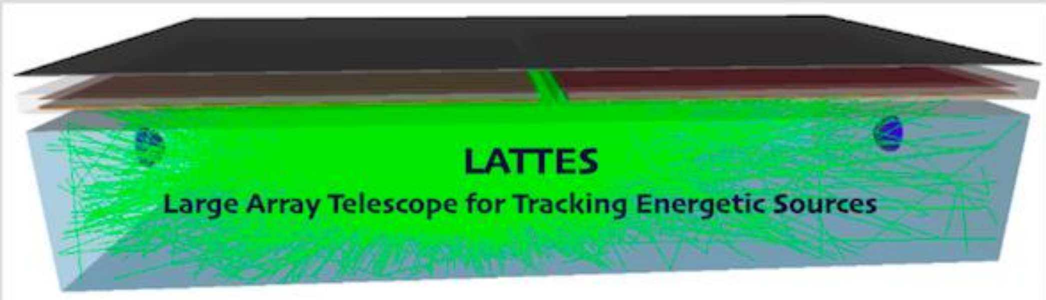


6th LATTES Meeting

29-30 May 2018
Institute of Physics of the Czech Academy of Sciences
Europe/Prague timezone

R&D of RPCs for outdoor experiments

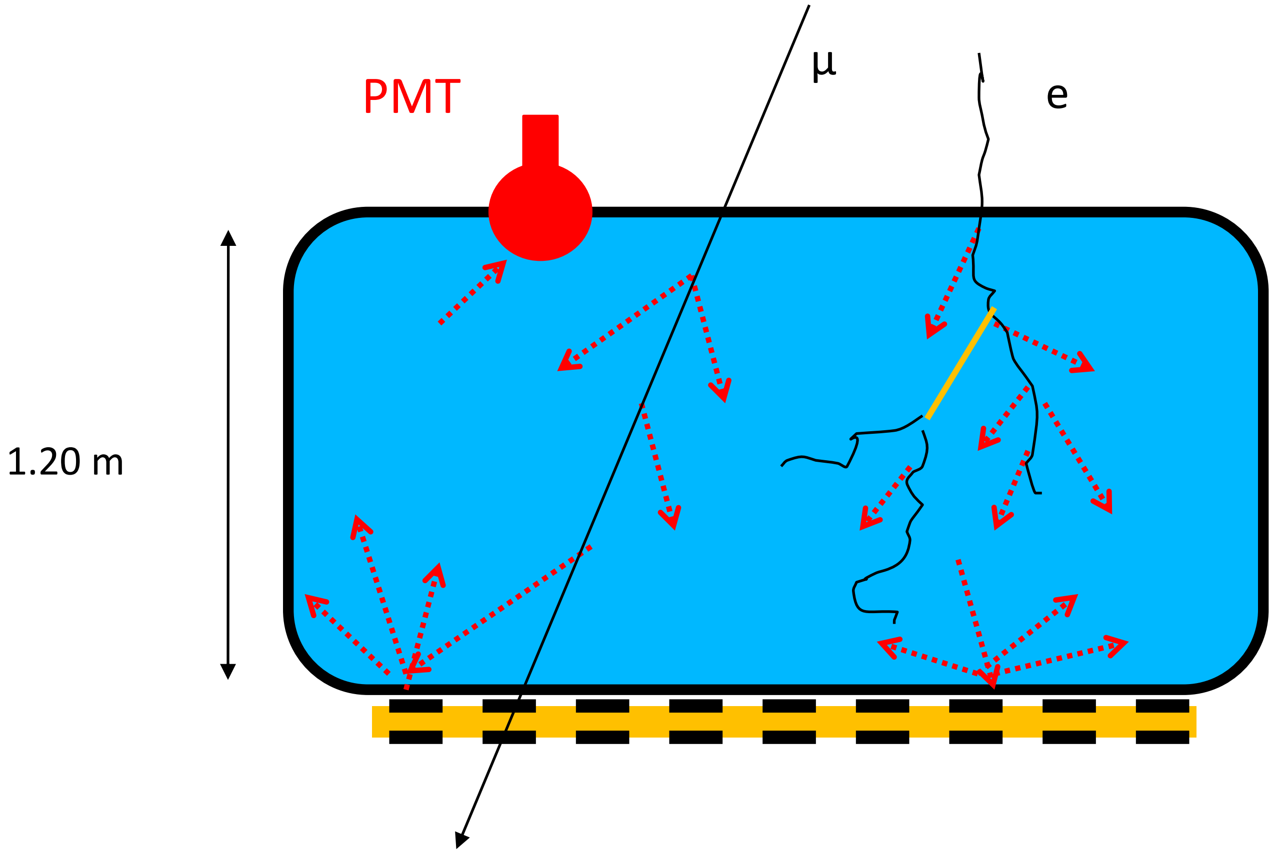
P. Fonte (LIP)

For the MARTA team

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_μ (mean and RMS) as well as extend the determination of the Muon Longitudinal profile (X^μ_{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.

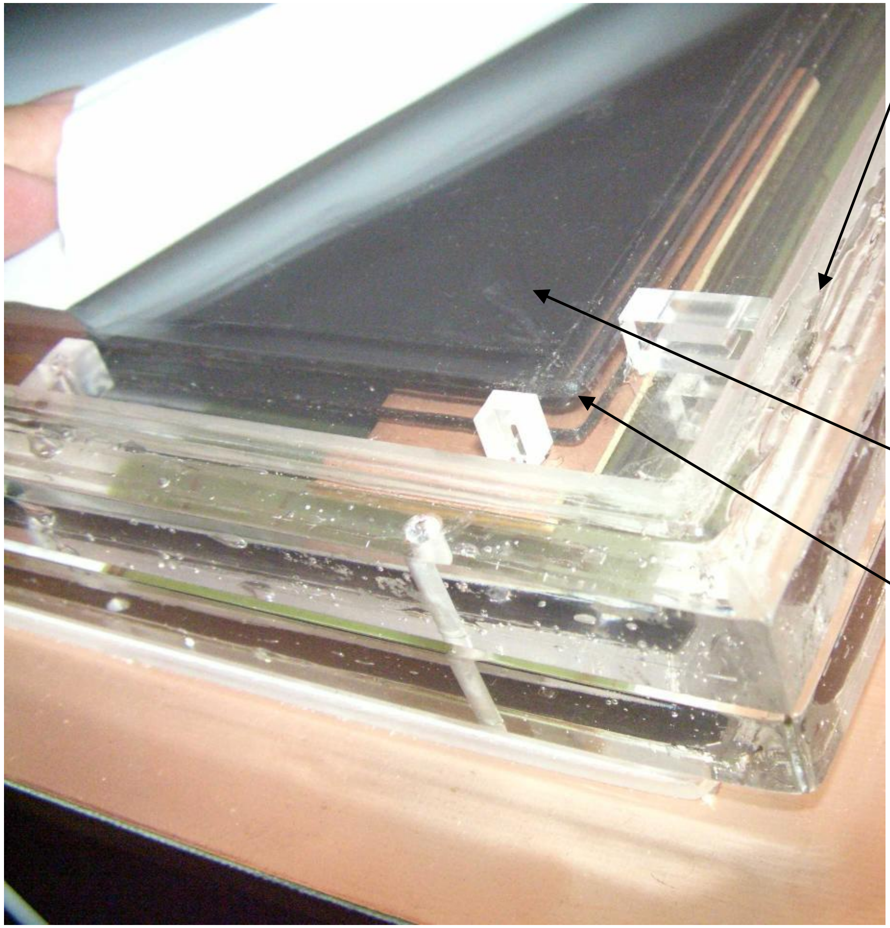
Main challenges:

- 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



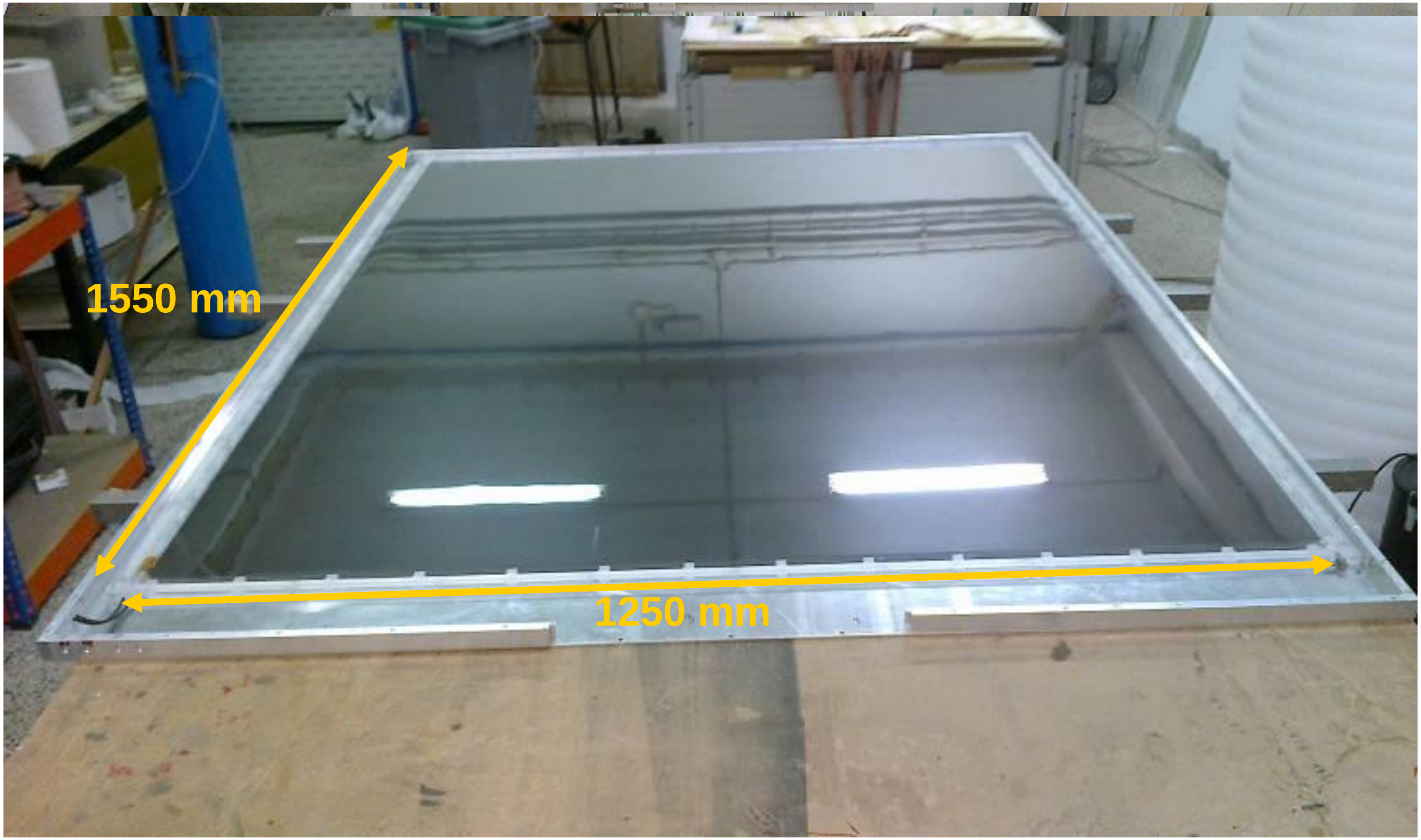
- Signal-transparent and nice looking acrylic box, 1mm thick covers
- Permanently glued
- RPC fits tightly inside
- ✓ good electrode support mechanics
- ✓ excellent HV insulation
- ✓ excellent gas tightness

HV layer, also signal-transparent

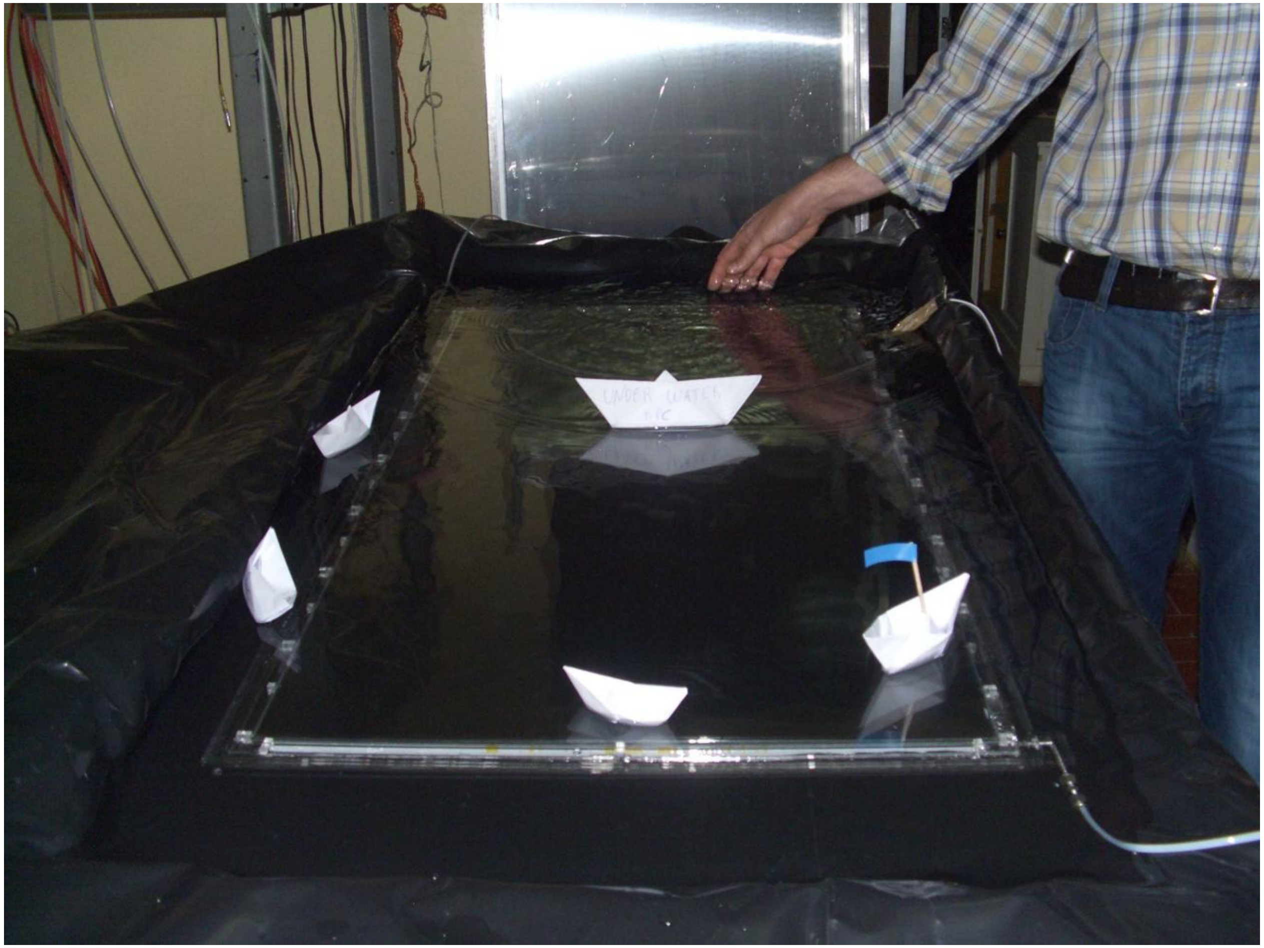
3 RPC glasses (2mm soda-lime)

External pickup electrodes (only HV and gas feedthroughs)

RPC & gas volume

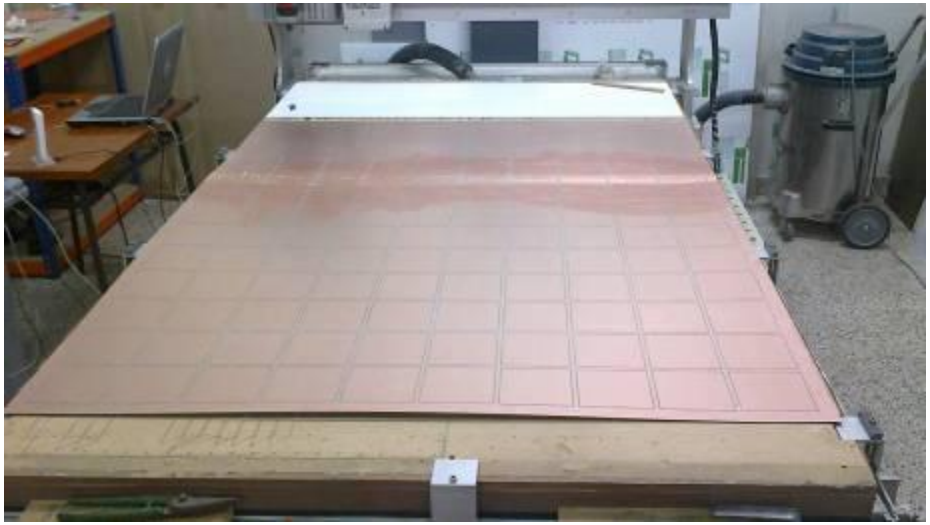


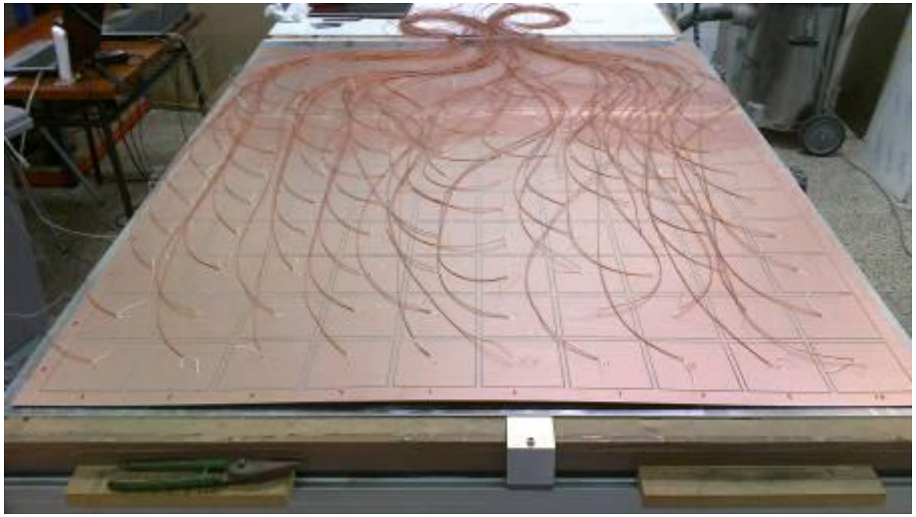
Humidity resilience test

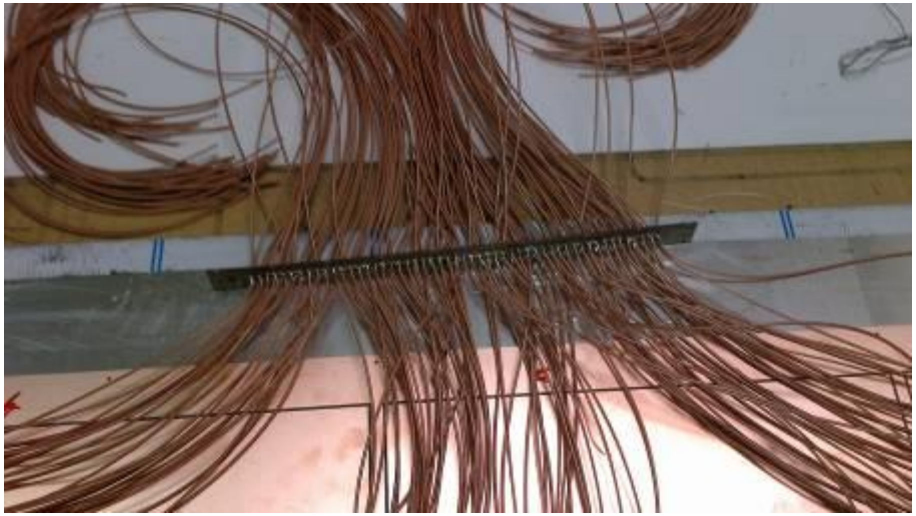


The chamber was actually on for 15 days!

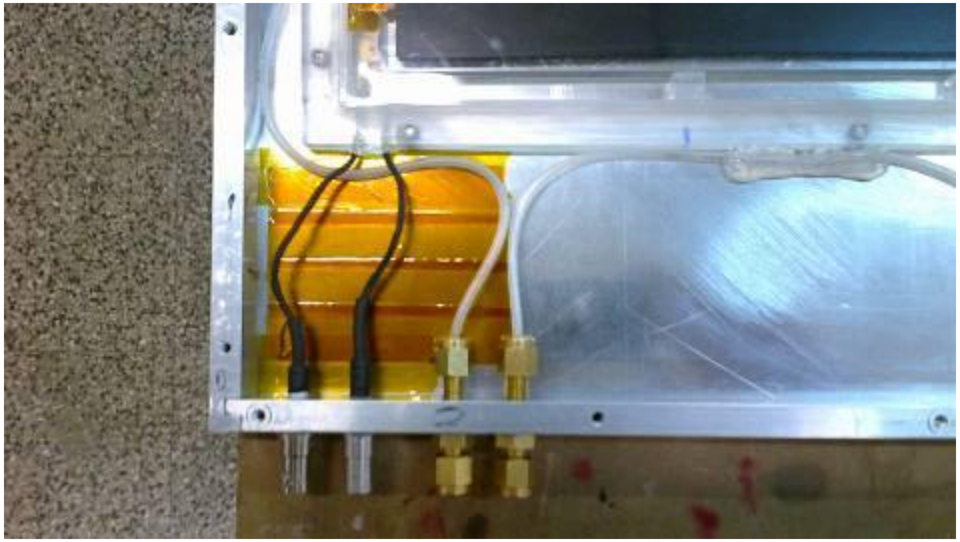
Readout: 64 external pads (or something else)

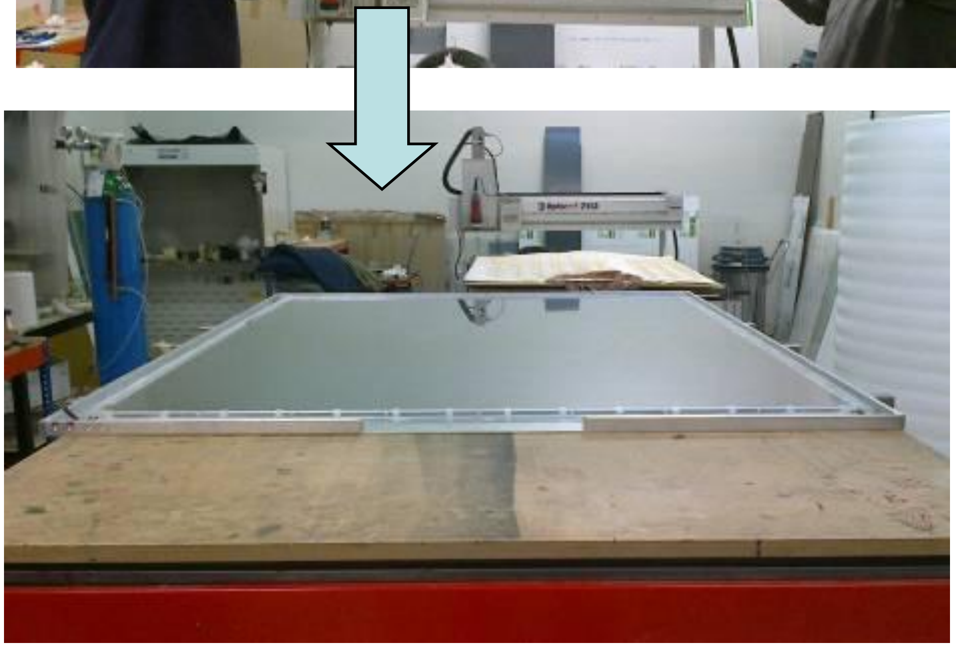




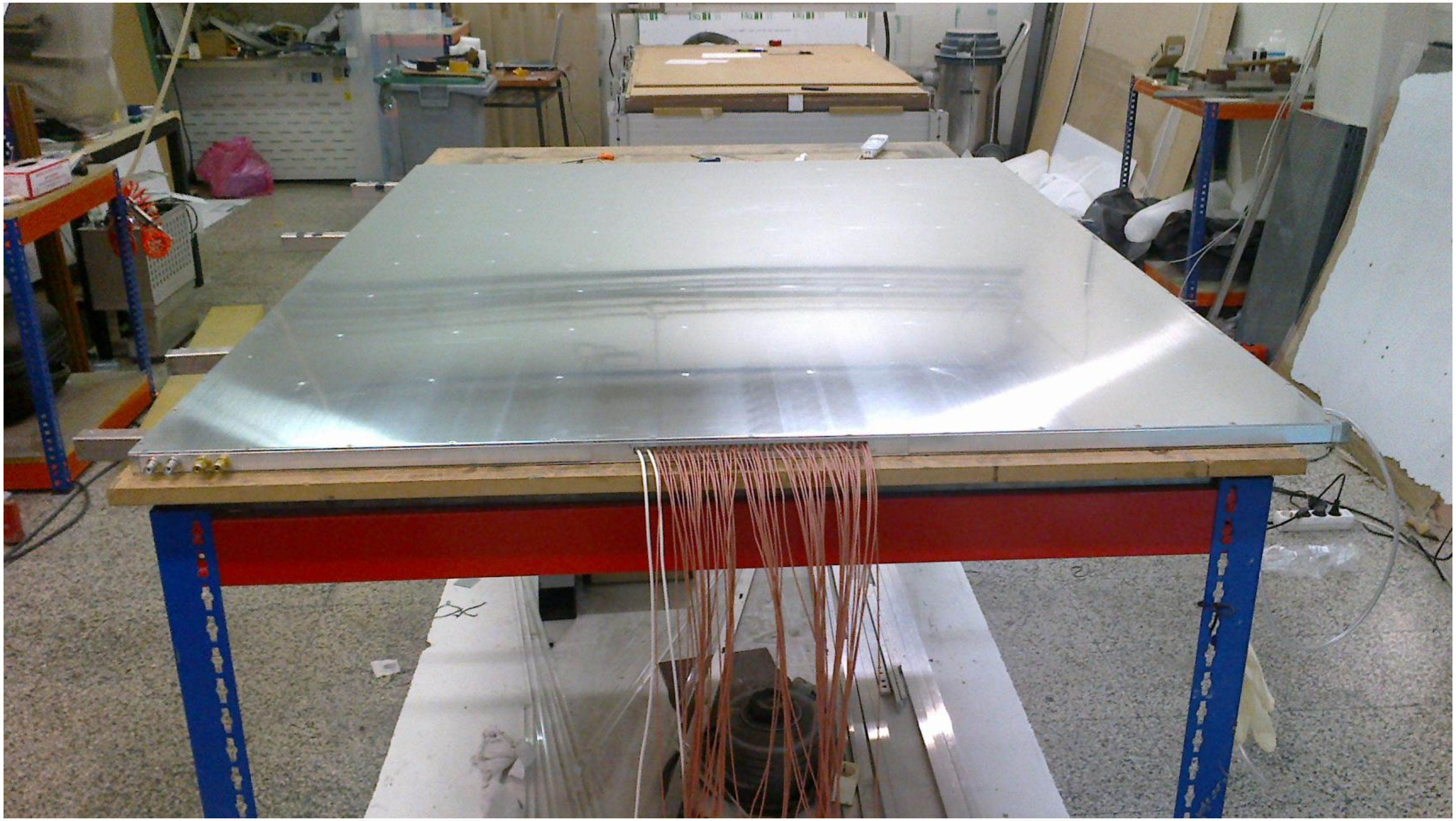


Assembly



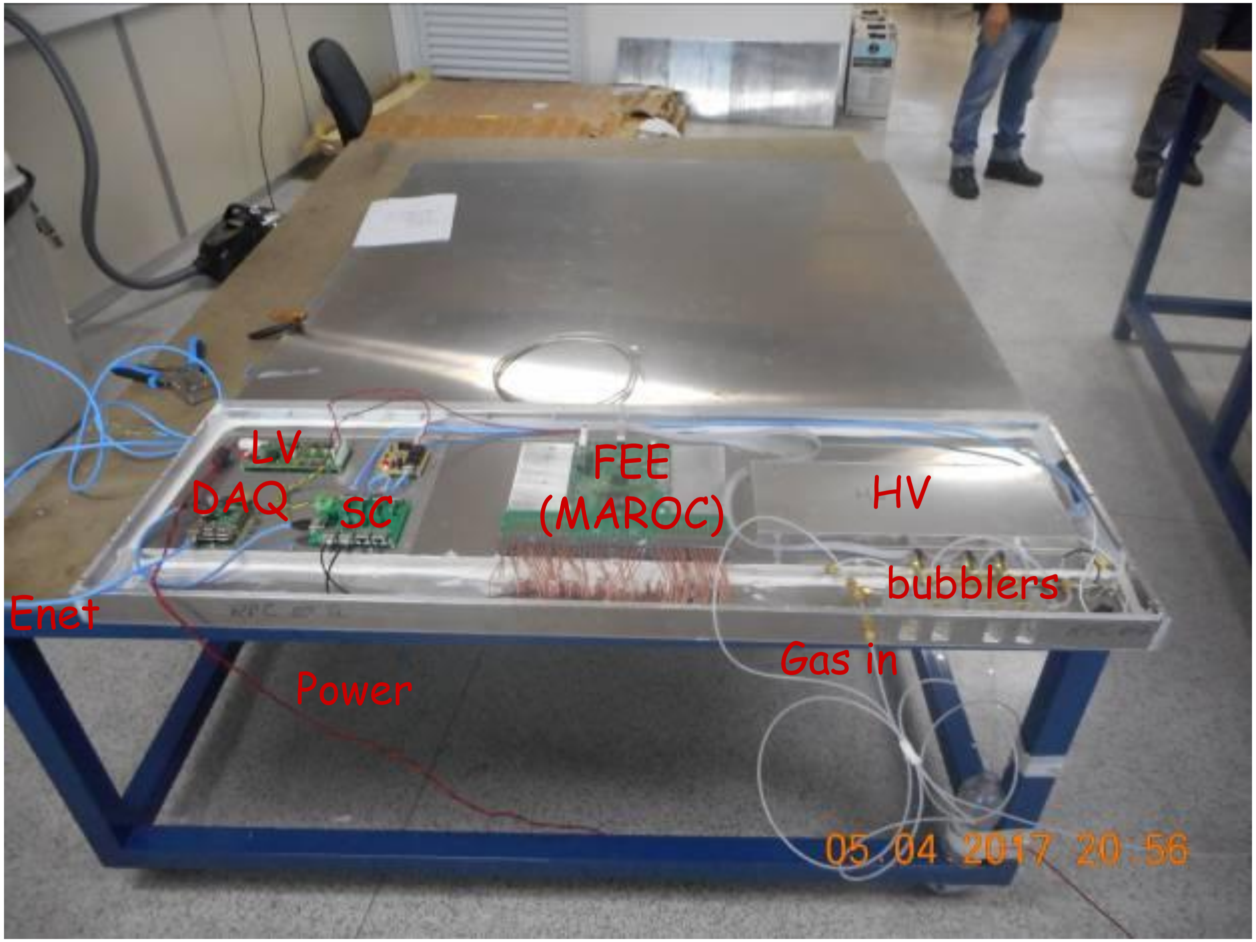


La carrosserie en place



- 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.

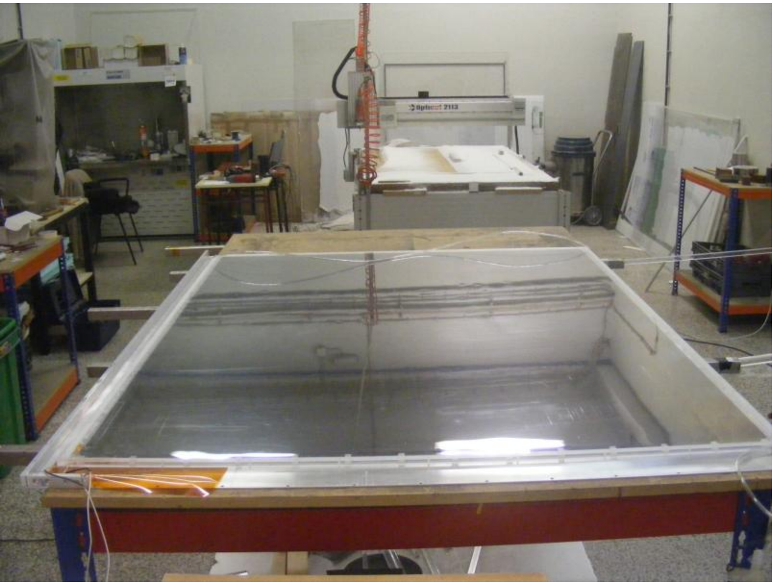
An integrated detection system

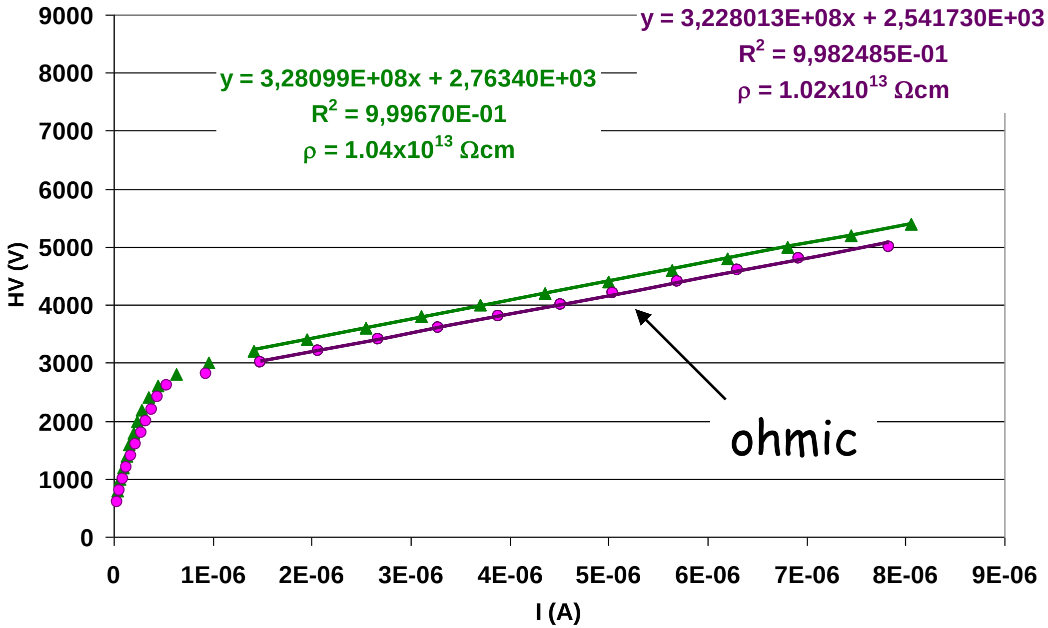


Assembled in São Paulo, Brasil for the engineering array

- 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



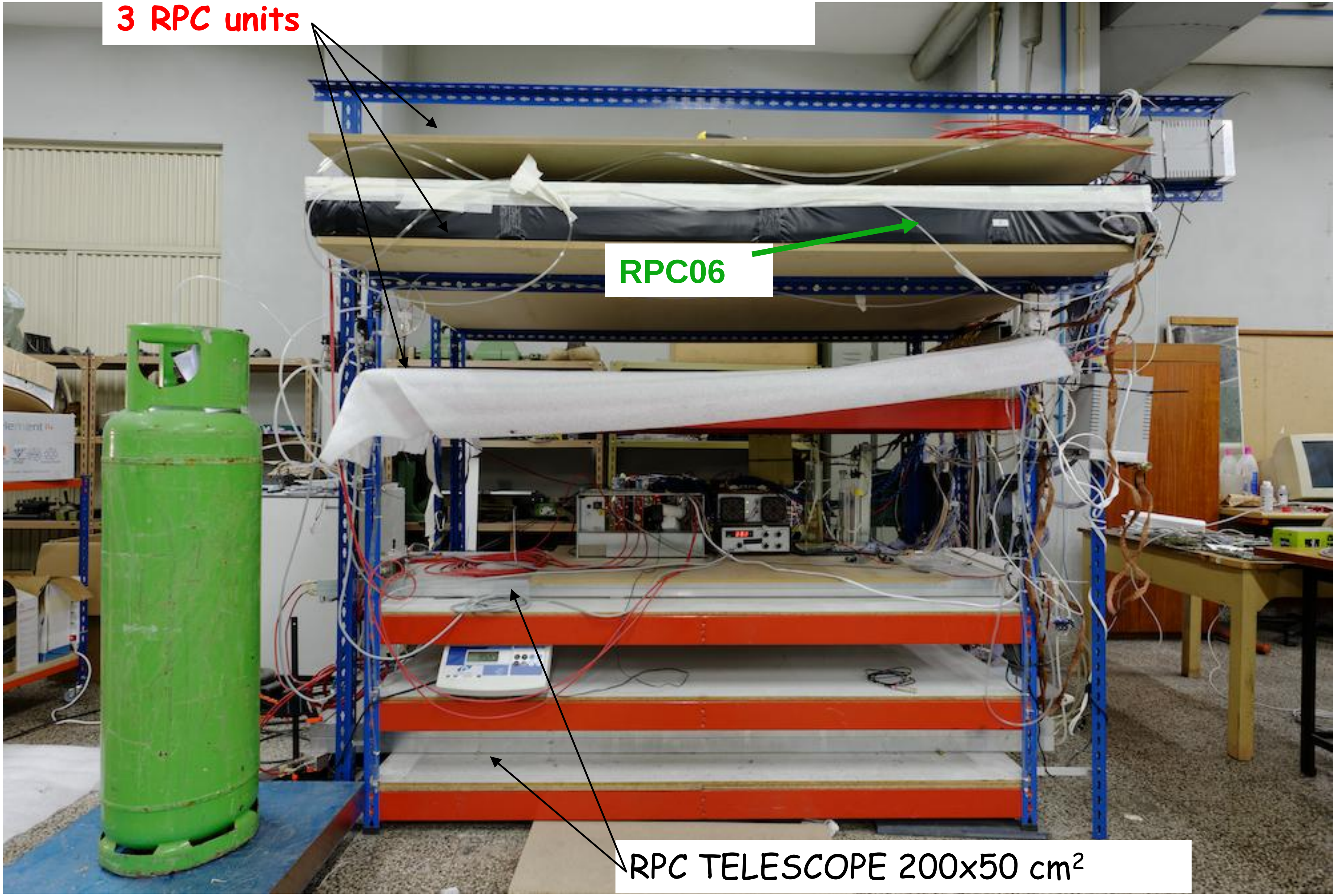


$$\begin{cases} \dfrac{1}{R_{eq}} = \dfrac{150\times 120}{R_{cm^2}} \\ \rho = R_{cm^2}\dfrac{A}{l} \end{cases} \Leftrightarrow \rho = 18000\times\frac{R_{cm^2}}{3\times l}, [\Omega cm]$$

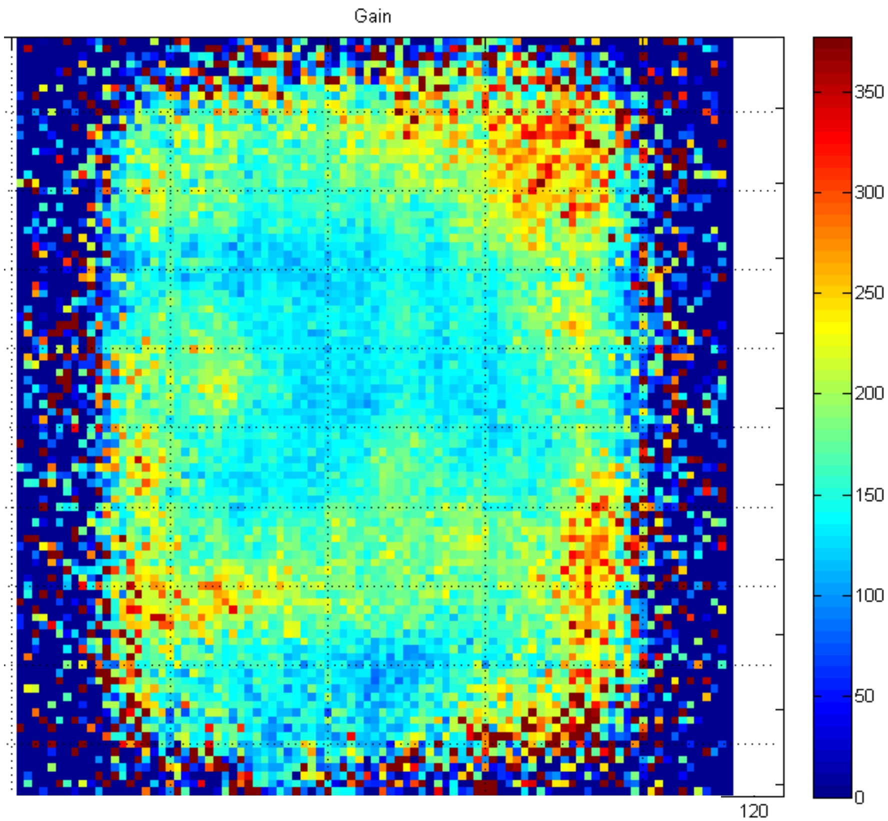
3 glass electrodes

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

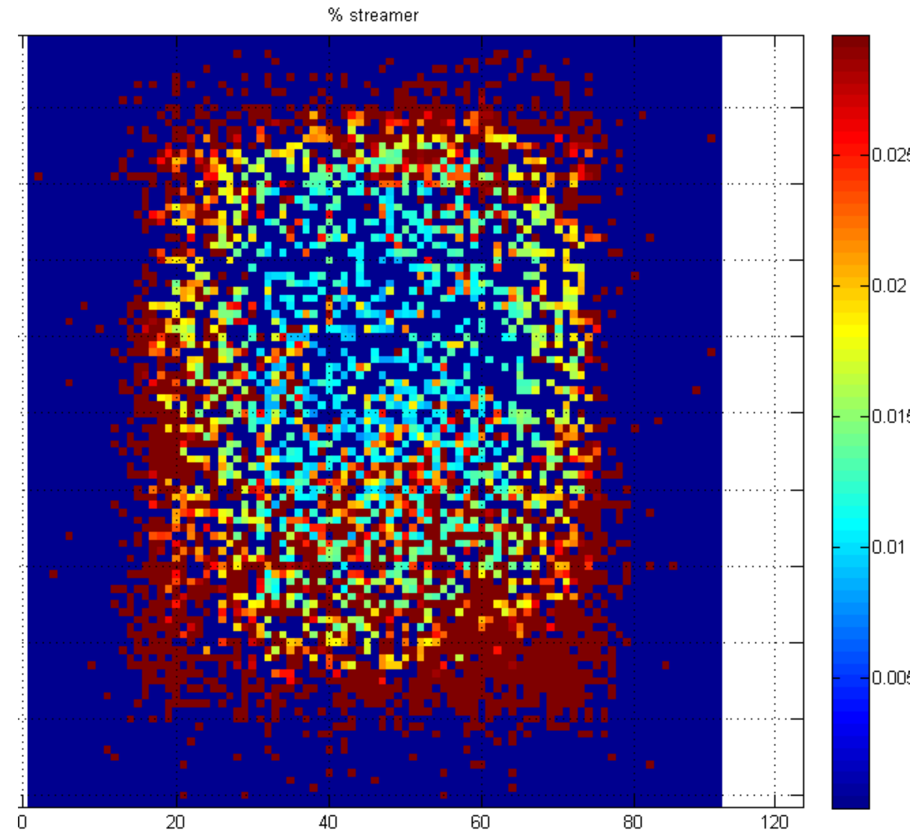
Test setup @ Coimbra



Typical measurements: full area charge and streamer fraction

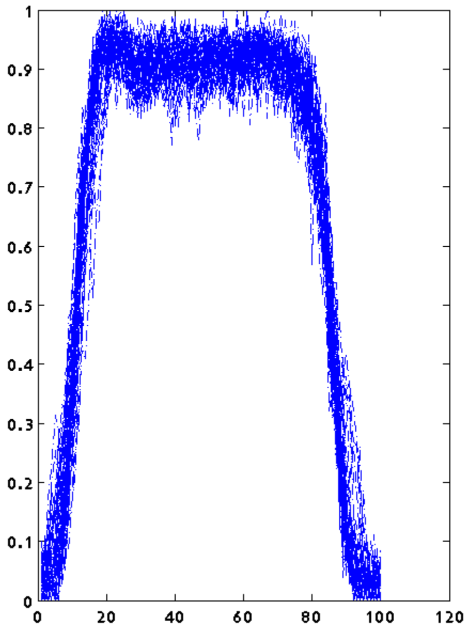


Average charge produced

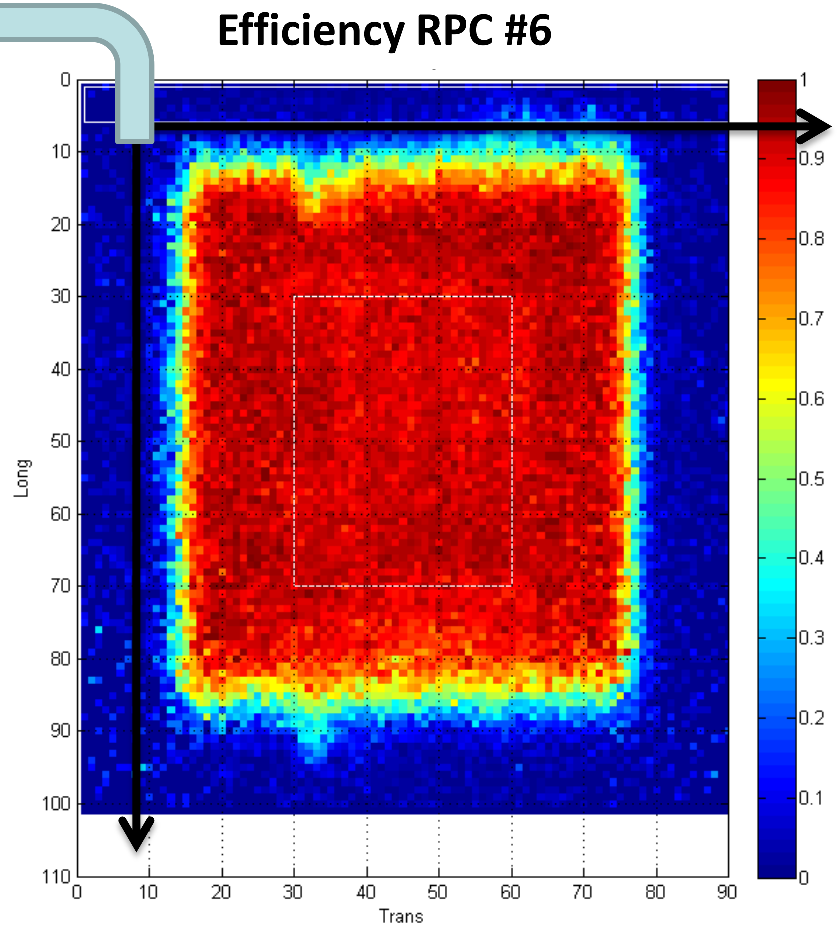


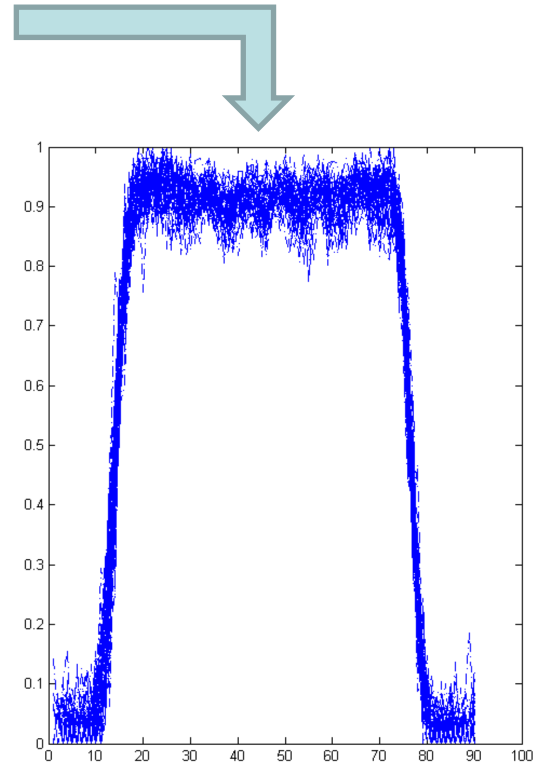
Streamer fraction

Typical measurements: efficiency



Vertical profile



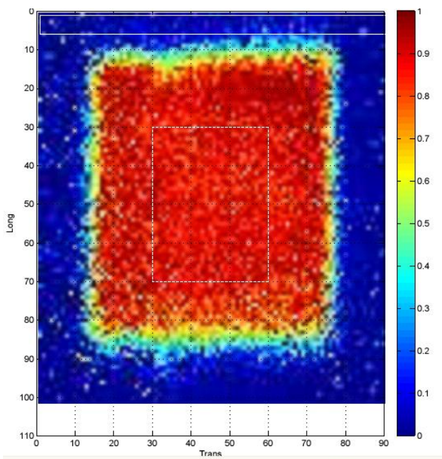


Horizontal profile

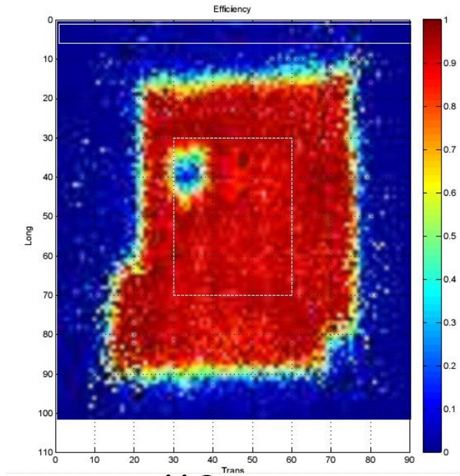
Homogenous efficiency on the entire area

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

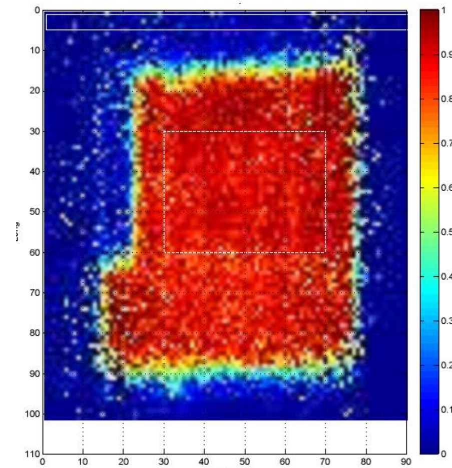
Typical measurements: reproducibility



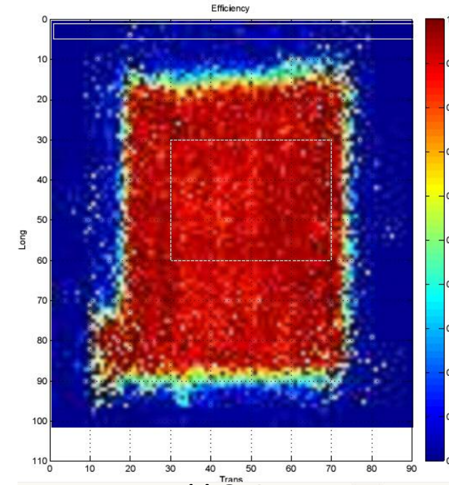
#06



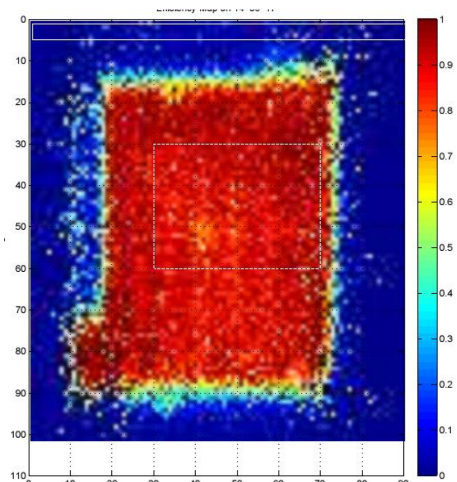
#07



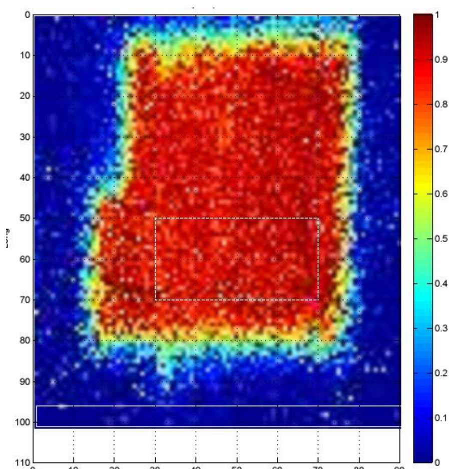
#08



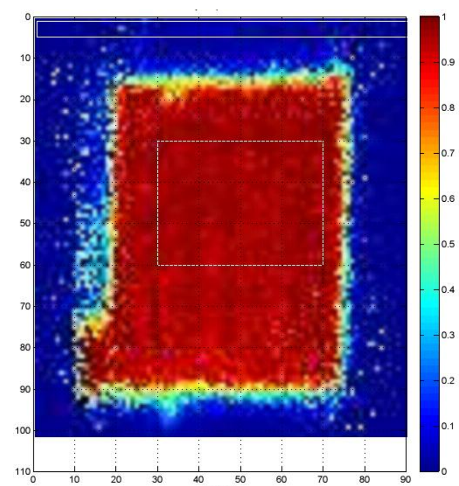
#09.



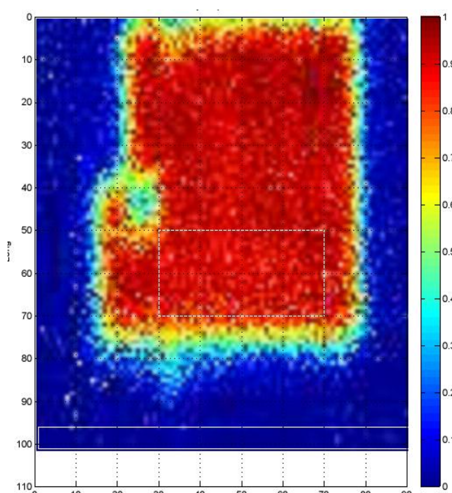
#10



#11



#12



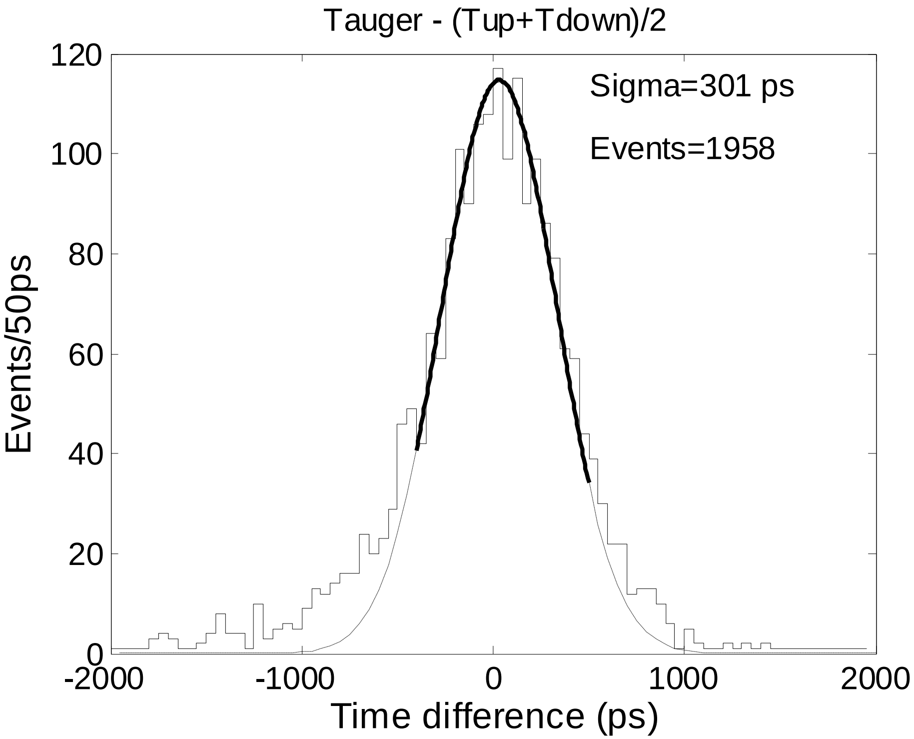
#13.

(Obtained not exactly in the same conditions)

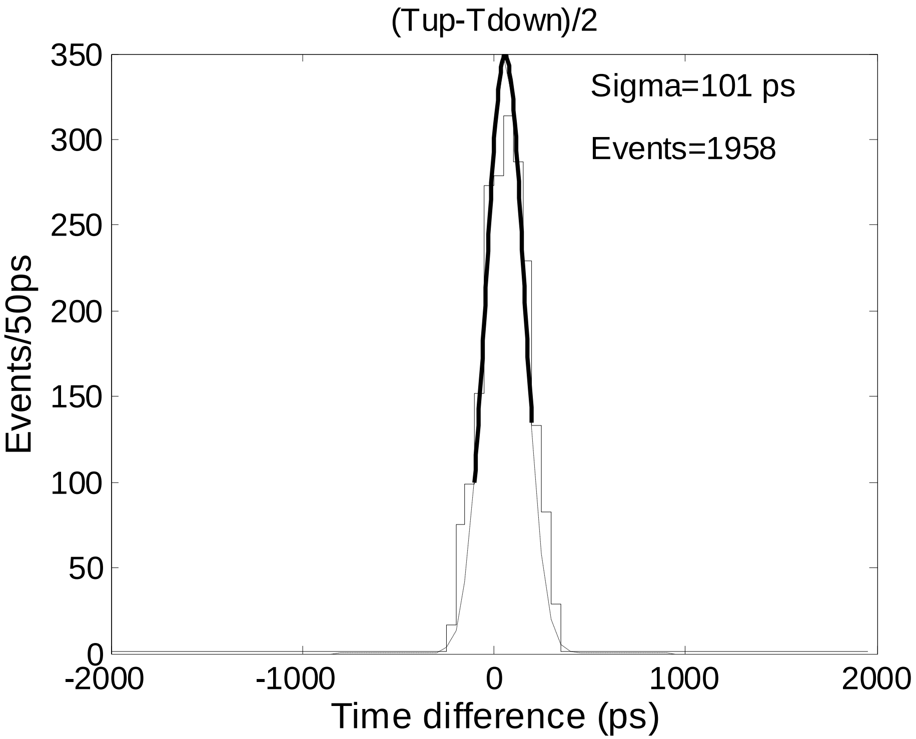
Over 60 RPC sensitive volumes were produced and successfully tested

Typical measurements: time resolution

RPC-telescope



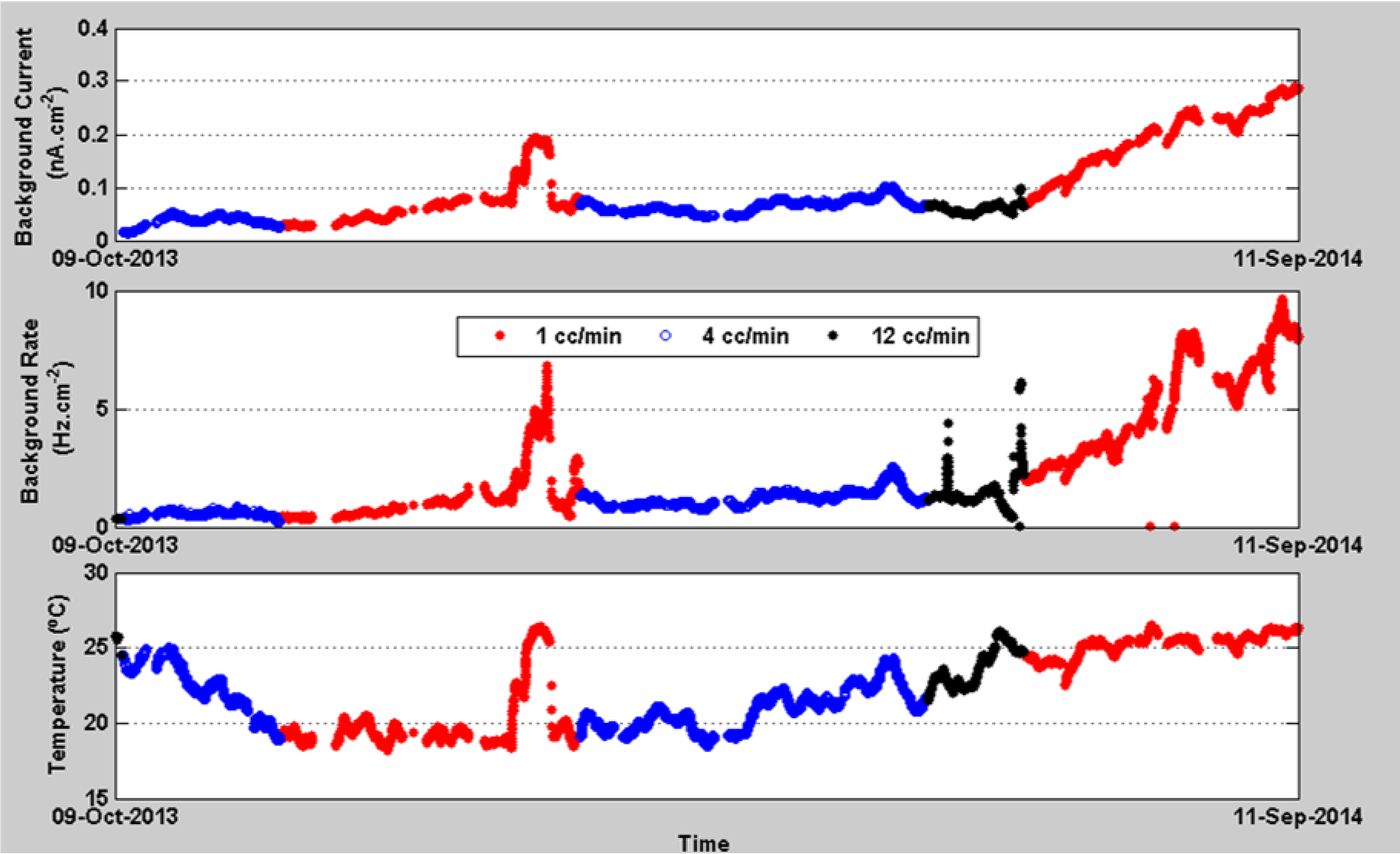
Telescope



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

Some dependencies (longitudinal position p, ex) remain uncorrected

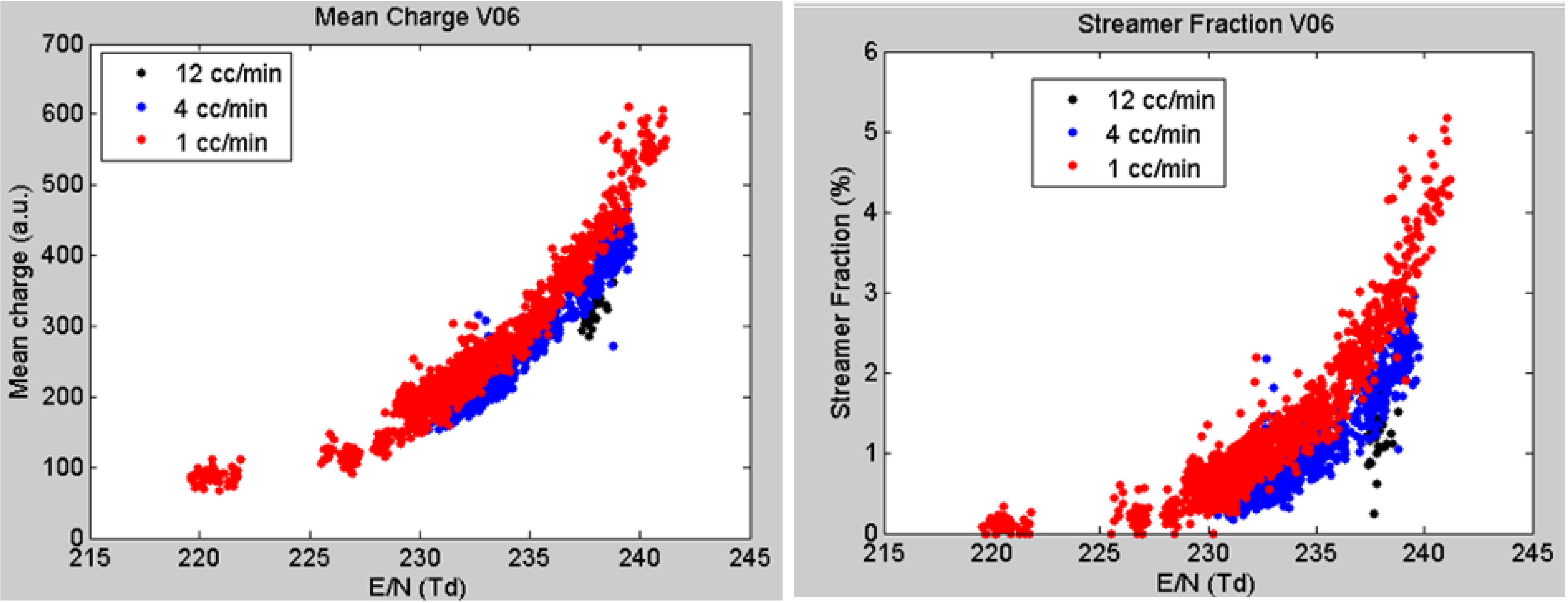
Long term behavior at low gas flow (RPC06) - raw data



~1 year of data @ different gas flow rates

Currents, counting backgrounds strongly correlated with temperature

Long term behavior at low gas flow (RPC06)

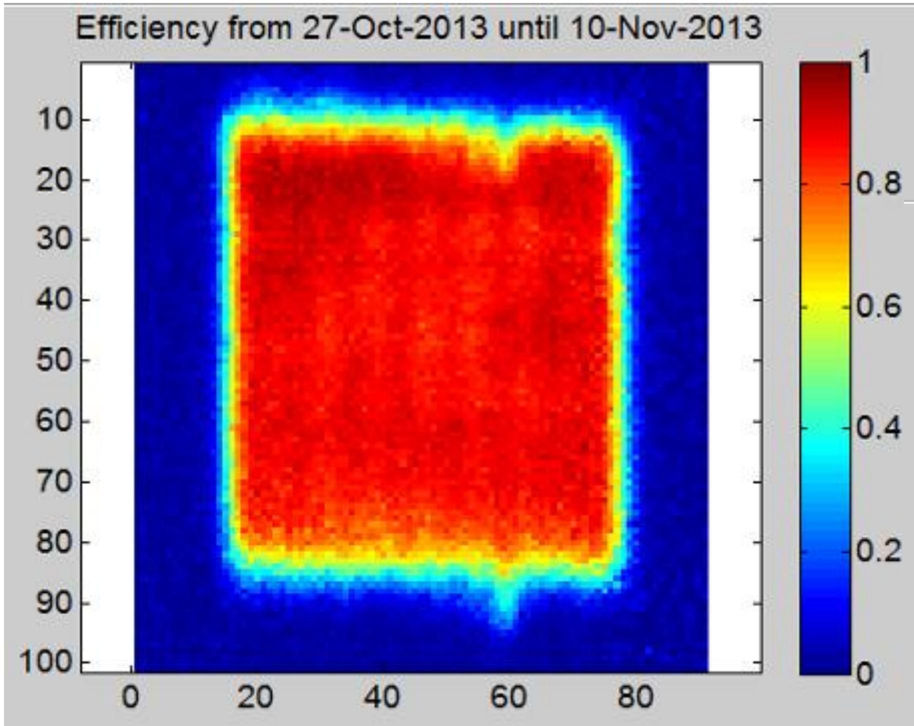


Charge and Streamer Fraction well correlated with E/N

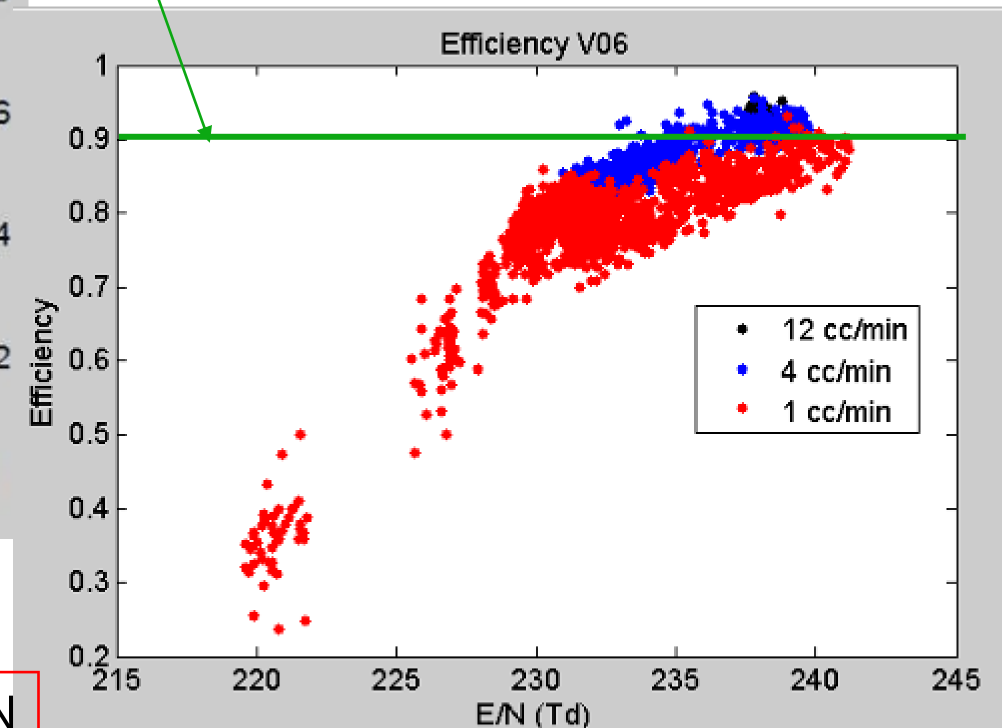
E/N = electric field in the gas/gas density

Long term behavior at low gas flow (RPC06)

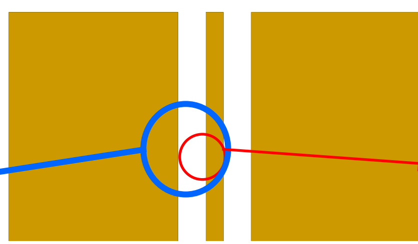
Efficiency well correlated with E/N



Active Pad area fraction



High E/N

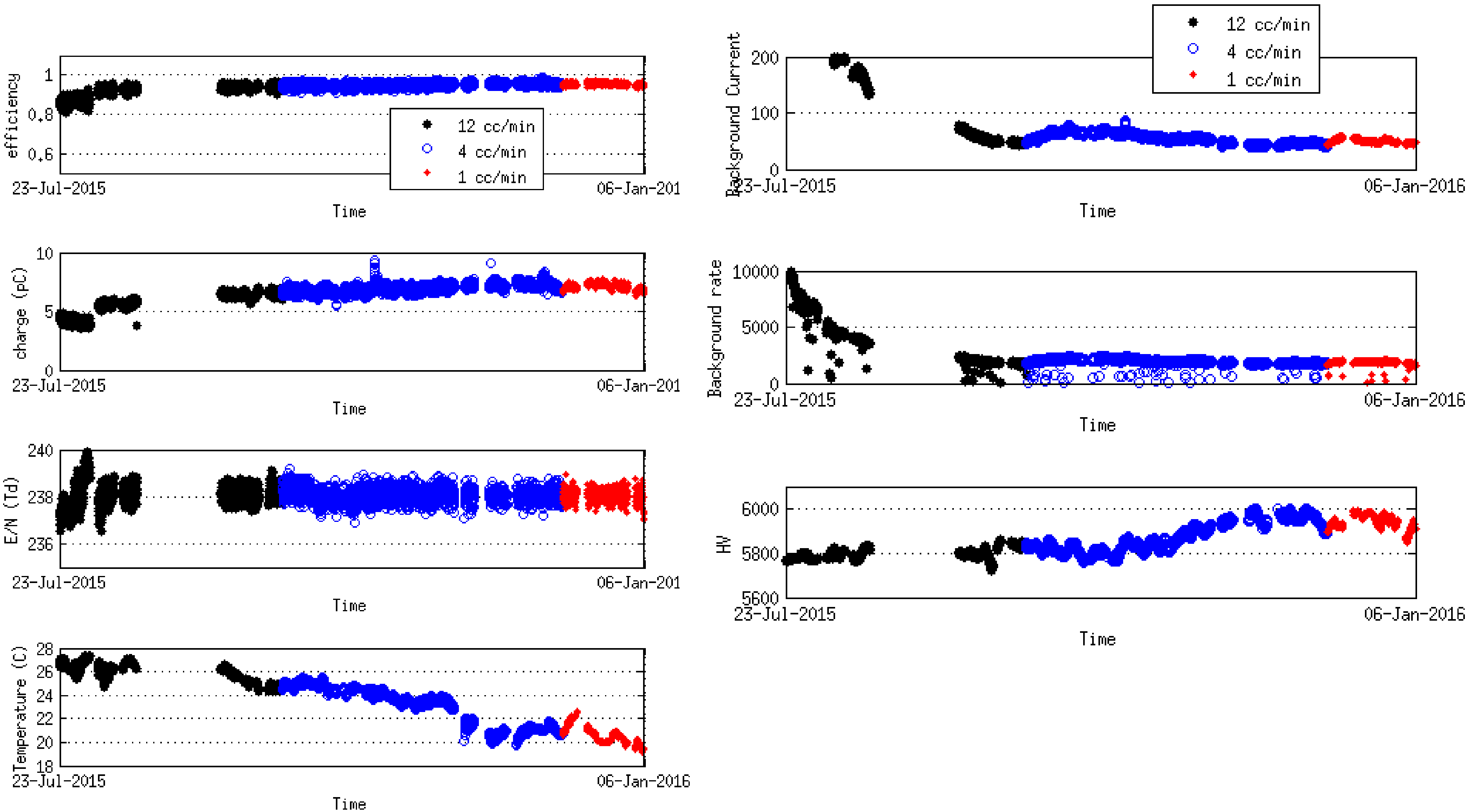


Low E/N

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.

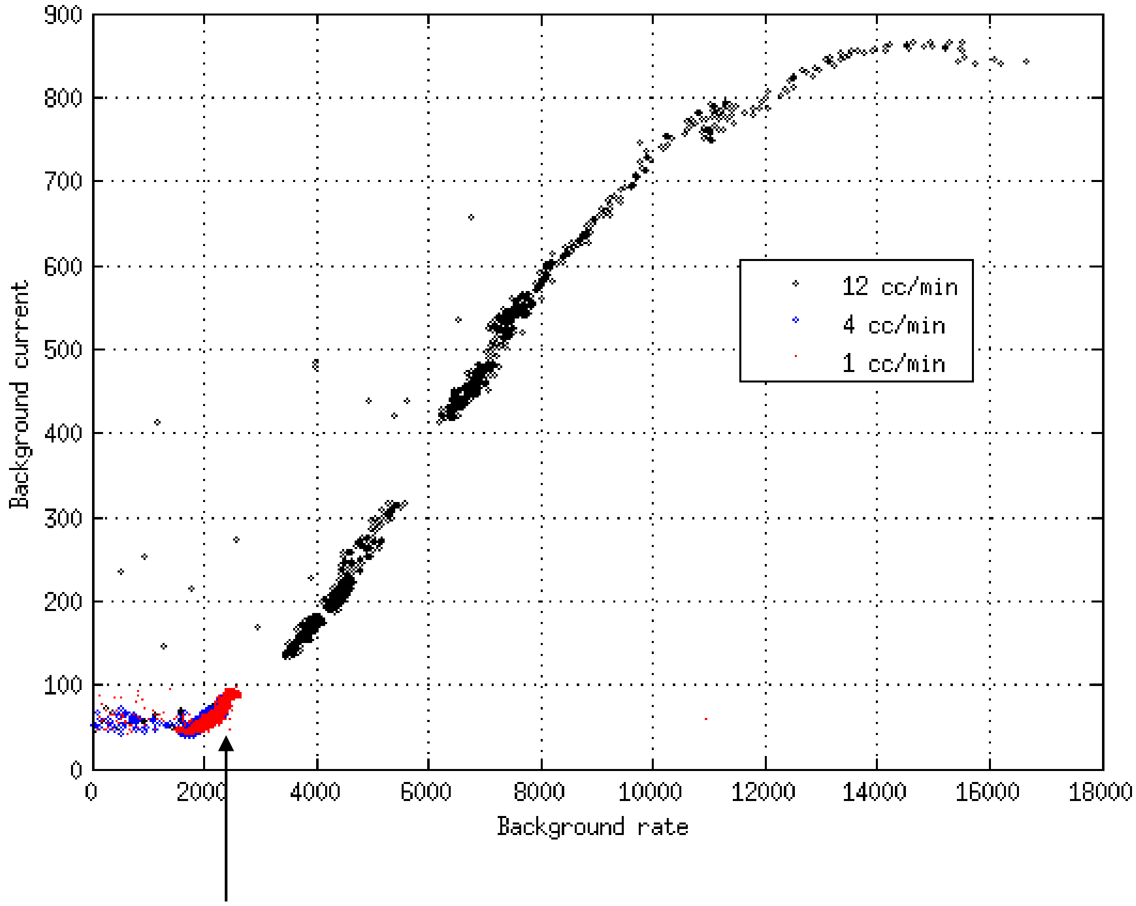
Long term behavior at low gas flow (RPC23) @ E/N=cte

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.
Chambers with HV on since January 2014. Some periods without HV on because of humidity problems in HV connectors (solved), gas (empty bottle) and setup updates.

Field experience@Malargüe – "Gianni Navarra" tank

Really harsh conditions

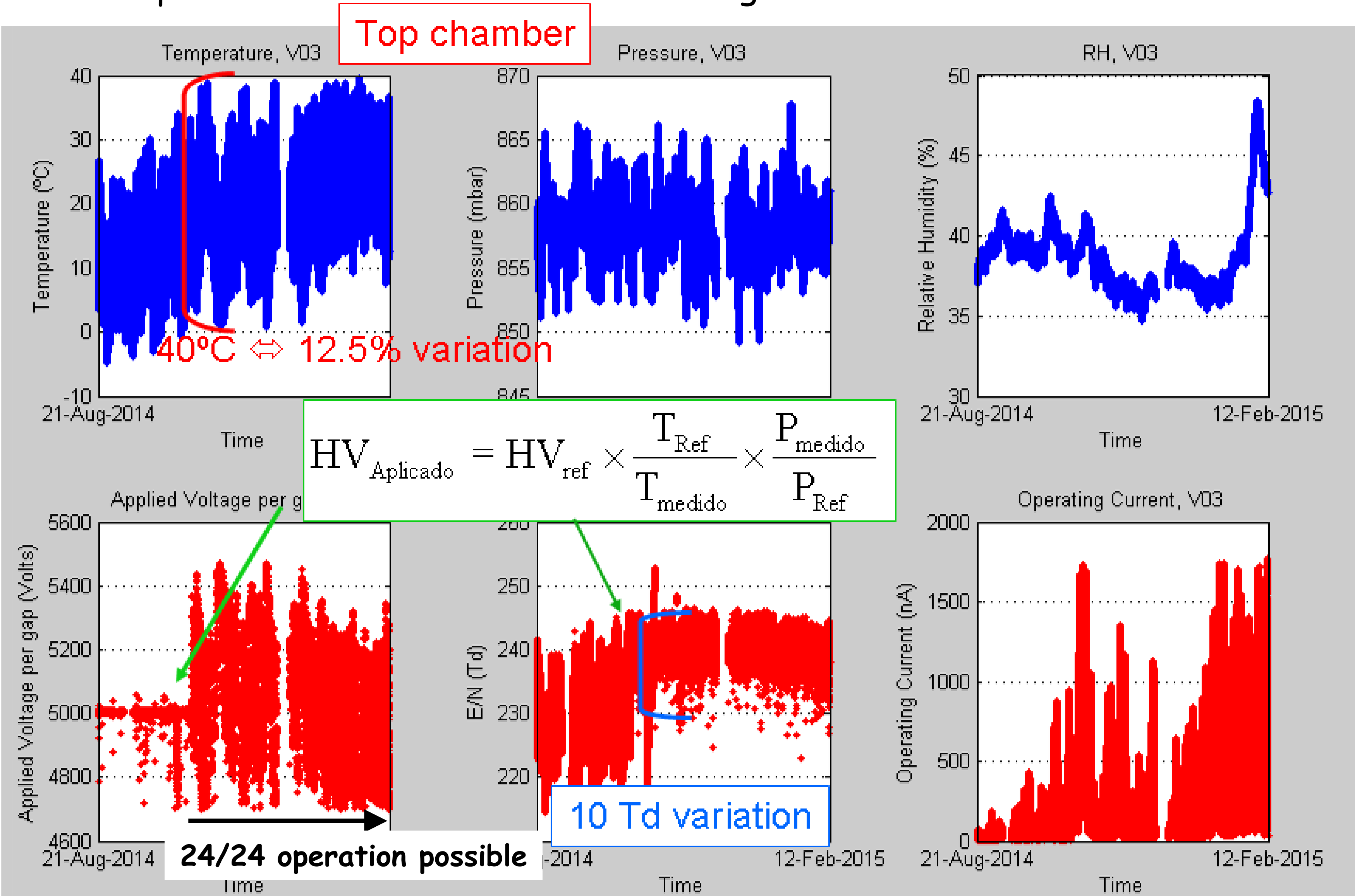
Top detector subject to all environmental variations. Only a small roof avoiding direct Sunlight. This way daily temperature excursions will be very large, so this setup should be a reliable test concerning the robustness of the RPC to operate outdoor.

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

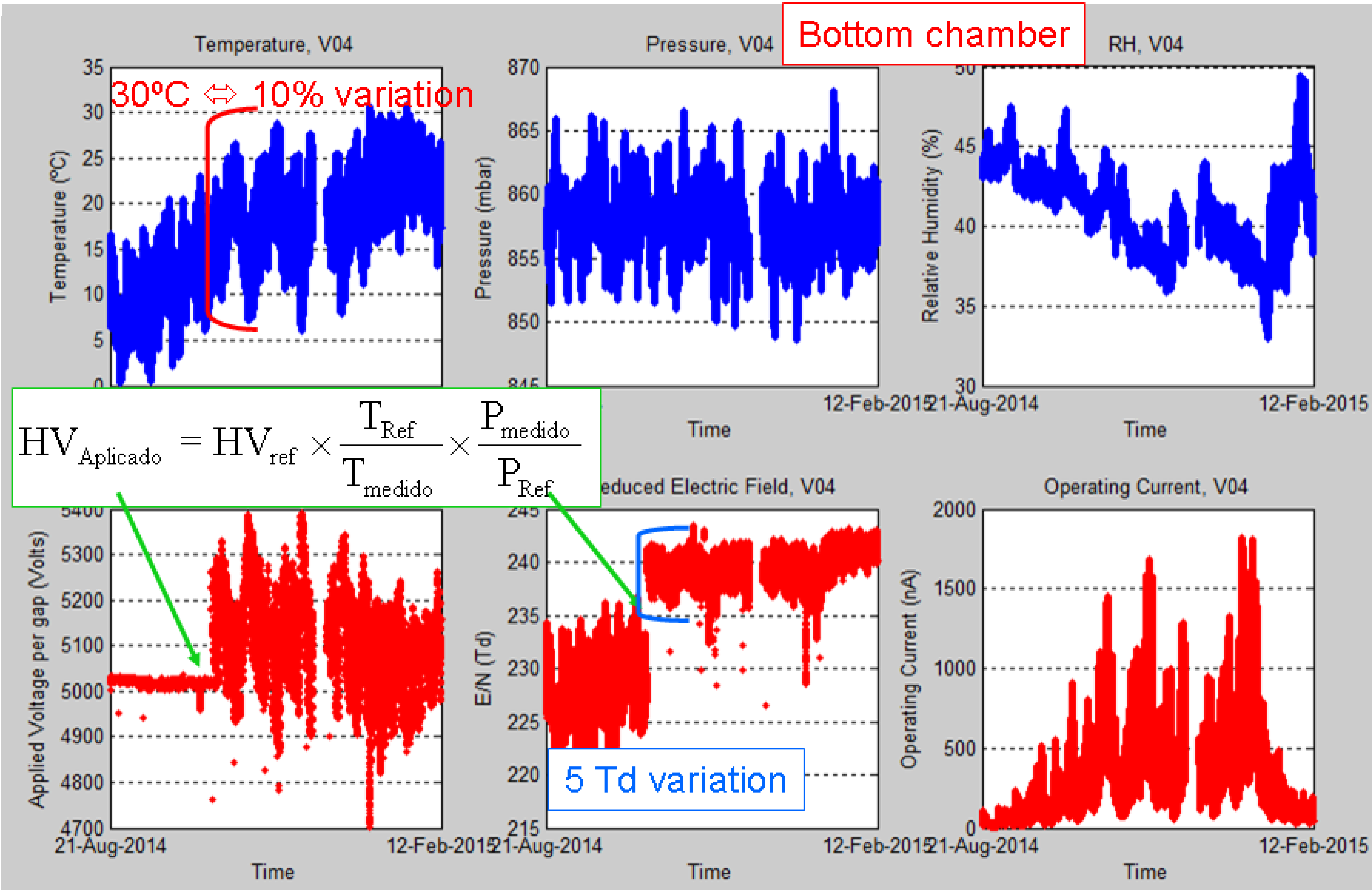
Extreme daily temperature excursions!

Exceeds operational limits at constant voltage



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

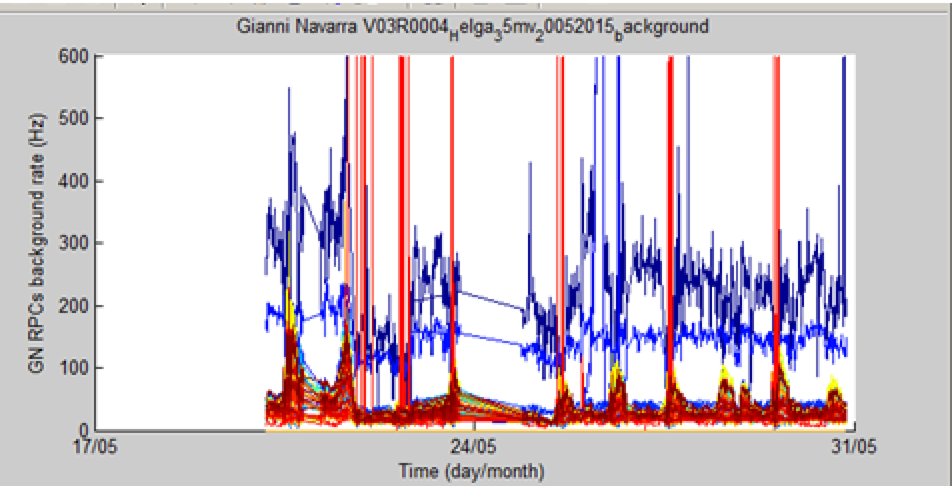
Field experience@Malargüe – "Gianni Navarra" tank

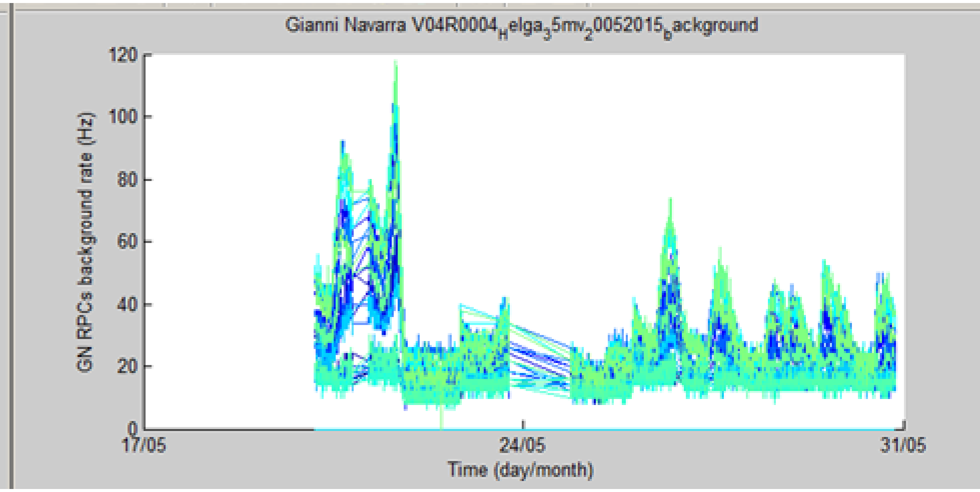


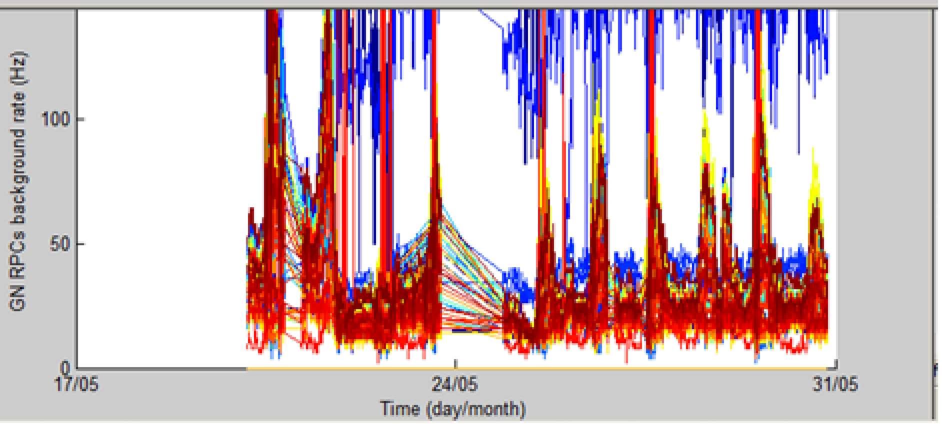
$$HV_{Aplicado} = HV_{ref} \times \frac{T_{Ref}}{T_{medido}} \times \frac{P_{medido}}{P_{Ref}}$$

Field experience@Malargüe – "Gianni Navarra" tank

Background rates







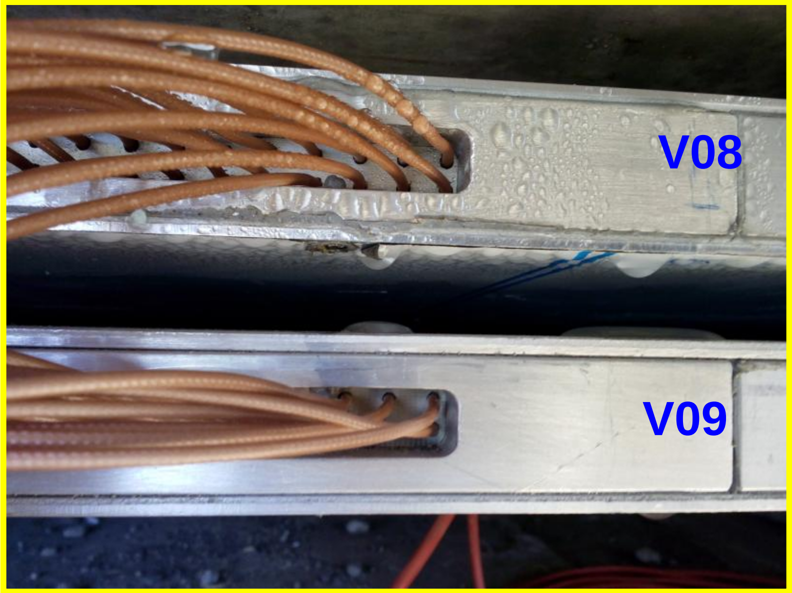
Only a couple of pads with more 100 Hz (0.4 $Hzcm^{-2}$). Which is a very good value.

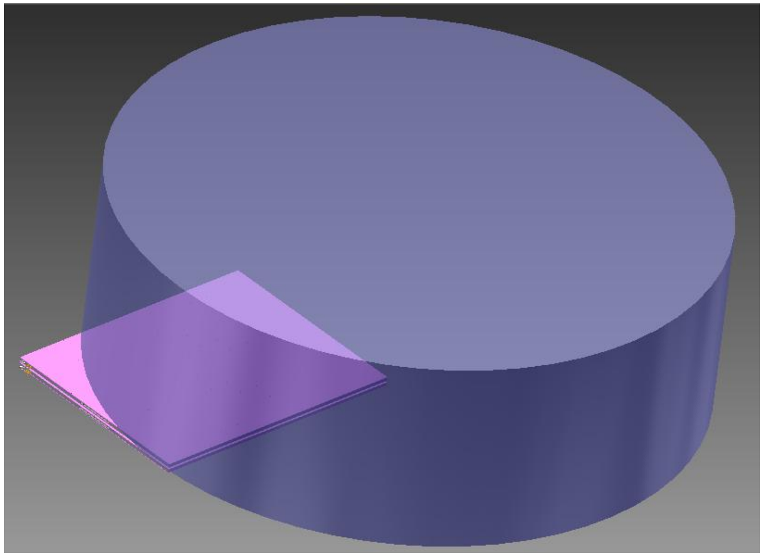
Correlated with temperature even at a "constant" E/N. Higher temperature, higher background rate.

Data from May 2017, PREC electronics

Field experience@Malargüe - 1st MARTA station

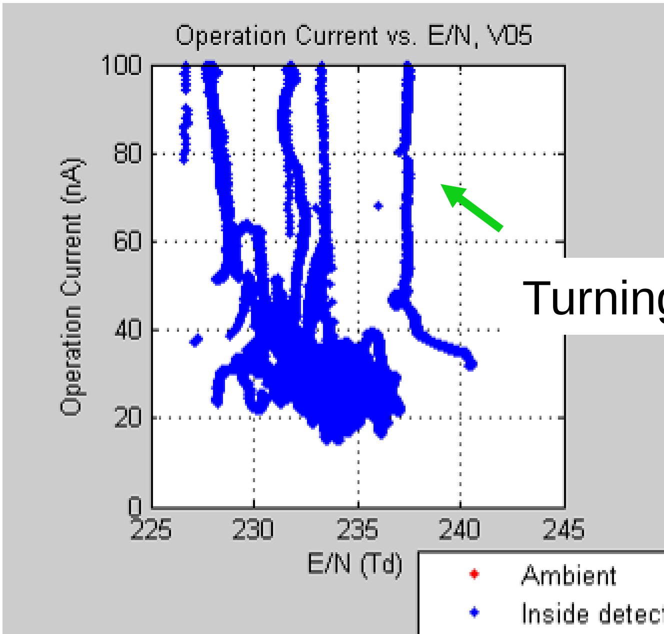
Field experience@Malargüe – 1st MARTA station



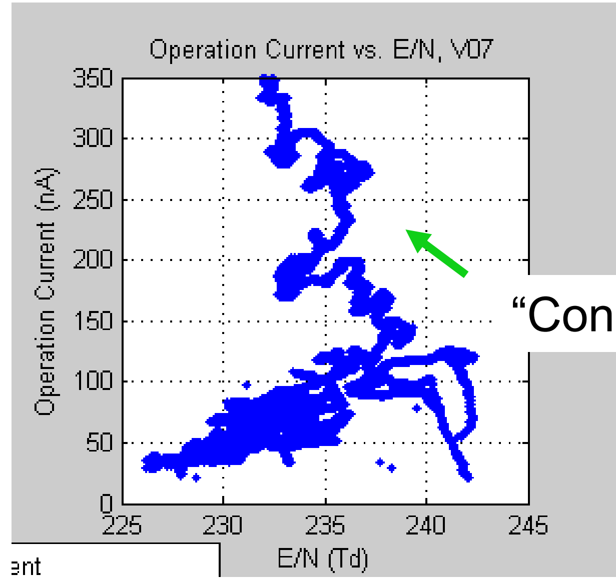


A concrete precast structure is needed to support the tank, filter the electromagnetic component of the shower and act as a protecting house for the RPCs.
Two overlapping RPCs underneath the tank.
This way we can use the tank and one RPC to define the trigger and measure the efficiency in the other RPC

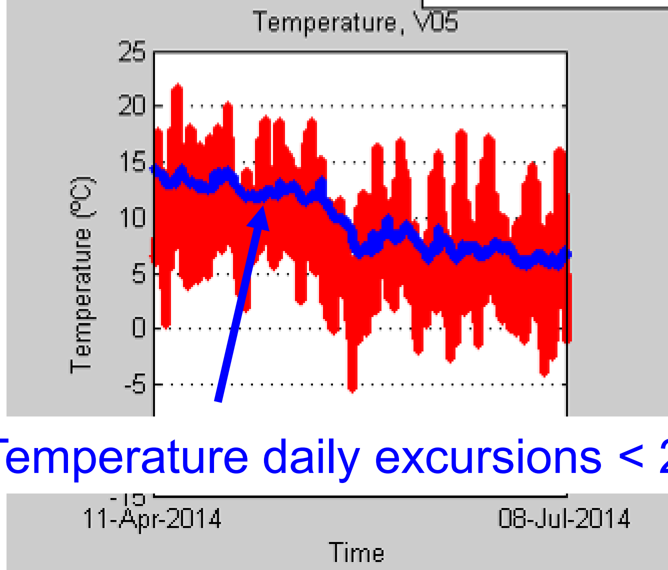
Field experience@Malargüe - 1st MARTA station



Turning on/off

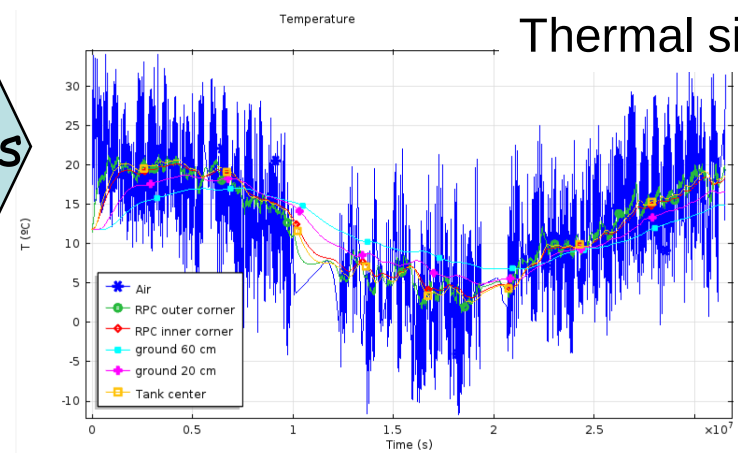


"Conditioning"



agrees

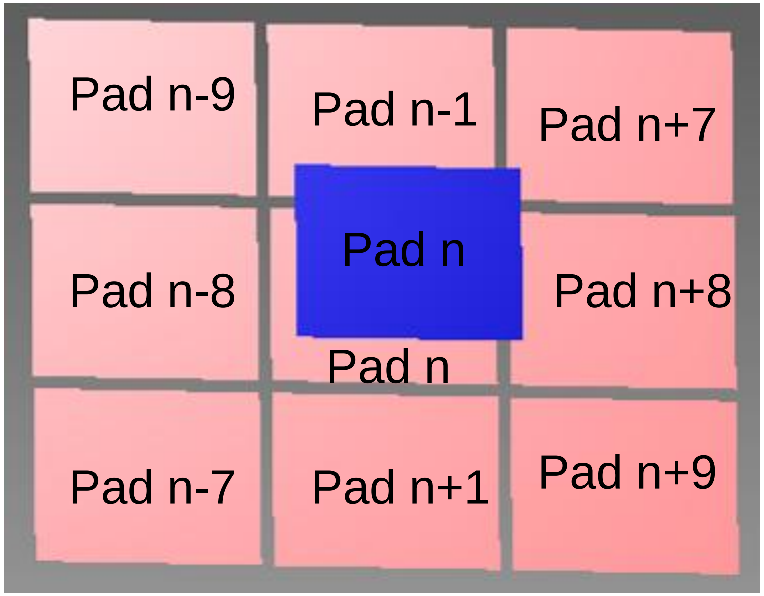
Thermal simulation



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

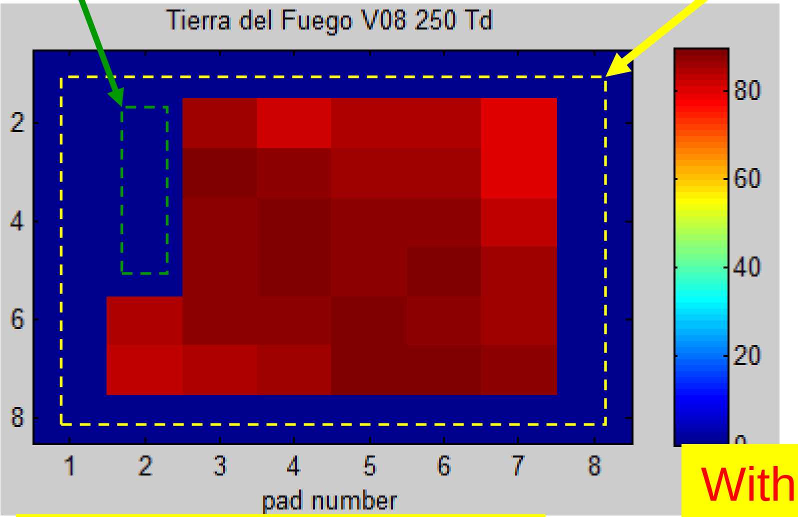
Field experience@Malargüe - 1st MARTA station

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

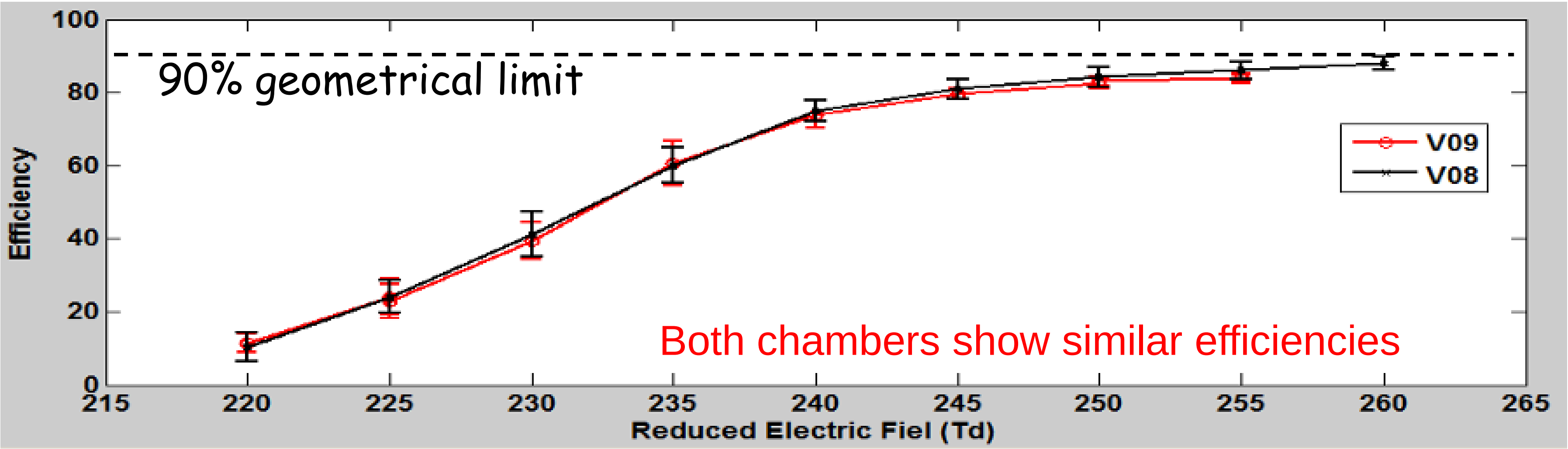


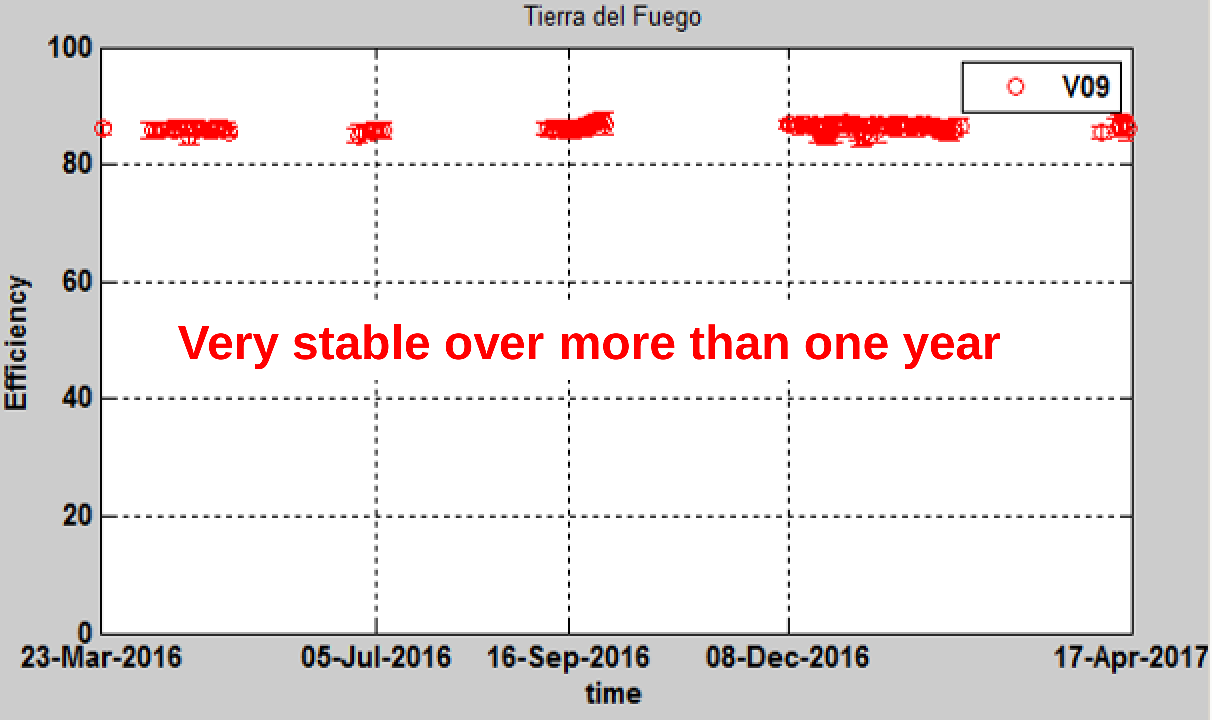
E/N constant

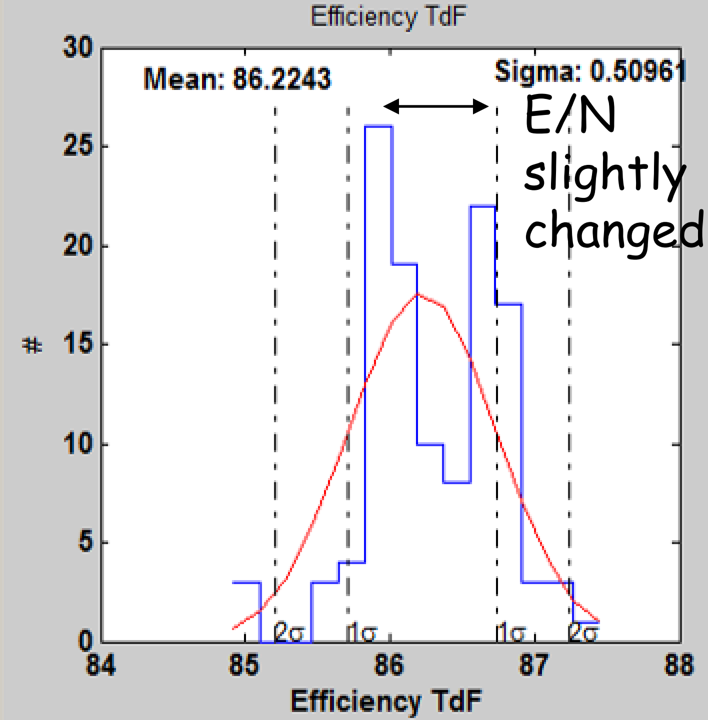
With muons
1 day / point

Uniform over all area

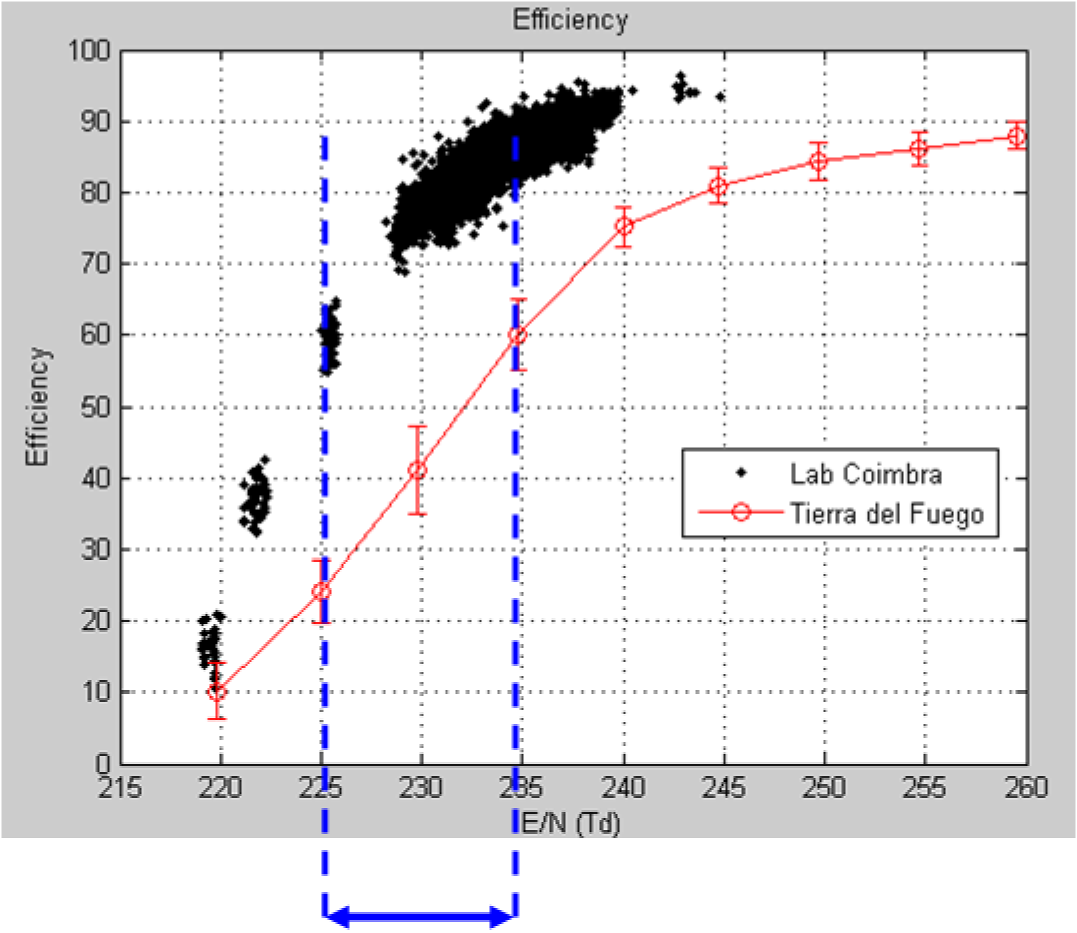
Field experience@Malargüe - 1st MARTA station







Field experience@Malargüe - 1st MARTA station



200 V/gap (1 mm gap)
ΔP=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

Resistive plate chambers performances at low pressure

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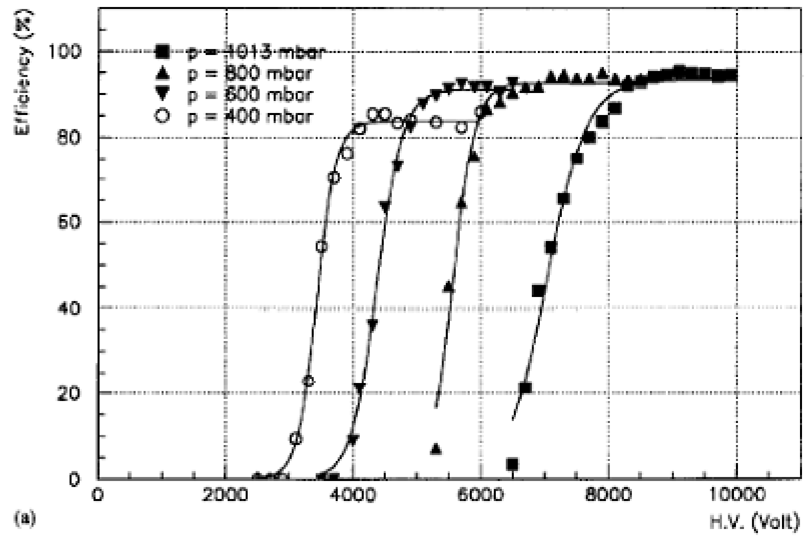
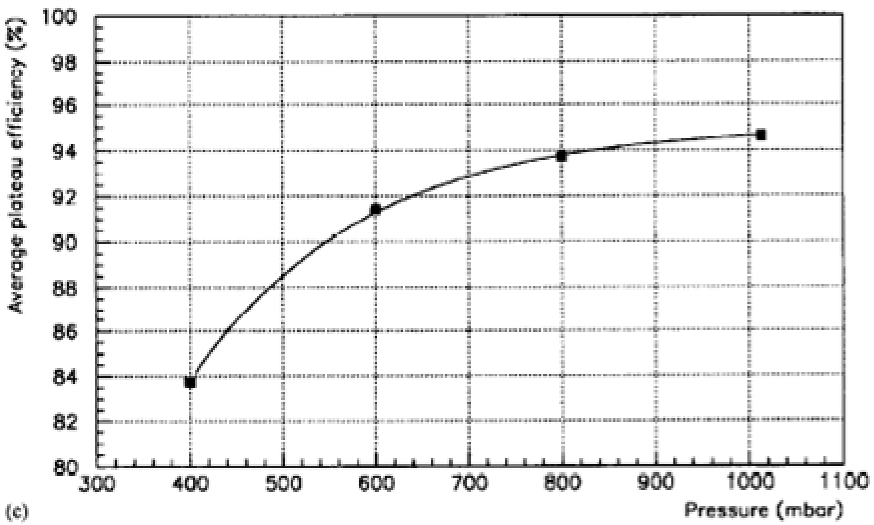
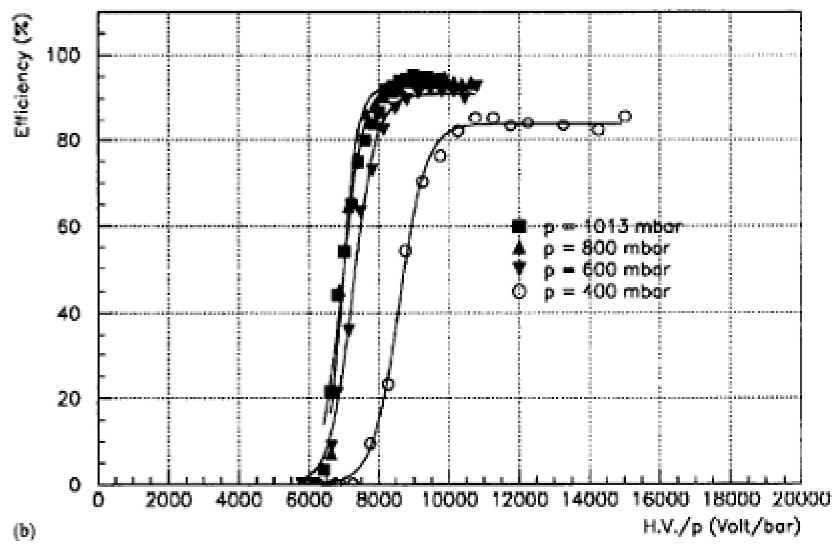
Received 30 December 1996



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

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

$(n = n^{o}\ of\ gaps)$

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*

Whereabouts

Santiago Compostela, Spain

Coimbra, Portugal

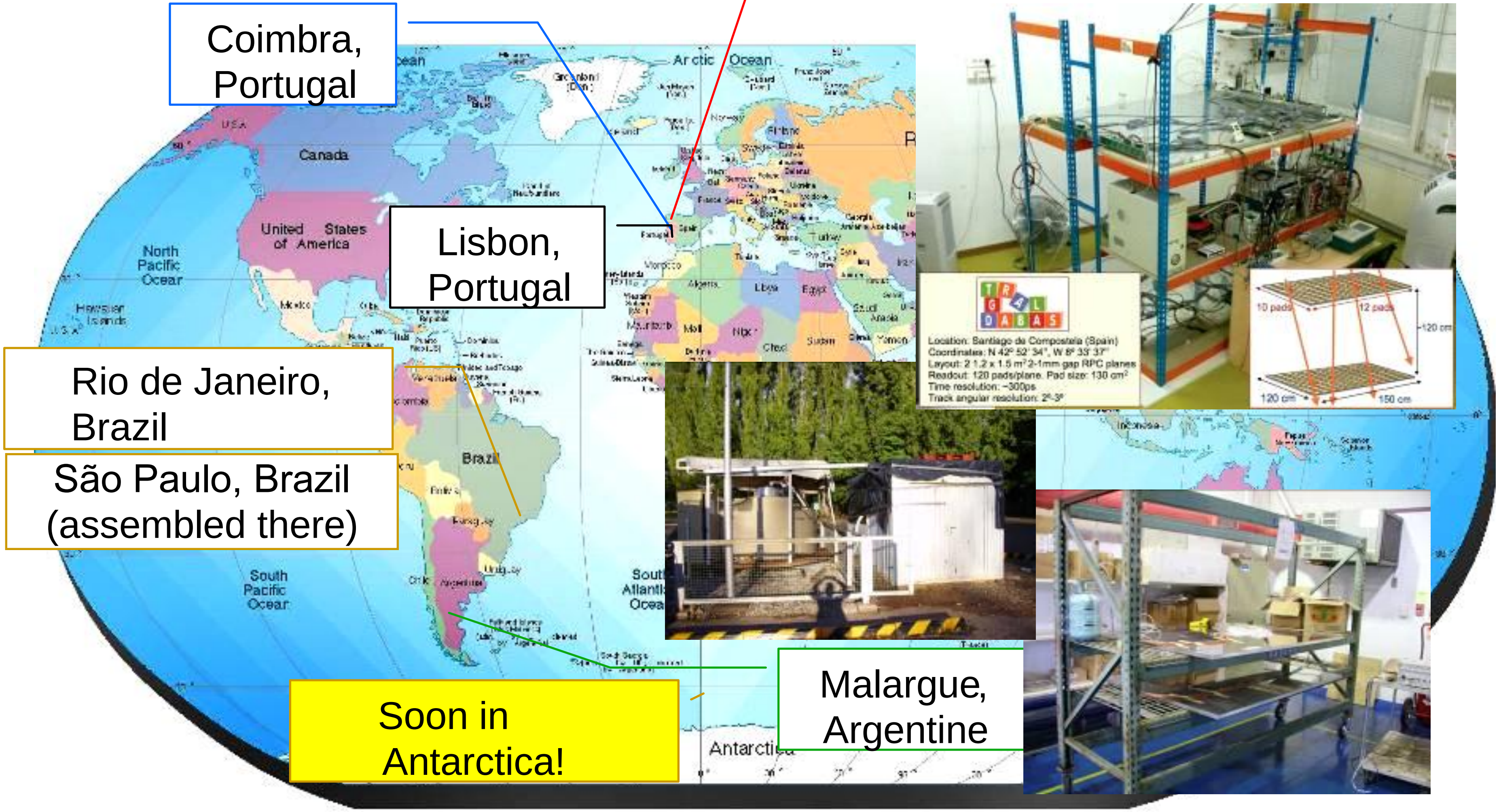
Lisbon, Portugal

Rio de Janeiro, Brazil

São Paulo, Brazil (assembled there)

Malargue, Argentine

Soon in Antarctica!



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 60 RPC volumes were produced and successfully tested. Of these, 29 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.
- To be further deployed in other locations.

For high-altitude operation in Lattes

- Adjust the chamber structure (double nºgaps x gap width)
- Test at realistic low pressure and temperature (talk by Ron Shellard)