Wide field-of-view gamma-ray observatory in the Southern hemisphere

20-22 May 2019
LIP
Europe/Lisbon timezone

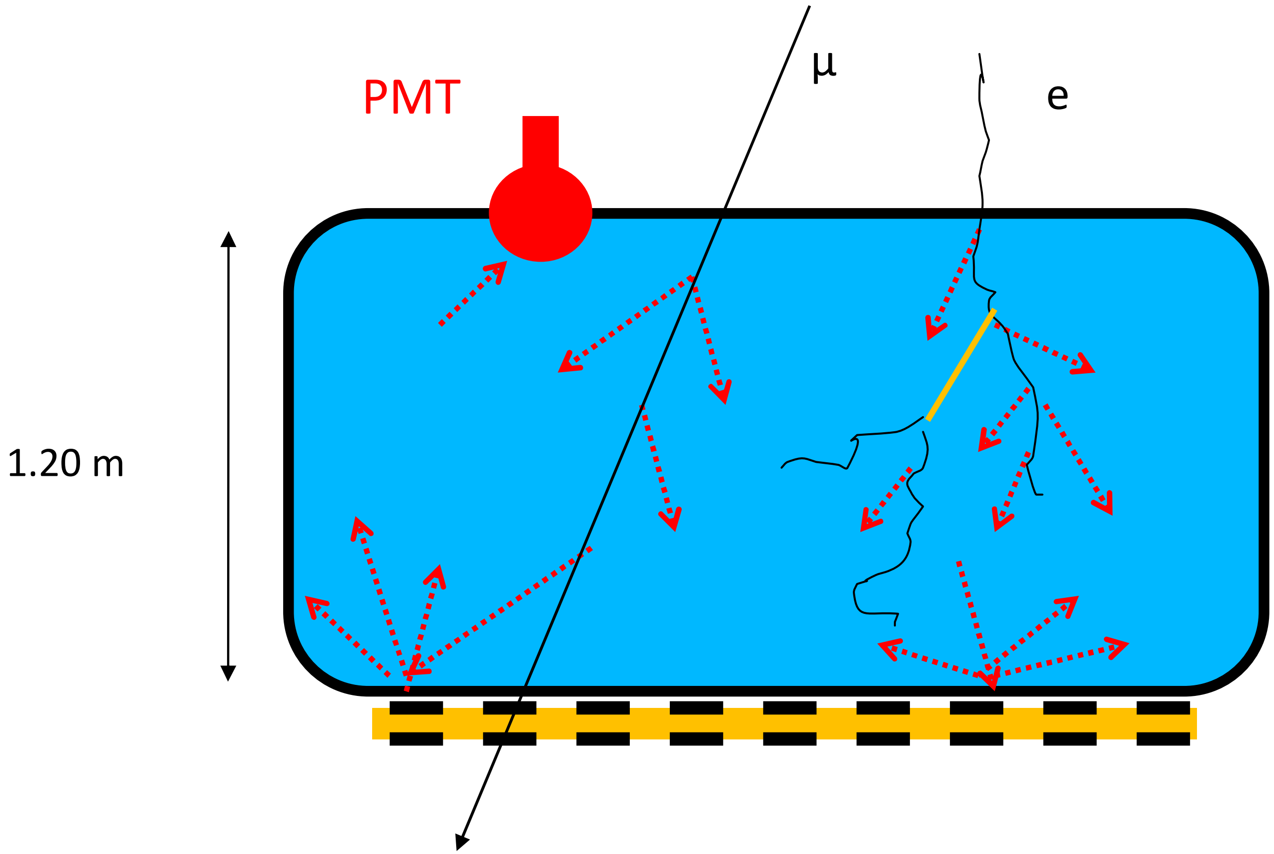
# Autonomous RPCs for outdoor experiments

L. Lopes, P. Assis, A. Blanco, N. Carolino, M.A. Cerda, R. Conceição, O. Cunha, M. Ferreira, P. Fonte, R. Luz, L. Mendes, A. Pereira, M. Pimenta, J. Saraiva, R. Sarmento, B. Tomé

# MARTA

RPCs under the Cerenkov tanks...

The tanks provide partial shielding from the EM signal




To allow independent and precise measurements of E and $N_{\mu}$ (mean and RMS) as well as extend the determination of the Muon Longitudinal profile ($X^{\mu}_{max}$, ...)

# 1st MARTA station

# In progress: MARTA engineering array @ AUGER site

## 10 stations, 40 RPCs

An independently funded collaboration between

LIP and Univ. Campinas, SP, Brasil

# Requirements

1-Very large area @ low cost -> gaseous detector

2-Segmented readout for particle counting,
fiducial area selection, etc. -> gaseous detector

3-Reasonable timing (~5ns) -> gaseous detector

4-Standalone operation

5-Outdoors operation -> resilience to environmental effects

6-Low maintenance -> very low gas flow

7-Little aging at zero particle flow (mostly dark current)

**RPCs** fit well requirements 1-4 and we believe have fair chances for the rest.

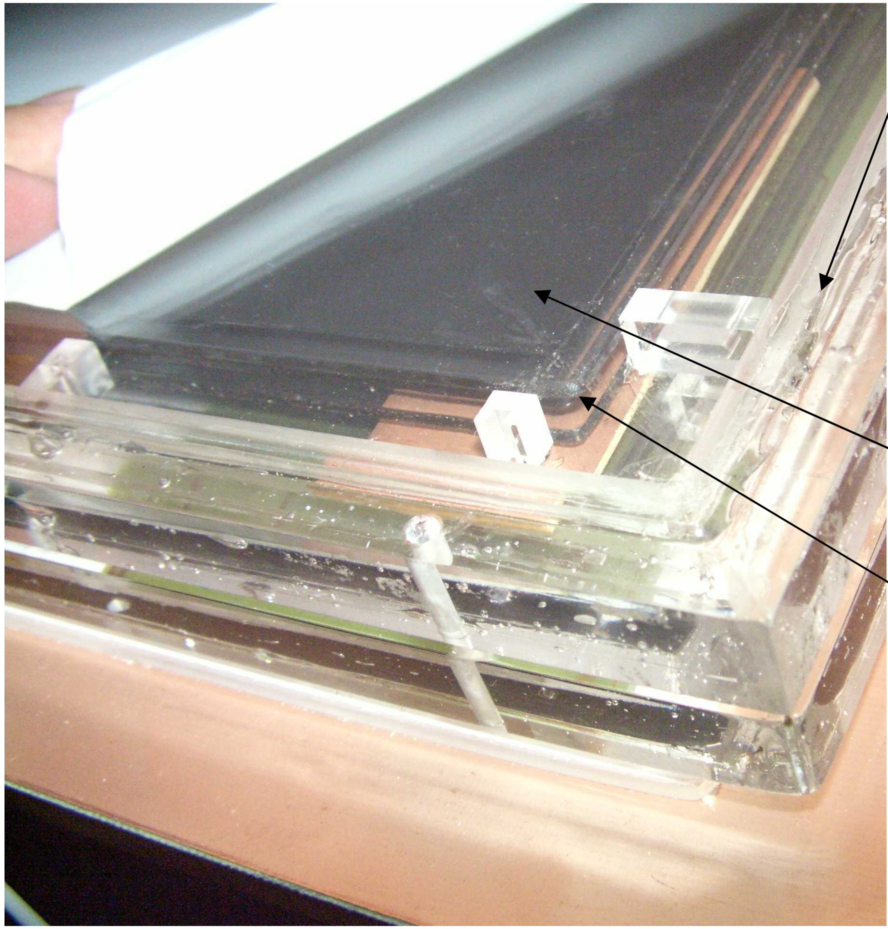
Main challenges:

- Very low gas flow operation
- Resilience to humidity

# Choices, choices…

| | |
|---|---|
| Electrodes | 2 mm soda-lime glass |
| Gap thickness | 2 x 1 mm gaps, "multigap" construction |
| HV, signal-transparent layer | Controlled-resistivity acrylic paint |
| Gas tightness, HV insulation | Acrylic box, permanently glued |
| Mono-component gas mixture | R-134a (tetrafluorethane) |
| Gas flow rate | 1 cc/min, equivalent to 1 kg/year |
| Signal pick-up electrodes | 8x8 pad matrix, with 180x140 $mm^2$ |
| Electromagnetic shielding and structural case | Aluminium box |

# Construction details



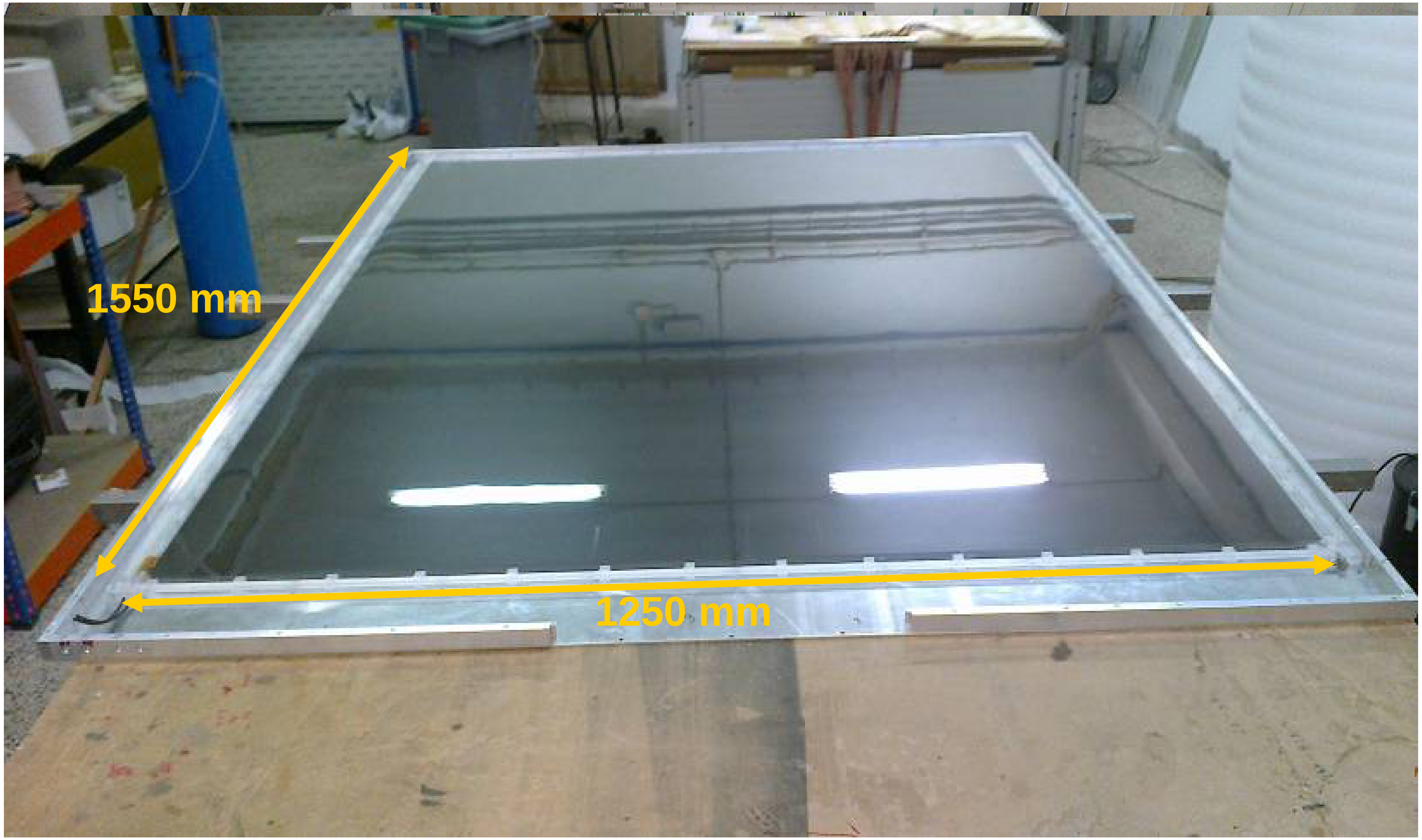
- Signal-transparent and nice looking acrylic box, 1mm thick covers
- Permanently glued
- RPC fits tightly inside
  - ✓ good electrode support mechanics
  - ✓ excellent HV insulation
  - ✓ excellent gas tightness

HV layer, also signal-transparent

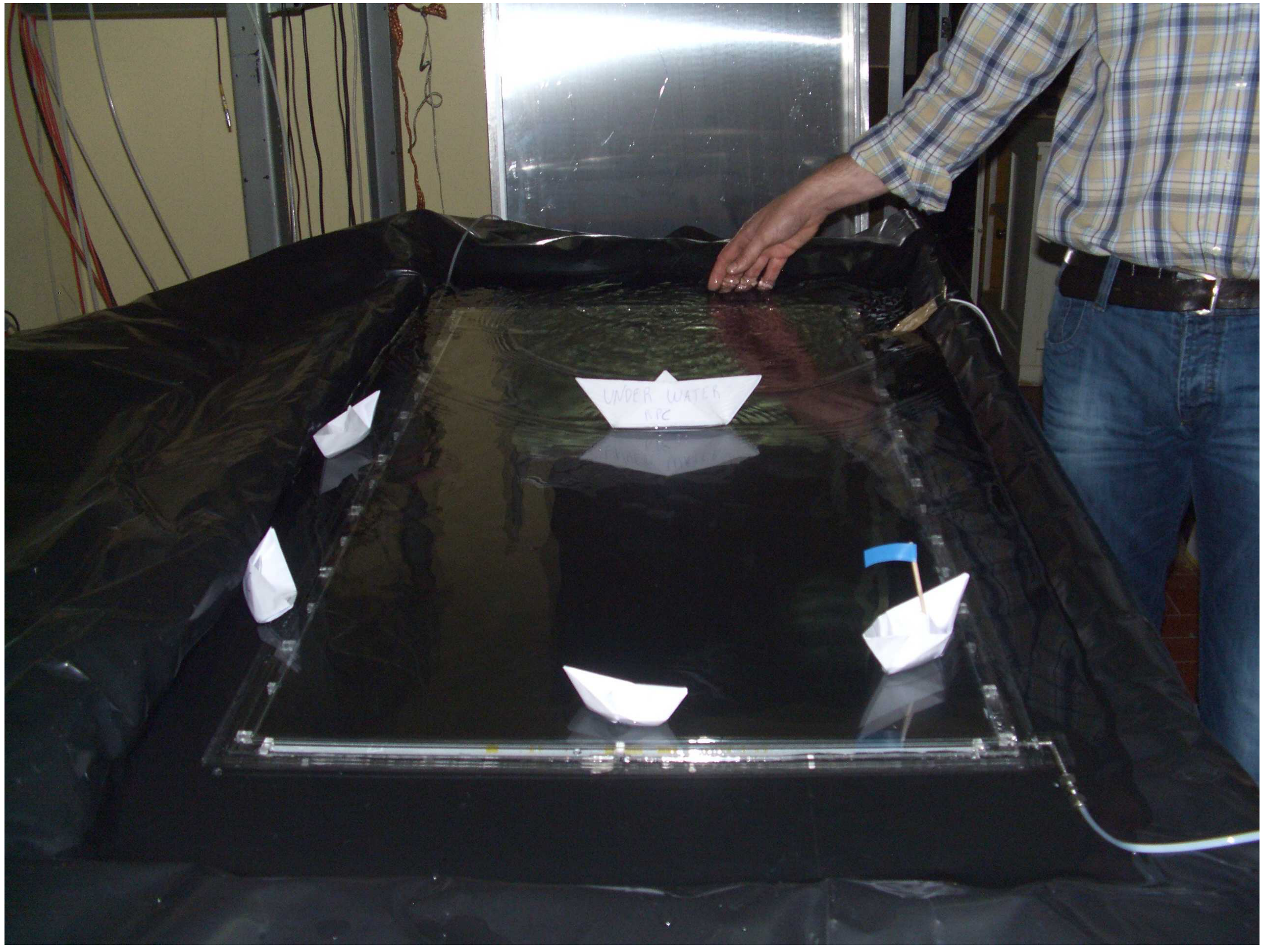
3 RPC glasses (2mm soda-lime)

External pickup electrodes (only HV and gas feedthroughs)

# RPC & gas volume

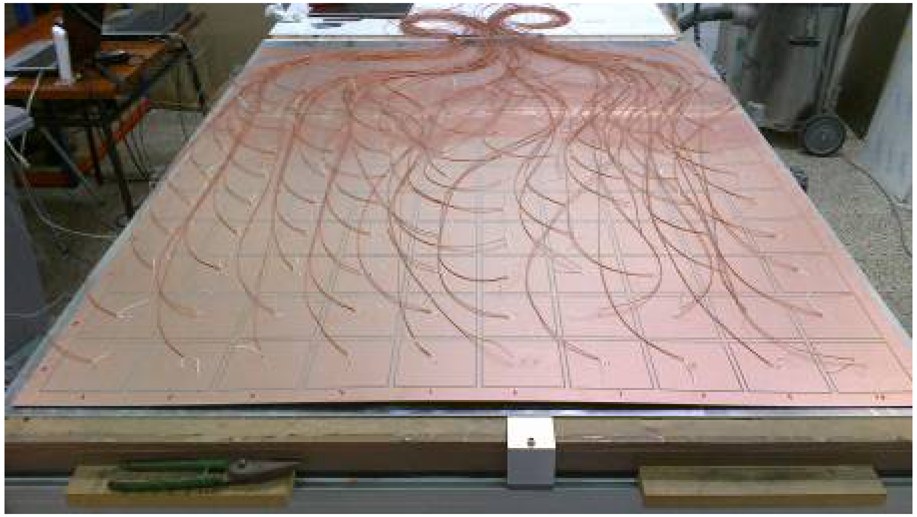


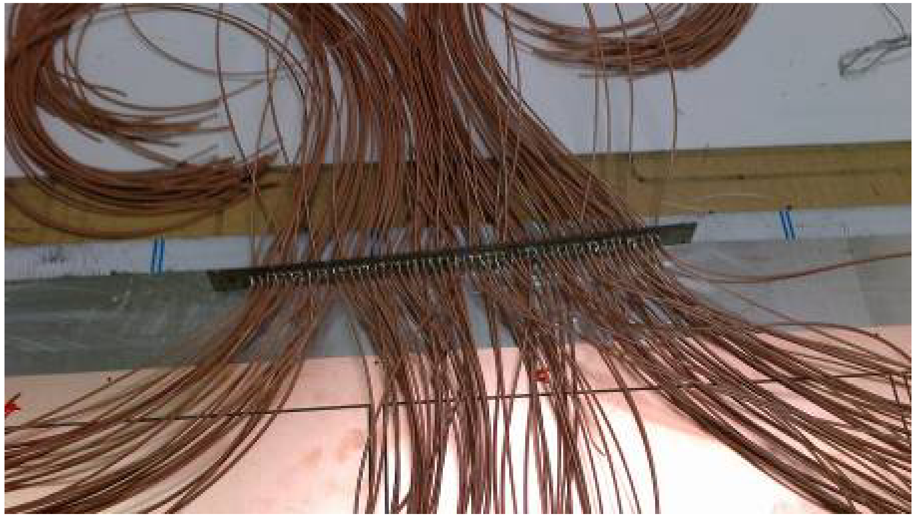
# Humidity resilience test



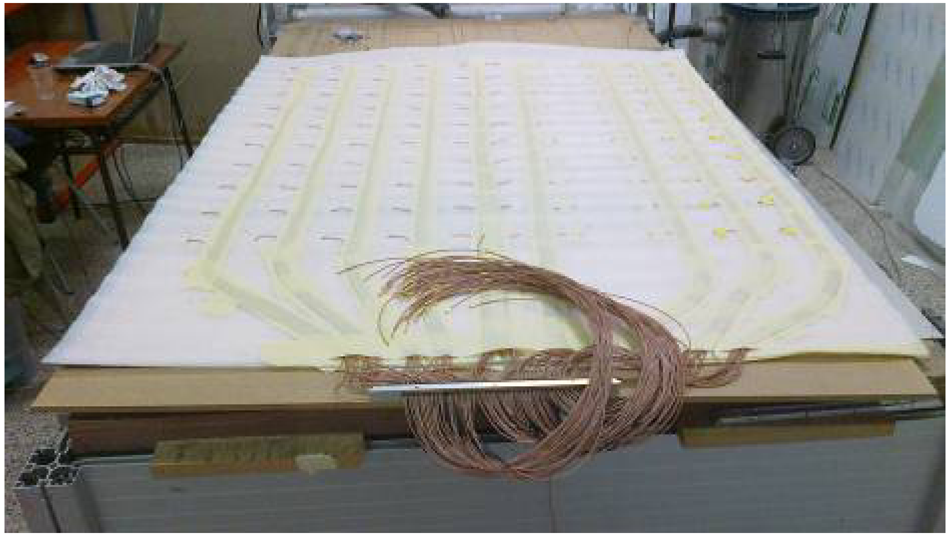
The chamber was actually on for 15 days!

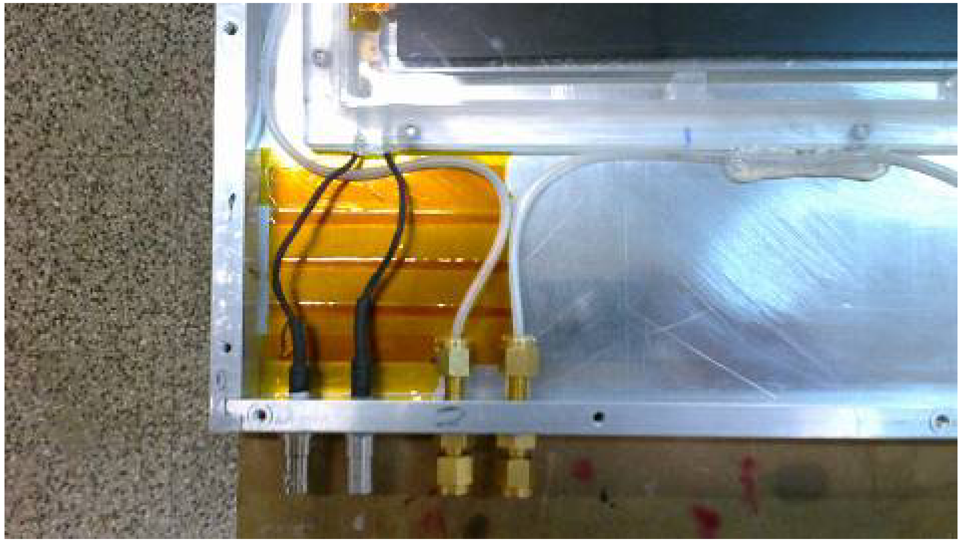
# Readout: 64 external pads (or something else)

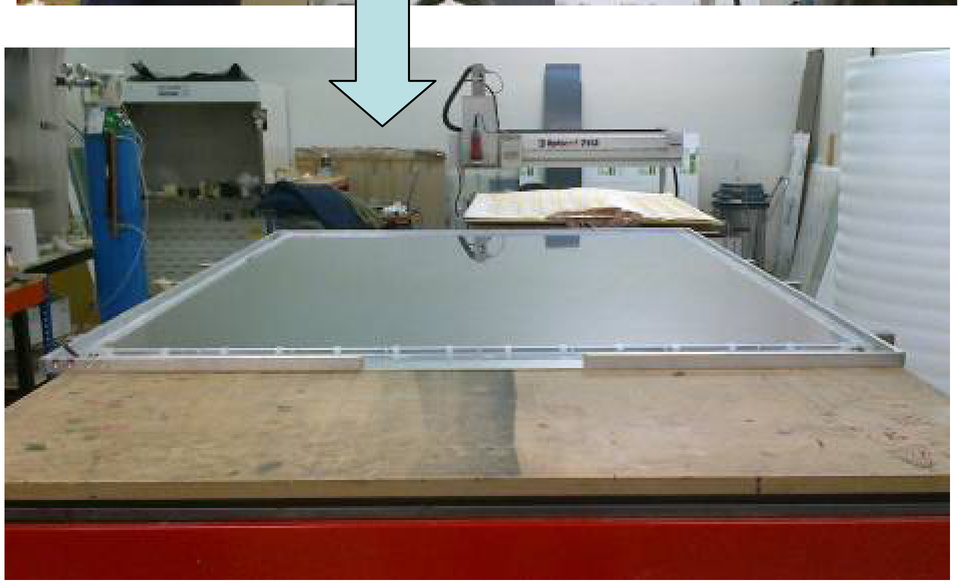





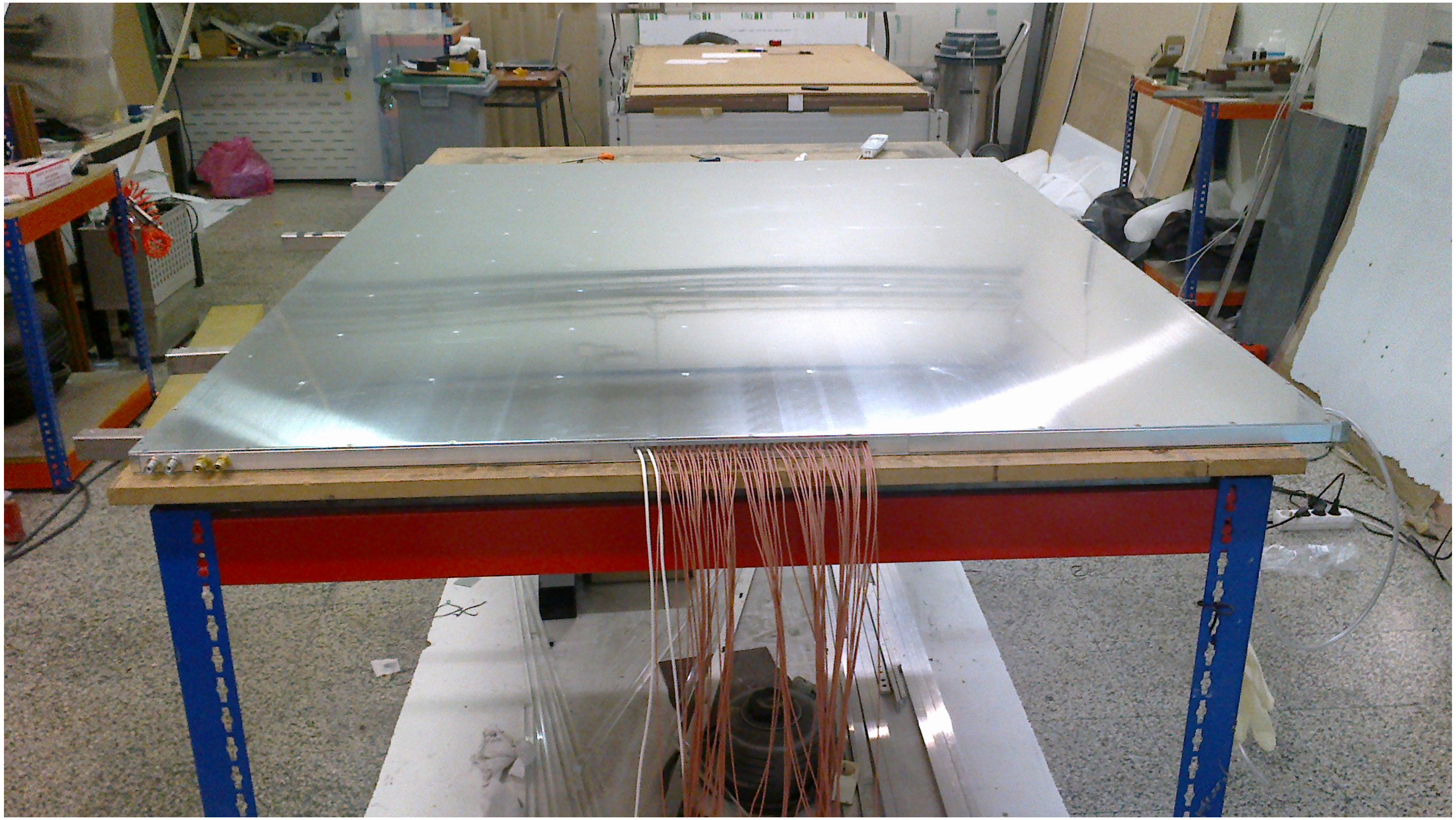
# Assembly





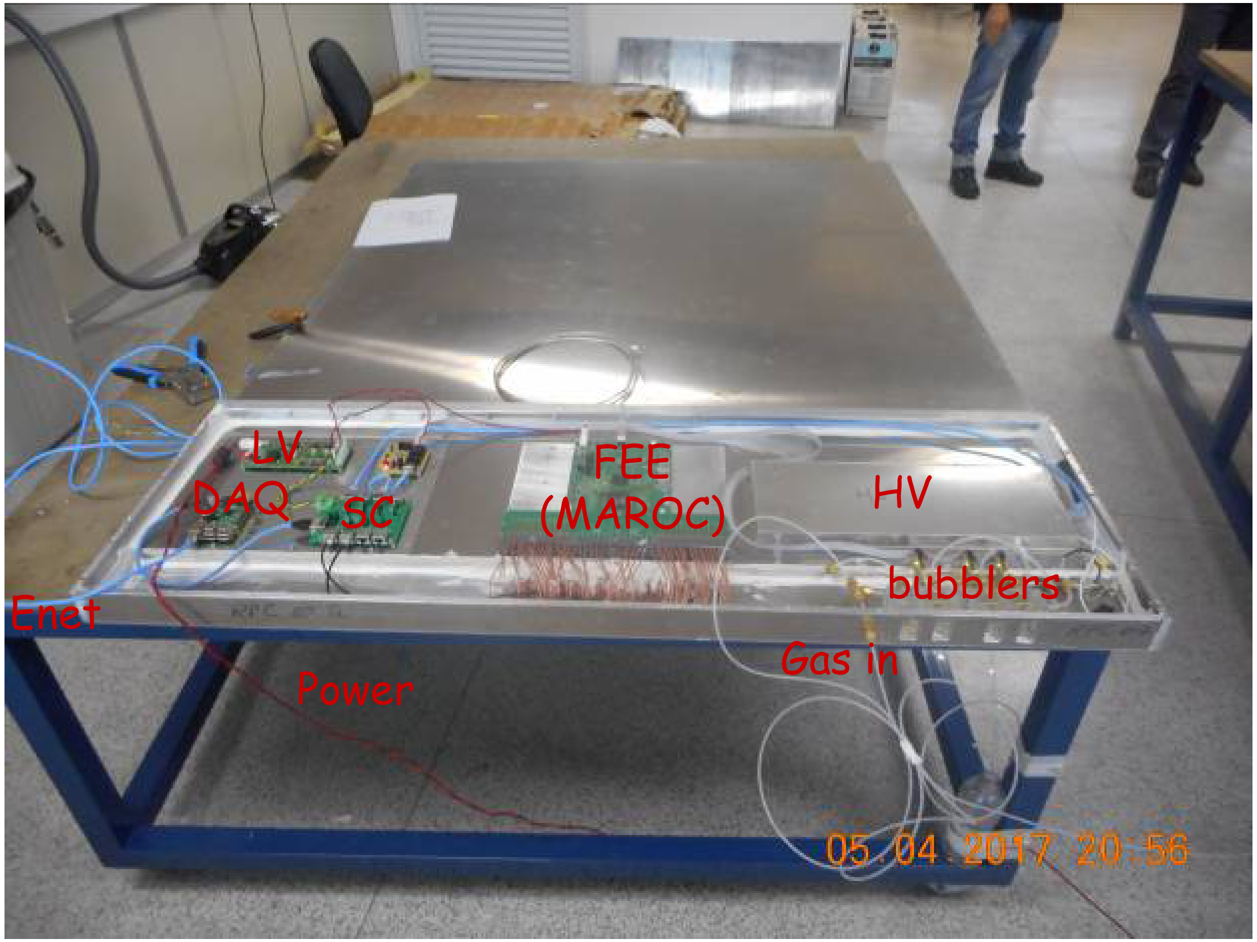


# Assembled



- Totally flat: no protrusions
- The Al box is also glued with silicon (not permanently) and the exhaust gas is reinjected into this volume to minimize humidity intake.

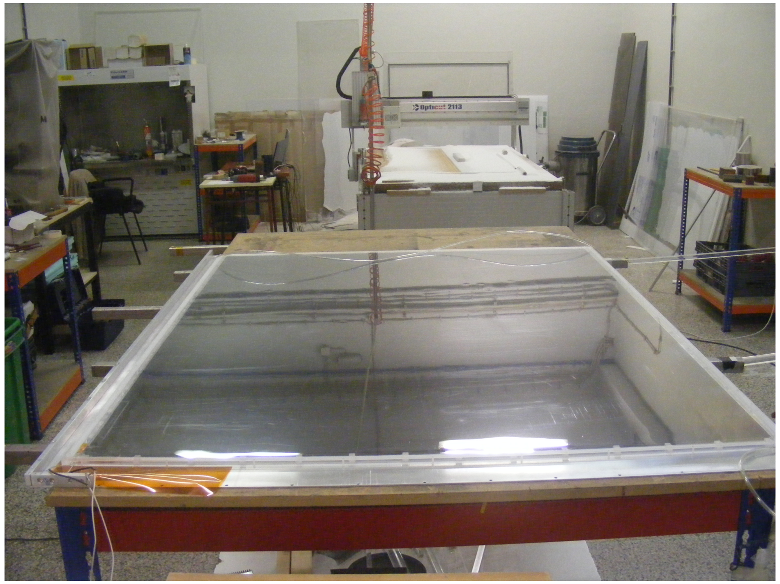
# An integrated detection system

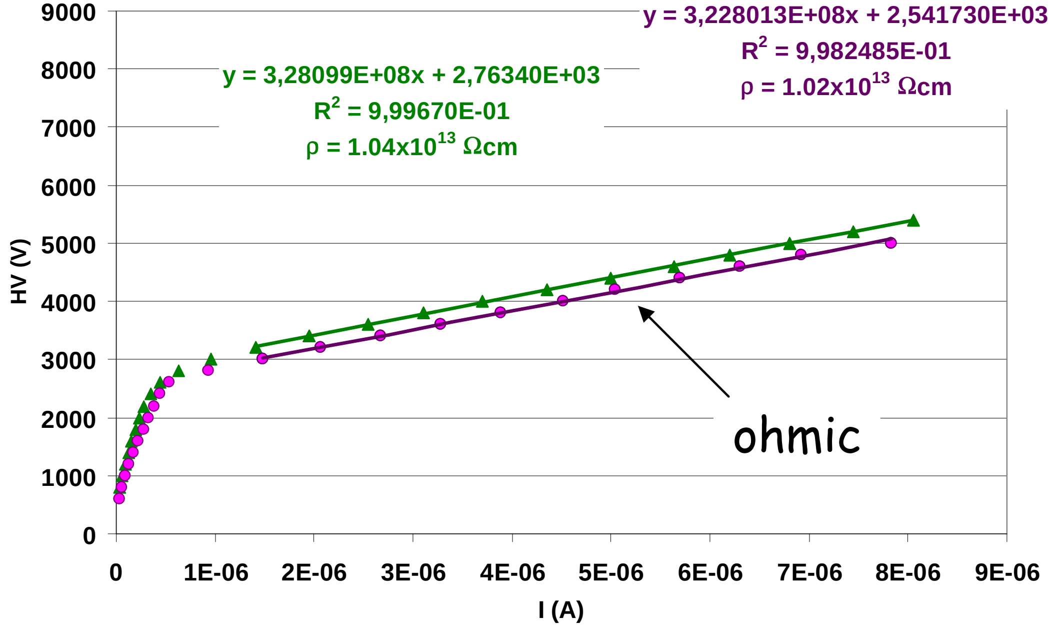



Assembled in São Paulo, Brasil for the engineering array

- The whole electronics is now housed in a second, integrated, compartment.
- In the future it may be as thick as the detector itself and in the same plane (no protrusions)

# On every chamber: argon discharge test



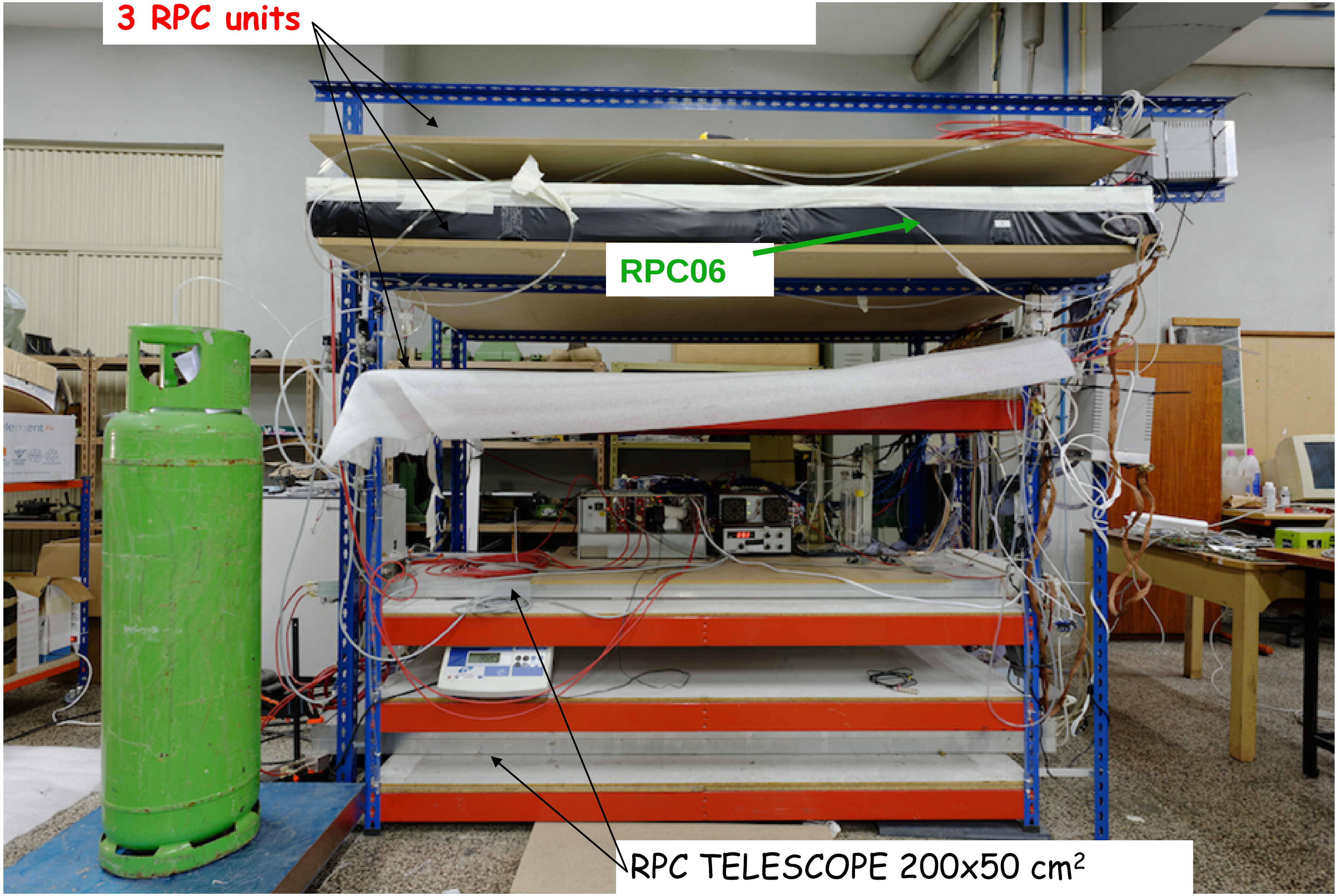



$$\begin{cases}\dfrac{1}{R_{eq}} = \dfrac{150\times120}{R_{cm^2}} \\ \rho = R_{cm^2}\dfrac{A}{l}\end{cases} \Leftrightarrow \rho = 18000\times\frac{R_{cm^2}}{3\times l}, [\Omega cm]$$

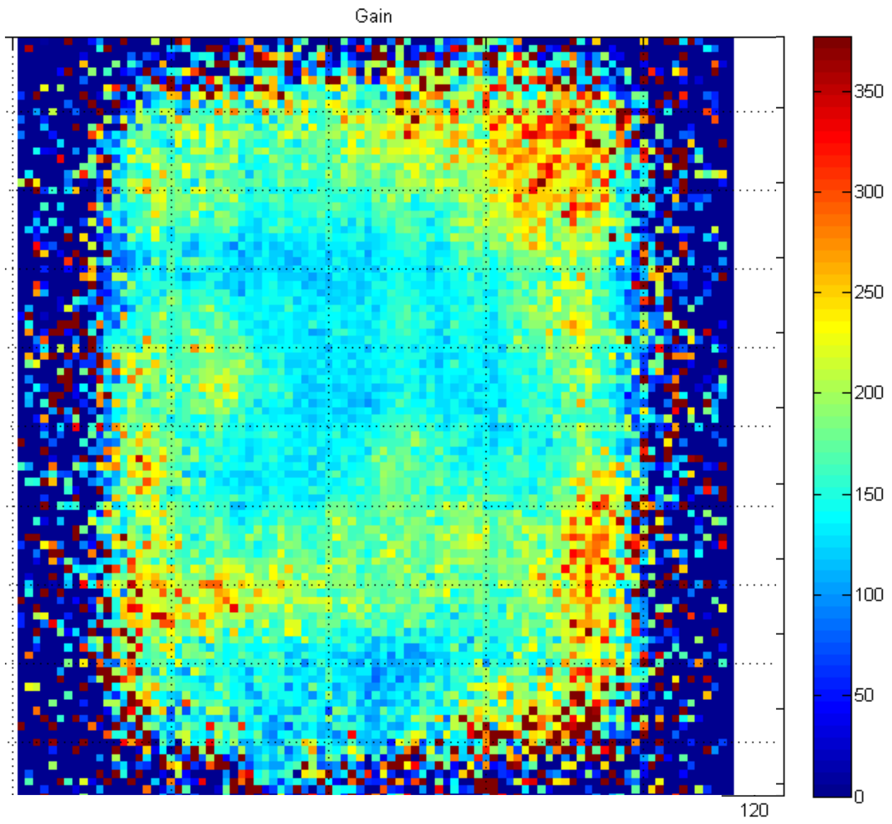
**3 glass electrodes**

**Check/do:**
- **gap uniformity**
- **glass electrodes resistivity**
- **miscellaneous defects**
- **clean the gap (conditioning)**

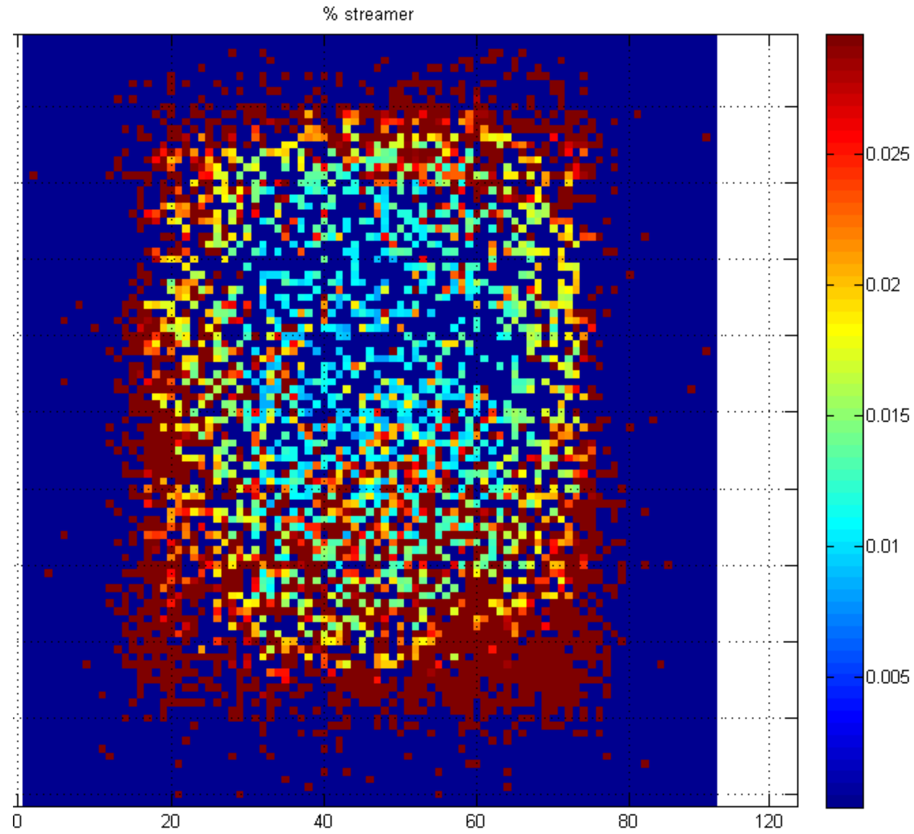
# Test setup @ Coimbra



# Typical measurements: full area charge and streamer fraction

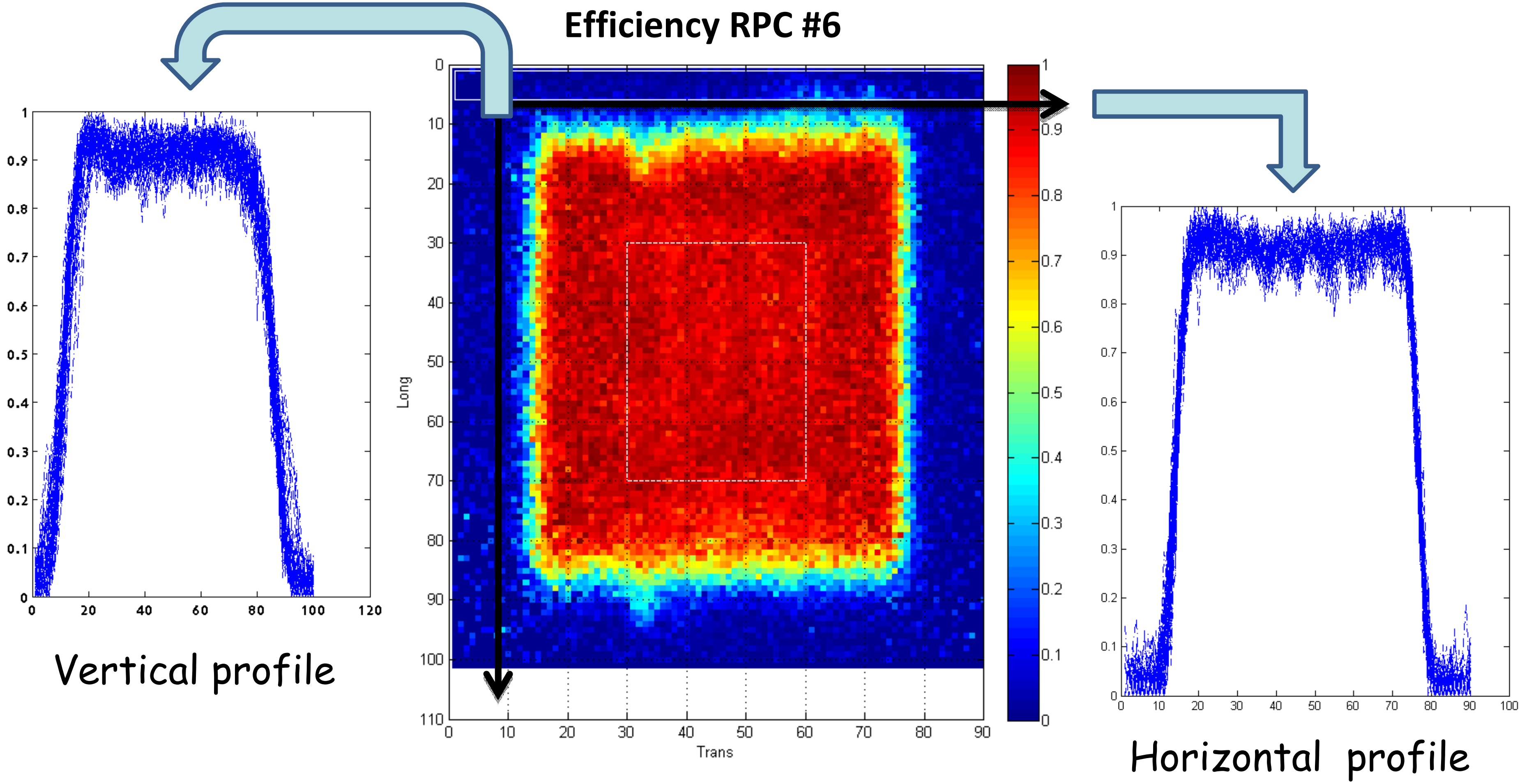



Average charge produced




Streamer fraction

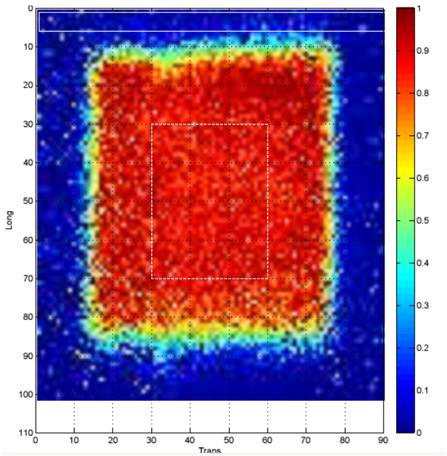
# Typical measurements: efficiency



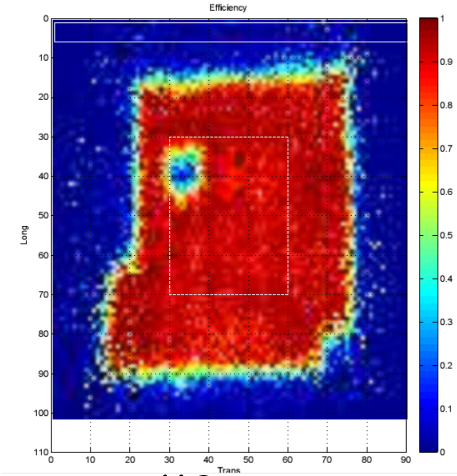

Homogenous efficiency on the entire area

Up to 92% including inefficient areas (guard ring) and intrinsic inefficiency of the setup

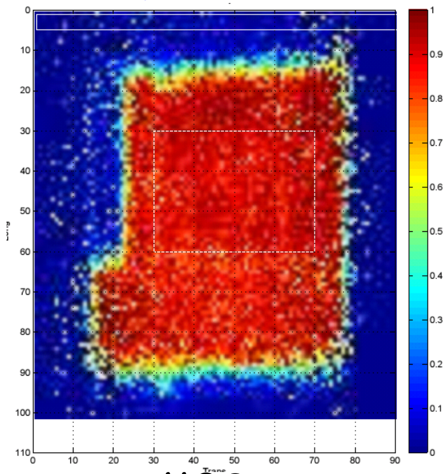
# Typical measurements: reproducibility



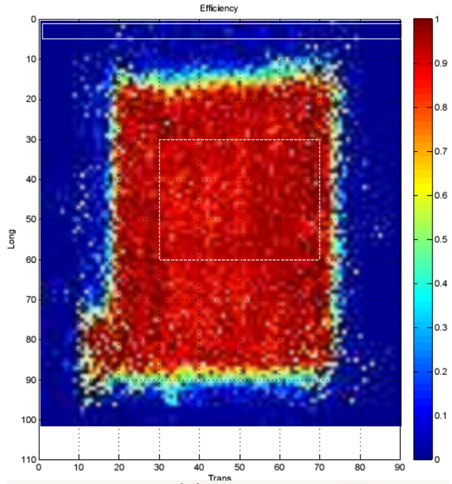
#06



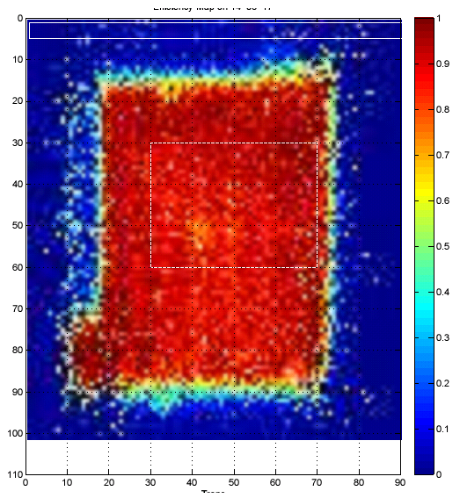
#07



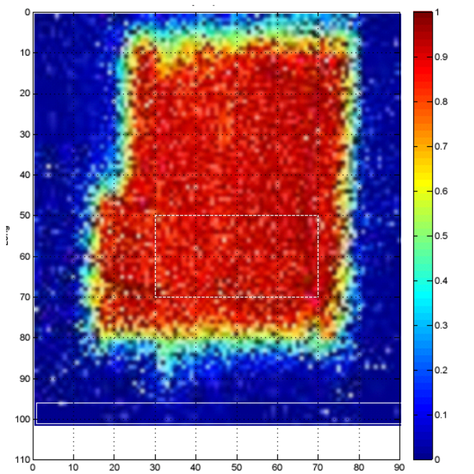
#08



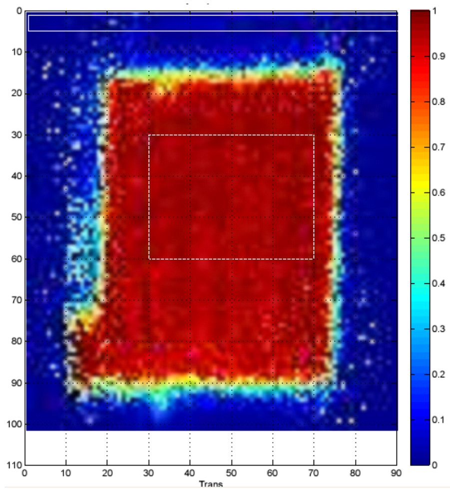
#09.



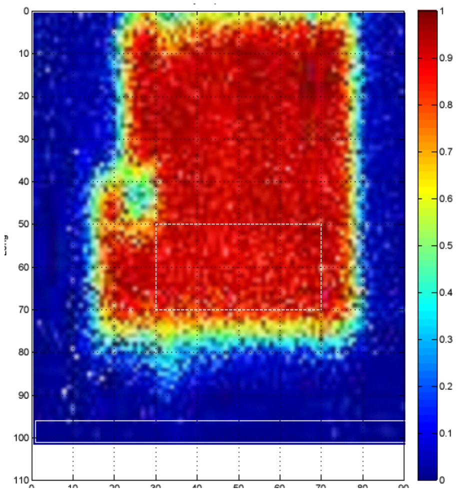
#10



#11



#12



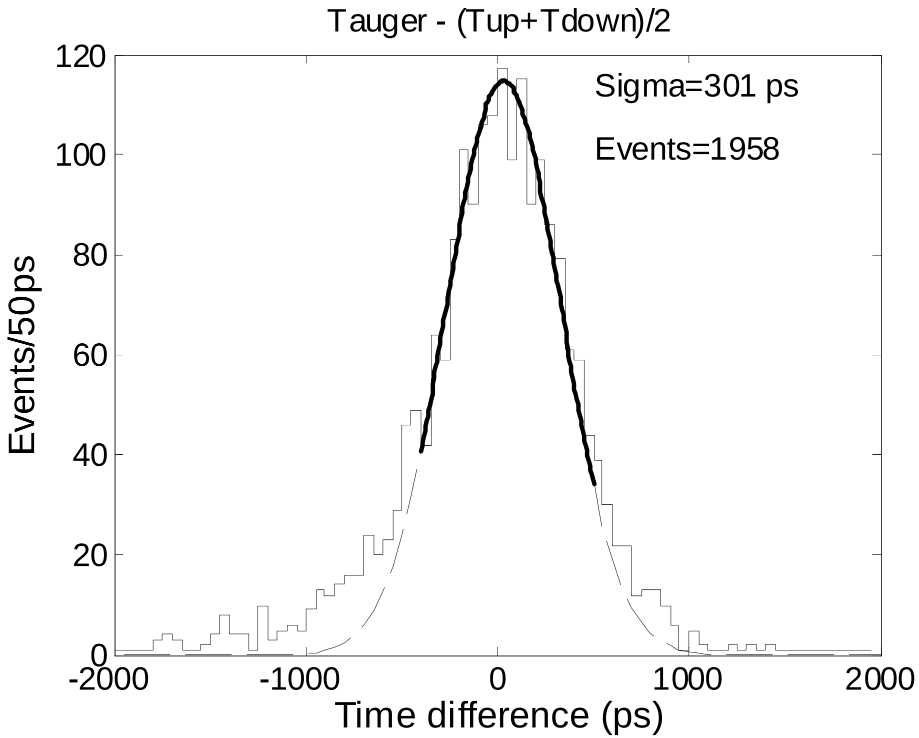
#13.

(Obtained not exactly in the same conditions)

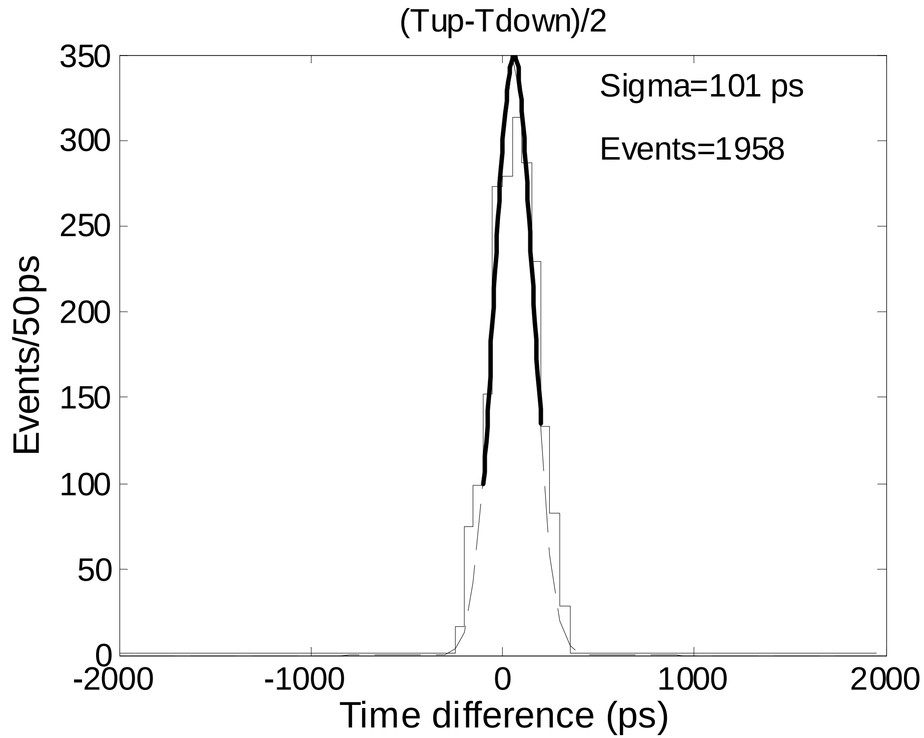
Over 100 RPC sensitive volumes were produced and successfully tested

# Typical measurements: time resolution

RPC-telescope



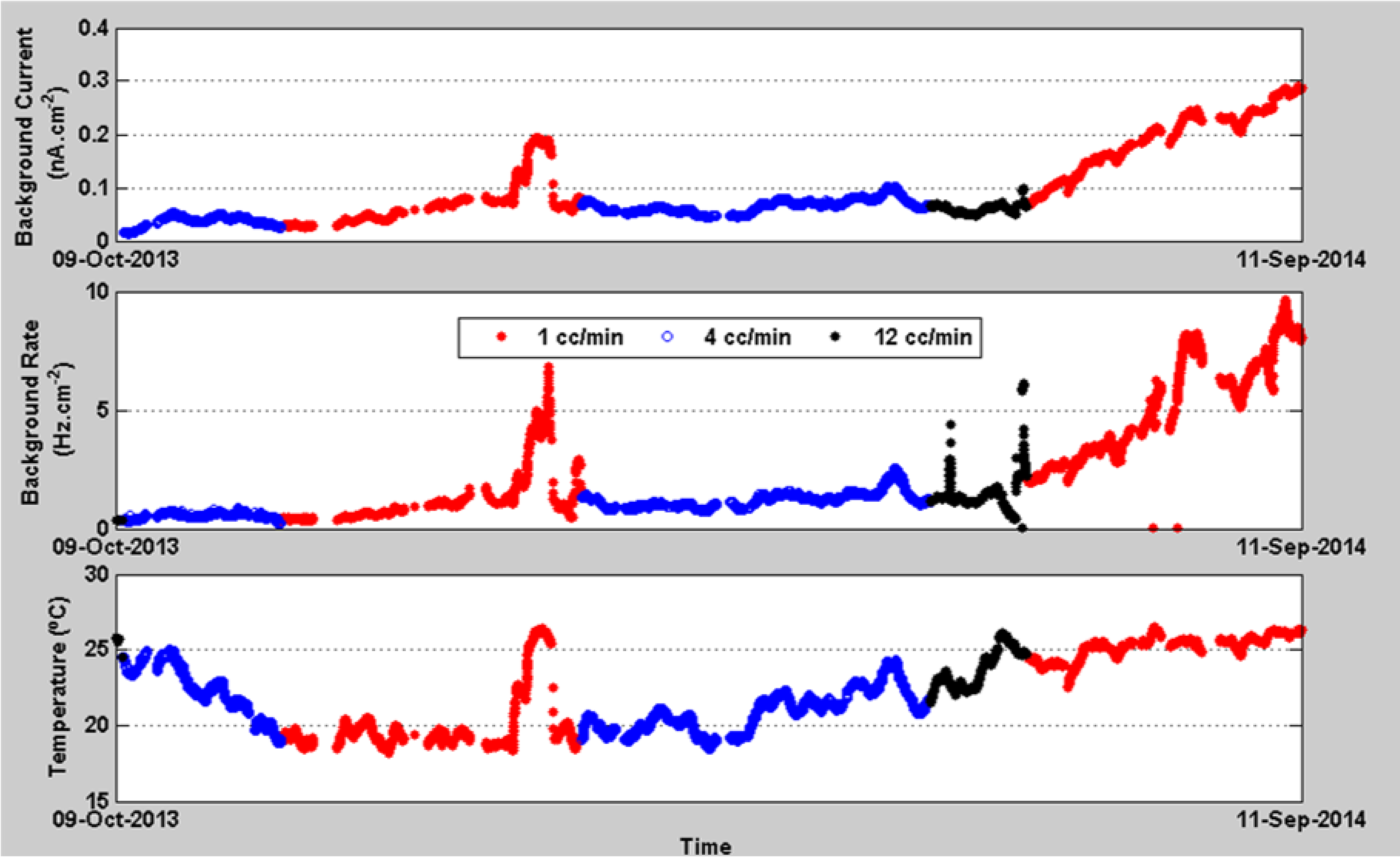

Telescope




$$\sigma_{auger} = \sqrt{301^2 - 101^2} = 283\text{ps}$$

Some dependencies (longitudinal position p, ex) remain uncorrected

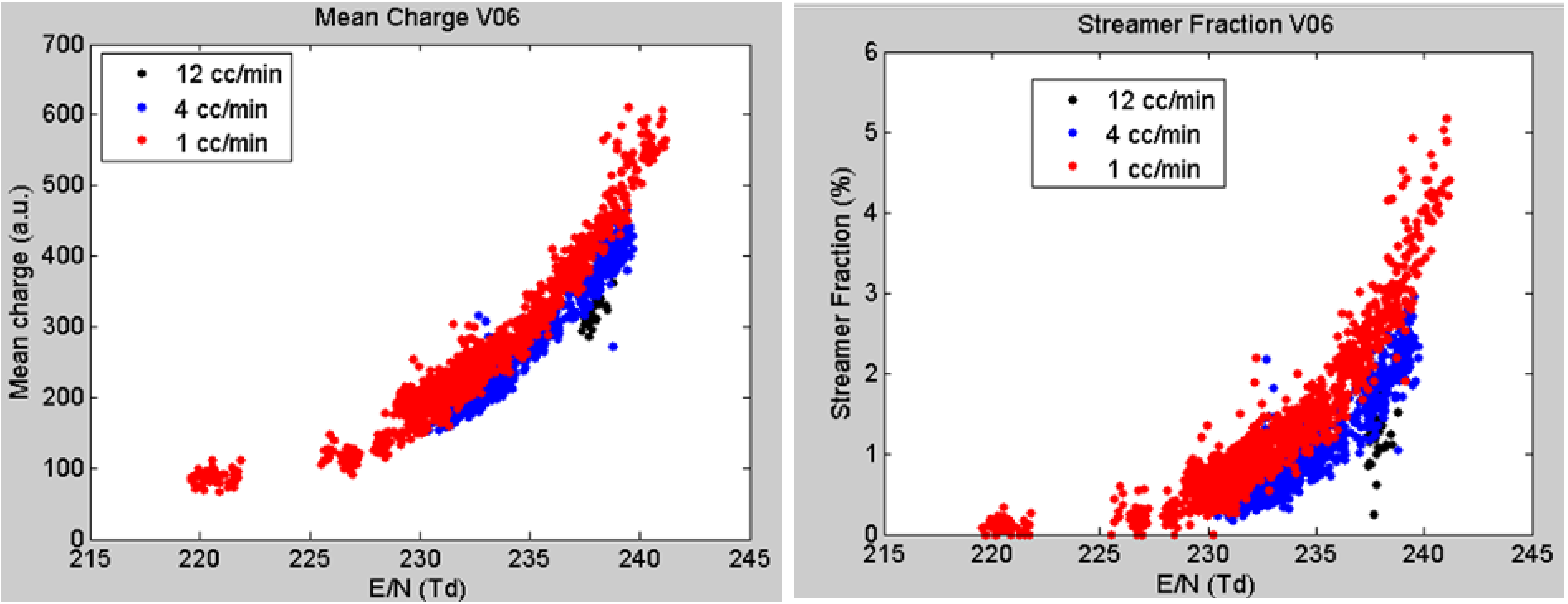
# Long term behavior at low gas flow (RPC06) - raw data




~1 year of data @ different gas flow rates

Currents, counting backgrounds strongly correlated with temperature

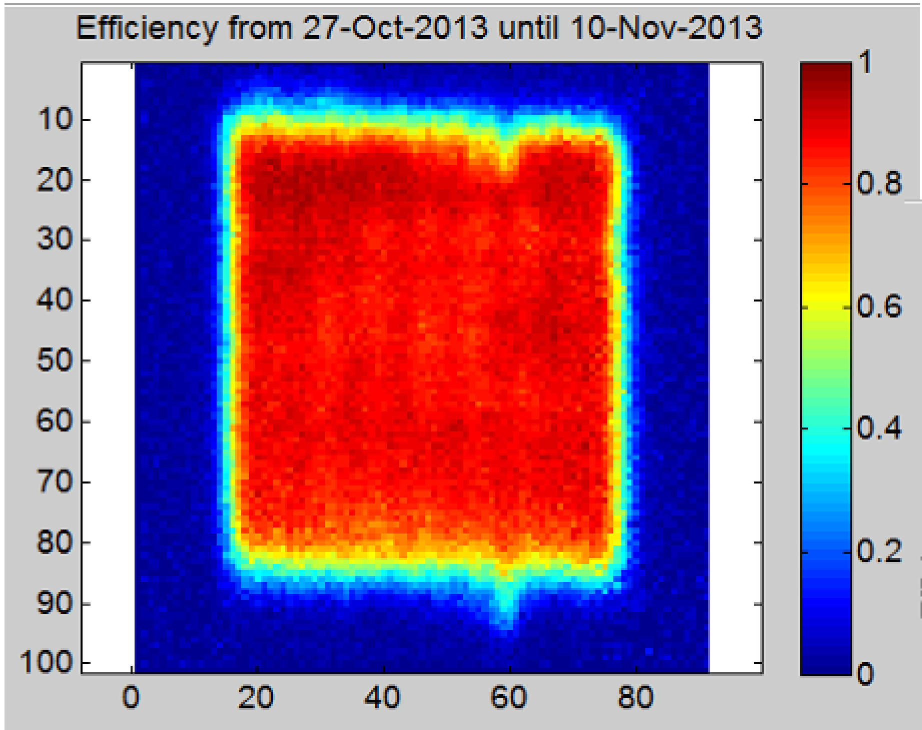
# Long term behavior at low gas flow (RPC06)



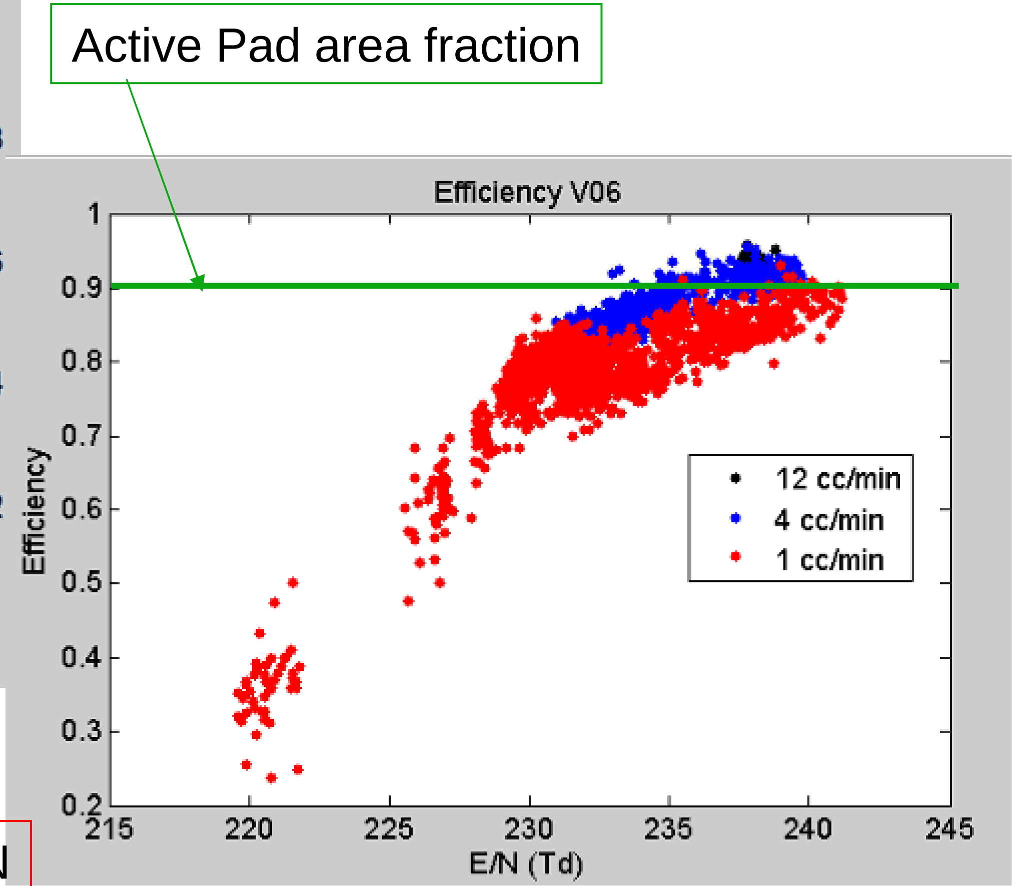

**Charge and Streamer Fraction well correlated with E/N**

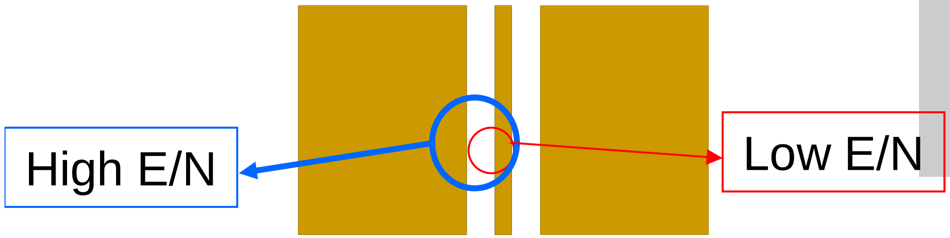
E/N = electric field in the gas/gas density

# Long term behavior at low gas flow (RPC06)




**Efficiency well correlated with E/N**

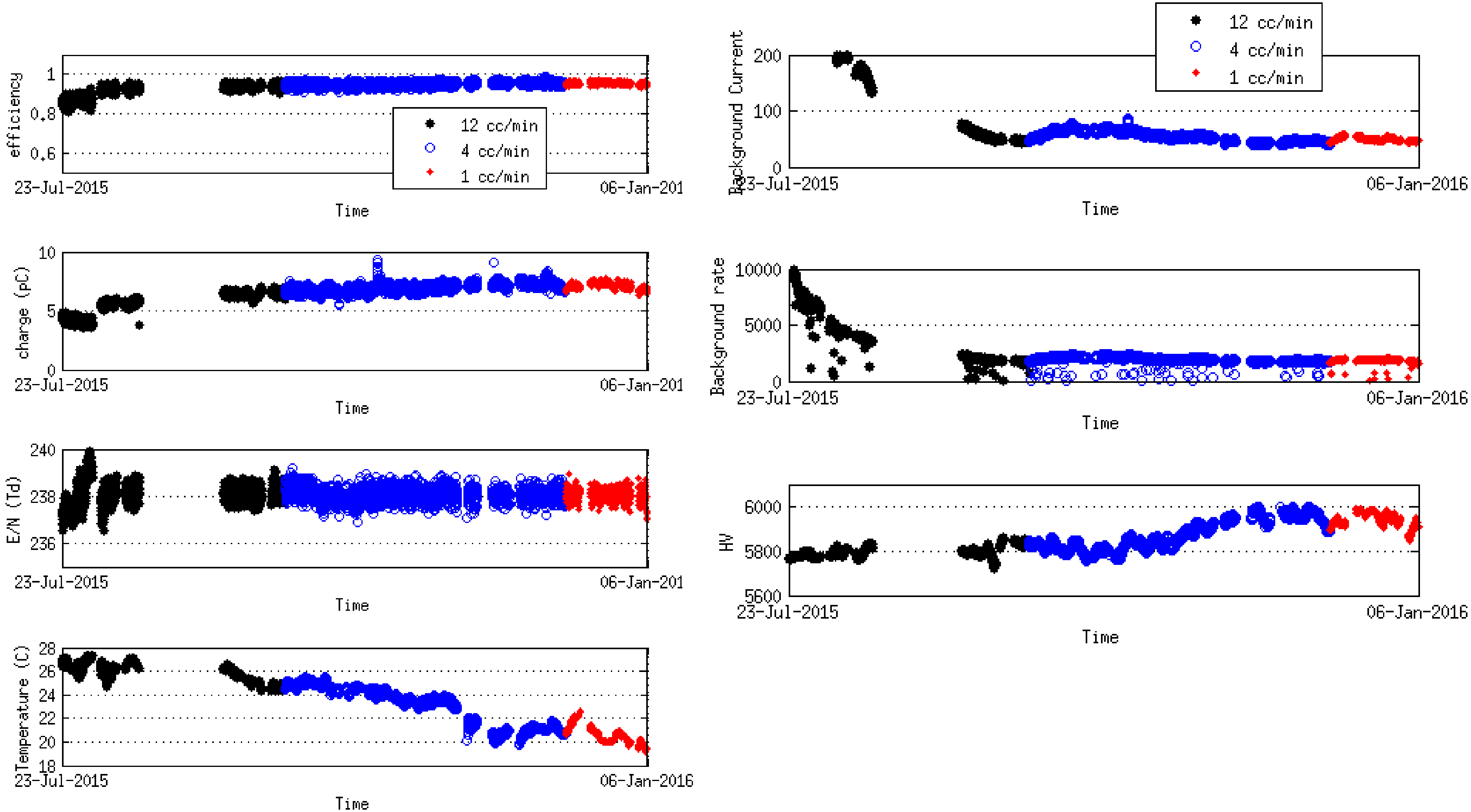



Increasing E/N we will decrease the effect of the guard rings in the efficiency. Once the area with “visible” charge per event will increase, becoming visible in the neighbor pads.

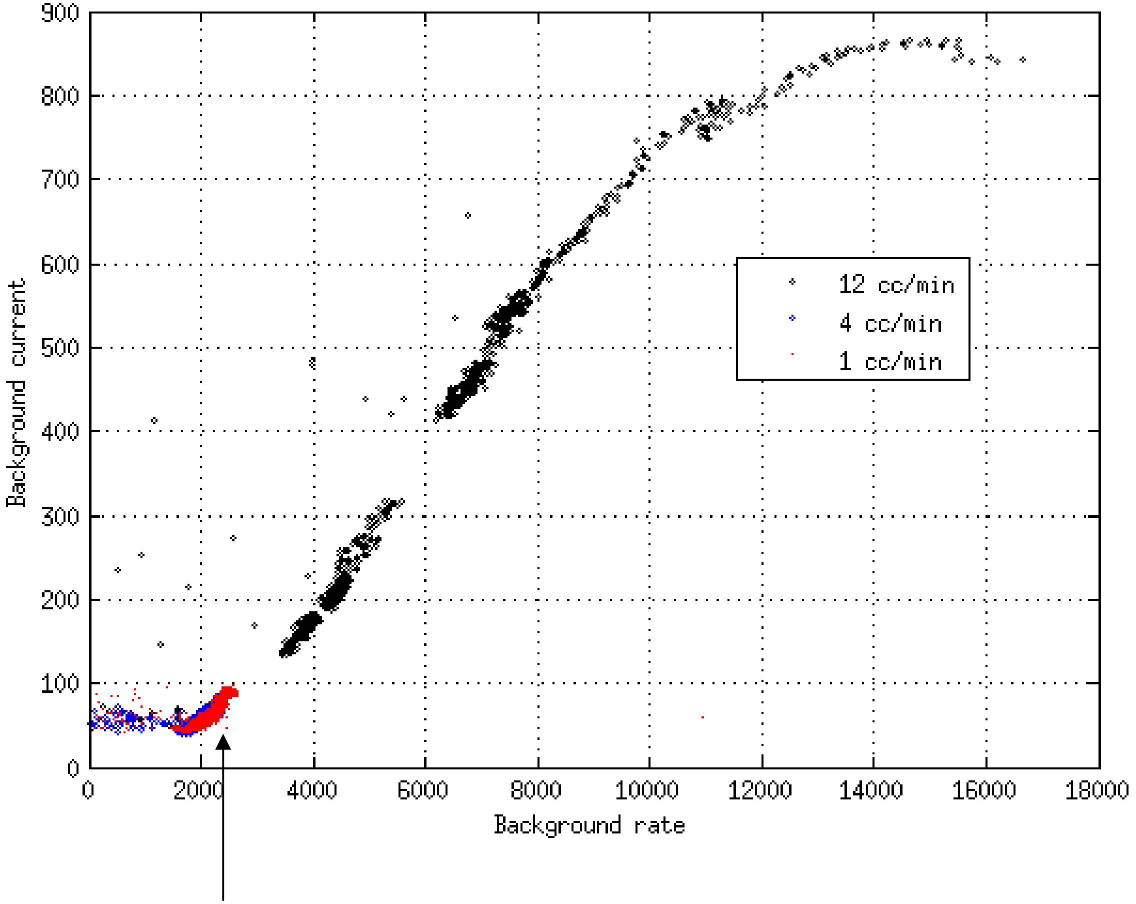
# Long term behavior at low gas flow (RPC23) @ E/N=cte

5 months of data @ different gas flow rates, E/N stabilization 19°C<T<28°C
performance STABLE down to 1cc/min



# Long term behavior at low gas flow (RPC23) @ E/N=cte

Conditioning process



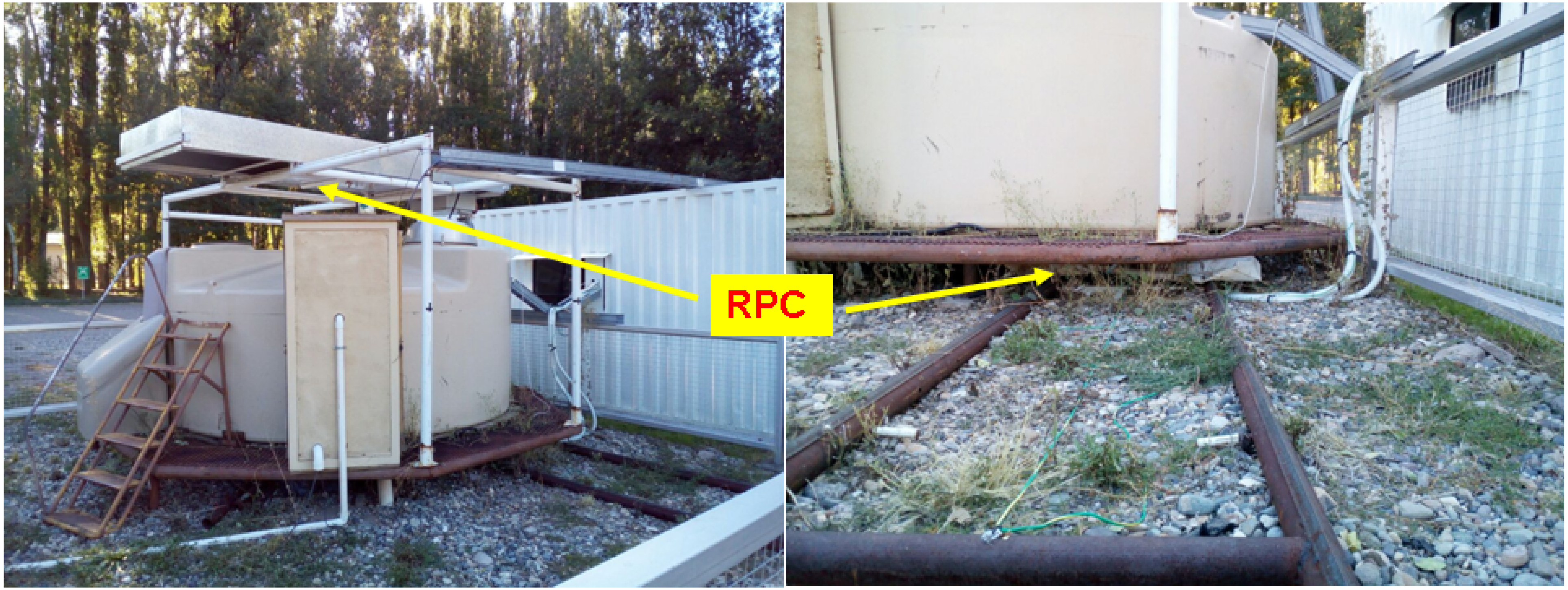

Final background rate 2-3kHz/detector (1.8m2)

# Field experience@Malargüe – "Gianni Navarra" tank

A hodoscope formed by two stand-alone low gas flow RPCs with the water Cherenkov detector placed in between. The hodoscope is used to trigger and select single muon events in different geometries. The objective is to study the tank response to single muons.

One chamber @ the top of the tank and other beneath the tank.

# Field experience@Malargüe – "Gianni Navarra" tank




## Really harsh conditions

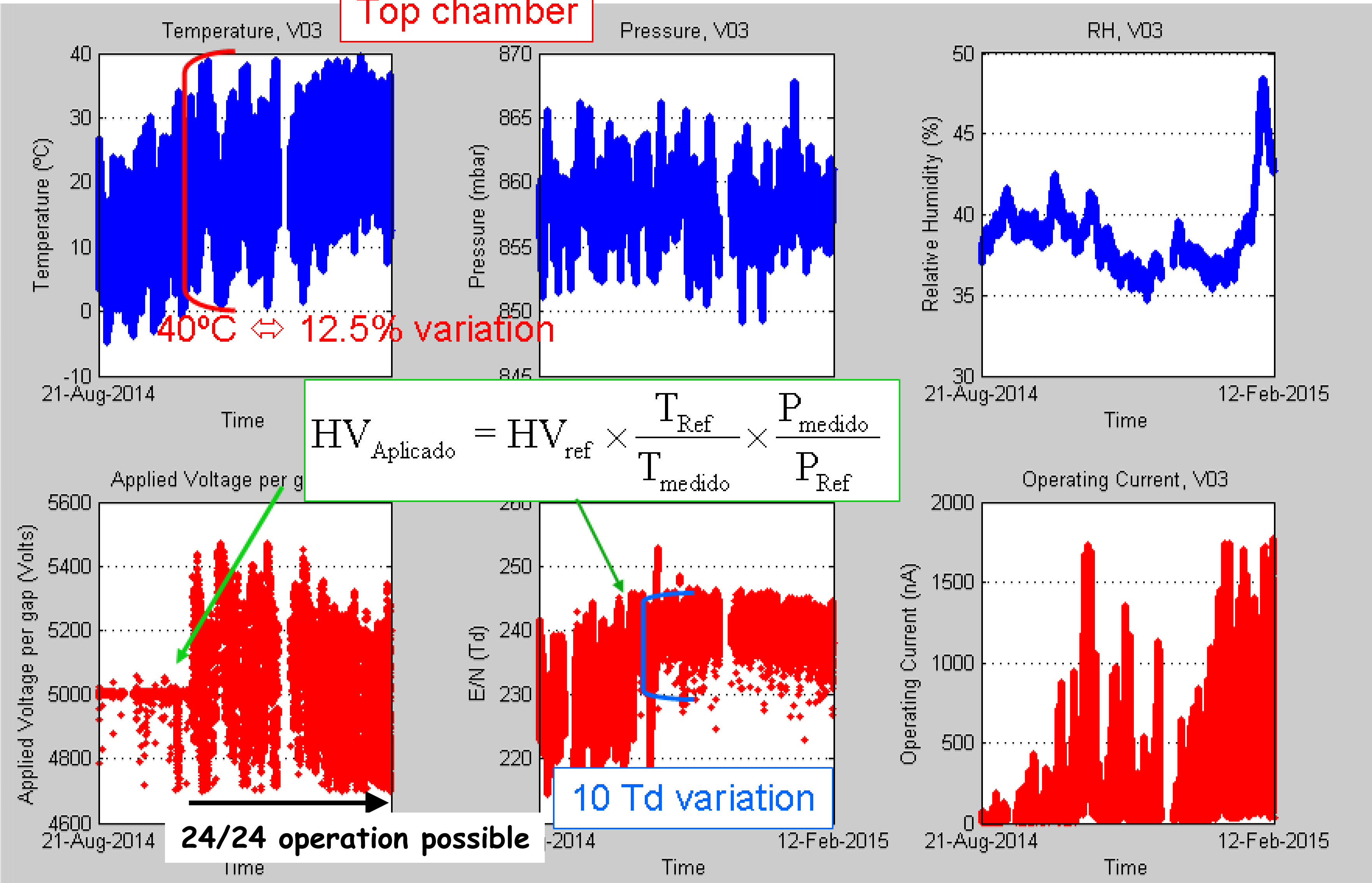
Top detector subject to all environmental variations. Only a small roof avoiding direct Sunlight. This way daily temperature excursions will be very large, so this setup should be a reliable test concerning the robustness of the RPC to operate outdoor.

The bottom detector is in a less aggressive situation since it is protected by the tank and also very close to the ground, so daily temperature excursions should be smaller.

# Field experience@Malargüe – "Gianni Navarra" tank

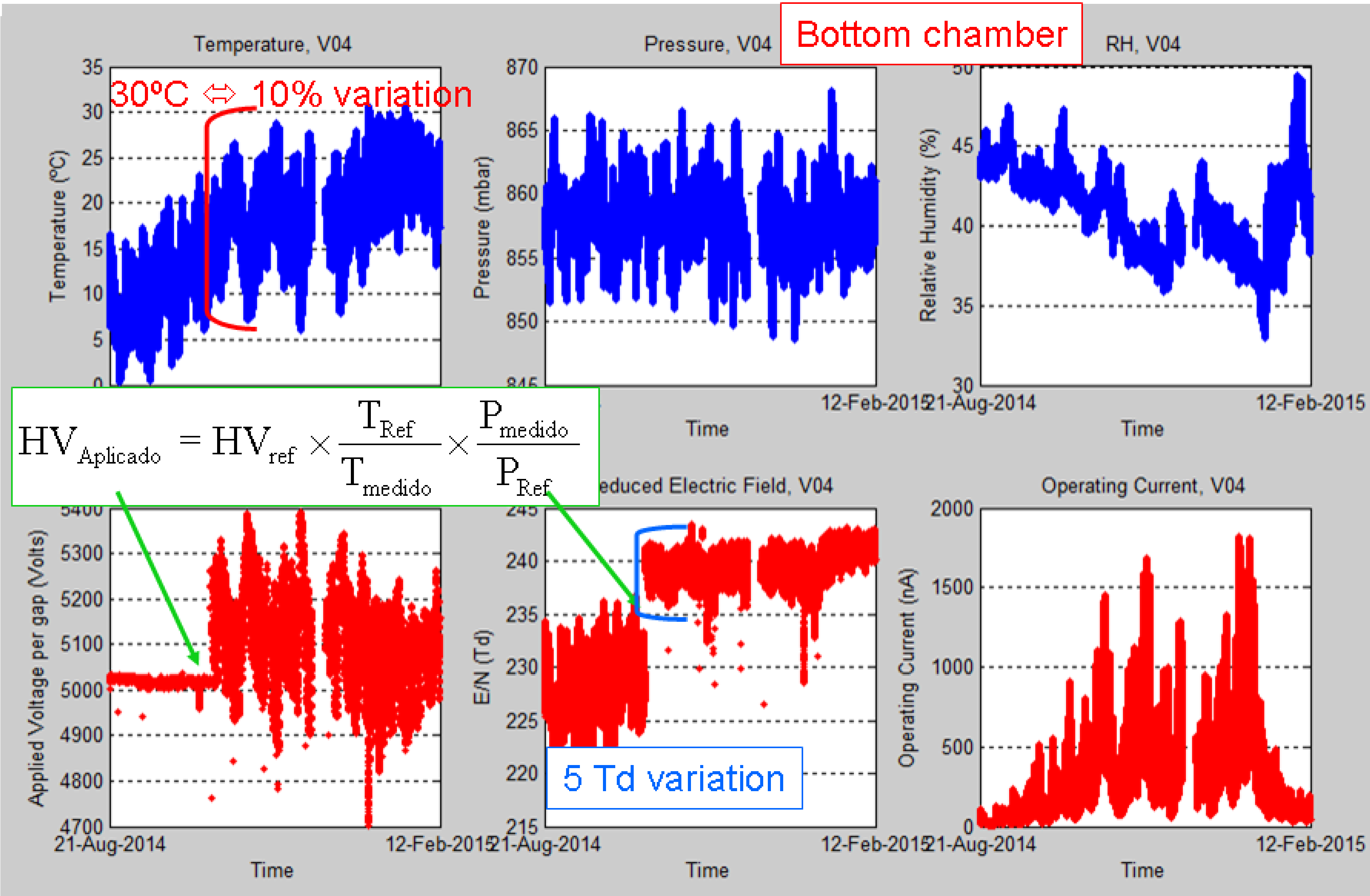
Extreme daily temperature excursions!

Exceeds operational limits at constant voltage



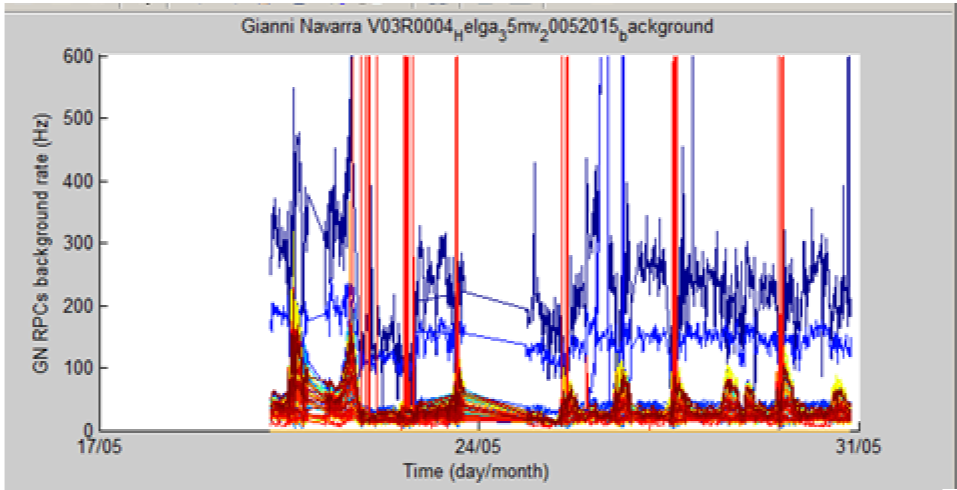

$$HV_{Aplicado} = HV_{ref} \times \frac{T_{Ref}}{T_{medido}} \times \frac{P_{medido}}{P_{Ref}}$$

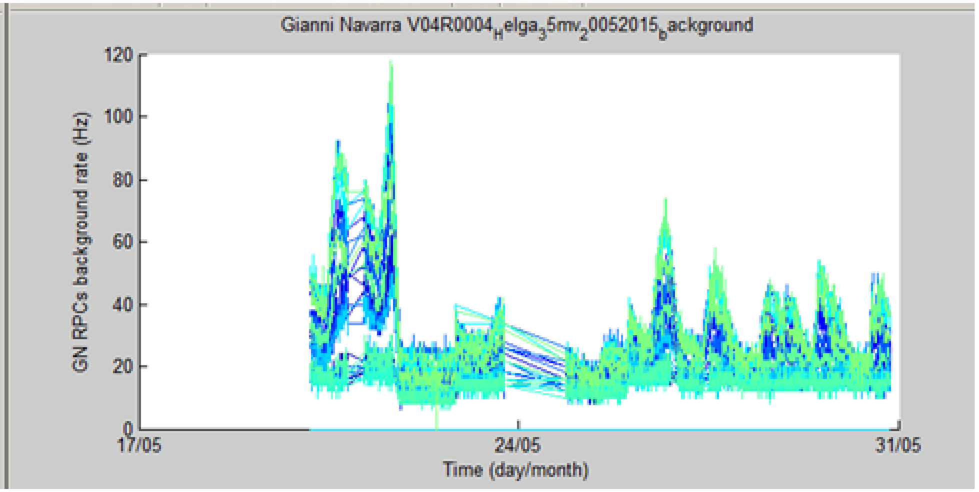
# Field experience@Malargüe – “Gianni Navarra” tank

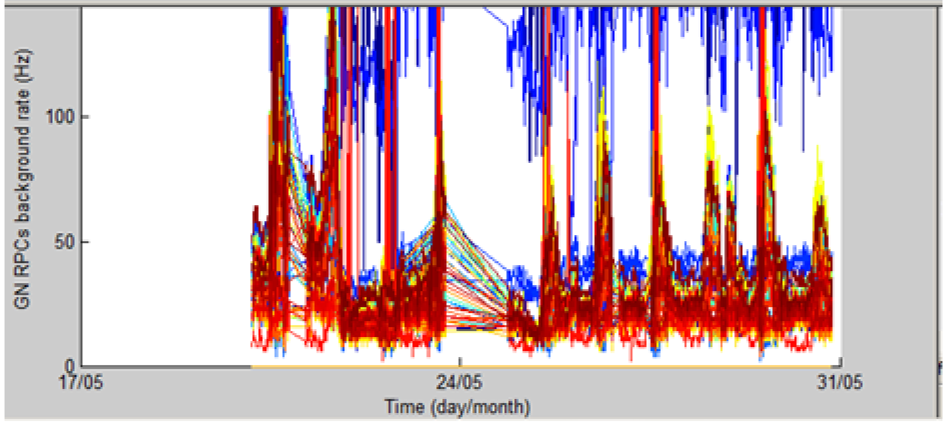


# Field experience@Malargüe – "Gianni Navarra" tank

**Background rates**




Only a couple of pads with more 100 Hz ($0.4\ Hzcm^{-2}$). Which is a very good value.

Correlated with temperature even at a "constant" E/N. Higher temperature, higher background rate.

Data from May 2017, PREC electronics

# Field experience@Malargüe – “Gianni Navarra” tank

PROCEEDINGS OF SCIENCE

## Measurement of the water-Cherenkov detector response to inclined muons using an RPC hodoscope

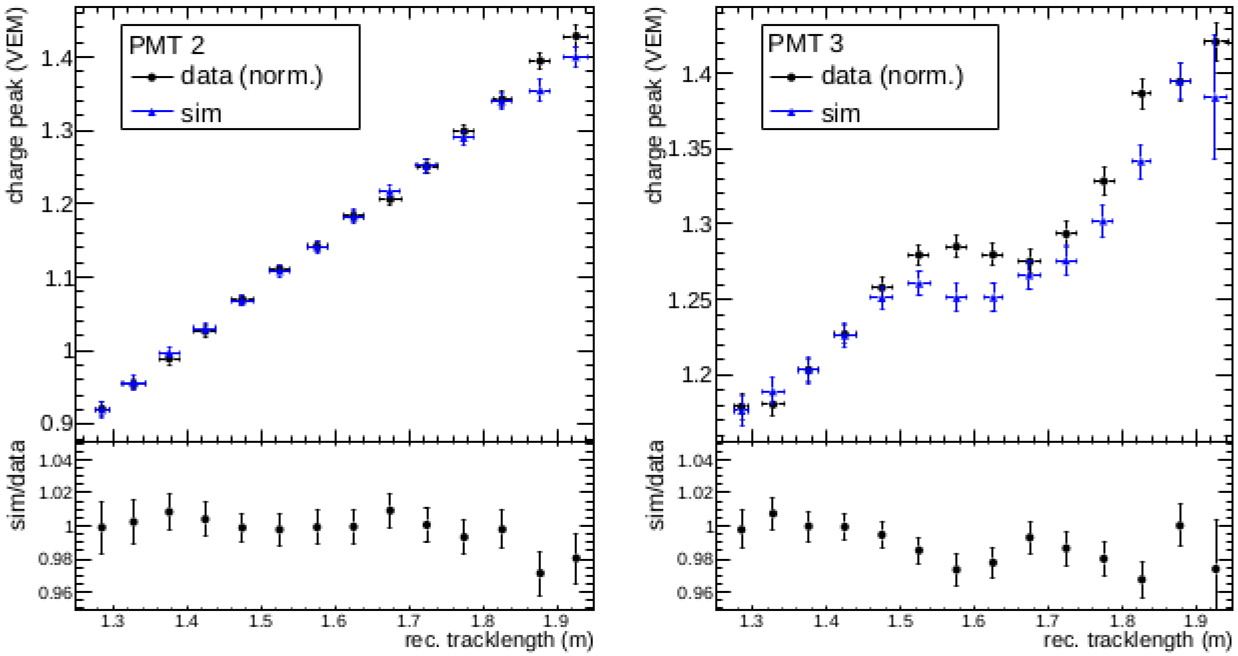
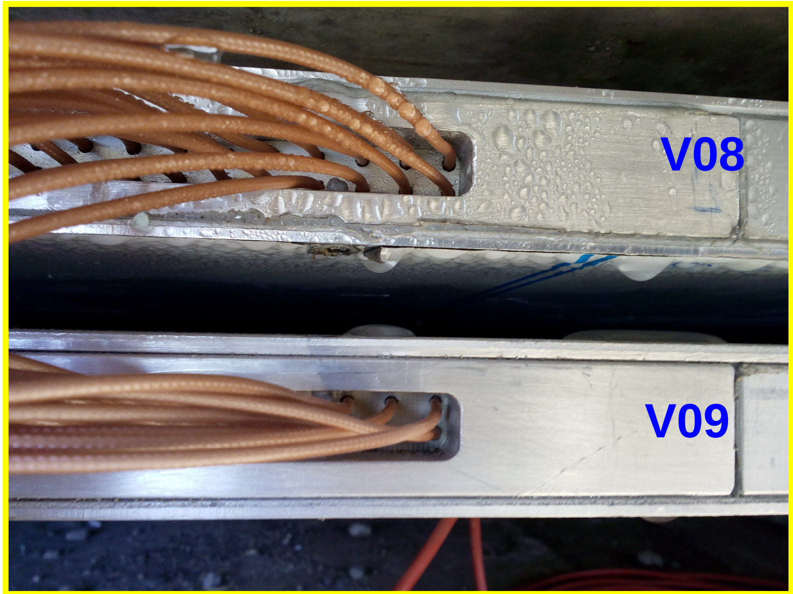
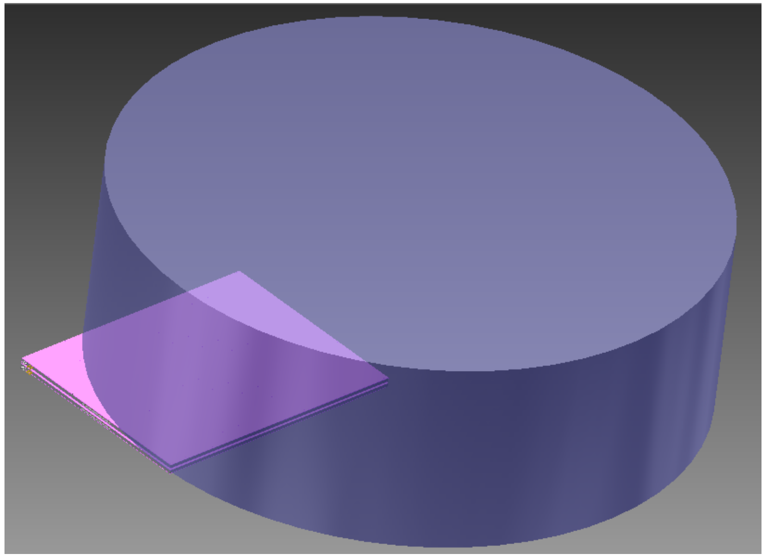



**Figure 6:** Peak of the charge distribution as a function of the muon tracklength in the WCD water, for the total PMT signal (top left) and for individual PMTs in campaign 3. Data were rescaled to the simulation value for $L \in [1.25, 1.3]$ m. The ratio between simulation and data is also shown at the bottom.

# Field experience@Malargüe – 1st MARTA station

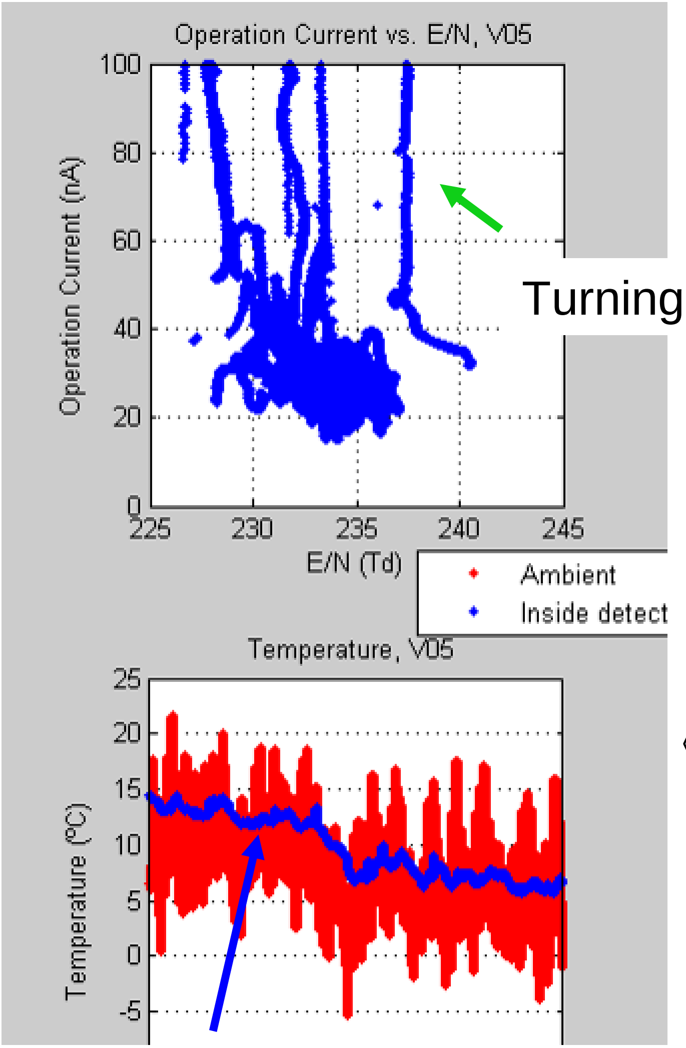
# Field experience@Malargüe – 1st MARTA station



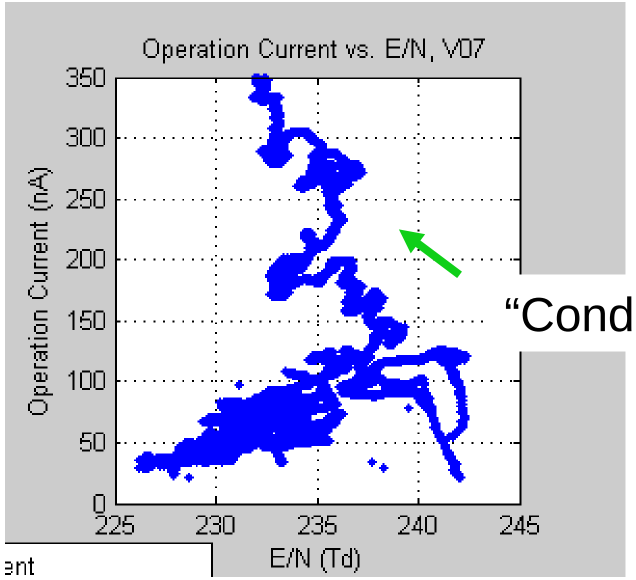



A concrete precast structure is needed to support the tank, filter the electromagnetic component of the shower and act as a protecting house for the RPCs.
Two overlapping RPCs underneath the tank.
This way we can use the tank and one RPC to define the trigger and measure the efficiency in the other RPC

# Field experience@Malargüe – 1st MARTA station



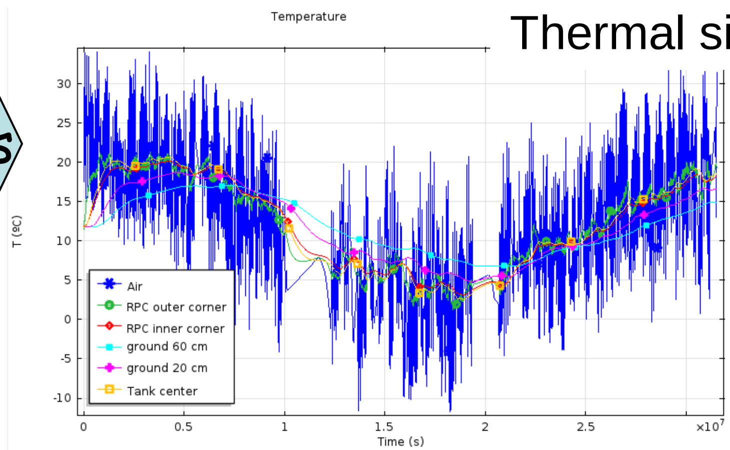

Turning on/off



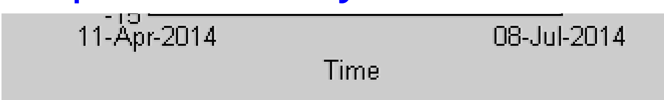

"Conditioning"

agrees

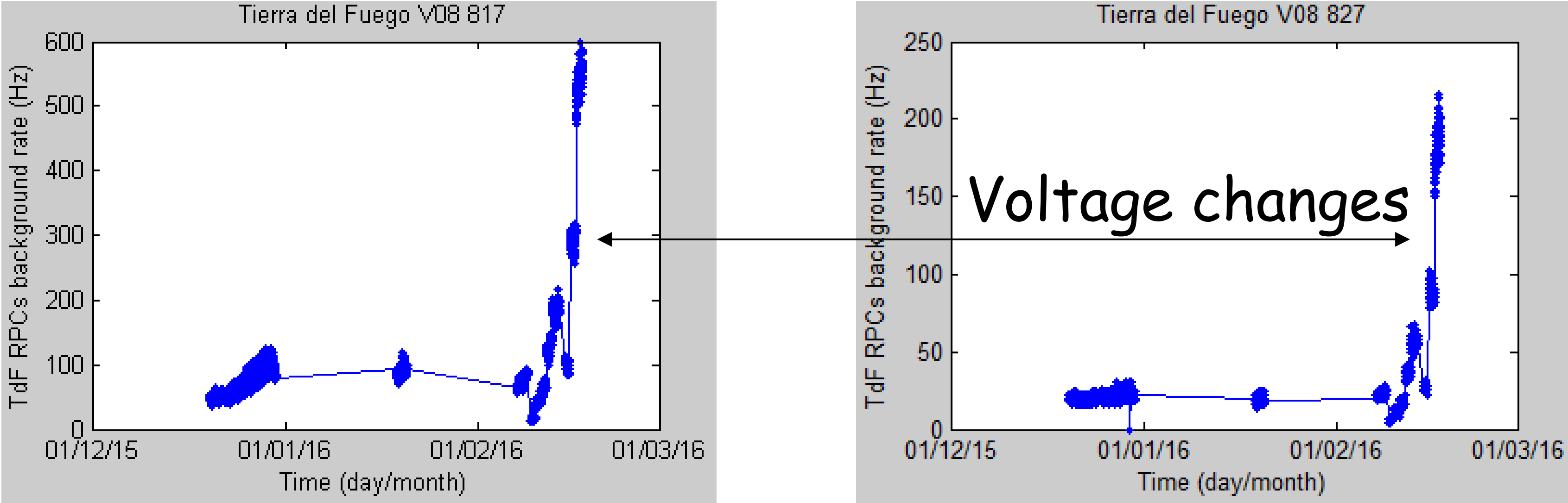
Thermal simulation

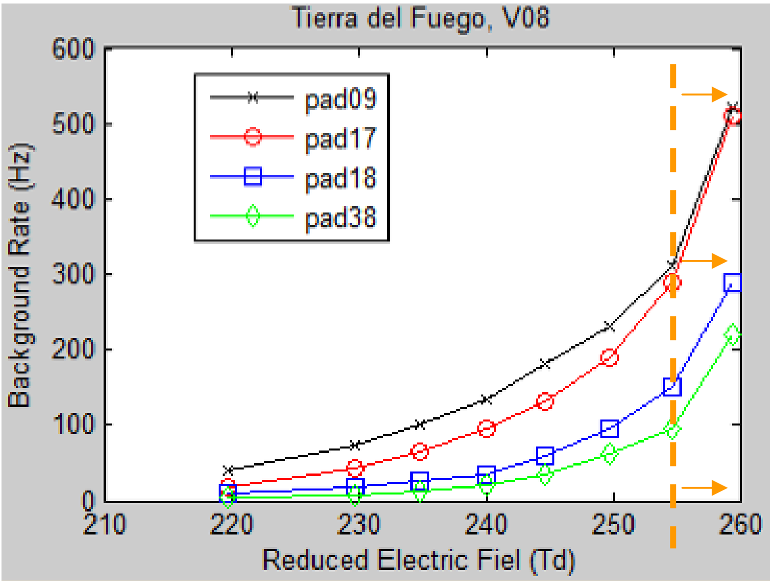



Temperature daily excursions < 2 ºC ⇒ Very narrow E/N range



# Field experience@Malargüe - 1st MARTA station



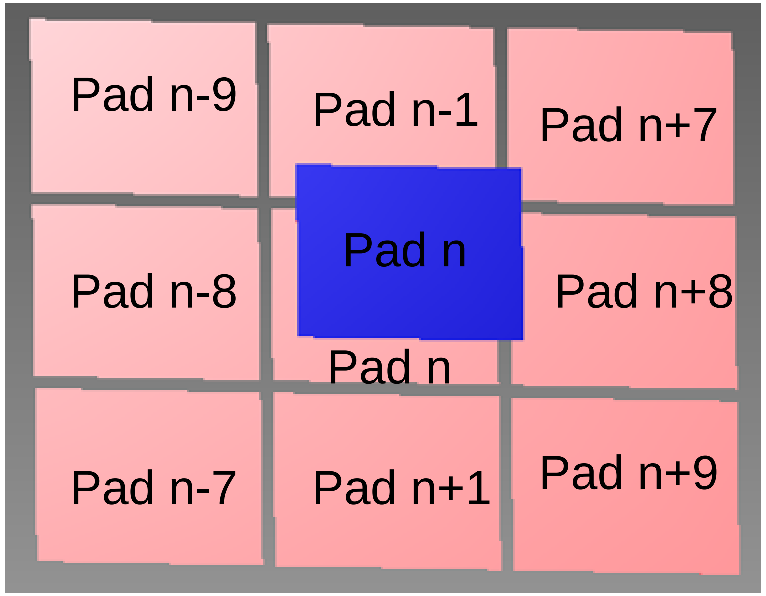




Background rates similar to the ones observed in the lab. Border pads show higher rates, but it's a mechanical issue already understood and corrected in new RPCs.

Large increase in Background rate in the last 5 Td, without charge spectra to crosscheck we should keep detectors below 255 Td.

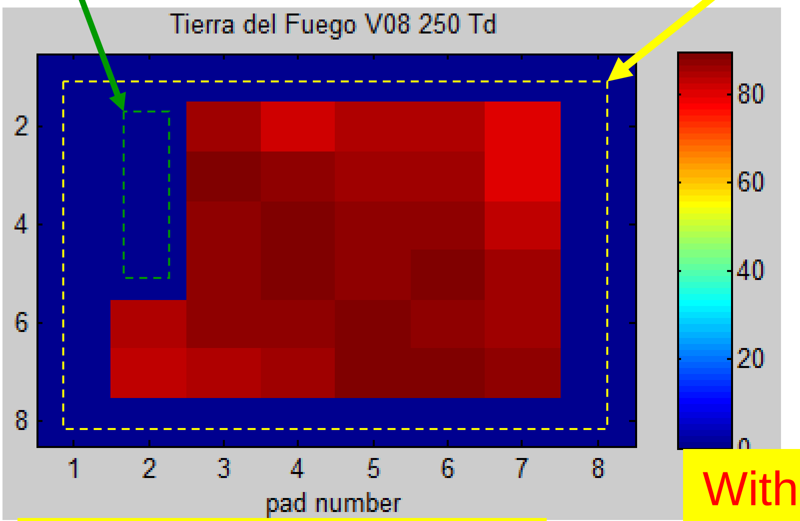
# Field experience@Malargüe - 1st MARTA station

Trigger is defined by a coincidence between tank and chamber 9.
Efficient event is when we have a hit in a pad in chamber 9 and one hit in the same pad of chamber 8 or in any neighbor pad




Due to the efficient-event definition, all the border pads are not taken into account

Dead channels

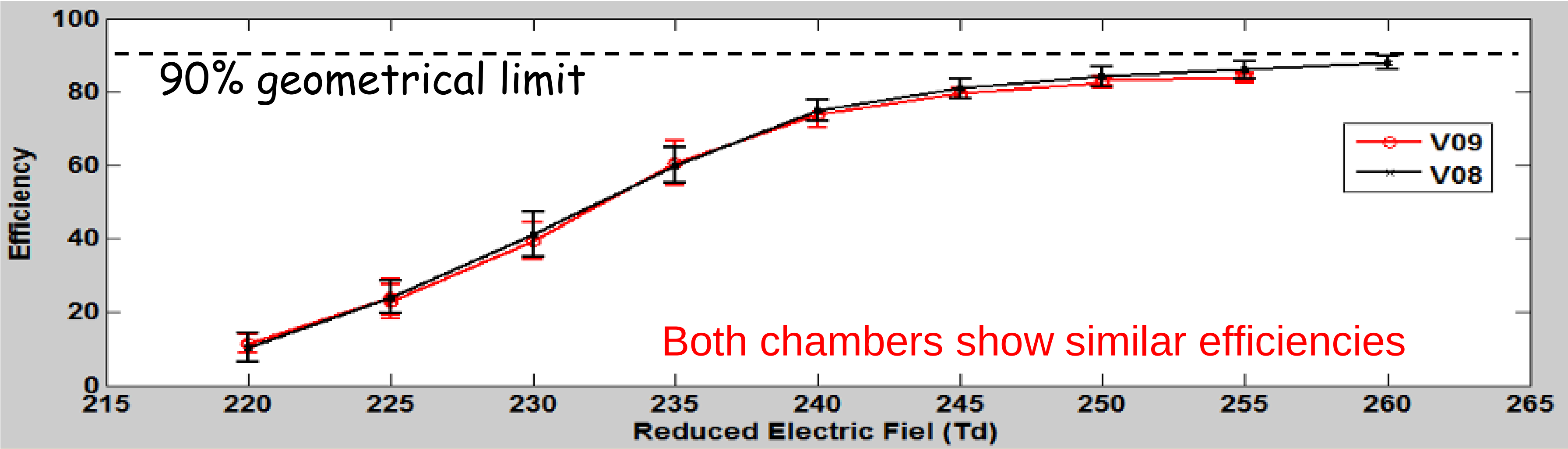


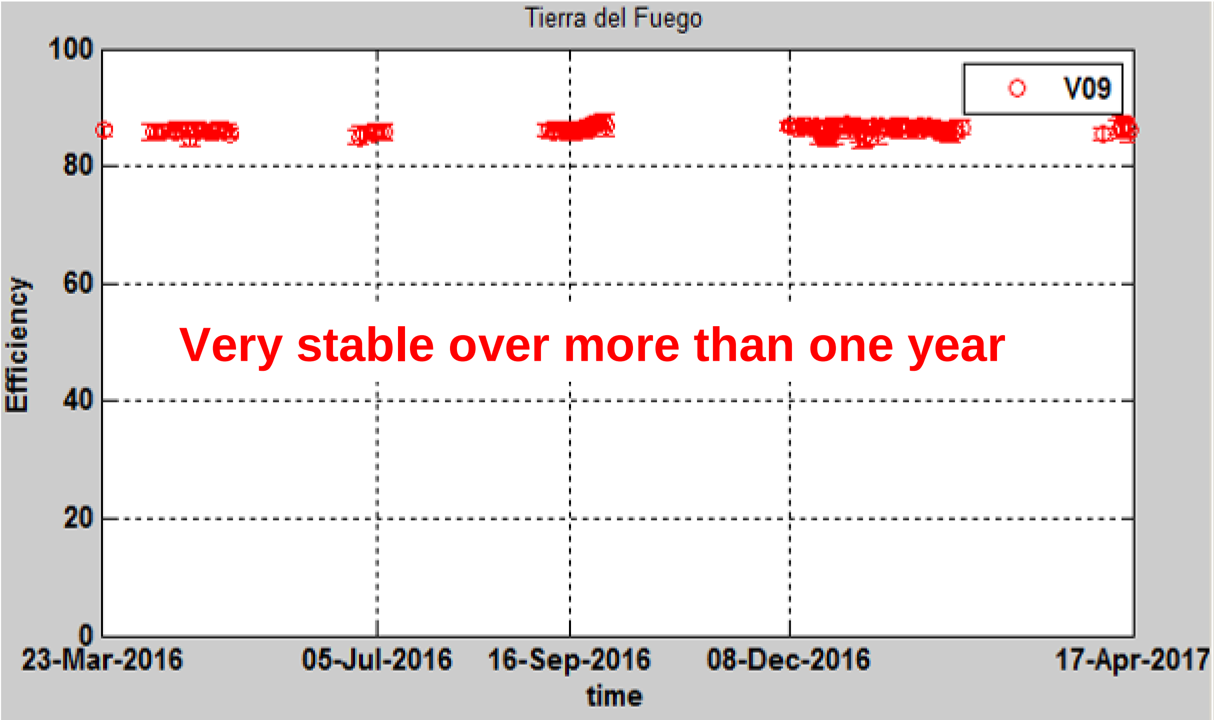

Uniform over all area

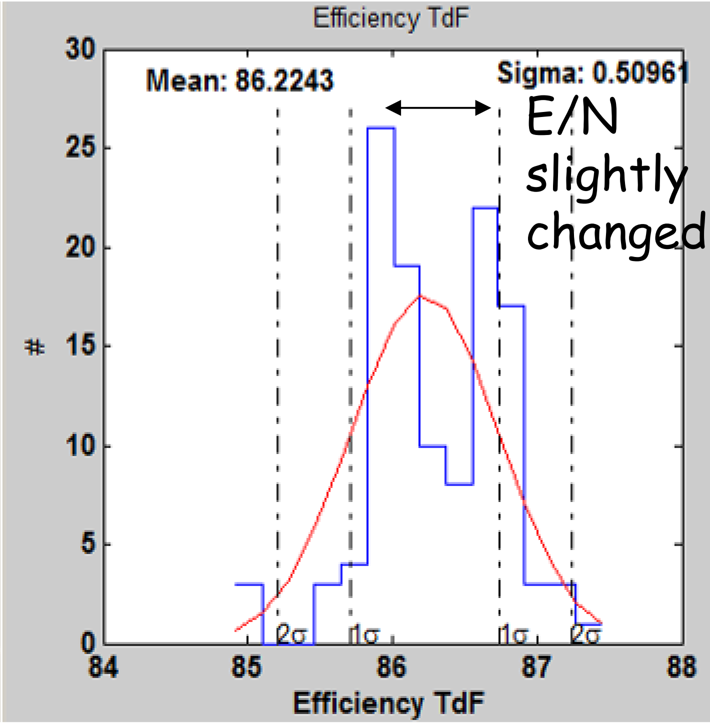
With muons
1 day / point

E/N constant

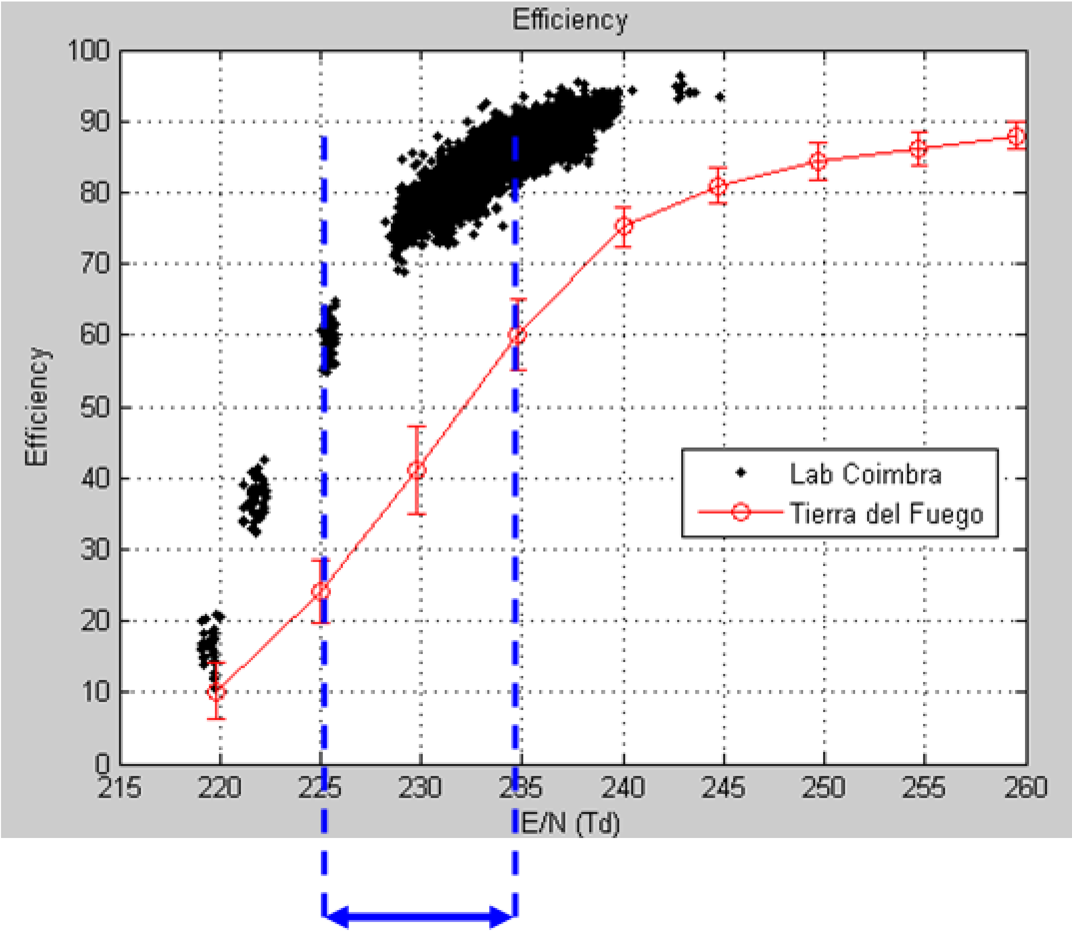
# Field experience@Malargüe - 1st MARTA station



# Field experience@Malargüe - 1st MARTA station




200 V/gap (1 mm gap)
$\Delta$P=150 mbar
"same" temperature

Different front end electronics…

Different gas supplier/manufacturer?

Lowering electronic threshold did not increase efficiency

We don't have charge measurement, so can not compare charge spectra

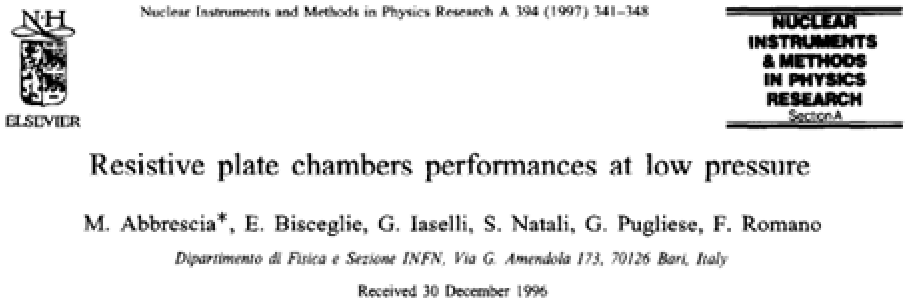
Lower pressure implies lower gas density…

Other authors observe similar behavior in streamer mode…

Some low pressure test will be done in the lab very soon.!!

# Field experience@Malargüe – 1st MARTA station

Streamer mode


Nuclear Instruments and Methods in Physics Research A 394 (1997) 341–348

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

Resistive plate chambers performances at low pressure

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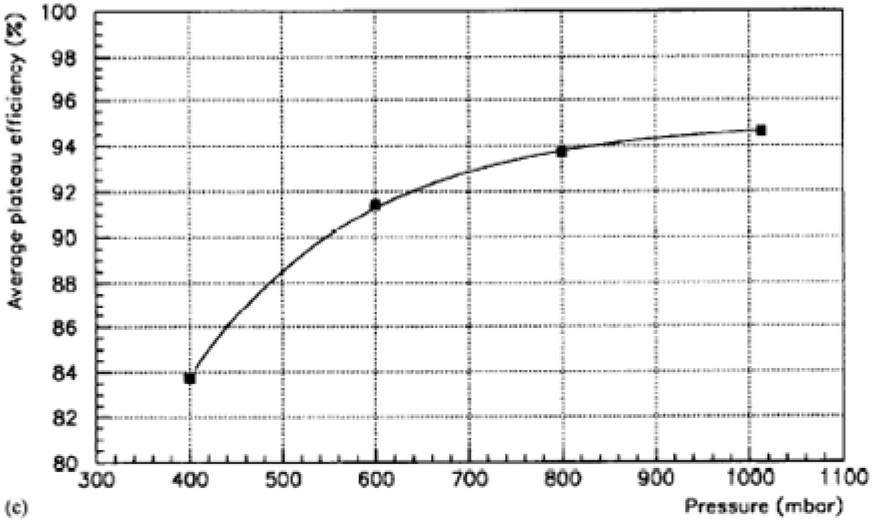
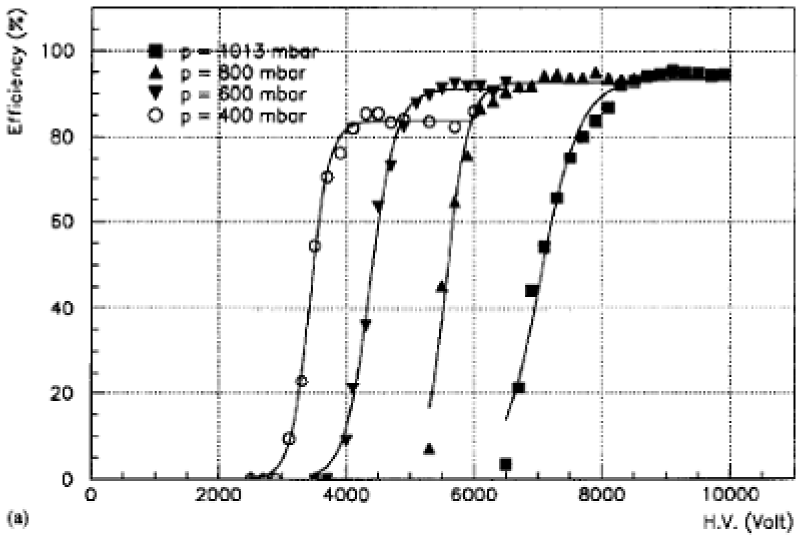
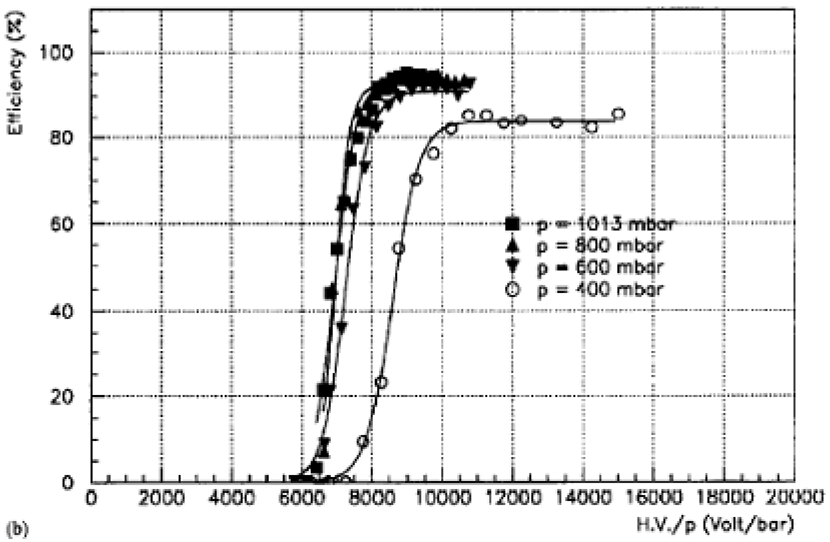
Received 30 December 1996

Lower pressure ⇒ Lower efficiency plateau



# Keeping efficiency at altitude

Compensation of low pressure ⇒ reduced λ
(in the proportional-avalanche limit)

$$1-\varepsilon \approx G^{-\nu} + \frac{1}{\nu\,\Gamma(\nu)}\left(\frac{N_{e,th}}{G/r}\right)^{\nu} \qquad \text{if} \left(\frac{N_{e,th}}{G/r}\right) << 1$$

$G = e^{\alpha g}$ = maximum gas gain; $\nu = n\lambda/\alpha$ shape parameter

$$\nu = \frac{n\lambda}{\alpha} = \frac{\overbrace{\lambda}^{ionization\ density\ \propto\ pressure}\quad ng}{\underbrace{\alpha g}_{\sim cte}} = \frac{\#of\ \ primary\ ionization\ clusters}{\#of\ \ gas\ \ ionization\ steps}$$

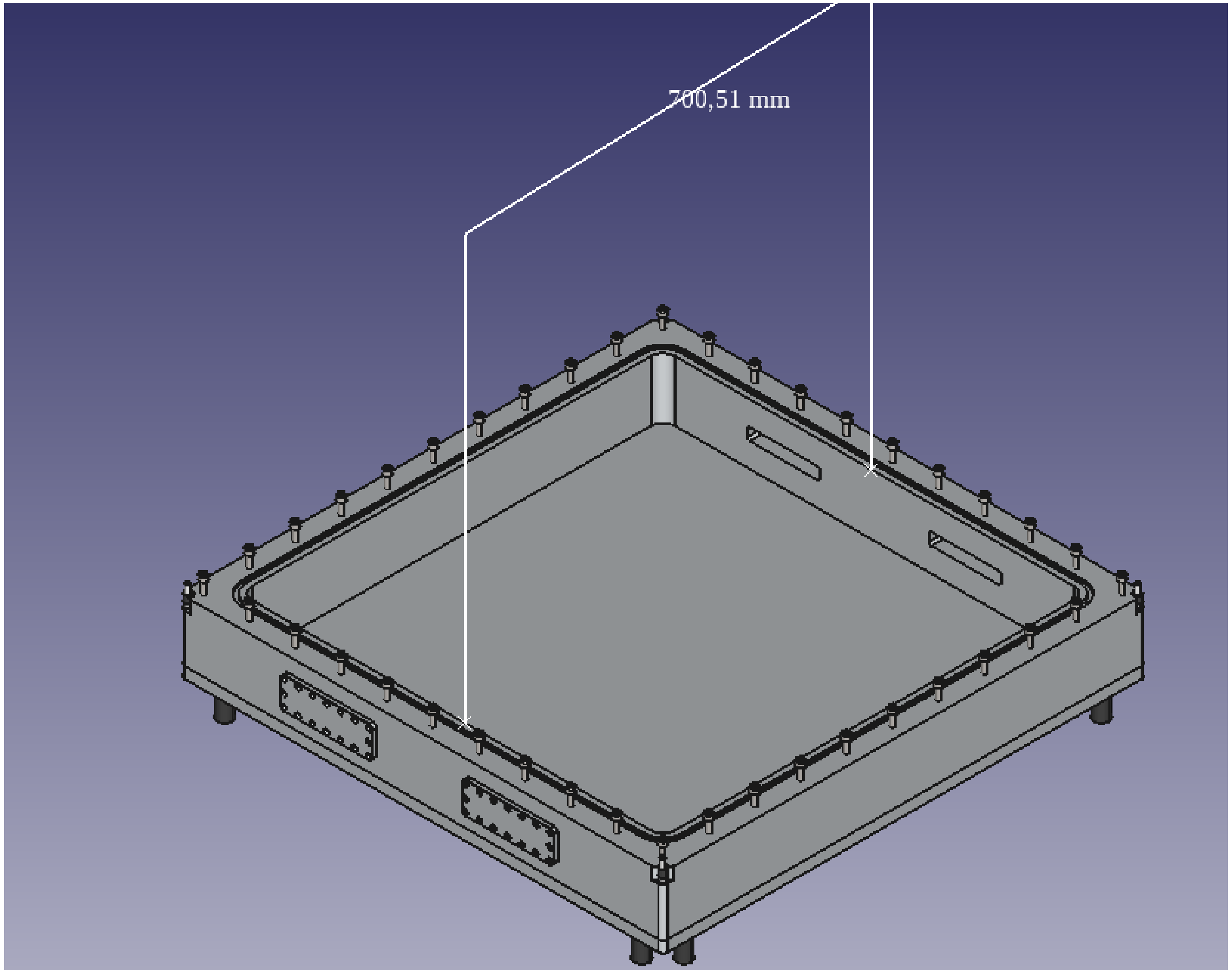
$$(n = n^{o}\ of\ \ gaps;\ g = gap\ width)$$

To keep everything constant with pressure

- Adjust voltage to keep αg constant
- Increase the total gap width ng to keep ν constant

*M. Abbrescia et al., NIM A 431 (1999) 413* *P.Fonte, 2013 JINST P11001*

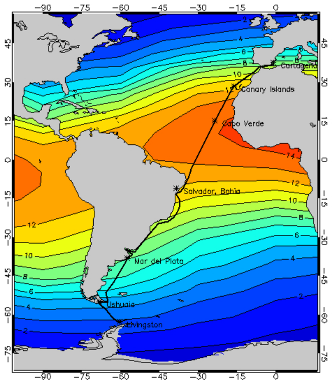
# Hypobaric chamber



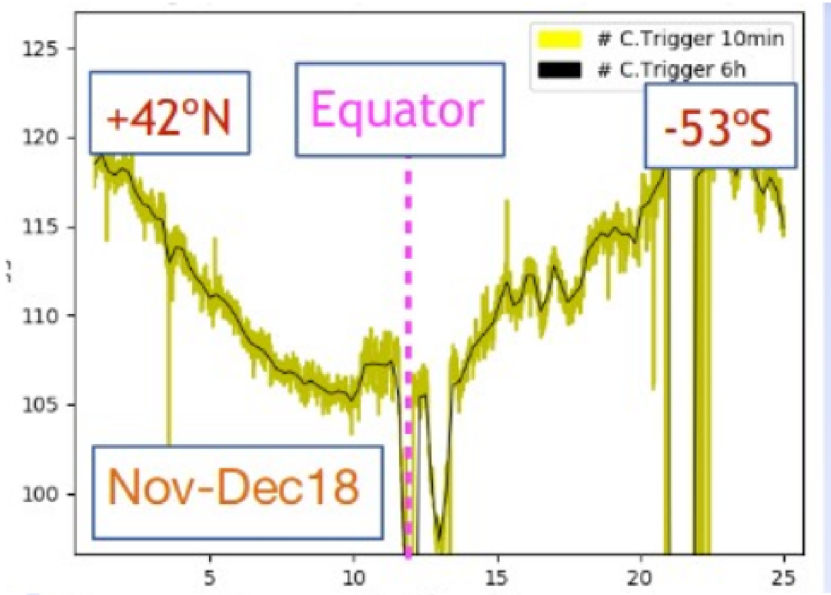

In the pipeline for mechanical production.

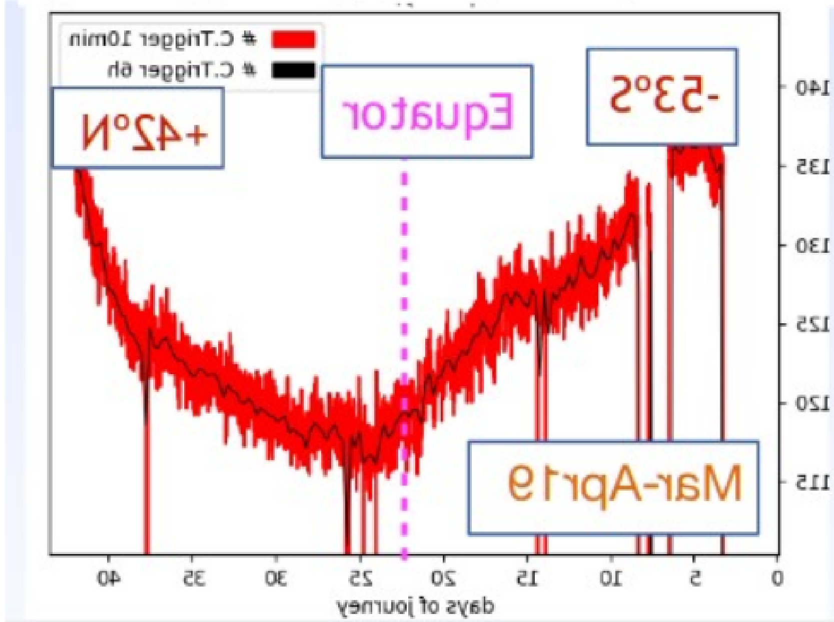
# TRISTAN detector @ ORCA* collaboration (very preliminary)

3 MARTA-type chambers



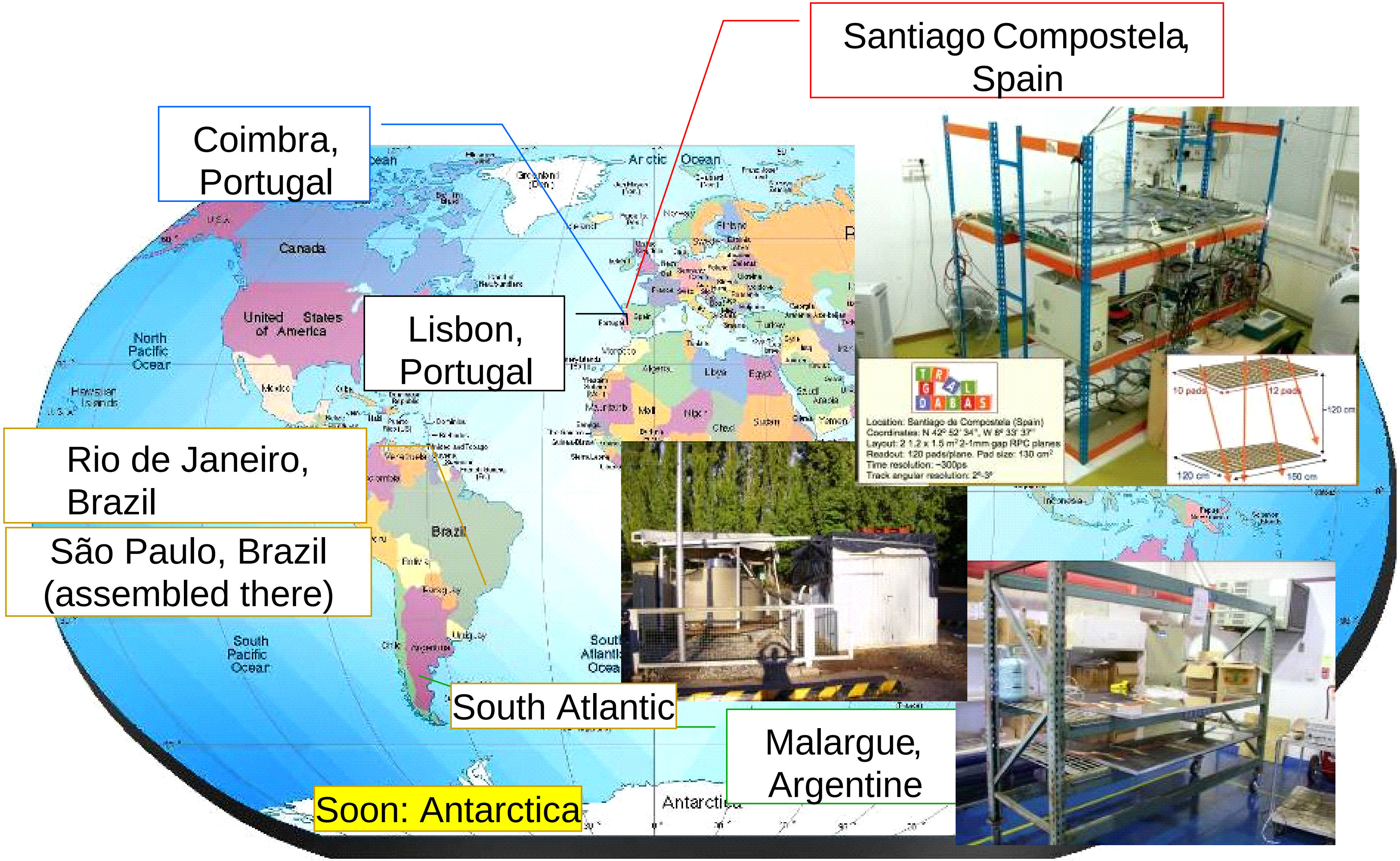




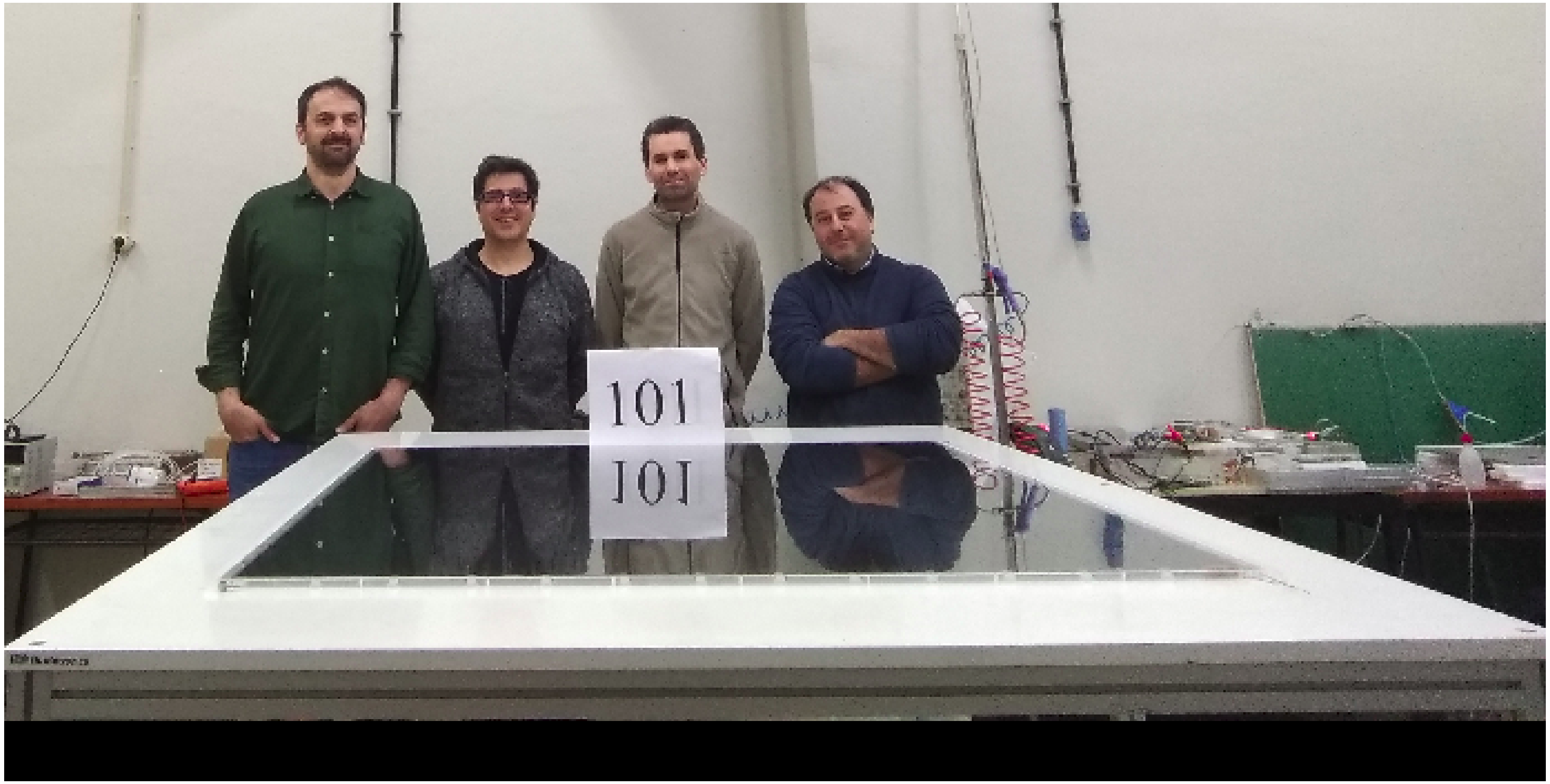

* Antarctic cosmic ray observatory

# Whereabouts



# 101 RPCs = 182m$^2$

February 2019, LIP's Detector Lab



# Summary

- An RPC solution for robust operation at remote locations was developed with 92% eff (inc. guard ring) and 300 ps intrinsic time resolution
- Temperature changes can be accurately offset by voltage changes
- Reduced gas flow operation (~1 kg/year) checked for more than 6 months in the lab
- Over 100 RPC volumes were produced and successfully tested. Of these, ~50 where full chambers with integrated readout.
- Accumulated many months (almost 2 years) of field experience in Malargüe, Argentina, under harsh outdoors conditions, observing very stable efficiency over 1 year at a MARTA station.
- Noticed the effect of atm. pressure.
- Successful South Atlantic campaign in 2018/19. Antarctica deployment expected in 2020.

For high-altitude operation

- Adjust the chamber structure (double nºgaps x gap width)
- Test at realistic low pressure and temperature
- Dedicated prototype in preparation.