

# A Transparent Detector for beam monitoring in Intensity Modulated Radiotherapy

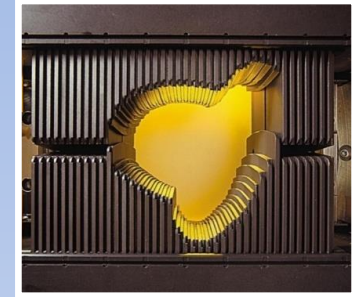


LABEX PRIMES 12 juin 2014  
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## Context

Increased complexity of external beam radiotherapy techniques :

- IMRT
- ArcTherapy
- Flattening Filter Free with larger dose rates (up to 2400 MU/min)



*Mu et al. 2008* : showed that 1 mm error on leaf positions can induce dosimetric changes up to 10 %.

*Need for treatment monitoring...*



*1D detectors*

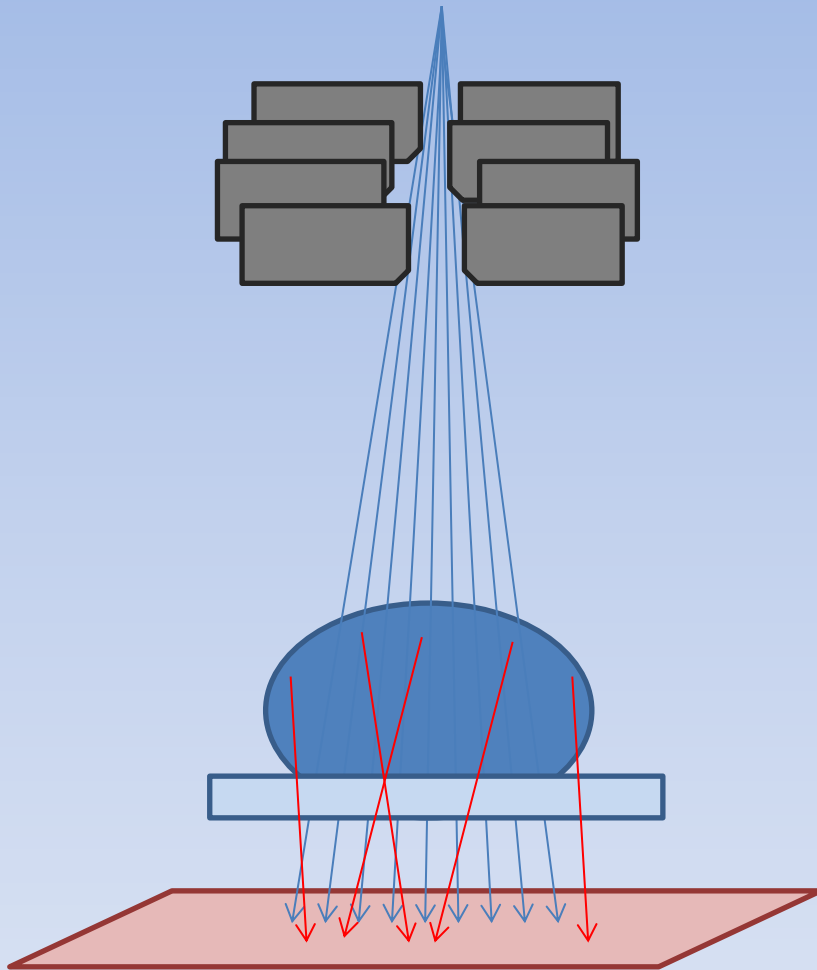


*2D detectors after the patient*

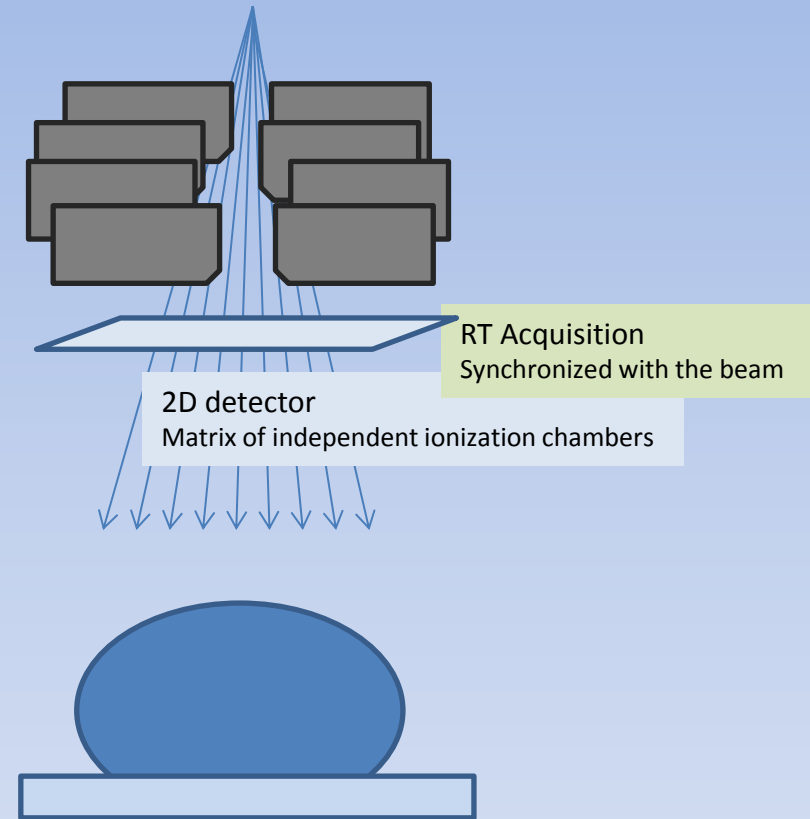


*2D detectors before the patient*

## 2D beam monitoring down stream / up stream to the patient



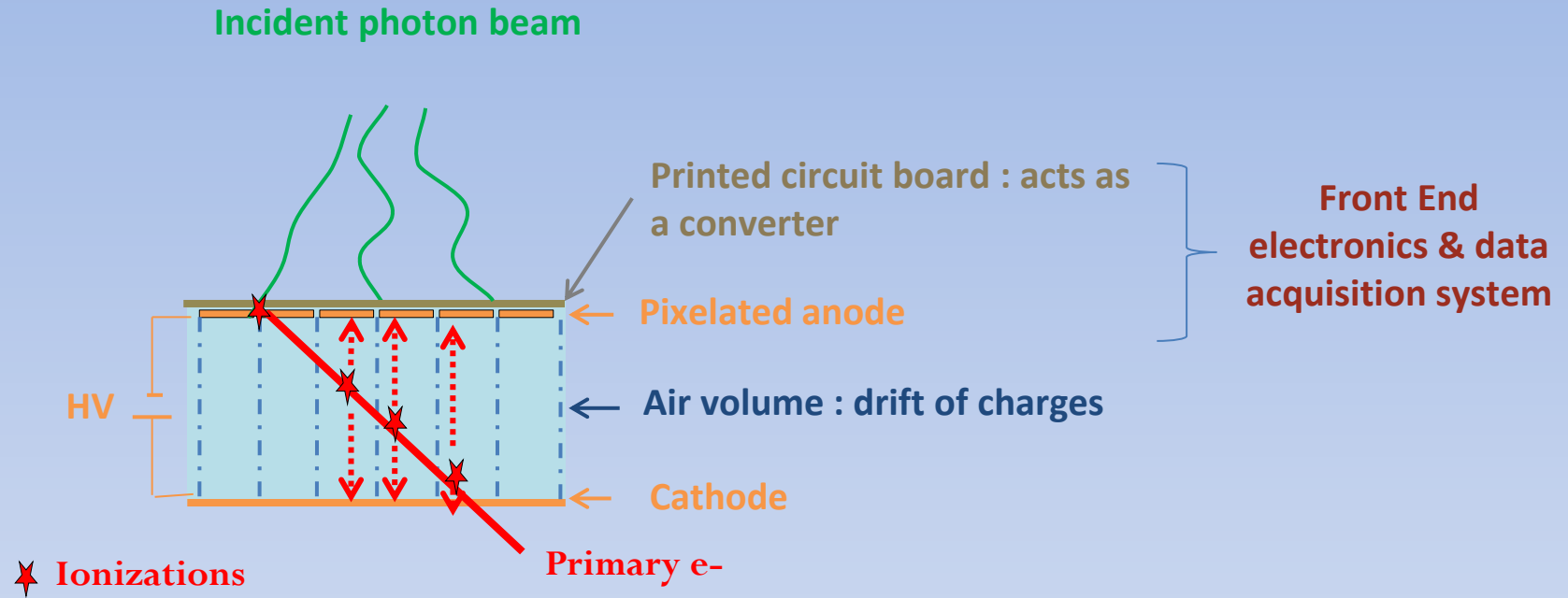
QA using EPID : final image contains both the transmitted beam and the scattered beam



Trace origin of disagreement ?

- Patient related (e.g. weight loss, PTV modification, ...)
- Beam related (e.g. MLC off by a few millimeters, beam asymmetry, ....)

# TraDeRa, a Transparent Detector for external beam Radiotherapy



Air vented detector based on pixelated matrix of ionization chambers

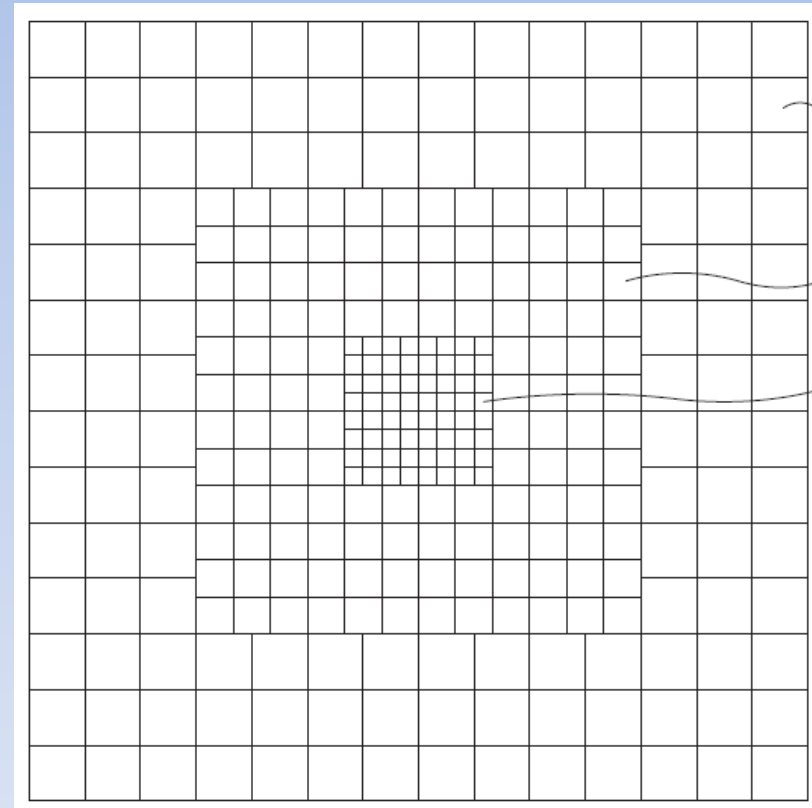
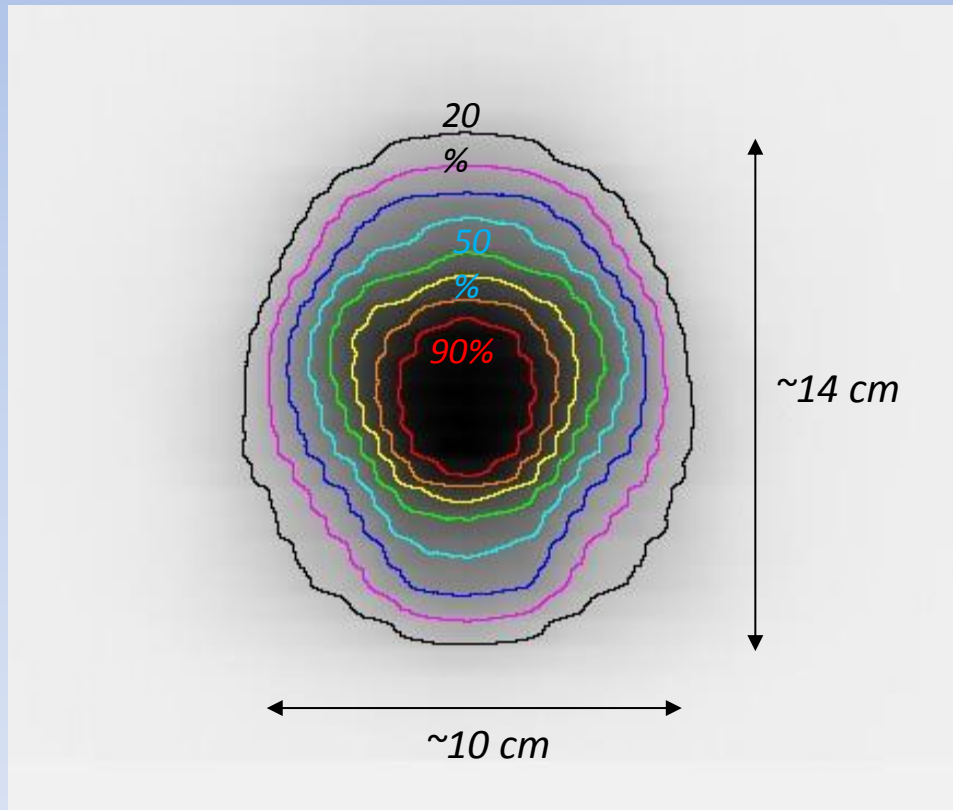
- 40 x 40 cm<sup>2</sup>, no dead zone
- Uniform and minimized beam attenuation
- Real time monitoring
- Radiation hard

## Optimization based on most probable beam location

Accumulation of EPID data from IMRT treatments

(CHU Grenoble)

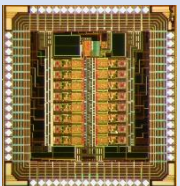
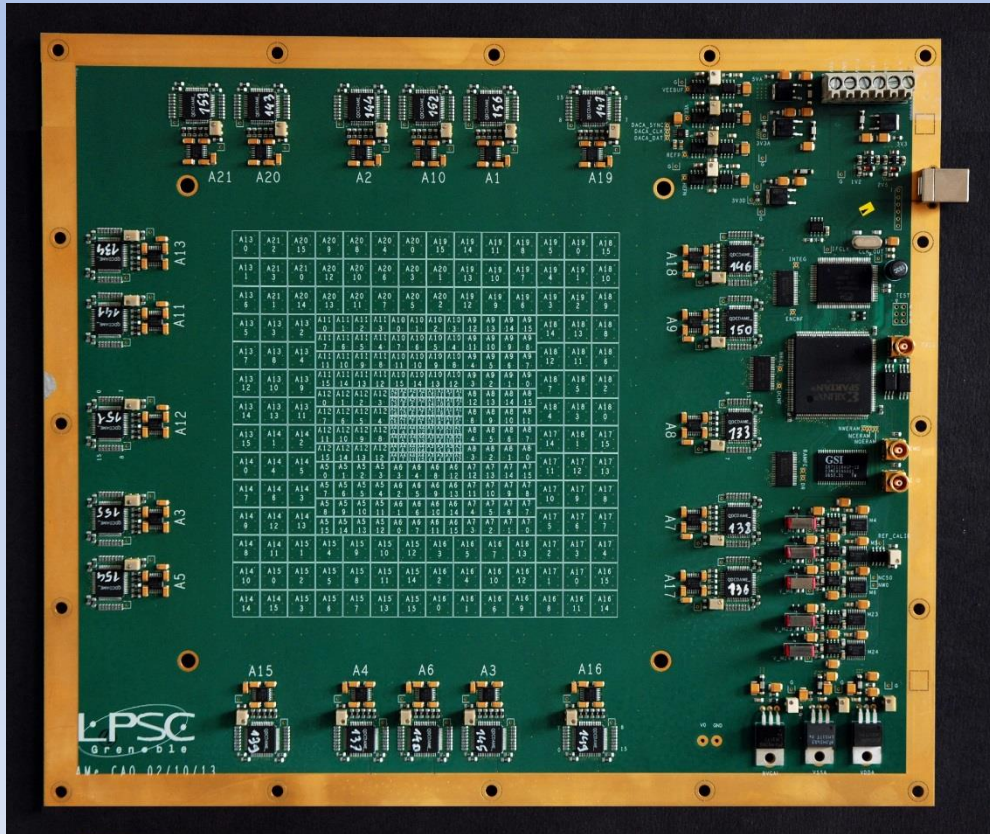
200 patients, 20 locations



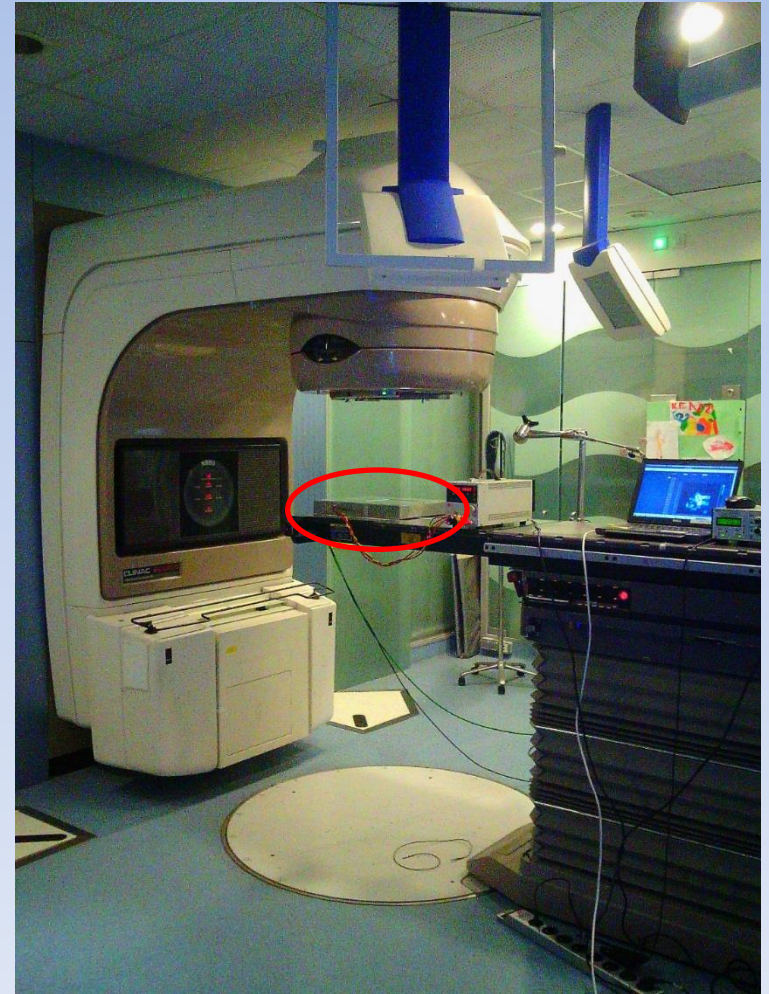
Current prototype (scale  $\frac{1}{4}$ ) : 14 x 14 cm<sup>2</sup> , SSD 100 cm

Compact detector, including both the electrodes and the readout electronics (in house ASIC, FPGA).

Bluetooth Data transmission.

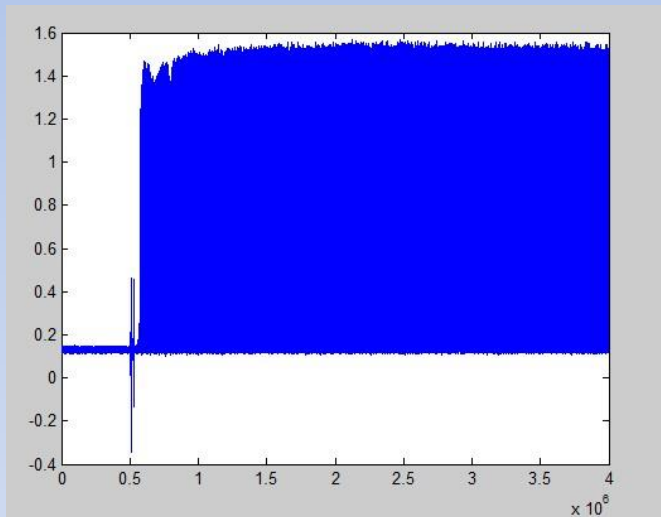


In-house 16 channels QCD, linearity better than 0,1%  
Charge integration at the linac pulse scale

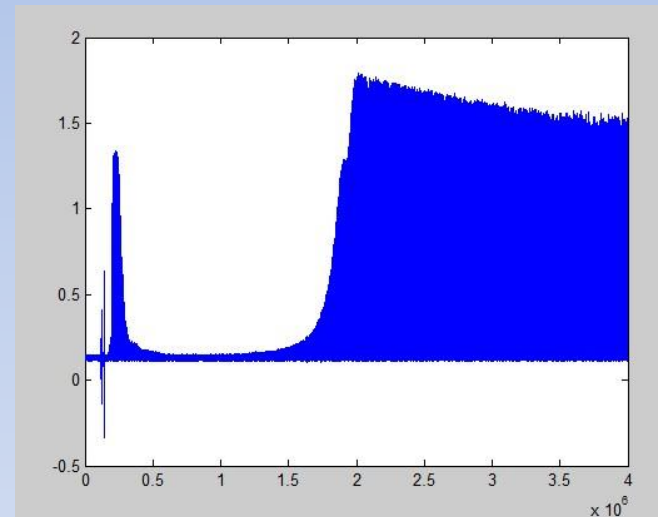


## Results : set of independent measurements

Focusing on one electrode : charge contents vs time

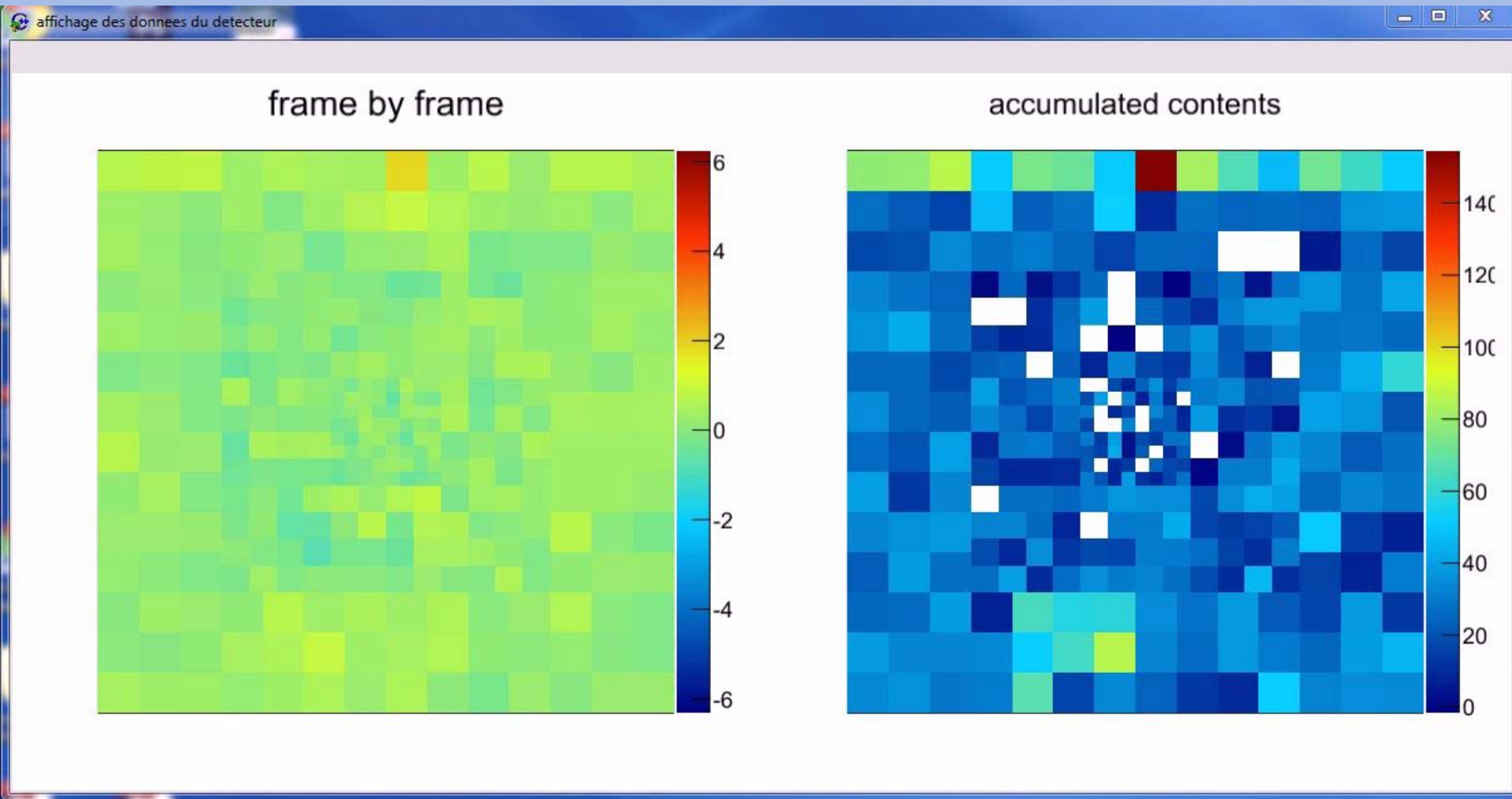


Normal beam delivery session.  
Linac reaches a stable working point.



Unstable startup : intensity decreases before a sharp rise. Then short decrease until stability is reached after 3 seconds.

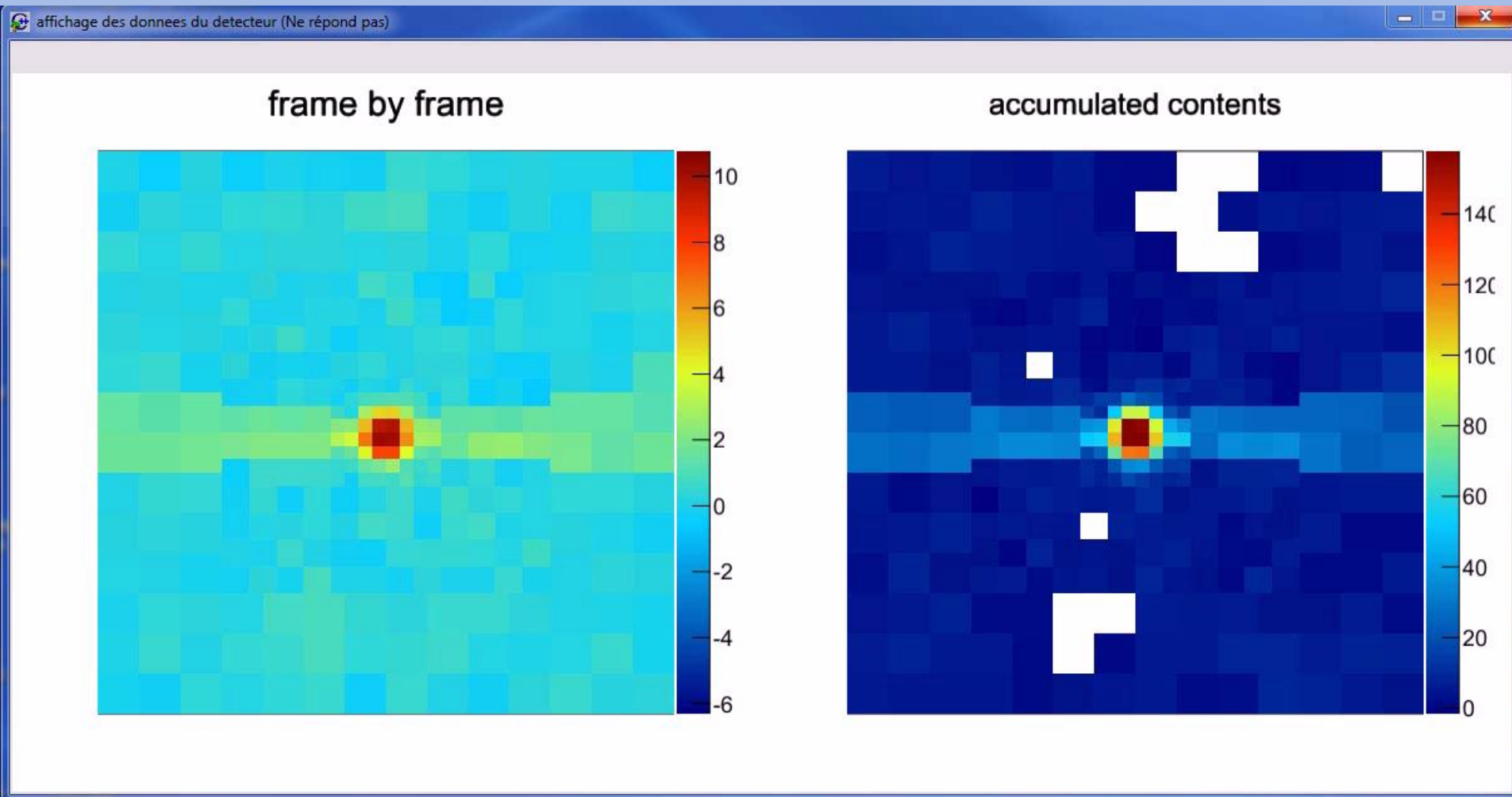
*Clinac 2100, CHU Grenoble*  
*Dynamic filter 14x14, SSD 100 cm (6MV, 200 UM @ 300UM/min)*



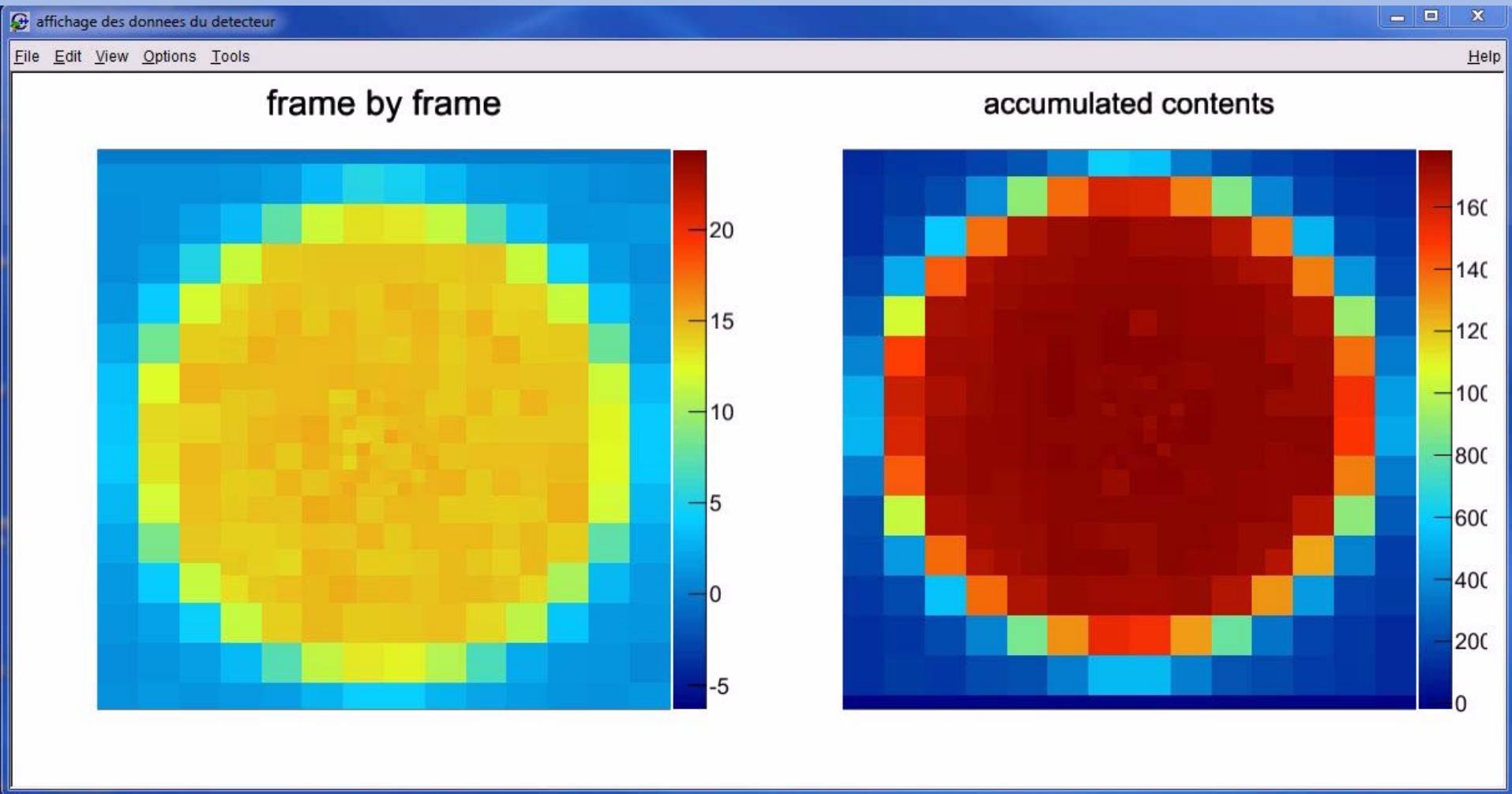
Right : 1 frame out of 64 is displayed

Left : all accumulated frames

*Detector under the linac head*  
*Dynamic field @ SSD 70 cm (200 UM, 300UM/min)*



*Detector under the linac head*  
*Dynamic field @ SSD 100 cm (200 UM, 300UM/min)*



## Conclusion

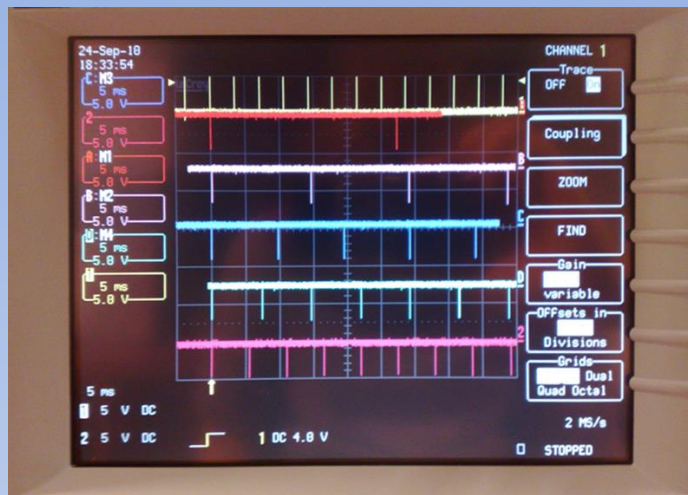
Full 2D measurement in real time, upstream to the patient.

Next prototype with 1600 embedded electrodes and Bluetooth transmission to be build by the end of summer.

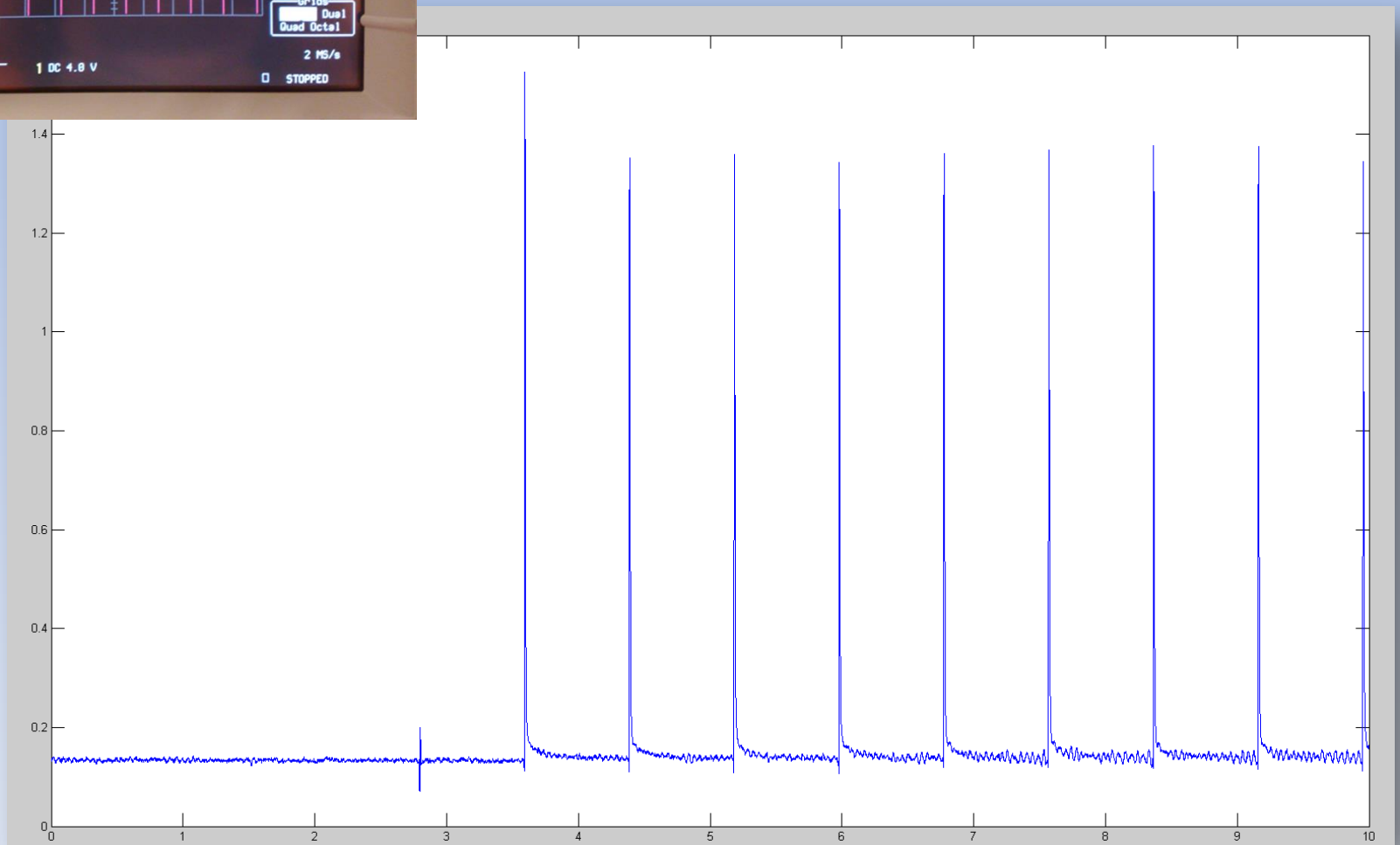
- Traceability of the beam characteristics during treatment delivery
- Will provides a 2D dose map
- Independent measurement

Near future : develop a dedicated down stream detector, and merge both upstream and downstream measurements

Additional slides



Mesure du signal sur chacune des chambres et pour chaque impulsion du faisceau

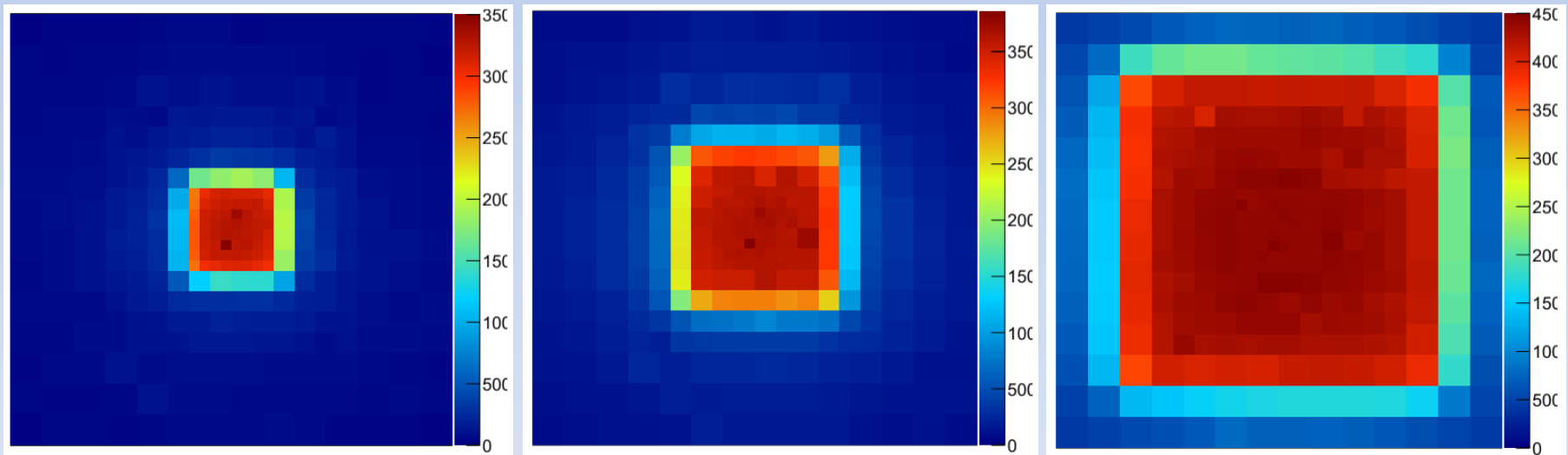


## Results : 2D measurements

Complex and static fields data acquisitions.

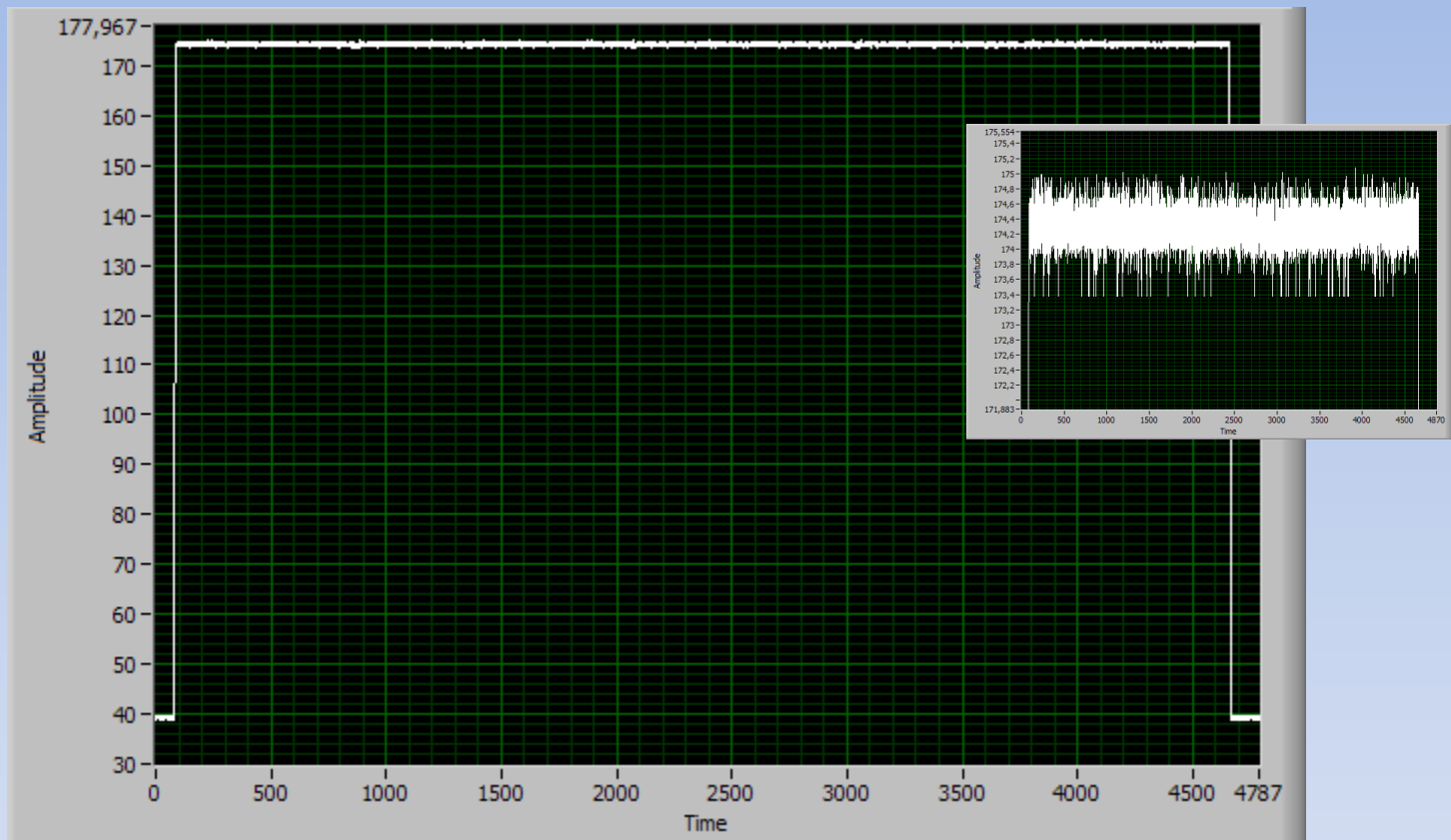
- Integrated mode
- Pulse by pulse mode

*Static mode : 3x3, 5x5 et 10x10 cm<sup>2</sup> fields*



# Mesures conjointes à l'ESRF

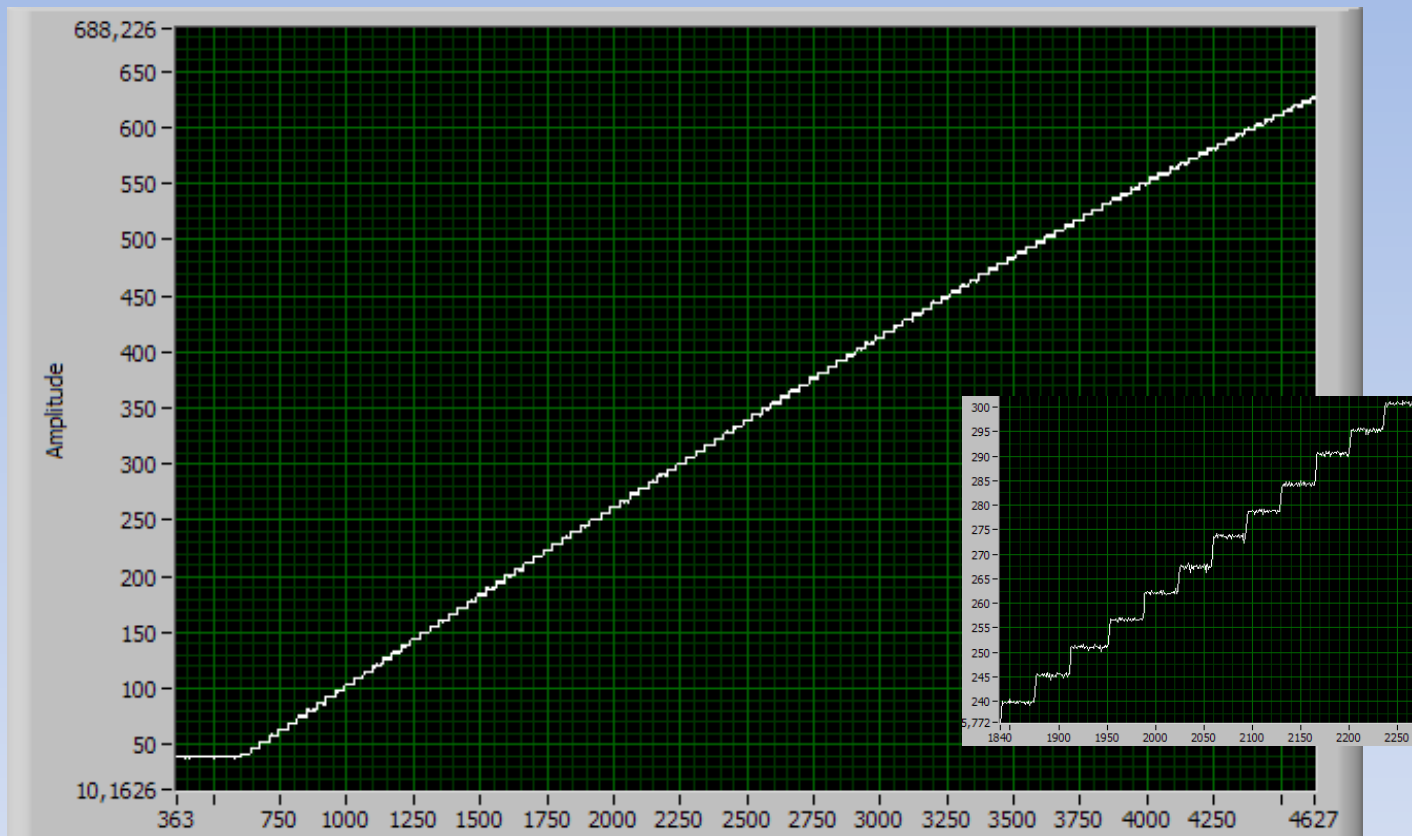
## Stabilité temporelle



Mesure des charges sur une électrode. Irradiation continue pendant 3,5 minutes.  
Stabilité exemplaire !

# Mesures conjointes à l'ESRF

## Linéarité et dynamique



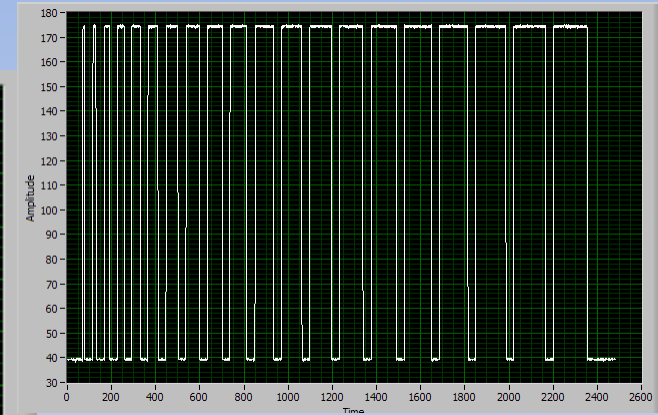
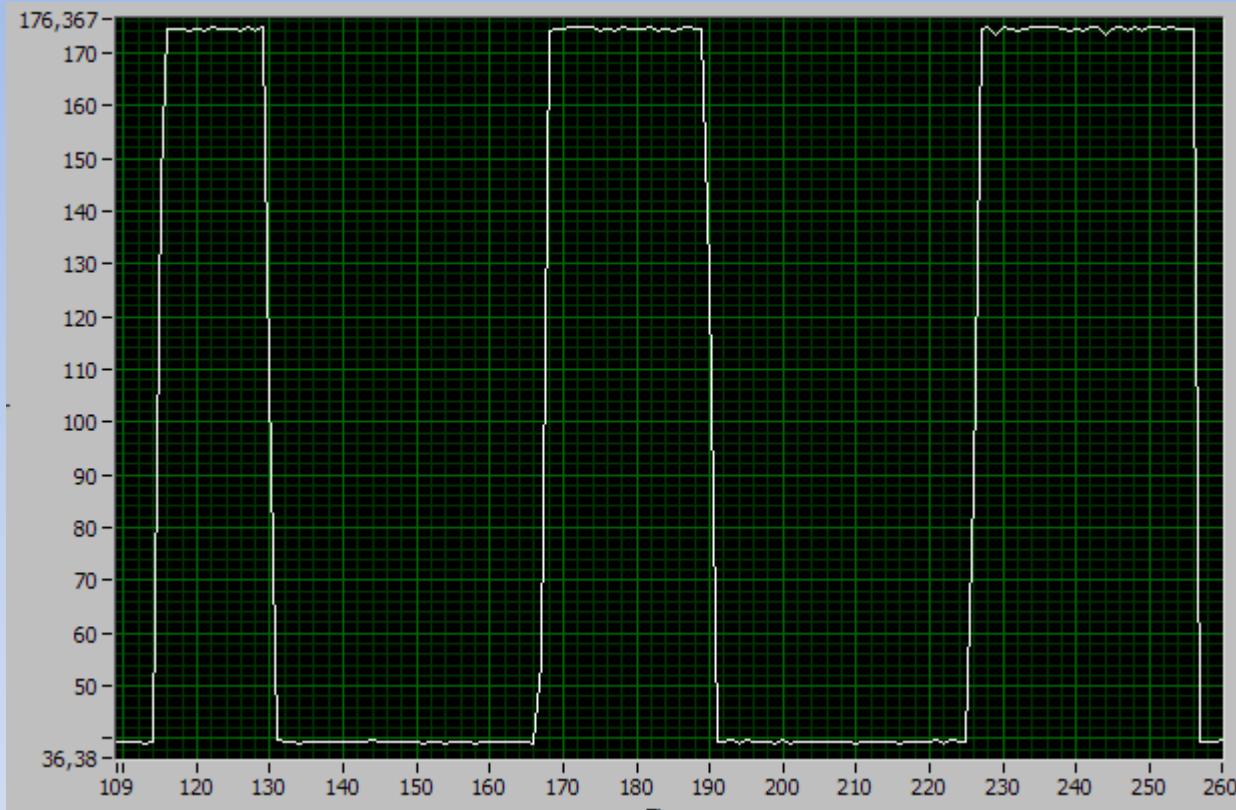
Mesure du signal sur une électrode.

Faisceau d'épaisseur 0 à 4,5 mm par pas de 25  $\mu\text{m}$ .

A comparer au signal qui a été enregistré sur une chambre d'ionisation.

# Mesures conjointes à l'ESRF

## Régime transitoire

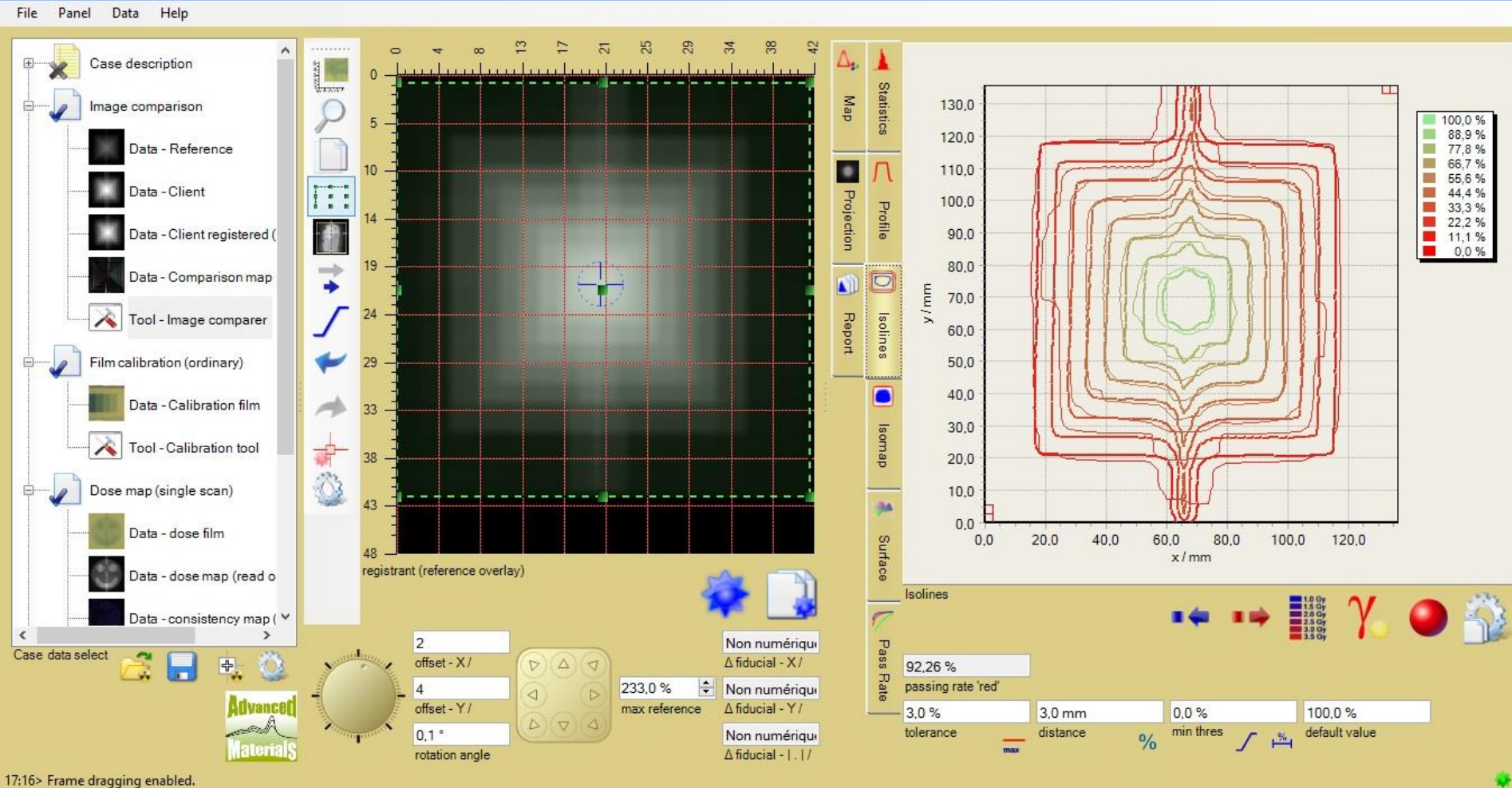


Mesure du signal sur une électrode.

Faisceau de 500  $\mu\text{m}$  pendant 1 seconde puis 1,5 secondes, puis 2 secondes

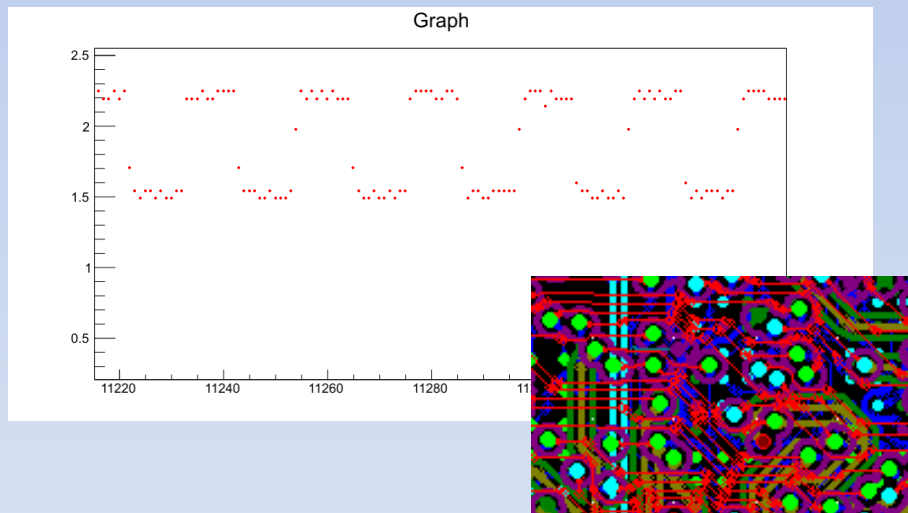
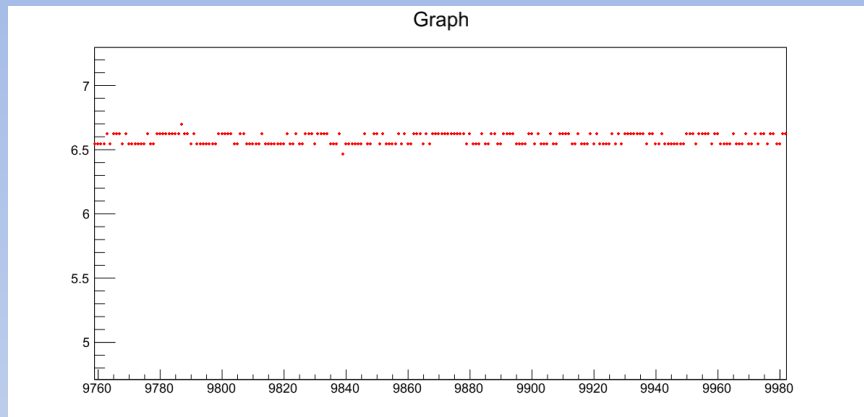
Signaux comparables à ceux obtenus avec une chambre crayon,

# Comparison with EBT3 radiochromic films



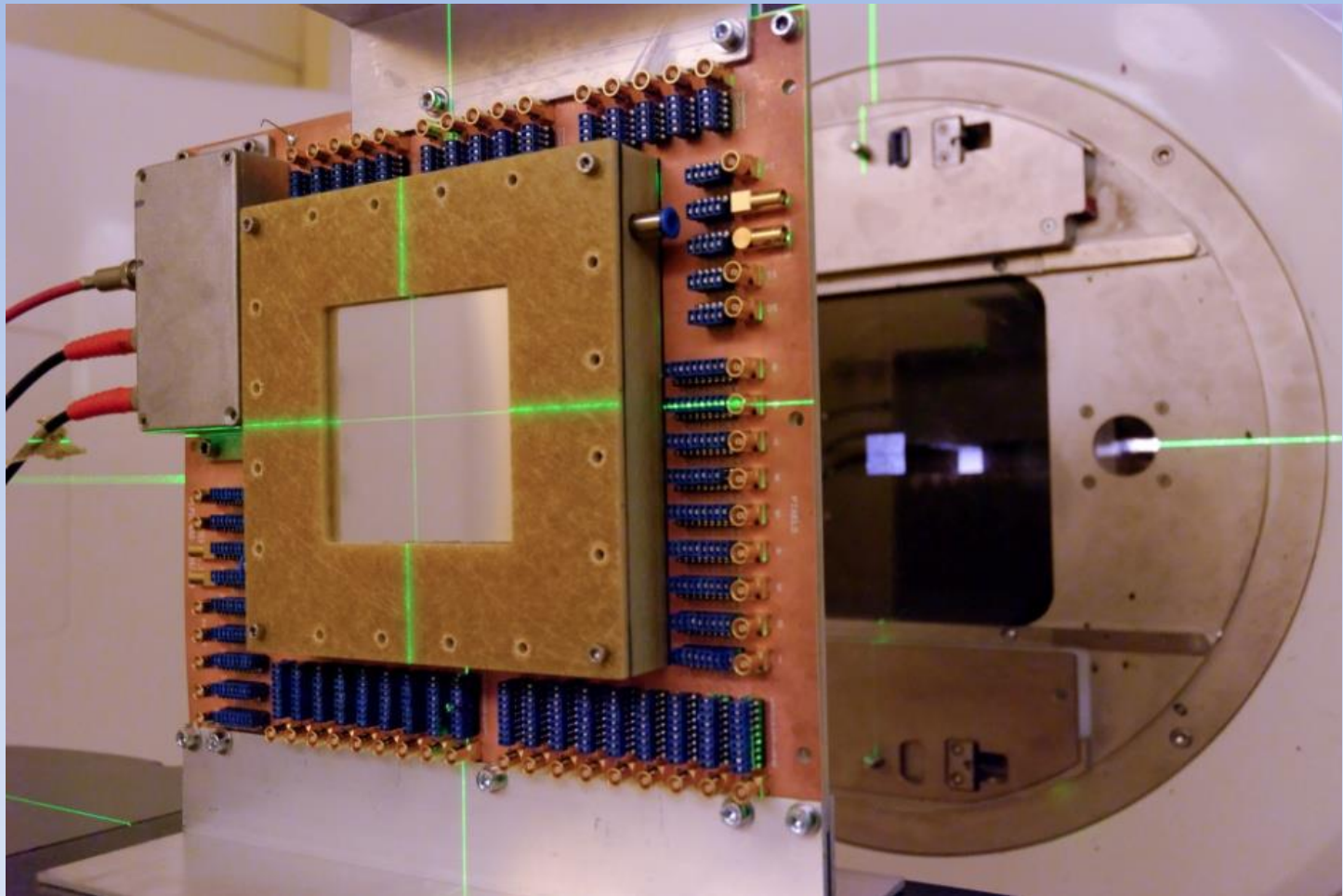
Need Cobalt 60 calibration (under way...)

## Voies bruyantes

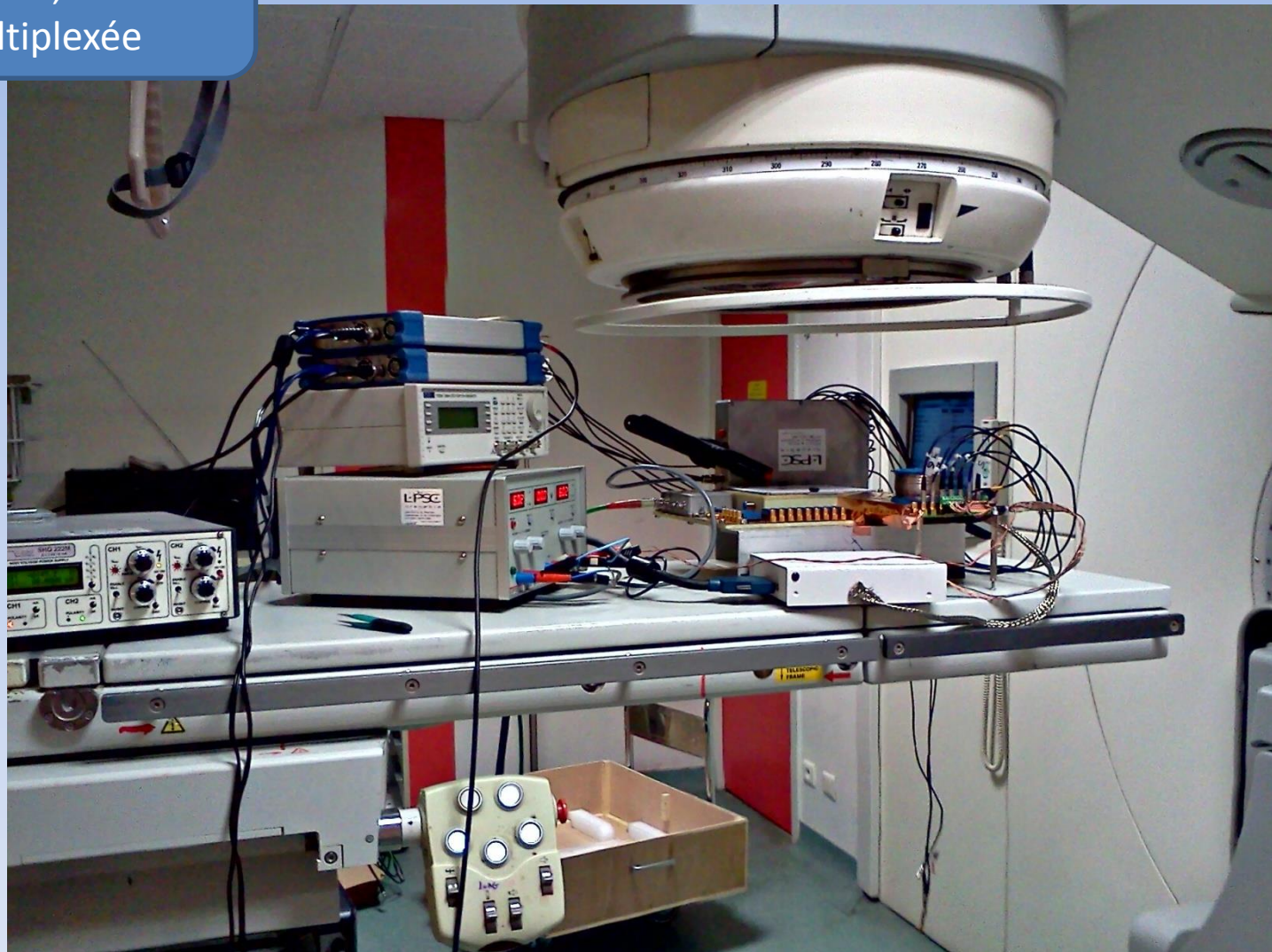


- Contenu d'une voie « normale » au cours d'une irradiation constante
- Certaines voies ont un comportement instable ?!?
- Après analyse et débogage, le routage du PCB introduit de la diaphonie entre bus de contrôle numérique et transport des charges depuis les électrodes.

## 1<sup>er</sup> détecteur



Evolution du 1er  
détecteur, lecture  
multiplexée



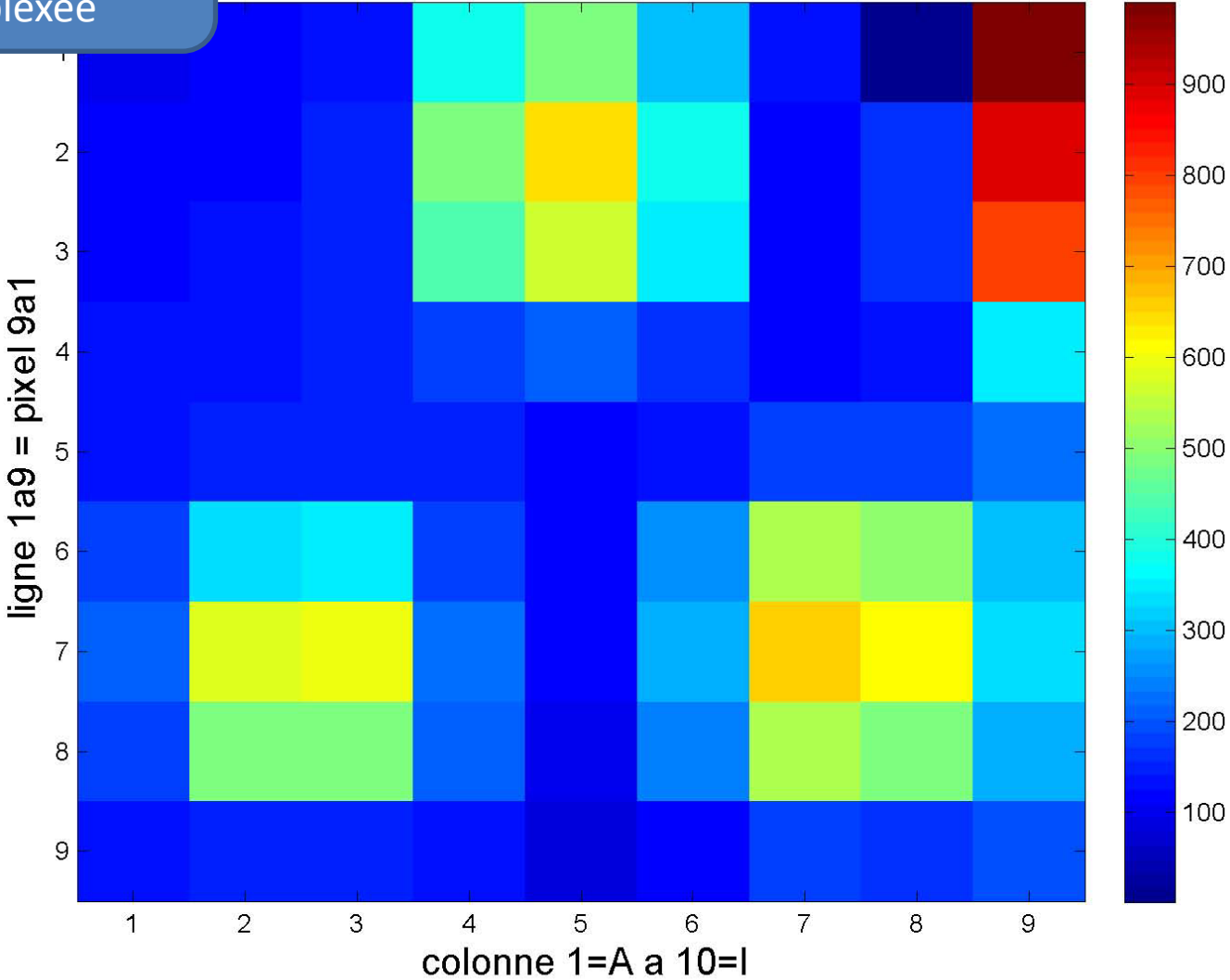
Evolution du 1er  
détecteur, lecture  
multiplexée

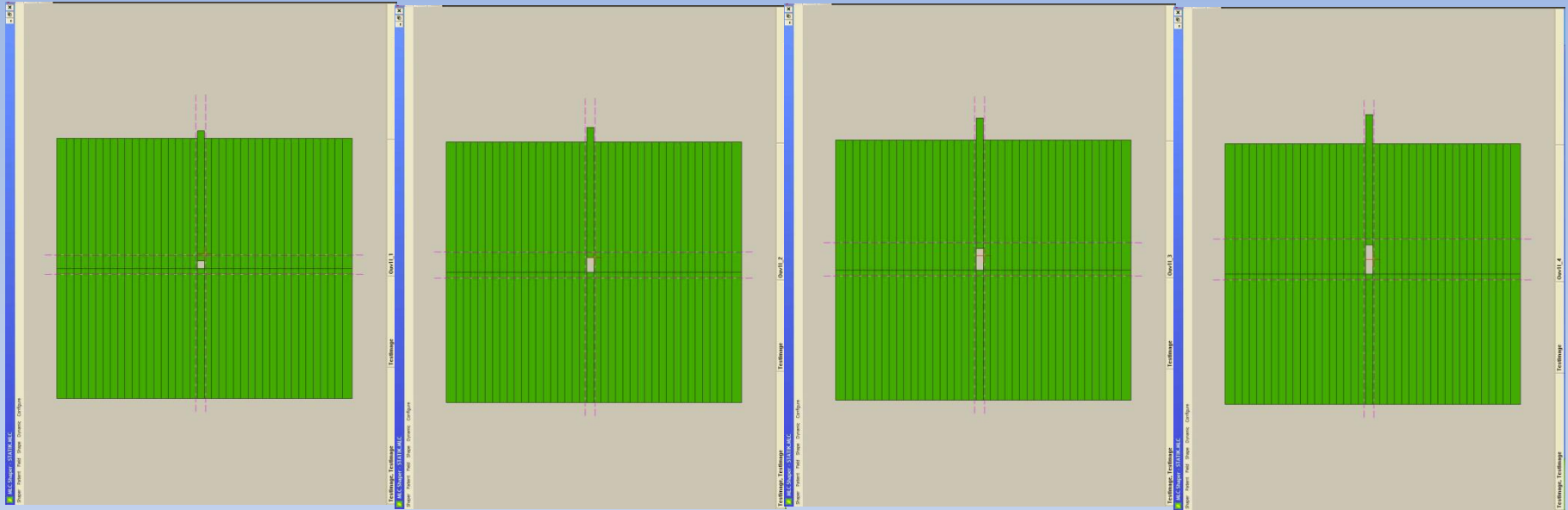




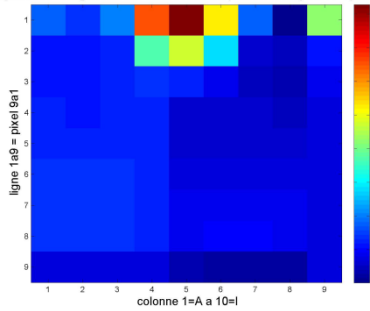
Evolution du 1er  
détecteur, lecture  
multiplexée

PageDetecteur sans correction pixel Avec Moy sur 225 pulses

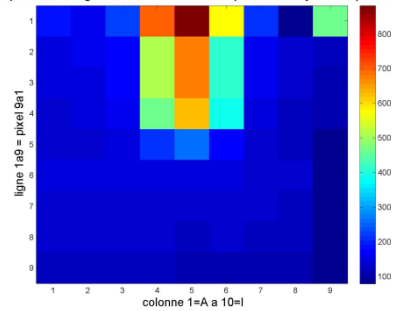




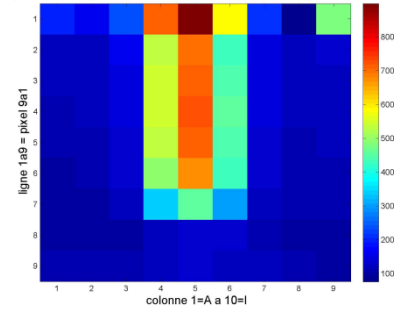
18pico6000--ImageDetecteur sans correction pixel Avec Moy sur 224 pulses



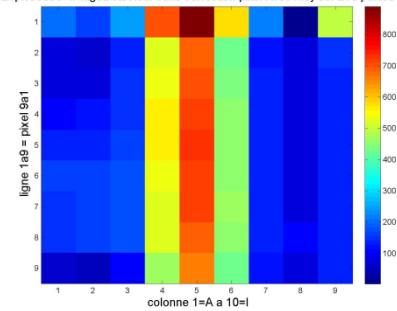
19pico6000--ImageDetecteur sans correction pixel Avec Moy sur 230 pulses



20pico6000--ImageDetecteur sans correction pixel Avec Moy sur 229 pulses

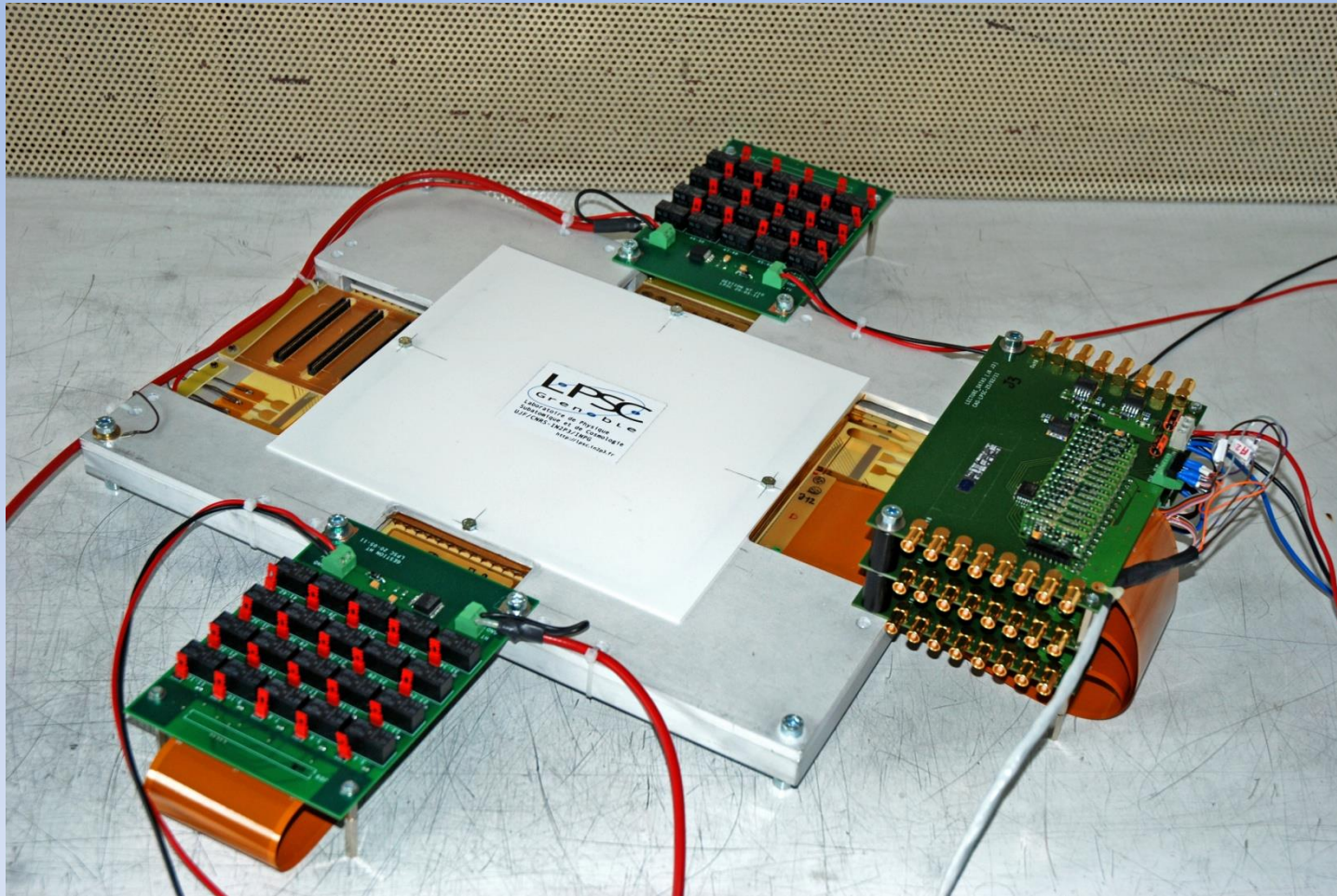


21pico6000--ImageDetecteur sans correction pixel Avec Moy sur 216 pulses



## 2<sup>ème</sup> détecteur

2<sup>nd</sup> prototype with embedded electronics, patented



## 2<sup>ème</sup> détecteur

