Development of a new compact and 2D-multiplexed Time Projection Chamber for muon tomography

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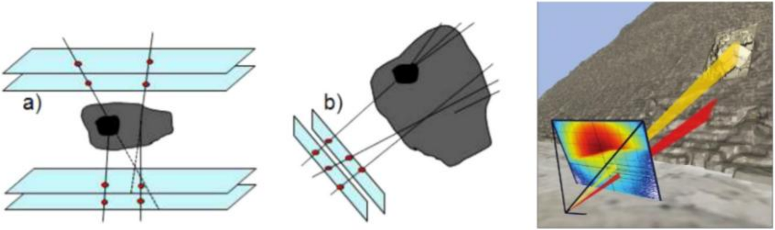
Presentation Overview

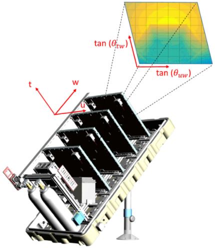
Muon Tomography at CEA Saclay

Before D3DT

Use of cosmic muons to **probe the density of an object** in a non-destructive way.



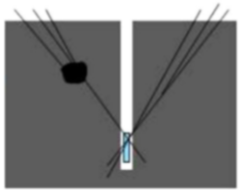
Different modes of the muon tomography: particle deviation (a) and absorption (b)



Muon telescope limitations

- Limited angular acceptance
- Need to operate several detectors
- Compacity

Not suited for probing the underground



New applications: probing the underground

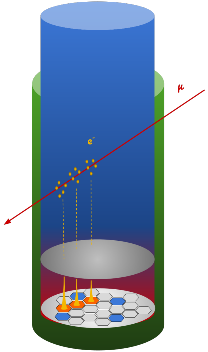
- Civil engineering (prospecting & monitoring)
- Geothermal fields sounding
- Mining exploration

Constraints & Requirements

- **Underground operation:** minimum electric consumption
- Use **existing drilling holes:** Ø < 20 cm
- Almost **2π angular acceptance**
- 3D reconstruction

Technical solution

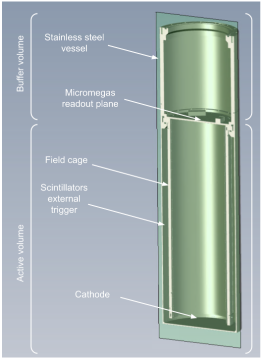
- a cylindrical Time Projection Chamber
- 2D-multiplexed
- 14 cm Ø Micromegas readout plane

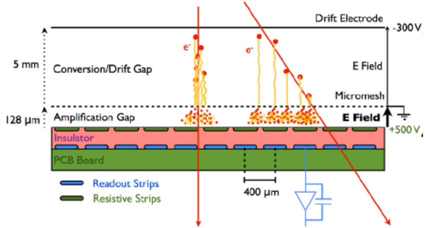


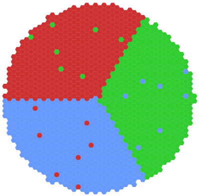
D3DT detector

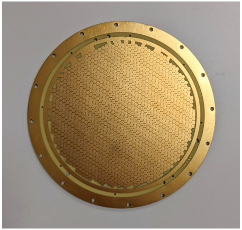
Detector 3D for muonic Tomography

- Funded by **DRF Impulsion**
- **First 2D-multiplexed** TPC
- Mapping generated using **reinforcement learning**
- **14-cm Ø Micromegas** readout plane
- 1344 hexagonal pixels, $\sim$ 3 mm side
- 40-cm double clad field cage
- Scintillators as external trigger
- Gas: Ar-iC_4H_{10}-CF_4 (95:2:3)
- HV: $\sim$ 10 kV on cathode









Feasibility studies with GEANT4 simulations

Simulations conducted using **G4TomoMu** *(developed by H. Gómez and based on GEANT4)*

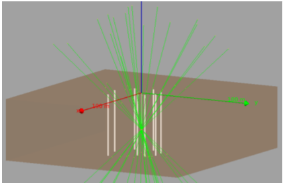
H. Gómez et al 2020 J. Phys.: Conf. Ser. 1498 012047

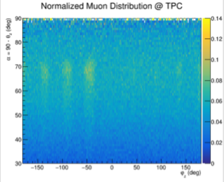
Conditions of simulation:

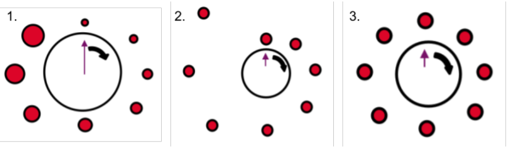
- Detector at a 30 m depth
- 2.2 g/cm^3 uniform soil
- Network of cavities to test multiple parameters

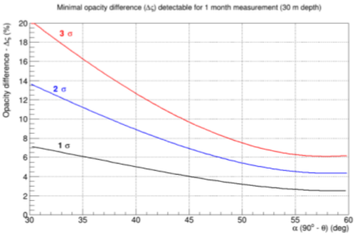
Parameters tested:

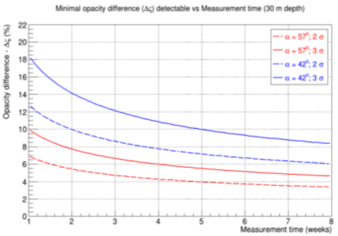
1. Cavity radius
2. Cavity distance
3. Density of filling material





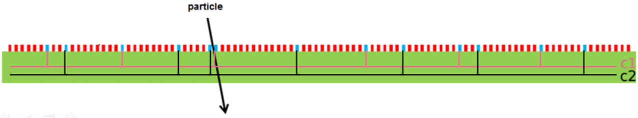




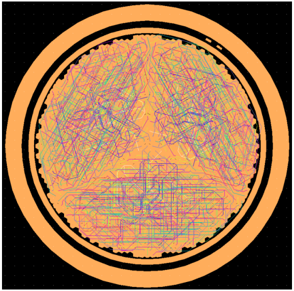


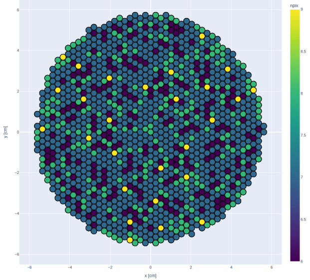
More on the 2D-multiplexing

From **1D genetic multiplexing**:



- Generalized to 2D using **reinforcement learning**
- Each electronic channel is connected to 6-9 physical pixels
- Identical mapping rotated from an asic to another



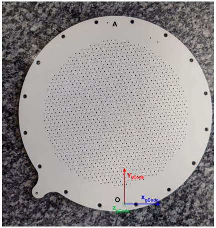


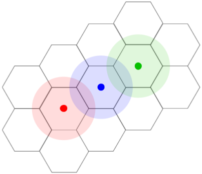
Can such **variations of multiplexing factor affect the uniformity of the detector performances** ?

Objective

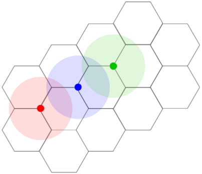
Measure the **detector performances over multiple positions** on the readout plane

- Design cathode to collimate the source/fix positions
  - Center of pixel or intersection of 3 pixels ?
  - What diameter for the collimation hole ?
- Reconstruct the ^{55}Fe energy spectrum for each position

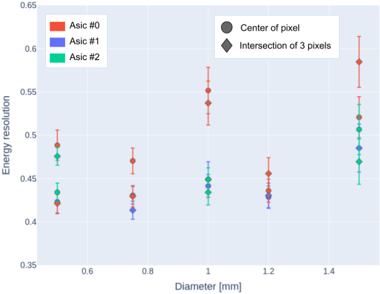


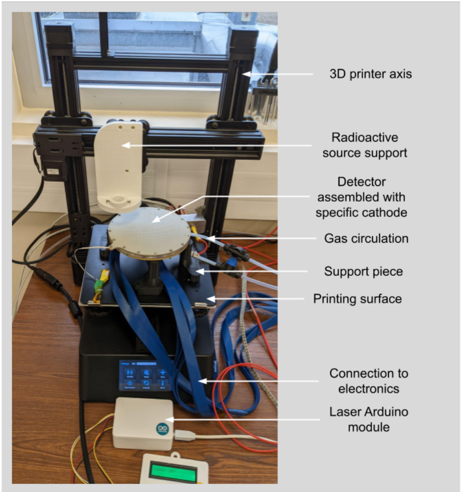


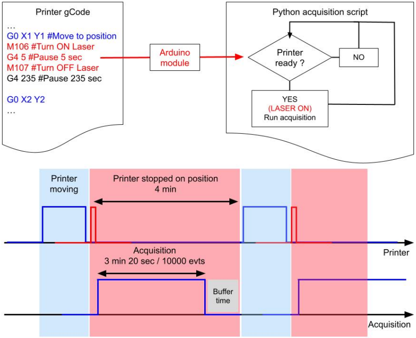
Option A: Center of Pixel (CoP)



Option B: Intersection of 3 Pixels (IoP)



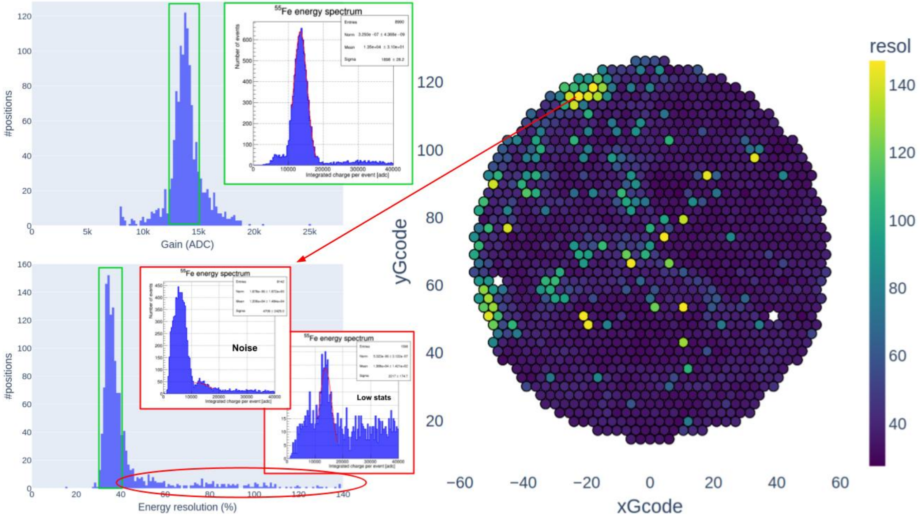


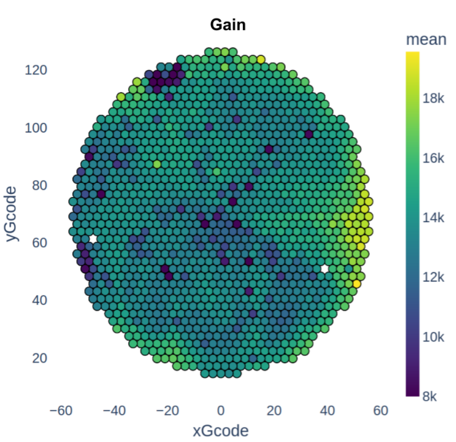


- Automatized acquisition
- Automatized data processing

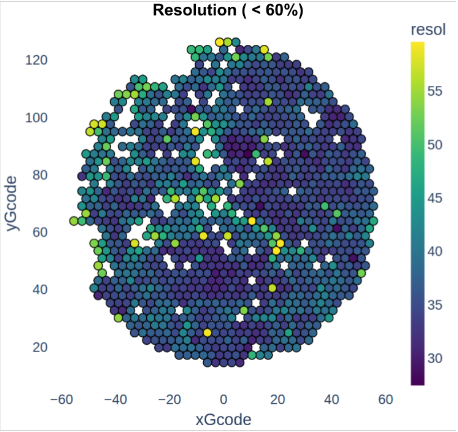
Automatized test bench for local readout plane characterization

Results





Gain
mean
18k
16k
14k
12k
10k
8k
yGcode
120
100
80
60
40
20
−60
−40
−20
0
20
40
60
xGcode



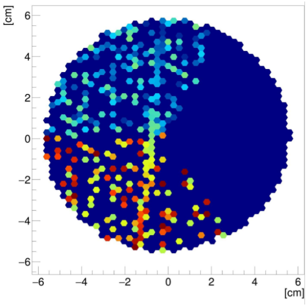
Resolution (< 60%)
resol
55
50
45
40
35
30
yGcode
120
100
80
60
40
20
−60
−40
−20
0
20
40
60
xGcode

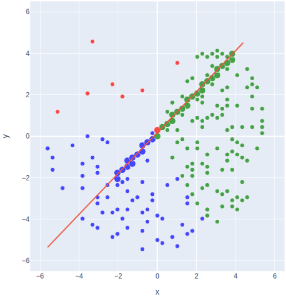
Conclusion & Prospects

- Successful operation of the **first 2D-multiplexed Time Projection Chamber**
- Development of a **new automatized characterization** method for MPGDs
- Allows for validation of Micromegas readout planes

Next steps

- Assembly of full-size prototype with scintillator trigger
- Data taking with full-size prototype
- Ongoing work on **track reconstruction algorithm**



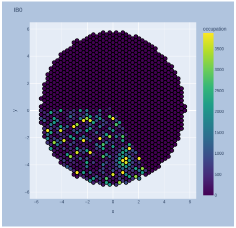


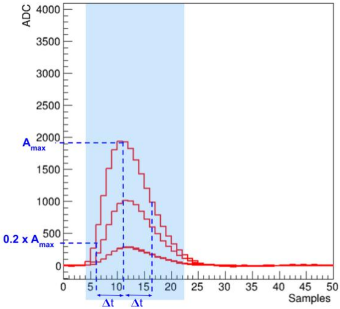
Backup slides

- Iron energy spectrum reconstruction
- Monitoring of meteo conditions during acquisition

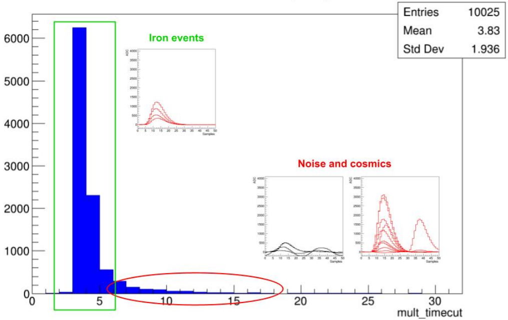
Iron energy spectrum reconstruction

- Estimate charge as integral of waveform
- Integrate charge over padplane
- Apply selection over multiplicity to select iron events





Event multiplicity



Conditions of pressure and temperature