS on helium

- Measured with CLAS at Jefferson Lab
  - **With the addition of a recoil detector to detect helium nuclei**
- We observed large beam spin asymmetry

Interpretation

- This strong signal shows we isolated coherent DVCS

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

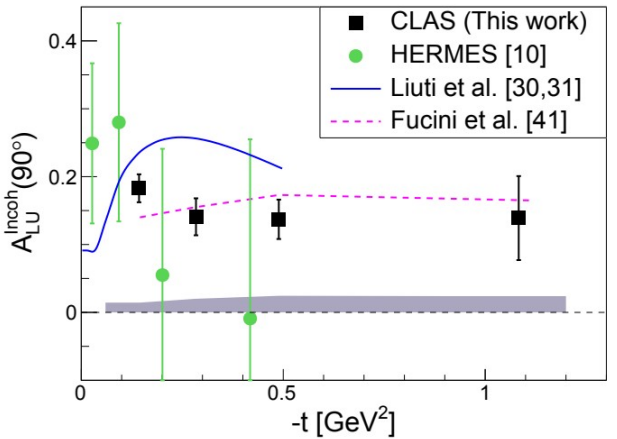
A New kind of EMC effect?

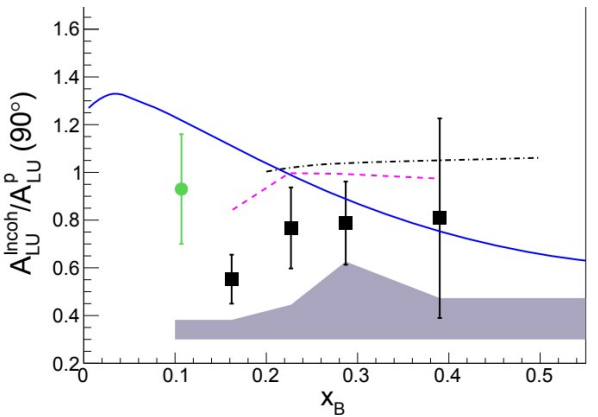
- It could be a nuclear effect
- Or it could be due to final state interactions
  - **Can be very complicated in DVCS**

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 Detector

A Low Energy Recoil Tracker

- Hyperbolic drift chamber
- Time-of-Flight array

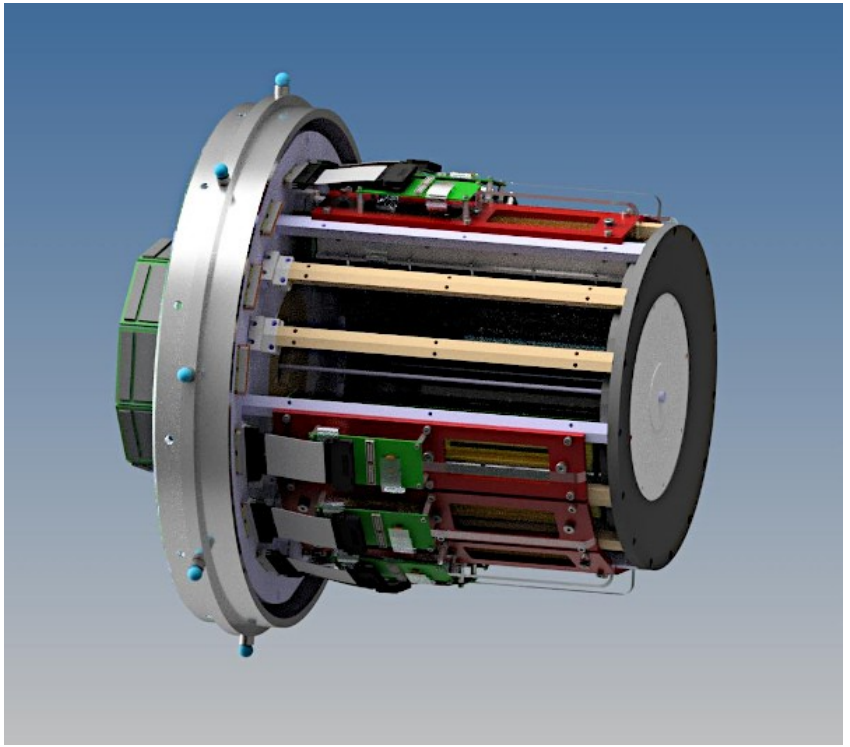
It will be used for a large array of experiments

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

Collaborative effort within CLAS12

- ANL, IJCLab, JLab, NMSU, 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



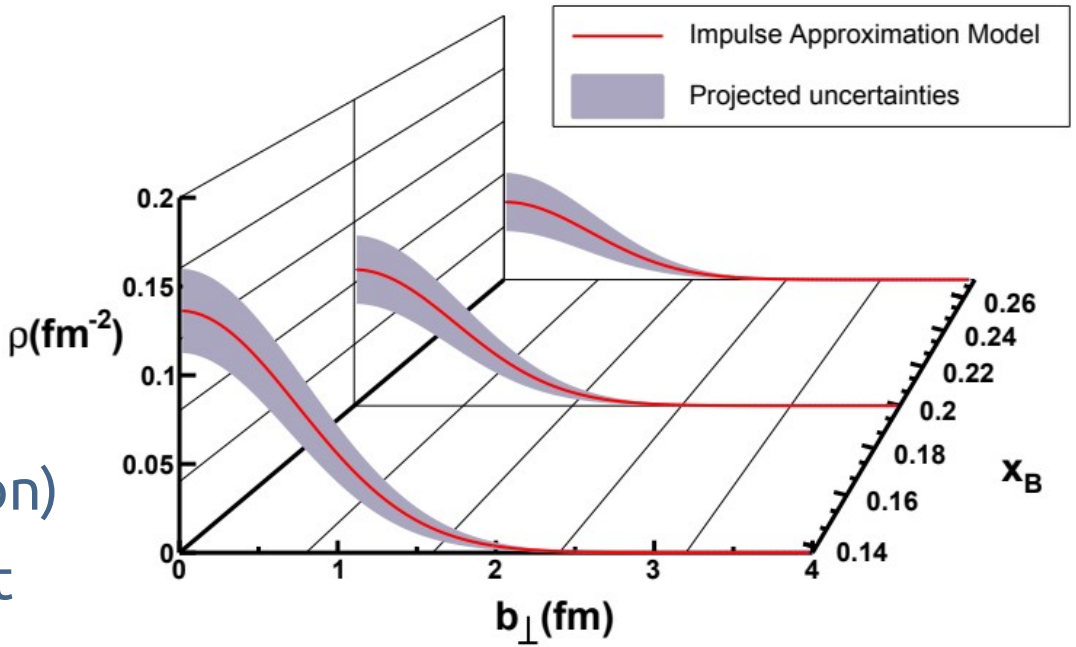
On the side of GPDs

Tomography of a nucleus

- A view into the nucleus in three dimensions
- Using the wider phase space and larger statistics

Extension to the gluons

- We will measure DVMP (Phi meson)
- We hope to obtain a similar result for gluon tomography



What is happening at 22 GeV

This is a full GEANT4 simulation of coherent DVCS on helium-4

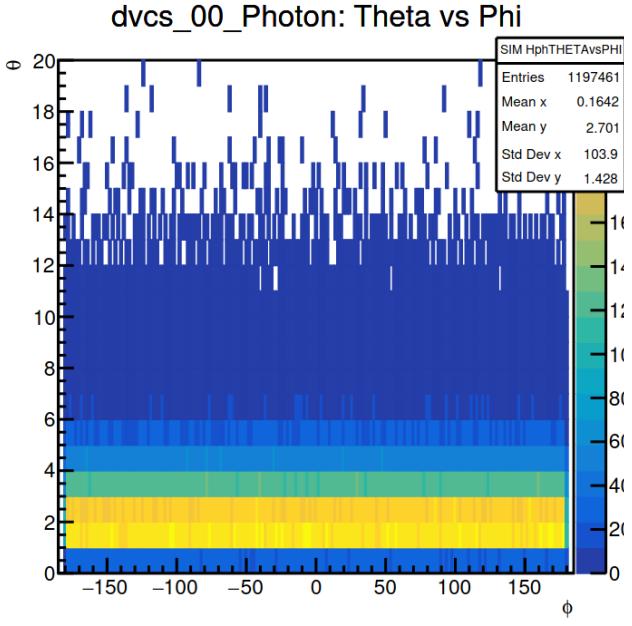
- We use TOPEG for events, GEMC for CLAS12, and CLAS12 recon
  - **Thanks to Mikhail Yurov (MSU) and L. El Fassi (MSU)**

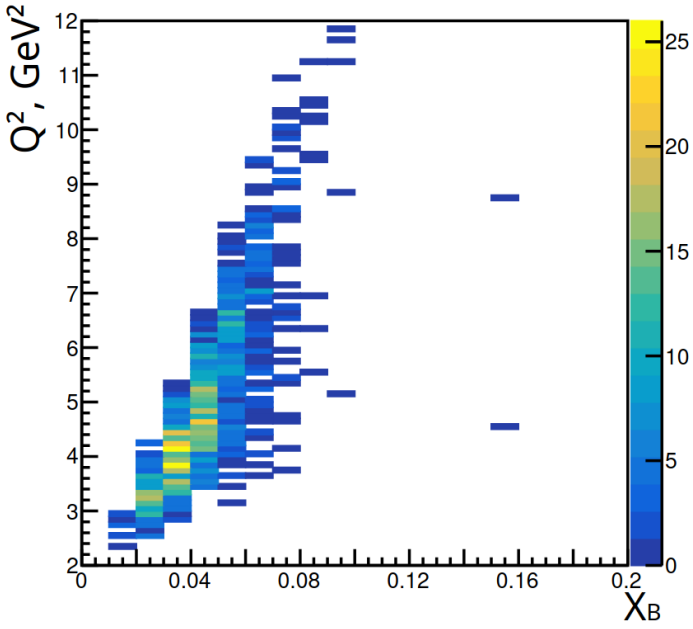
Results :

- Very few events are fully detected (less than 1%)
- This is mostly due to low t and q
  - **Not in CLAS acceptance**

Conclusions :

- We get access to lower x
- To make full use of 22 GeV
  - **We need to improve detectors**
  - **Do without photon detection ?**

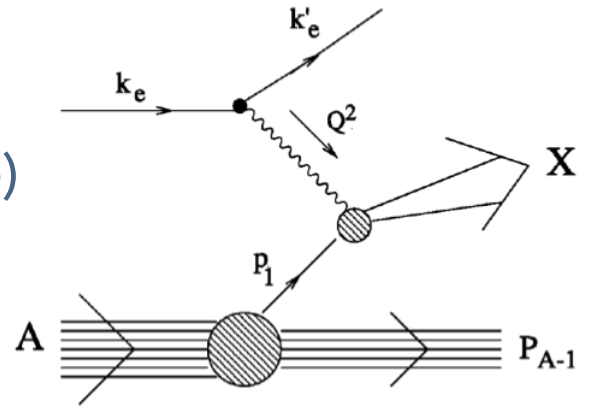




Tagging Nuclear Reactions

What is a Tagged processes

- They are semi-inclusive hard processes (GeV+ scale)
- In which, we also detect nuclear fragments (MeV scale)
- They give unique information on the state of the nucleus right before the hard interaction



Can help for many physics topics

- Study of the neutron structure with deuterium or helium-3 target
- Study of the pion structure through Sullivan process
- Study of nuclear effects, in particular EMC, with momentum dependent measurements

Tagging to Access Offshellness

Tagging links EMC to nucleon kinematics

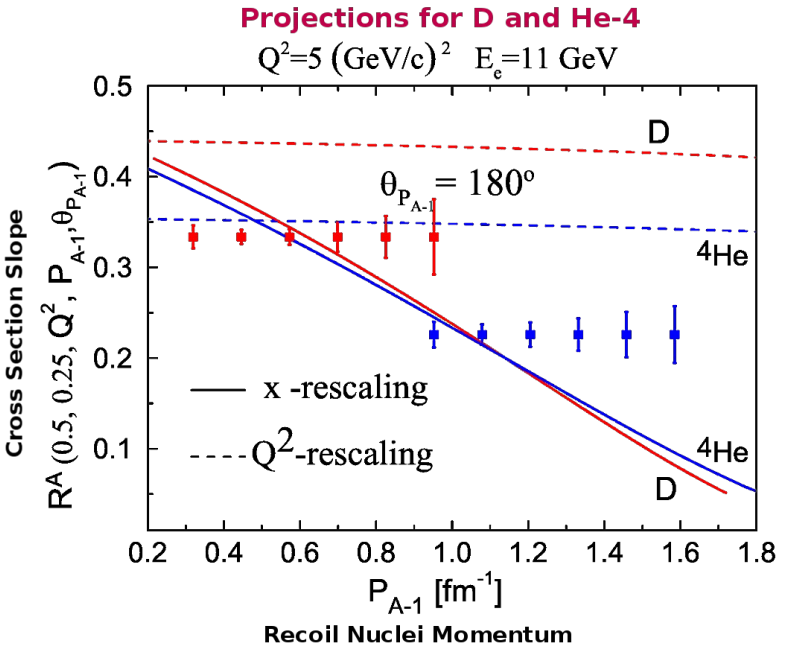
- Linked to virtuality
- Differentiate mean field from SRC

Test models and more

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

Different nuclei

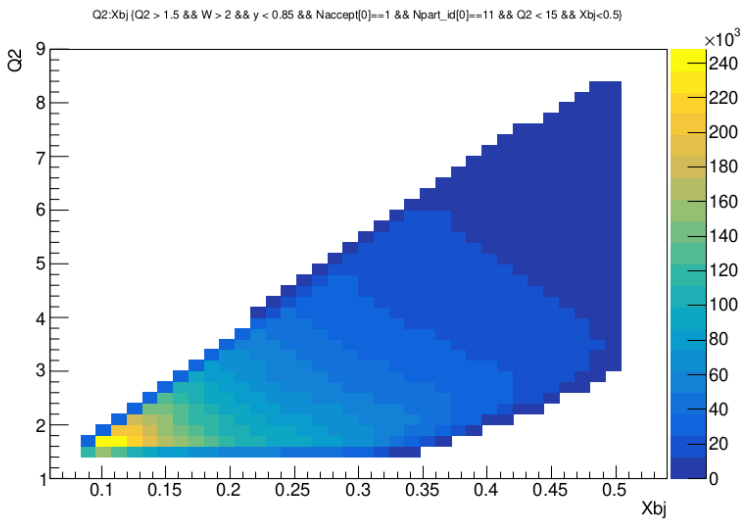
- Cover different momentum ranges
- Mean field vs SRC

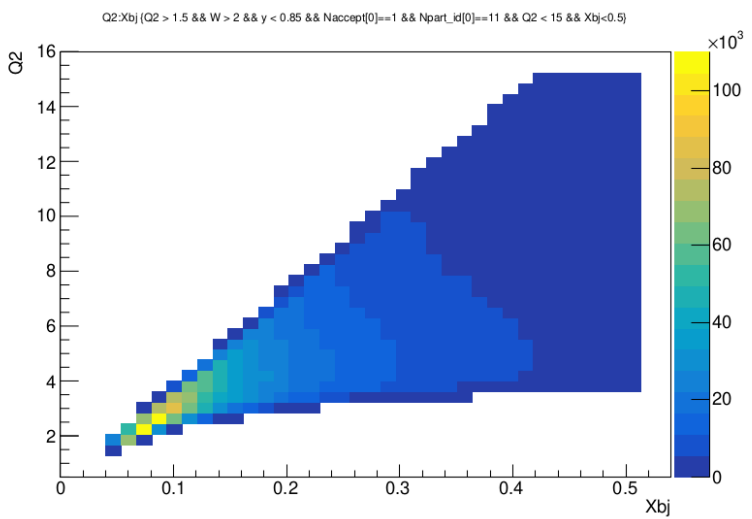


What is happening at 22 GeV

That is a basic simulation of tagged helium-4

- Event generator Pythia + Fermi motion PWIA nuclear fragments
- Geometric selection to mimic CLAS12 (not ideal but much faster)

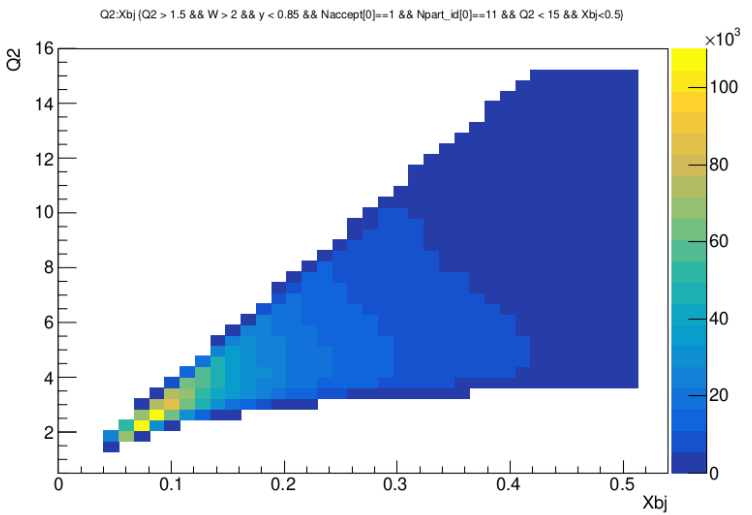


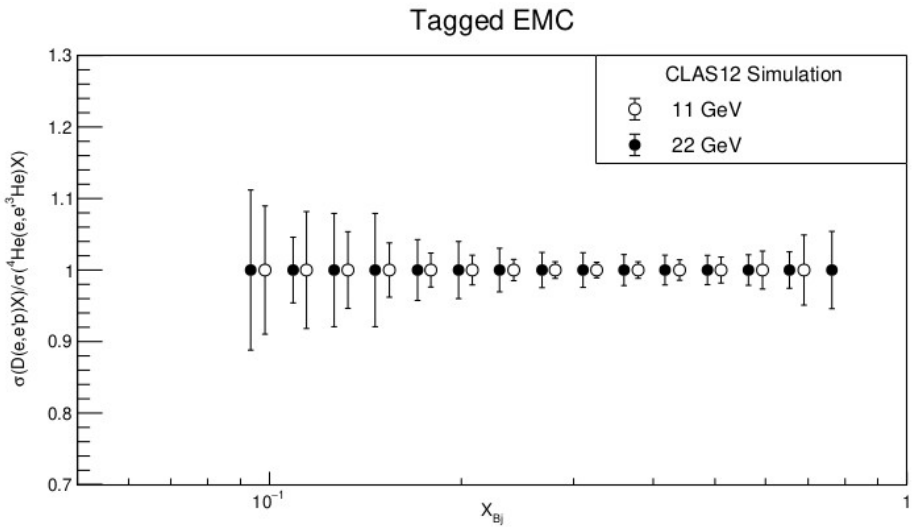


What is happening at 22 GeV

Results :

- We can access larger Q2 and slightly lower x → Interesting to study anti-shadowing
- Without high luminosity, high energy is not very helpful
- CLAS12 design is really not optimal for 22 GeV
  - **Acceptance is too small at low angles**





Finally…

We can get new grounds with nuclear DVCS

- Lower x and higher q than at 11 GeV
- To make full use of this energy, we need to get better
  - **At detecting DVCS without photons**
  - **At placing a small angle calorimeter**

Similar with tagged processes

- Can explore anti-shadowing region in details
- Luminosity is going to be a limiting factor as well

There are plans for luminosity upgrade of CLAS12

- **However, the question is how much ALERT can take ?**