ALERT - A Low Energy Recoil Tracker

EIC nuclear physics before the EIC

Whitney R. Armstrong

Argonne National Laboratory

June 1, 2017

1. ALERT Run Group's Proposed Measurements
   - "Nuclear Exclusive and Semi-inclusive Measurements with a New CLAS12 Low Energy Recoil Tracker"
2. Why ALERT?
3. The ALERT Detector
   - ALERT Design
4. Studying pions and kaons with ALERT

The ALERT Experiments

A comprehensive program to study nuclear effects

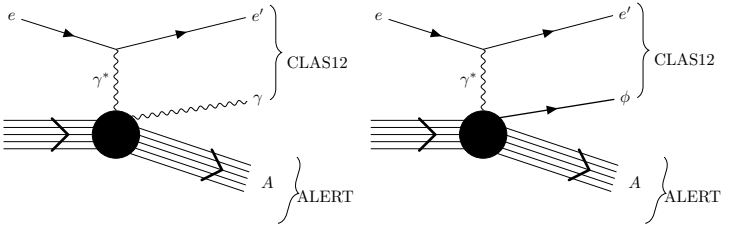
The ALERT Experiments

A comprehensive program to study nuclear effects

Coherent Processes on ^{4}He

- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \gamma)$
- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \phi)$

Explores the partonic structure of ^{4}He



The ALERT Experiments

A comprehensive program to study nuclear effects

Coherent Processes on ^{4}He

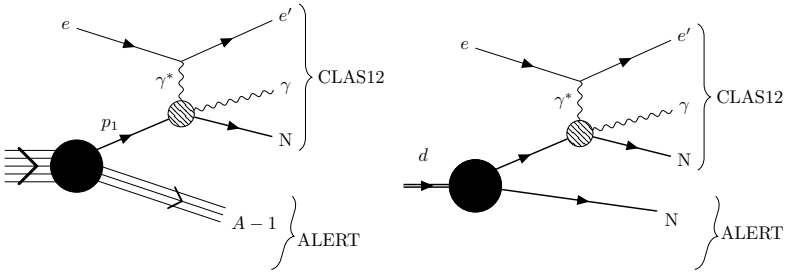
- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \gamma)$
- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \phi)$

Explores the partonic structure of ^{4}He

Incoherent processes on ^{4}He and ^{2}H

- $^4\mathrm{He}(e, e'\gamma\, p{+}^3\mathrm{H})$
- $^4\mathrm{He}(e, e'\gamma + {}^3\mathrm{He})\mathrm{n}$
- $^2\mathrm{H}(e, e'\gamma + p)n$

Identify medium modified nucleons



The ALERT Experiments

A comprehensive program to study nuclear effects

Coherent Processes on ^{4}He

- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \gamma)$
- $^4\mathrm{He}(e, e'\ ^4\mathrm{He}\ \phi)$

Explores the partonic structure of ^{4}He

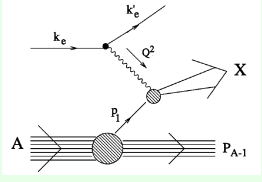
Incoherent processes on ^{4}He and ^{2}H

- $^4\mathrm{He}(e, e'\gamma\, p{+}^3\mathrm{H})$
- $^4\mathrm{He}(e, e'\gamma + {}^3\mathrm{He})\mathrm{n}$
- $^2\mathrm{H}(e, e'\gamma + p)n$

Identify medium modified nucleons

DIS on ^{4}He and ^{2}H : Tagged EMC Effect

- $^4\mathrm{He}(e, e'{+}^3\mathrm{H})\mathrm{X}$ (DIS on proton)
- $^4\mathrm{He}(e, e'{+}^3\mathrm{He})\mathrm{X}$ (DIS on neutron)
- $^2\mathrm{H}(e, e' + p)\mathrm{X}$ (DIS on neutron)



Test FSI and rescaling models

And many more channels for free

Nuclear Physics and the ~~Nucleon~~ α Particle

From the first textbook on Nuclear Physics

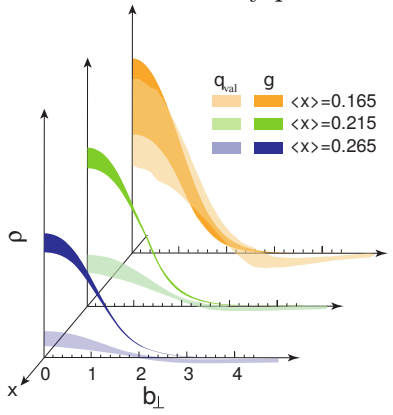
"The general evidence on nuclei strongly supports the view that **the α particle is of primary importance as a unit of the structure of nuclei** in general and particularly of the heavier elements. It seems very possible that the greater part of the mass of heavy nuclei is due to **α particles which have an independent existence in the nuclear structure**."

— Rutherford, Chadwick, and Ellis (1930)

Note: this is roughly 2 years before the discovery of the neutron.

ALERT Nuclear GPD projected results

Transverse density profiles

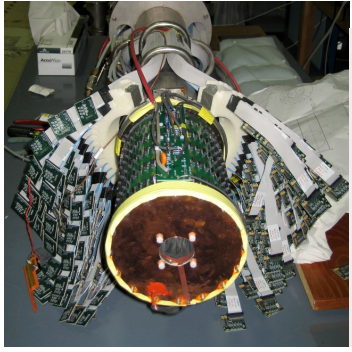


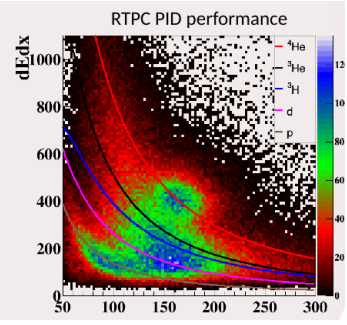
- Extract **quark and gluon radii!**
- Significant impact on EIC physics

Why ALERT?

A new detector is needed

- Existing and proposed detectors (RTPCs) do not meet experimental needs

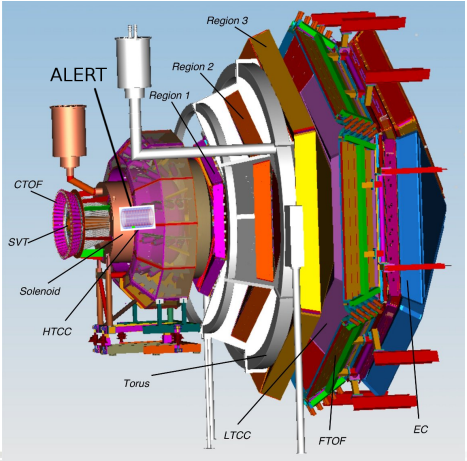




- Designed to operate in CLAS12 5 T field
- Runs at **CLAS12 luminosity limit** and **Hall-B beam current limit**
- PID of ions from protons to ^{4}He
- Independent trigger (can be adjusted to operate with higher luminosities).

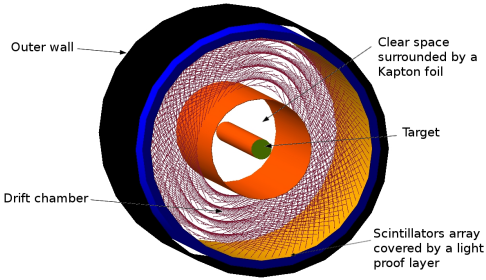
Proposed Setup: CLAS12 + ALERT

- Use CLAS12 to detect scattered electron, e', and forward scattered hadrons.
- A low energy recoil tracker (ALERT) will detect the spectator recoil or coherently scattered nucleus



ALERT requirements

- Identify light ions: H, ^{2}H, ^{3}H, ^{3}He, and ^{4}He
- Detect the **lowest momentum** possible (close to beamline)
- Handle **high rates**
- Provide **independent trigger**
- Survive high radiation environment
  $\rightarrow$ **high luminosity**



ALERT Design

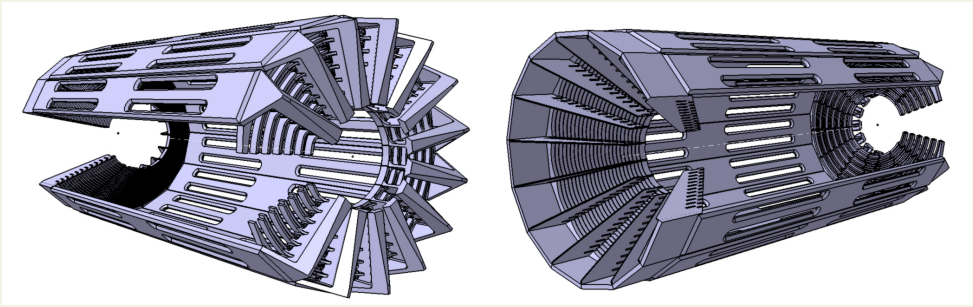
Basic Design

- Detector will surround a ∼3 atm gas target cell which is 6 mm in radius and constructed with 25 μm kapton walls
- Hyperbolic drift chamber with 10° stereo angle.
- Outer scintillator hodoscope for PID

Drift Chamber Design

- 2 mm wire separation
- 10° stereo angle
- Minimize material (windows/walls)
- Detects $\theta \sim 30°$ to 170°

Ongoing work led by IPN Orsay



ALERT Design

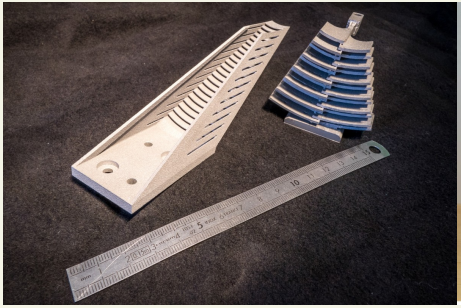
Basic Design

- Detector will surround a ∼3 atm gas target cell which is 6 mm in radius and constructed with 25 μm kapton walls
- Hyperbolic drift chamber with 10° stereo angle.
- Outer scintillator hodoscope for PID

Drift Chamber Design

- 2 mm wire separation
- 10° stereo angle
- Minimize material (windows/walls)
- Detects $\theta \sim 30°$ to 170°

Ongoing work led by IPN Orsay



ALERT Design

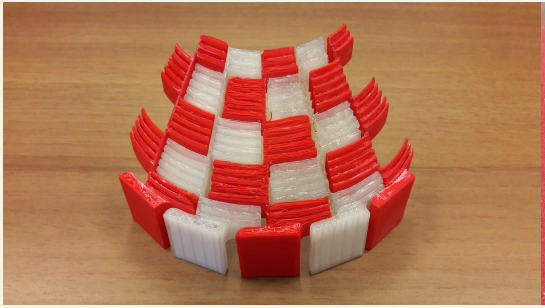
Basic Design

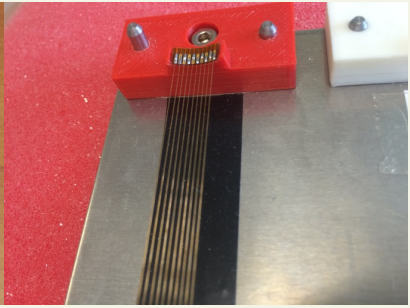
- Detector will surround a ∼3 atm gas target cell which is 6 mm in radius and constructed with 25 μm kapton walls
- Hyperbolic drift chamber with 10° stereo angle.
- Outer scintillator hodoscope for PID

Drift Chamber Design

- 2 mm wire separation
- 10° stereo angle
- Minimize material (windows/walls)
- Detects $\theta \sim 30°$ to 170°

Ongoing work led by IPN Orsay

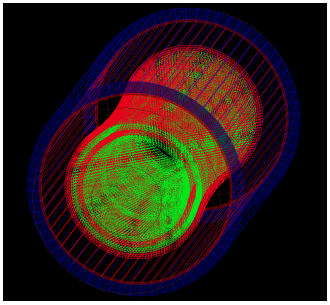




ALERT Design

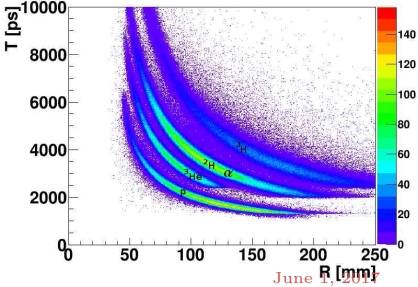
Scintillator Hodoscope Design

- 2 cylindrical layers ∼30 cm long
  - Inner thin strips - 2 mm × 9 mm × 30 cm w/ SiPM at each end
  - Outer thick wedges - 2 cm × 9 mm × 3 cm w/ SiPM on outer surface
    Segmented along beam axis (10 wedges per inner strip)
- Good time resolution → need fast scint, fast SiPMs with good resolution, and small segmentation of scintillator cells.
- ^{4}He and ^{3}He dominate the signals coming from inner layer
- ^{1}H, ^{2}H, and ^{3}H will typically make it to the second layer depositing most of their energy.

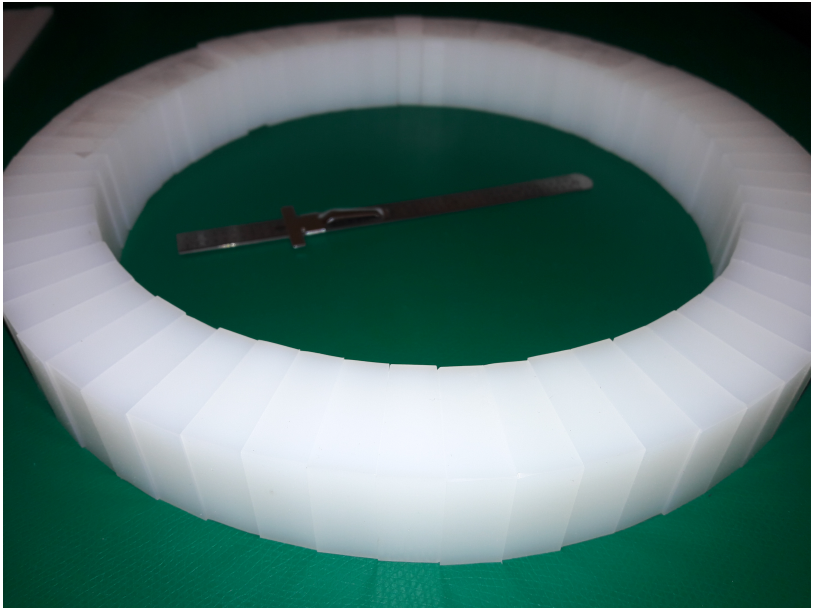


Basic Operating Principles

- By design, ALERT is blind to minimum-ionizing particles (where the threshold can be tuned through the gas or electronically)
- For coherent processes where the cross sections are low, so we will compensate by running at the highest possible luminosity with a high threshold, hence, we will cut out all the high energy particles.



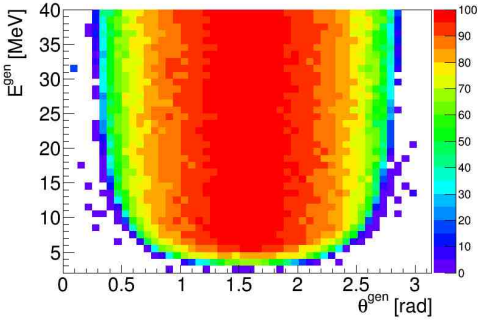
Scintillator

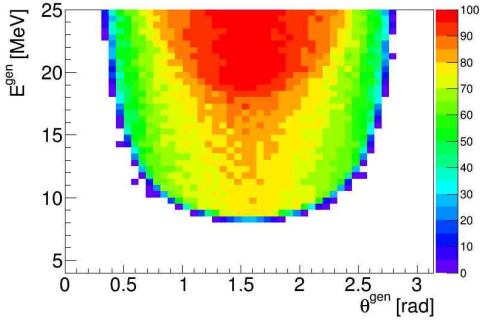


ALERT Simulation

Full Geant4 Simulation

- Acceptances minimum momenta: 70 MeV/c for protons, 240 MeV/c for ^{4}He

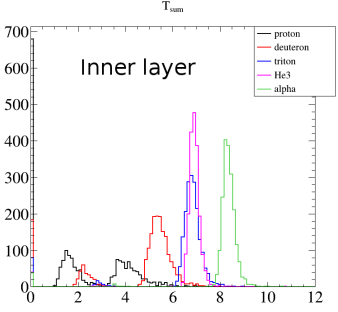


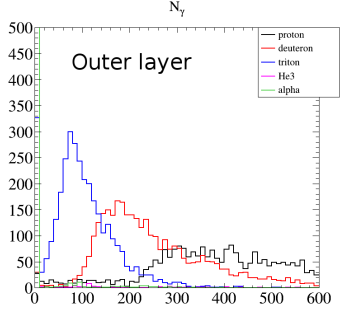


ALERT Simulation

Full Geant4 Simulation

- Acceptances minimum momenta: 70 MeV/c for protons, 240 MeV/c for ^{4}He
- Detailed scintillator photon yields and timing information → optimize geometry to provide the best PID

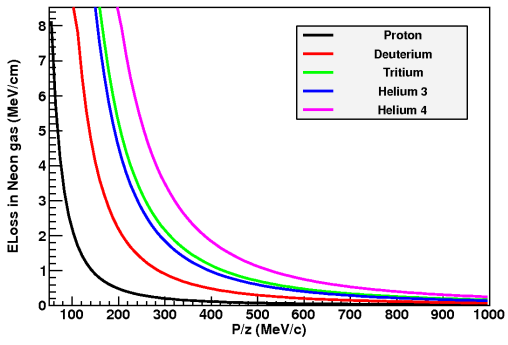


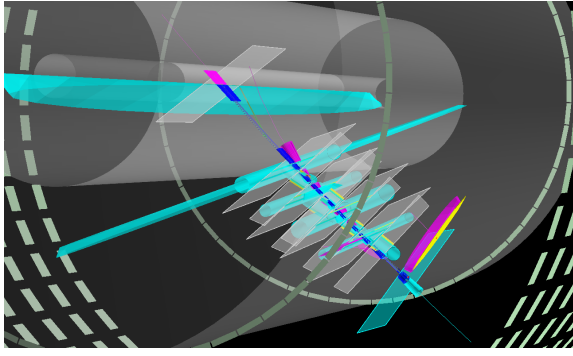


ALERT Simulation

Full Geant4 Simulation

- Acceptances minimum momenta: 70 MeV/c for protons, 240 MeV/c for ^{4}He
- Detailed scintillator photon yields and timing information → optimize geometry to provide the best PID
- Working on Kalman Filter based track reconstruction → optimize DC wire layout; Also get track dE/dx for PID

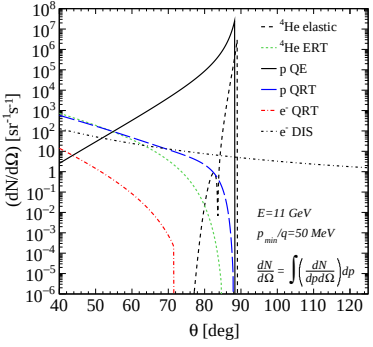


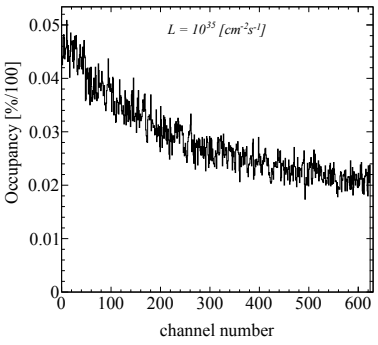


ALERT Simulation

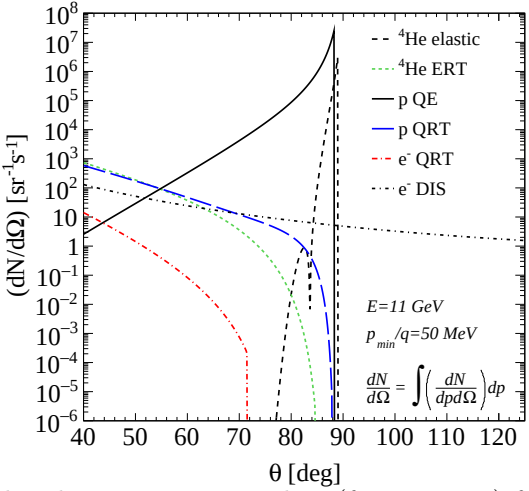
Full Geant4 Simulation

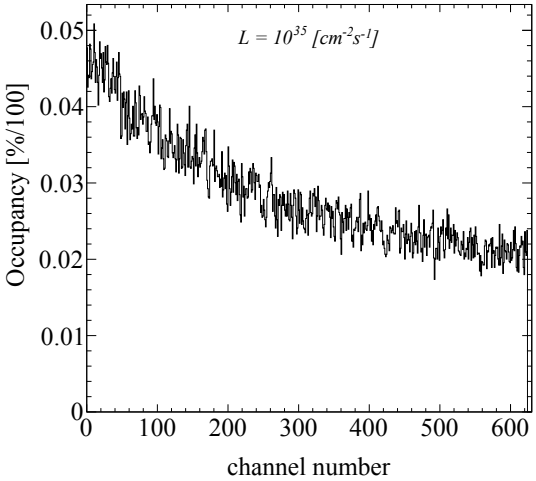
- Acceptances minimum momenta: 70 MeV/c for protons, 240 MeV/c for ^{4}He
- Detailed scintillator photon yields and timing information → optimize geometry to provide the best PID
- Working on Kalman Filter based track reconstruction → optimize DC wire layout; Also get track dE/dx for PID
- DC hit occupancies simulated - can operate comfortably at nominal CLAS12 luminosity





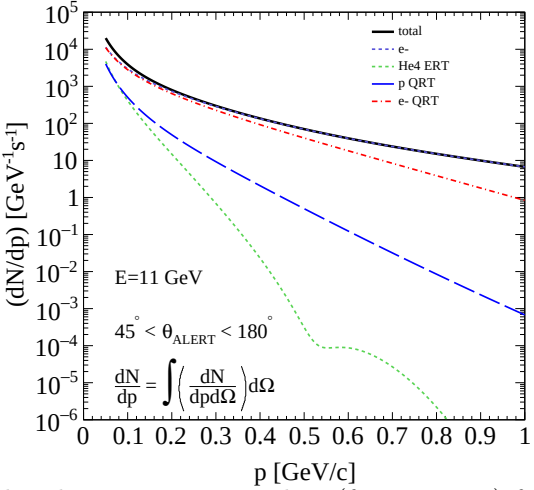
Rates

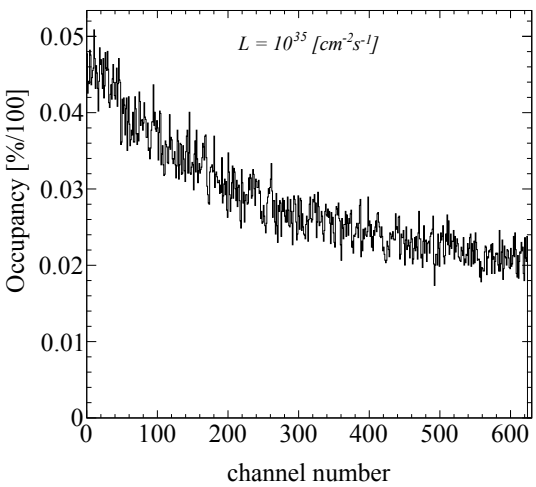




Need to keep occupancies low (few percent) for efficient reconstruction.

Rates





Need to keep occupancies low (few percent) for efficient reconstruction.

Conclusion

Studying pions and kaons with ALERT

TDIS Experiment

- Using RTPC similar to CLAS eg6
- Need to handle high rates and occupancies.
- Limited PID for targets with $A > 2$.

ALERT Detector

- ALERT is the high rate alternative to RTPCs
- ALERT will have better PID, time resolution, tracking efficiency, and provide flexible trigger.

Using ALERT outside of CLAS12

- Pion and Kaon structure function with light nuclear targets
- Tagged Λs or Σs (and hyper-nuclear effects)
- Adding an outer spectator neutron detector.

All interesting physics requires pushing operational luminosities higher.