Micromegas R&D for muon imaging activities at Saclay

Christopher Filosa
(CEA/DRF/IRFU/DPhN)

Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

DE LA RECHERCHE À L'INDUSTRIE
cea

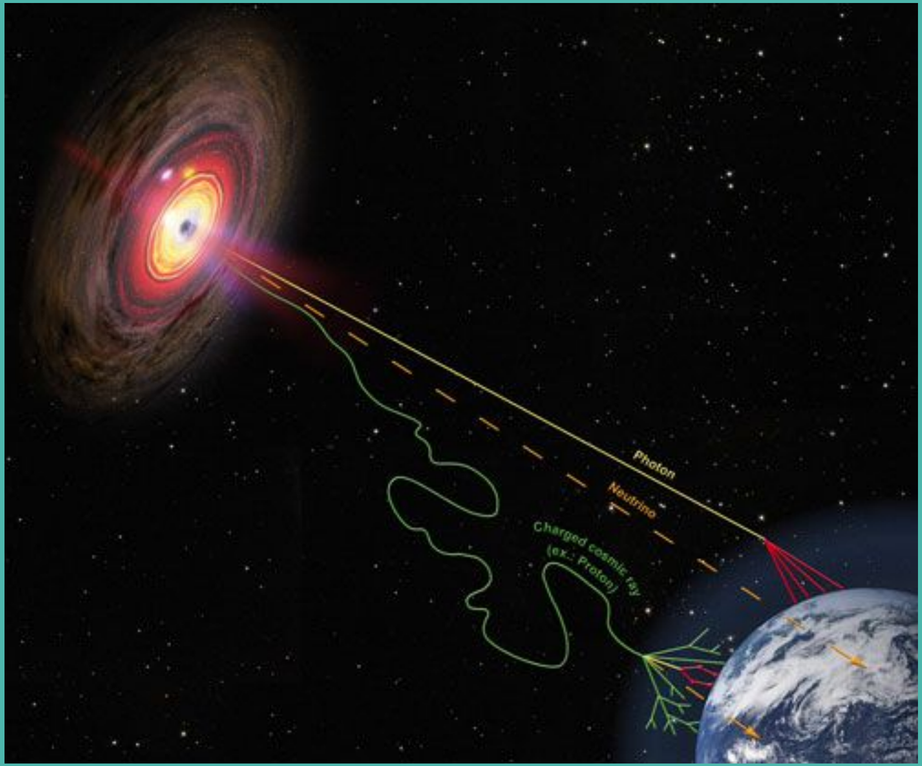

Bruxelles
Cologne
Southampton
Brighton
Lille
Belgique
Plymouth
Manche (mer)
Luxembourg
Guernesey
Jersey
Paris
Strasbourg
Brest
Extreme North
Rennes
Tours
Nantes
Suisse
France
Genève
Limoges
Clermont-Ferrand
Lyon
North
Grenoble
Turin
Bordeaux
Golfe de Gascogne
Toulouse
Montpellier
Monaco
Santander
Saint-Sébastien
Cannes
Bilbao
Vitoria-Gasteiz
South
Andorre
Gérone

Outline

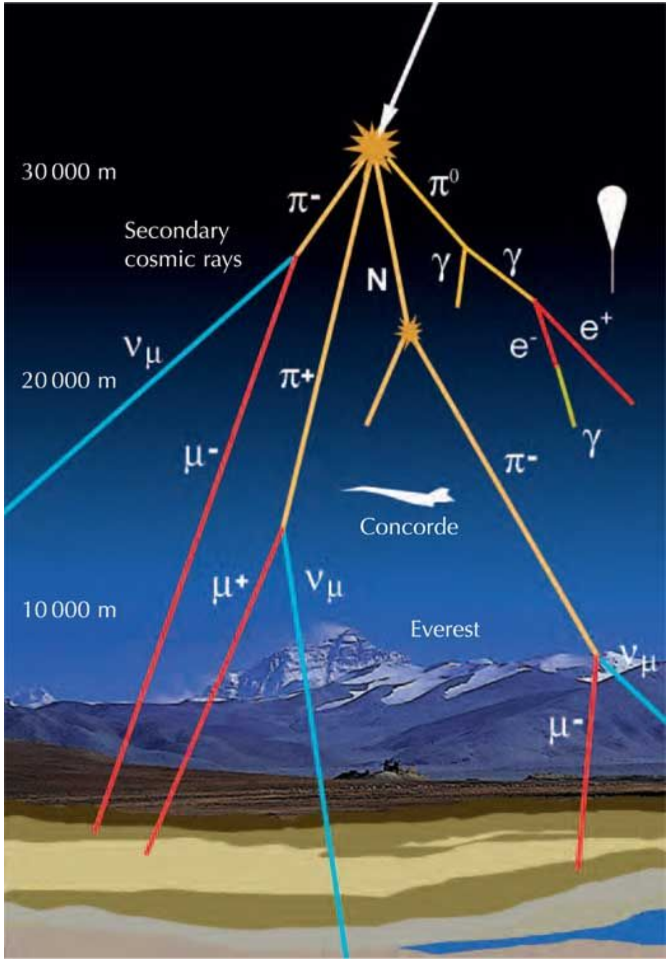
- A Brief reminder about cosmic muons
- Micromegas R&D
  ➞ improve spatial and time resolution
- Gas R&D
  ➞ improve gas consumption
- Detection of faults in concrete slab
  ➞ first step into tomography

Close encounters of the Third Kind

A permanent cosmic bombing raid



A cosmic shower !



Primaries : mainly protons

Muon flux at ground : 150/m^2/s ➡ cos(ϴ)^2 distribution

Mean Energy ~ 4GeV ➡ Kinetic energy of grain of sand at 1m/s

Celerity ~ c

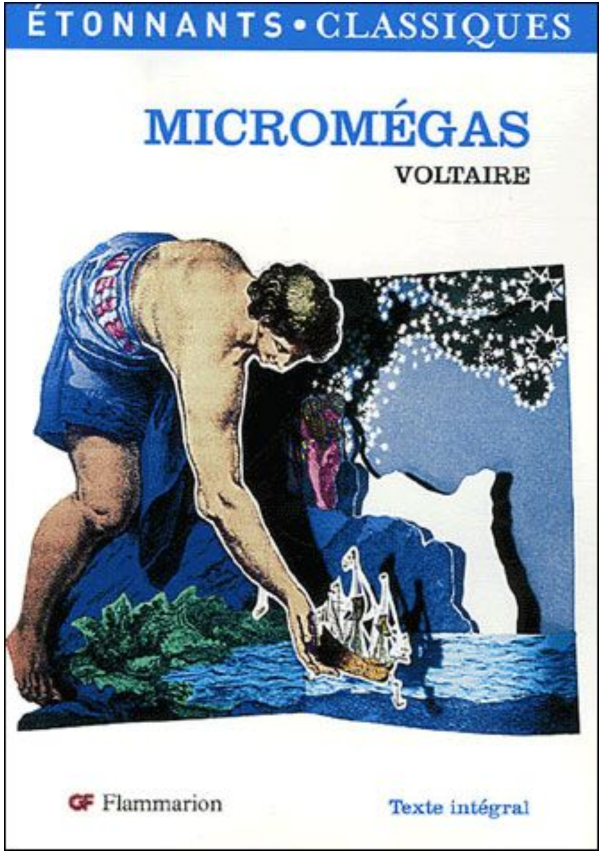
Lifetime ~ 2µs

Natural radiation, free and harmless !

MicroMegas detectors

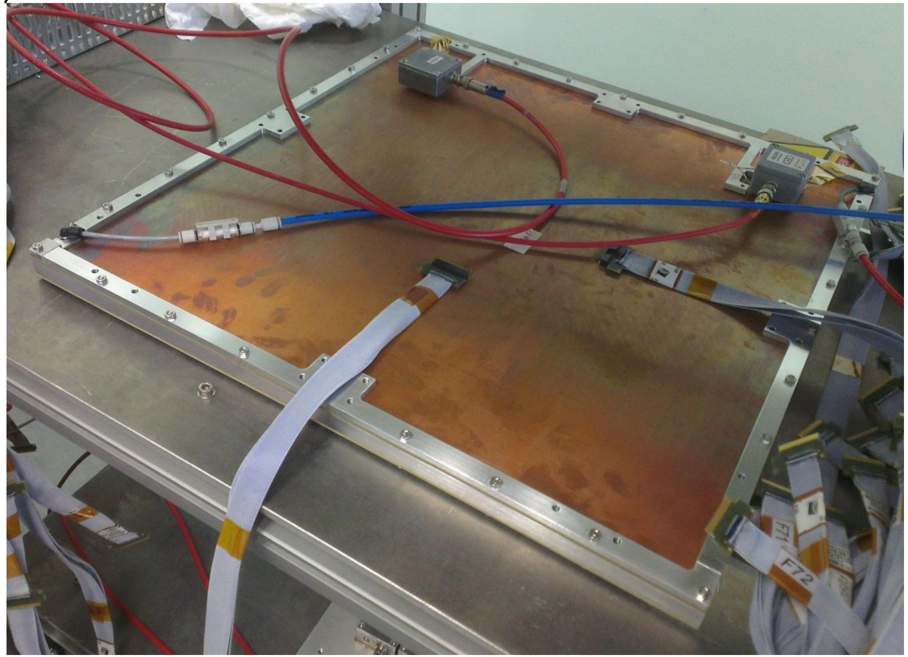
Main principles

MicroMegas detector



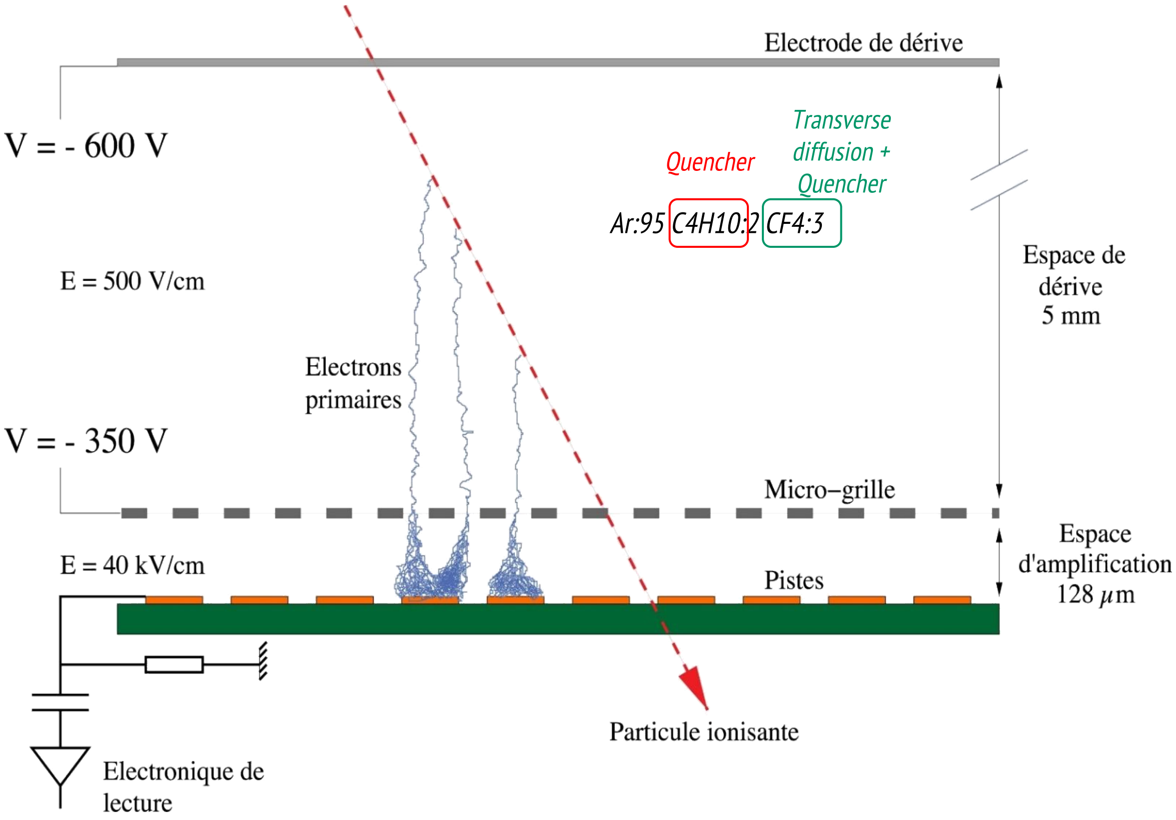
MICROMEGAS = **MICRO MEsh GAseous Structure**

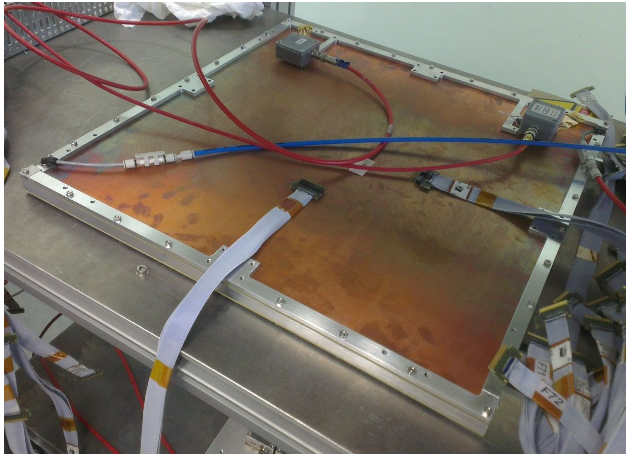
Gaseous Detector developed at CEA Saclay in 1996
by I. Giomataris, Ph. Rebourgeard et G. Charpak
(Nobel prize 1992)



MicroMegas detector

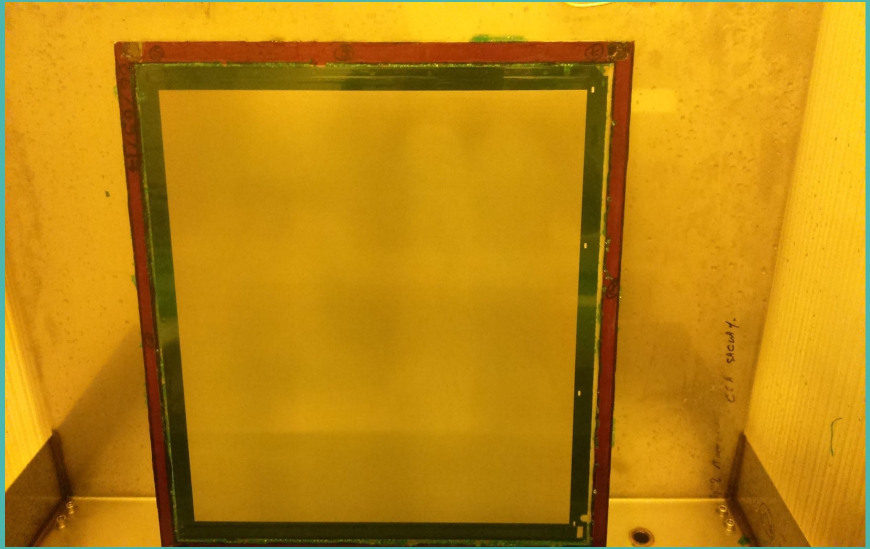
Main idea :
Separate the conversion and the amplification zone



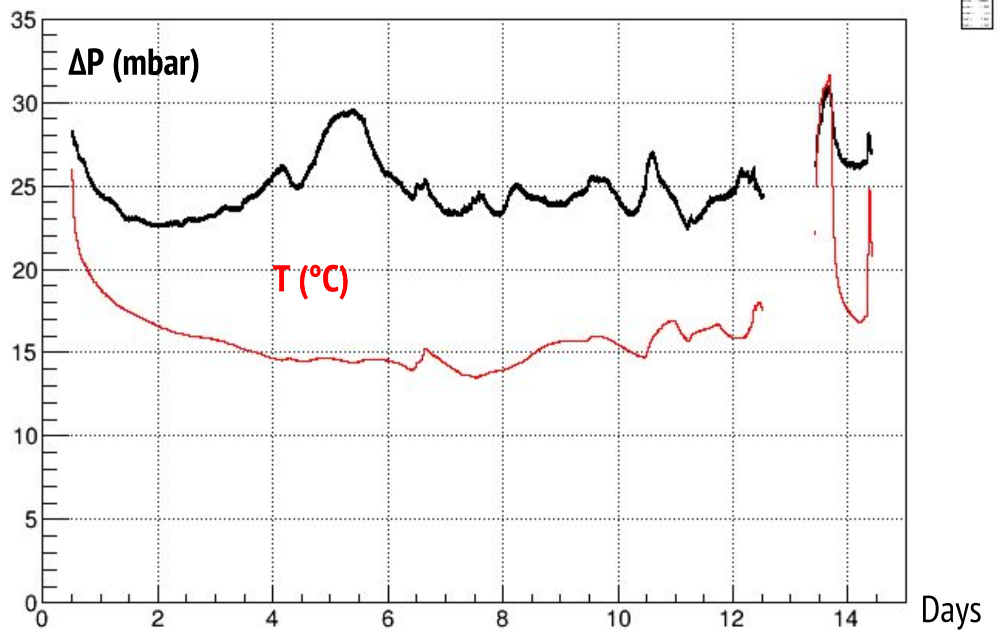


Gain ~ 10^4-10^5
Time resolution ~ 10ns
Spatial resolution ~ 100μm

Gas R&D



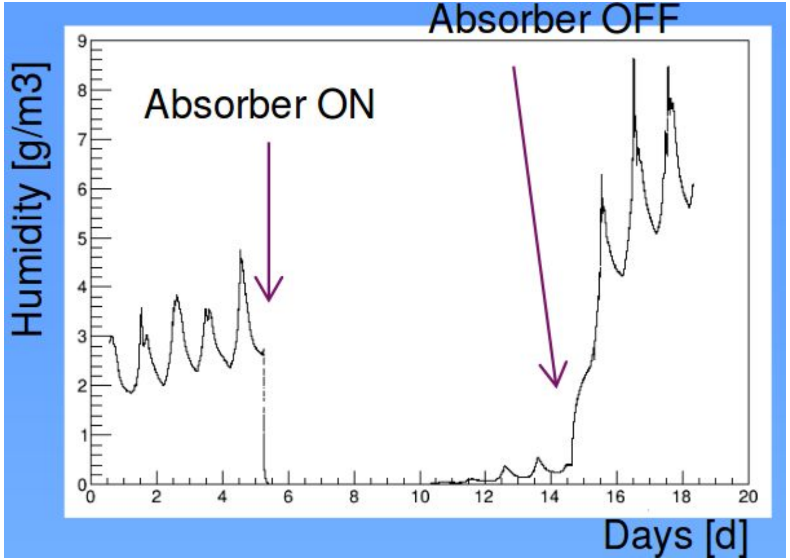
Reducing gas consumption



- Idea : Sealed detector to reduce drastically the leak of gas
  - ➞ Leak < 30µL/h (Measure taking into account T variations)
  - ➞ Next step : stuck only PCB anode.

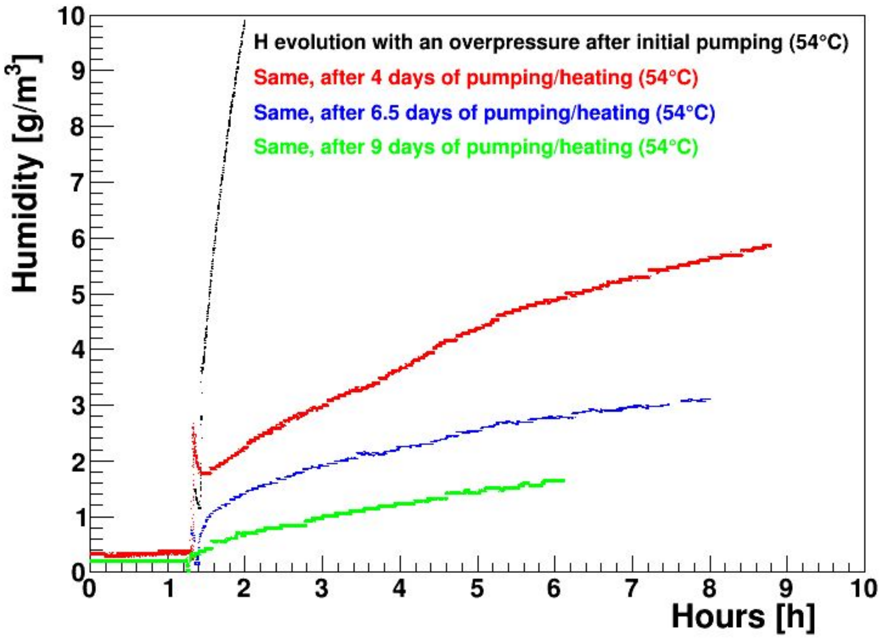
- Electronic control of gas consumption (2 to 3 times less).
  - ➞ Make sure about gain stability

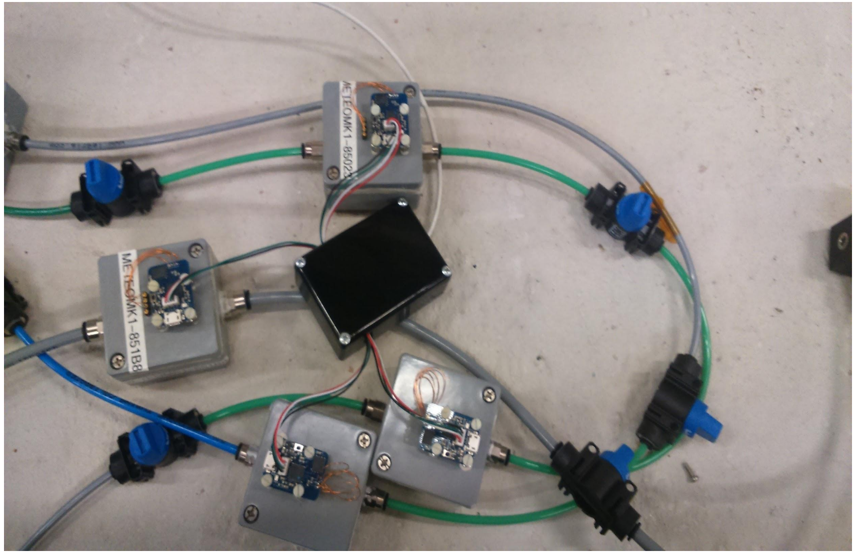
Problem of outgassing



- PCB outgassing issue
  - ➞ Humidity + gaseous pollutant through the outgassing of PCB
  - ➞ Degradation of gas : Recirculation + purification system
  - ➞ Heated process for PCB (à la HARPO) tested
  - ➞ New vacuum chamber to make tests

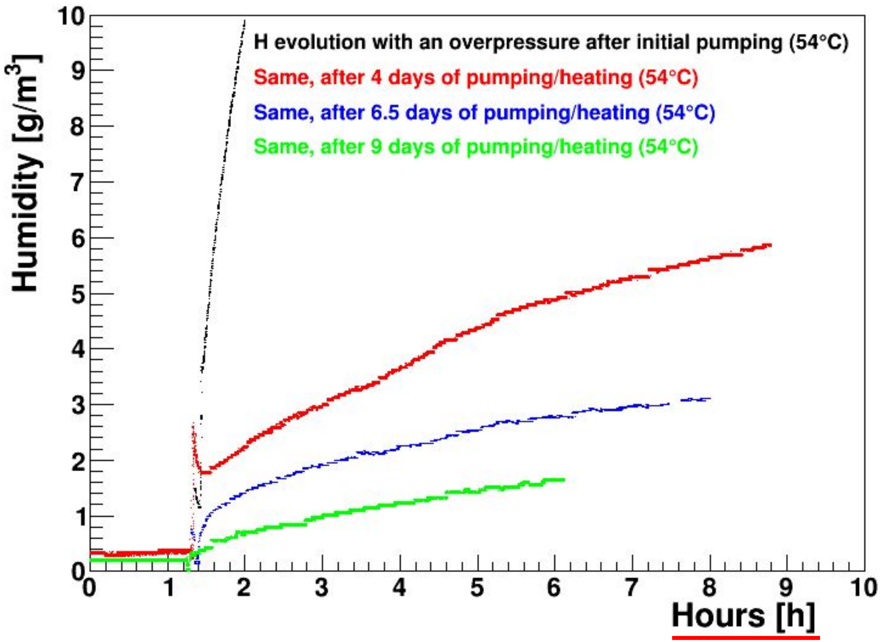
Problem of outgassing

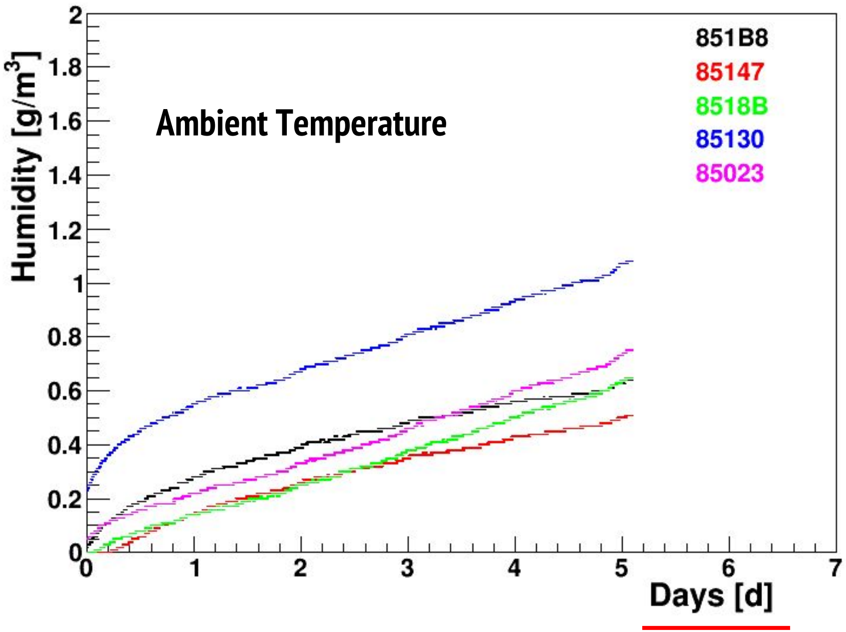




- For sensors boxes, seems to be the good method

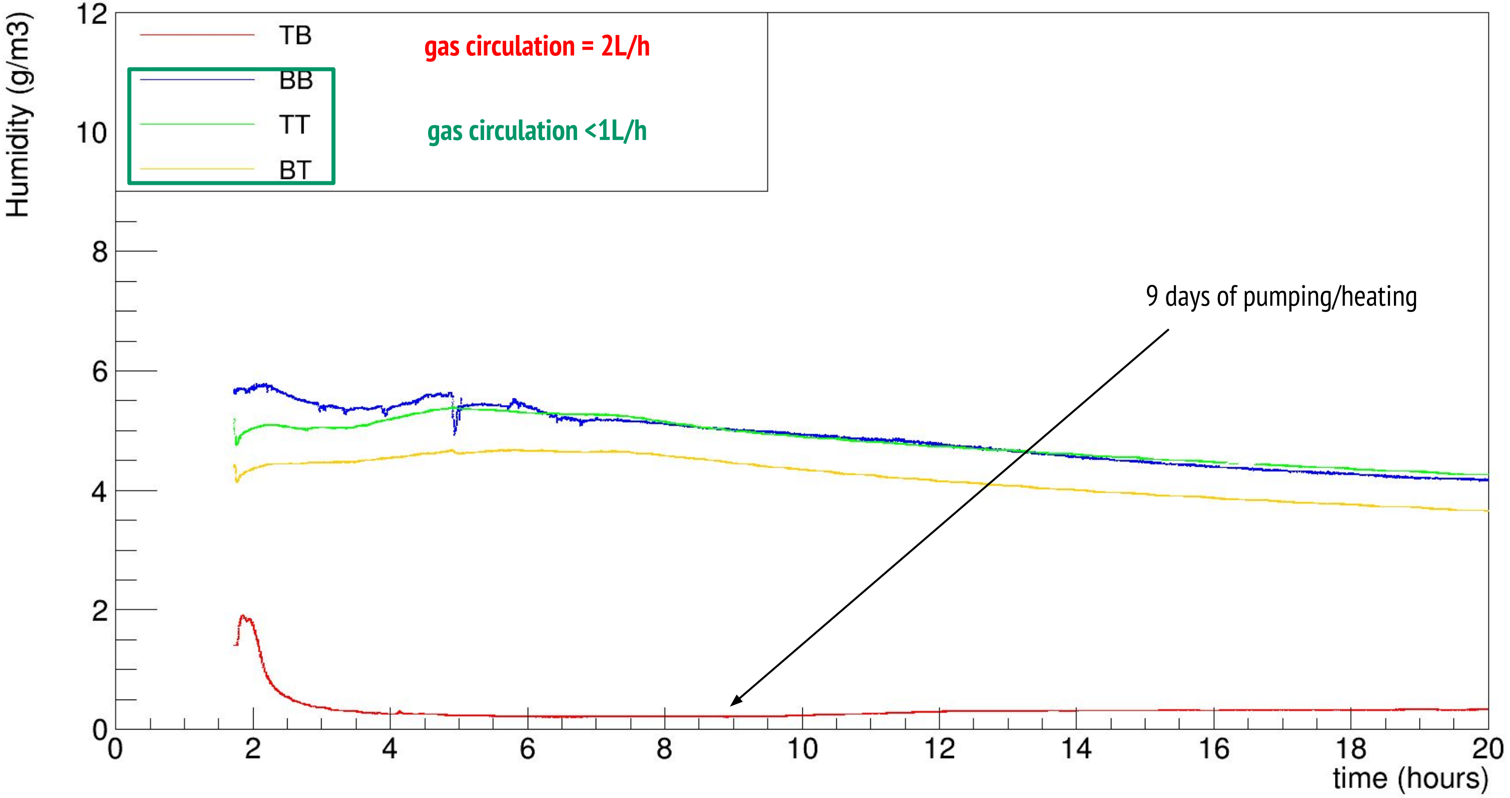
Problem of outgassing





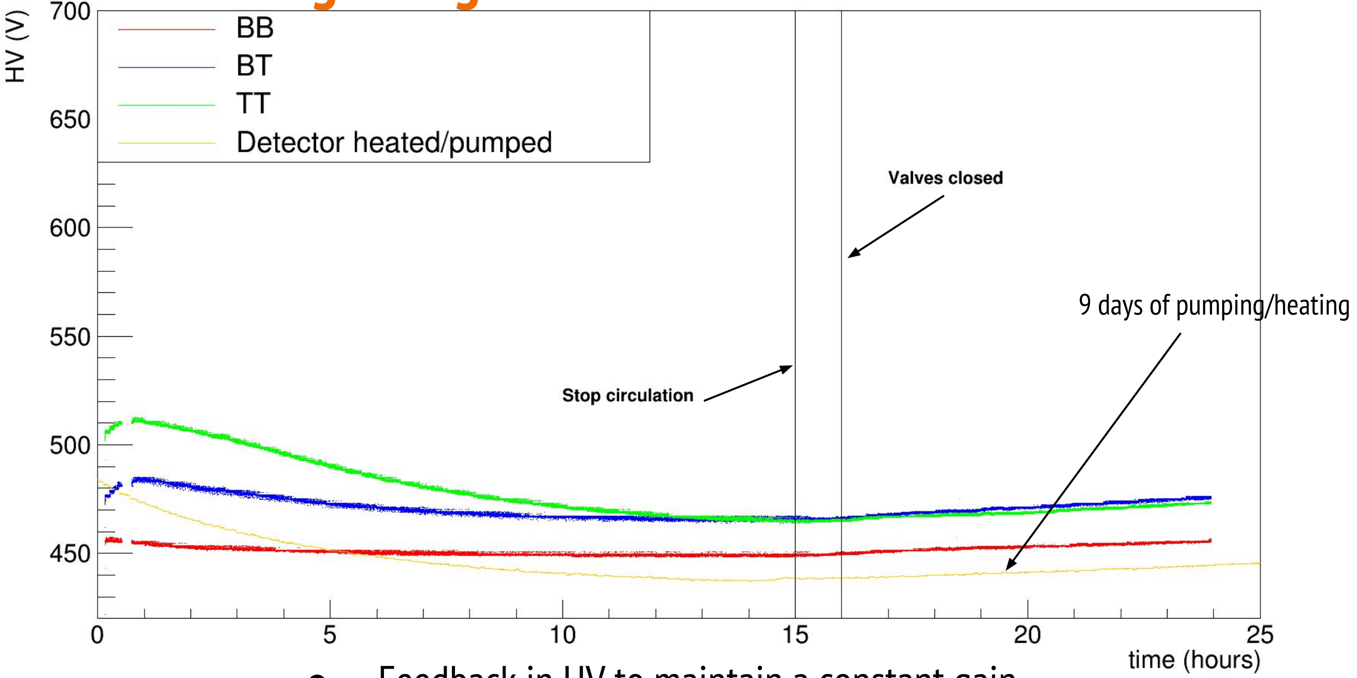
- For sensors boxes, seems to be the good method
- Other pollutants outgassed ? Humidity from outside ?
- No degradation of the boxe caused by pumping/heating
- The same for detector ? (PCB porosity, resistivity degradation ...)

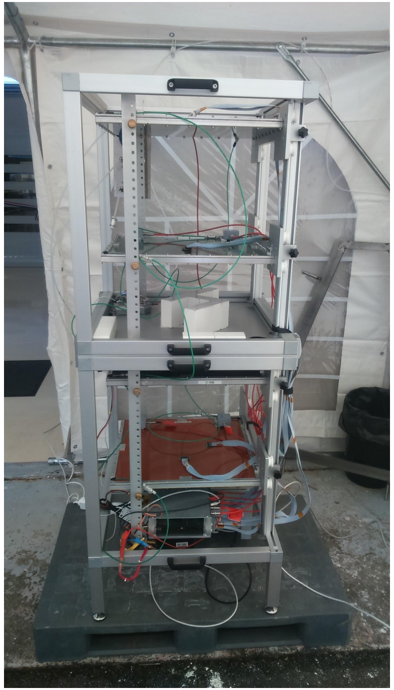
Problem of outgassing



Humidity 15 times lower in TB than other detectors (with gas circulation)

Problem of outgassing

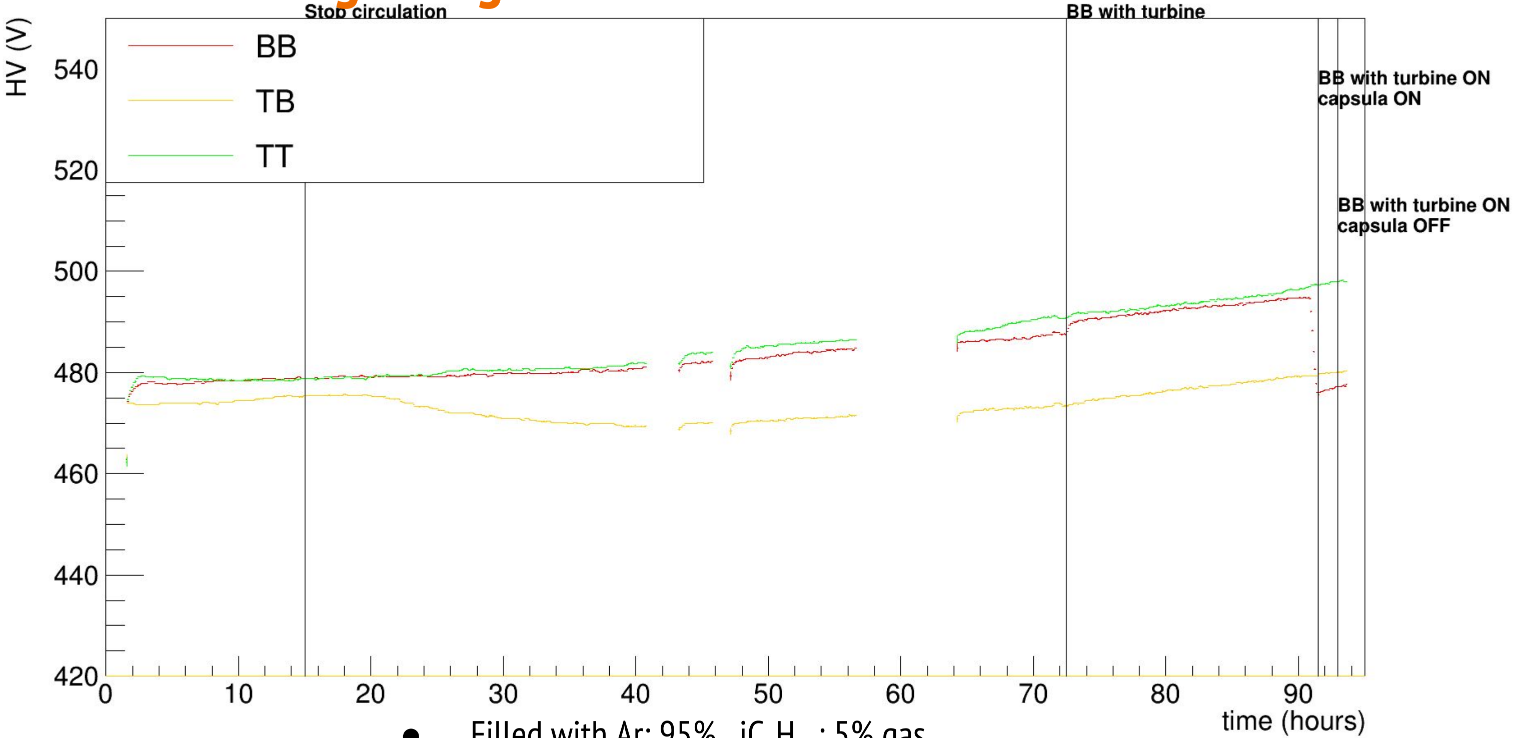


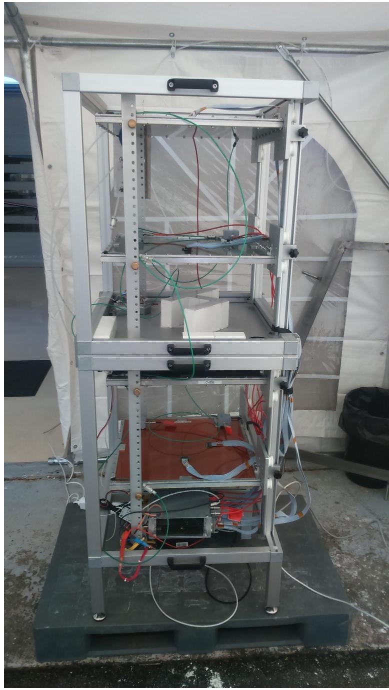


- Feedback in HV to maintain a constant gain
- ΔV between Bottom and Top detectors
- Slope in V/h to compensate the gas degradation
- Filled with T2K gas
- Less humidity, but same slope in V/h : (T variation)

➔ 0.67 V/h, 1.16 V/h, 0.93 V/h , 0.85 V/h

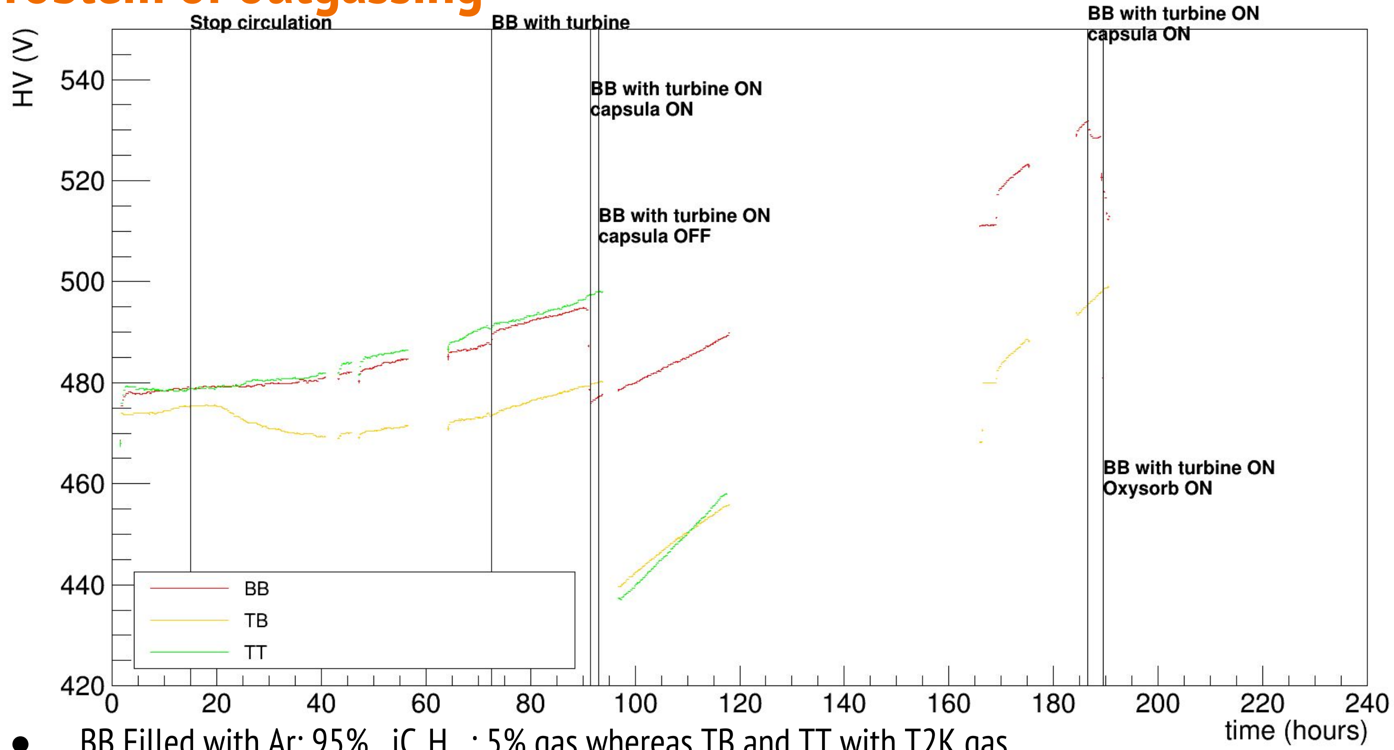
Problem of outgassing

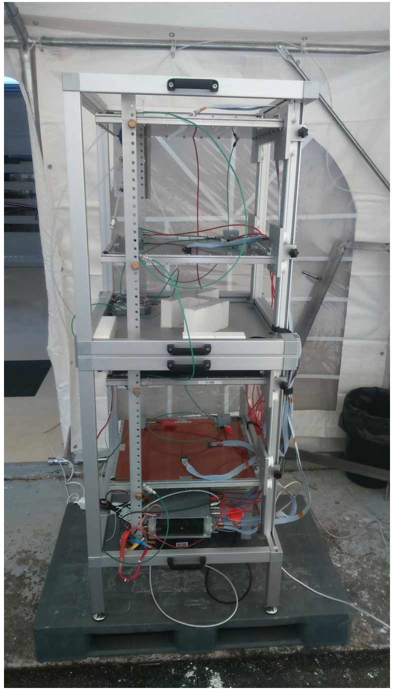




- Filled with Ar: 95% , iC_4H_{10}: 5% gas
- No more ΔV between Bottom and Top detectors (gaz leak for TB detector)
- The same Slope in V/h with turbine on BB : 0.25V/h, 0.10V/h, 0.18V/h
- Capsula ON :
  - ➔ Increase of gain correlated with a 20V loss
  - ➔ Increase of slope in V/h : 0.78V/h

Problem of outgassing





- BB Filled with Ar: 95% , iC_4H_{10}: 5% gas whereas TB and TT with T2K gas
- Different slopes in V/h with the two gas :
  - ➔ Ar-Iso : 0.52V/h
  - ➔ T2K : 0.75V/h , 1.05V/h
- Capsula ON : Humidity divided by 2 in one hour. But only 3V lost
  - ➔ Other pollutant than humidity

- Oxysorb ON flushed with Ar: 95% , iC_4H_{10}: 5% :
  - ➔ Oxysorb absorbs something else
  - ➔ Perhaps Oxygen

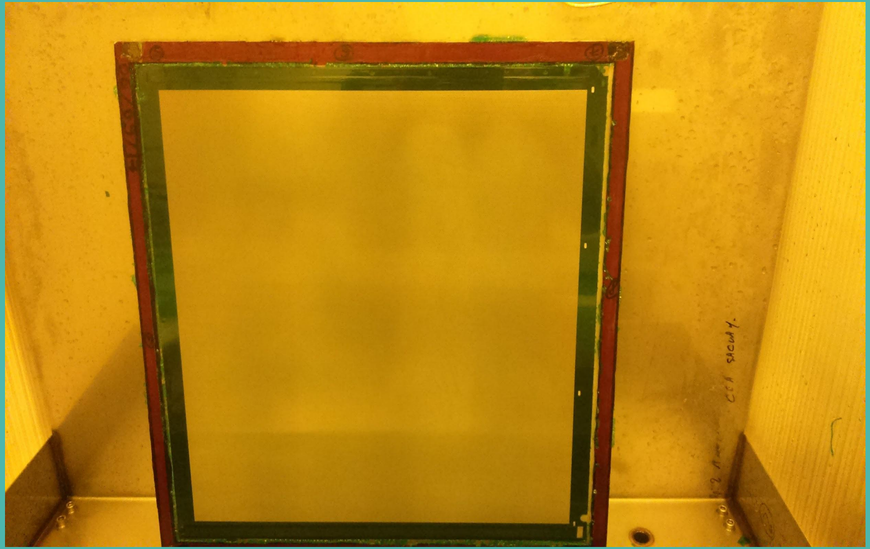
Problem of stability

- Humidity could induce gas degradation
  - → PCB porosity ?
  - → Other sources ?

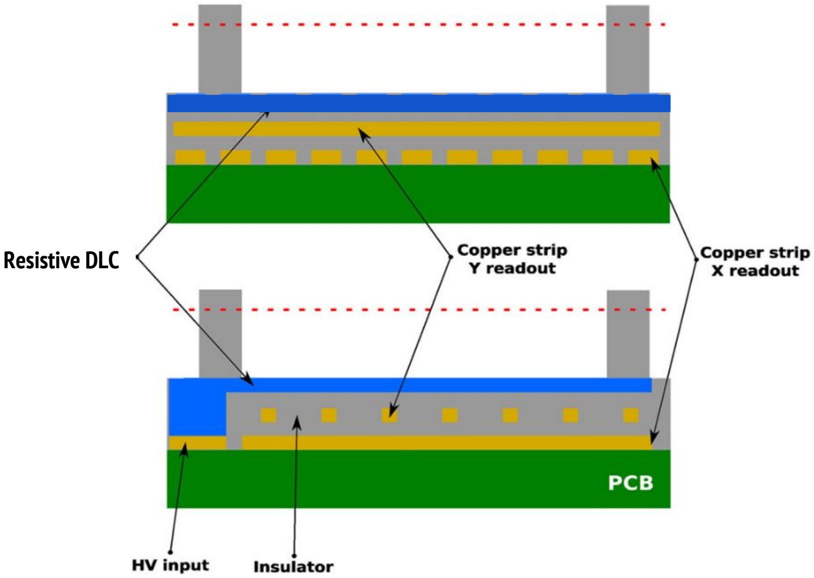
- Stronger effect with CF4 :
  - → HF production ? But no visible clues (Liquid under 20°C + aging)

- Other unknown pollutant
  - → Could it be Oxygen
  - → No major gas leak in our detector. Need to investigate.

Micromegas R&D



Diamond Like Carbon (DLC) Micromegas



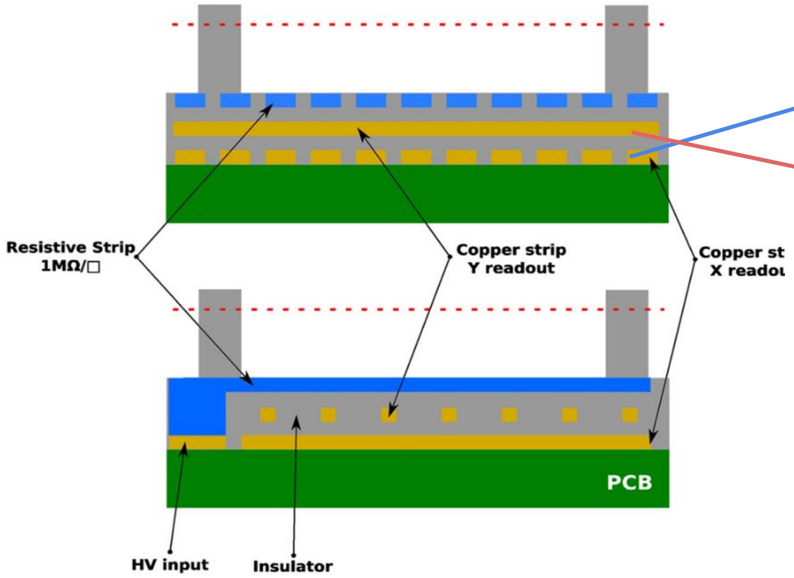
- 50 x 50 cm^2 active surface

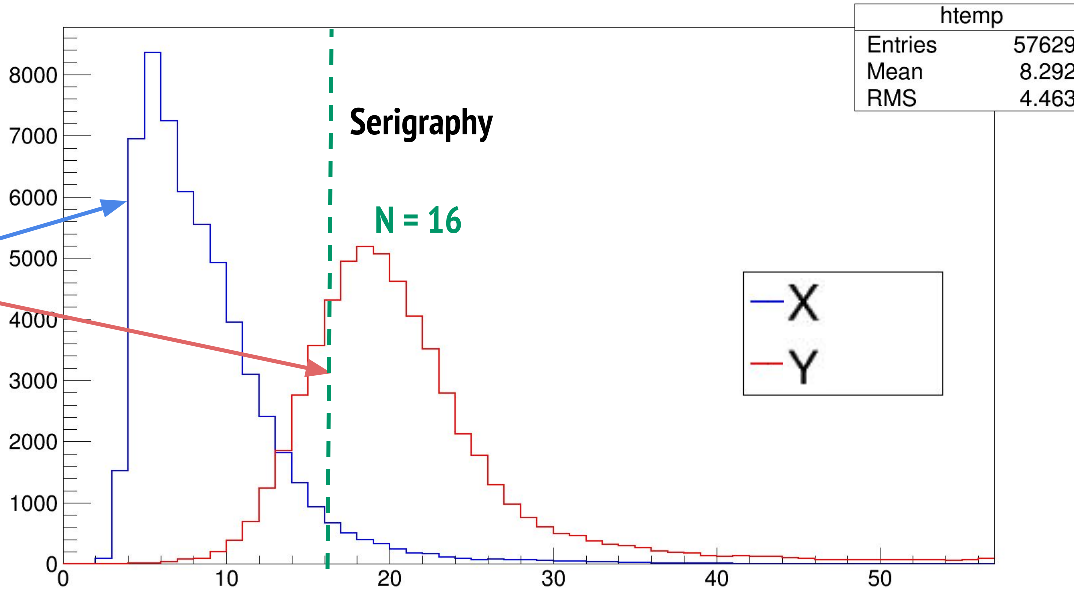
- Resistive DLC
  - ➞ Chemical deposition technique
  - ➞ No alignement needed
  - ➞ More homogeneous than strips
  - ➞ Pressed and glued by Rui de Oliveira at CERN
  - ➞ Bulked at Saclay

- Integrated resistivity ~ 50MΩ
  - ➞ higher than resistive strips
  - ➞ Clusters' size are expected to be equal in X/Y readout

Characterization of DLC Micromegas

Cluster size distribution



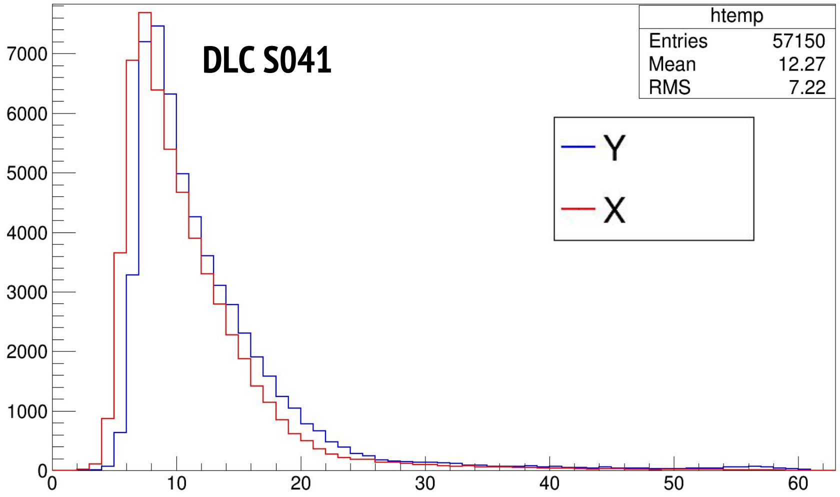


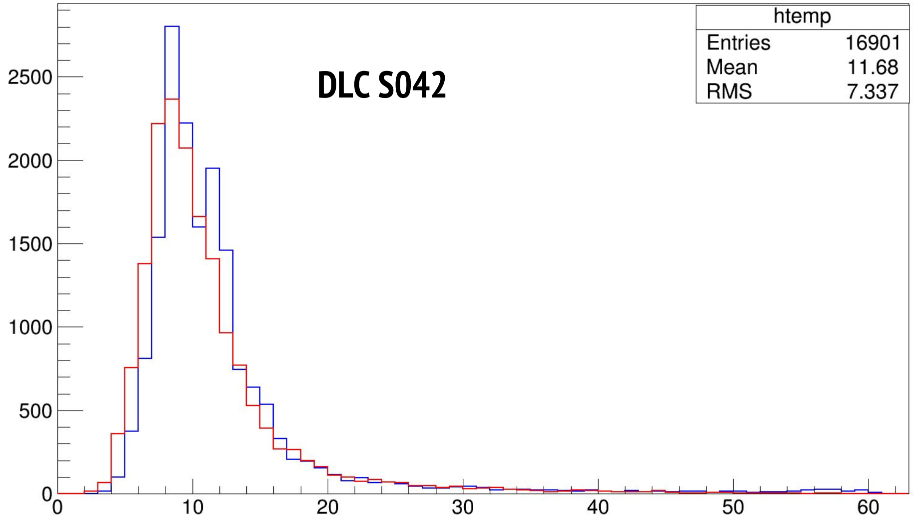
- Increasing of clusters' size due to the position of Y strips (Charge collection along the resistive strips)

- For cluster size >16
  - ➞ Ambiguities can appear
  - ➞ Spatial resolution degraded
  - ➞ Need to improve X coordinate

Characterization of DLC Micromegas

Cluster size distribution

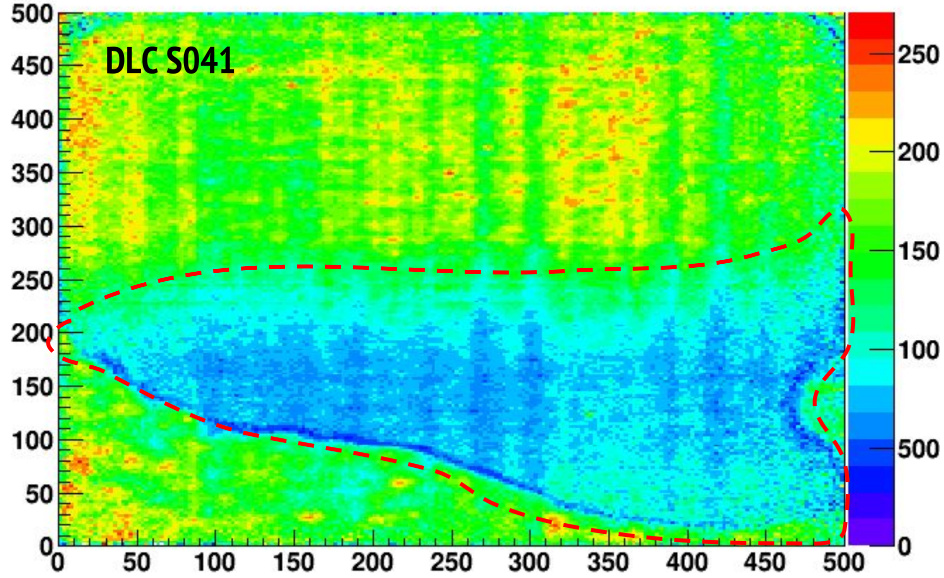


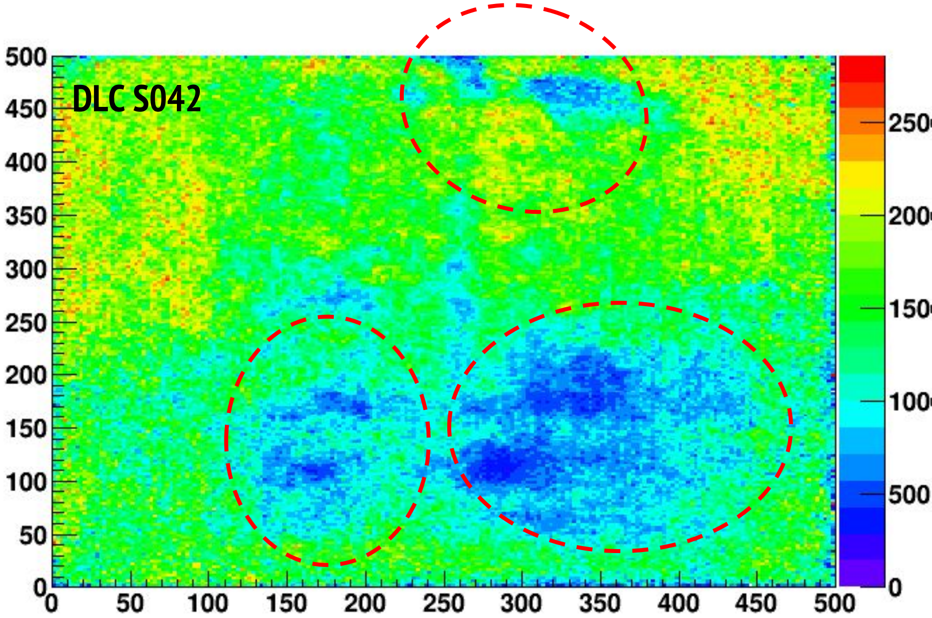


- Higher resistivity for DLC + no strips structure
  - ➞ Less spreading
  - ➞ DLC Clusters' size are equal in X/Y readout

Characterization of DLC Micromegas

2D Map of amplitude



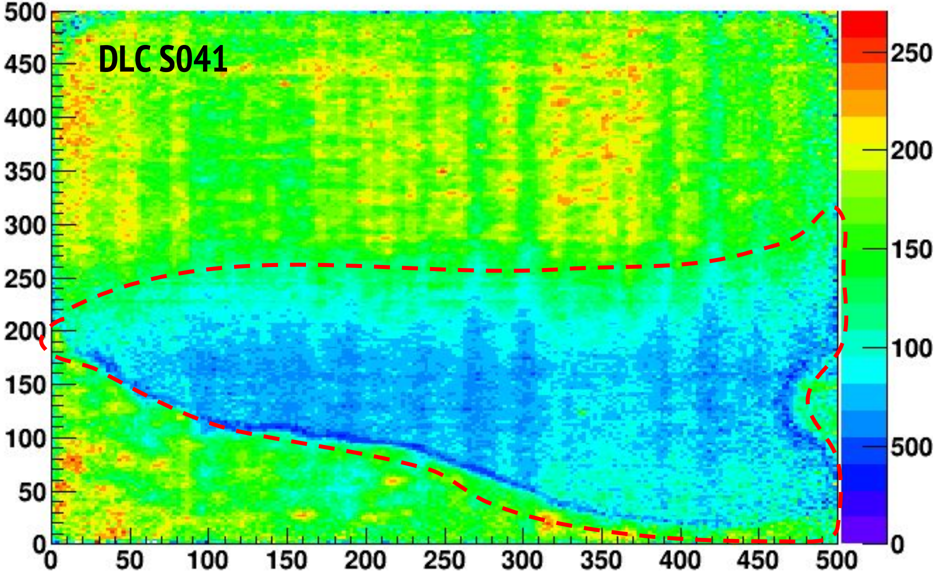


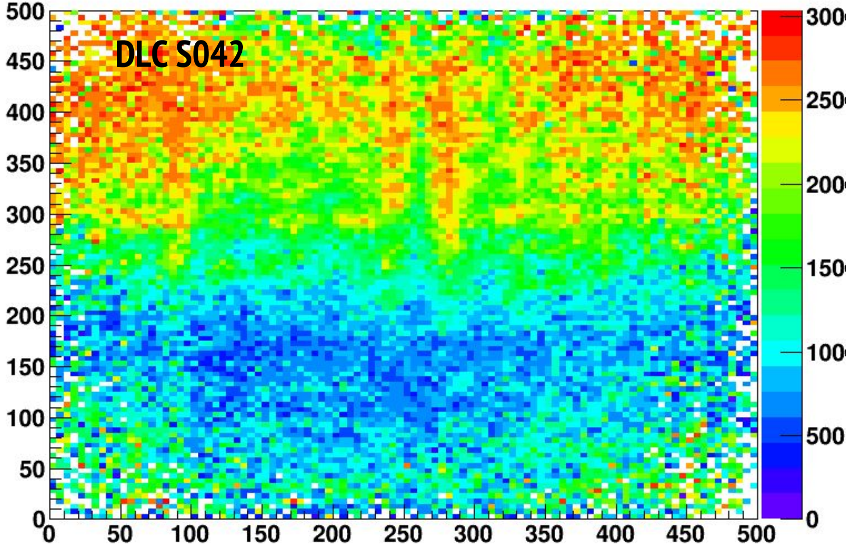
- Problem during bulk process
  - ➞ Unstuck pillars zone
- Nevertheless, the unstuck zone is still efficient when the HV increases

- No problem with pillars
- Inhomogeneous zone of gain
- Problem during cleaning process
  - ➞ Development bath
  - ➞ Remnant of photoresist film

Characterization of DLC Micromegas

2D Map of amplitude





- Problem during bulk process
  ➞ Unstuck pillars zone

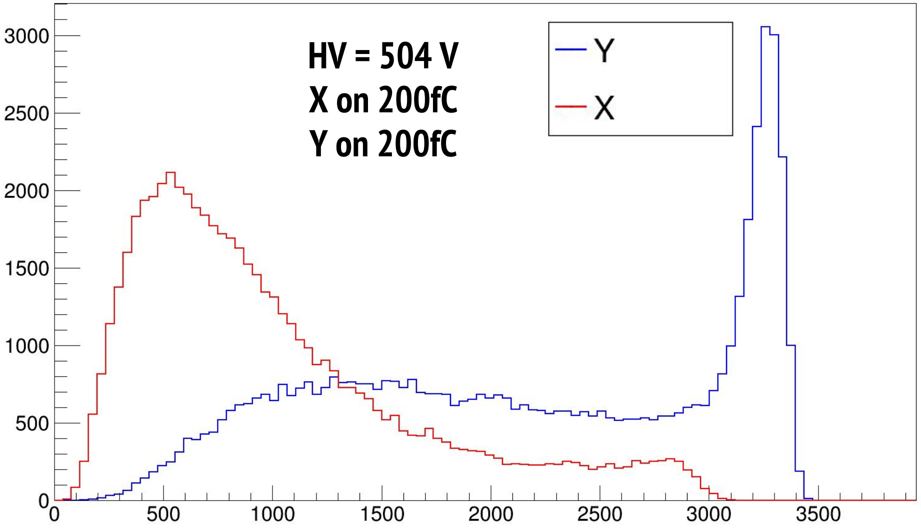
- Nevertheless, the unstuck zone is still efficient when the HV increases

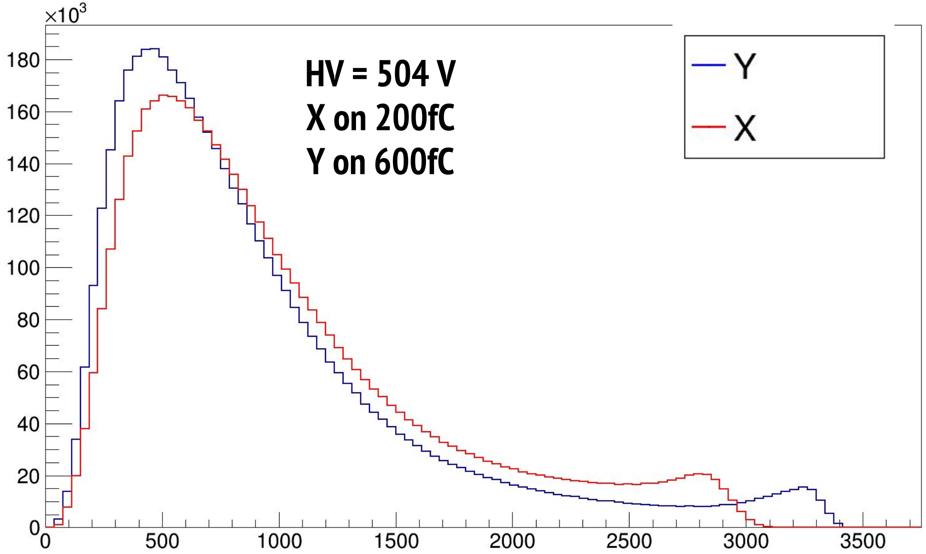
- Still Inhomogeneous zone of gain after alcool + karcher

- Deposit of photoresist film (change of mesh color observed)

Characterization of DLC Micromegas

Amplitude distribution S041

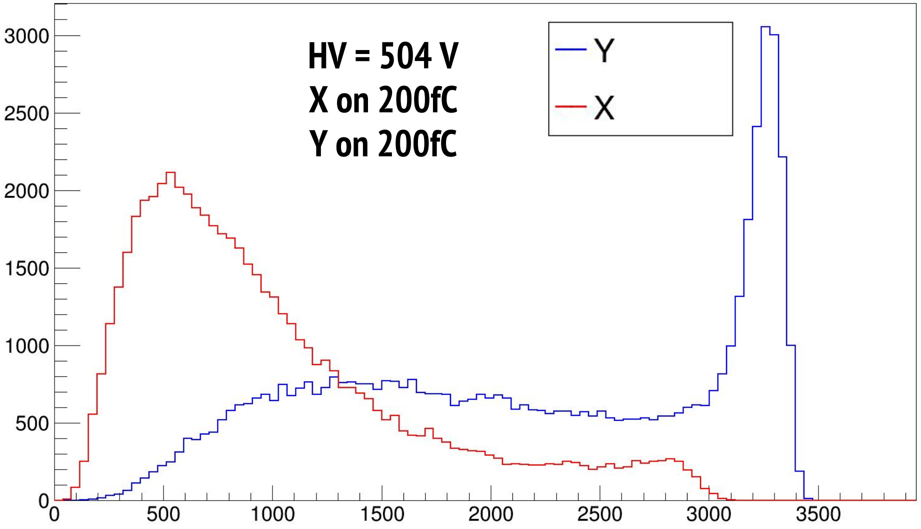


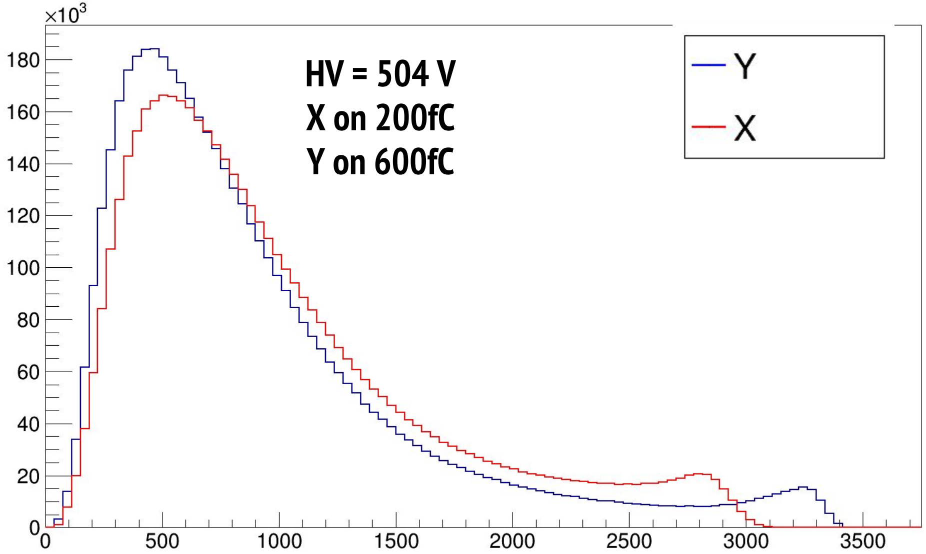


- Charge mostly received by upper strips
  - ➞ Factor 3 between Y (up) and X (down) strips
  - ➞ Capacitance coupling

Characterization of DLC Micromegas

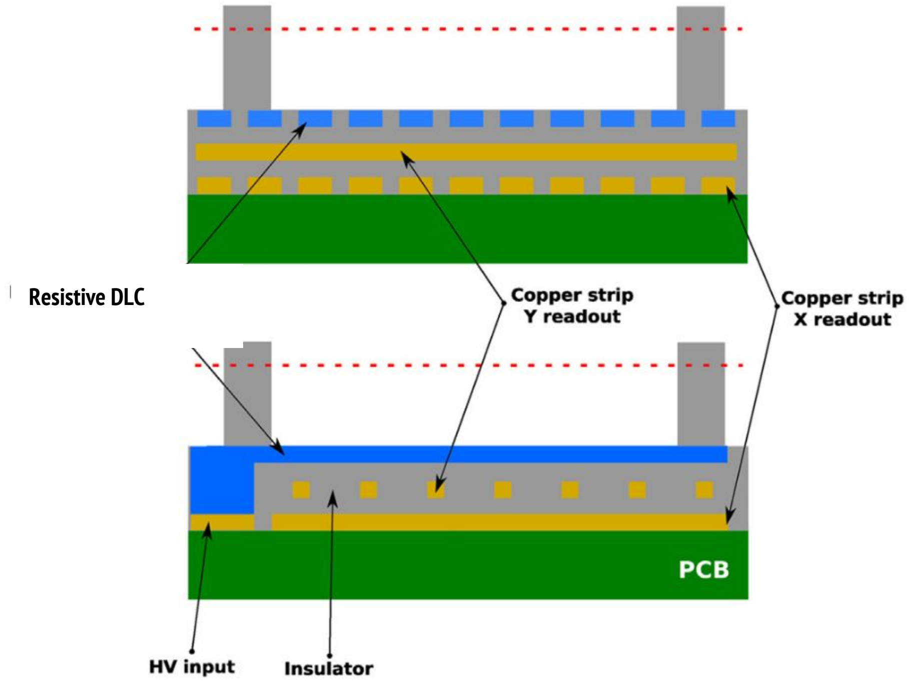
Amplitude distribution S041





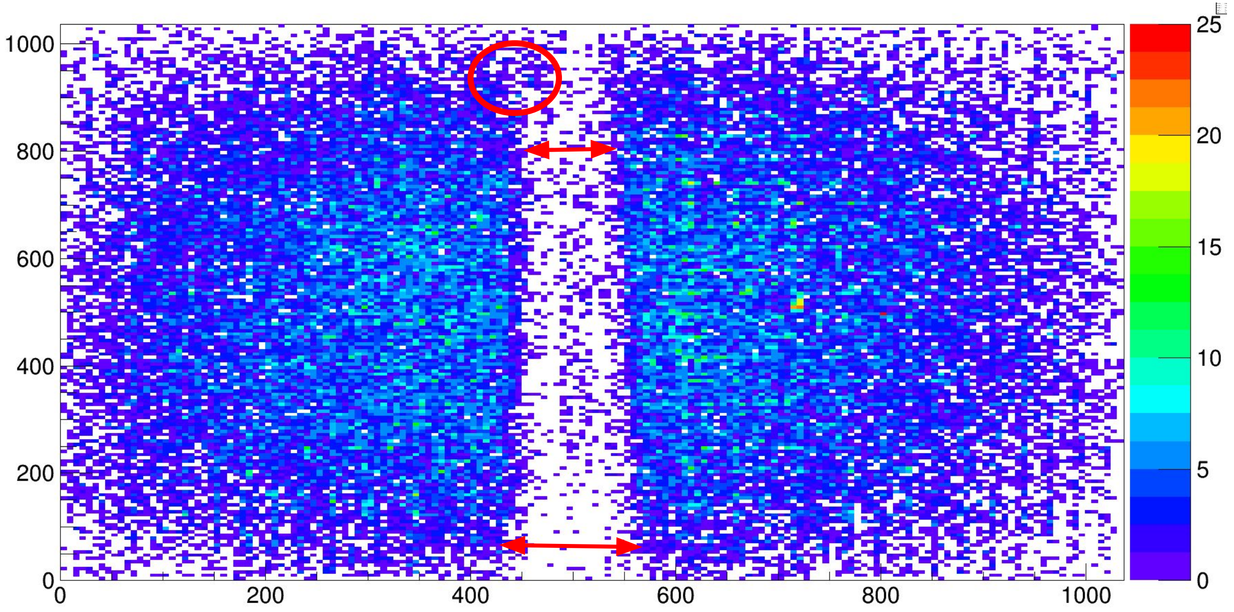
- Charge mostly received by upper strips
  - ➞ Factor 3 between Y (up) and X (down) strips
  - ➞ Capacitance coupling
  - ➞ If strips on DLC, better coupling between X and Y

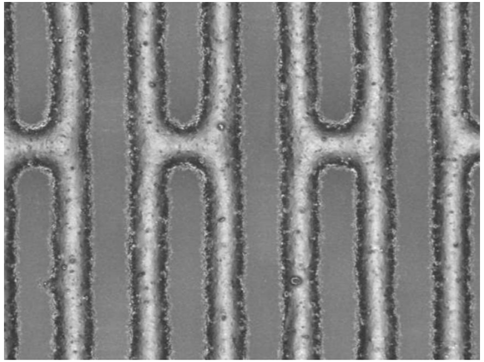
Stripped DLC

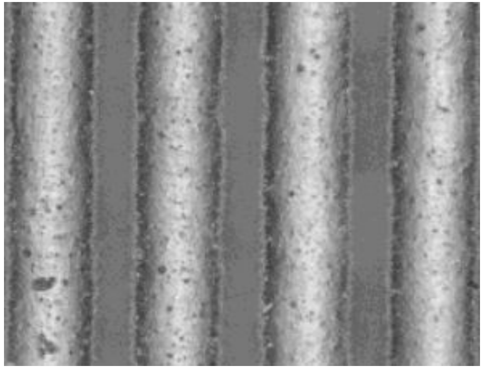


- Standard DLC with photoresist films above
- Abrasion done with harsh stones to eliminate the DLC between the strips
- Photolithography to eliminate the photoresist film
- At the end, only DLC strips
- Homogeneity + good capacitance coupling

Stripped DLC







- Map of hits position : zone of inefficiency
  - ➞ Current due to remanent of photoresist
  - ➞ laddered stripped on PCB
- Issue observed in CLAS12
- Factor 2 between X and Y strips

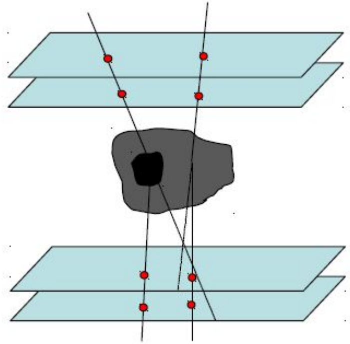
Discovery of a big void in a concrete slab by observation of cosmic-ray muons

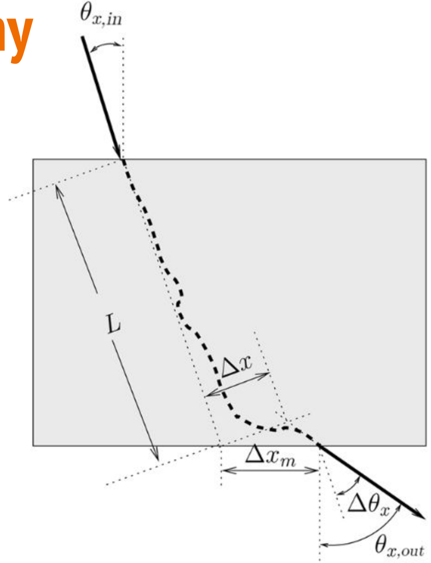
nature

International weekly journal of science

Two modes of tomography

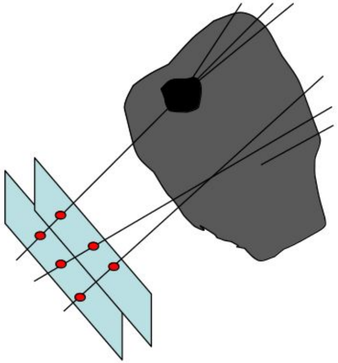
Deviation





- Coulomb diffusion
  - ➞ deflection angle depend of density
  - ➞ 10 cm of lead ~ 1° of deflection
- 3D Imaging
- Use for homeland security
- Spatial resolution is drastic
- Faster than transmission

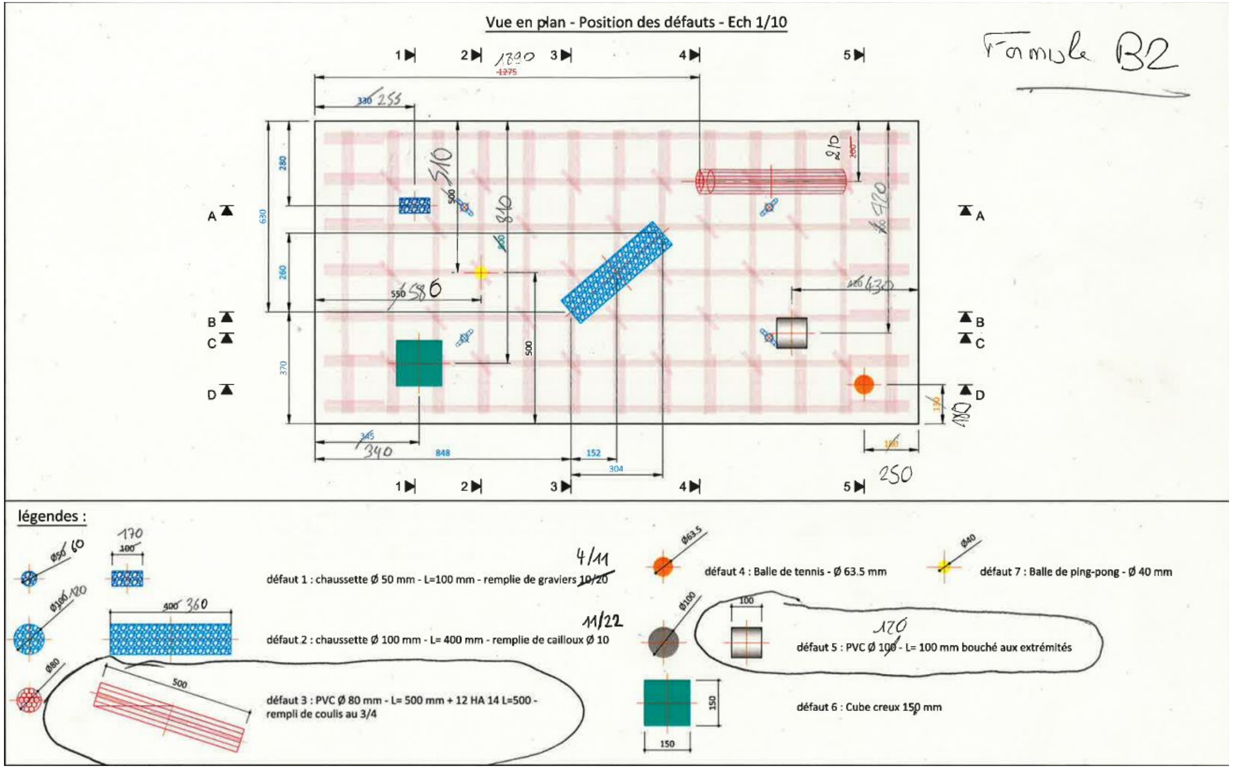
Transmission



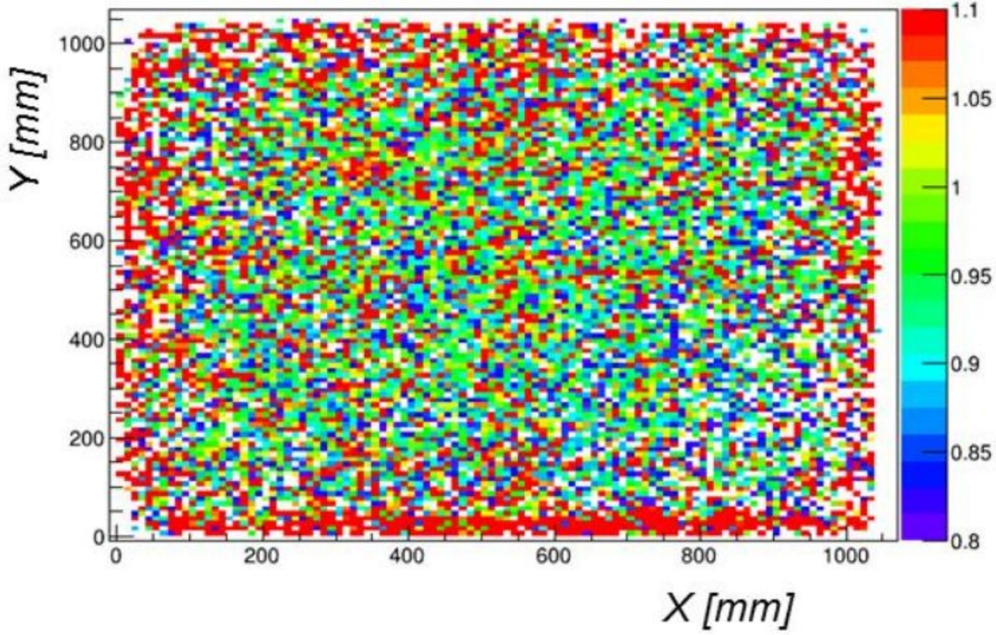
$$-<\frac{dE}{\rho dx}>=Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left(\frac{1}{2}\ln\frac{2m_ec^2\beta^2T_{max}}{I^2}-\beta^2-\frac{\delta(\beta\gamma)}{2}\right)$$

- Muon survival probability depends of the density
  - ➞ A density map can be made from the muon flux
  - ➞ Volcanoes
  - ➞ Geological prospection
- Muon flux at ground : 1 muon/cm^2/mn
  - ➞ Tradeoff between sensitivity and acquisition time
  - ➞ Better precision can extract the most information of each muon

Imaging faults in a concrete slab

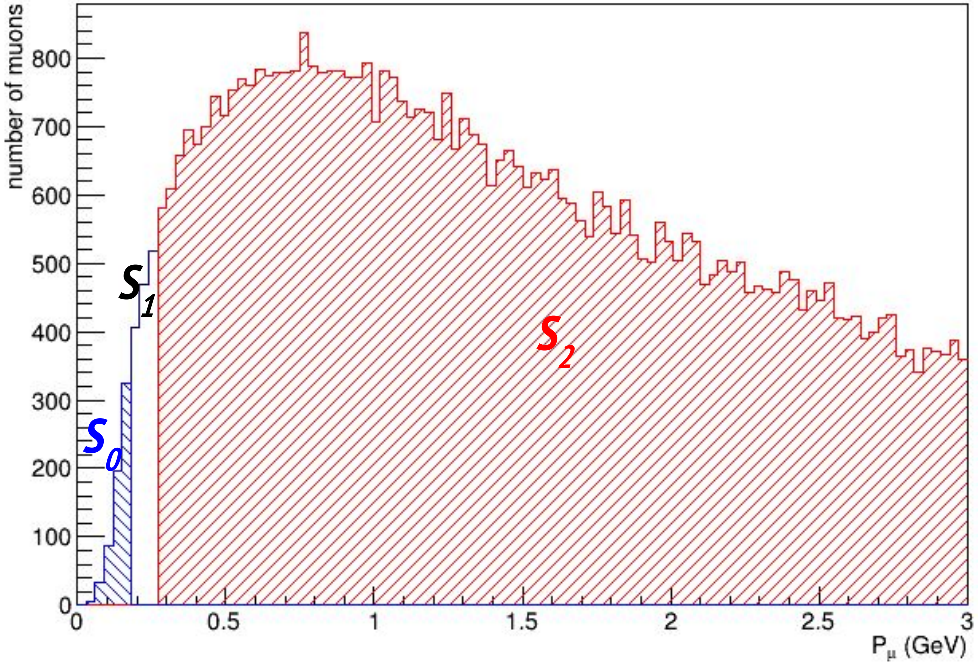


Imaging faults in a concrete slab



→ Two mode tested : transmission and absorption (deviation not adapted. Not dense enough)

New mode in Tomomu : absorption

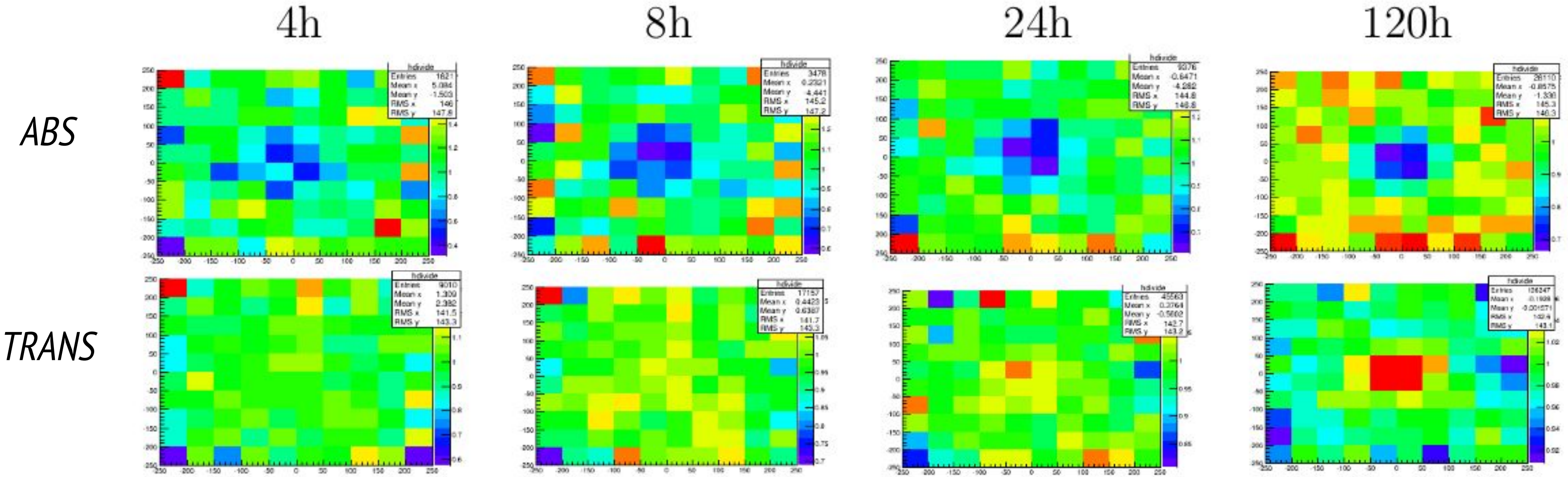


Corsika simulation of muon flux at ground . Blue = E_μ < 180 MeV. Red = E_μ > 270 MeV.

Relative muons excess in transmission = S_1 / S_2 ➡ Object with high density (pyramids, volcanoes, buildings)

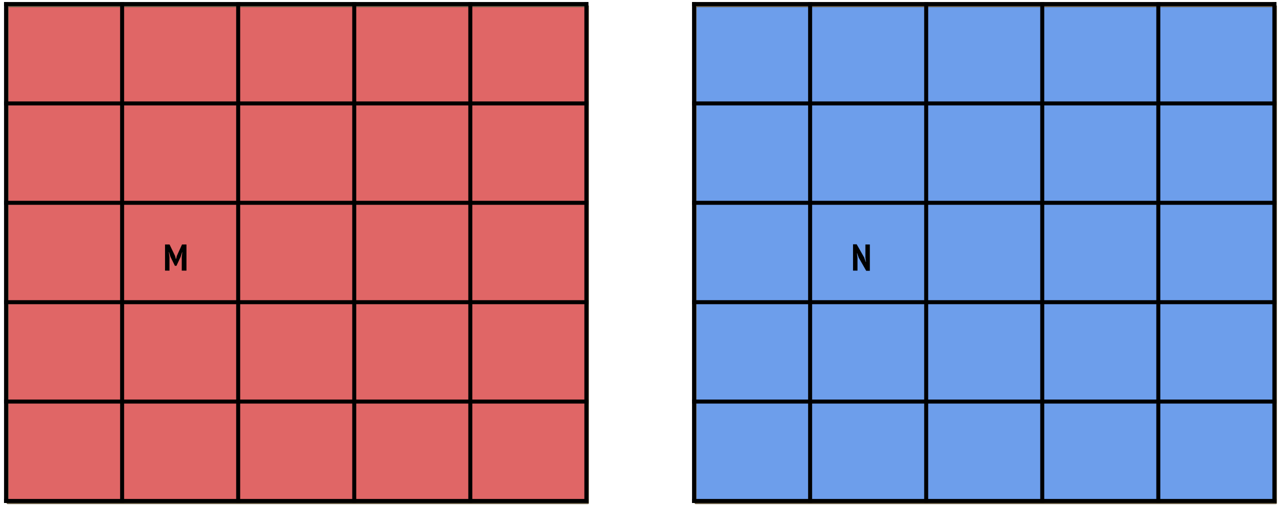
Relative muons excess in absorption = $S_1 / (S_1 + S_0)$ ➡ Object with low/intermediate density

Simulations



- Better in absorption than transmission because of the sensibility
- Simulations also made with a 97% efficient Cerenkov detector

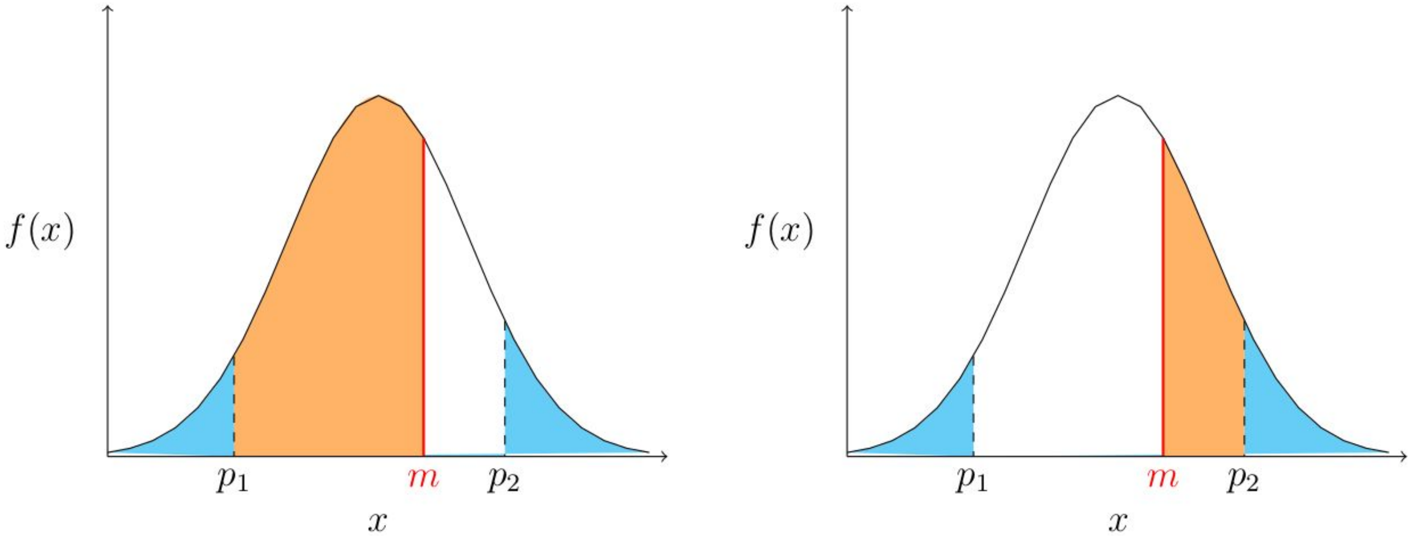
Help us Bayes



- H0 : M and N are distributed with the same poisson distribution with λ.
- H1 : M and N are distributed with differents poisson distribution (λ and μ)

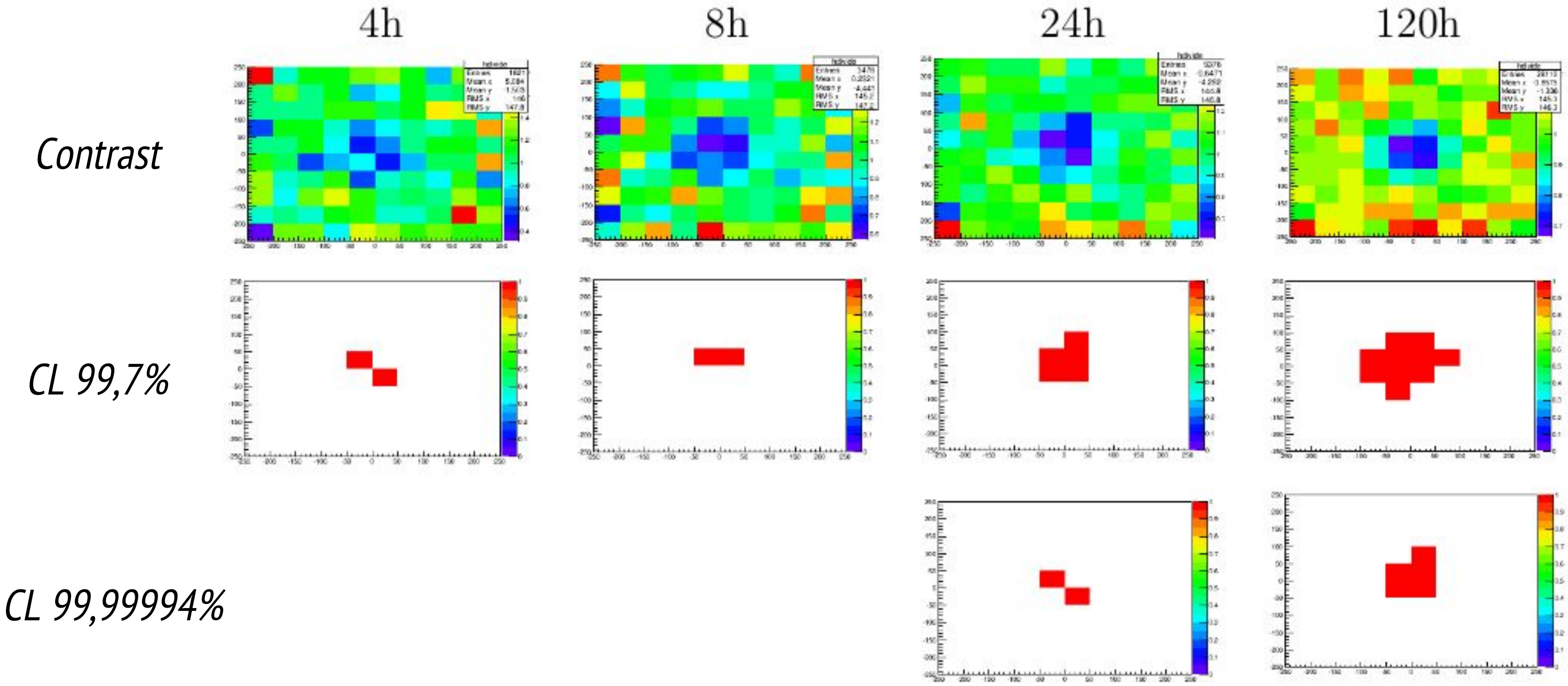
$$P(m|n,\lambda) \propto \frac{\Gamma(m+1/2+n)}{m!\,\Gamma(n+1/2)} 2^{-(m+1/2+n)} \quad \text{avec } \Gamma \text{ la fonction } \Gamma(t) = \int_0^\infty u^{t-1} e^{-u} du$$

Help us Bayes

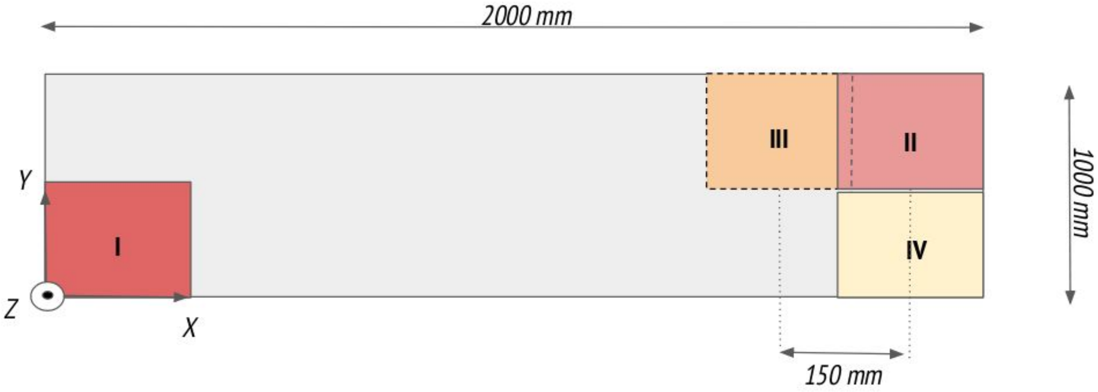


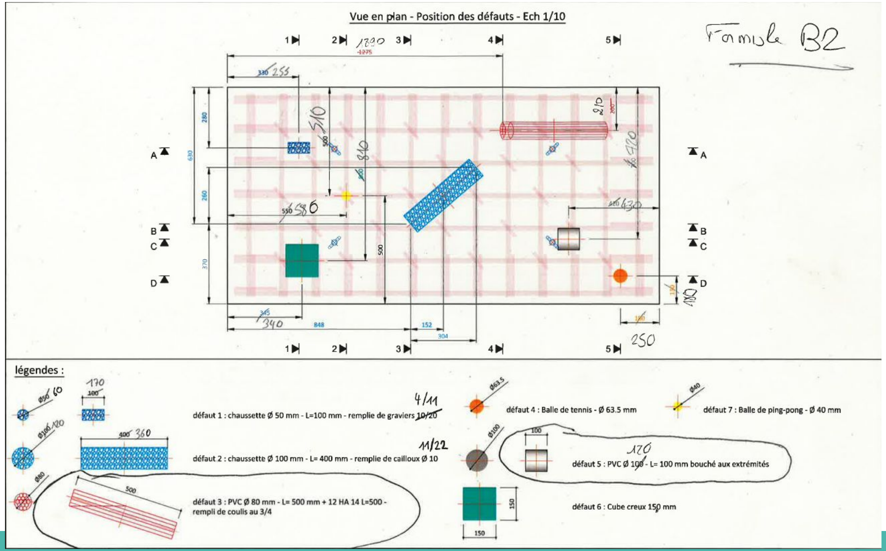
Once we found the probability, we have to take the cumulative to reject or accept the hypothesis H0

Simulations in absorption - results



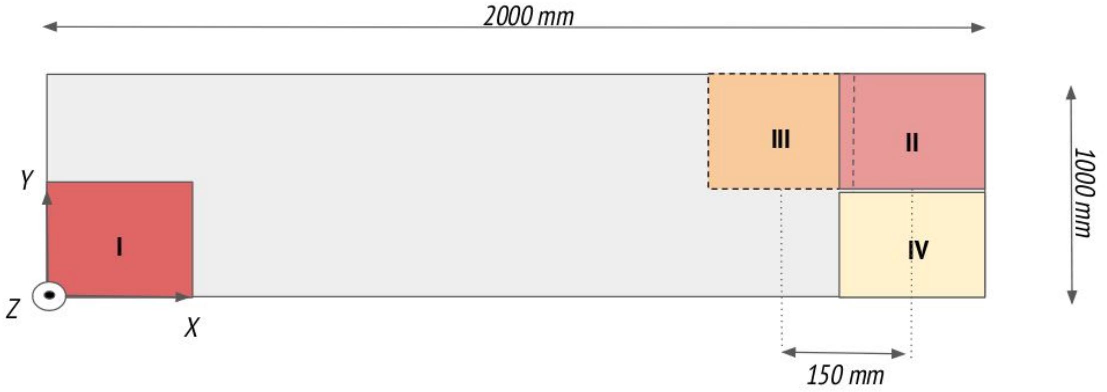
Imaging faults in a concrete slab

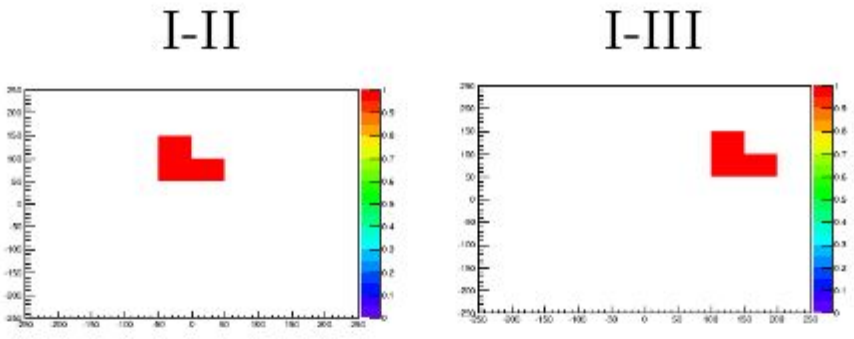




- Two position allowed for the void
  - ➡ Symmetry by 180° rotation
- Analysis done between I vs II and I vs III
  - ➡ Detectors were moved by 15cm
  - ➡ No faults appeared after dividing the two histograms
  - ➡ Blurring due to acceptance (geometry and efficiency) and diffusion of muons in the concrete slab

Imaging faults in a concrete slab

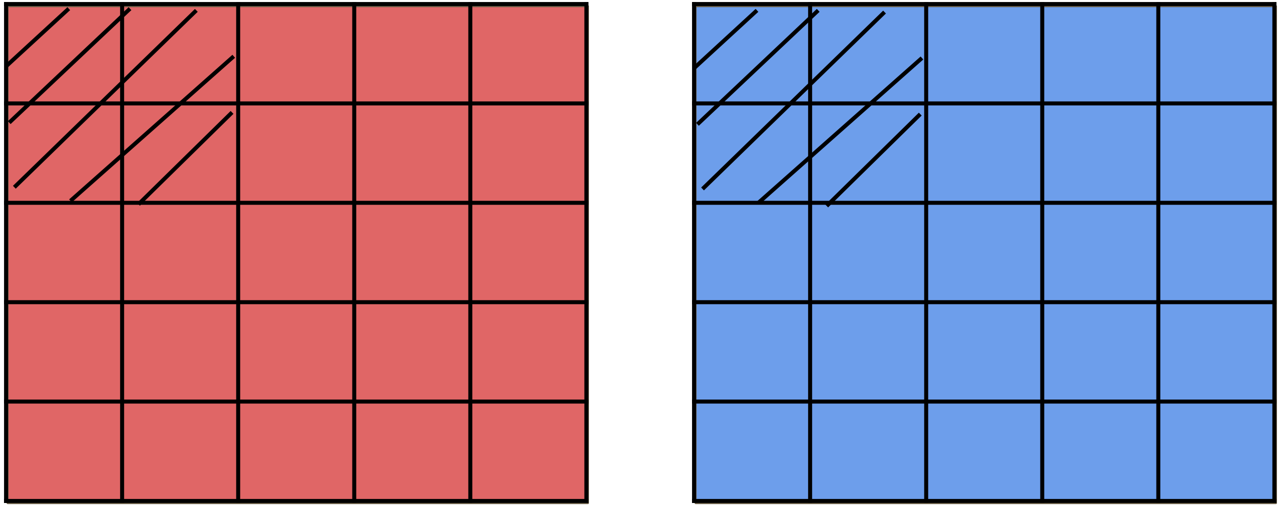




CL 99,7%

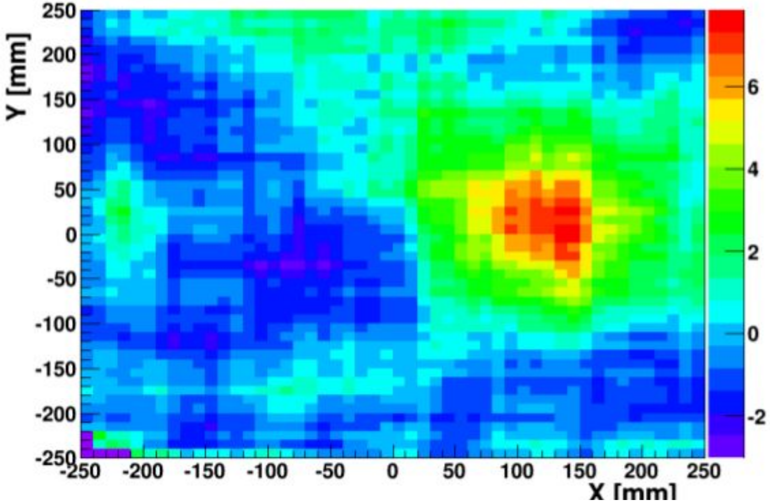
- Two position allowed for the void
  - ➡ Symmetry by 180° rotation
- Analysis done between I vs II and I vs III
  - ➡ Comparison shows a significant difference
  - ➡ the fault moved by 15cm as we hoped

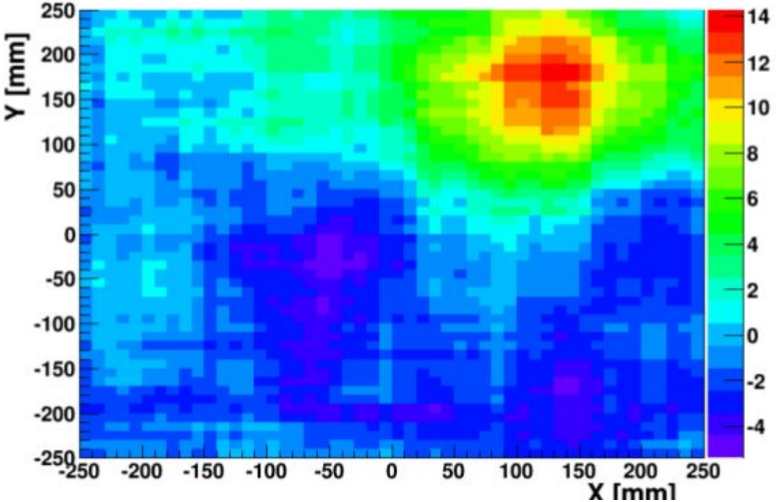
Other method



- Calculate the nb of muons in controlled size square in both 2D distribution : N1 , N2
- Estimate the difference of these two numbers and normalised it : $(N1-N2) / \sqrt{(N1^2+N2^2)}$

Other method





T (h)	1	2	3	4	6	8
σ	2,7	3,8	5,1	6,7	7,2	7,9

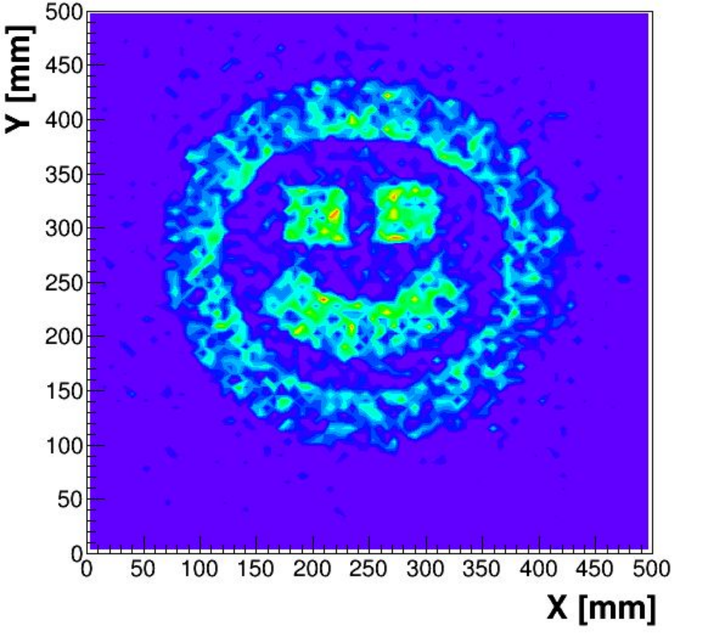
Recap

- **More R&D on Micromegas**
  - → Choose between two technologies (serigraphy or DLC)
  - → Make sure the spatial and time resolution are improved to plan μTPC algorithm
  - → Understand gain unstability

- **Reconstruction**
  - → Detection of faults in concrete slab with a new method
  - → Next time : 3D reconstruction and tomography !?

Thursday 22th Mars 2018
at 6 pm
Gif sur Yvette : salle de la terrasse
Registration : MT180 paris saclay

THANKS



Irfu - CEA Saclay
Institut de recherche
sur les lois fondamentales
de l'Univers

DE LA RECHERCHE À L'INDUSTRIE
cea