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PYRAMIDS

HiP

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HERITAGE  
INNOVATION  
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ARAB  
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ANTIQUITIES



FACULTY OF  
ENGINEERING  
CAIRO  
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# New MPGD-based muon telescopes for ScanPyramids and gas R&D

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B. Gallois, H. Gomez, M. Kebbiri, P. Magnier, I. Mandjavidze  
CEA / IRFU

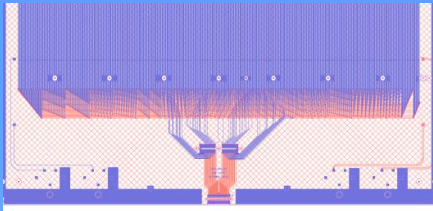
La Rochelle, 09/05/2019



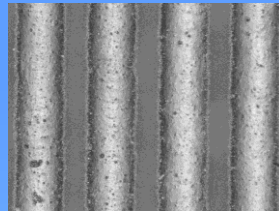
- Starting point
- New telescopes
- Gas R&D
- Maintenance & data taking
- Perspectives

## Development of telescopes for HD muon imaging

*Genetic multiplexing on MM*    *Resistive strips, reverse grounding*

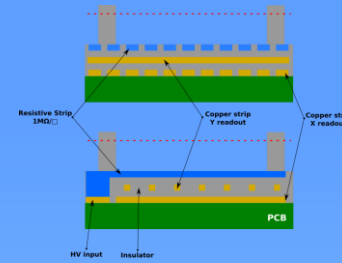


$$\Rightarrow \sigma \cong \frac{p'}{40}$$



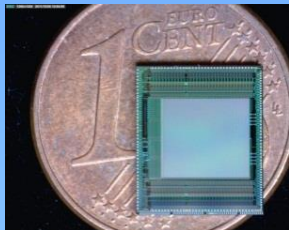
$\Rightarrow$  **large & stable gain**

*2D readout*

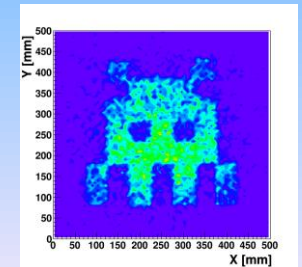
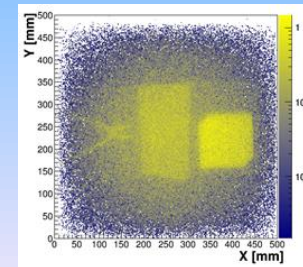
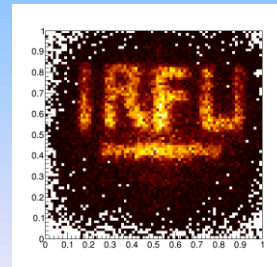
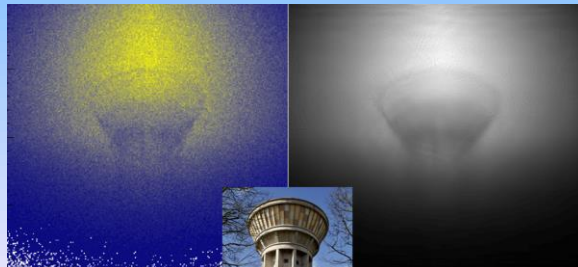
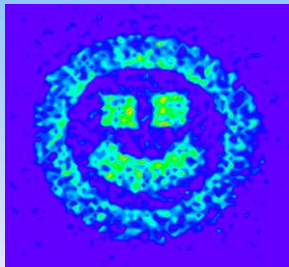


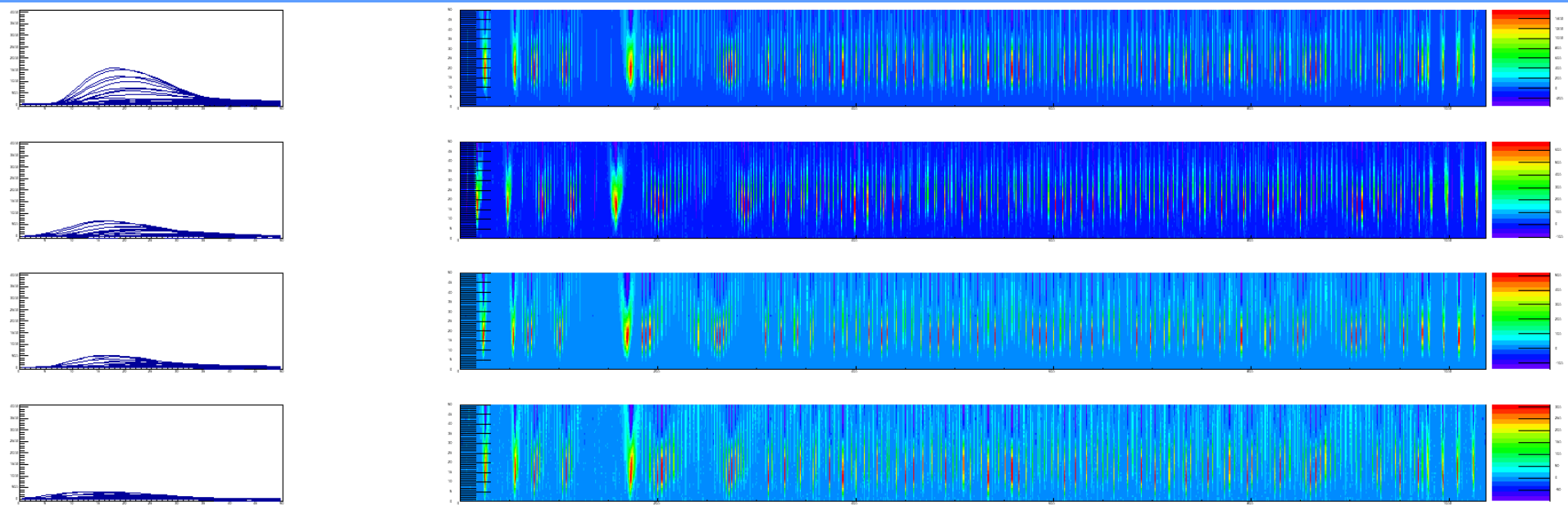
$\Rightarrow$  **less detectors**

*Miniaturized equipment*



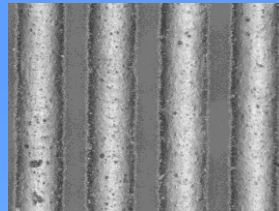
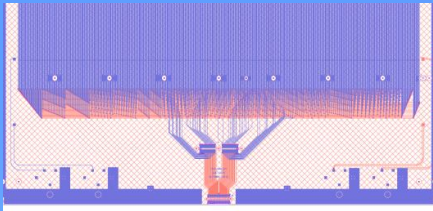
$\Rightarrow$  **low consumption**





## Development of telescopes for HD muon imaging

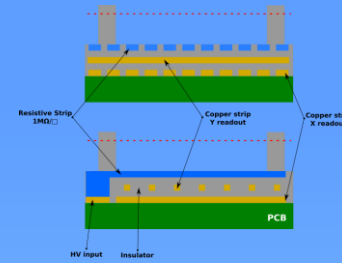
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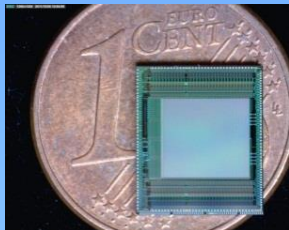
$\Rightarrow$  **large & stable gain**

*2D readout*

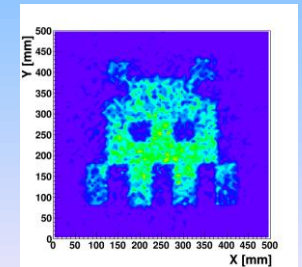
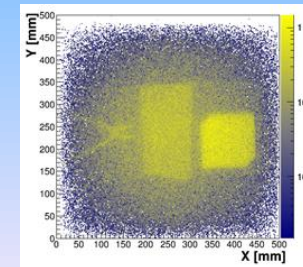
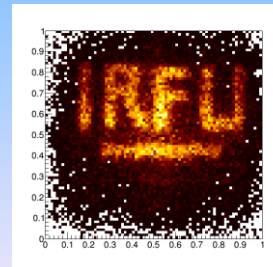
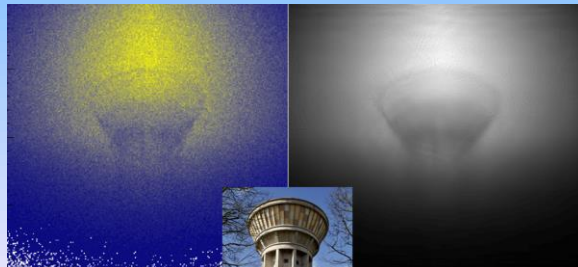
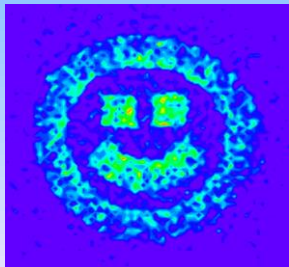


$\Rightarrow$  **less detectors**

*Miniaturized equipment*

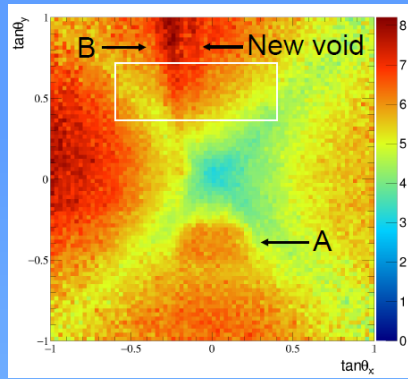


$\Rightarrow$  **low consumption**

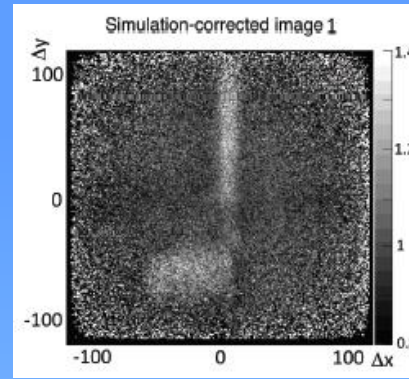


## Discovery of the ScanPyramids Big Void in 2017

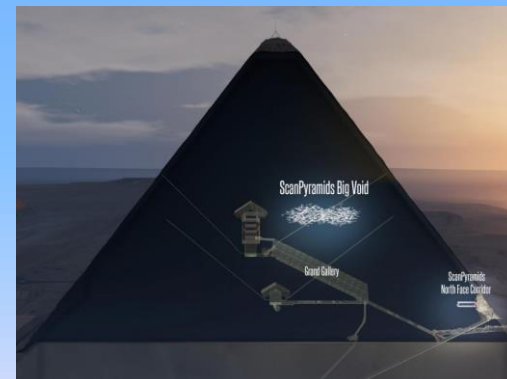
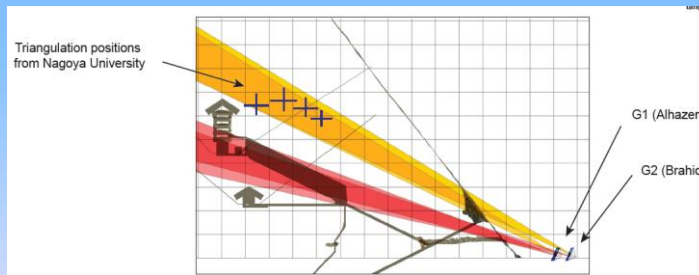
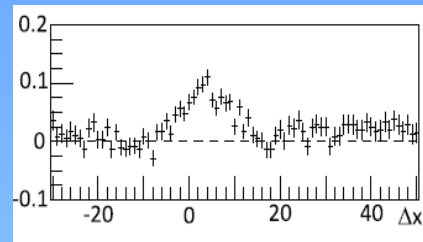
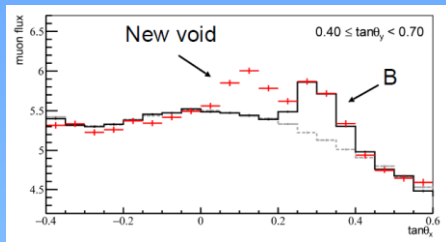
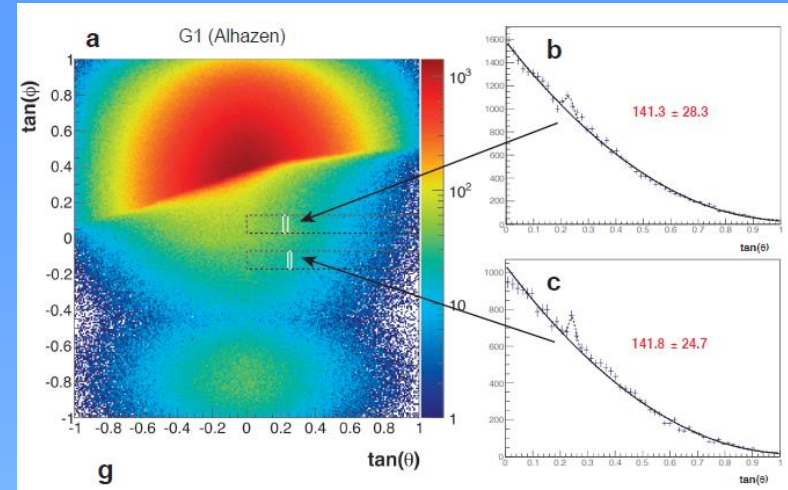
*Nagoya*



*KEK*



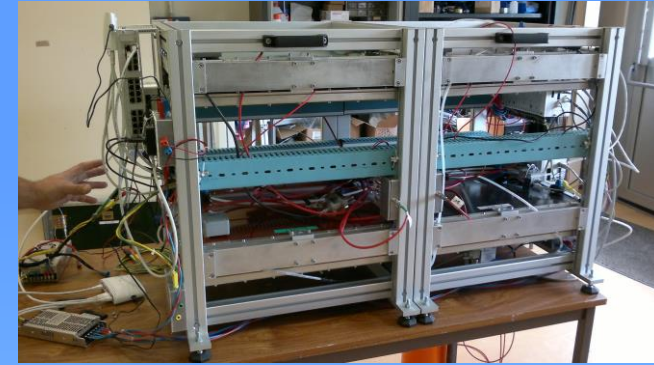
*CEA*



⇒ **Best place to study it in more details is the Grand Gallery...**

## Bigger telescopes, to be competitive with other teams (Nagoya)

- Surface doubled ( $1/2 \text{ m}^2$ ): 4  $\rightarrow$  8 detectors
- 2 telescopes  $\rightarrow$  16 detectors



## Have to be compatible with operation in Grand Galery

- Gas? (high pressure bottle, evacuation, autonomy)
- Small corridors...
- Tourists...
- Network / remote access...

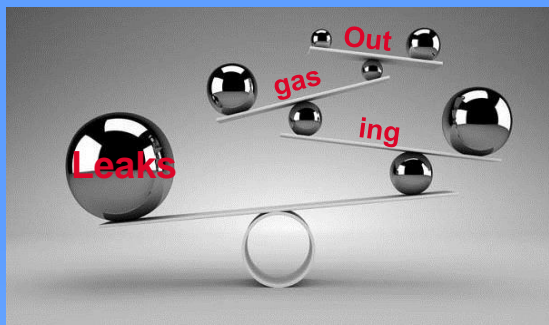


$\Rightarrow$  **Gas R&D to reduce consumption**

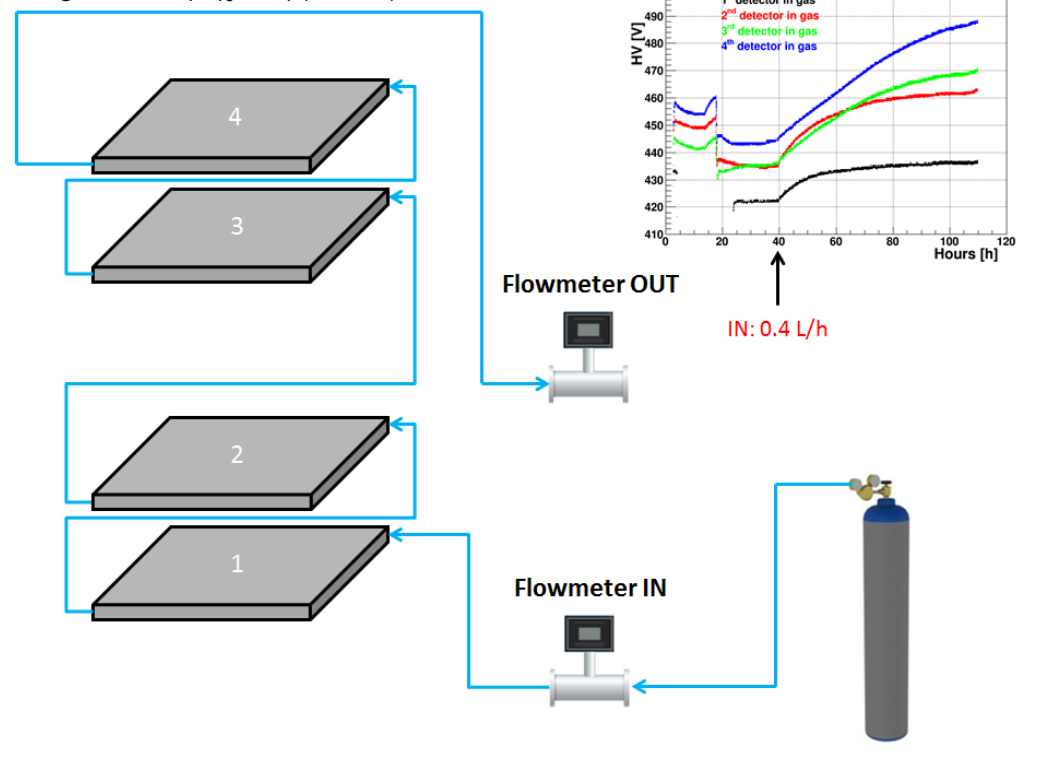
## ... btw, why do we flush MPGDS with gas?

- A priori combination of leakage & outgasing
- Measured leak < 1 mL/h for most of the detectors

Effects easy to observe: just reduce the gas flow ☺



T2K gas: Ar-iC<sub>4</sub>H<sub>10</sub>-CF<sub>4</sub> (95-2-3)



**NB: HV automatically adjusted to keep constant gain**

- ⇒ Large HV gradient between detectors
- ⇒ Accompanied by signal degradation & efficiency loss
- If flow is stopped: ~+1V/h to maintain the same gain

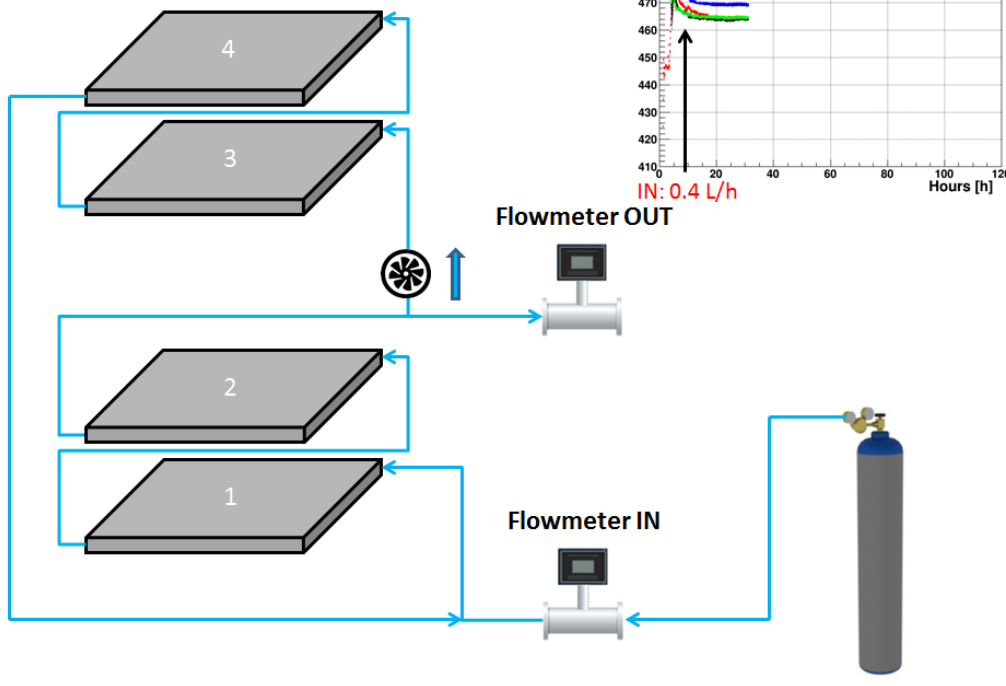
→ Problem: small injection rate = small circulation rate...



## Can we reduce injection and keep circulation rate high (at small cost & low consumption)?

- make use of a turbine developed for HARPO (D. Attié & P. Magnier)
- Introduce a *semi-sealed* setup

T2K gas: Ar- $iC_4H_{10}$ - $CF_4$  (95-2-3)



**NB: HV automatically adjusted to keep constant gain**

⇒ Better homogeneity and efficiency by « mixing the shit »

⇒ Similar HV for all, but quite high

→ **By how much is the circulation rate increased?**



## Not easy to measure the flow without a flowmeter...

- Solution to measure the pressure drop in a circuit, via the Darcy-Weisbach equation:

$$\Delta P = f \frac{L}{D} \frac{\rho v^2}{2} \Rightarrow \Delta P = \frac{8}{\pi^2} f \frac{L}{D^5} \rho F^2$$

- Typical Reynolds number below  $\sim 10 F$  [L/h]

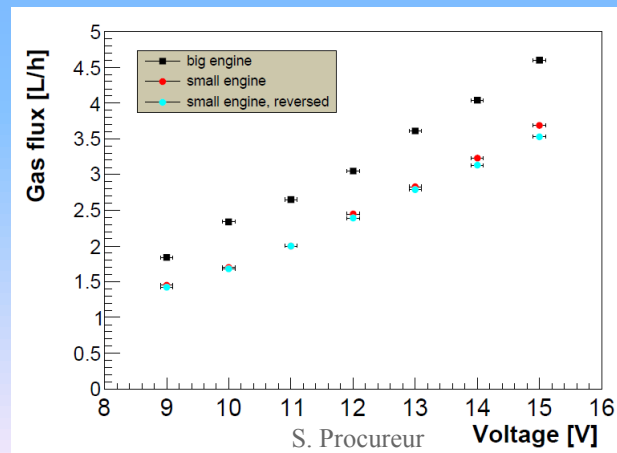
$$Re = \frac{\rho v D}{\mu}$$

$$\Rightarrow f = \frac{64}{Re}$$

$$\Rightarrow \Delta P = \frac{128}{\pi} \frac{\mu L F}{D^4}$$

F [L/h]	0.1	0.2	0.3	0.5	1.0	2.0	3.0	4.0	5.0
$\Delta P_{calc}$ [mbar]	0.10	0.19	0.29	0.48	0.96	1.92	2.88	3.84	4.80
$\Delta P_{mes}$ [mbar]	0.09	0.20	0.32	0.50	0.93	1.94	2.91	3.88	5.01

$\Rightarrow$  **Measuring  $\Delta P$  in a given setup with the turbine gives the corresponding flow:**



Measured with T,P,H probes (Yocto-Meteo) used since 2016 in ScanPyramids



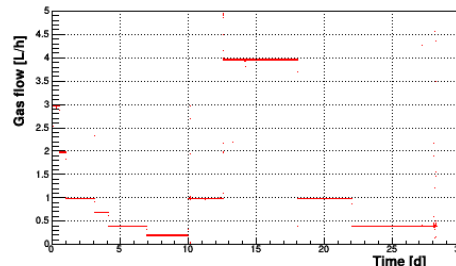
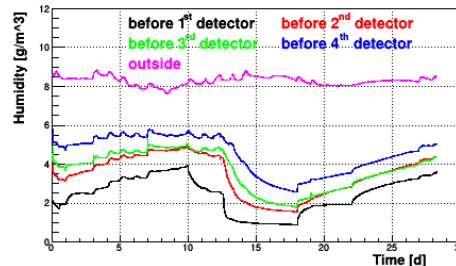
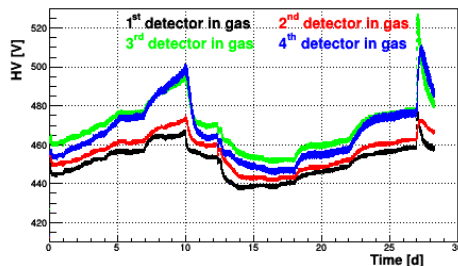
- Relative humidity around 10-40% routinely measured in telescopes



yields less than 1% of H<sub>2</sub>O in volume (only)

Ex: 4.5 g/m<sup>3</sup> of water yields 0.6% of H<sub>2</sub>O in the gas

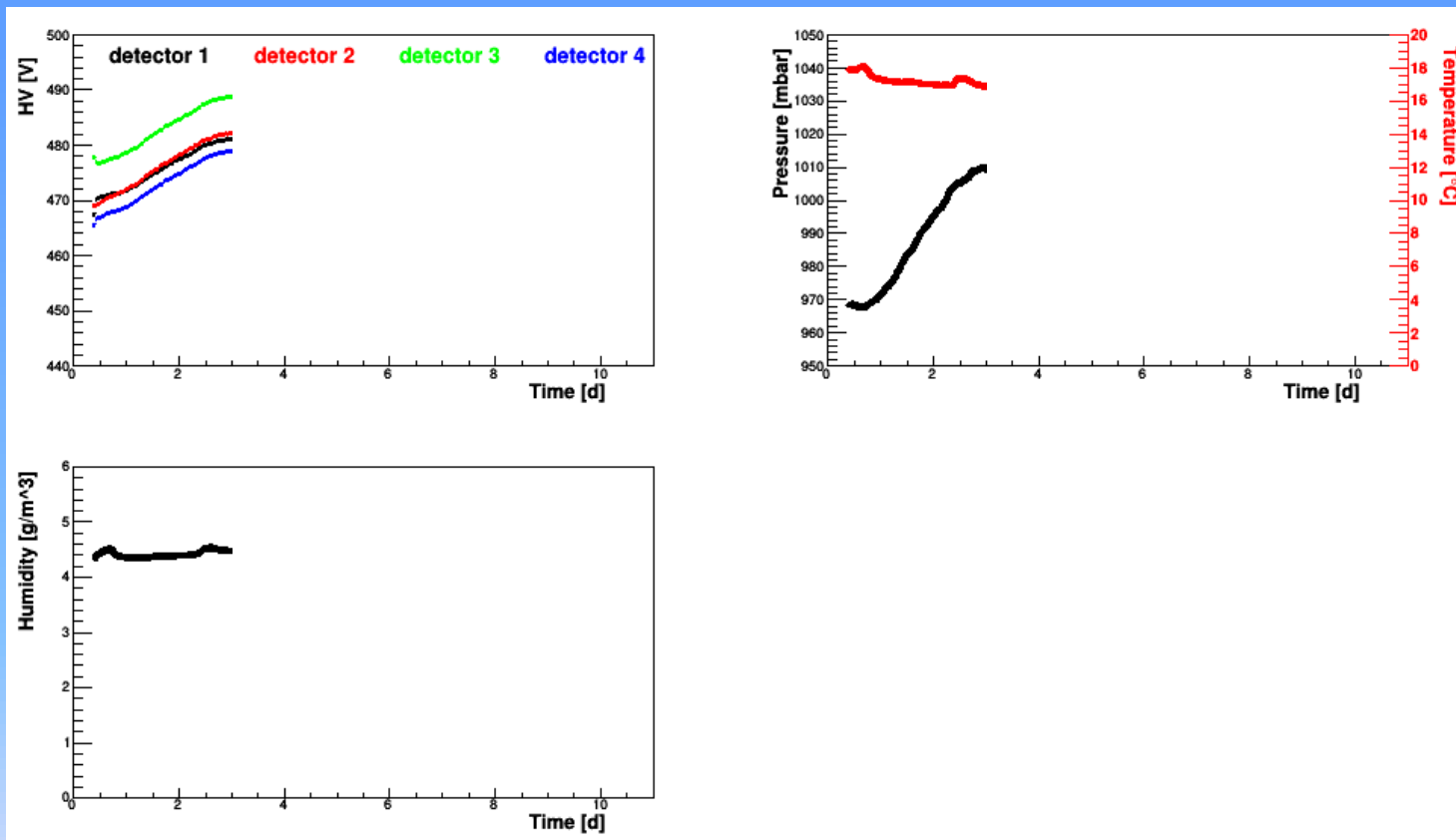
- Humidity goes essentially with 1/F (gas injection flow)



⇒ **Good candidate to explain gain drop and HV gradient**

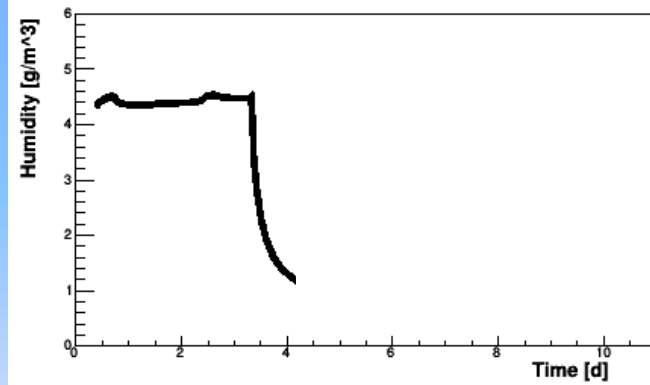
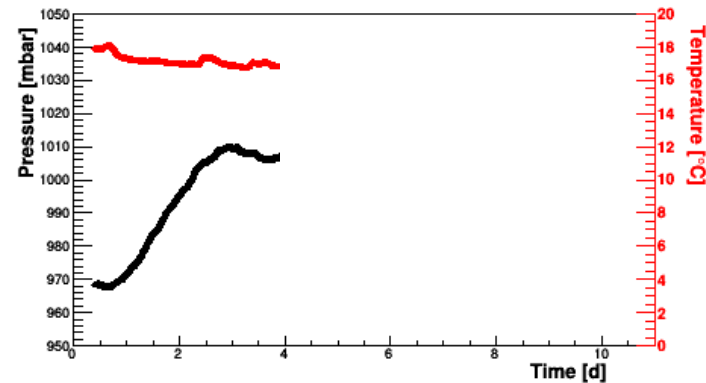
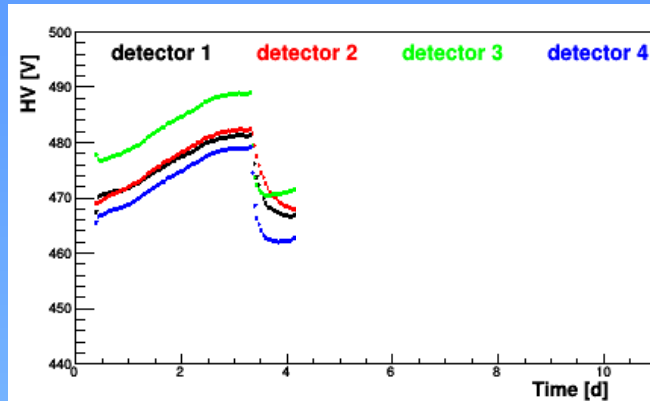
## Tests with H<sub>2</sub>O absorbers

- As before, HV adjust automatically to keep constant gain (see pressure effect!)



## Tests with H2O absorbers

- As before, HV adjust automatically to keep constant gain (see pressure effect!)



⇒ Reduces humidity by a factor 4 in a few hours

⇒ HV drop by 18V!

⇒ **Much better gas quality**

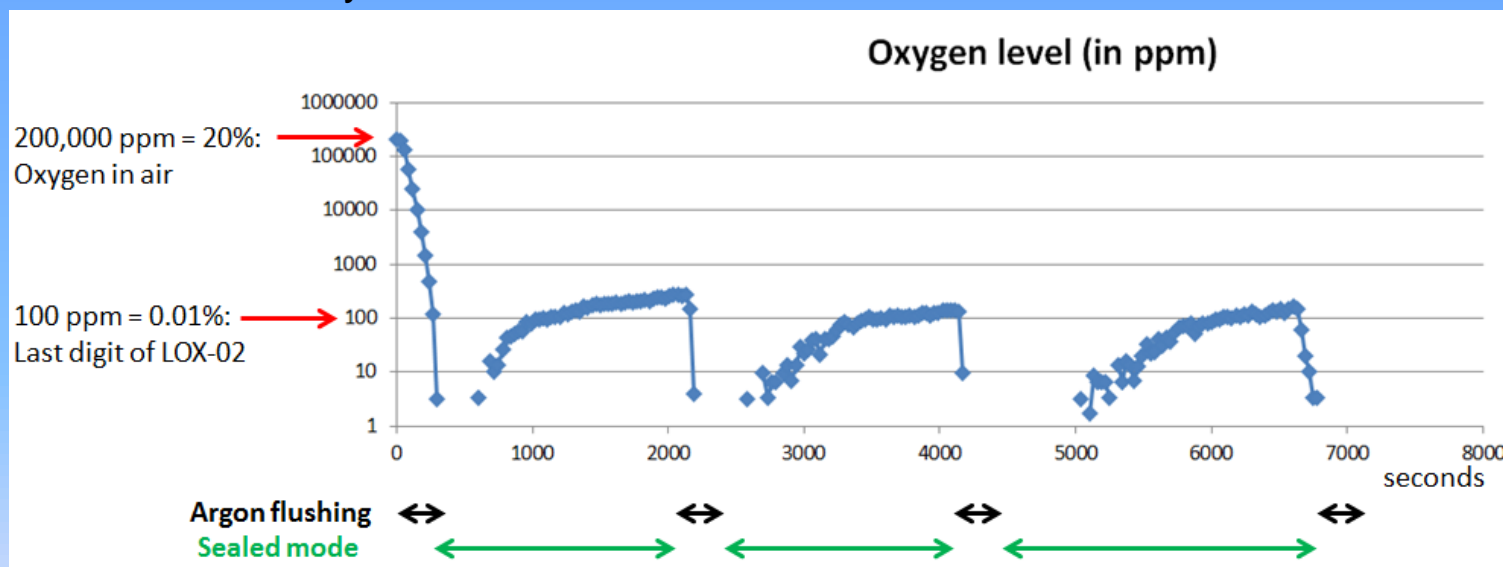
- What about Oxygen?

## Measured with Yocto-serial coupled with Luminox sensor (SST sensing)



- Price: 120 euros for Yocto+Luminox

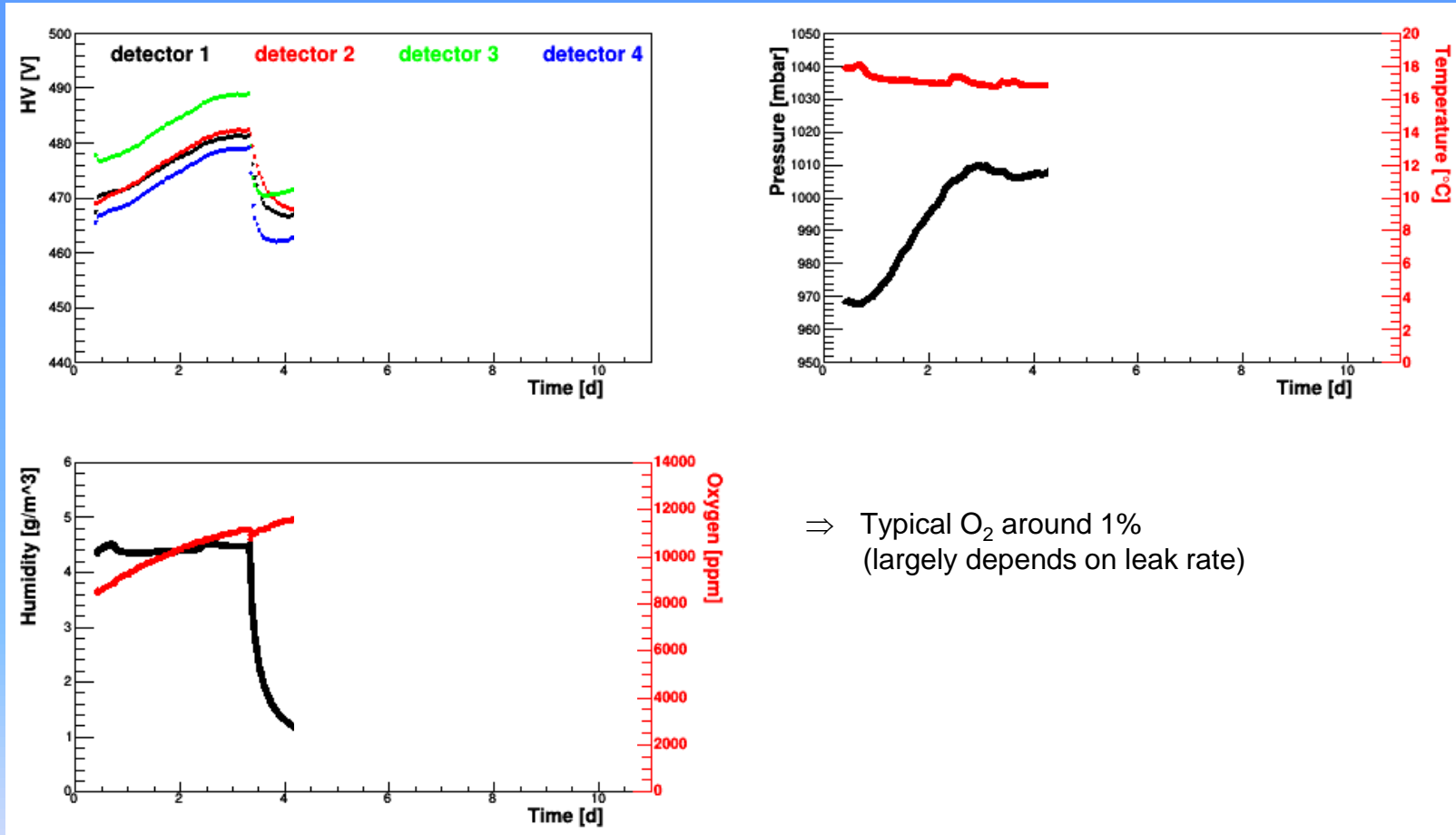
- Tests of the sensitivity:



⇒ (relative) accuracy of 100 ppm, but can reach better than 10 ppm by time integration

## Test with O2 absorbers

- As before, HV adjust automatically to keep constant gain (see pressure effect!)

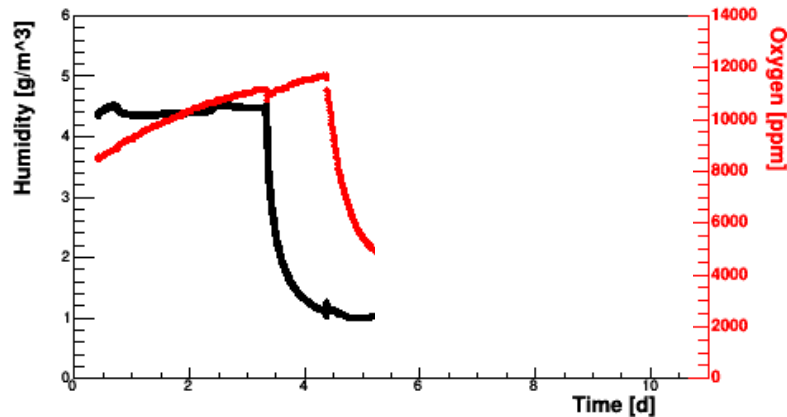
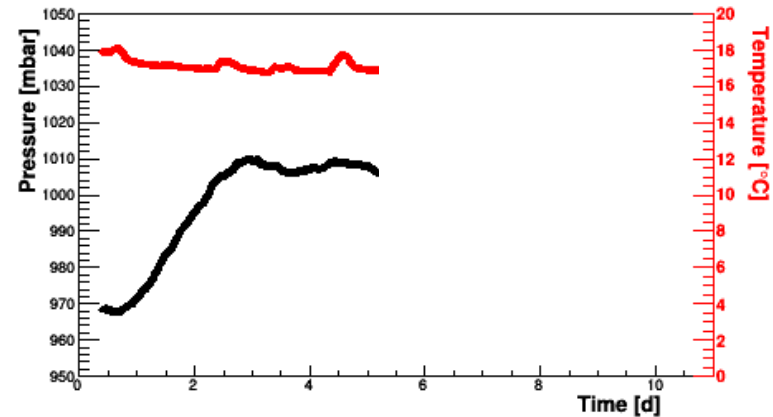
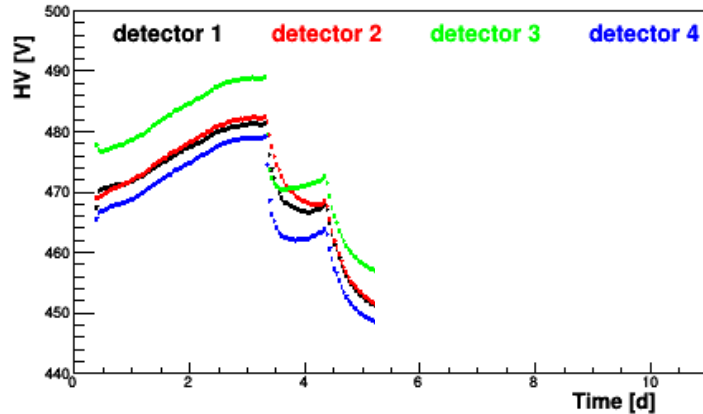


⇒ Typical O<sub>2</sub> around 1%  
(largely depends on leak rate)



## Test with O2 absorbers

- As before, HV adjust automatically to keep constant gain (see pressure effect!)



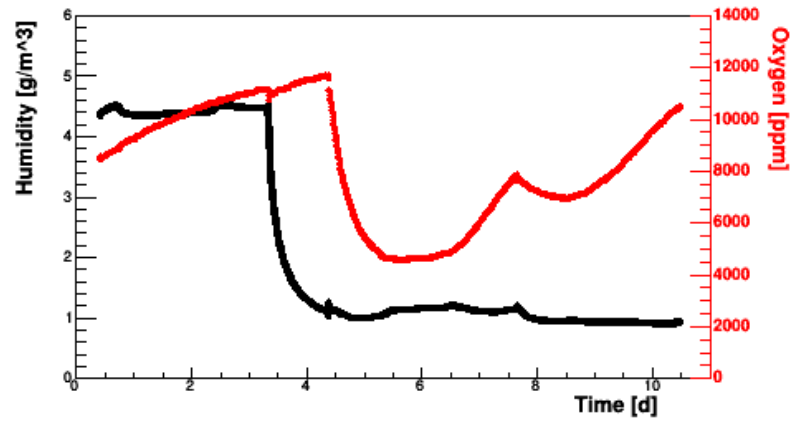
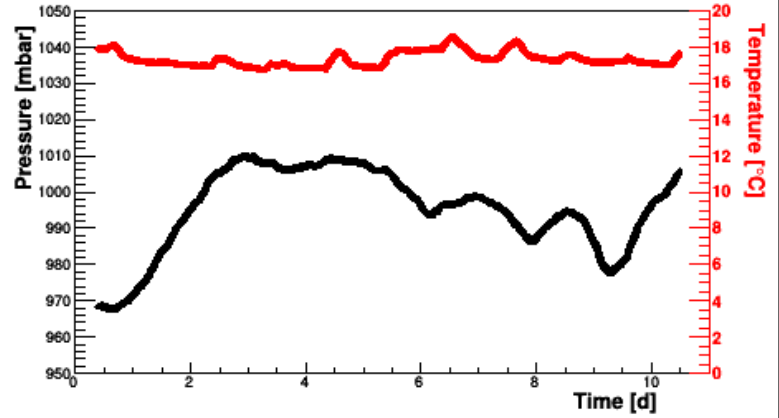
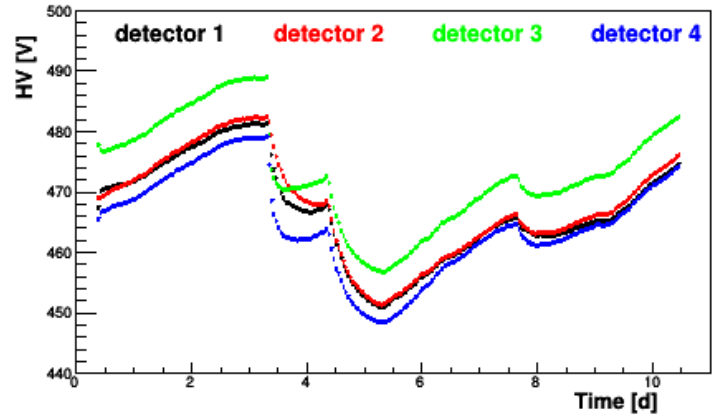
⇒ Another ~18V drop by Oxygen absorption!





## Test with O2 absorbers

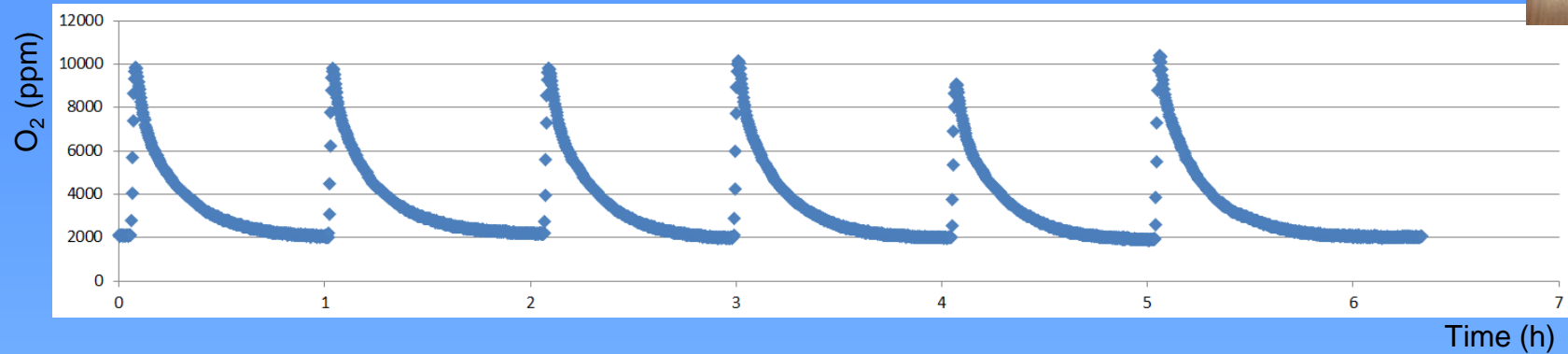
- As before, HV adjust automatically to keep constant gain (see pressure effect!)



- ⇒ Another ~18V drop by Oxygen absorption!
- ⇒ HV correlate maximally with O<sub>2</sub> concentration



Pure argon flushed in 1 m pipes during 1 hour (80 volume flushes)

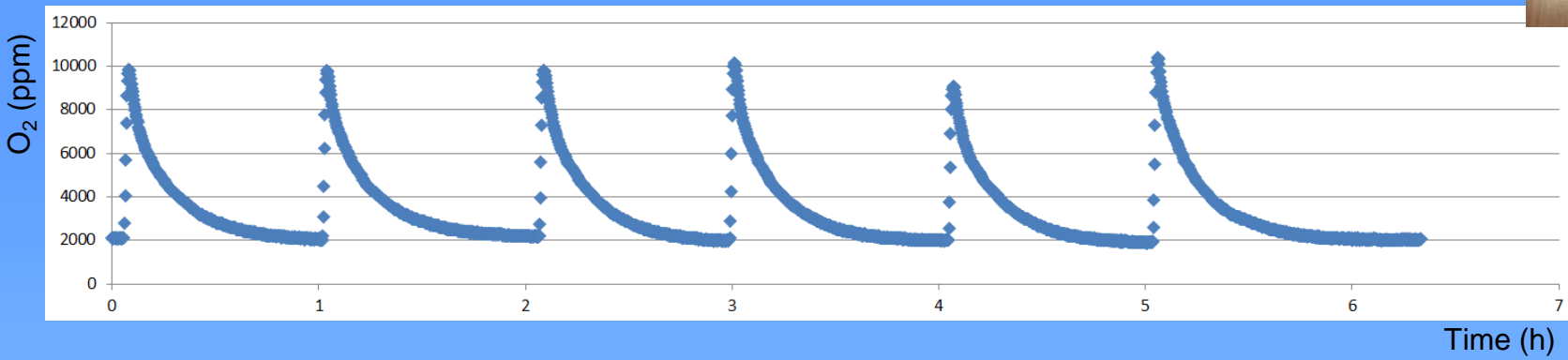


pipe	PA (nylon,1)	PTFE (teflon)	PUN (1)	PA (nylon,2)	PUN (2)	Aluminum
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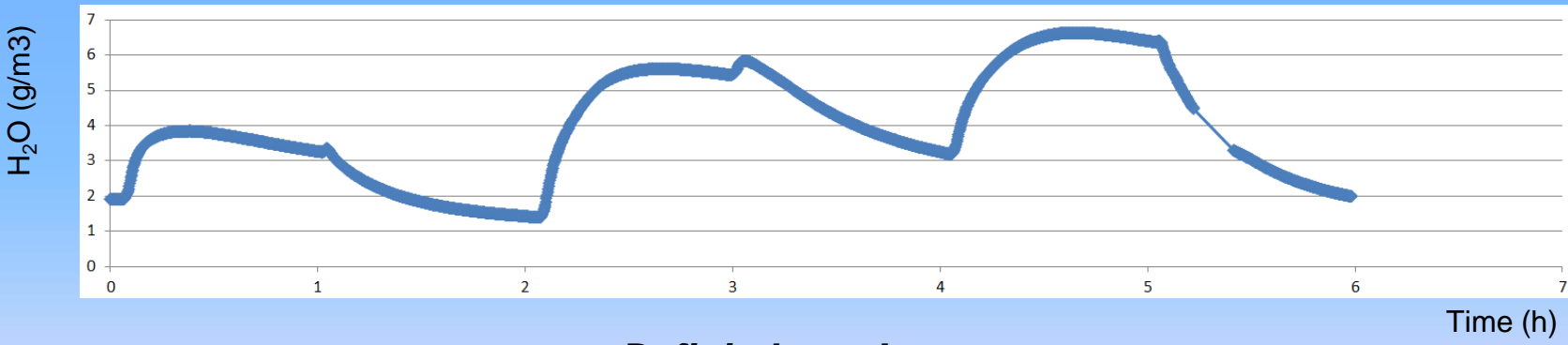
⇒ *All pipes equivalent?*



## Pure argon flushed in 1 m pipes during 1 hour (80 volume flushes)



pipe	PA (nylon,1)	PTFE (teflon)	PUN (1)	PA (nylon,2)	PUN (2)	Aluminum
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⇒ **Definitely not!**

## All gas improvements implemented

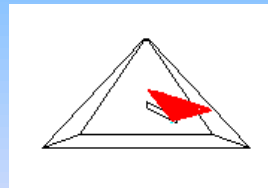
- Better gas tightness
- Semi-sealed mode
- Change of gas pipes & elements

⇒ **>1 L/h for 4 detectors (15L) in 2016, 0.5 L/h for 16 detectors (50L) in 2019**

## 1<sup>st</sup> installation in July 2018



- Data taking from July '18 to January '19

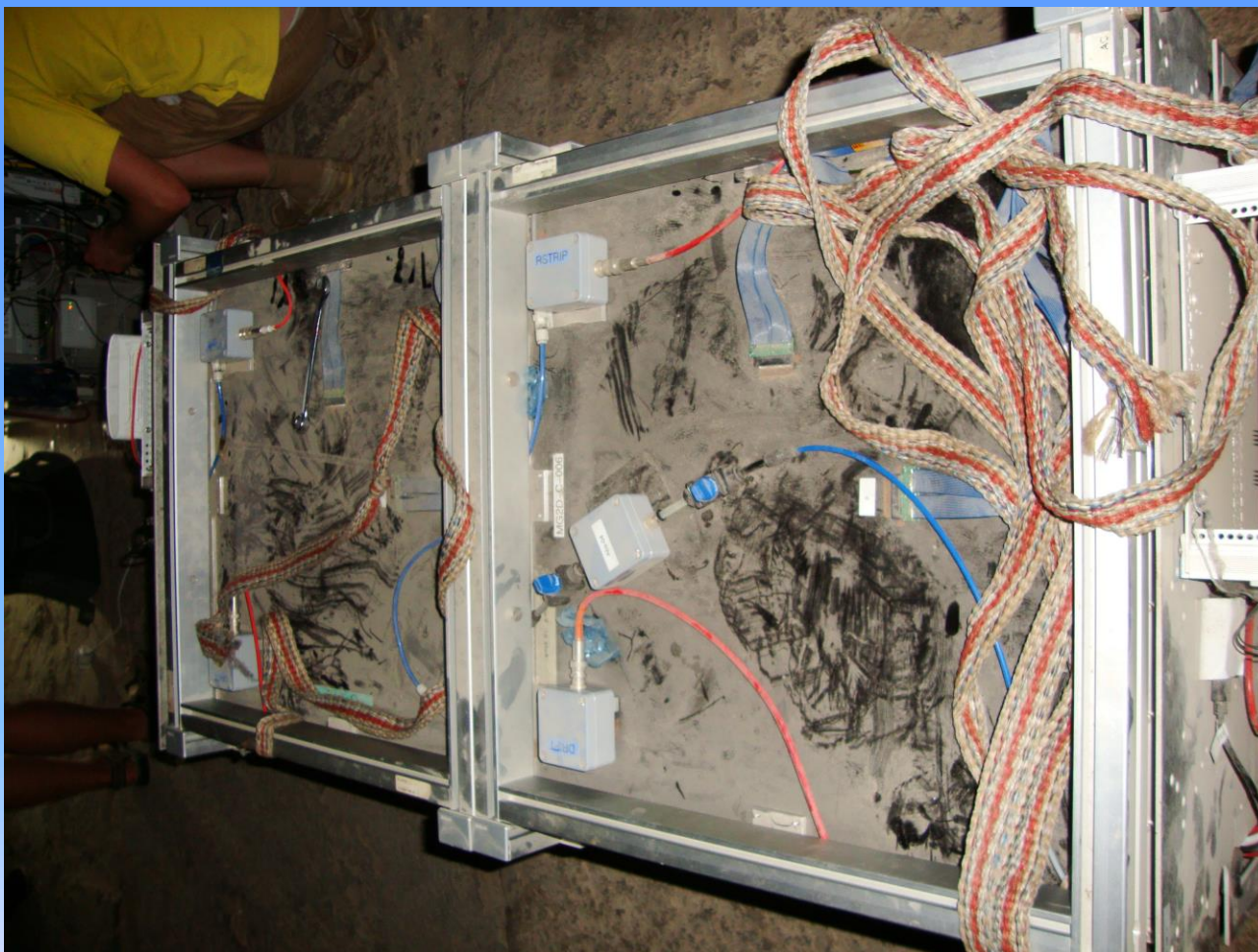


- Some strange issues with detectors and probes...

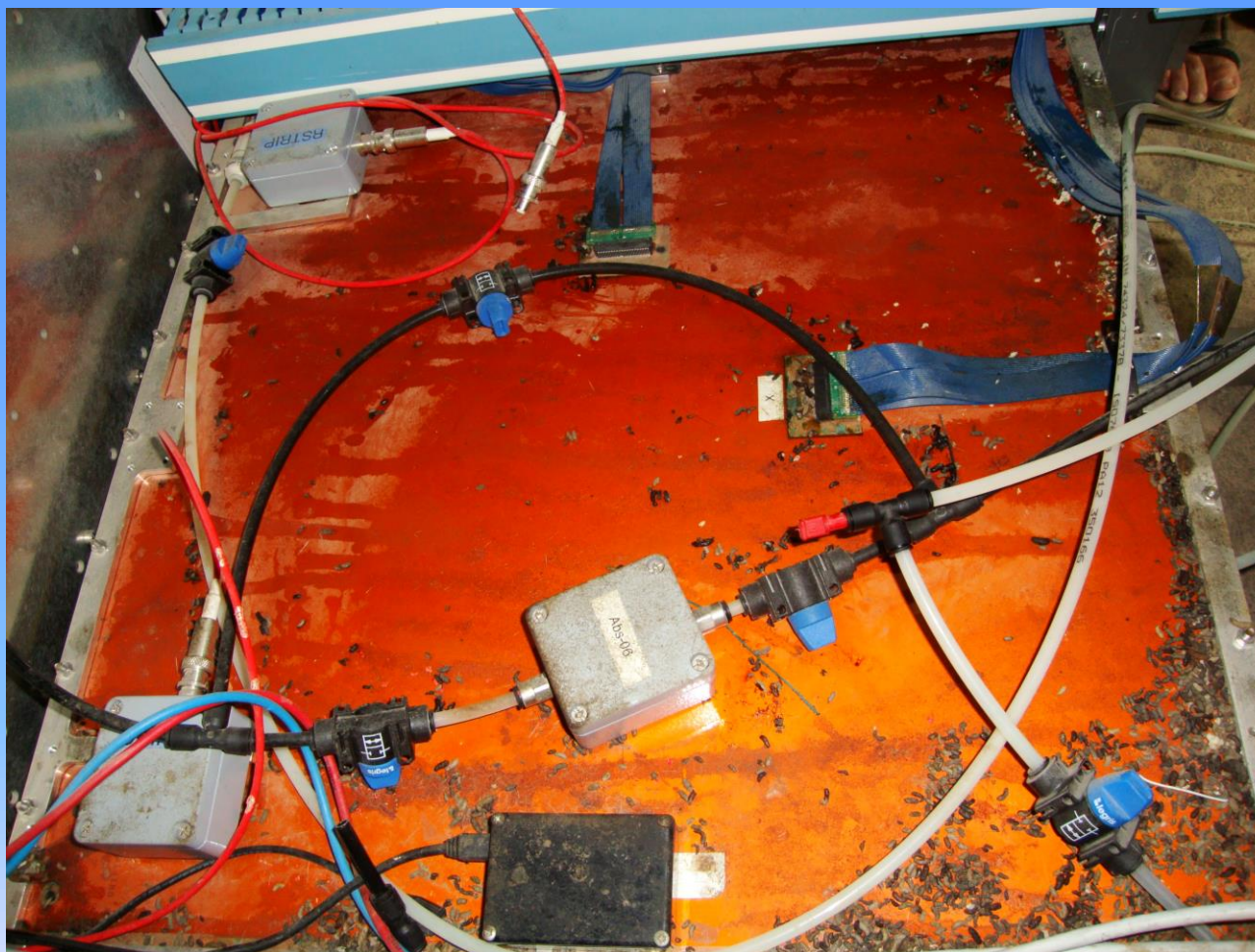


**Another mission in March '19 for maintenance and new bottle...**

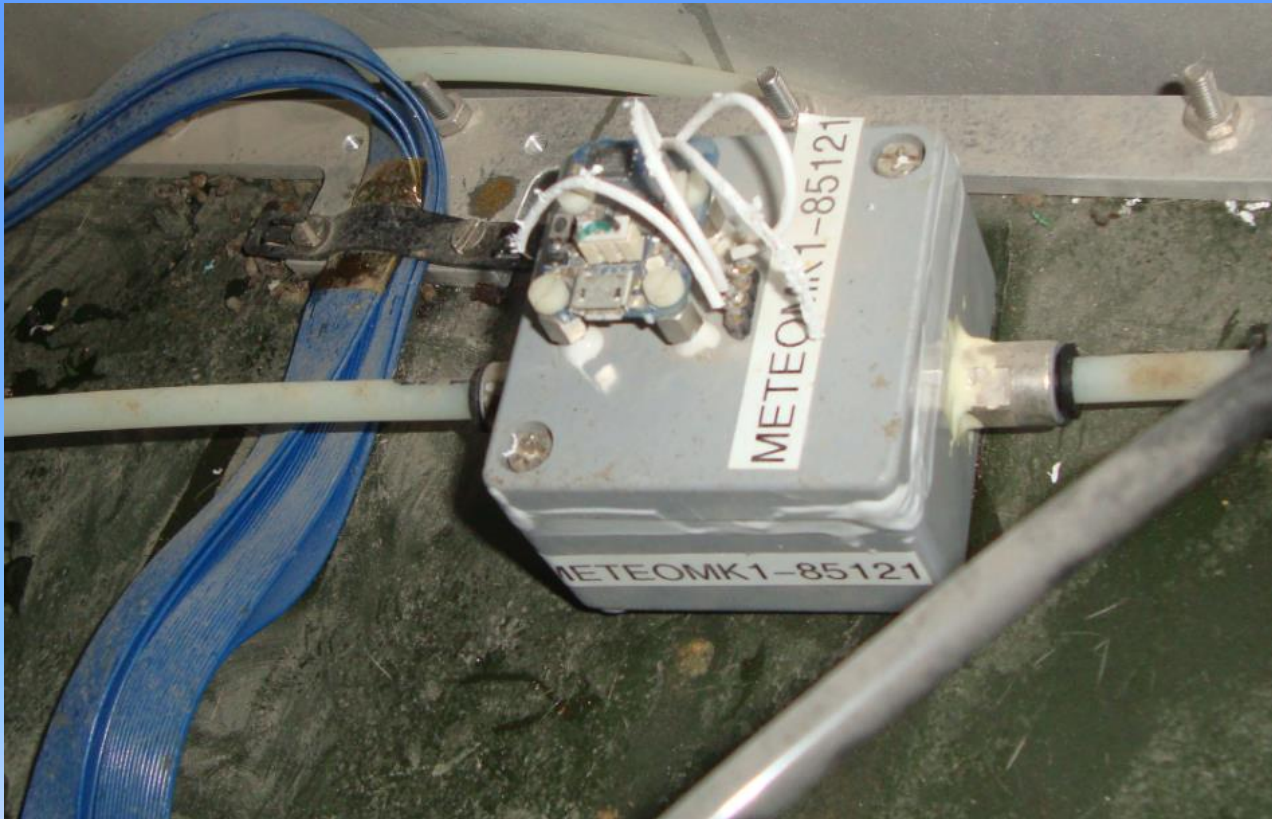
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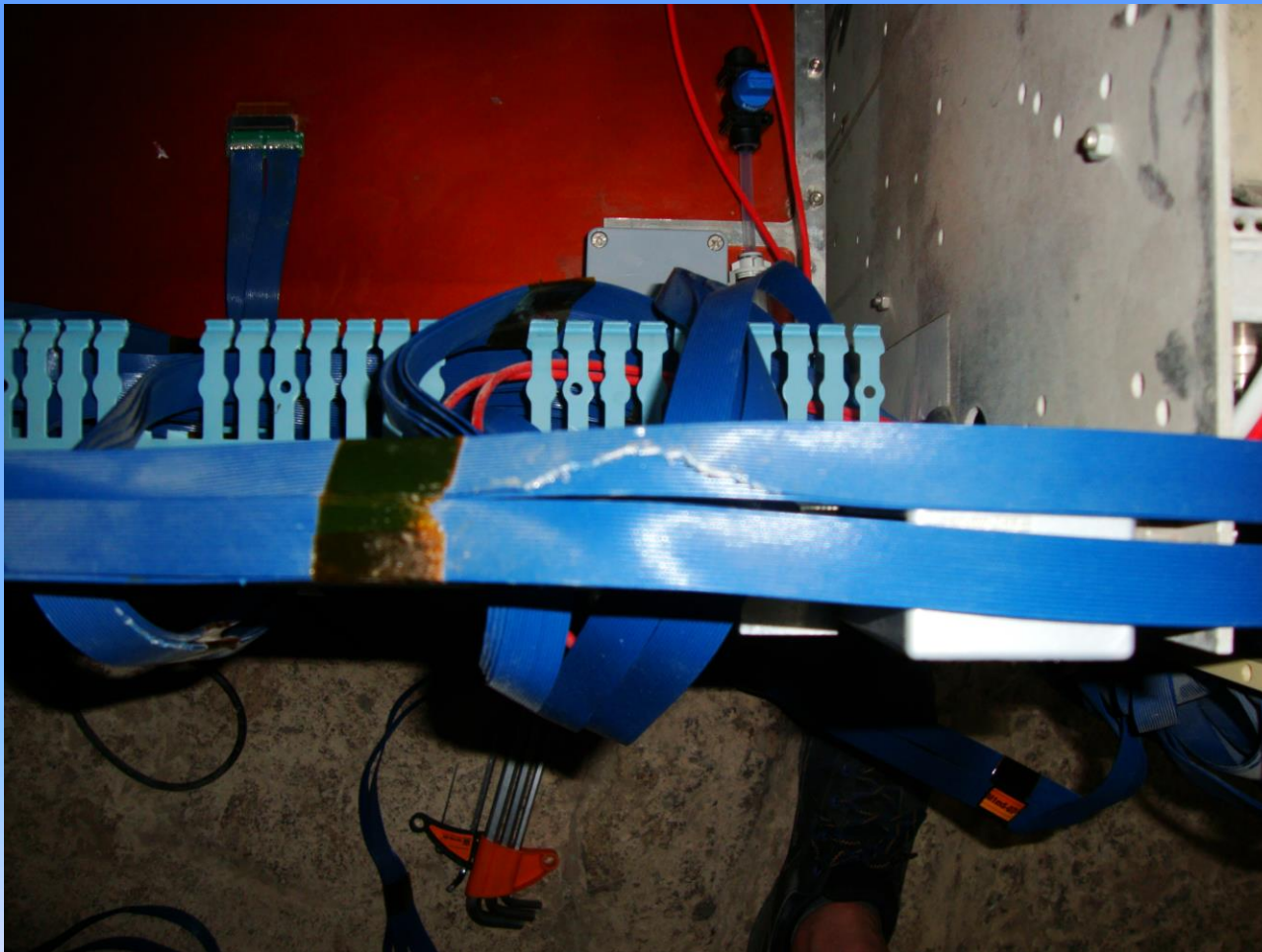


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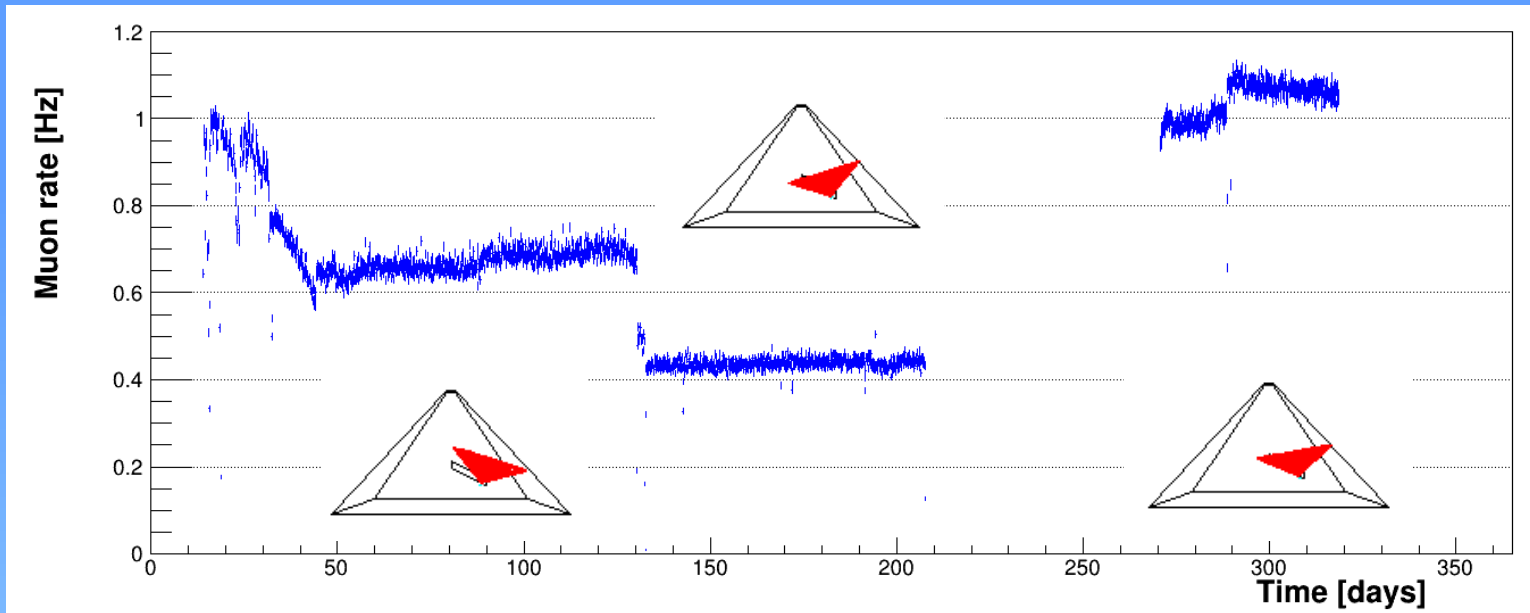




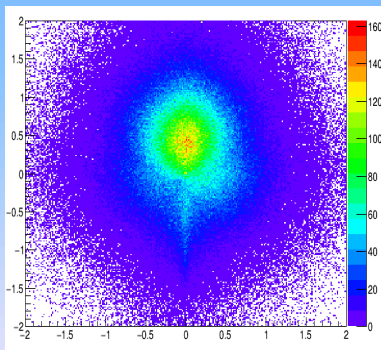
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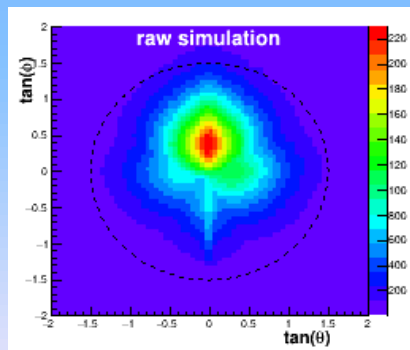
Accumulated ~ 25 millions of reconstructed muons so far



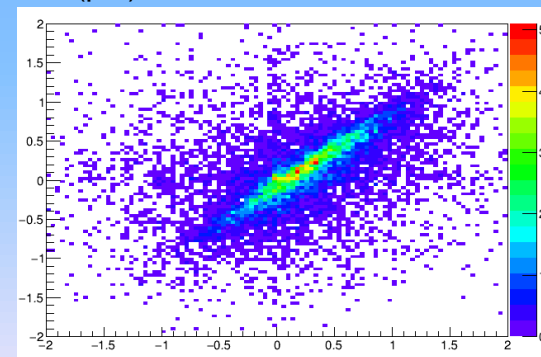
Real muography (9 days)



simulation

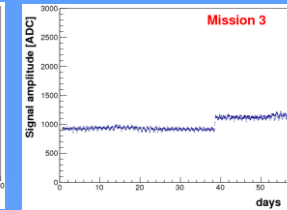
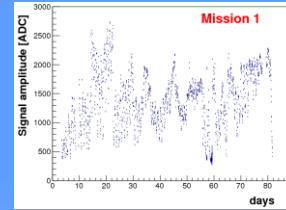


Tan(phi) direction for di-muon events



## MPGDs validated in more and more difficult conditions

- Dust, storms, large temperature variations, humidity, mice



## Successful gas R&D to lower gas consumption by a factor close to 10

- Be careful with gas pipes you use!
- Still a lot to understand (gas spectrometer to be purchased)
- T2K gas extremely sensitive to pollutants

## More telescopes & detectors currently under test

- Plug & play, 1m<sup>2</sup> telescope (used on Gbar)
- See Hector's poster on multiplexed TPC



