Possibilities with Tagged Data

Raphaël Dupré

Univ. Paris-Saclay
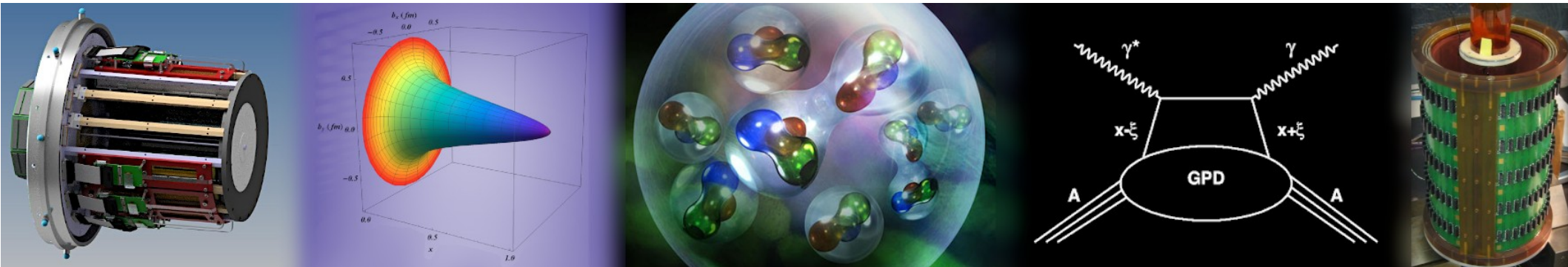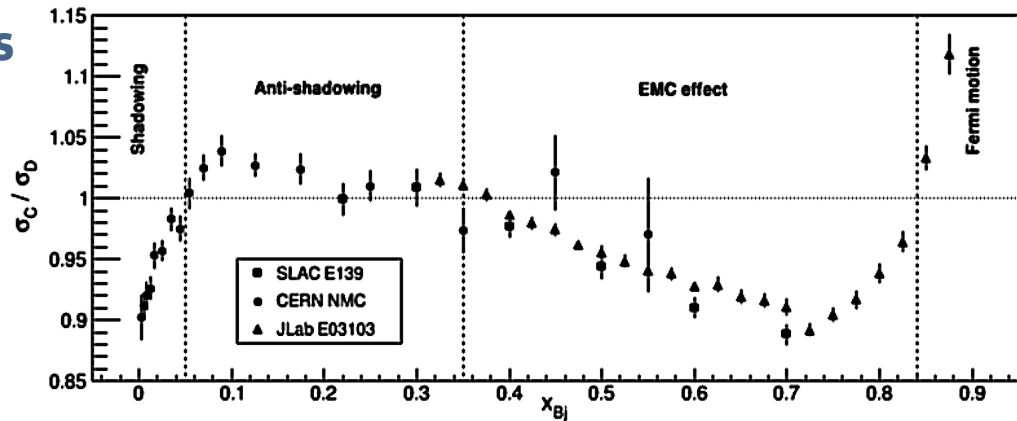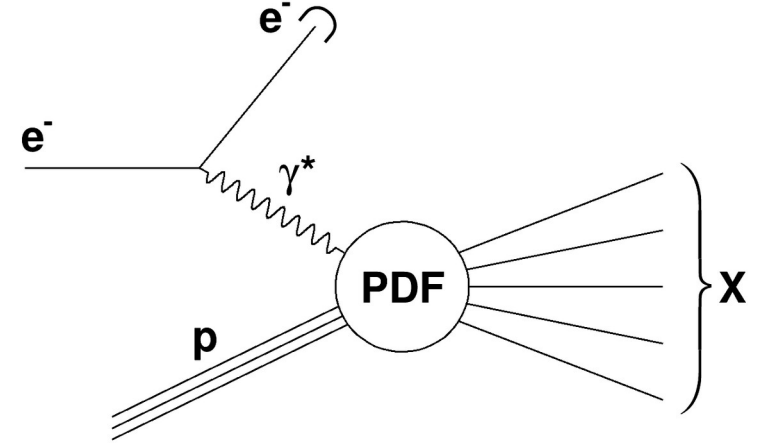
The Nucleus Quark Structure

The nuclear PDFs show many suprises

- Quarks are affected by the nuclear medium

- Limits between effects can be drawn in different ways

  - **Anti-shadowing is the junction between shadowing and EMC regions**

Lots of Theory

- 30+ years of discussion

- No consensus reached

# Few Keys on the EMC effect

Different nuclei tested

- EMC increases with A, mostly...

- Some abnormalities in light nuclei

No counter effect in anti-quarks

- The quark momentum does not appear to be redistributed to anti-quarks

- Which was expected by some early models

A correlation found with SRC pairs

- The number of short pair correlations in a nuclei is correlated with the EMC slope in this nuclei
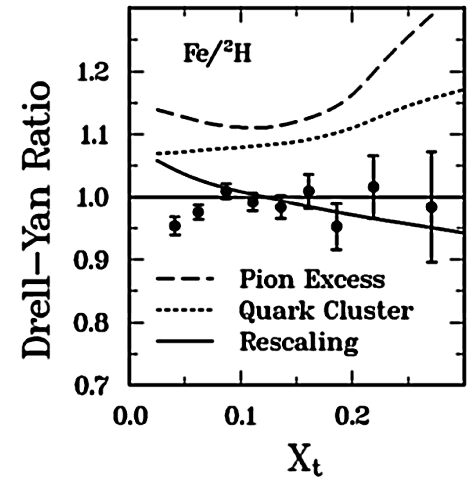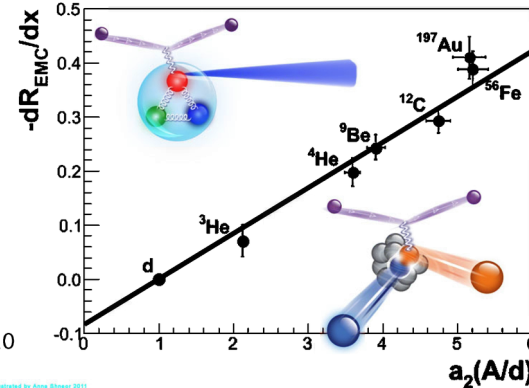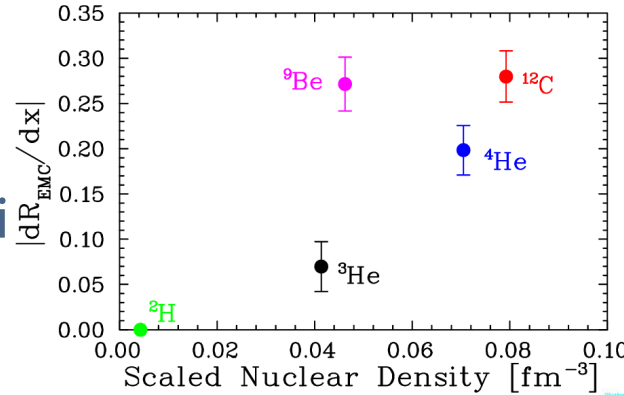
Is there a flavor dependence ?

Some model suggest it

– We show here an example

Cloet et al. Phys.Rev.Lett. 102 (2009) 252301

– The effect is predicted to extend into the anti-shadowing region

– A relation of EMC effect with SRC pairs would also suggest a flavor effect
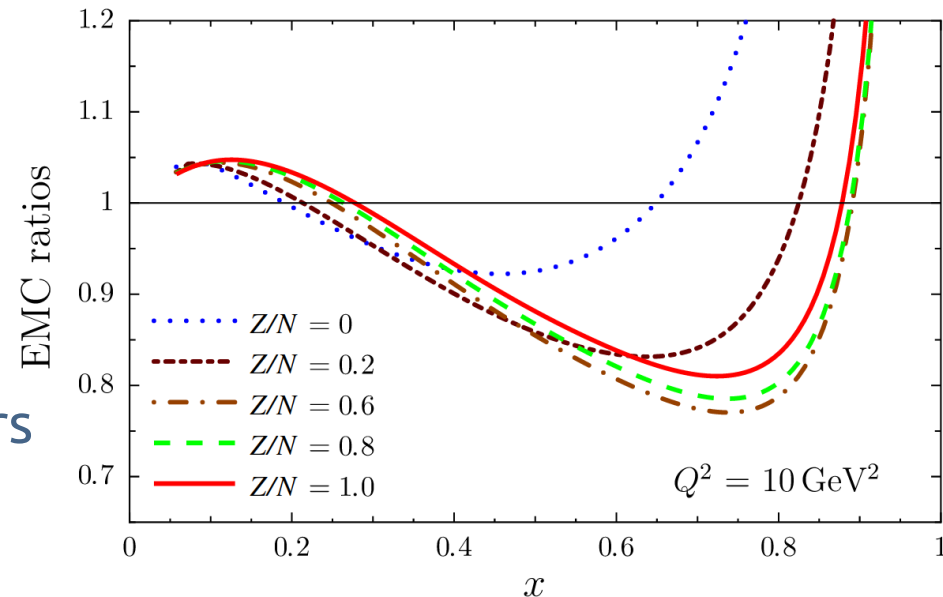
Can we measure this ?

– Or did we actually measured it already ?

   • **Kind of... as this interpretation allows to explain the NuTeV anomaly**

– But we can directly measure it using tagging !

Shadowing side of things

Linked to multiple scattering

- Screening of some nucleons leads to reduced cross section

- Calculations diverge largely at lower x where no direct measurement is available
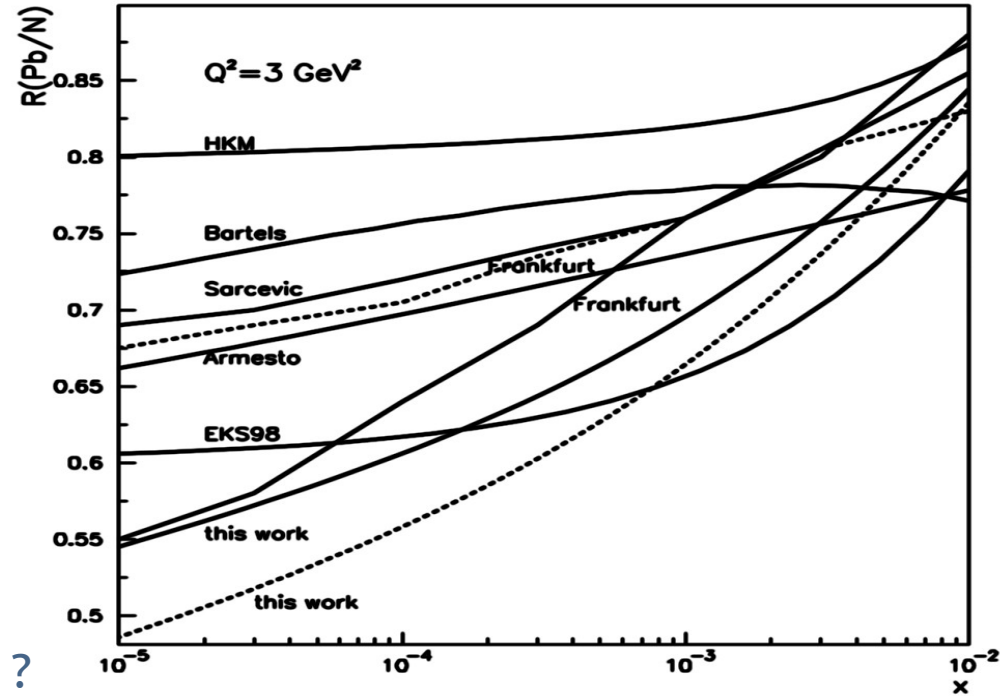
Data is very limited

- Below x of 10^{-2} it is barely explored

- That shows in theoretical predictions

Shows that we are not that clear

- So how does it merge into anti-shadowing ?

N. Armesto, J.Phys. G32 (2006) R367-R394

Focus on a theory calculation

Shadowing / anti-shadowing description
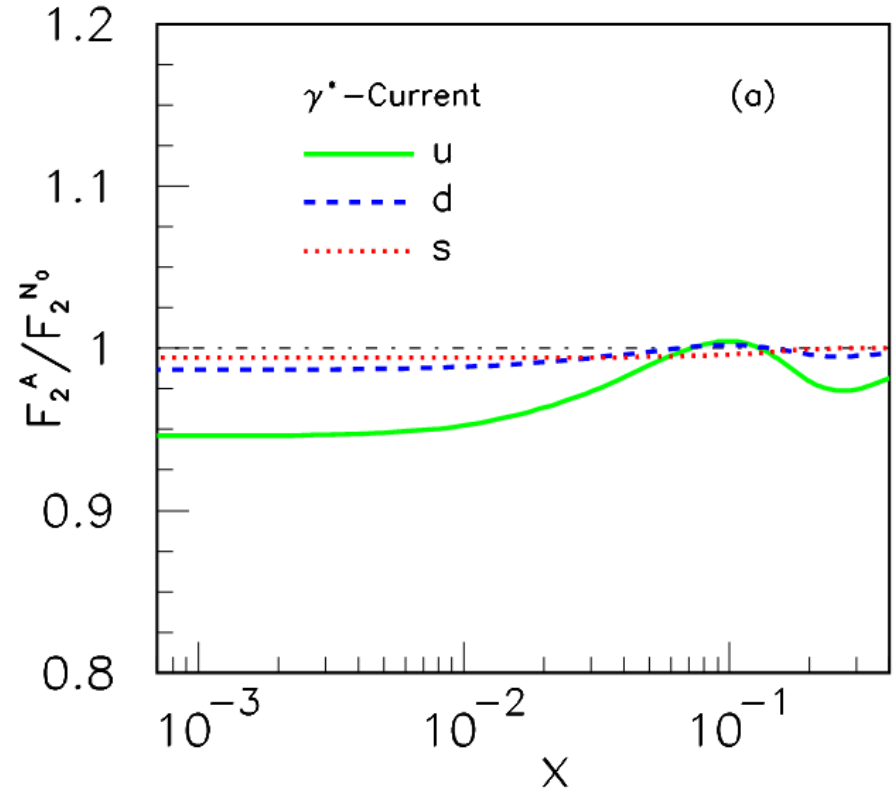
– Linked to destructive/constructive interferences

Leads to very significant effects for neutrino scattering

– Massive effect is predicted for F3

– It can also explain the NuTeV anomaly

Can it be tested in JLab ?

– It predicts flavor differences

– Effect is small for the photon probe but it spreads into anti-shadowing region

Brodsky et al. Phys.Rev.D 70 (2004) 116003

So what can we do ?

Clearly JLab is an anti-shadowing region machine

- At both 11 and 22 GeV much of our reach is there
- 22 GeV allows to go lower in x and fully explore this region

The flavor symmetry of the PDFs in this region is unknown

- Some assume it, but evidence accumulates to show other wise
- We do not have much anti-shadowing dedicated theory
  - **We have shadowing and EMC theory that leak into the anti-shadowing**

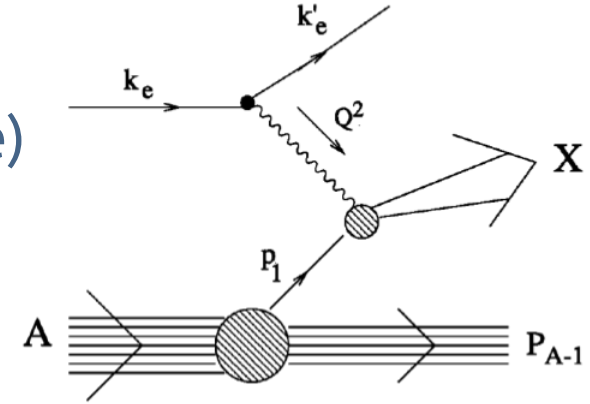**We have many predictions for flavor effects**

- Tagging is the perfect tool to measure flavor symmetry !

What Do We Call Tagging ?

What is a Tagged process

– They are semi-inclusive hard processes (>GeV scale)

– In which we detect nuclear fragments (MeV scale)

– They give unique information on the state of the nucleus right after the hard interaction

Allows to control the struck nucleon virtuality

$$v(|\mathbf{p}|, E) = \left(M_A - \sqrt{(M_A - m_N + E)^2 + \mathbf{p}^2}\right)^2 - \mathbf{p}^2 - m_N^2$$

Allows to control the amount of final state interactions

– Backward and lower momenta are best for reduced FSI
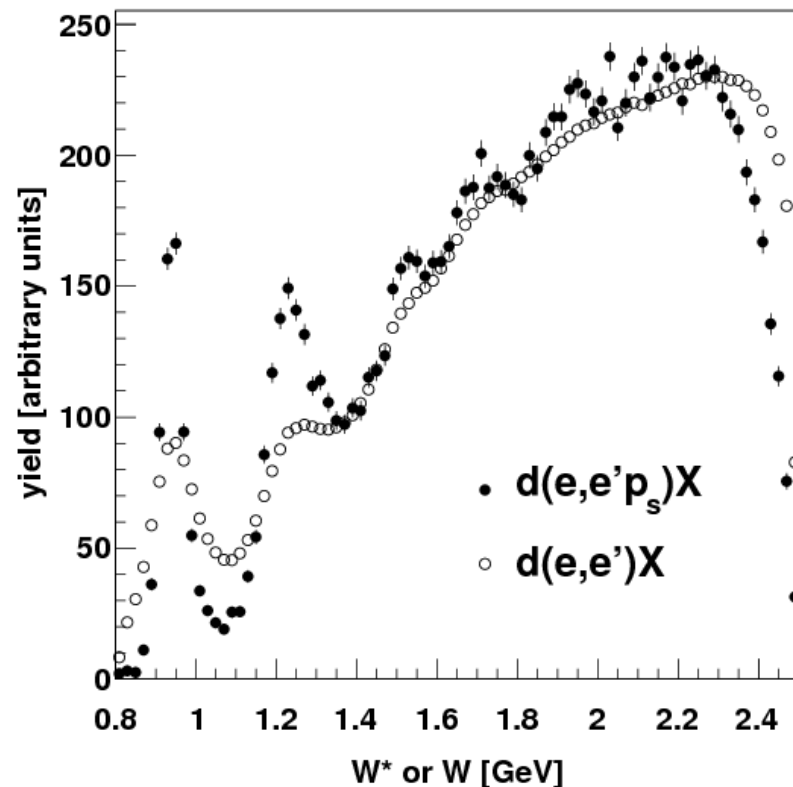
Tagging Nuclear Reactions

Can we do tagging?

– Done only for deuterium as of yet

  • **Bonus measurement from CLAS --->**

– Need of a recoil detector (fixed target)

– Or a forward detector (collider)

Many projects incoming

– Mostly in JLab in the near future

– Large section in the EIC project

Tagging at JLab

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)
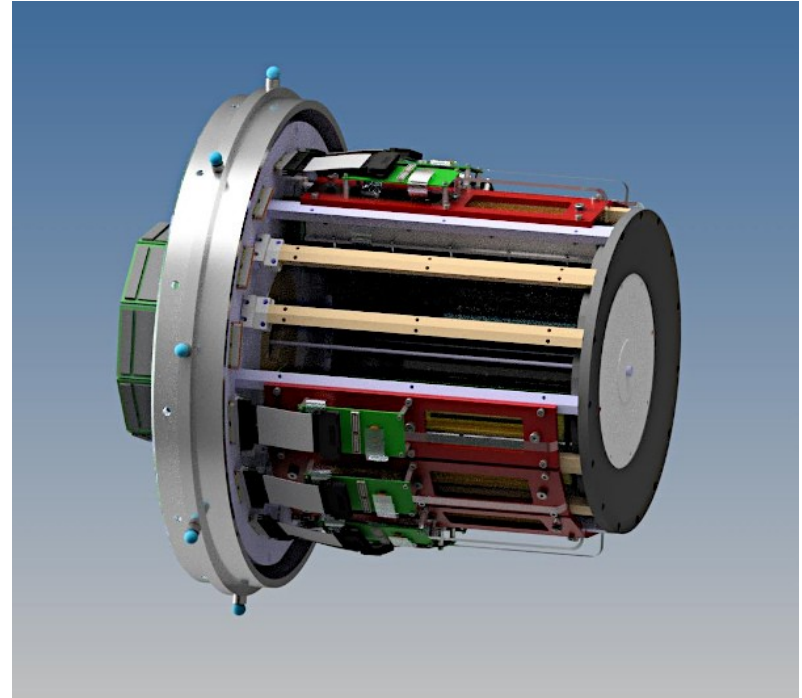- Effective polarized neutron

Helium-4
- Study bound nucleons (ALERT @ JLab)
- Study of EMC and SRC (ALERT @ JLab)

Heavy targets
- Centrality tagging

My biassed focus will be on ALERT
- The only one looking into the antishadowing region right now
- However, the different technologies are all likely to be able to do this

The ALERT Detector

A Low Energy Recoil Tracker
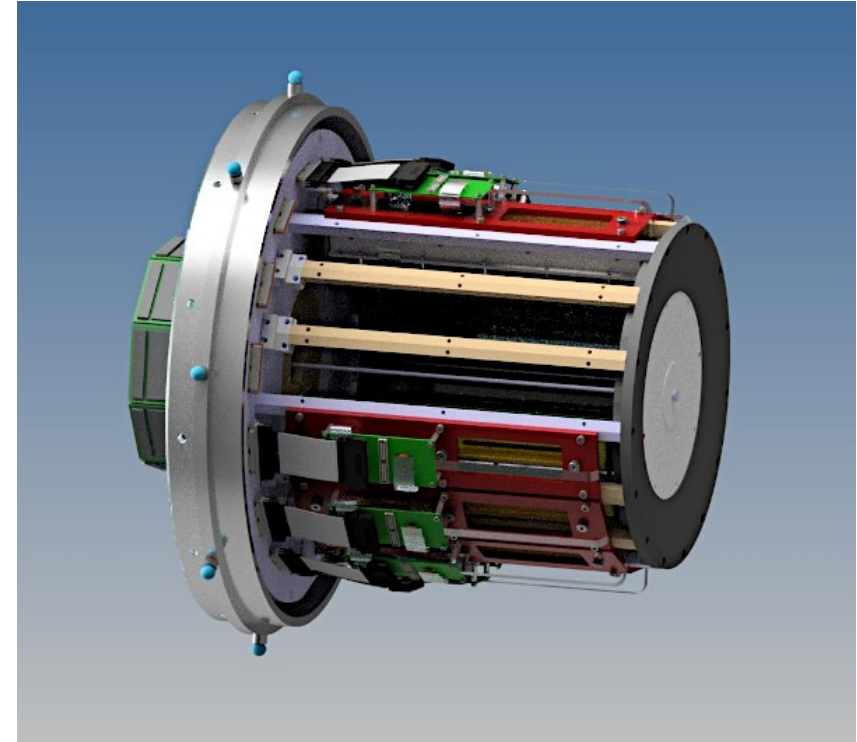
- Hyperbolic drift chamber
- Time-of-Flight array

It will be used for a large array of experiments

- Nuclear DVCS, DVMP…
- Tagged processes (DIS and DVCS)

Collaborative effort within CLAS12

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

We hope to take data in 2024

# ALERT specifications

Capabilities for 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}

– Maybe more ? Tests were very positive

Excellent PID and resolution

– Can identify isotopes of light nuclei precisely
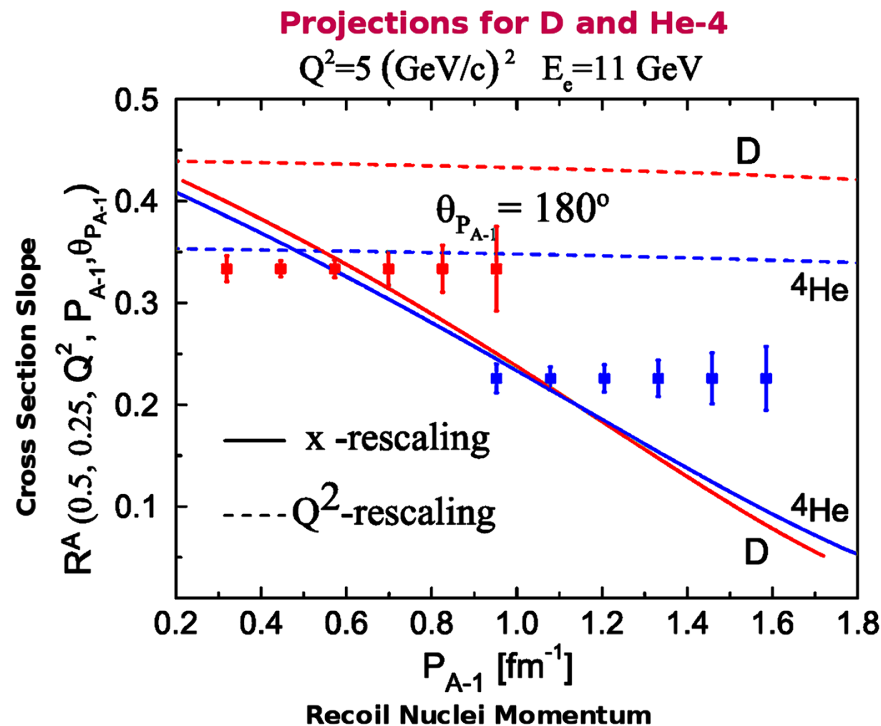
– It is the only way to go beyond A = 2
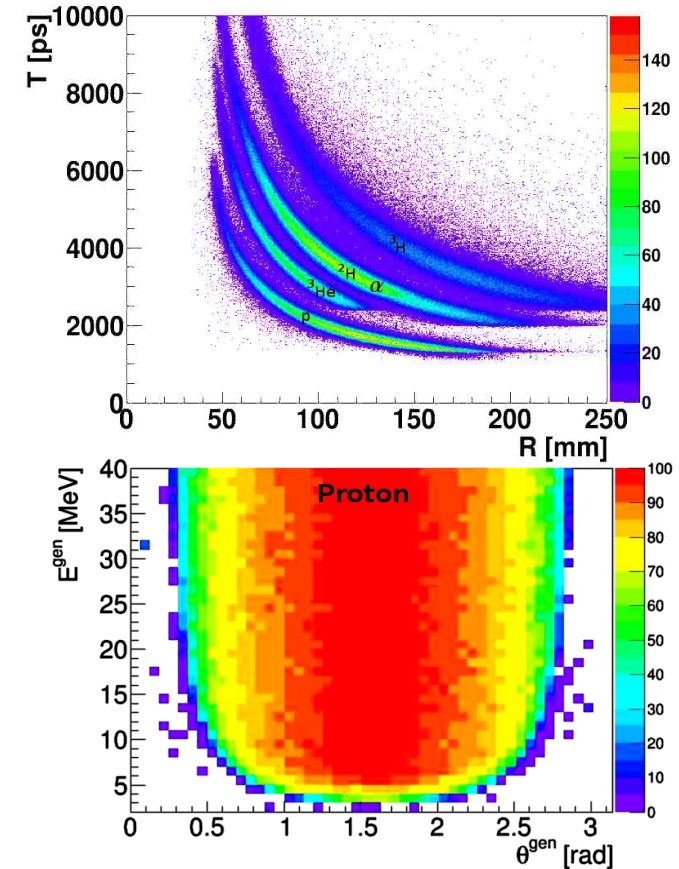
The EMC effect through tagging

Tagging the EMC effect

– Looking how the EMC slope is modified by the spectator kinematics

– Q^2 and x rescaling give drastically different predictions

– Will give an answer for EMC

Tagging other processes

– One can tag quasi-elastic or DVCS…

– Can look at many other observables

- **A large physics program has been laid out for the ALERT detector**

Projections for D and He-4

$Q^2 = 5 \ (\text{GeV/c})^2 \quad E_e = 11 \ \text{GeV}$

Cross Section Slope

$R^A (0.5, 0.25, Q^2, P_{A-1}, \theta_{P_{A-1}})$

$\theta_{P_{A-1}} = 180^o$

D

^{4}He

—— x -rescaling

----- Q^2-rescaling

^{4}He

D

$P_{A-1} \ [\text{fm}^{-1}]$

Recoil Nuclei Momentum

Other opportunities with tagging

Tagged DIS gives many other opportunities

- We can compare directly protons to neutrons in the nuclei

- Largely in the anti shadowing region already at JLab 11 GeV
  - **Here prediction for the ALERT run in CLAS12**
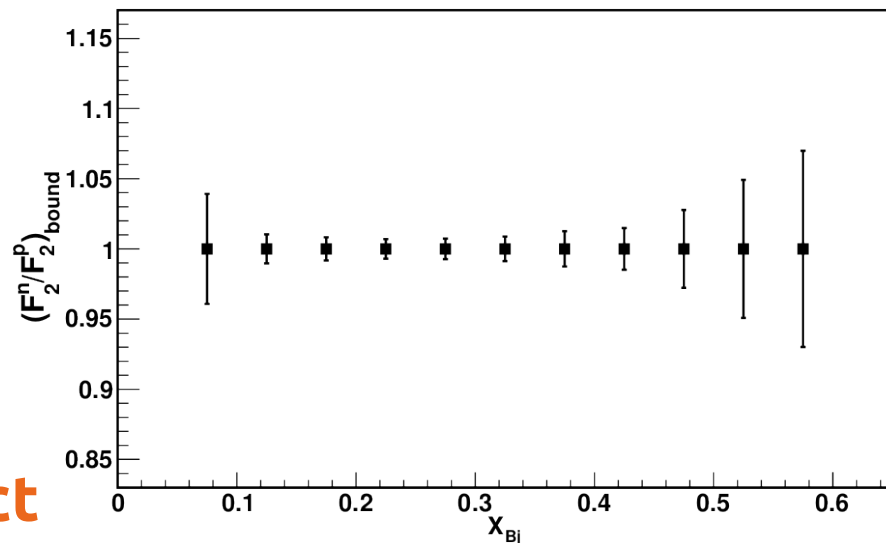
Tagged DIS can also be used to select nuclear configurations

- We did not go very far in this direction yet

Summary

We do not understand the nucleus well within QCD

- Either we do not understand the mechanisms at play

- Or we lack a quantitative calculation to demonstrate it

Either way tagging is a great way to progress

- Many measurements are incoming in JLab 11 GeV focussing on high x

- There is plenty of things to look at in the intermediate x region
  - **An energy upgrade will highlight the lower x transition inaccessible now**

We highlighted flavor symmetry effects

- Tagging can tell us more about the links between nuclear dynamic and quark structure if any exists in this region !