Multiplexed Micromegas for muography

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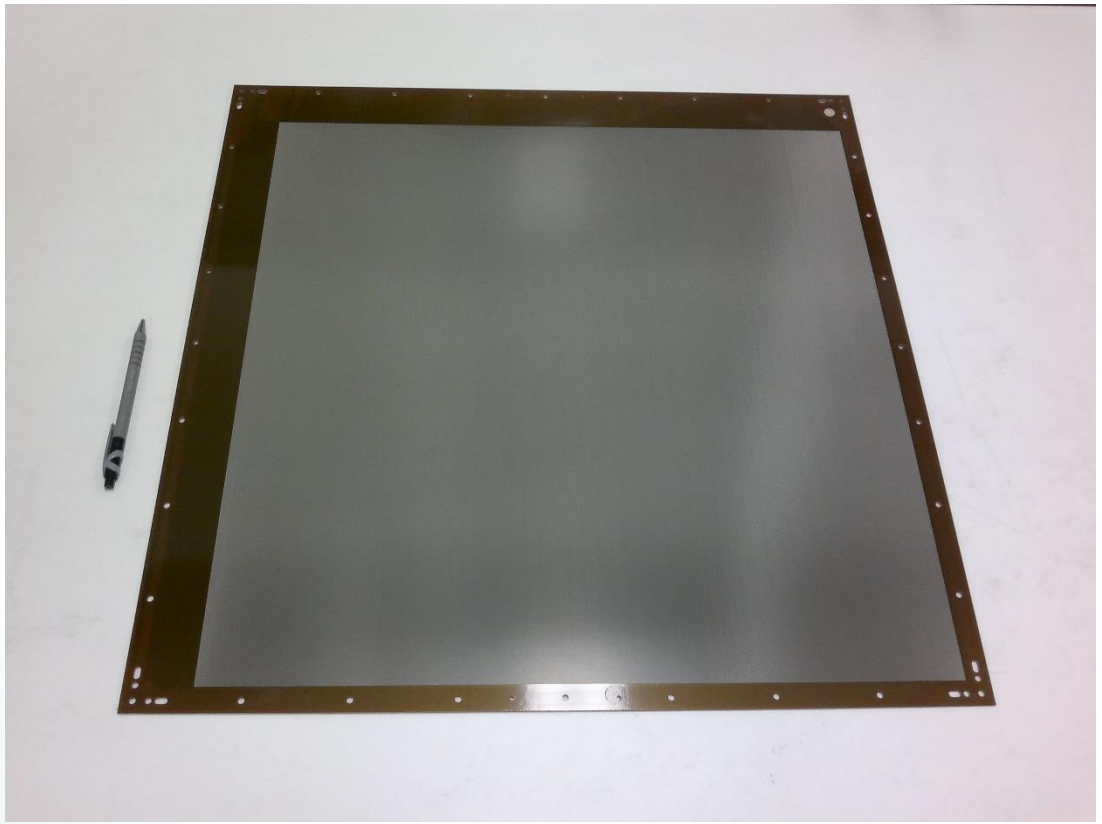
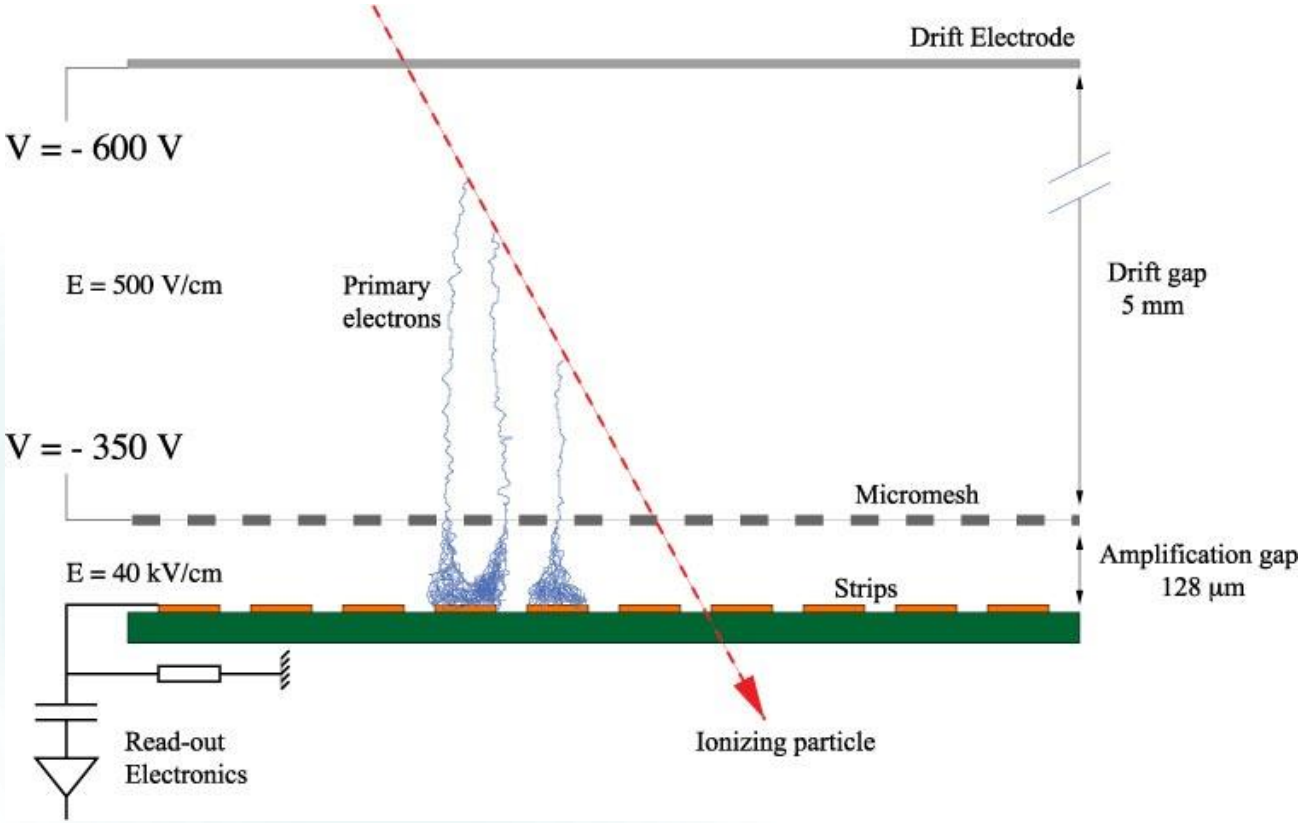
CEA/Irfu/SPhN



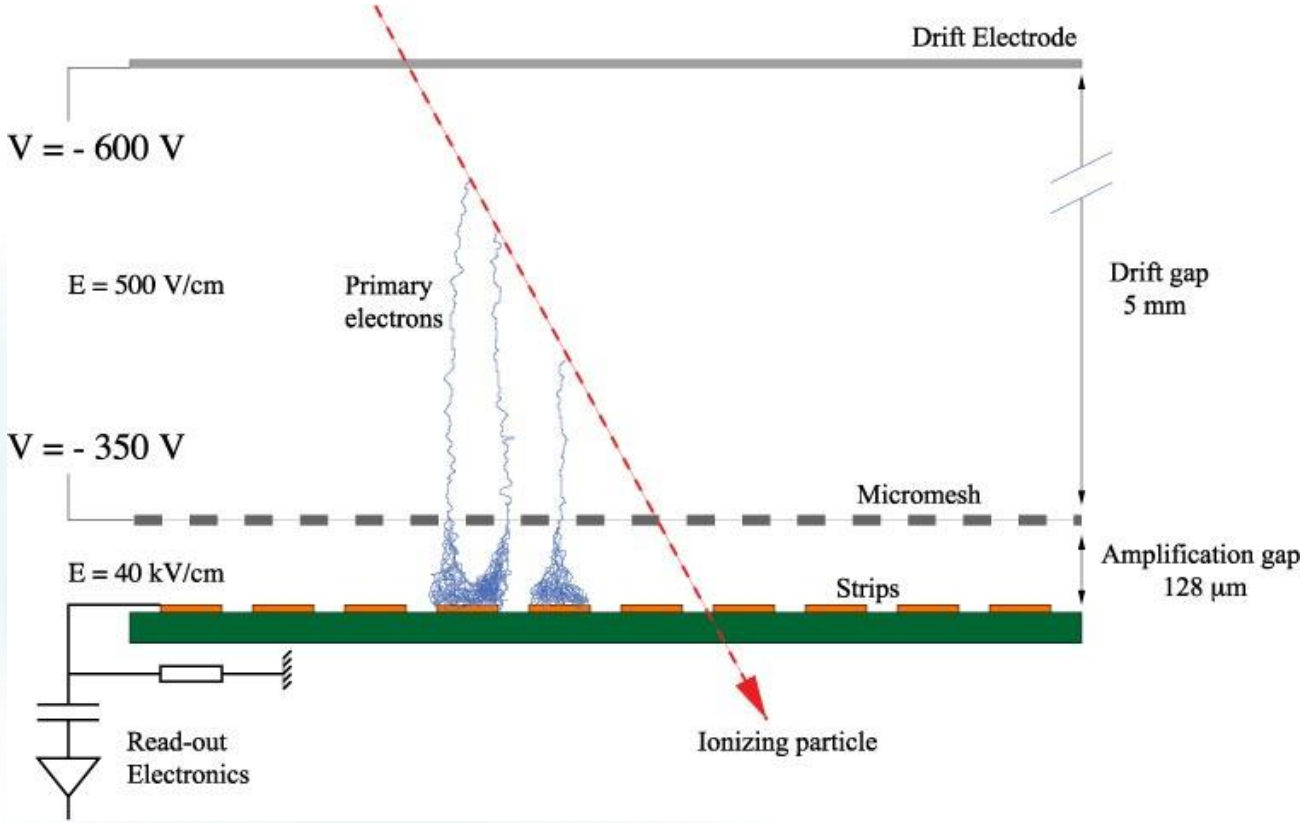
The Micromegas Detector

Detector Principle

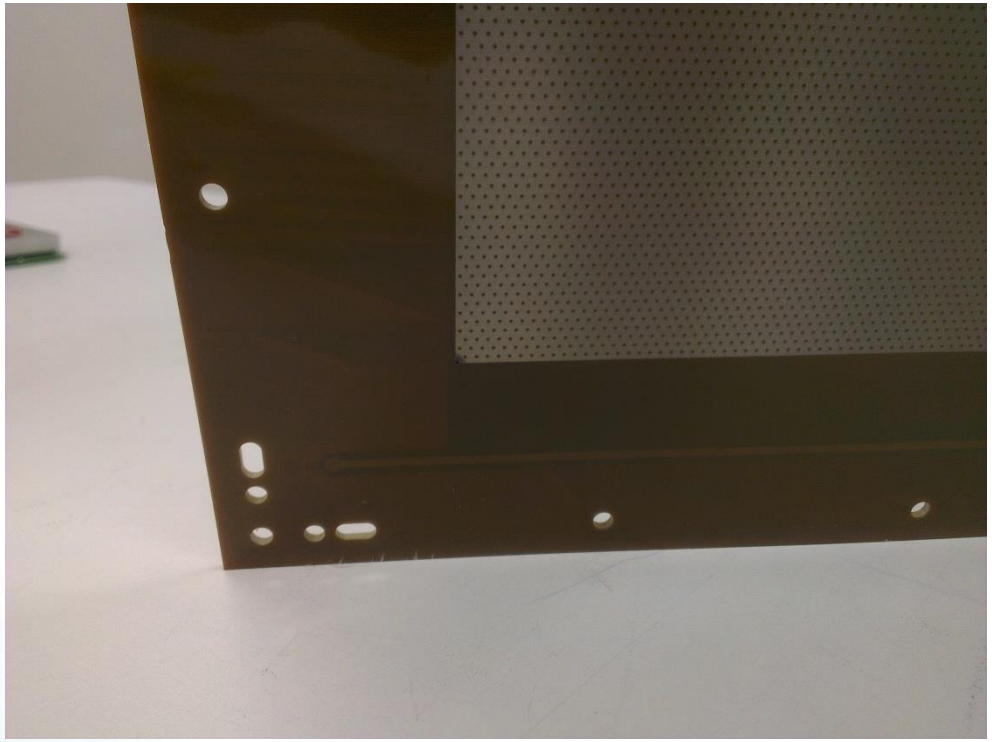


- Invented in 1996
  - G. Charpak, I. Giomataris, Ph. Rebourgeard
- Developped at CEA/Irfu
- High performance tracker detector
  - Spatial resolution < 300µm
  - Time resolution ~ 10ns
  - Can stand high flux
- Gaseous Detector
  - Primary signal : ionization
  - Electron shower amplification
  - Copper strips/pad collects the signal
- Very robust
  - Bulk technology (2006)

Detector Principle

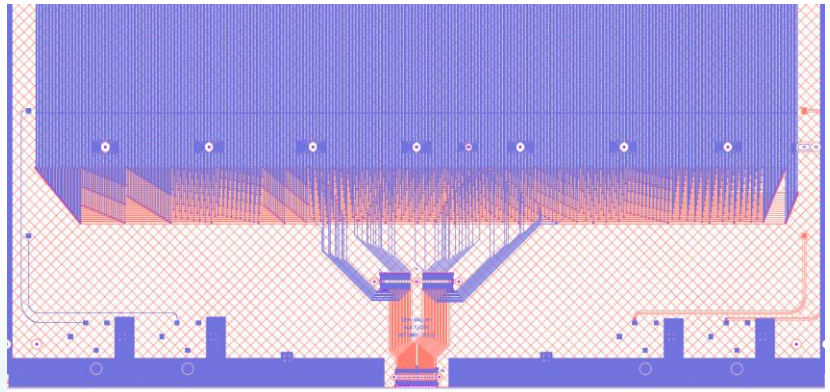


- However :
  - High granularity
  - High number of strips
  - High number of electronic channels
  - Complex readout
  - Not suitable for portable devices
- Need for further development



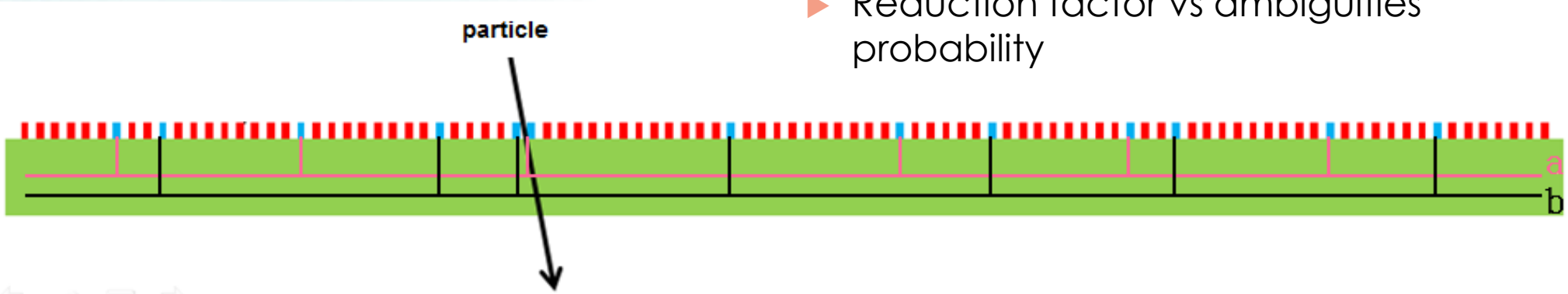
Detector Development

Genetic Multiplexing

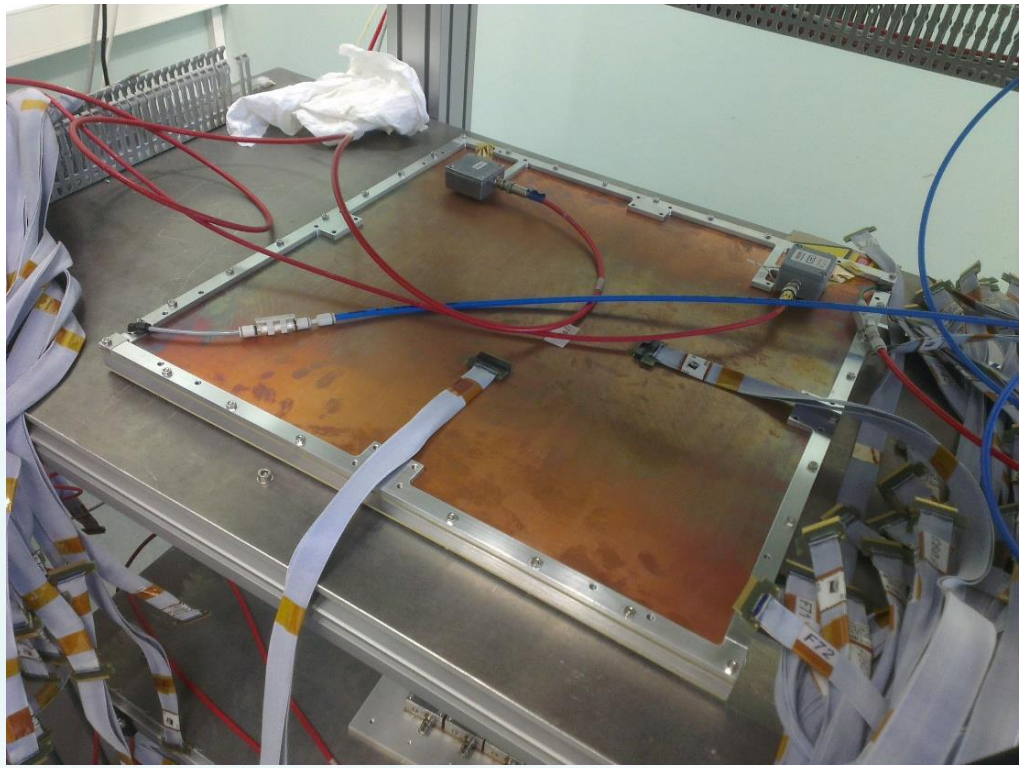


Multiplexing layout

- Use signal spread over strips
  - Detect unique k-uplets
  - Doublet of channel are connected to a unique doublet of consecutive strips
- 1037 strips read by 61 channels
  - Reduction factor > 15
- Multiplexing factor is adjustable w.r.t. flux inside the detector
  - Reduction factor vs ambiguities probability



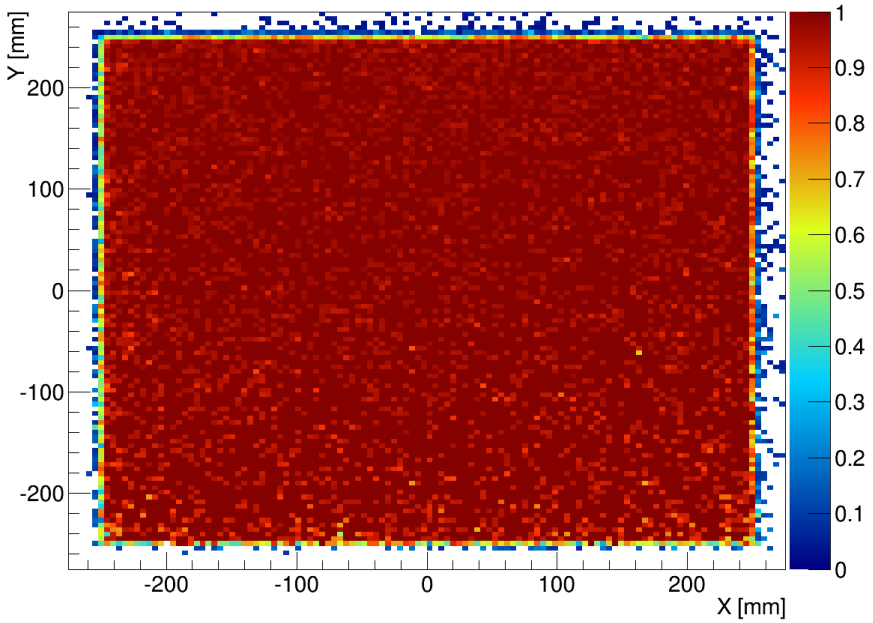
Design



MultiGen detector inside
Saclay cosmic test bench

- 50x50 cm² active area
- Bulk technology
  - Very robust
- Resistive (1MΩ/□)
- 2D readout
  - 3 strip layers : resistive (X), Y readout and X readout
- Second prototype
- 1.5cm conversion gap
- Limited dead zone
  - Mosaic capable
- Industrialization nearly complete
  - Mostly made by circuit board industry

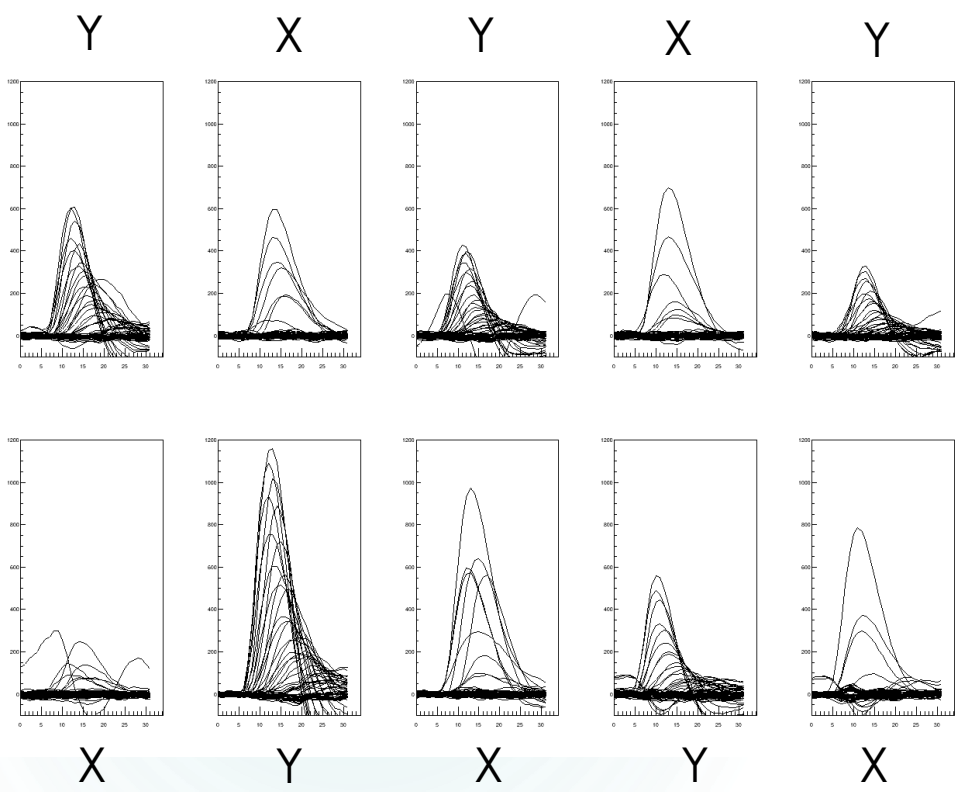
Performances



2D efficiency

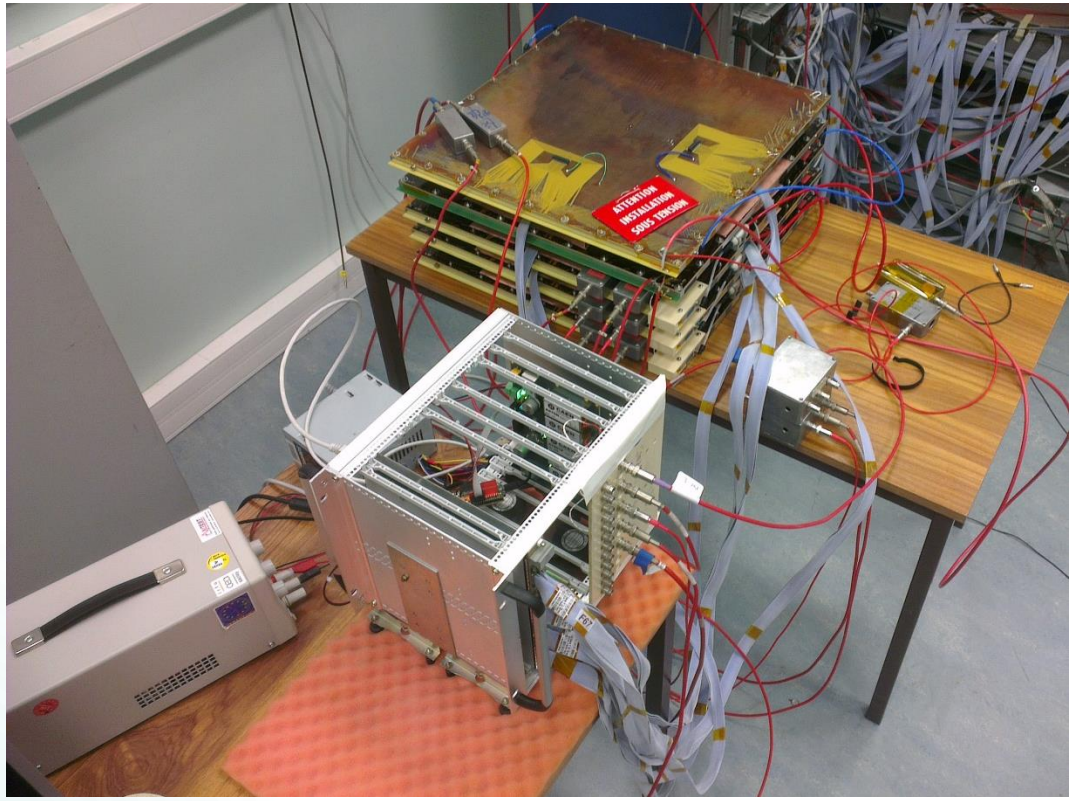
- Operated with 2 gas mixtures
  - Ar-iC_4H_{10} (95:5)
  - "T2K gas" : Ar-iC_4H_{10}-CF_4 (95:2:3)
- Over 96% 2D efficiency
  - Good homogeneity
- High capacitance (1nF) because of multiplexing
  - Decrease S/N
- 300µm resolution

Performances



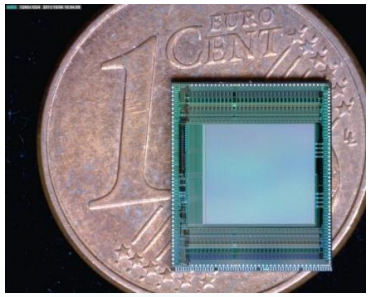
Signal amplitude vs sample bin, 1 plot by projection (5 detectors)

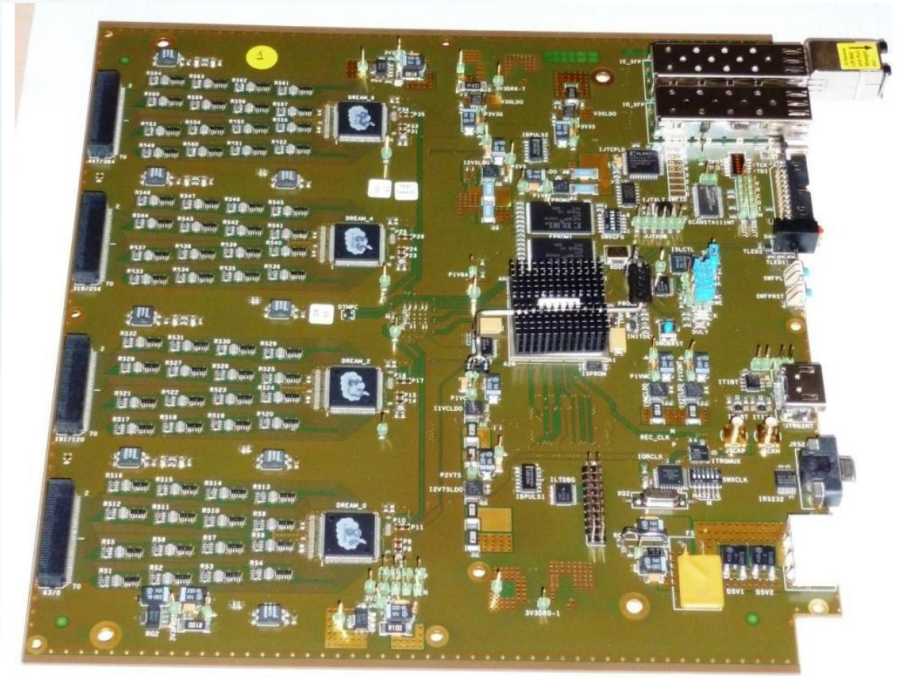
- Limited resolution
  - Greater than pitch/√12 = 140µm
  - Charge spread
    - Signal can be discontinuous
- Solutions are currently investigated
  - New prototypes designed
  - Software reconstruction improvements



Electronics development

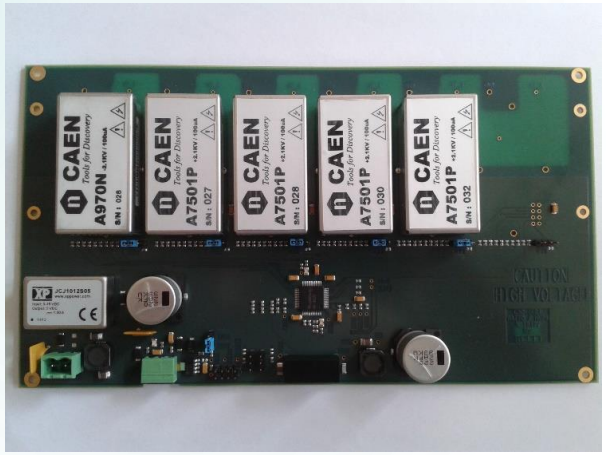
Readout Electronics





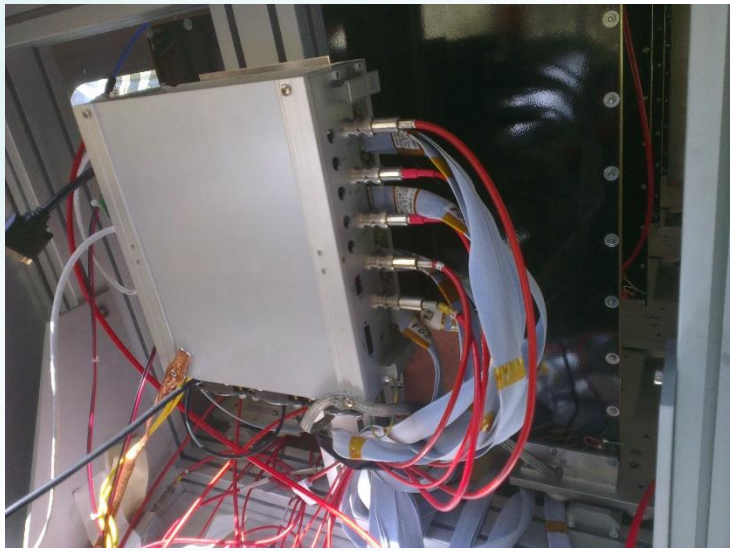
- DREAM Chips in FEU Cards
  - CLAS 12 electronics
    - Jefferson Lab experiment
  - Adapted to high capacitance
  - Self triggering capability
    - No need for triggering detectors
  - Can read 4 detectors

High voltage power supply

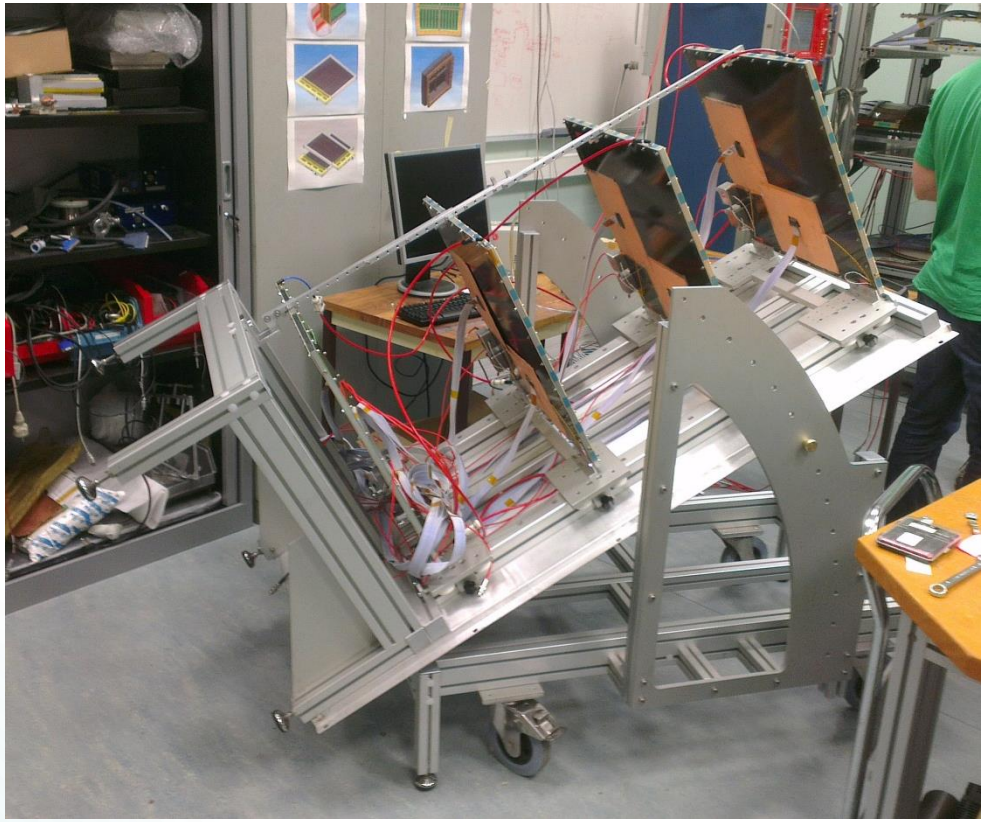


- Need for low consumption power supply
- CAEN modules
  - Up to 2.1kV
  - Powered by 12V DC
  - <0.6W consumption
- Dedicated control card
  - Designed in CEA/Irfu
  - Up to 6 HV channels
  - Control and monitoring
    - Temperature feedback

Data acquisition system



- Readout electronic control
- HV power supply control
- Data storage
  - Hard Disk (2To)
- Nano-PC
  - ARM based (smartphone)
- Total consumption : 30W
  - Less than light bulb
  - Include HV, readout and DAQ
  - Can be powered by battery and solar panels



The WatTo experiment

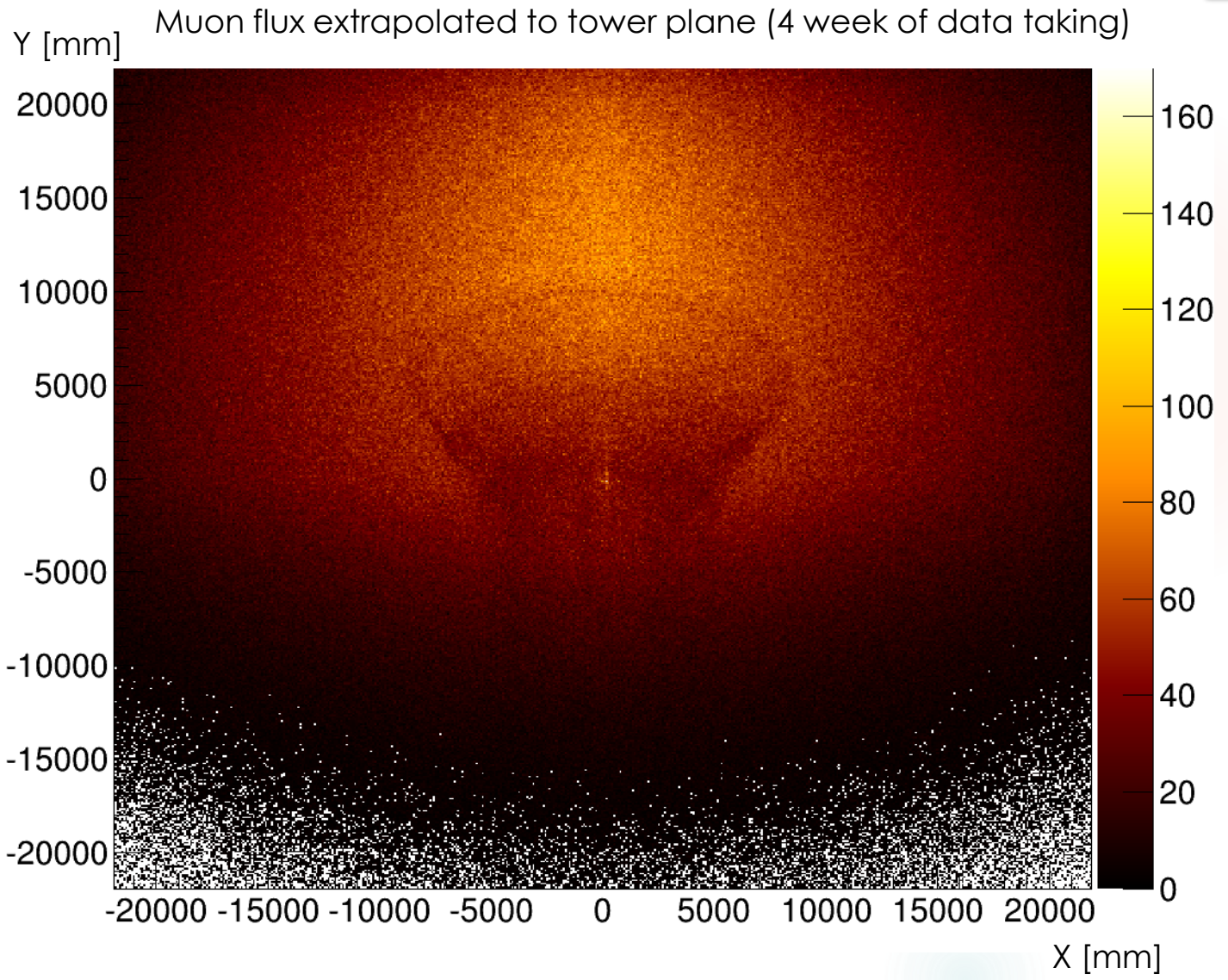
Purpose

- Proof that Micromegas can work outside of labs
  - Worldwide first operation of a Micromegas tracker outside a lab
- Proof of concept validation
- Test self-trigger
- Test battery power operation
- Check noise levels
- Check outside environment influence
- Make an experiment in a semi-controlled environment
  - Inside Saclay center
    - Easy operation but in real conditions
  - Muography of the water tower

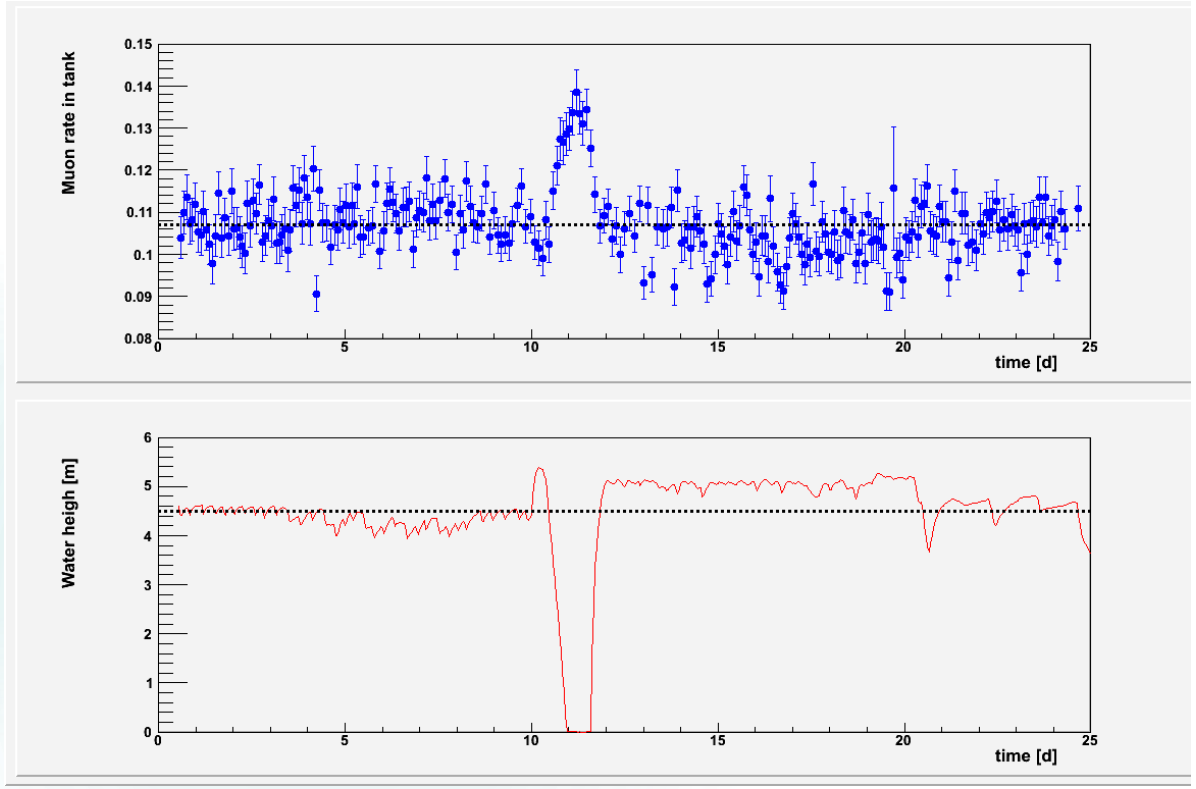
Experimental setup

- Telescope protected by tent
- First phase (end of may to mid july 2015)
  - With power plug and network
  - At 40m of the tower
  - Telescope at 30° from the horizontal
- Second phase (mid july to end of august 2015)
  - Battery/solar panel operation without remote access
    - 12V truck battery
    - ~1.5m² solar panel
  - At 25m of the tower
  - Telescope at 35° from the horizontal
    - More flux

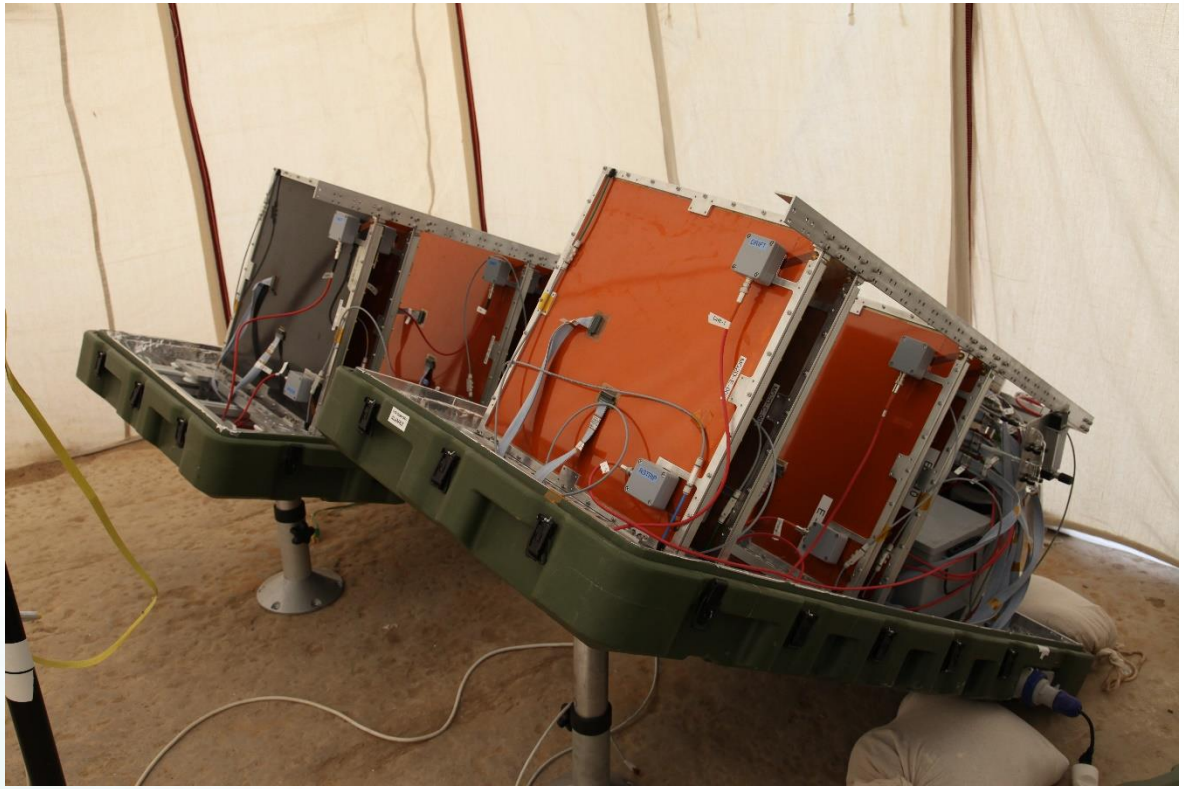
Results


Muon flux extrapolated to tower plane (4 week of data taking)
Y [mm]
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
-20000 -15000 -10000 -5000 0 5000 10000 15000 20000
X [mm]
160
140
120
100
80
60
40
20
0

Results



- Dynamic studies done even with cosmic muon low flux
  - Tank water level monitoring
  - Do not need atmospheric pressure correction



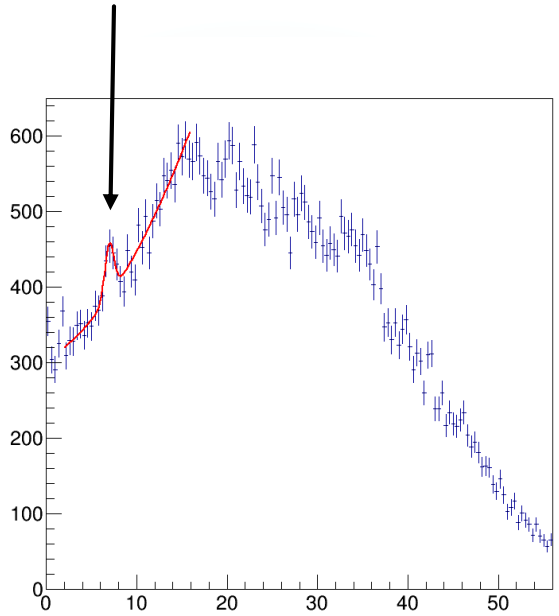
ScanPyramids Mission

Experimental setup

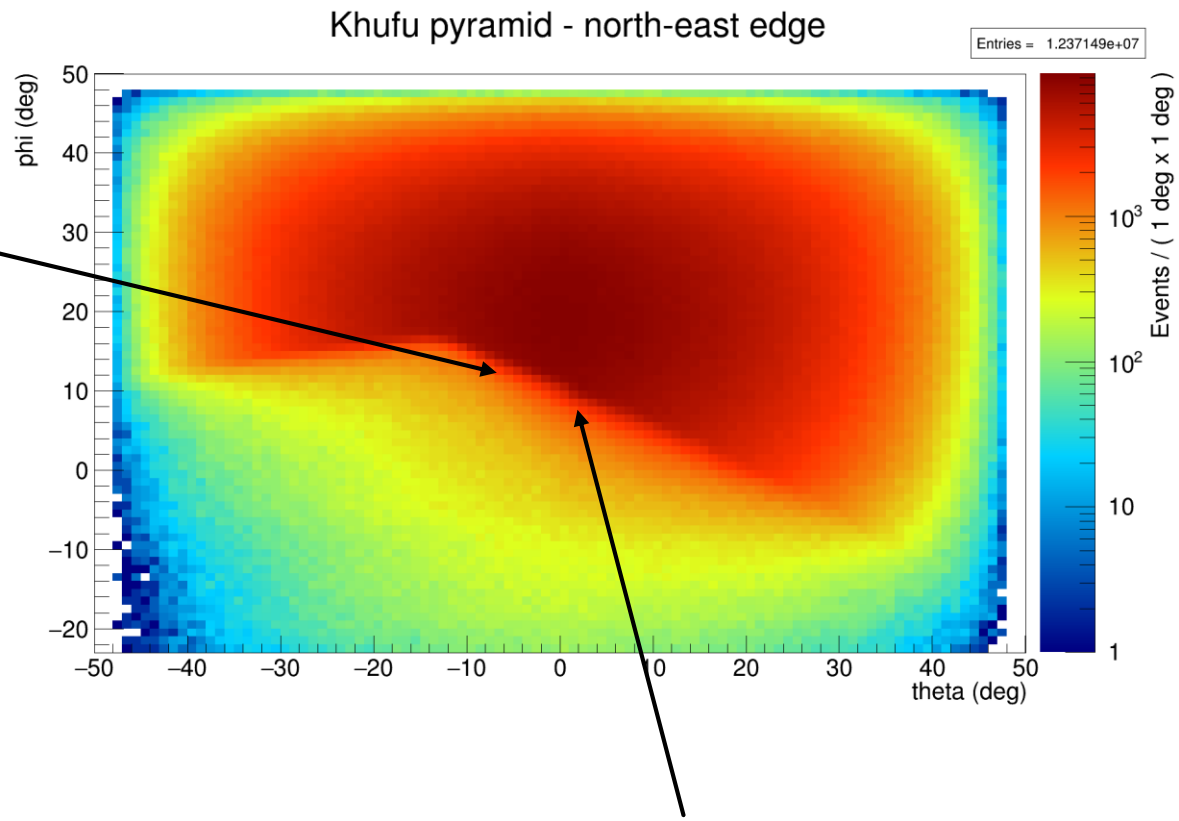
- Scan of the Khufu pyramid of Gizah
- Focus on North-East edge
  - Telescopes placed 20m away from the pyramid
  - 1 already known cavity
    - Behind the notch (crumbling)
  - Highest expected contrast from outside
- 3 identical telescope deployed
  - 1 placed on the north side
  - 2 placed side by side on the east side
- 3 month of data taking
  - Beginning of june to end of august 2016

Results

Smaller notch.
Cavity discovered behind !



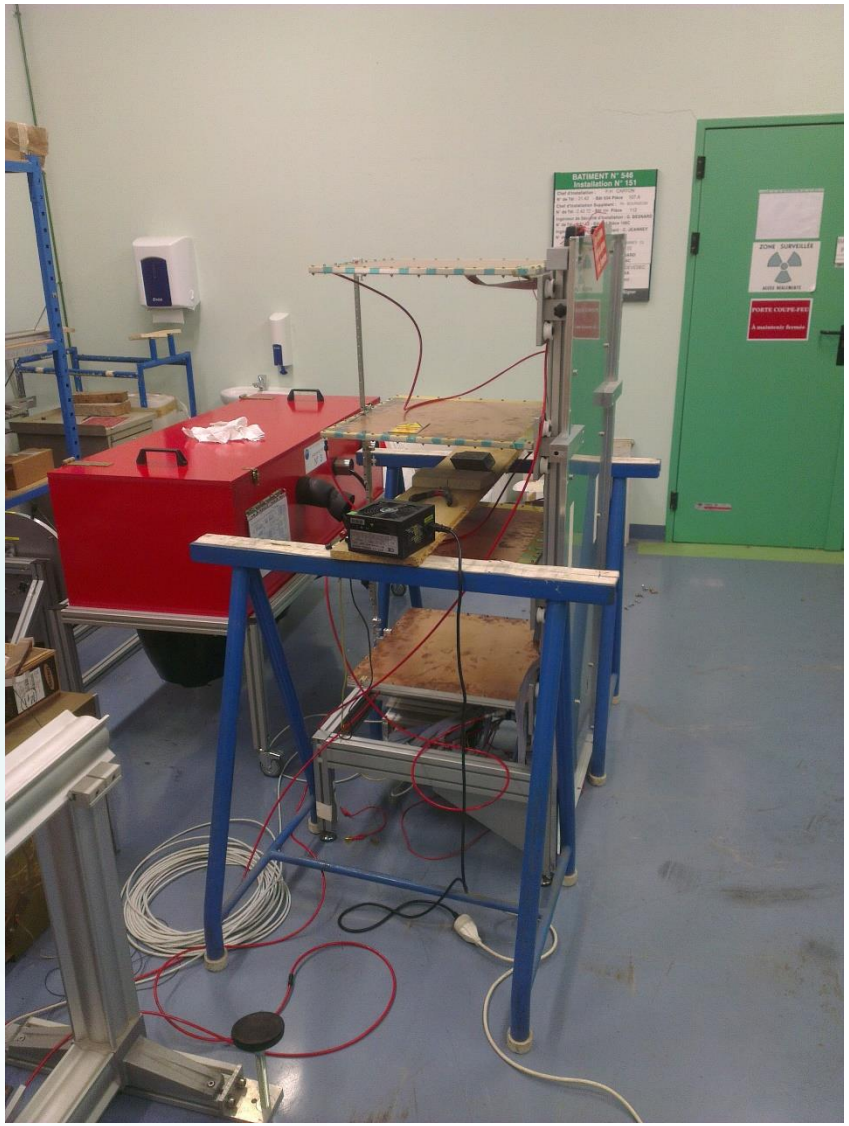
Slice parallel to the edge



Notch with a known cavity behind

TomoMu Scattering Setup

Experimental setup

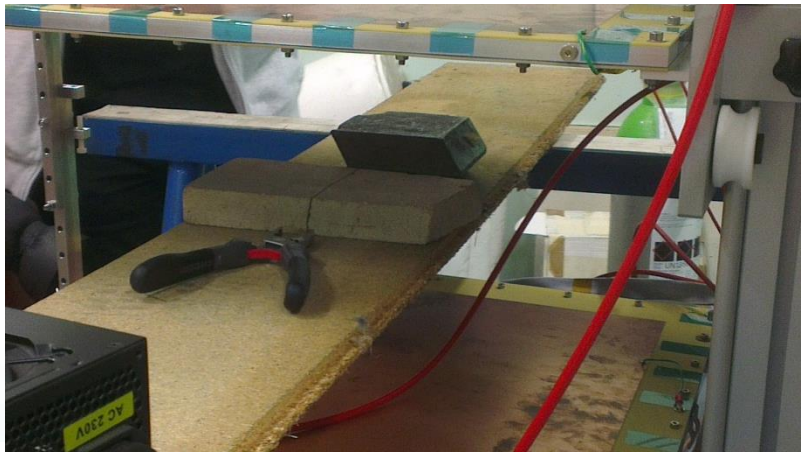


- Use the scattering technique
  - Faster
  - Can only scan small objects
- 2 doublet/trackers
  - 40cm lever arm to reach sufficient angular resolution
- Small portable device
  - Educational portable device
  - 0,25m² surface

Results

Simon Bouteille | CEA/Irfu/SPhN | Muographers 2016
2016-11-07

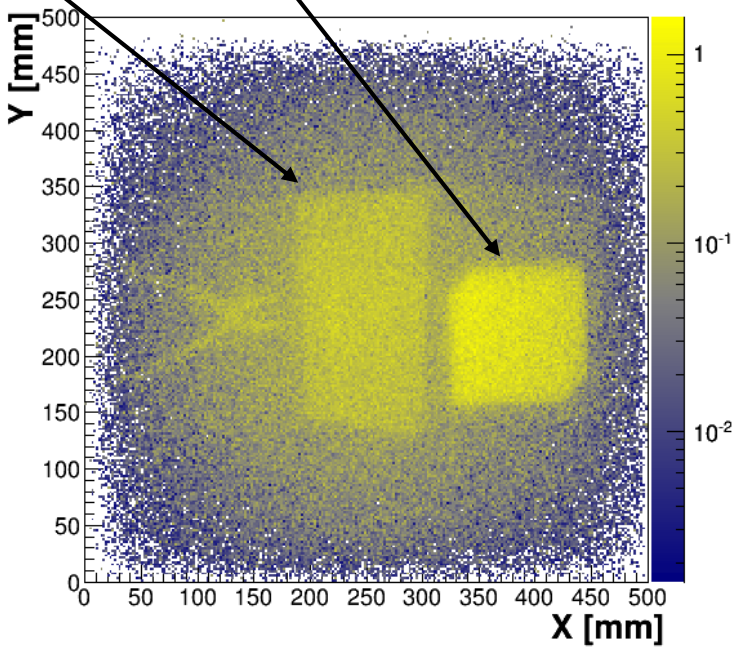
Scattering position density weigthed by scattering angle

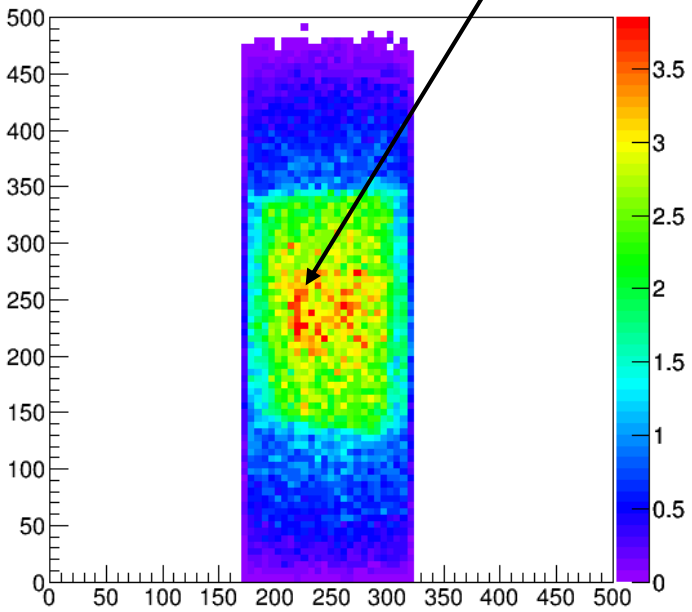


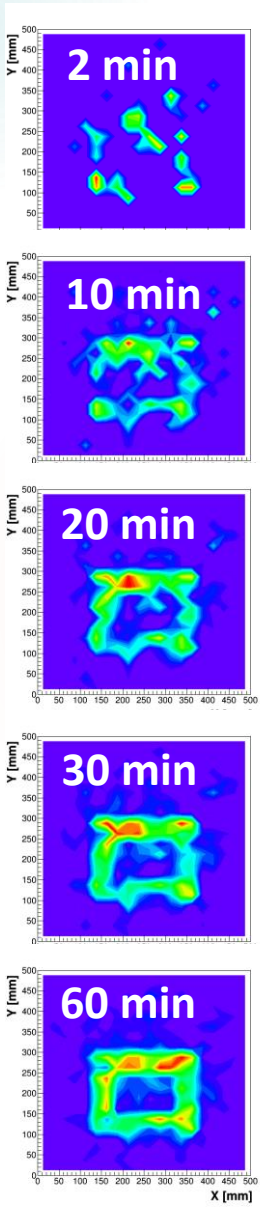
Lead

Limestone

Iron bar inside the stone



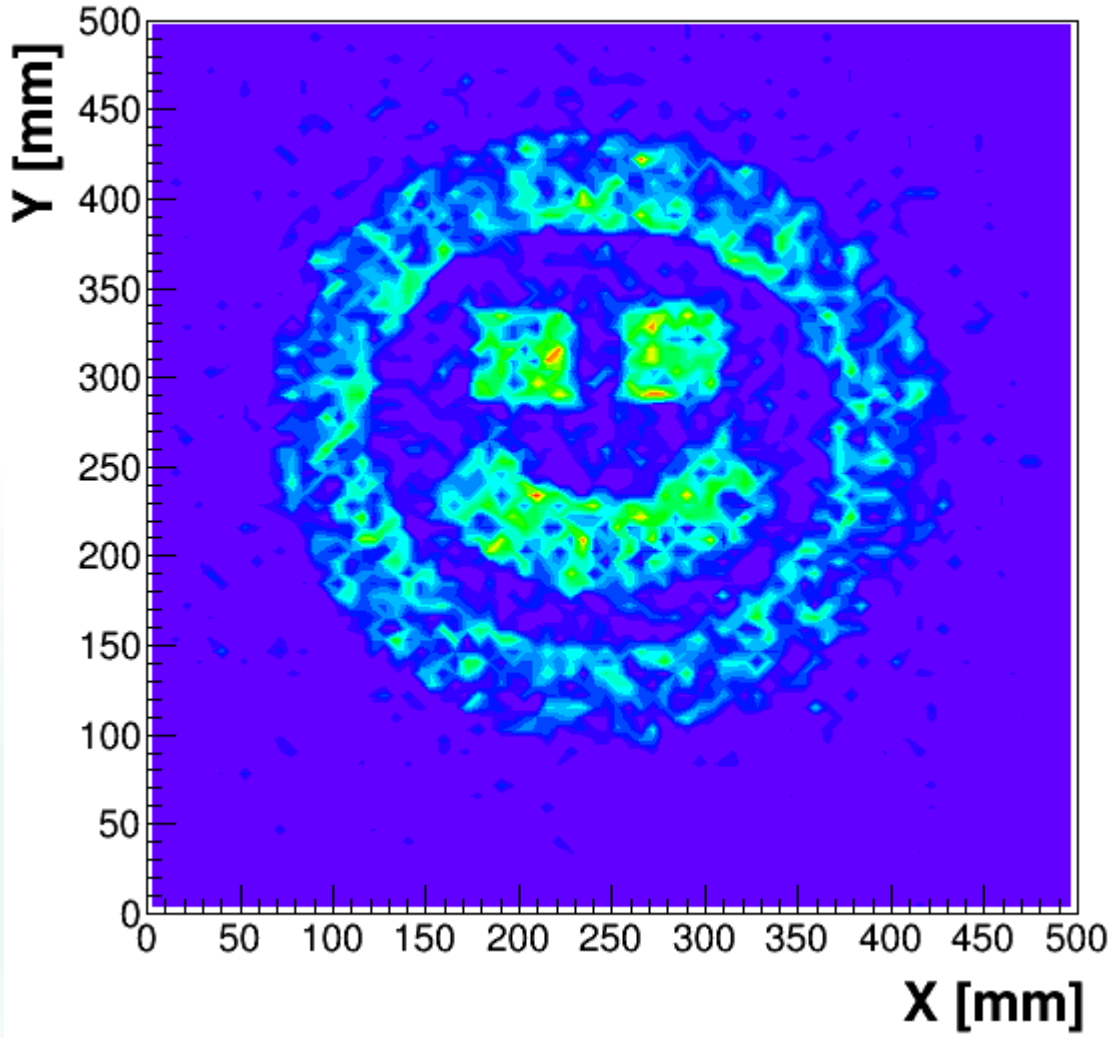




5cm height lead bricks

Conclusion

- We successfully operated Micromegas muography telescopes both in Paris and Egypt
- Attempt to make a full 3D view of an object using the scattering technique is ongoing
- 34 50x50cm² Micromegas had been made so far for the muography projects
  - 2/3 of them were made by Elvia (French industry)



Thank you for your attention