U.S. DEPARTMENT OF ENERGY JSA

Tagged EMC Measurements on Light Nuclei

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An ALERT Run Group Proposal for JLab PAC 44

N. Baltzell

on behalf of the ALERT Collaboration

ALERT Run Group

Nuclear Exclusive and Semi-inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker

- Suite of studies of ^{4}He nucleus
  - new measurements of SIDIS, DVCS, DVMP reactions
  - to study nuclear models of the EMC effect (including their treaments of off-shellness and FSI), and partonic (including gluonic) structure with GPDs
  - requiring detection of low energy p, ^{3}H, ^{3}He, ^{4}He recoils

- 3 PAC 44 Proposals
  - *Tagged EMC Measurements off Light Nuclei*
  - *Tagged DVCS Off Light Nuclei* *
  - *Partonic Structure of Light Nuclei* *

- Detector System
  - CLAS12 Forward Detectors
  - ALERT Recoil Detector

This Talk

* = The following talks in this session

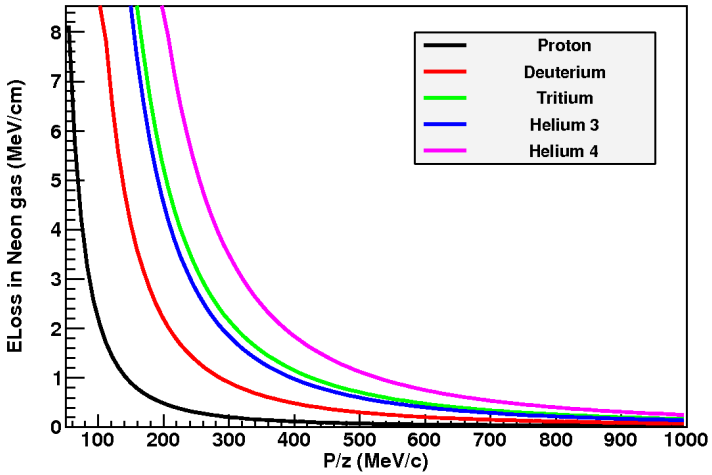
Primary Institutions:
- Argonne National Laboratory
- Institut de Physique Nucléaire d'Orsay
- Temple University
- Jefferson Laboratory

Run Group Contact: K. Hafidi

ALERT Detector

New Recoil Detector Motivations

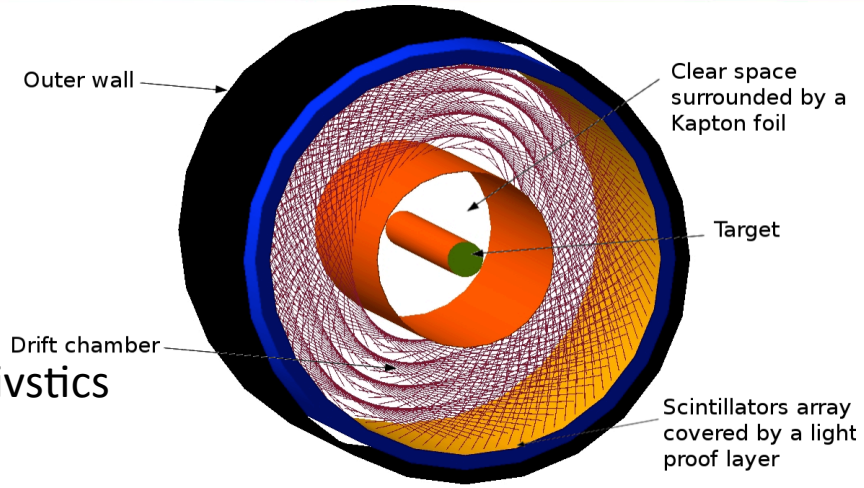
- Fast response for use in trigger
  - Only ~10% of DIS on ^4He or D_2 result in detectable recoils due to energy loss, as seen by EG6
  - BoNuS and EG6 were luminosity-limited by DAQ
- Separate all nuclear recoils up to ^4He
  - The dE/dx resolution of a TPC alone cannot distinguish ^3H and ^3He
- Minimize recoil nuclei detection threshold
  - CLAS12 central detector thresholds are too high for ALERT's physics measurements



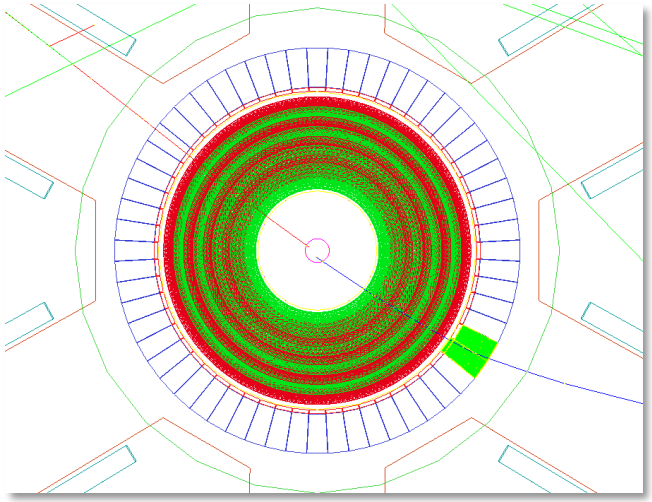
→ ALERT Detector designed to satisfy these goals, inside of CLAS12 solenoid and in place of the SVT and all but outermost layer of MicroMegas

ALERT Detector

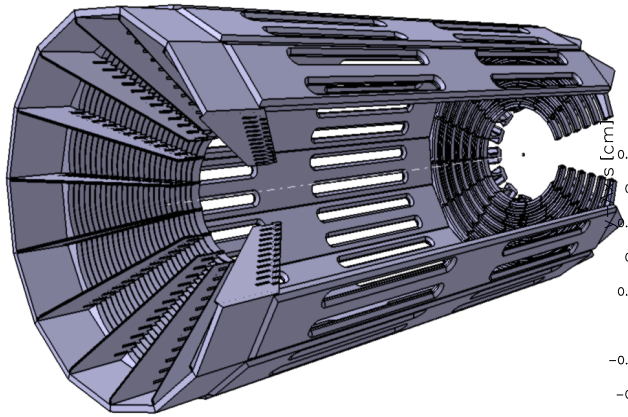
- Gas Target
  - 30 cm effective length, 6 mm radius
  - 3 atm, 25 um Kapton walls
- Hyperbolic drift chamber (32 < R < 85 mm)
  - 30 cm longitudinal wires with 10^{o} stereo
  - 8 ~circular layers of 2 mm hexagonal cells
  - Light gas mixture ~1 atm, insensitive to relativstics
- Two Segmented Scintillator Cylinders
  - TOF and total energy measurements for PID
  - Total thickness ~20 mm
  - SiPMs directly attached

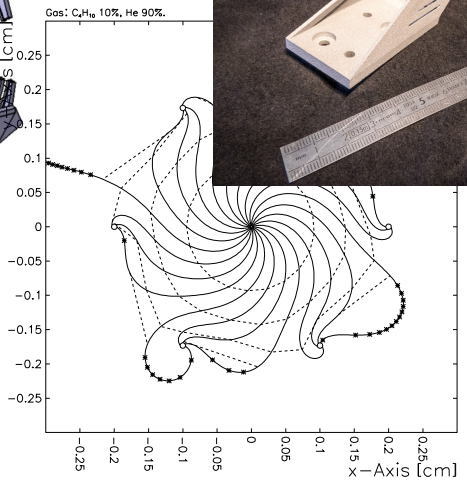


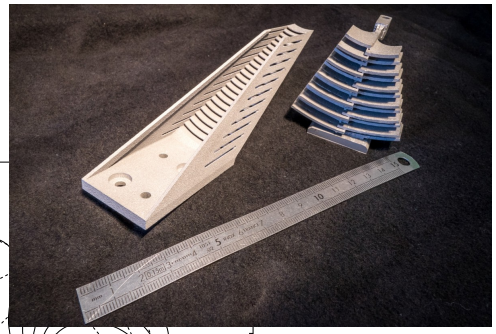
- Full GEANT 4 Simulation
  - Used to optimize the detector design
  - Evaulate drift chamber occupancies, thresholds, time and tracking resolutions (used in phsyics projections)
- To Do
  - Evaluate/finalize electronics
  - Mechanical integration on going

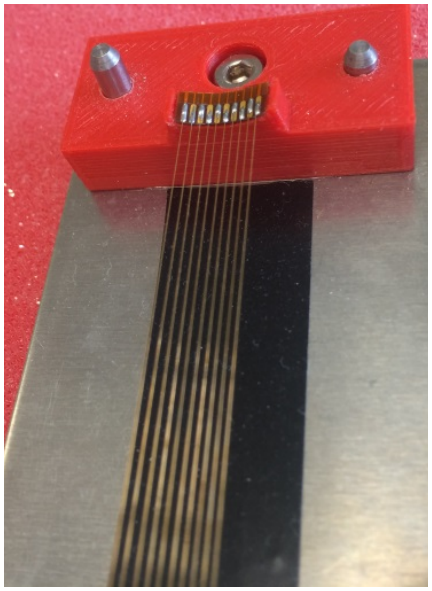


ALERT Drift Chamber Prototyping, Testing



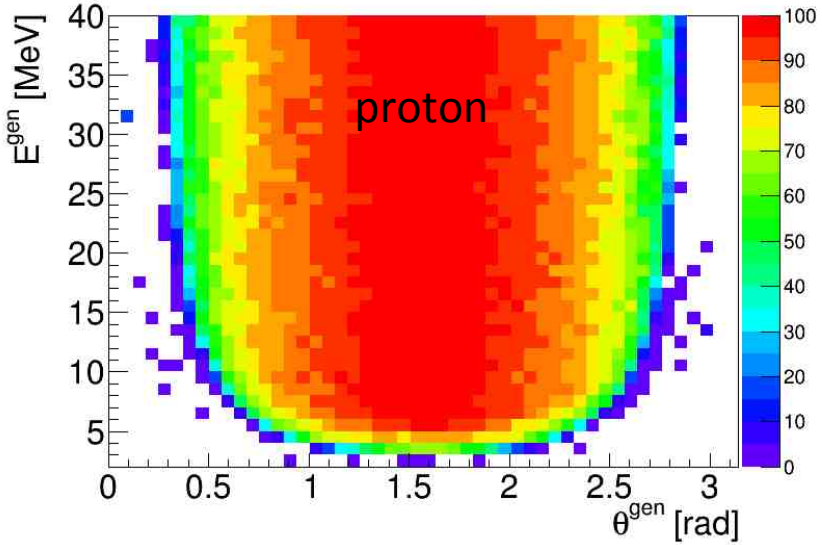


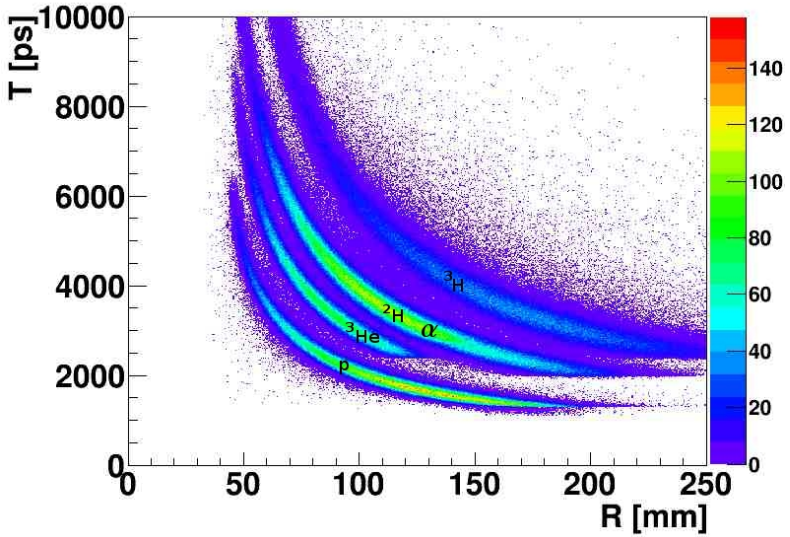




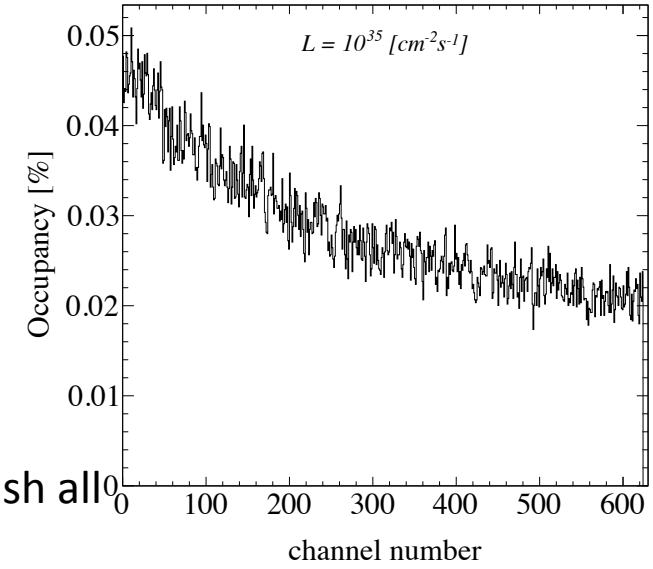
- **Testing Progress:**
  - – Full wire layout and support structure design, MAGBOLTZ field simulations
  - – Gluing and soldering wires with 2 mm gaps on curved structure
  - – 3D printed tests of 18-sector design (with one empty) for ensuring independent sector removal/replacement
  - – Carbon and titanium support structures to handle the expected < 600 kg tension
- **First prototype is designed and being ordered**
- All part of a larger R&D program on drift chambers at Orsay

ALERT Capabilities



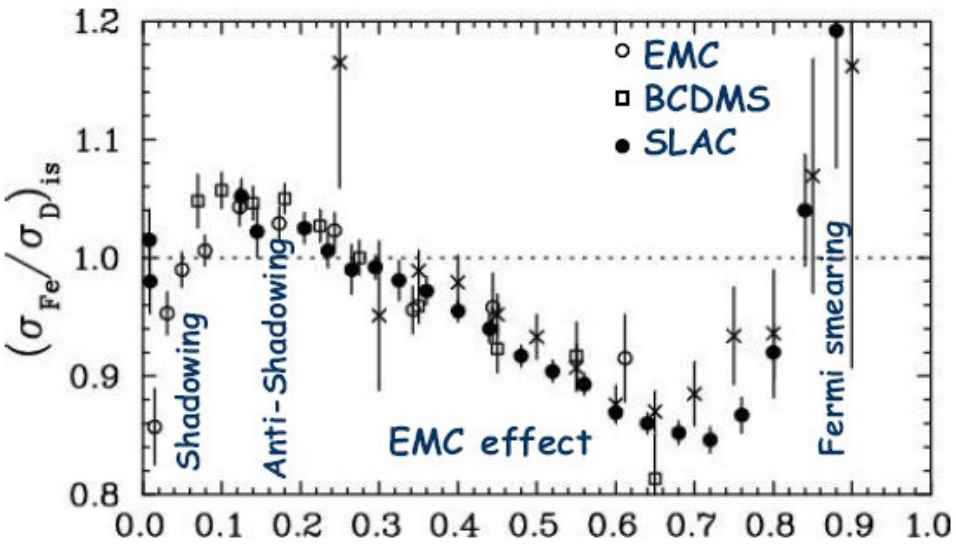


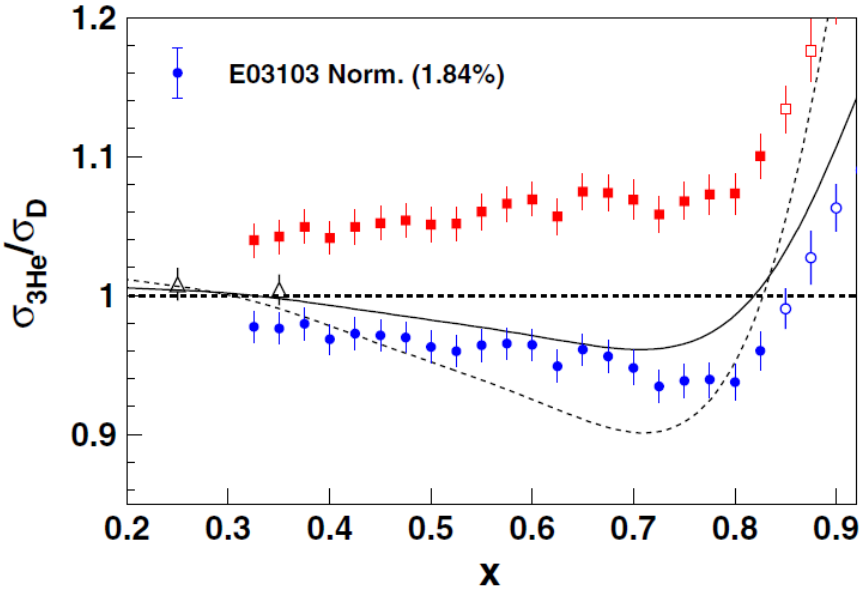
– **Large p/theta Acceptance**
  – Down to ~75 MeV/c for protons, and 25°
– **Ability to handle high rates**
  – Short drift time <250 ns (5 μs in RTPC) → trigger
  – Acceptable drift chamber occupancies at few 10^{34}
    – For ^{4}He-detection only running, can increase thresholds & luminosity
– **Particle Identification**
  – Timing and tracking resolutions sufficient to distinguish all
    – Except ^{4}He and ^{2}H, separable with dE/dx



Tagged EMC Measurements on Light Nuclei

The EMC Effect





- Quarks in nuclei behave differently and in a non trivial way than quarks in a free nucleon
- EMC effect fundamentally challenged our understanding of nuclei
- Specific origins of the modification are not clearly identified yet
  - Need new observables → semi-inclusive

$$F_2(x) \sim \sum_f e_f^2 q_f(x) \quad f = u,d,s$$

Because

nuclear binding (MeV) << energy scale of the probe, nucleon excitations (GeV)

One expects that

$$F_2^A(x) \approx Z F_2^p(x) + N F_2^n(x)$$

is insensitive to the details of the nuclear structure beyond Fermi motion

Models of the EMC effect

Nucleon Structure is modified in the nuclear QCD medium

- Nucleon "swelling"
- Dynamical rescaling
- Multiquark clusters (6q, 9q "bags")

Nucleon Structure is modified due to Hadronic effects

- More detailed binding calculations: Fermi motion + binding+ N-N correlations
- Nuclear pions

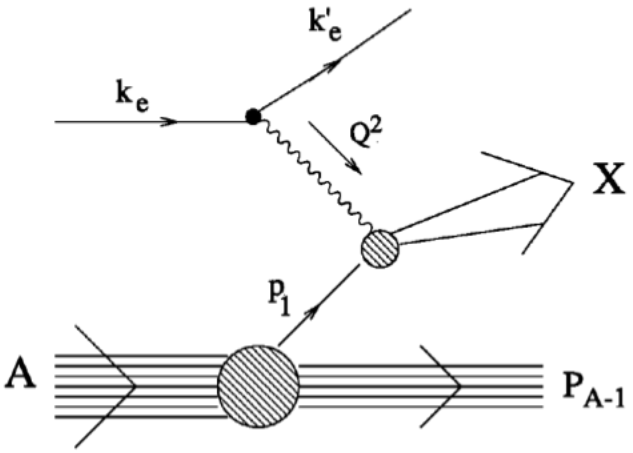
Many models but no complete and accepted picture that is consistent with other data (e.g. Drell-Yan)

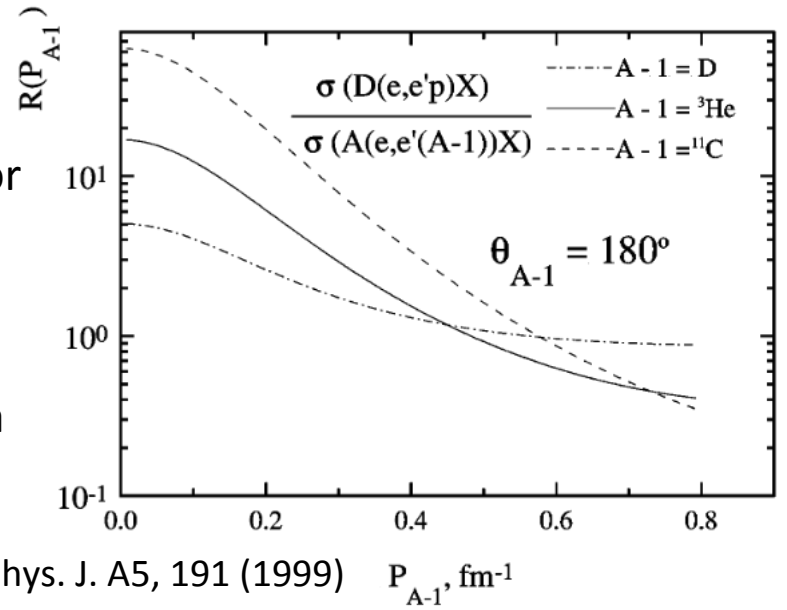
The Spectator Mechanism

- **Plane Wave Impulse Approximation, no FSI**
  - low momunetum p_1, A-1

- **Spectator recoil nucleon**
  - –Part of the nuclei that do not interact with the virtual photon and other hadronic products of the reaction
  - –Necessary to control final state interactions with hadrons produced and nucleon knocked out
  - –Need to select the right kinematic (usually backward and moderate momentum)
  - –Used by the BoNuS experiment successfully for neutron PDF

- **Spectator recoil nuclei**
  - –The integrity of the recoil nuclei gives an extra guarantee against FSI
  - –But reduced at high momentum
    - –C. Ciofi degli Atti, L. P. Kaptari, and S. Scopetta, Eur. Phys. J. A5, 191 (1999)

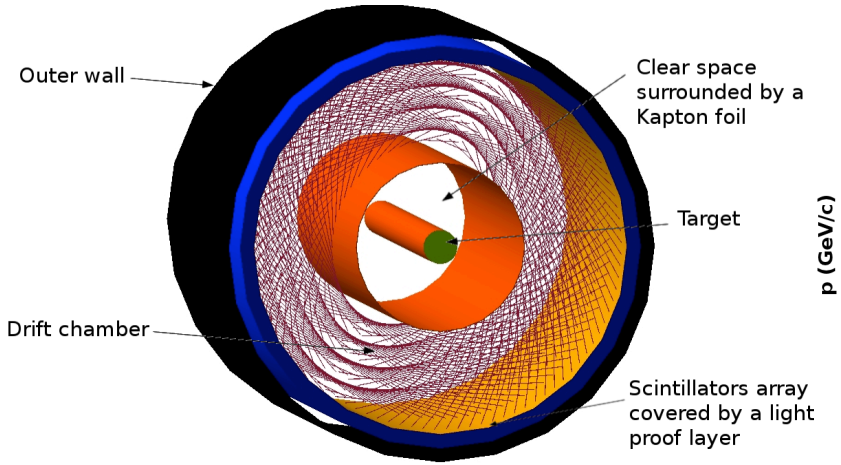




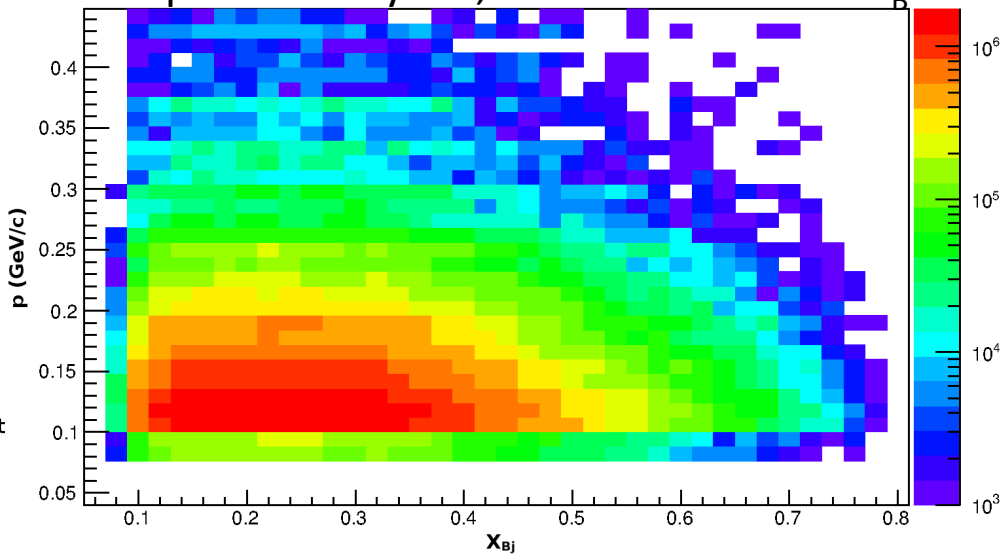
ALERT Beam Time Request

Measurements	Particles detected	Targets	Beam time request	Luminosity*
ALERT Commissioning	p, d, ^{4}He	H and He	5 days	Various
Tagged EMC	p, ^{3}H, ^{3}He	^{2}H and He	20 + 20 days	3.10^{34} cm^{-2}s^{-1}
Tagged DVCS	p, ^{3}H, ^{3}He	^{2}H and He	20 + 20 days	3.10^{34} cm^{-2}s^{-1}
Nuclear GPDs	^{4}He	He	extra 10 days on He	6.10^{34} cm^{-2}s^{-1}
Additional Topics	p, d, ^{3}H, ^{3}He	^{2}H and He	20 + 20 + (10) days	$3(6).10^{34}$ cm^{-2}s^{-1}
TOTAL			**55 days**	

11 GeV



Expect event yield, ^{3}H momentum vs x_B



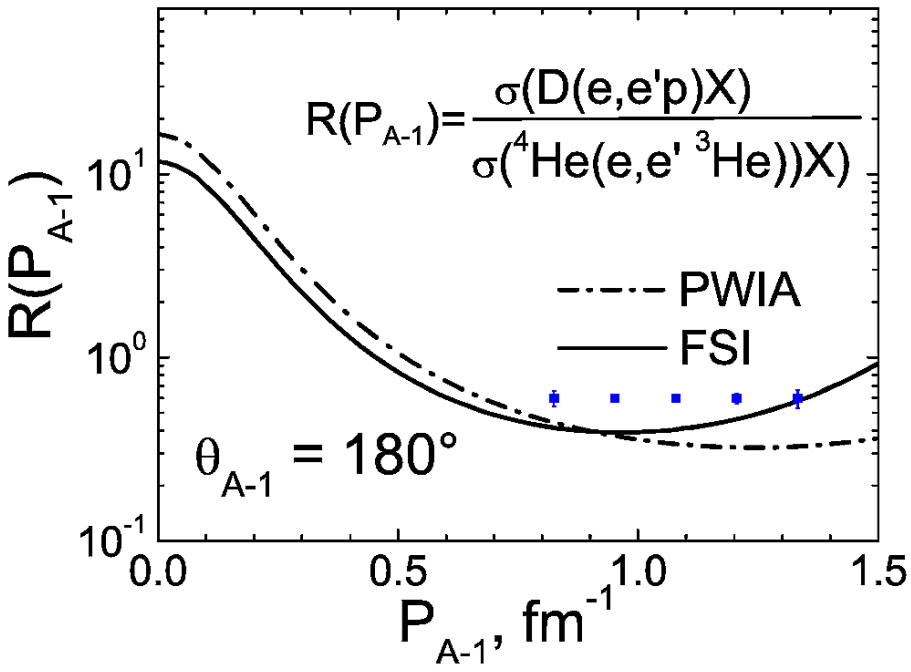
Testing the Spectator Model and FSI Effects

• Can be tested on a large spectrum with very good precision

–Comparison of Helium and Deuterium targets

– measured at same values of x and Q^2 and recoil (A-1) momentum

–The A dependence of R is entirely dominated by the A dependence of the nucleon momentum distribution, which is strong at low momenta and fairly well-known

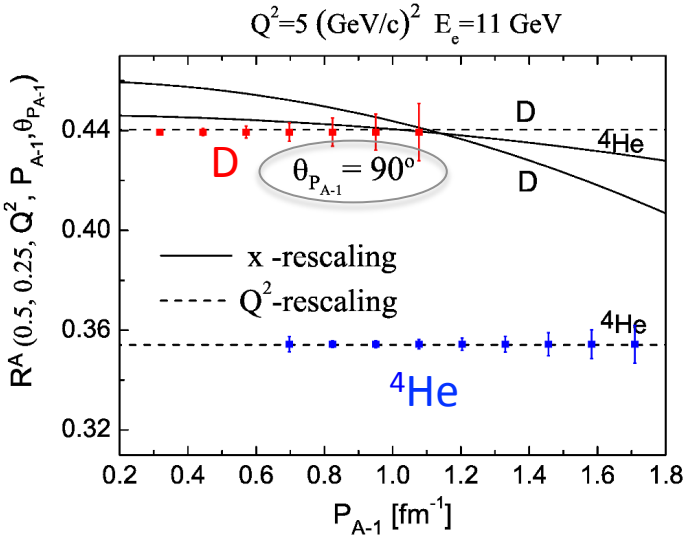


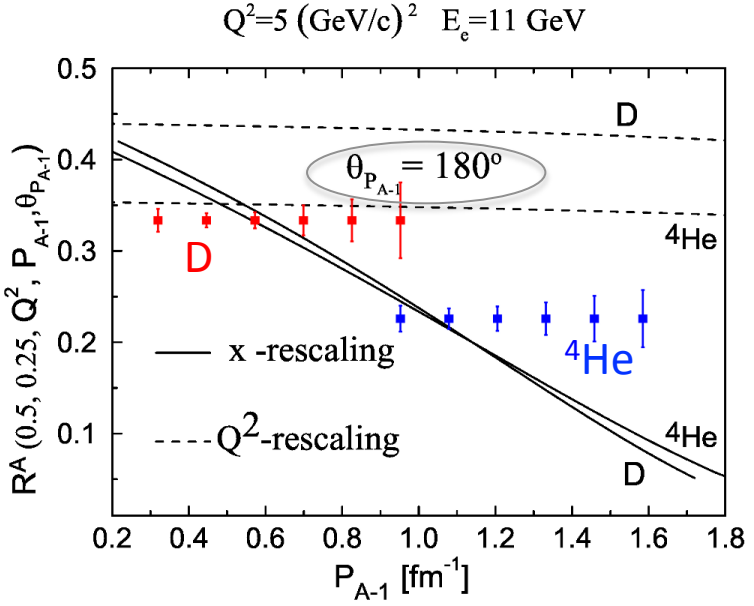
$$R(x,Q^2,|\vec{P}_{A-1}|,{}^2H,{}^4He) \equiv R(|\vec{P}_{A-1}|) \approx \frac{n_0^D(|\vec{P}_{A-1}|)}{n_0^{^4He}(|\vec{P}_{A-1}|)}$$

–C. Ciofi degli Atti, L. P. Kaptari, and S. Scopetta, Eur. Phys. J. A5, 191 (1999)

Rescaling x or Q^2?

- **Rescaling models**
  - –Impossible to differentiate x and Q^2 rescaling with inclusive measurements but gives strong signature with semi-inclusive
    - –Measure cross sections for same-A and recoil momentum, but different x
  - –Comparison of D to ^{4}He is particularly interesting, no isospin issues but already strong EMC effect!
  - –We will be able to give clear confirmation or exclusion for these models





$$R(x,x',z,Q^2)=\frac{x'}{x}\frac{F_2^{N/A}(x/z^A,Q^2)}{F_2^{N/A}(x'/z^A,Q^2)}$$

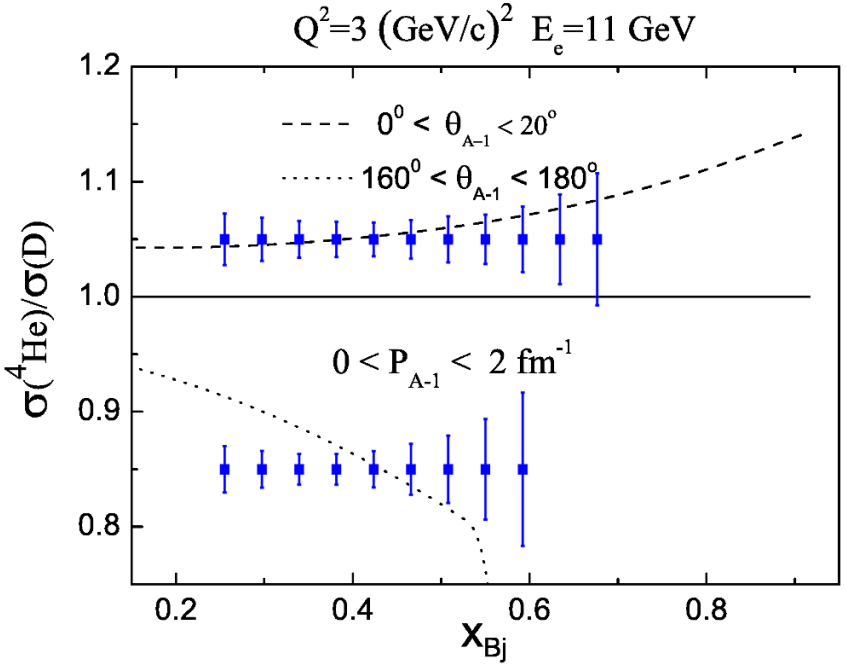
For x-rescaling, R depend on $P_{(A-1)}$

$$R(x,x',Q^2)=\frac{x'}{x}\frac{F_2^{N/A}(x,\xi_A(Q^2))}{F_2^{N/A}(x',\xi_A(Q^2))}$$

For Q^2-rescaling, R independent of $P_{(A-1)}$

–C. Ciofi degli Atti, L. P. Kaptari, and S. Scopetta, Eur. Phys. J. A5, 191 (1999)

Local EMC Model



- **EMC effect due to local conditions and offshellness of the nucleon**
  - In this model EMC effect is due to the cancellation of much larger effects that can be separated with spectator detection
    - slope of the ratio of structure functions is generated by the average value of the nucleon removal energy <E>
  - Separate the contribution between weakly and deeply bound nucleons
  - We will be able to give clear confirmation or exclusion for this model

  - C. Ciofi degli Atti, L. P. Kaptari, and S. Scopetta, Eur. Phys. J. A5, 191 (1999)

Summary

- New ALERT Run Group
  - Comprehensive physics program on structure of ^{4}He
  - Proposals submitted to PAC 44 covering SIDIS, DVCS, DVMP
    - Proposed Tagged-EMC measurements on ^{4}He/D_2
      - part of next-generation studies into EMC effect, over large range of kinematics, to isolate FSI effects, offshellness, x_B/Q^2-rescaling
  - New ALERT Recoil Detector development in progress
    - drift chamber + scintillators for triggering, tracking, nuclear PID