

Assemblée Générale du GDR DI2I

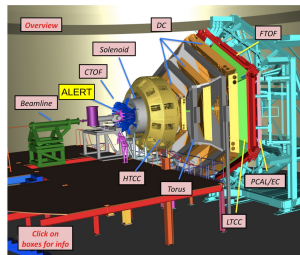
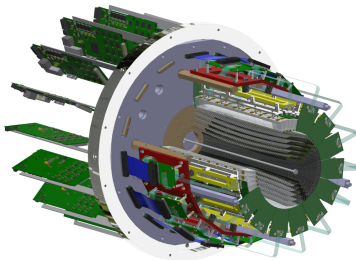
The ALERT Drift Chamber at Jefferson Lab

Felix Touchte Codjo

IJCLab

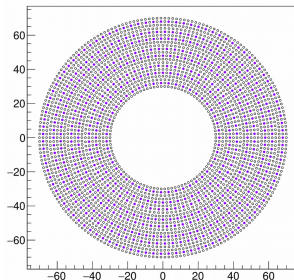
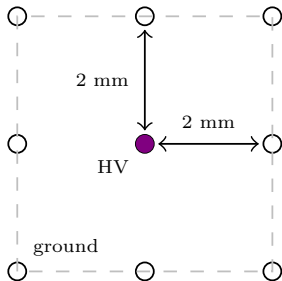
June 18, 2026

- ▶ A requirement for a new physics program at Jefferson Lab
 - physics process of interest: $eN \rightarrow eX\gamma$
 - need to detect recoil fragments X : p, d, H^3 , He^3 , He^4
 - kinematics range of interest: $70 < p < 400 \text{ MeV/c}$, $\theta > 45^\circ$
 - the default CLAS12 setup can only detect particles with $p > 250 \text{ MeV/c}$ ¹
- ▶ We needed **A** (new) **L**ow **E**nergy **R**ecoil **T**racker
- ▶ The detector had to be placed at the center of the 5T solenoid
- ▶ Drift Chamber (IJCLab) + Time-Of-Flight (ANL)

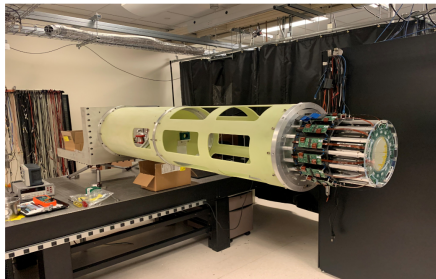
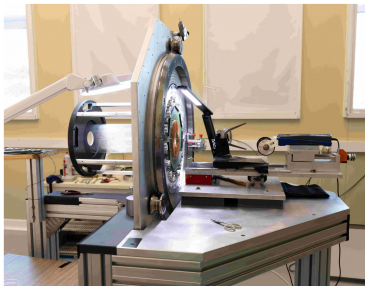


¹ $p = 250 \text{ MeV/c} \leftrightarrow E_c \sim 31.25 \text{ MeV}$ for a proton

- ▶ Cylindrical wire chamber filled with He4/CO₂ (80/20)
- ▶ Novelty :
 - All wires have the same $\varnothing$, 30 μm , and AlMg5 material
 - Total of 3026 wires, 576 are readouts with positive charge
 - Superlayer structure : 3-5-5-5-3, resulting in 8 detection layers
 - It has stereo angles varying from 3.8° to 7.4° between superlayers for the v_z reconstruction
- ▶ Use the DREAM electronics developed at CEA

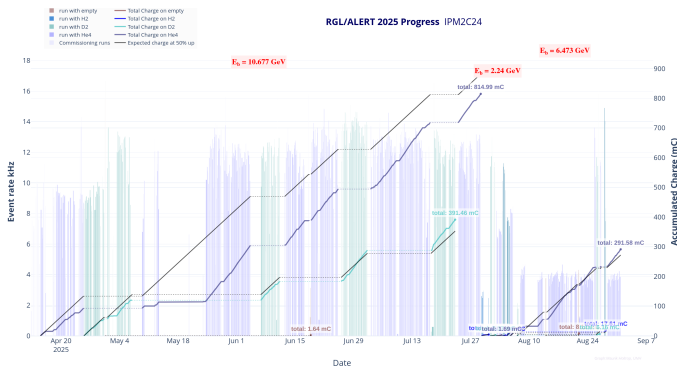


- ▶ Assembly time : 3 months (last wire mounted on March 1, 2024 ²)
- ▶ AHDC fully assembled in IJCLab and transported to JLab by plane without any issue

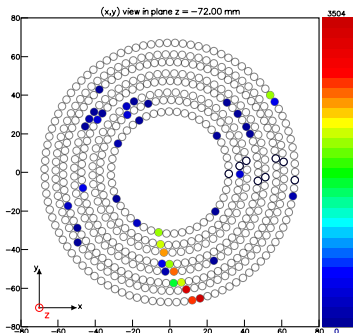


²My first day at IJCLab

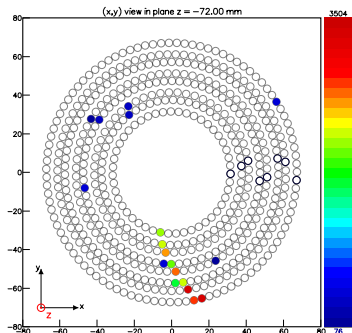
- ▶ The detector ran successfully during 5 months of data taking (from April 2025 to September 2025)
 - HV $\sim$ 1400-1500 V
 - Event rate $\sim$ 10 kHz
 - 6.42×10^{10} trigger events collected
 - beam current up to 325 nA
 - nb. samples per WF : 20
 - sampling window $\sim$ 1 μ s
- ▶ Ongoing work : software development and data calibration



- ▶ First step of the AHDC reconstruction software
- ▶ On average, we have 20-40 % occupancy on the first layer of the AHDC
- ▶ The noise presents a clear pattern that make it possible to classify hits into 7 categories (wfType 6 to 0)
- ▶ Good hits are those with $\text{wfType} \leq 2$ and within a calibrated time window



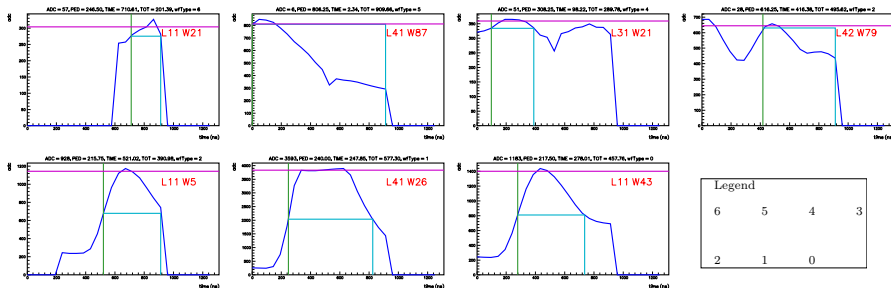
(a) All hits



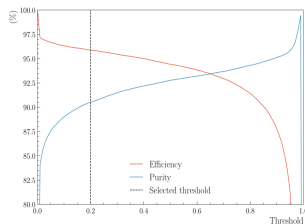
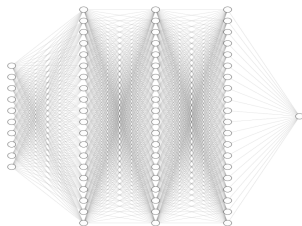
(b) Only hits passing the selection cuts

Figure: Typical event display in the AHDC

- ▶ We consider that good hits have $wfType \leq 2$
 - $wfType$ 6 $\rightarrow$ too short ($nsamples \leq 10$)
 - $wfType$ 5 $\rightarrow$ decreasing baseline
 - $wfType$ 4 $\rightarrow$ bad ToT ($ToT < 300$)
 - $wfType$ 3 $\rightarrow$ pileup but classified as 2
 - $wfType$ 2 $\rightarrow$ bad trailingEdgeTime
 - $wfType$ 1 $\rightarrow$ saturating
 - $wfType$ 0 $\rightarrow$ OK
- ▶ The occupancy drops at 7 % in the first layer
- ▶ Additional cuts based on the calibrated times are added before entering the Track Finder

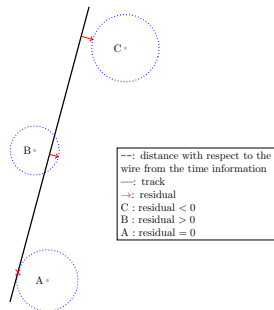
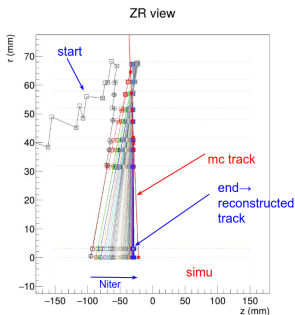
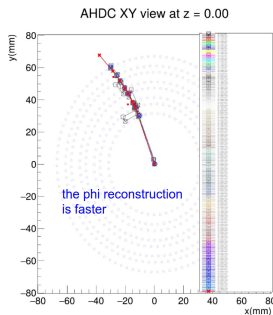


- ▶ Clustering problem: find which collection of hits belong to a track
- ▶ Machine Learning approaches ³ based on MultiLayer Perceptron and Graph Neural Network are currently used
- ▶ The MLP infrastructure
 - Inputs : X,Y coordinates of a set of hits
 - Output : 0/1 (bad/good) track
- ▶ The training is done on simulation
- ▶ Performance on real data: 96% efficiency and 90% purity for a 0.2 threshold

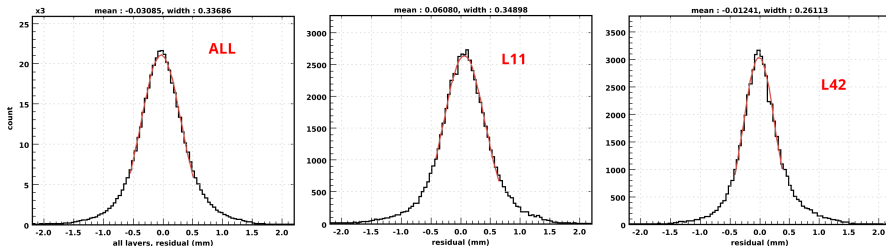


³Work by Mathieu Ouillon, see [GDR DI2I 2025](#)

- ▶ We use the Kalman Filter to reconstruct the initial position and the momentum of the particle $\mathbf{x} = (x, y, z, p_x, p_y, p_z)^T$
 - Prediction : propagate the track towards the next AHDC hit
 - Correction : compute the residual and correct the estimation vector $\hat{\mathbf{x}}$
- ▶ We already have good results whereas fine-tunings remain to be done:
 - Good initialization of the error covariance matrix
 - Precise process and measurement noises
 - Number of iterations and computing time

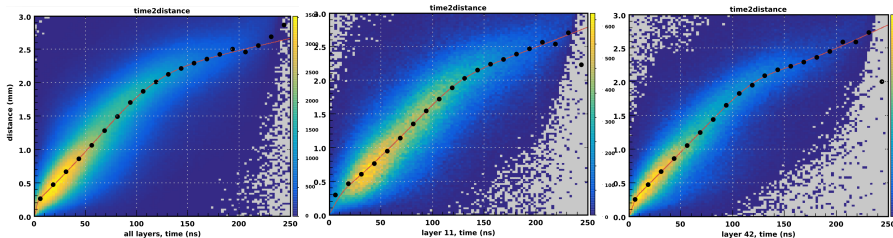


- ▶ The distribution of residuals ⁴ gives an overall indication of the quality of our tracking reconstruction
- ▶ The integrated resolution is about 336 μm
- ▶ However, some layer have a better resolution! E.g. layer 42 has 261 μm
- ▶ This difference between layer is symptomatic of an unfinished calibration



⁴The fit is made with a Crystal Ball distribution, the width is the σ parameter of the Gaussian part

- ▶ Active work on calibration is being done to improve the resolution
- ▶ These plots show the time versus distance distribution
- ▶ Remarks : the T2D vary considerably from one layer to another
- ▶ Room for improvements:
 - new iteration of t_0 calibration
 - T2D layer by layer; wire by wire



- ▶ The tracking algorithm and the calibration are not over, but we are already able to identify particle with the AHDC
- ▶ Better results are expected for ALERT as a whole by combining the information of the drift chamber with the time-of-flight

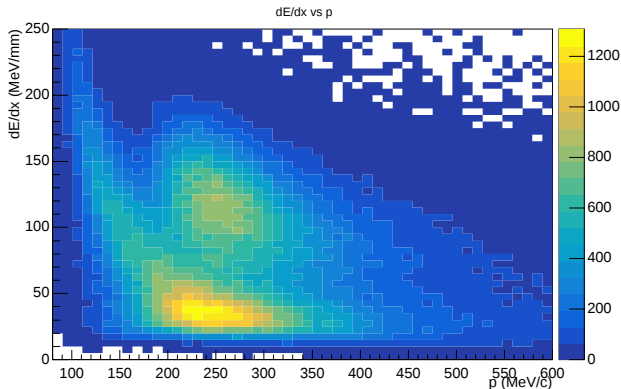


Figure: dE/dx versus p for elastic events: $3.5 < W^2 < 3.8 \text{ GeV}^2$, $|\Delta\Phi| < 20^\circ$, $n_{\text{hits}} \geq 7$, D2 target, Run 22712

- ▶ Developed at IJCLab, the AHDC plays a central role in the realization of the ALERT physics program at Jefferson Lab
- ▶ The detector worked perfectly during the data taking
- ▶ The development of the reconstruction software and the calibration of the data are ongoing
- ▶ A primary particle identification is already possible while better results are expected by the end of the calibration