



DE LA RECHERCHE À L'INDUSTRIE

cea



# MPGD: Muography of Pyramids with Gaseous Detectors



S. Procureur

RD51 mini-week, 14/12/2017

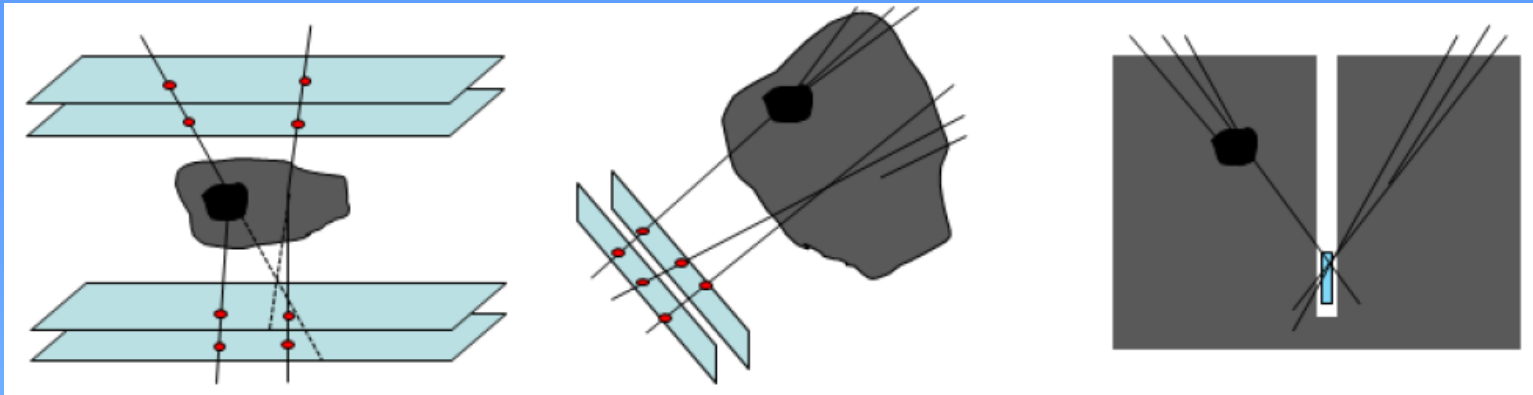


- Reminder on muography
- Muon telescopes
- ScanPyramids data taking, analysis and results
- Perspectives

→ Use natural cosmic rays to probe objects & structures

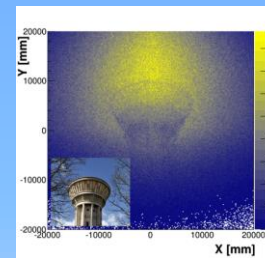
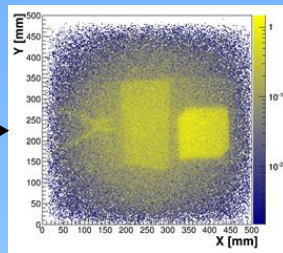
- *Multiple scattering*

- *Energy loss*



## Deviation

## Transmission (& Absorption)



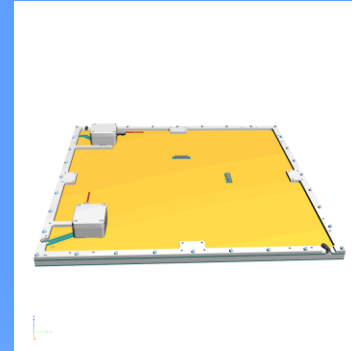
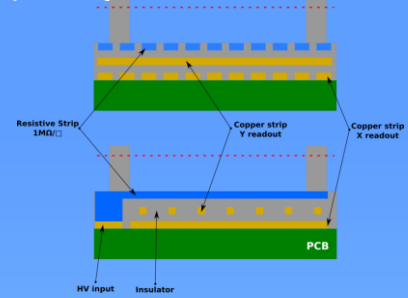
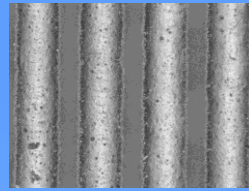
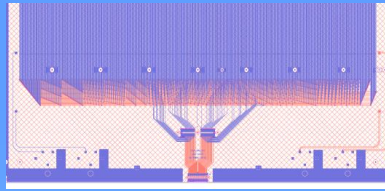
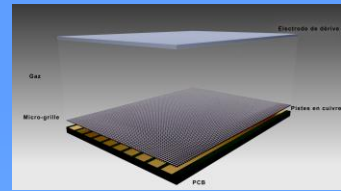
- *3D imaging (diffusion point)*
- *$\rho$  and  $Z$  measurement (deviation angle)*
- *« Fast » (from minutes to days)*

- *2D imaging (muon flux)*
- *Opacity measurement*
- *Slow (from days to months)*

→ Many applications: volcanology, archeology, civil engineering, nuclear reactor monitoring

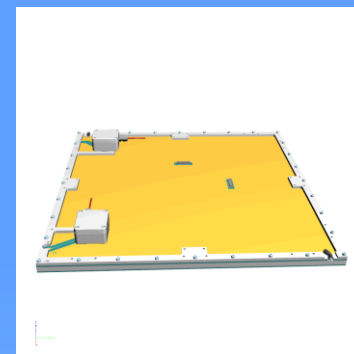
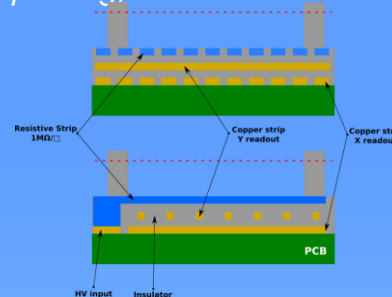
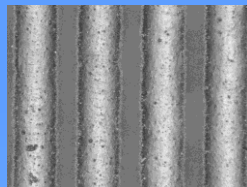
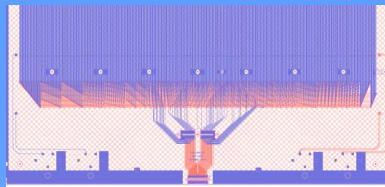
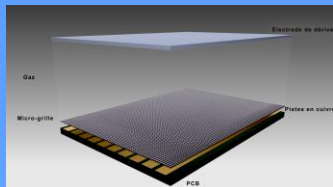
## • Detector

- *Micromegas*
- *Genetic multiplexing*
- *Resistive film (screen printing)*
- *2D readout*



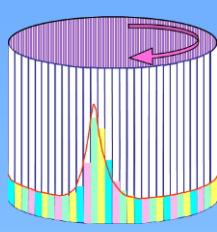
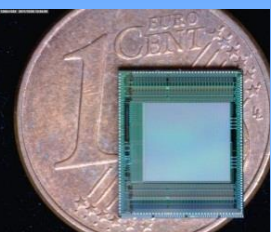
## • Detector

- *Micromegas*
- *Genetic multiplexing*
- *Resistive film (screen printing)*
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## • Electronics and other components

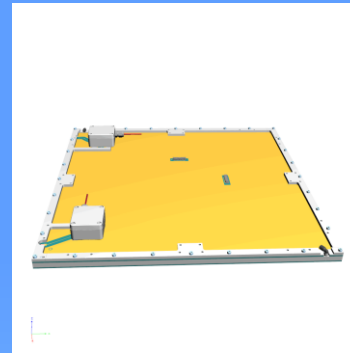
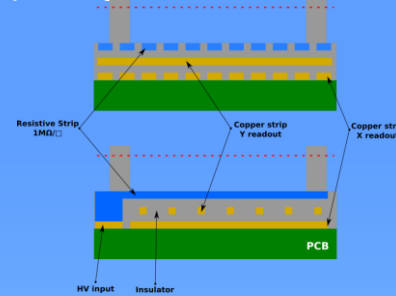
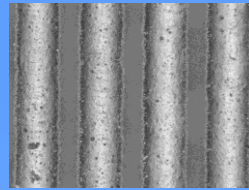
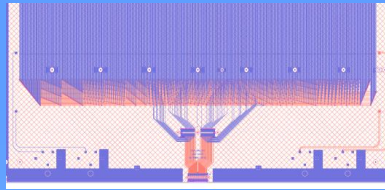
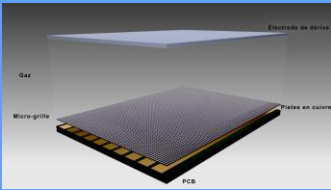
- *DREAM asic*
- *Self-triggering*
- *HV modules (CAEN)*
- *Nano-PC*





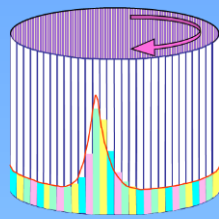
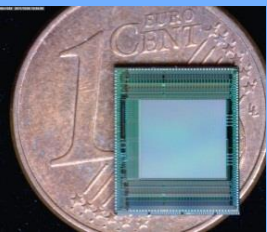
## • Detector

- Micromegas
- Genetic multiplexing
- Resistive film (screen printing)
- 2D readout

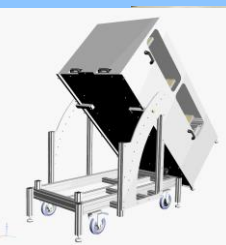


## • Electronics and other components

- DREAM asic
- Self-triggering
- HV modules (CAEN)
- Nano-PC



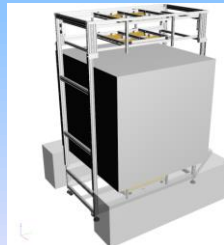
## ⇒ Final product



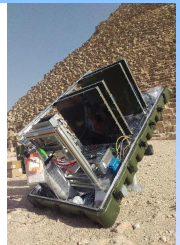
WatTo (2015)



TomoMu (2015-)

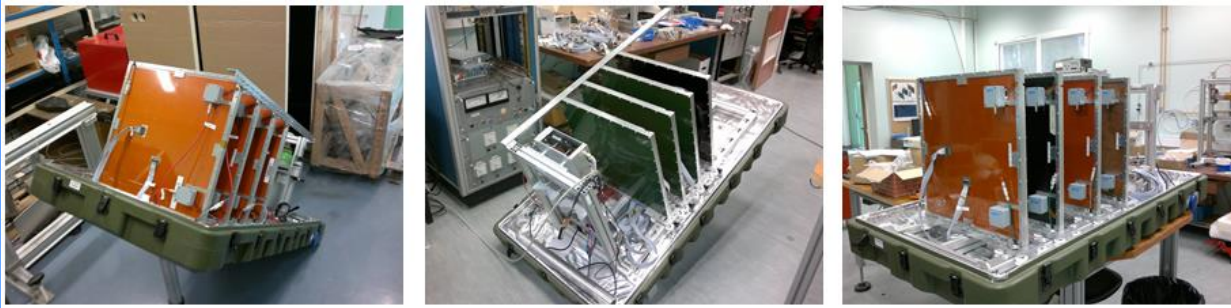


M-Cube (2016-2017)  
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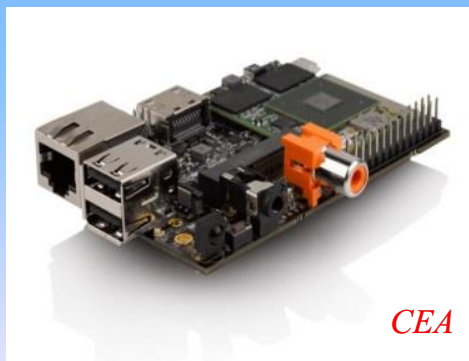


ScanPyramids (2016-)

- 3 telescopes, built in 2016
  - 12 detectors, 8 from EL VIA



- *Self triggering mode, requires at least 5 out of 8 coordinates*
- *Nano-PC performs common noise subtraction, clustering & track reconstruction*

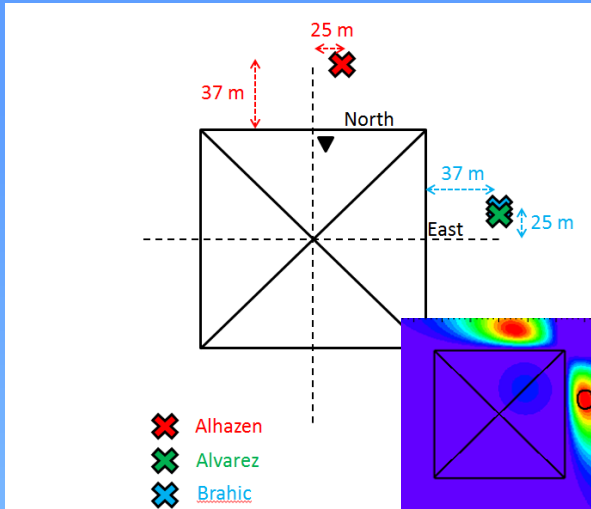


VS

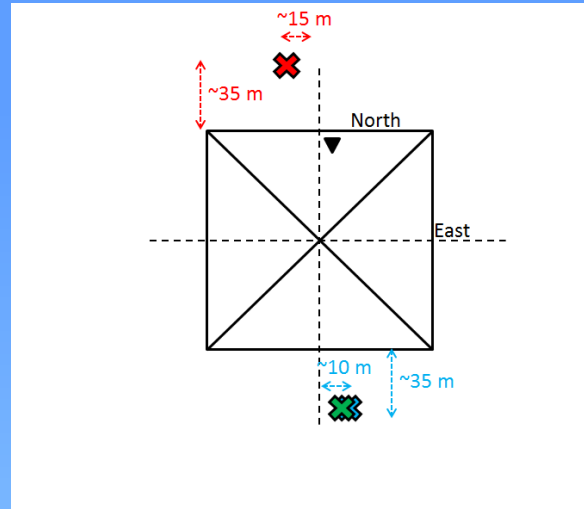


- 3 missions between 2016 & 2017

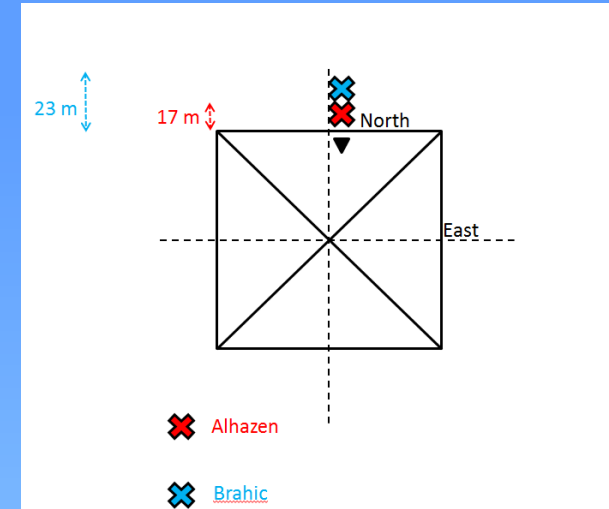
1<sup>st</sup> mission (jun-aug 2016)



2<sup>nd</sup> mission (jan-april 2017)



3<sup>rd</sup> mission 3 (may-jul 2017)

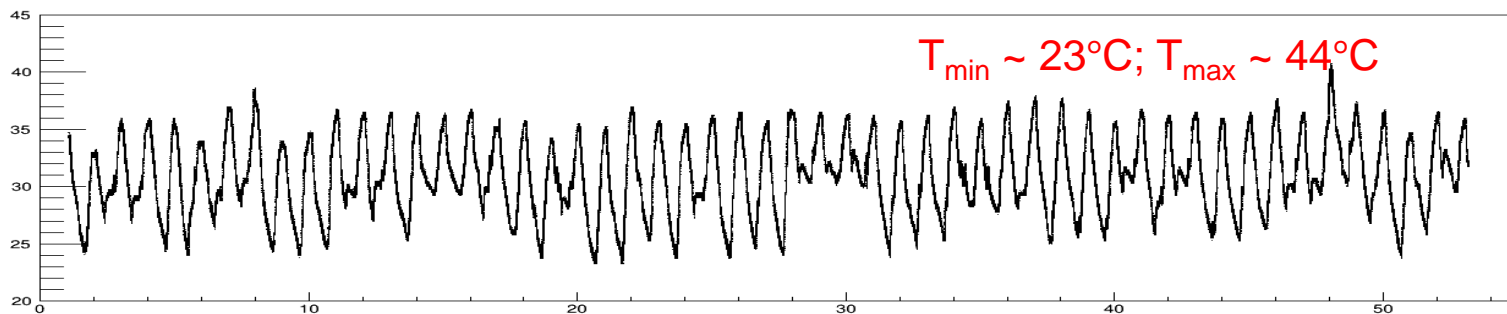




- Relatively smooth...



- ... with large temperature variations

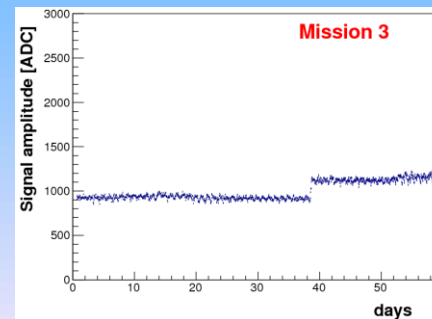
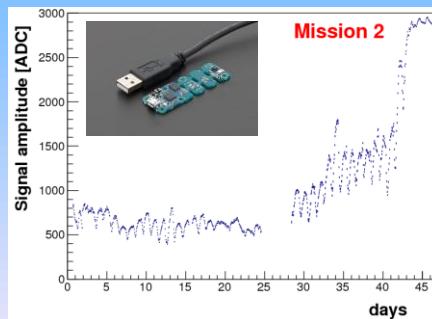
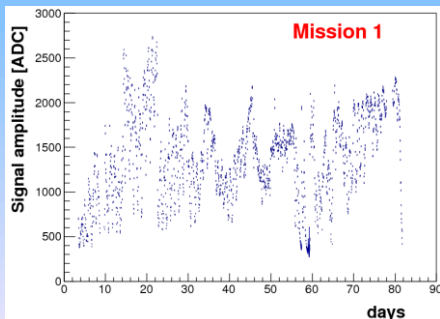


- Successive improvements on the signal stability

- *Feedback with outside T*

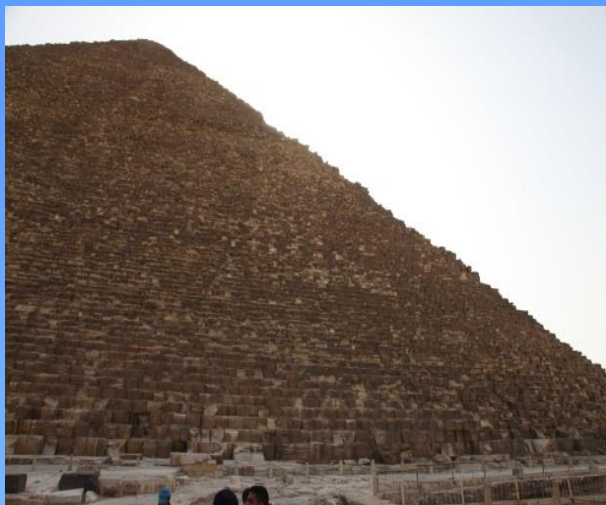
- *Feedback with inside T*

- *Amplitude feedback (S. P. & S. Bouteille)*

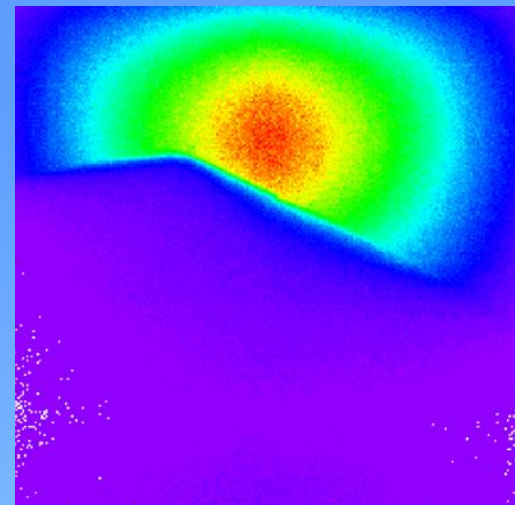


- Necessity to adjust photo and muo for comparison with 3D model

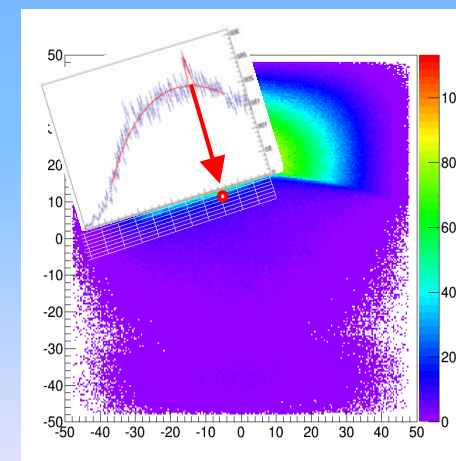
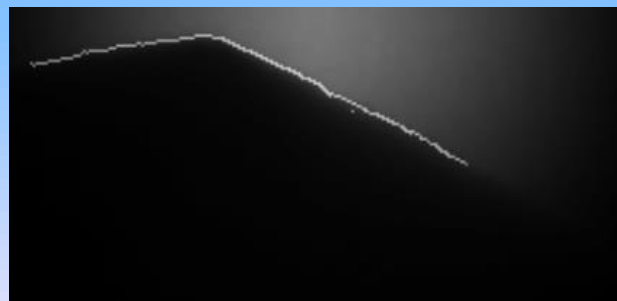
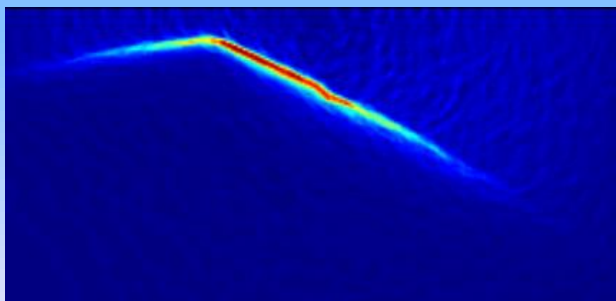
*photo*



*muo*



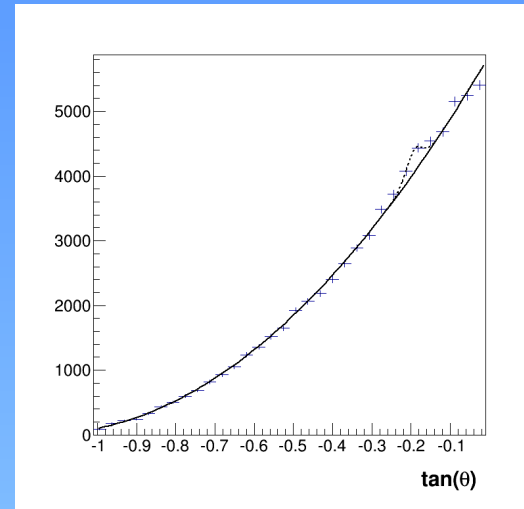
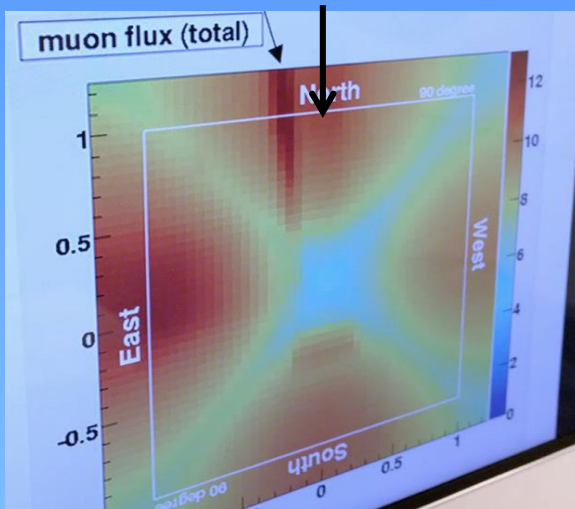
- Requires edge detection (image filtering)



- Early 2017: 1st results from Nagoya emulsion in Queen's Chamber...

*Significant muon excess close to the Grand Galery* ⇒ **void**

*Anomalies appearing also on KEK scintillator (Queen's Chamber), and on CEA telescope (North face)*



- 3D model suggests that all these anomalies point to the same direction

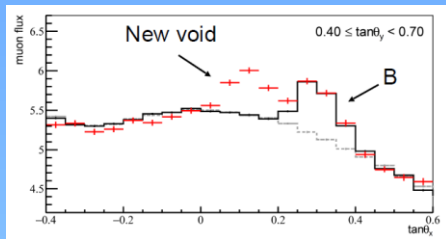
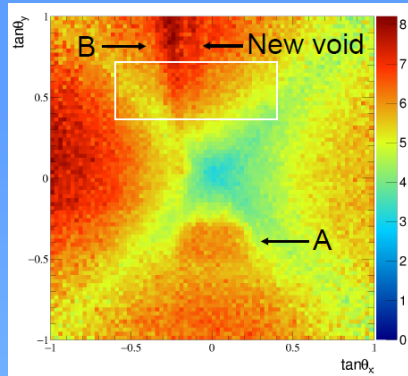
⇒ **Dedicated measurement campaign started**

- *Queen's Chamber: new emulsion from Nagoya and move of the KEK scintillator*
- *Outside: move of 2 telescopes in front of the North face Chevrons*

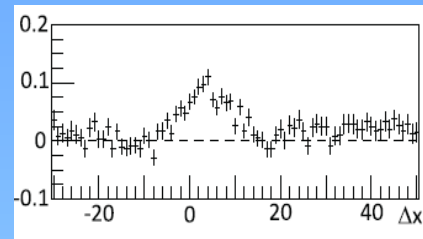
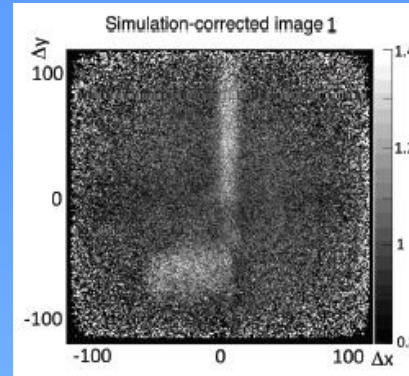


- All the measurements confirm a large void above the Grand Gallery

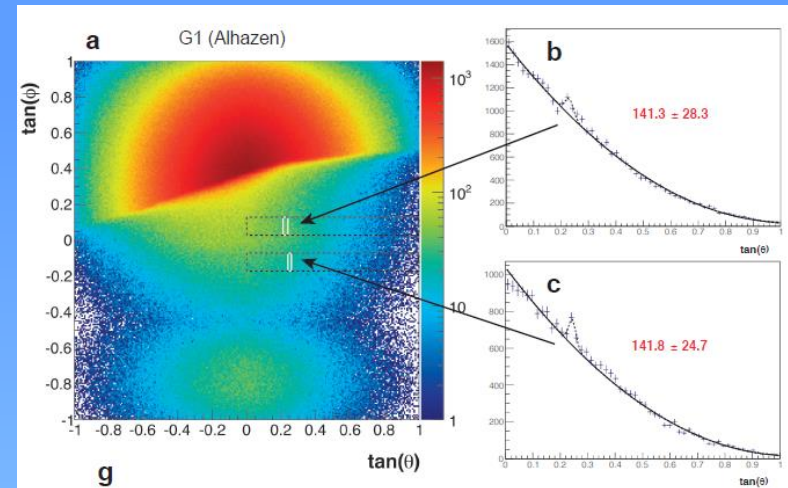
Nagoya



KEK

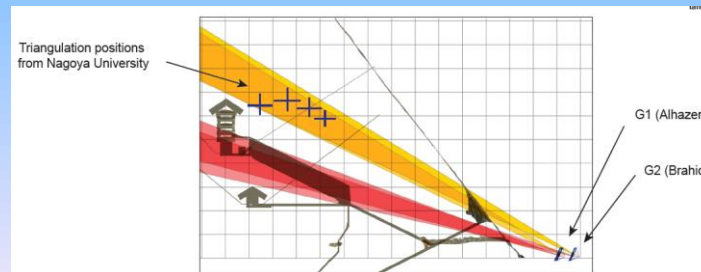


CEA

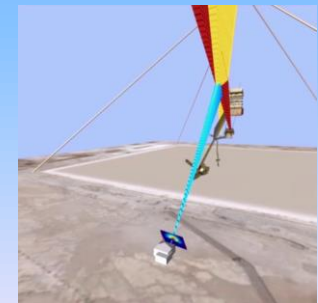


- Only 2 such voids detected
- 1<sup>st</sup> detection ever from outside of a deep structure

- Good triangulation with Nagoya and CEA instruments



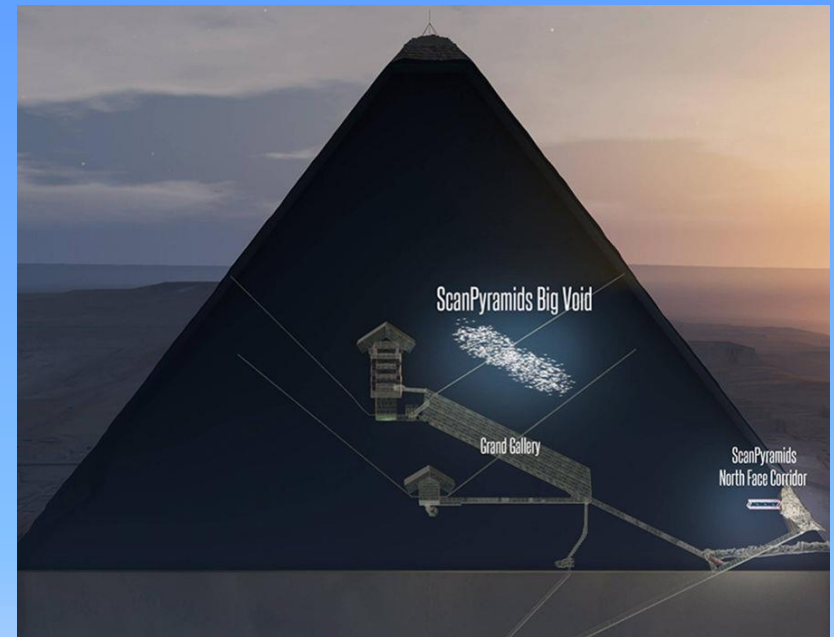
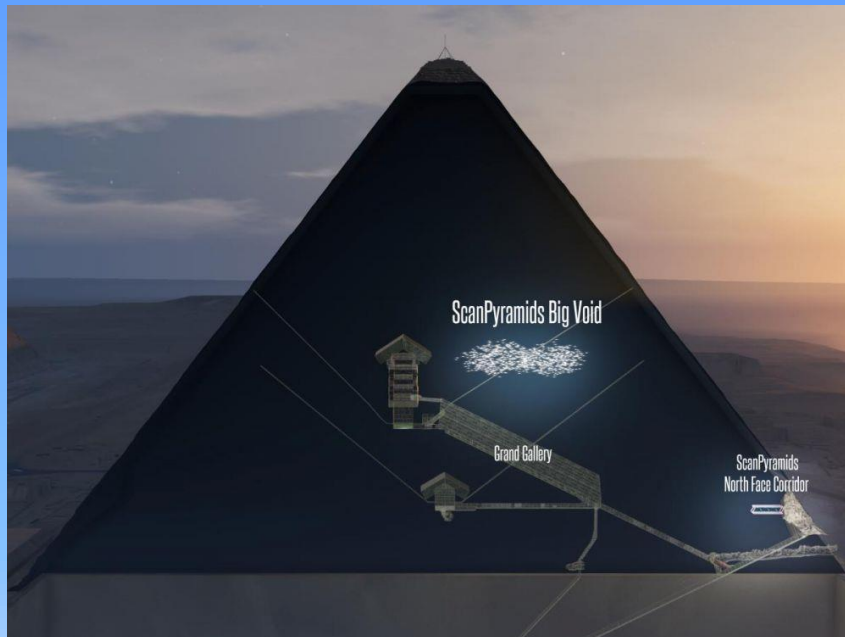
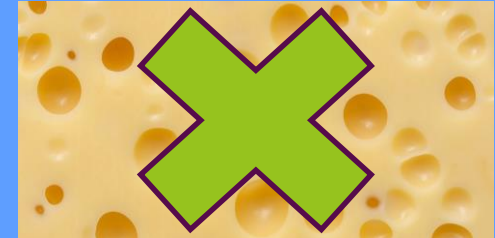
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- Remarkable features of the ScanPyramids Big-Void:

- *Within the same plane as all other known (big) structures*
- *Large under-density, only at this place*



- *Volume estimate: several hundreds of m<sup>3</sup>*
- *Length: > 30 m*
- *Inclined or horizontal...*

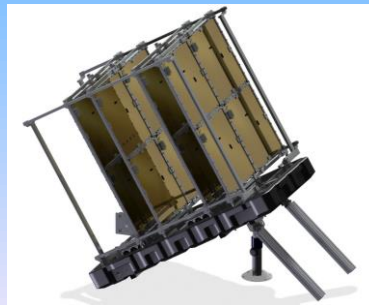
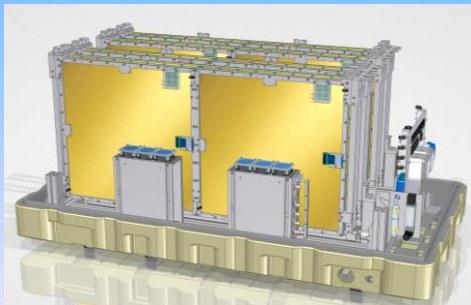
⇒ **More measurements needed!**



- Electronics management of the gas flow with new HVPS-v2 card
  - *Test in progress*



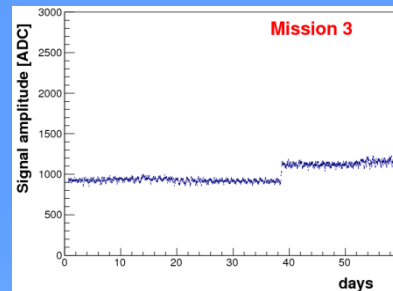
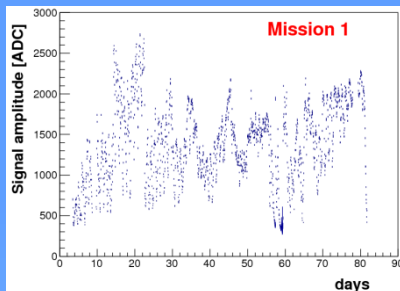
- Proposition of a mission inside the pyramid to better observe Big Void
  - *Goal: <math> < 1 \text{ m}^3 </math> in 4 months*
  - *Waiting for Egyptian agreement for 2018*
- Longer term: sealed, bigger telescopes and TPC
  - *Vacuum chamber at Saclay, test started (a la Harpo)*



# CONCLUSION (BEYOND BIG VOID!)



- MPGD robust enough for extreme condition applications in spite of gas



- Probably the best technology for precise muography

	Nuclear emulsion <i>Nagoya University</i>	Hodoscopes <i>KEK</i>	Gas detectors <i>CEA</i>
Angular Resolution	2-14 mrad	7-10 mrad	0.8 - 4 mrad
Angular Acceptance	45 degrees	34 - 45 degrees	45 degrees
Active area (for this analysis)	30 cm x 25 cm / unit: 0.75 m x 0.6 m (NE1) 0.9 m x 0.5 m (NE2)	1.2 m x 1.2 m	50 cm x 50 cm
Position Resolution	1 $\mu$ m	10 mm	400 $\mu$ m
Height	0.2 mm	1-1.5 m	60 cm
Power requirement	No	Yes (300W)	Yes (35W)
Data taking	Need development	Real time	Real time

- Key ingredients for large scale, societal or industrial applications

- **Manufacturer (ELVIA)**
- **Potential integrator (Iris Instruments)**
- **Media coverage (advertisement)**
- **Rui's help!**

- Painting



- Photography



- Muography?

