D3DT: an innovative TPC for muon tomography

For the Muographers team

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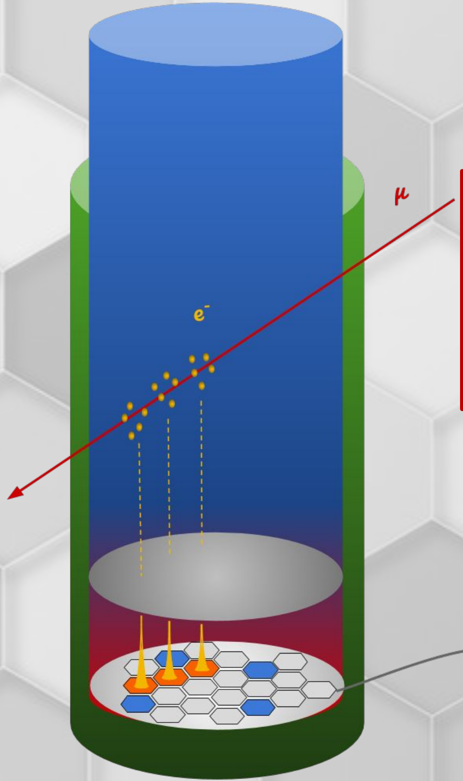

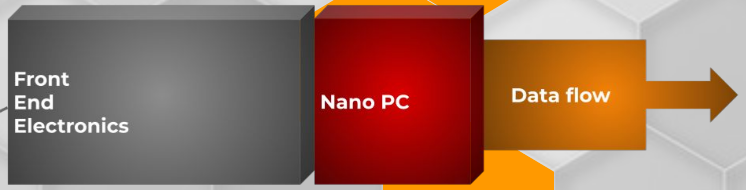

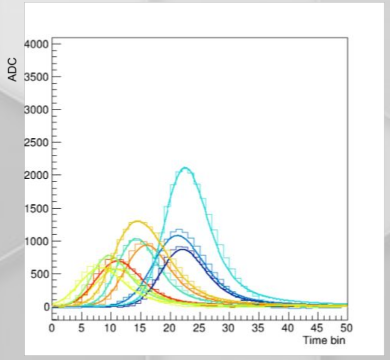

Outline

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- ❑ Muon tomography
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- ❑ First simulations

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- ❑ Description
- ❑ Prototypes and experimental setup
- ❑ Electronics & readout
- ❑ Readout plane characterization

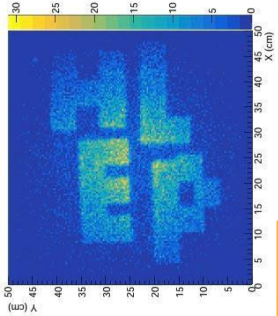
3 First data & track reconstruction

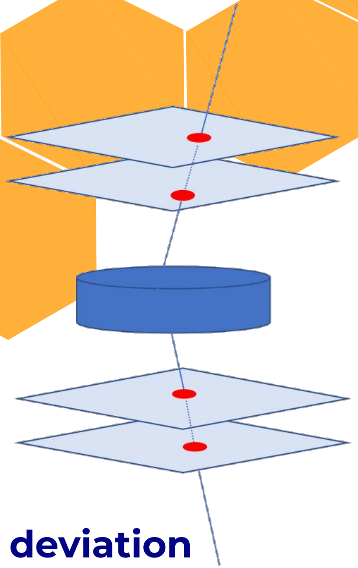
- ❑ First tracks
- ❑ Post processing & Reconstruction algorithms

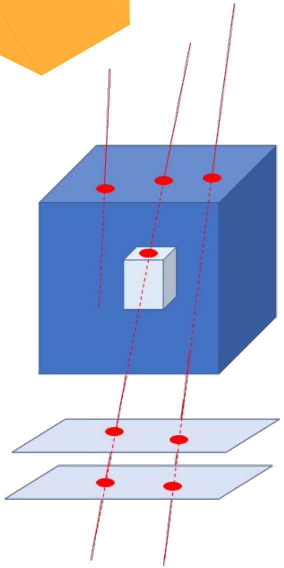
4 Perspectives & conclusion

Muon tomography

Use of atmospheric muons to probe in a non-invasive and non-destructive way the structure of an object.



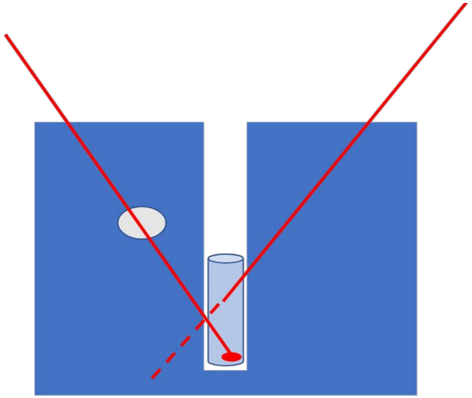




By deviation
(sensitive to the ***deviation angle*** *induced by* ***Coulomb scattering****).*

By transmission
(sensitive to the ***flux variations****, image of the* ***opacity variations****)*

New with D3DT



By transmission *with an improved angular acceptance up to 2π*

Motivations

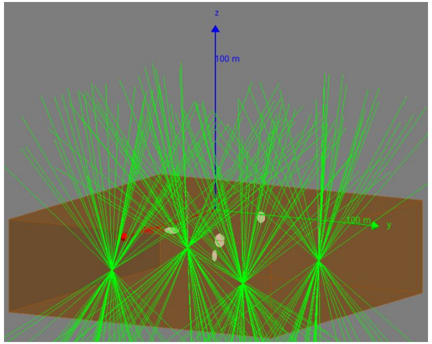
Develop a new instrument for muon tomography that meets specific requirements for new applications.

Characteristics of the new detector : a compact gaseous TPC

- ❑ 3D muon tracking
- ❑ 2π angular acceptance
- ❑ Geometry adapted to reduced spaces *(such as drilling holes)*
- ❑ Possibility to be installed in network

Fields of application

- ❑ Studies of drilling holes and its surroundings
- ❑ Mining exploration
- ❑ Geothermal fields sounding
- ❑ Civil engineering (prospecting & monitoring)

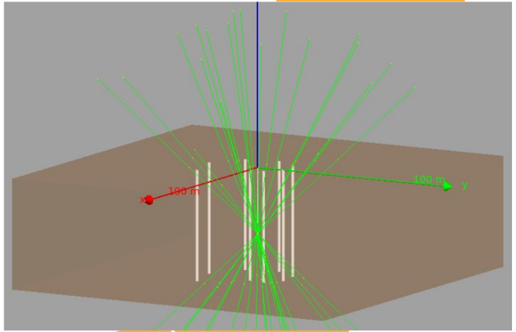


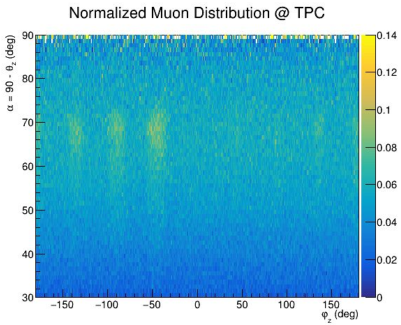
First simulations results

Simulations were conducted using G4TomoMu *(developed by Dr. Héctor Gómez and based on GEANT4 simulation framework).*

Conditions of simulation :

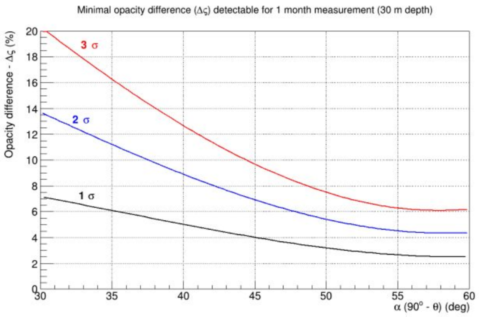
- Detector at 30 m depth
- 2.2 g/cm uniform soil
- Network of cavities to test different parameters in one simulation

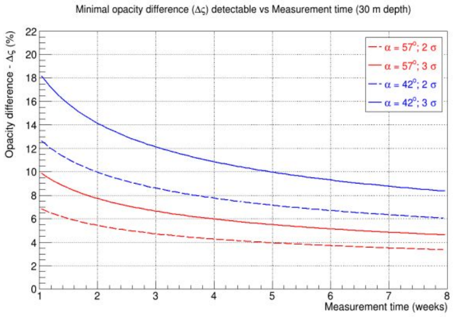


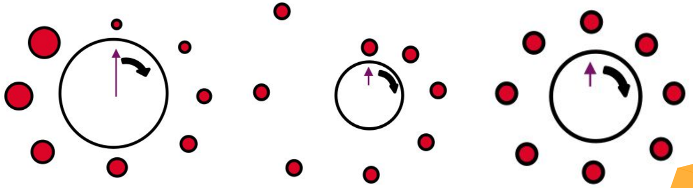


Parameters studied :

1. Diameter of the cavities
2. Distance of the cavities
3. Density of filling material



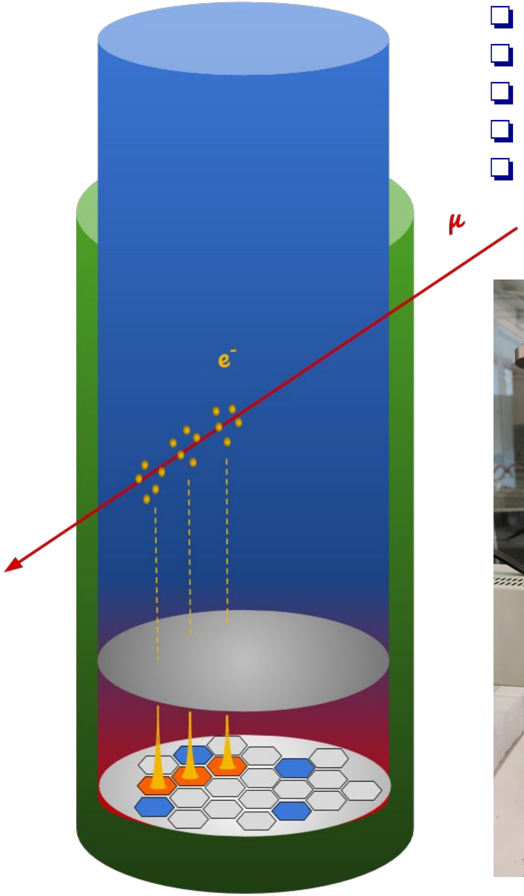




Conclusion : The relevant parameter to determine whether or not a cavity would be detected is actually the opacity difference induced by the cavity.

Description

The detector design & prototypes

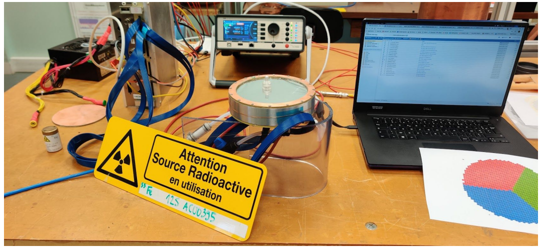


A compact Time Projection Chamber

- 40 cm drift space
- 13 cm ⌀ readout plane
- 18 cm ⌀ (with shielding)
- 10 kV on the cathode
- Double clad field cage

Prototypes

- 3 cm drift cage*
- 20 cm drift cage*
- Full size 40 cm drift cage : test and face assembly and noise issues
- 5mm drift cage : characterize the readout plane without any diffusion effects



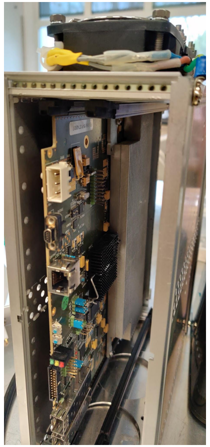
*temporary, waiting for the 40 cm mechanics

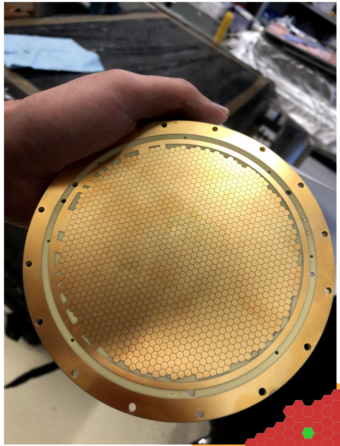
Experimental setup and data-taking conditions :

- Gas : Ar-iC_4H_{10}-CF_4 (95:2:3)
- Peaking time = 283 ns
- Sampling frequency = 125/6 MHz ie. 48 ns/sample

Electronics & readout

In order to minimize the volume occupied by the electronics, the readout plane is 2D-multiplexed allowing to read 1344 pixels using only 192 channels.



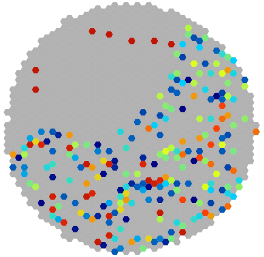


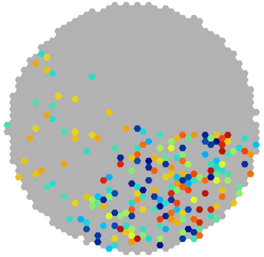
Readout plane characteristics :

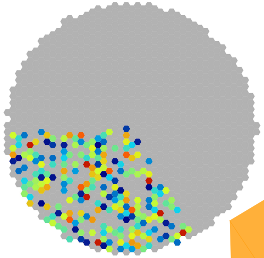
- ❑ Read by a FEU* electronic card
- ❑ Mapping of each sector obtained by rotation
- ❑ Each sector is read by an asic DREAM**
- ❑ Each asic is connected to 64 channels
- ❑ Each channel is connected to 6 to 9 pixels

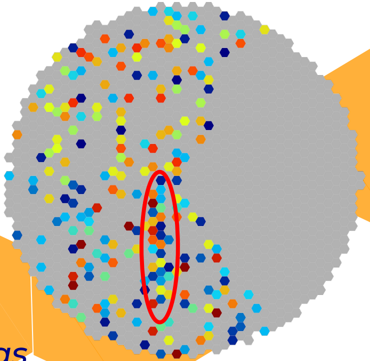
Difficulty for the post processing :

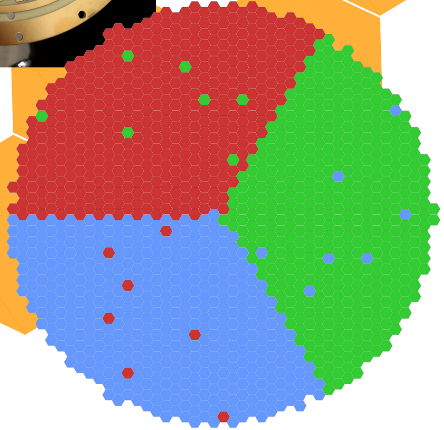
How to reconstruct tracks if 9 pixels light up when only one received charge ?











Channel 16 on each sector

**FEU : Front End Unit*

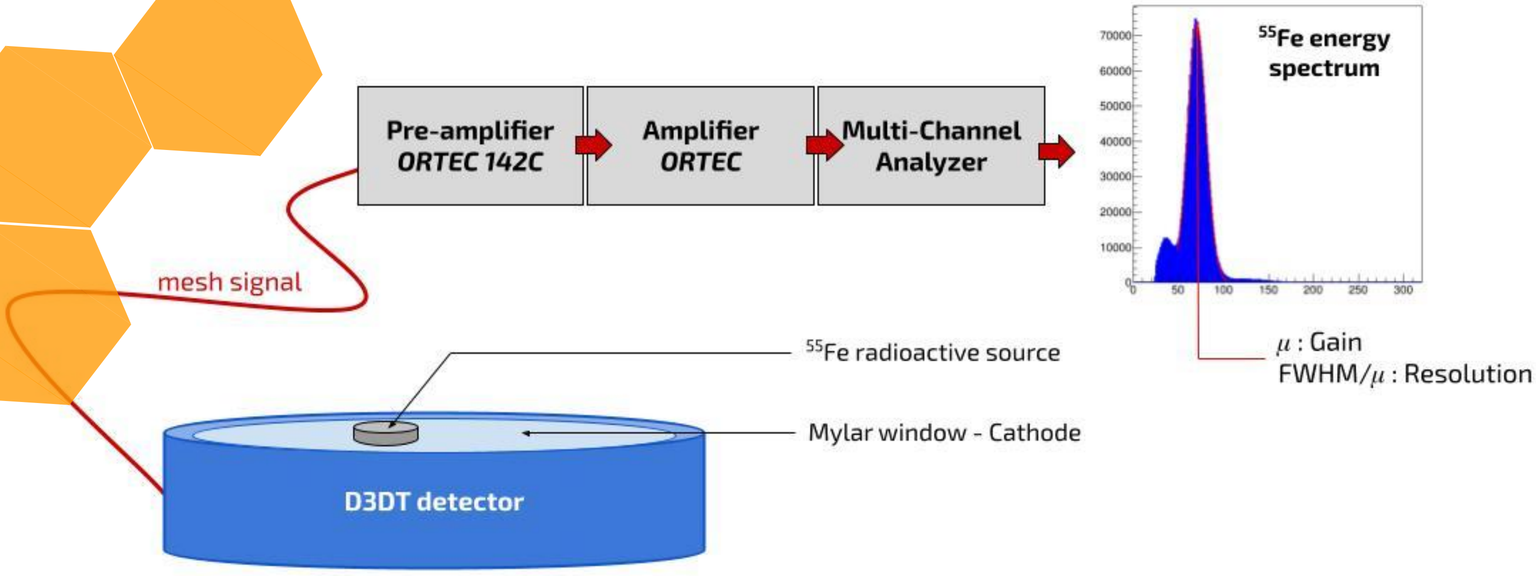
***DREAM : Dead timeless Readout Electronics Asic for Micromegas*

Readout plane characterization

As the multiplexage factor varies from channel to channel, it can affect the gain locally. In order to measure this effect, we need to conduct several characterization :

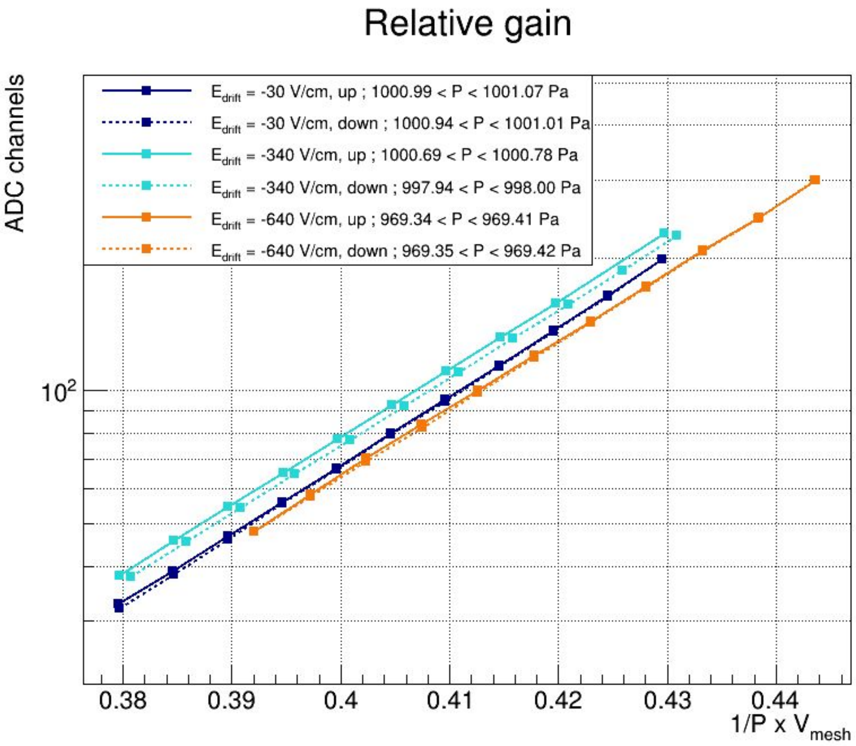
- ❏ Gain & Resolution curves of the global detector to verify the expected behaviour of a Micromegas detector and determine a working point
- ❏ Gain and resolution measures, locally for each pixel

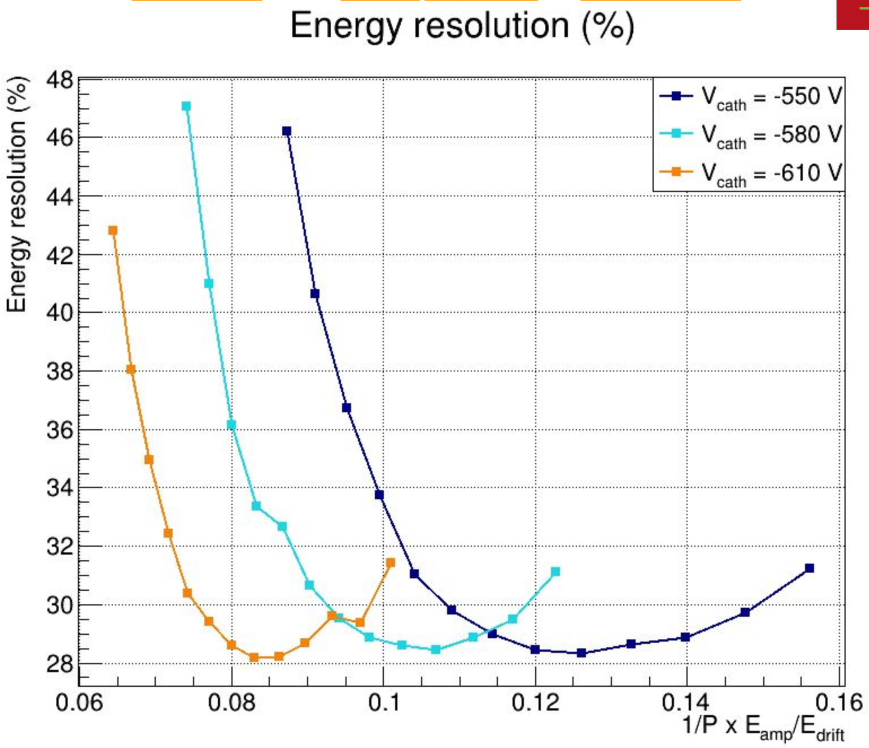
Global gain & resolution curves : reading mesh signal



Readout plane characterization

Global gain & resolution curves *(Results)*



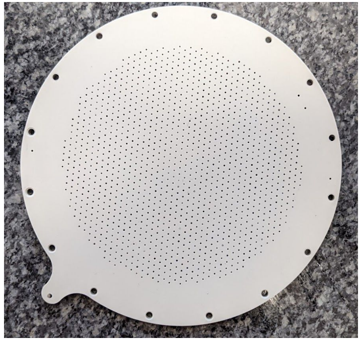


Myar foil is so thin (12 μm) that it is curved by the weight of the iron source on top which can modify the gap ie. the local gain. This needs to be addressed to conduct local gain measures.

Readout plane characterization

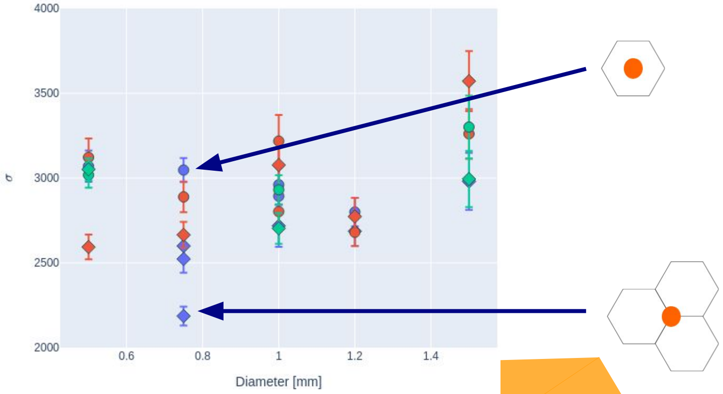
Local gain & resolution : reading pixels signal

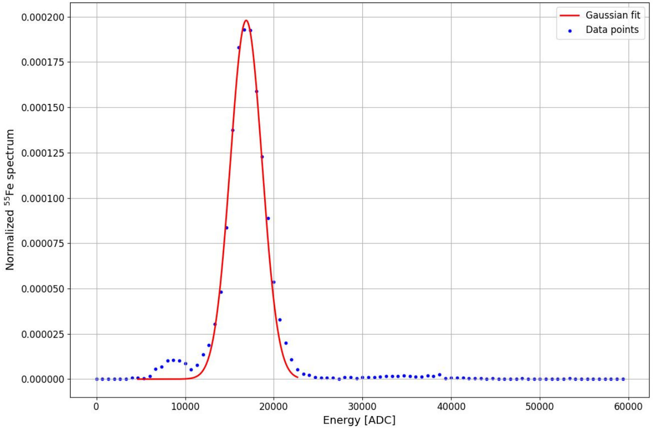
Idea : Reprogram a 3D-printer to use it as a radioactive source holder and design a solid cathode with a collimating hole in regard of each pixel.



New cathode design

Tests were conducted to choose the optimal diameter and positions for the collimating holes. It has been found that the optimal diameter is 0.75 mm and the resolution obtained is better when the hole is above the **intersection between 3 pixels**.

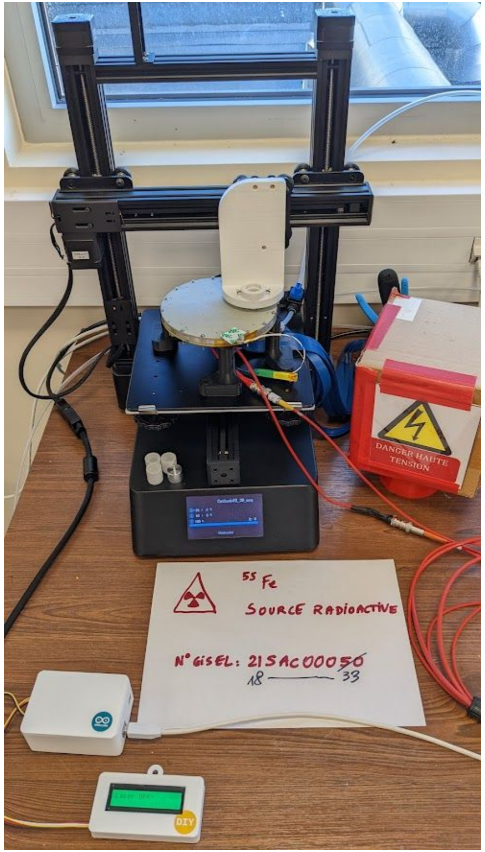




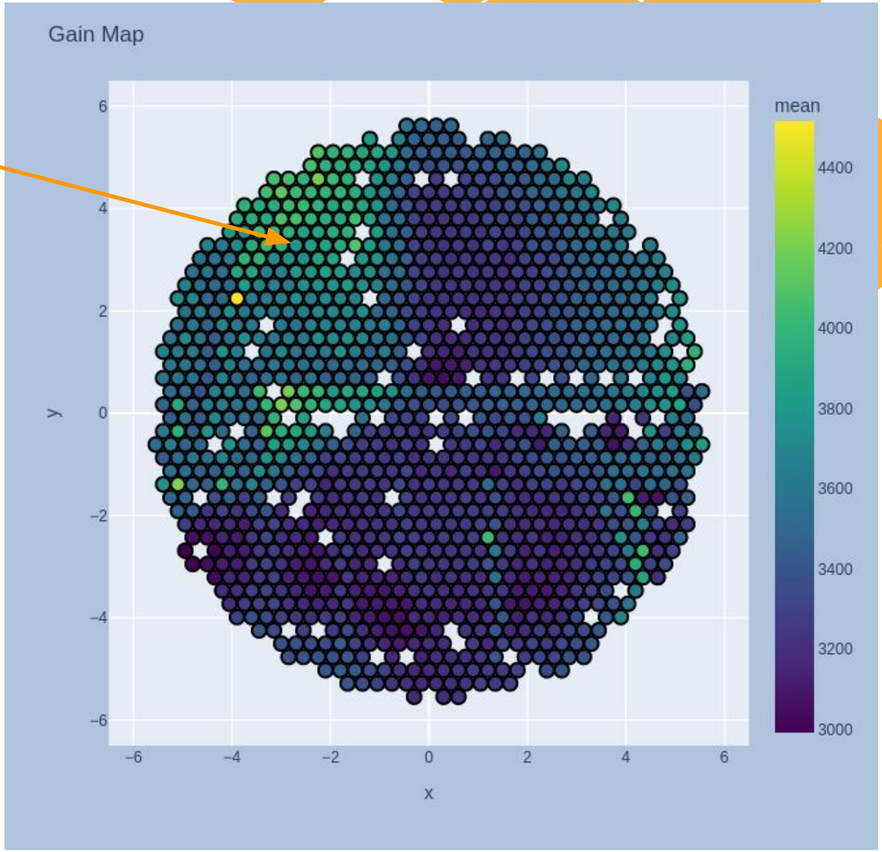
3 min 20 sec or 10000 events per position scanned

Readout plane characterization

Local gain & resolution : reading pixels signal *(Results)*

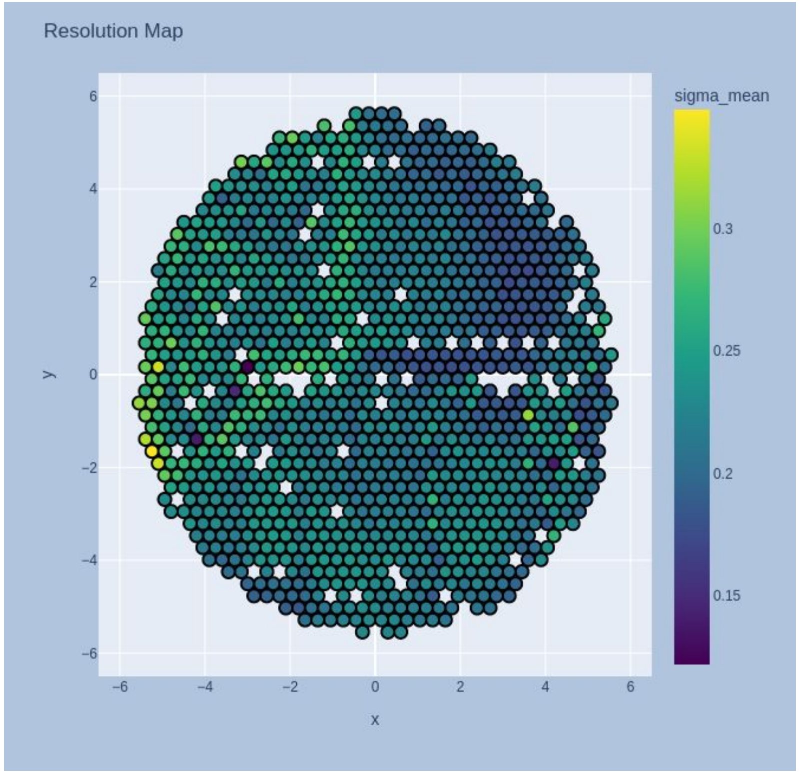


Sector known to be noisier than the other two.



Readout plane characterization

Local gain & resolution : reading pixels signal *(Results)*



- ❑ Need new acquisitions to get the full map without missing pixels
- ❑ Need to understand the few pixel with extreme values

First tracks

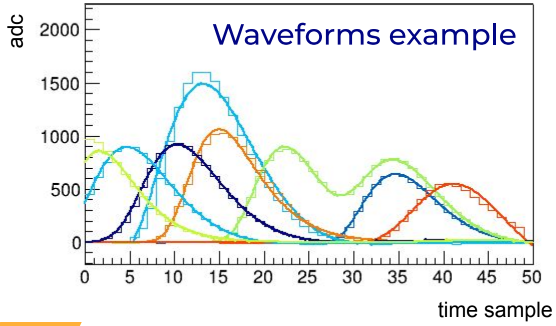
First data & track reconstruction

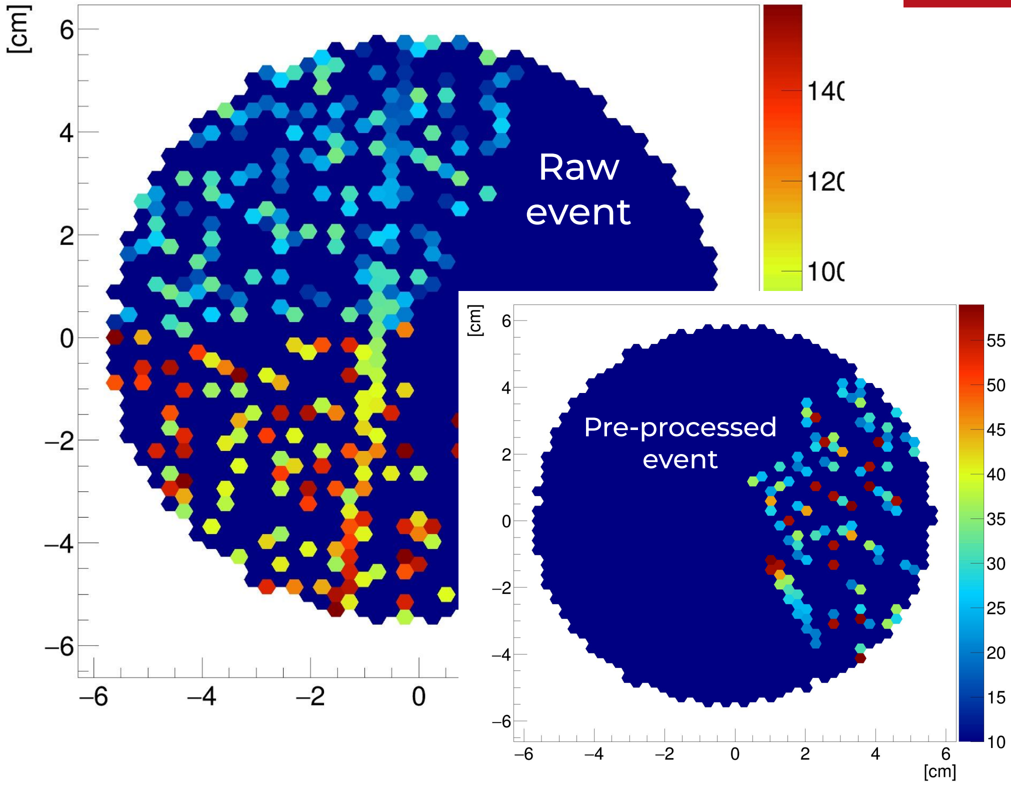
Data taken with 40 cm drift prototype

Experimental setup and data-taking conditions :

- Gas : Ar-iC_4H_{10}-CF_4 (95:2:3)
- Peaking time = 283 ns
- Sampling frequency = 125/6 MHz ie. 48 ns/sample
- Vcathode = 6000 V
- Vmesh = 380 V

Color scale represents the time hinting that the track observed is physical and not an artefact of multiplexage due to the continuity.

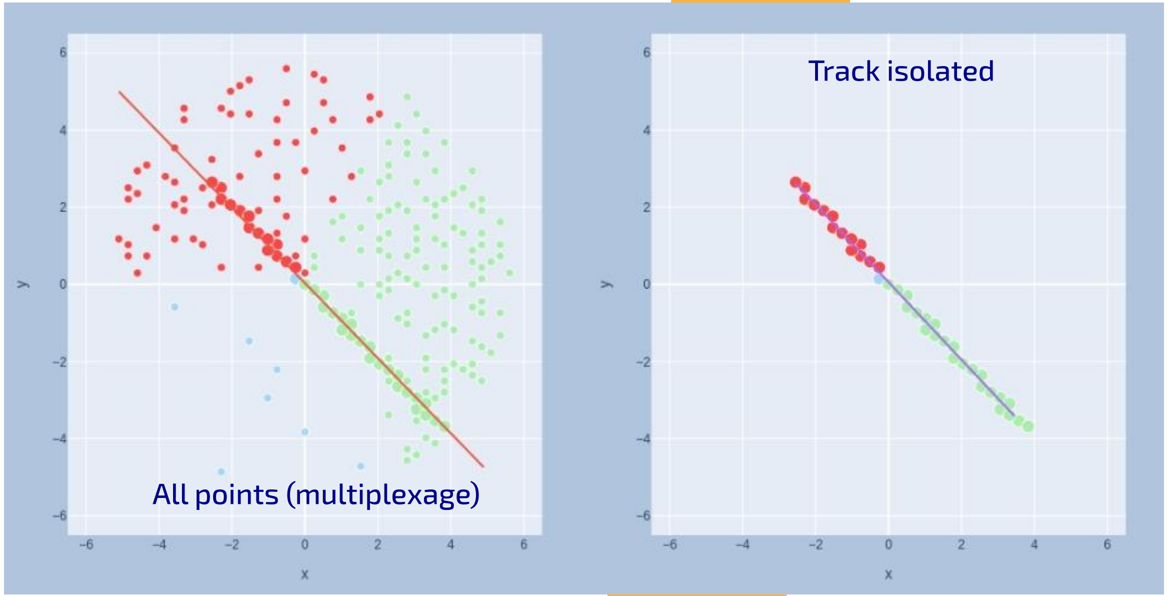




Post processing & reconstruction algorithm

At the moment the algorithms are only tested on simulated tracks because there are not enough real data with tracks due to some noise issue on the final size prototype.

Using a combination of DBScan and RANSAC algorithm it is possible to reconstruct the track. This is still under development.



Perspectives & Conclusion

- ❑ First prototypes assembled successfully !
- ❑ First tracks observed !
- ❑ Readout plane characterized *(final analysis ongoing)*
- ❑ Track Reconstruction Algorithm under development
- ❑ Check out our video !
- ❑ For any question feel free to contact us : marion.lehuraux@cea.fr