Journée des thésards
7 et 8 juillet 2016

Bouteille Simon

Cursus : Ecole Polytechnique, HEP Master

Contact : I used the CEA/INSTN website

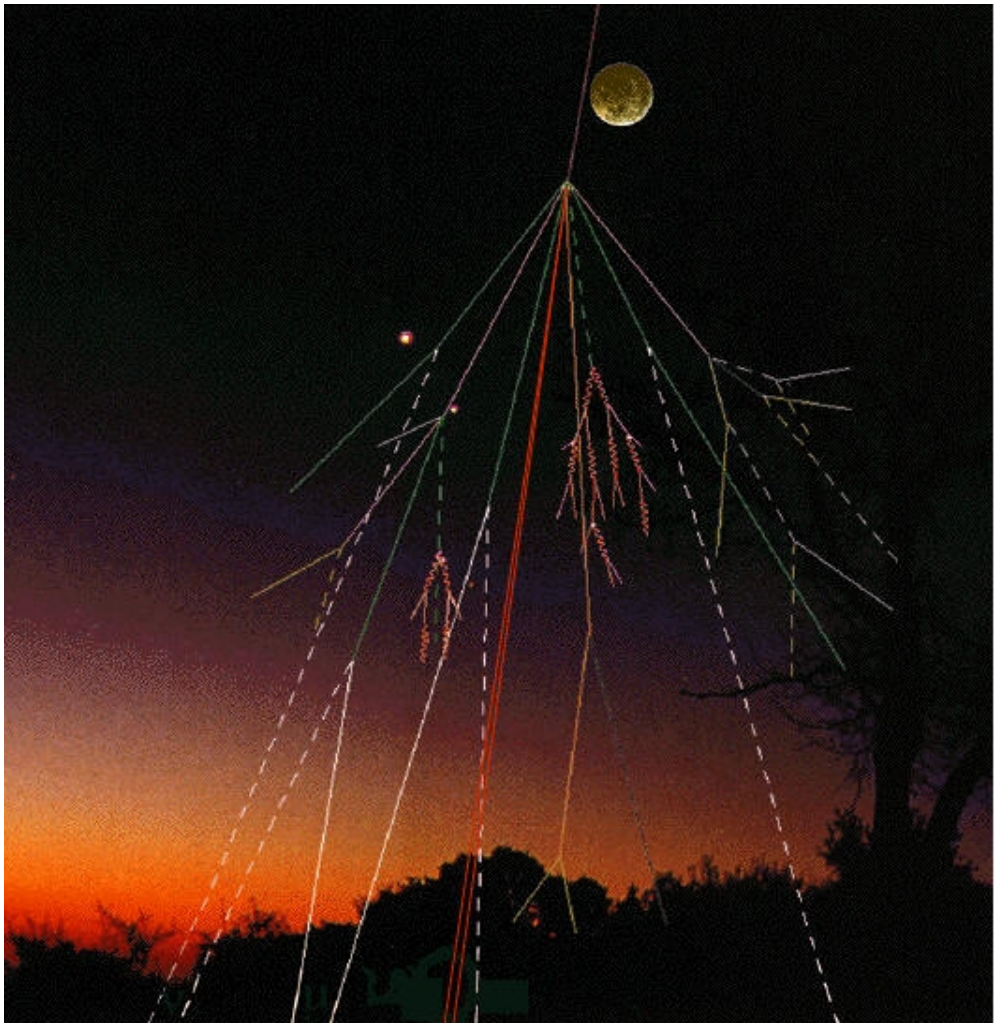
Motivation : The topic allow me to work in a lots of different fields : from instrumentation to data analysis developping cutting edge technology from fundamental science

Journée des thésards
7 et 8 juillet 2016

Topic : Development and application of micro-pattern gaseous detectors for muon tomography

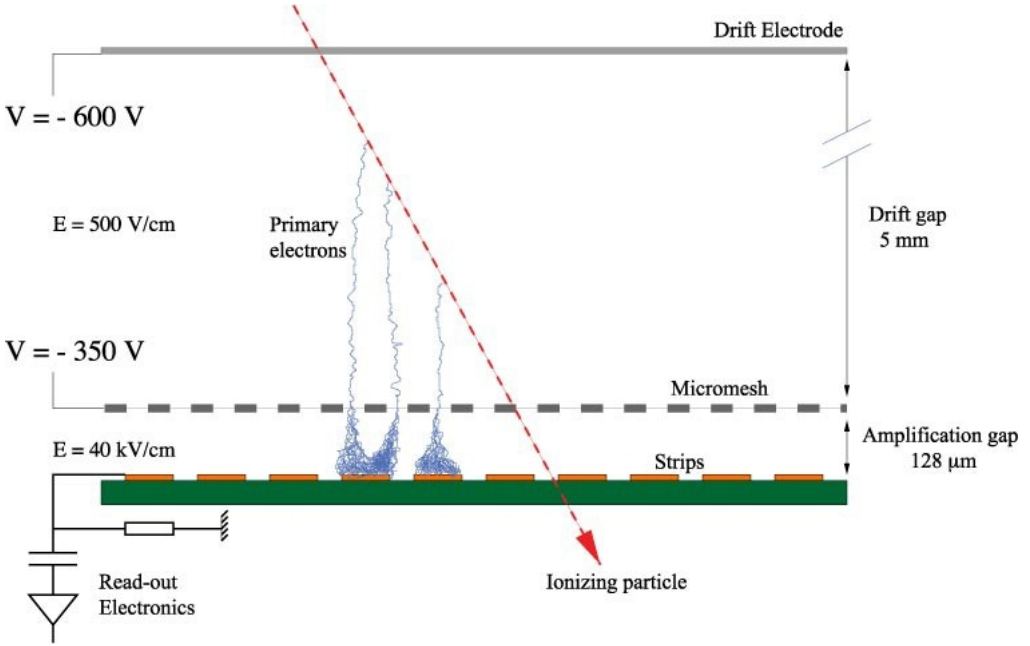
Explanation : Muon tomography aims to use the muons induced by cosmic rays to scan the inner structure of different type of object using the absorption or the scattering inside them. To detect those muons we use Micromegas detectors which are more and more used in fundamental physics experiments

Introduction



What is a Micromegas ?

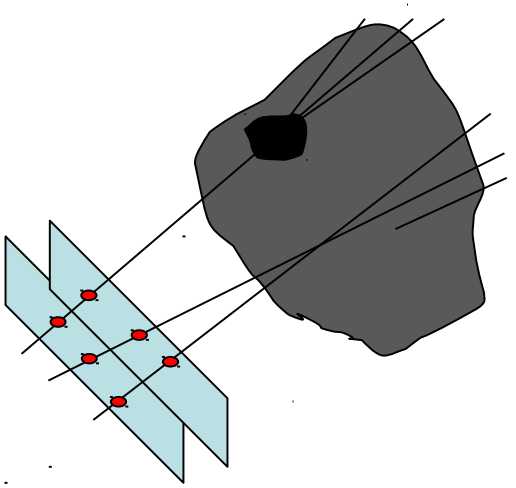
- CEA Saclay development
  - Giomataris, Charpak, Rebourgeard
- Conversion gap
  - Gas ionisation
  - Electron drifting
- Amplification gap
  - Electron shower
  - Make signal high enough to be read
- Use specific gas to optimize ionization, drifting and amplification processes
  - Example : Ar-iC_4H_{10} (95:5)
- Strips or pixel readout

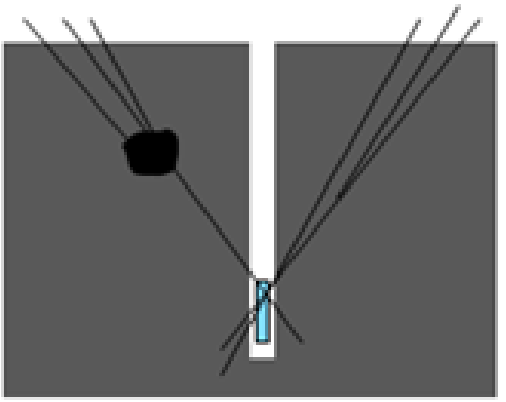


What is the muon tomography ?

Absorption method

- Detect flux of muon passing through the object
- Absorption depends on density
- Map of opacity (density x travelled length)
- Capable of imaging large objects
  - Volcanoes, pyramids
- Image resolution limited by low muon flux
  - 150Hz/m²
  - Large detection time

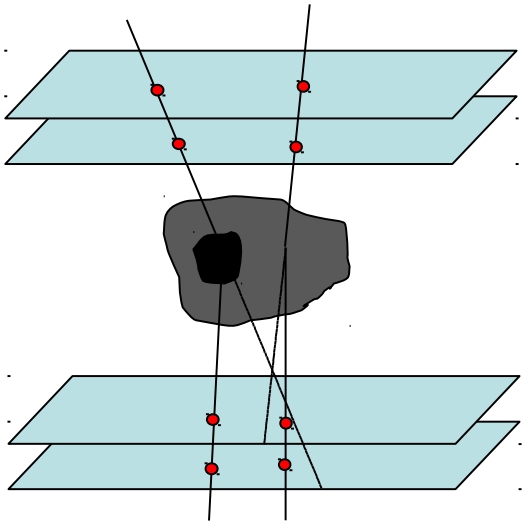


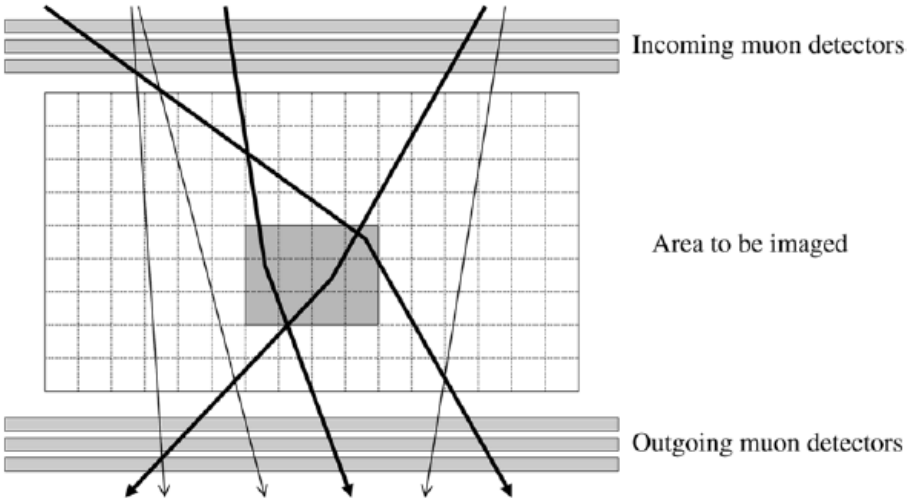


What is the muon tomography ?

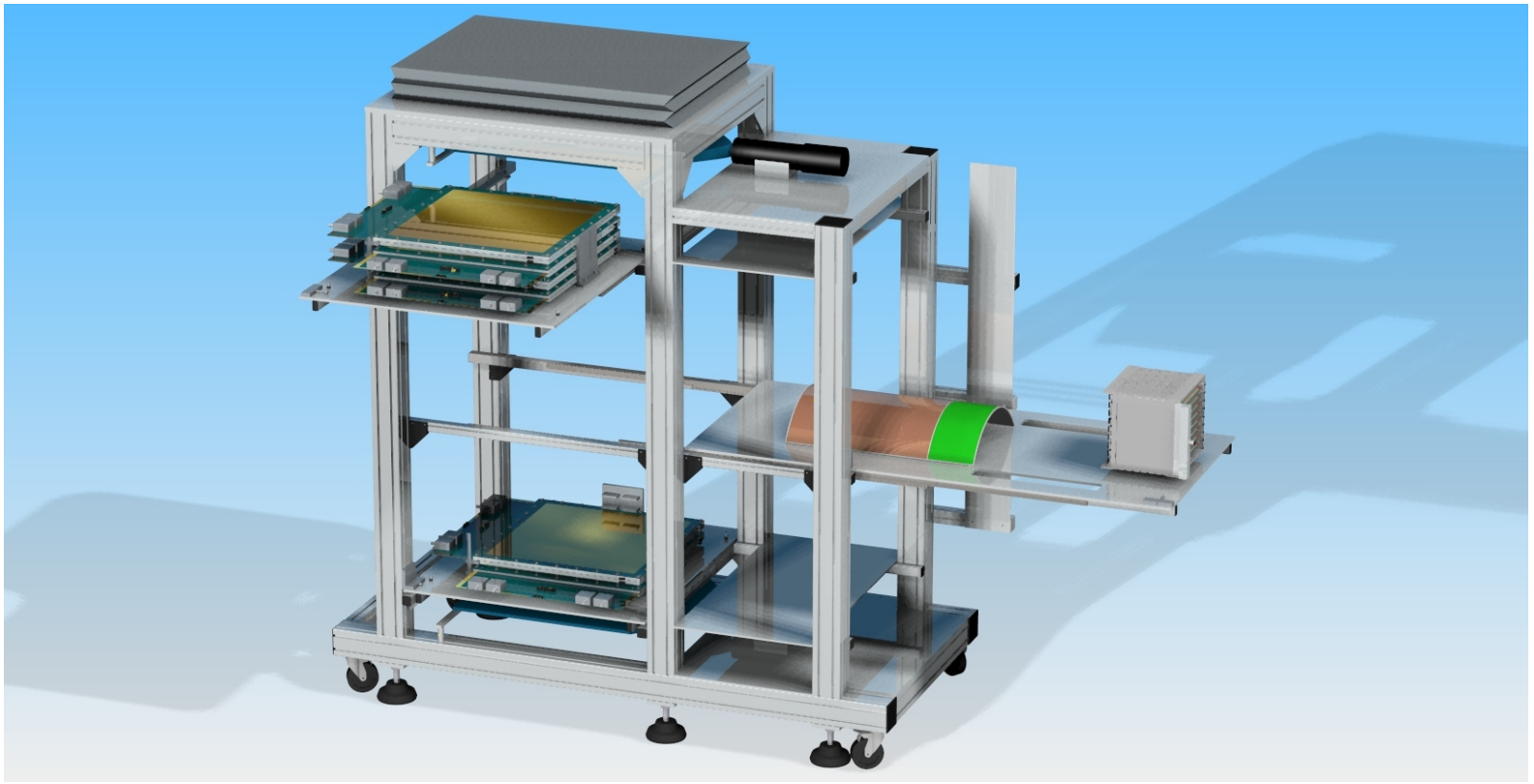
Deviation method

- Coulomb scattering inside material
  - Scattering angle distribution depends on material density
- 3D imaging using scattering location
- Faster than deviation method
- Need incoming and outgoing tracker
  - Limit scanned object size
- Tracker angle resolution is decisive
  - Scattering angle through 10cm of Pb : ~ 1°



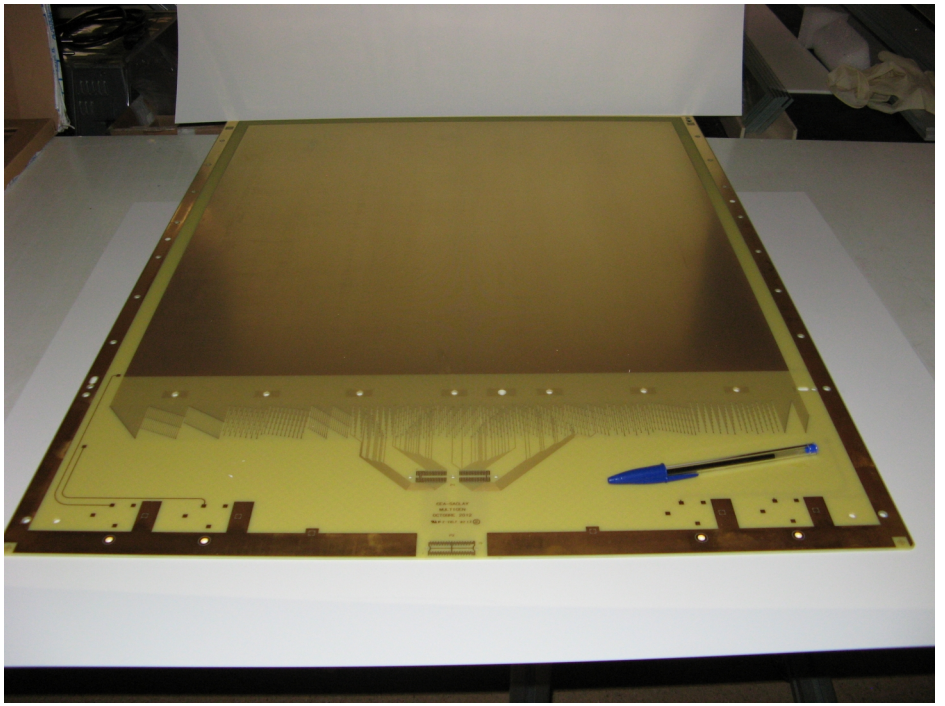


What we had



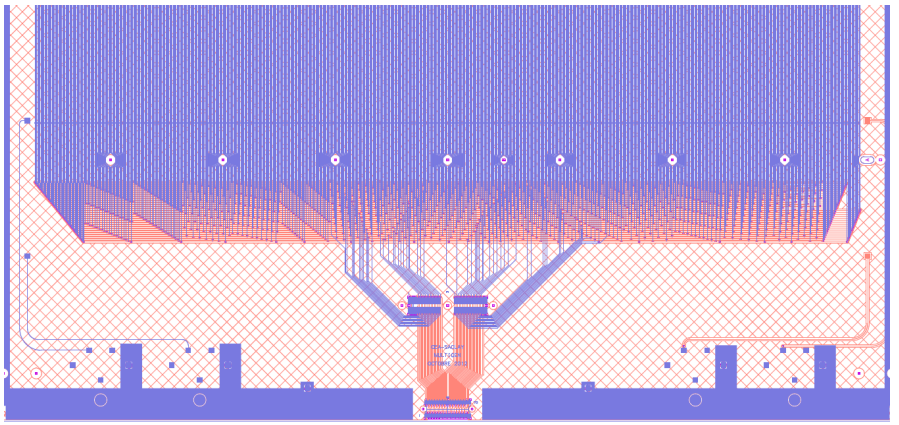
CLAS 12 Cosmic Bench

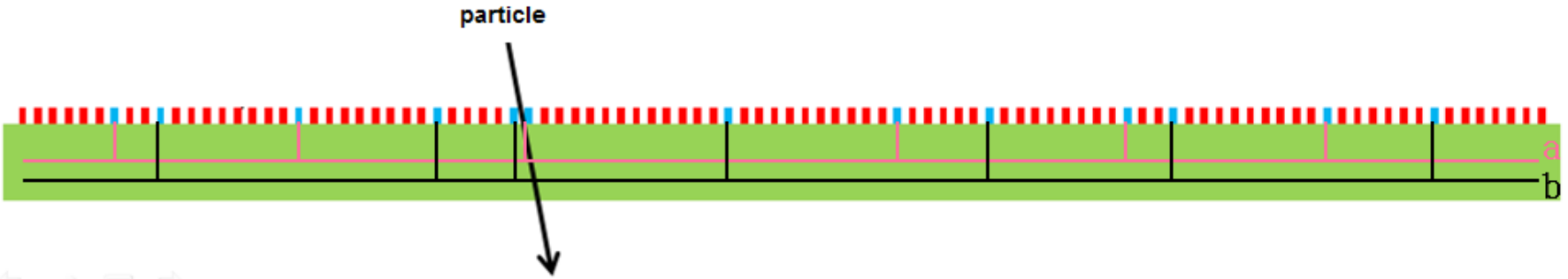
- CLAS12 need to test detectors
- Cost reduction
  - Need to reduce electronic channels of reference detectors
  - R&D on Micromegas multiplexing
- 512 channels for a full 50x50 cm² cosmic test bench of 300µm resolution



Multiplexing

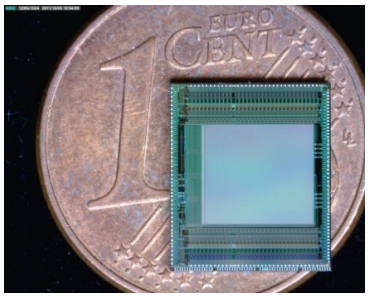
- Use channel multiplicity inside a Micromegas
  - Signal often spread over several strips
- The goal is to reconstruct n-uplet position instead of single strip position
- Patent in 2012
  - Sebastien Procureur
- Improved since then by a chinese team using graph theory

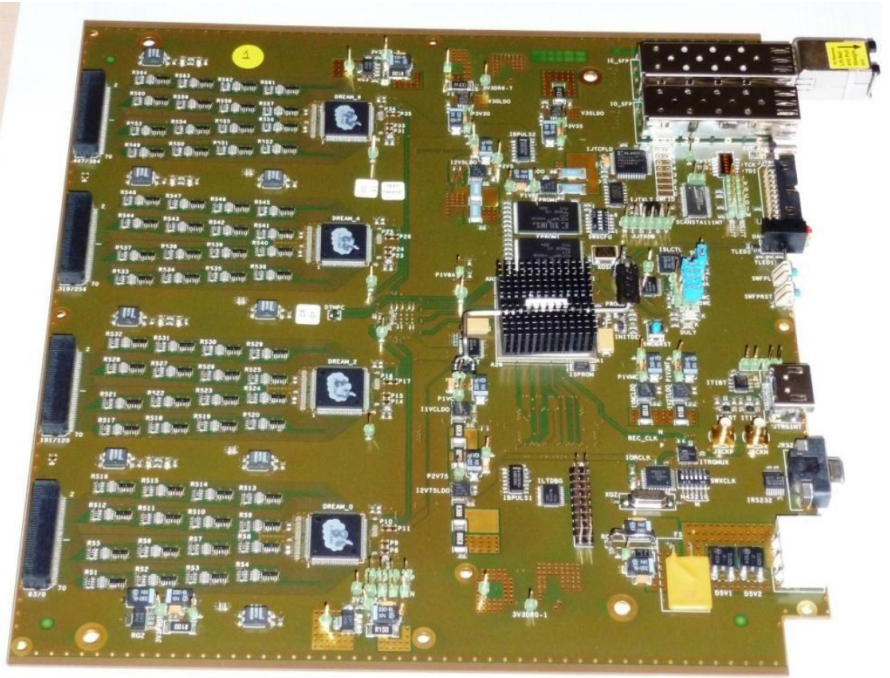




CLAS12 FEU

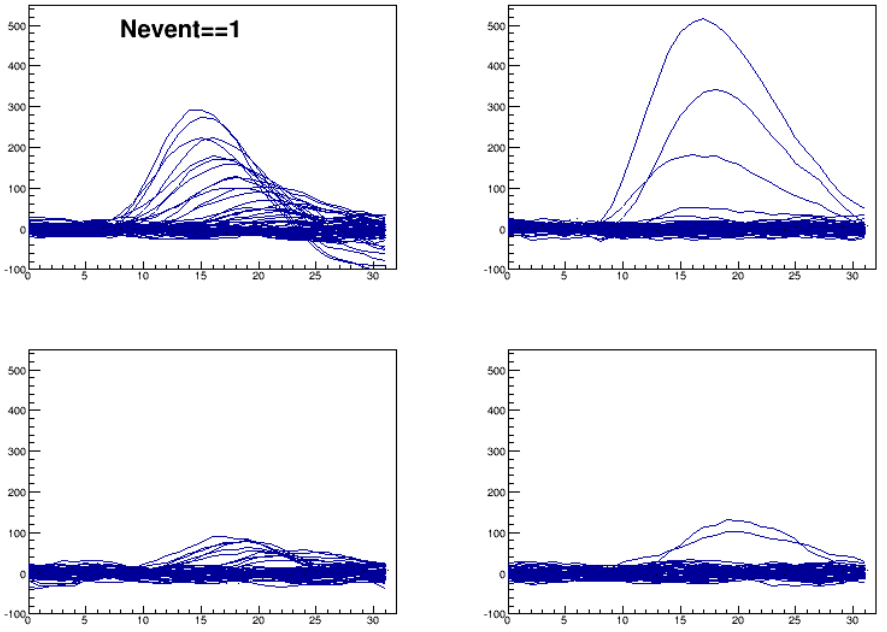
- Deported electronic
  - Impossible to put electronic inside the magnetic field
  - Cables add capacitance
- Capacitance increase noise levels
  - Need for adapted electronics
- DREAM – FEU
  - Pascal Baron
  - Irakli Mandjavidze
- Multiplxed detectors have higher capacitance
  - CLAS12 electronic is well suited



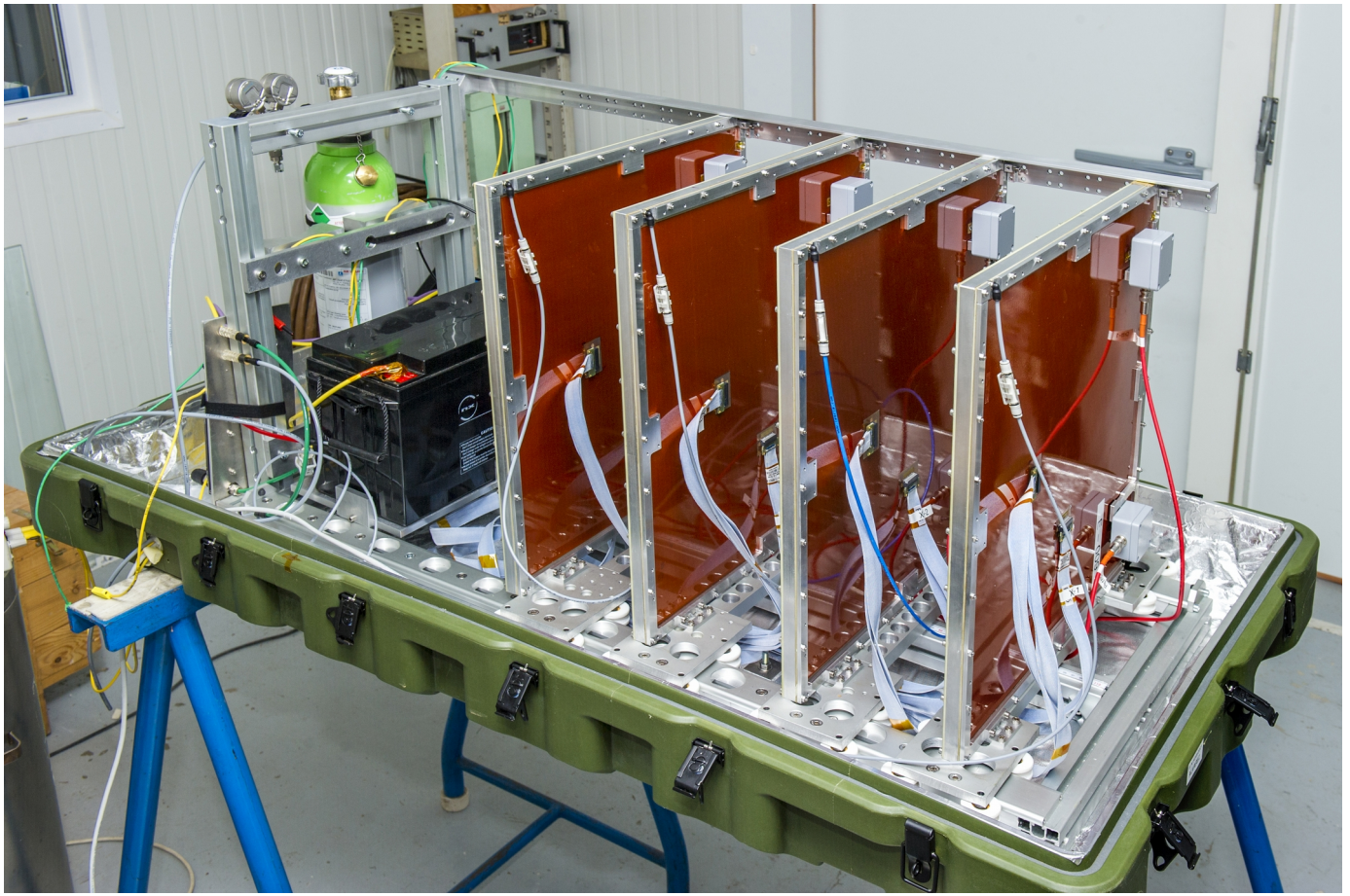


SelfTriggering

- Micromegas benches often use an external trigger
  - Coincidence from scintillators
- Use DREAM/FEU selftriggering capabilities
  - Signal on strip threshold
  - Coincidence threshold
- Highly dependant of noise levels
  - Common noise

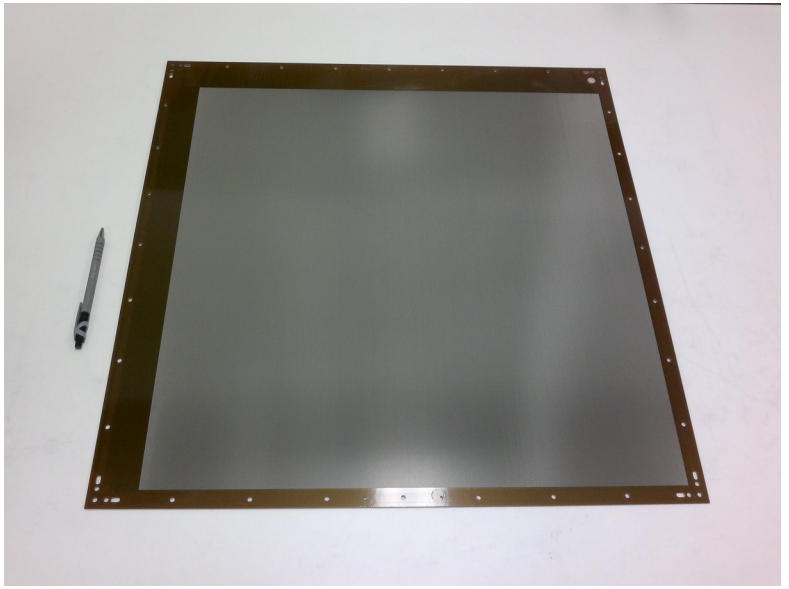


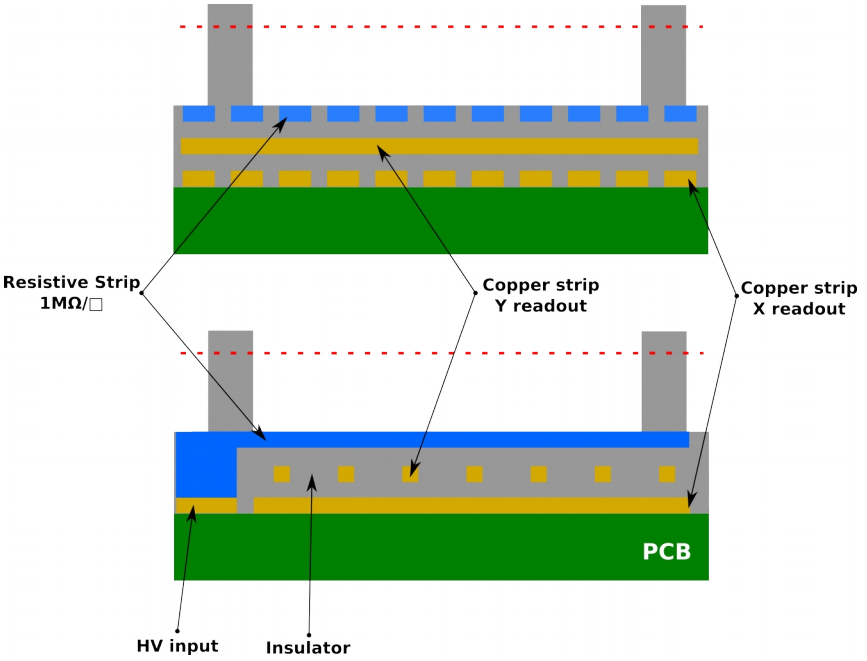
What we developped



MG2D

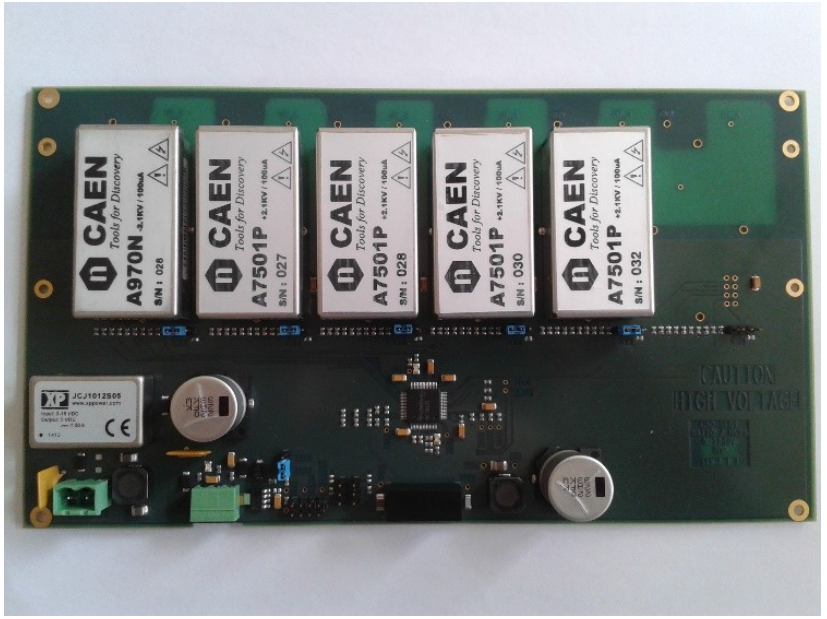
- Resistive technology
- Two layers of readout strips
  - Signal induced by capacitive effect
- 50x50 cm²
- 1024 strips by coordinate
- 61 channels by coordinate
- Second version
  - Solve design flaws
  - Decrease dead space for mosaics





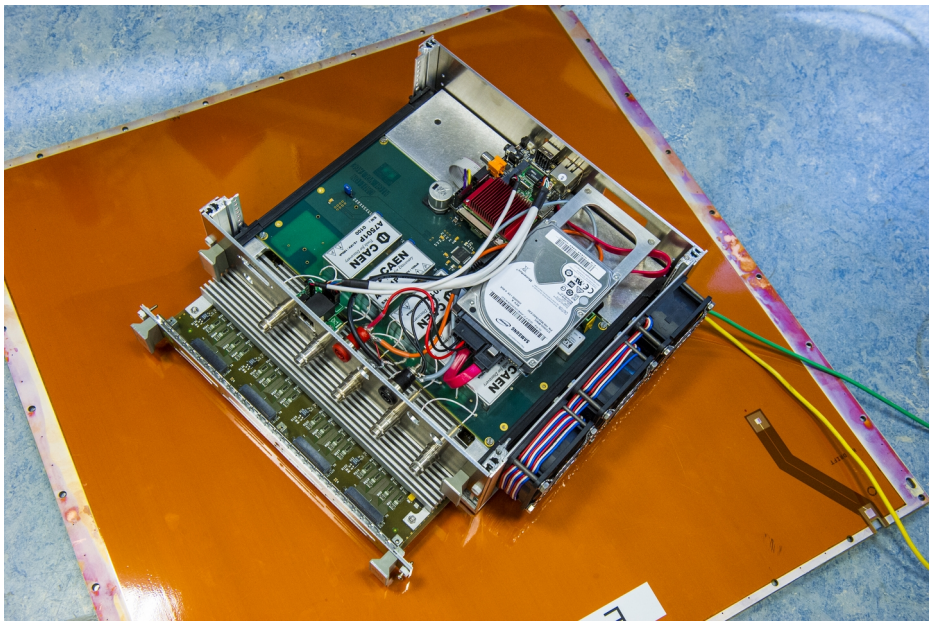
HVPS board

- Low consumption high voltage power supply
- New CAEN modules
  - Up to 2.1kV and 100µA
  - Power consumption < 0.6W
- Custom control board designed in SEDI
  - Denis Calvet
- Board can control and monitor up to 6 channels
  - Up to 5 detectors



Low consumption DAQ

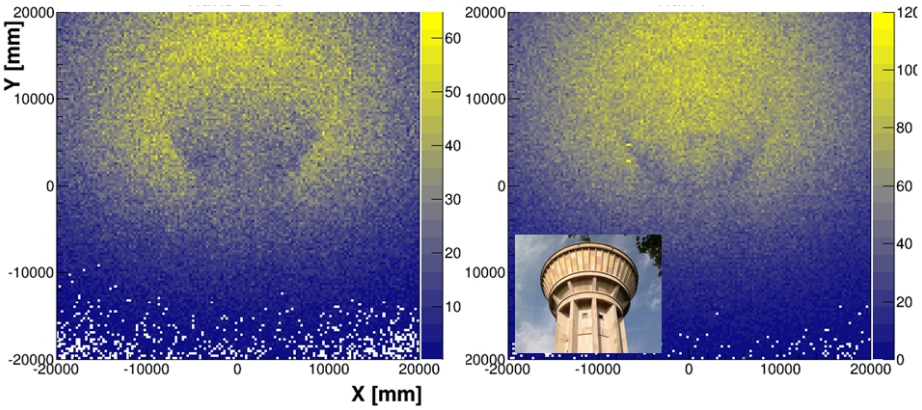
- Nano-PC
  - Smartphone technology (ARM)
- Control readout electronics
- Control and monitor high voltages
  - (T,P) feedback
- Online data processing
- Remote connection
  - Wire, 3G, WiFi

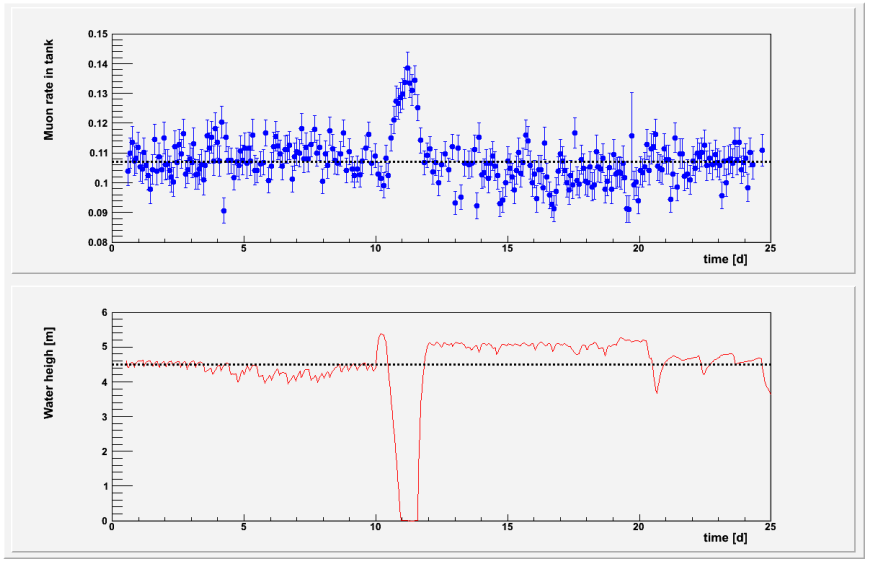


How do we use it

WatTo Experiment

- Worldwide first operation of a Micromegas tracker outside a lab
- 3 month of data taking
  - 1.5 month powered with solar panels
- Show imaging capabilities of muography
- Show dynamic capabilities
  - Water level monitoring
- Improve knowledge of Micromegas response to changes in the environmental conditions (T,P)
- Autonomous, low consumption (30W, solar panel powered) telescope can be deployed for a large number of applications
  - Volcanology, archeology, mining prospection



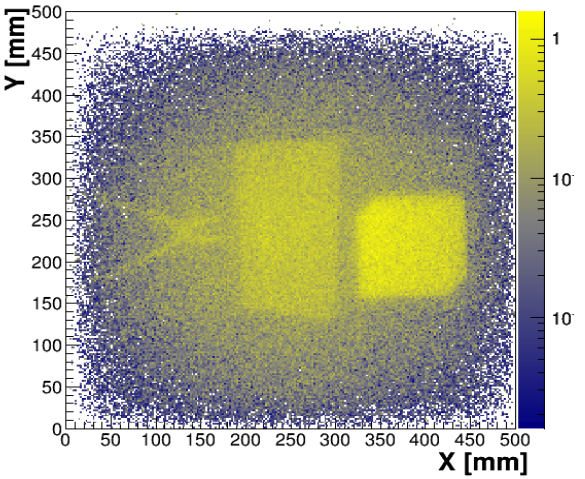


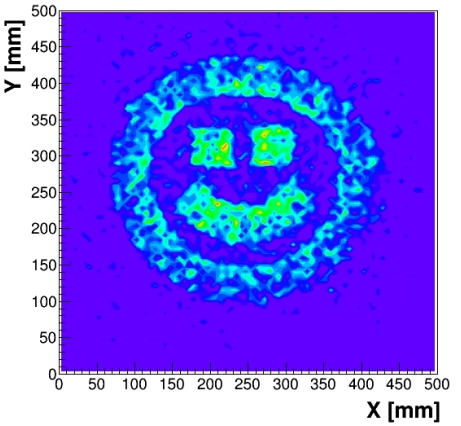
ScanPyramids Mission

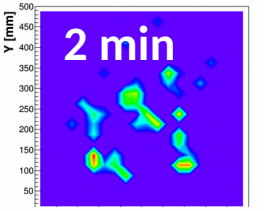
- 3 telescopes are taking data since the beginning of June
- Muography of the North-East edge of Gizah Great Pyramid
- Working with temperature up to 45°C
  - Tests up to 55°C were made in climatic chambers
- Pin pointed unplanned fluctuation due to the thermodynamic of the gas
- Gas recirculation test to increase autonomy

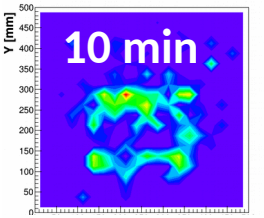
MCube Program

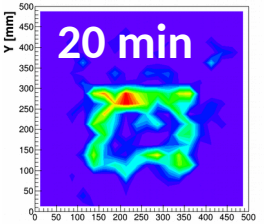
- CRBN funded
- Homeland Security
  - Port border control
- Detect high Z material
  - Special Nuclear Matter
- DNDO directive : detect 4kg of Uranium in less than 2min
- First detection then imaging
- Test with typical cointainer this summer
- 3D density map reconstruction is challenging

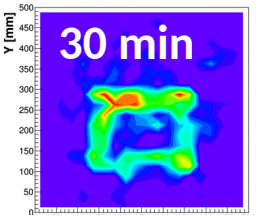


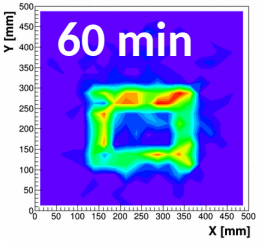












Conclusion

- Muon tomography is a spin-off of fundamental physics development
- Lots of applications are available
  - mining prospection with Areva
  - civil engineering with Vinci and RATP
  - ScanPyramids
  - Homeland Security with Smith Detection
- Applications in metrology
- Development made for the tomography can be reused by physics experiment
  - Multiplexing
  - Gas thermodynamics studies
  - Gas recycling
- Muon tomography apparatus can be used as cosmic bench to test detectors
  - ATLAS NSW