Resistive Plate Chambers for the Pierre Auger array upgrade

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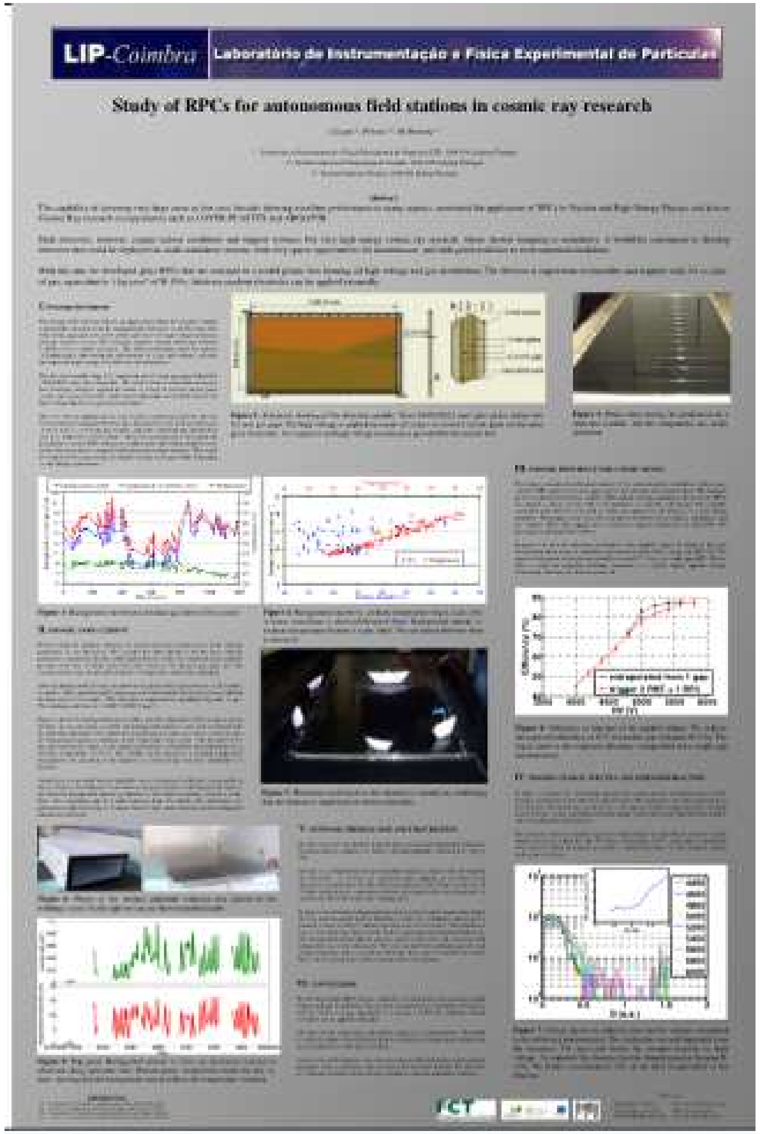
The begin - Outdoor



PoS PROCEEDINGS OF SCIENCE

Study of RPCs for autonomous field stations in cosmic ray research

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The capability of covering very large areas at low cost, besides showing excellent performance in many aspects, motivated the application of RPCs to Nuclear and High Energy Physics and also to Cosmic Ray research in experiments such as COVER-PLASTEX and ARGO/YBJ. Such detectors, however, require indoor conditions and support systems. For very high energy cosmic ray research, where shower sampling is mandatory, it would be convenient to develop detectors that could be deployed in small standalone stations, with very sparse opportunities for maintenance, and with good resilience to environmental conditions. With this aim we developed glass RPCs that are confined to a sealed plastic box housing all high voltage and gas distribution. The detector is impervious to humidity and requires only 0.4 cc/min of gas flow rate, equivalent to 1 kg/year of R-134a. Arbitrary readout electrodes can be applied externally.

XI workshop on Resistive Plate Chambers and Related Detectors (RPC2012)
INFN-Laboratori Nazionali di Frascati, Italy
February 5-10, 2012

1.Introdution

The abundance of available literature confirms that Resistive Plate Chambers [1] have been applied with great success in many High Energy and Nuclear Physics experiments over the

[1] Speaker

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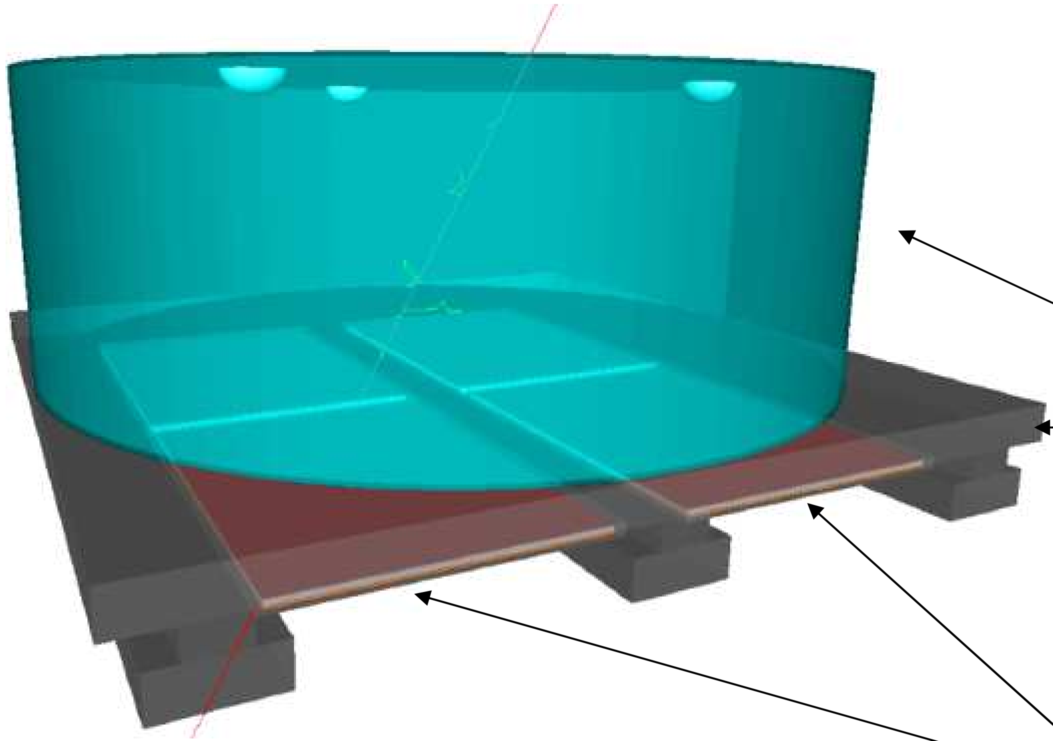
PoS (RPC2012) 043

Muon Auger RPC Tank Array

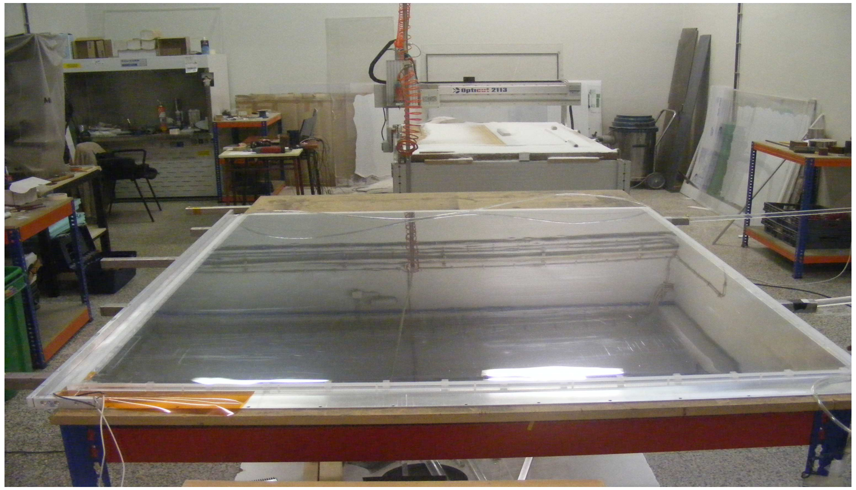


- Water tank
- Precast structure
  - Support the tank
  - Filter part of the electromagnetic component of the shower
  - Protect the RPCs from natural environment
- RPC modules

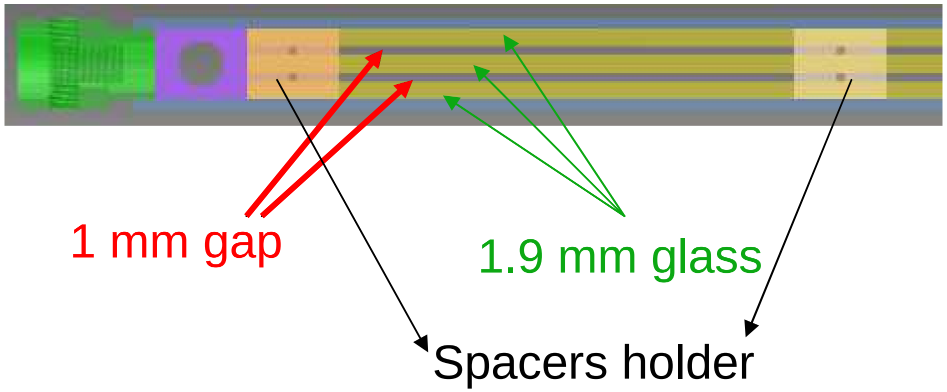
MARTA - Requirements

- Large area $\Rightarrow$ Low cost, ok
- Station should respect the natural environment, ok
- Very low maintenance, none is the goal, ok
- Time resolution, few ns, ok
- Low power consumption, under study
- Outdoor operation
  - Large temperature operation interval, out of normal indoor conditions, ok
  - Requires very low gas flow rate and mono-component gas mixture
    - Mono-component mixture, ok
    - Very low flow rate, equivalent to 1 kg/year or less, under study
  - HV insulation is of main importance
    - Physical independence between sensitive volume and readout electronics, ok
  - Stable efficiency over time, ok

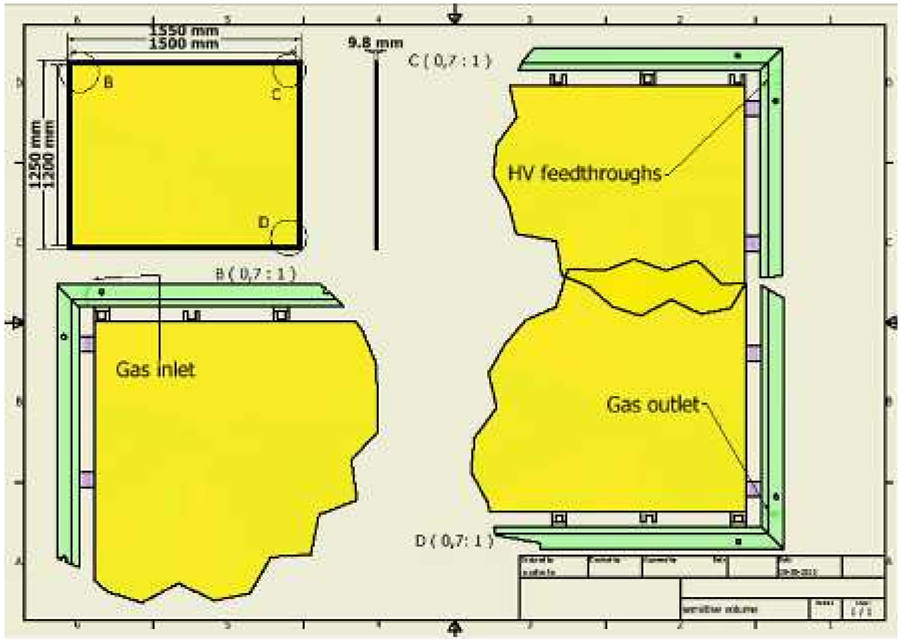
RPC MODULE



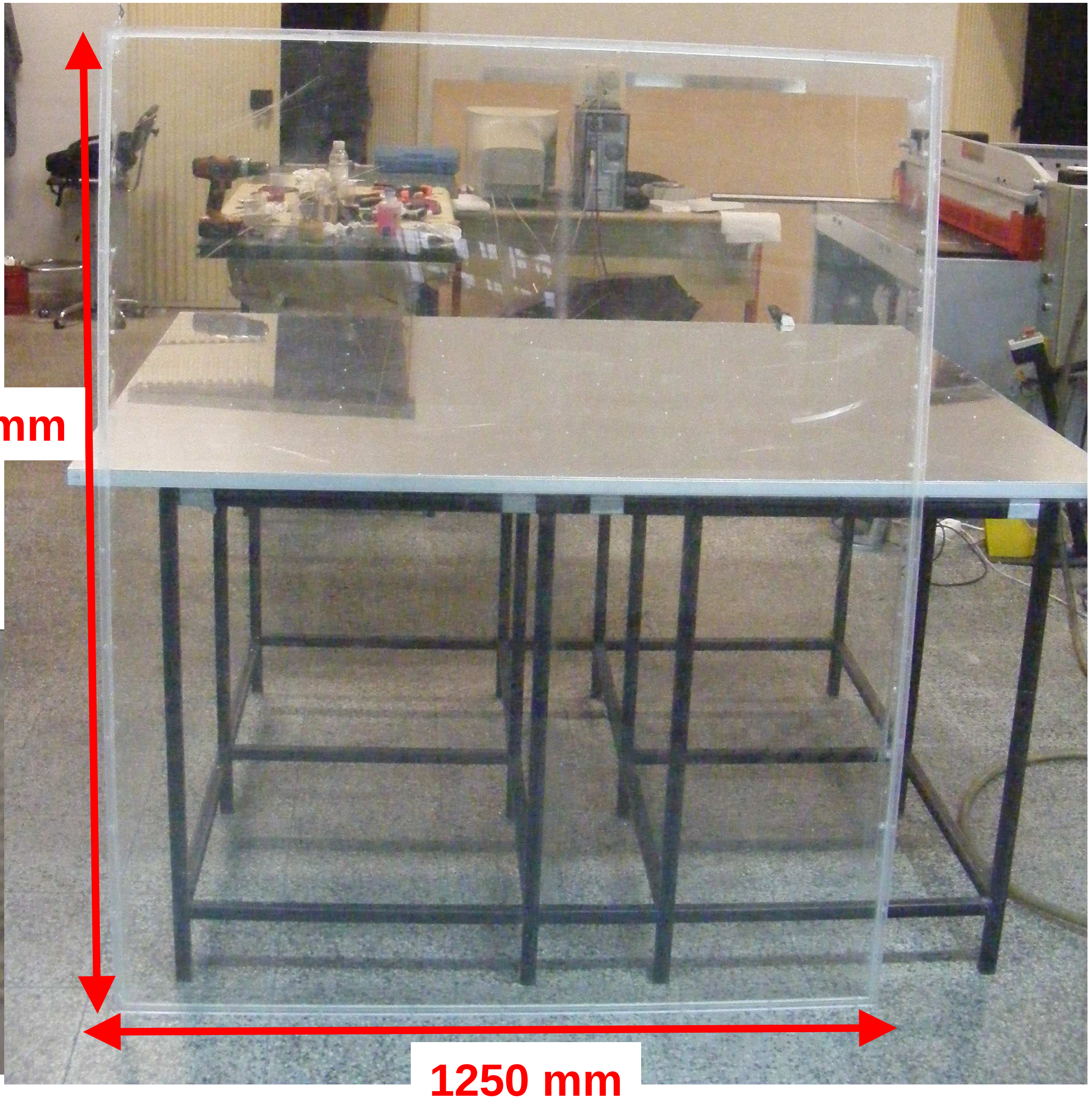
Glass RPC in avalanche mode



100 % R-134a, small commercial bottles



GAS VOLUME – **ACRYLIC BOX**



GAS VOLUME - **HV PAINT**

Glass storage room

Glass Wash

Glass Paint room

Paint resistivity Check point 1

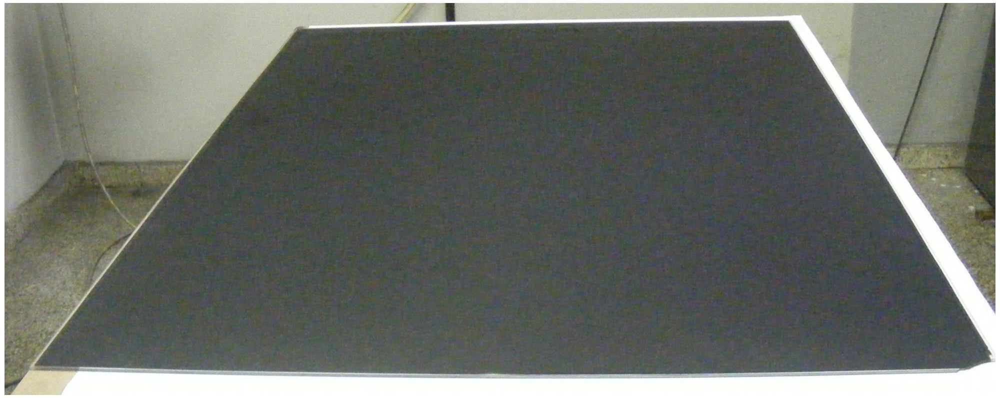
Paint resistivity Check point 2

measured by non-contact capacitive coupling

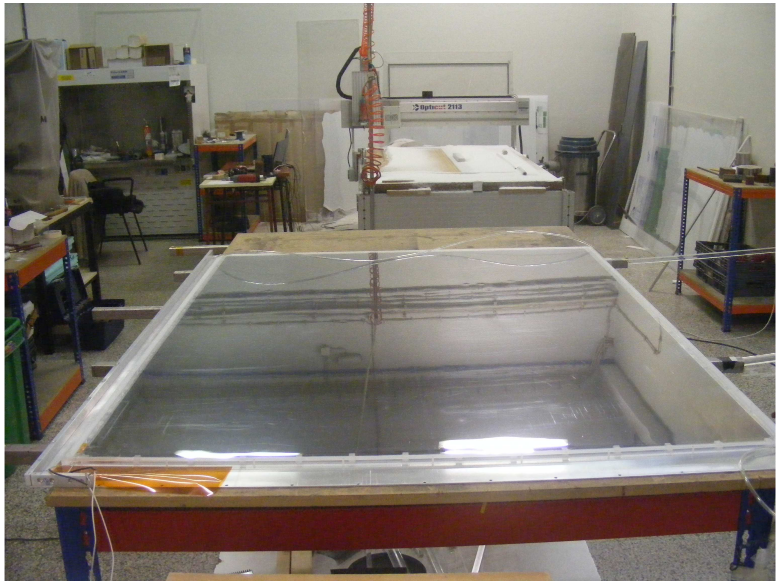
First layer

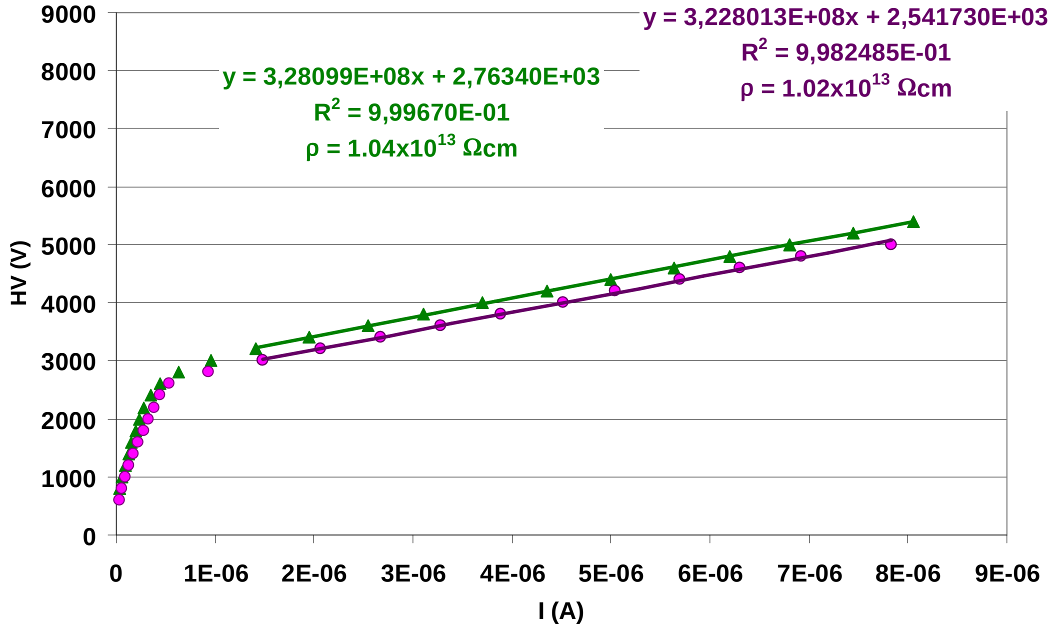
Second layer

Ready to assemble the detector



GAS VOLUME – **Argon Discharge**





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

3 glass electrodes

In this stage we check/do:

-Gaps uniformity

-Clean the gaps

-glass electrodes resistivity

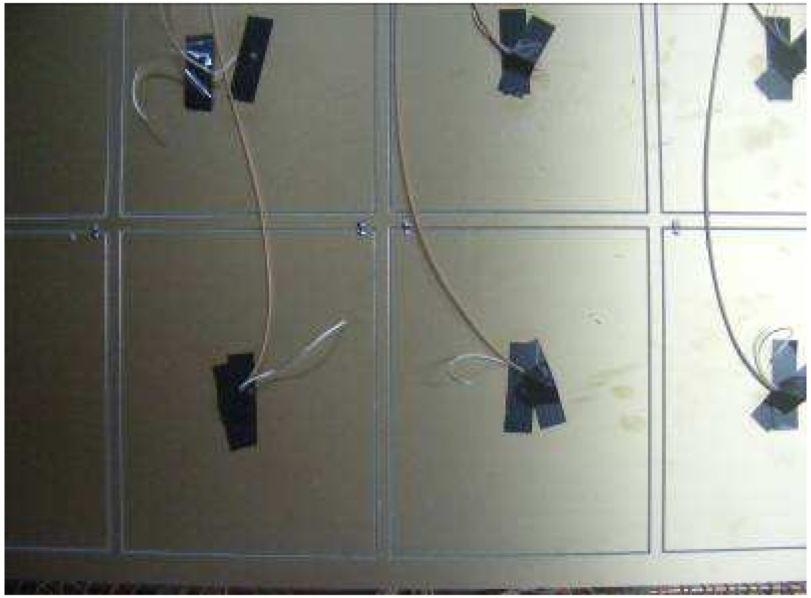
-Better to have the volume filled with Argon instead of air when start flushing with R-134a

SIGNAL PICKUP MODULE

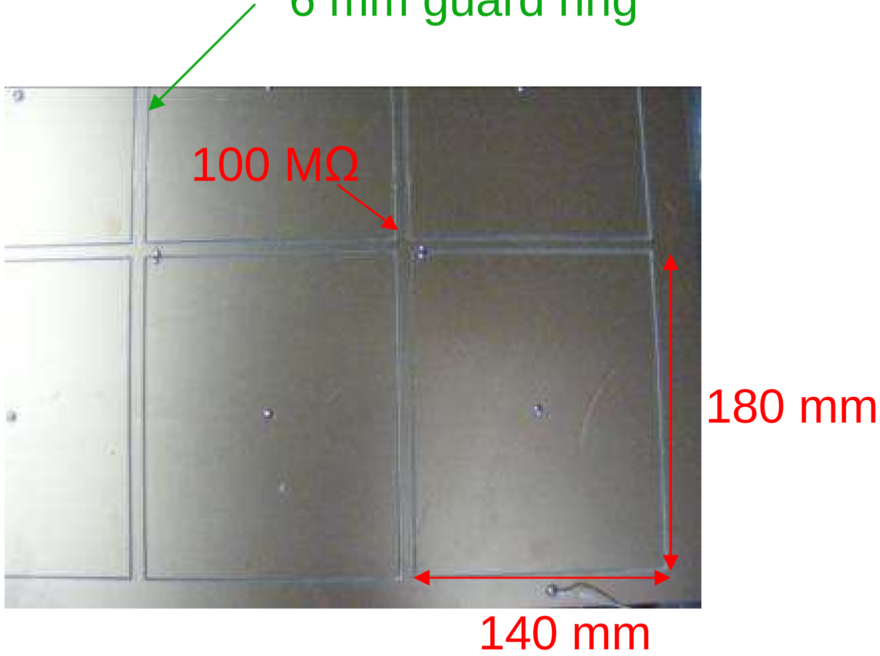
Total area 150x120 = 18000 cm^2

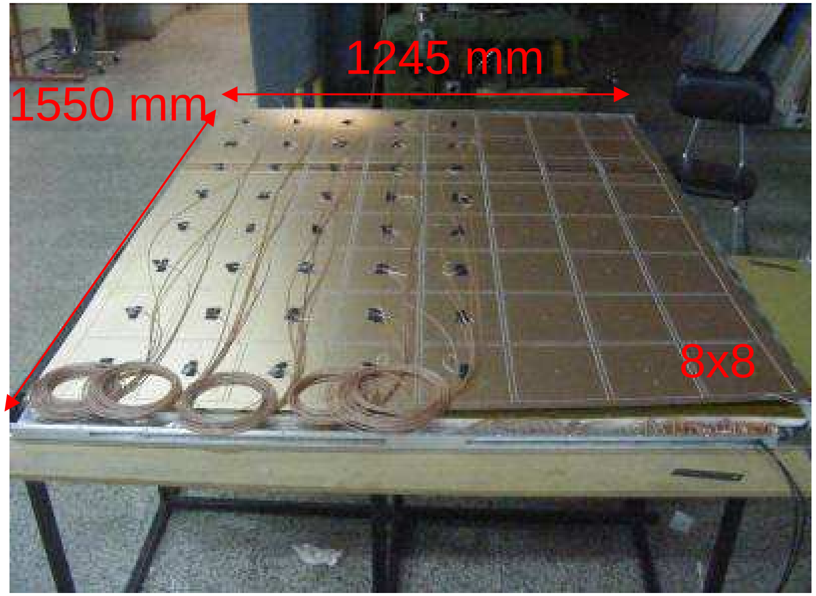
Area covered with pads, “efficient” area
64x18x14=16128 cm^2 ⇔ 90 % of the total area

Area covered with guard rings,
18000 - 16128 = 1872 cm^2 ⇔
10 % of the total area

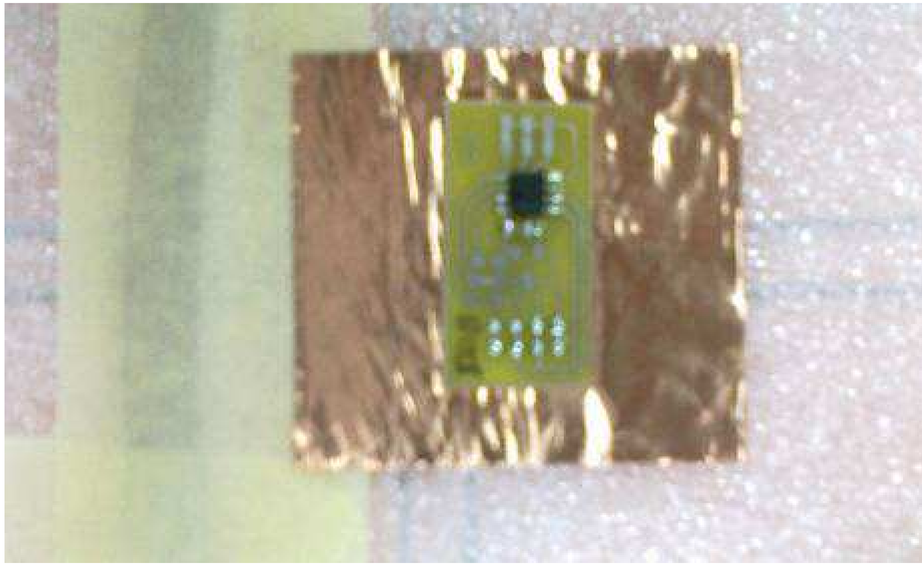


6 mm guard ring





AMBIENT MONITORING SYSTEM



I2C bus

Negligible Power Consumption

"Inside" the detector

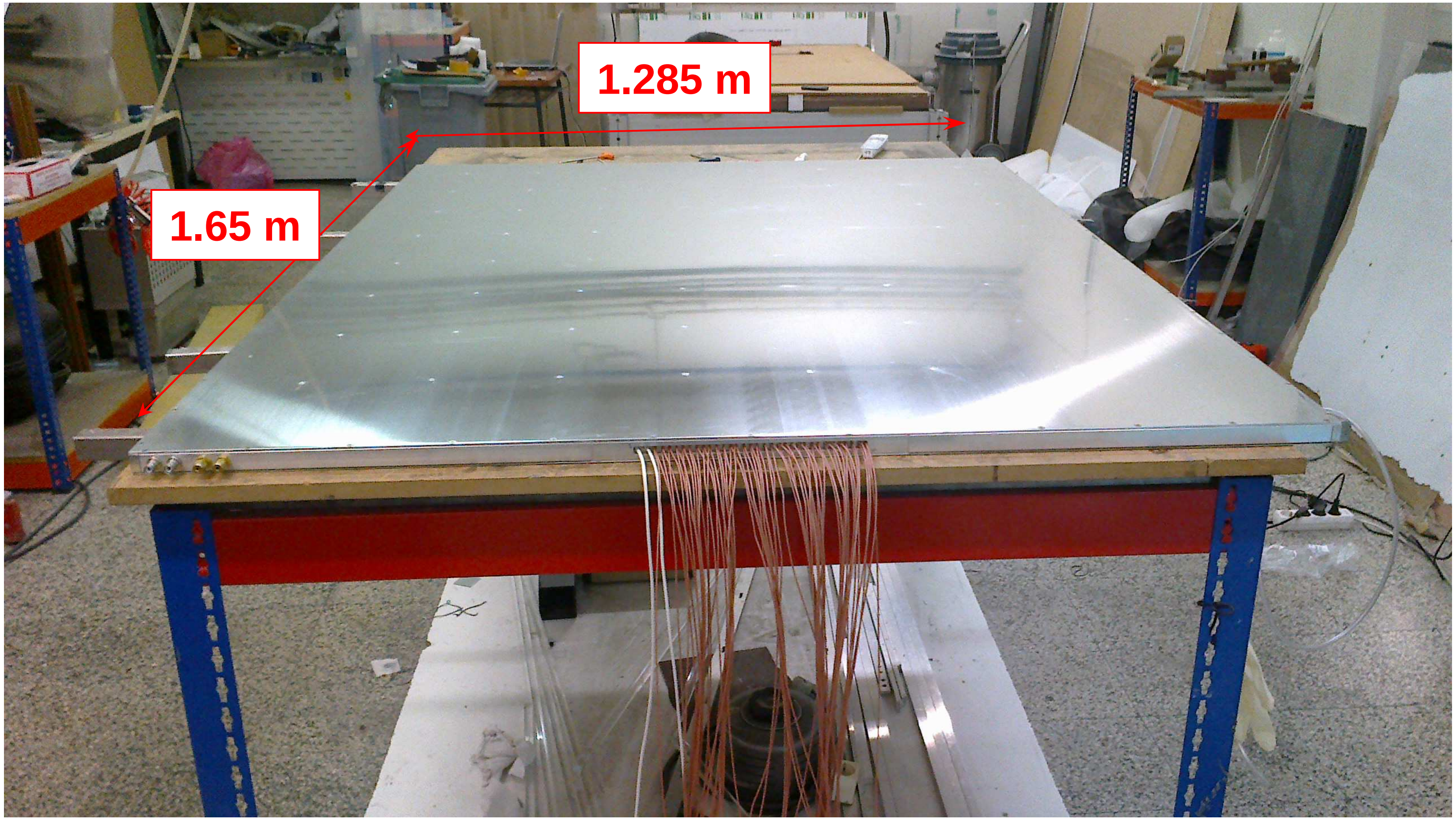
- 7 Temperature
- 2 Relative Humidity
- 1 Ambient Pressure

Outside the detector

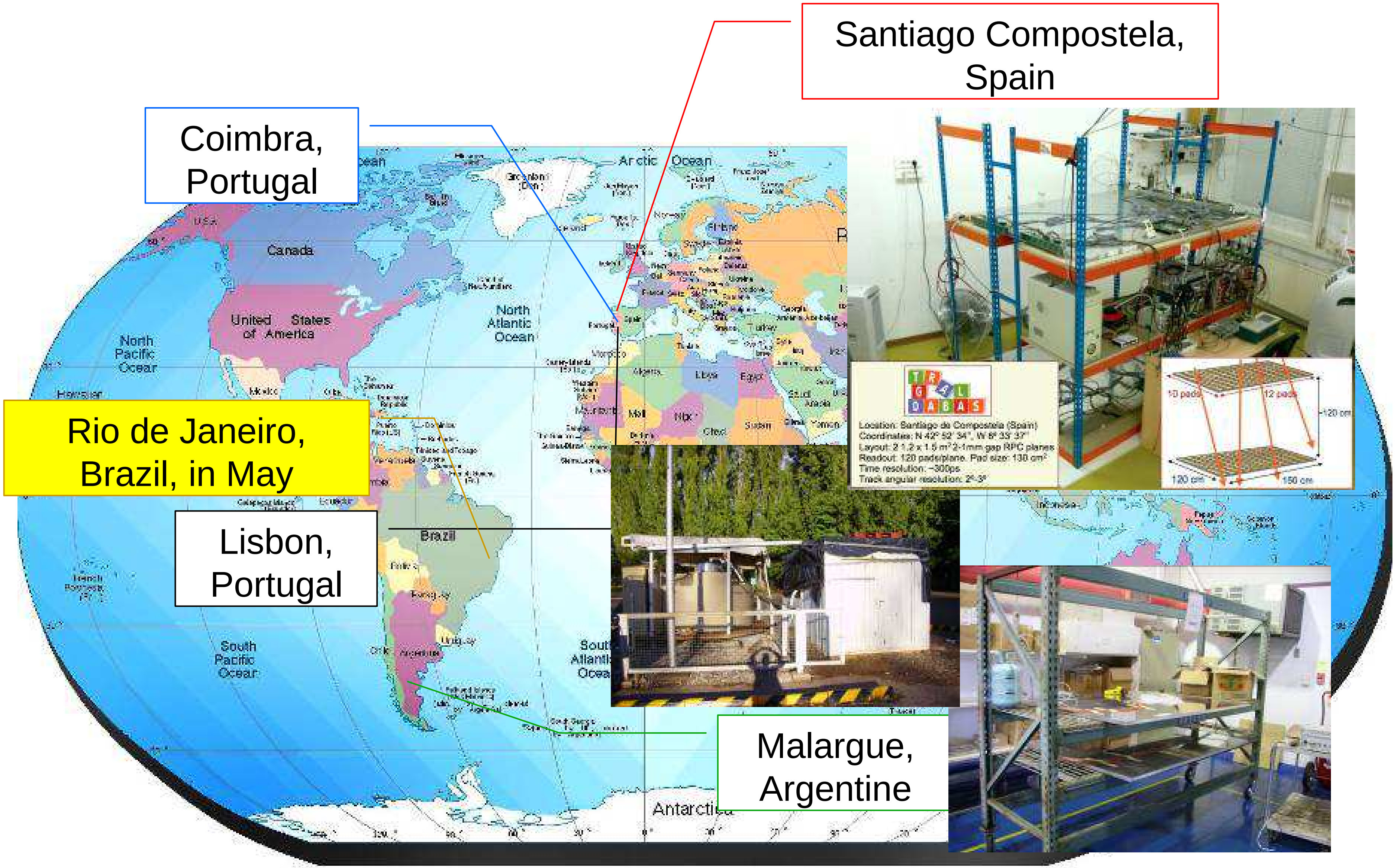
- 1 Temperature
- 1 Relative Humidity
- 1 Ambient Pressure

RPC – Module

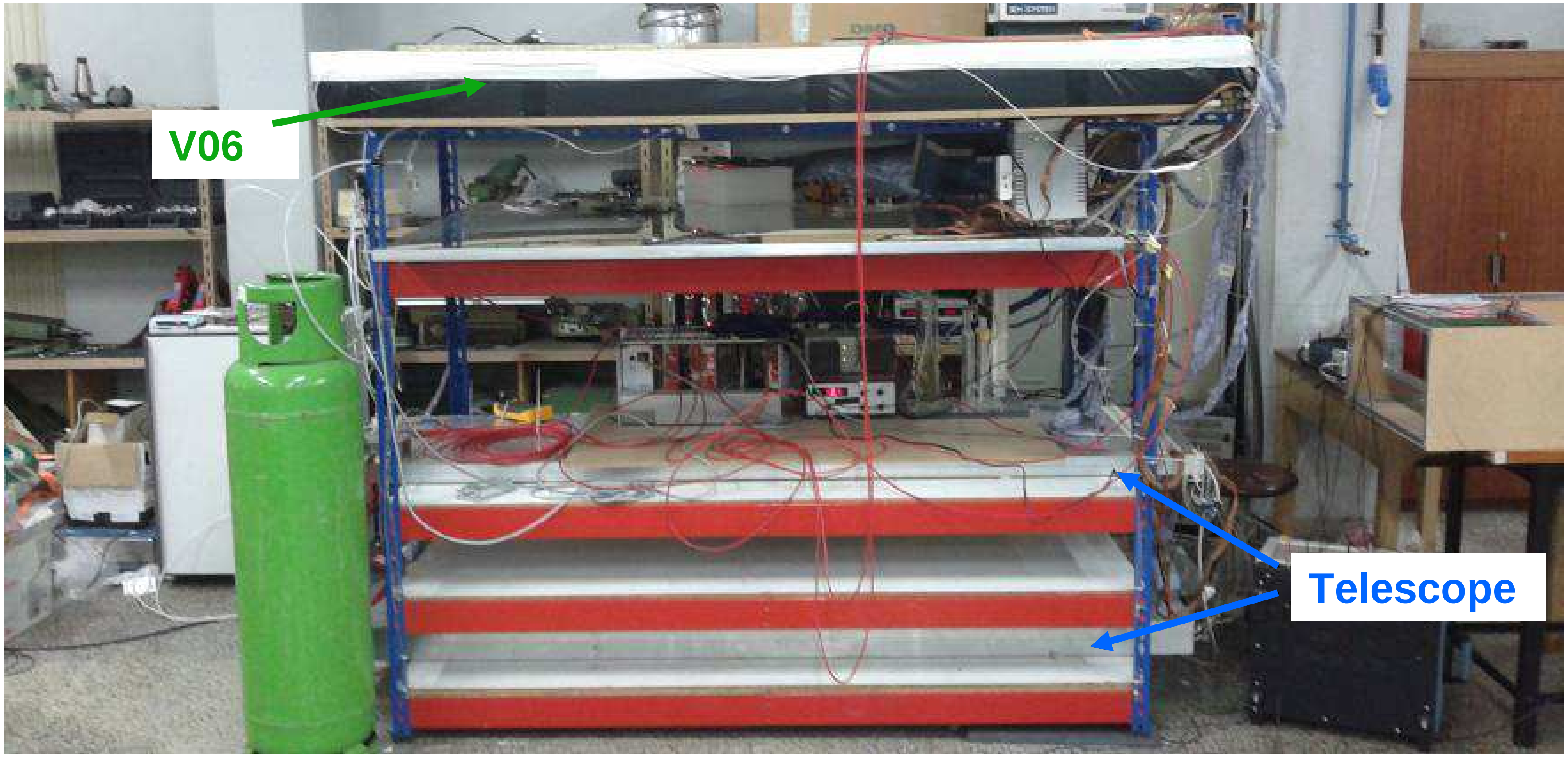
Aluminum case almost 100% sealed



RPC - where we can find them

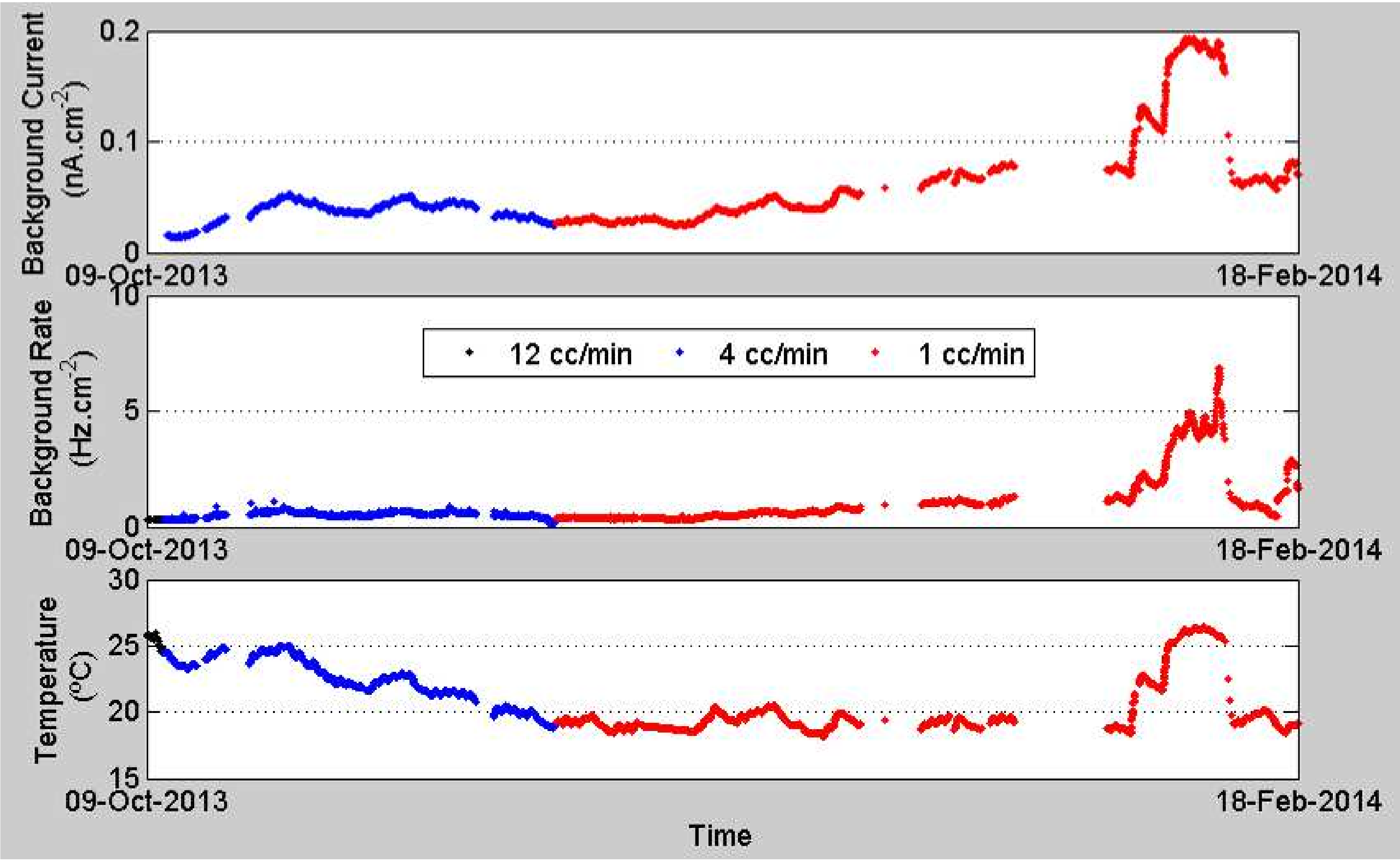


RPC test setup

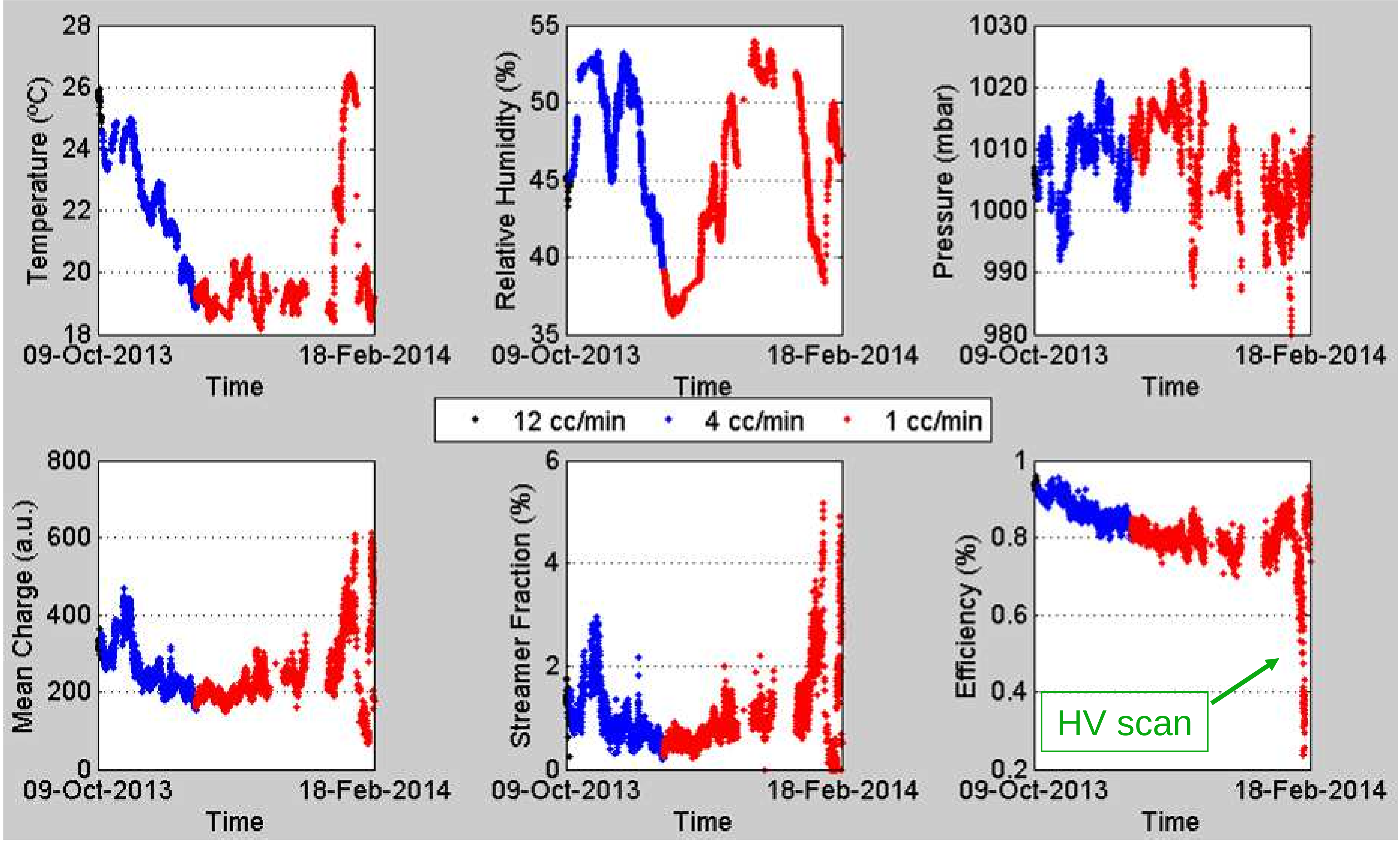


We are able to monitor "all" the practical quantities of the RPC module: current, counting rate, charge, streamer fraction, efficiency. At the same time we monitoring the ambient : temperature, pressure and relative humidity. With this data we easily validate each RPC module.

Analysis – raw data



Analysis – raw data

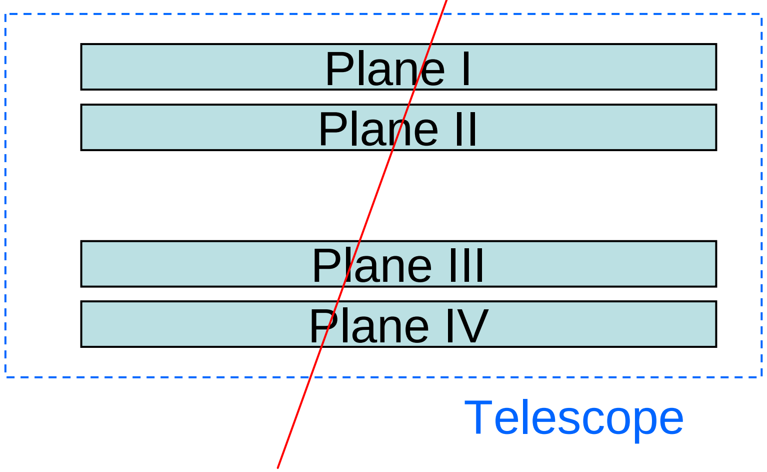


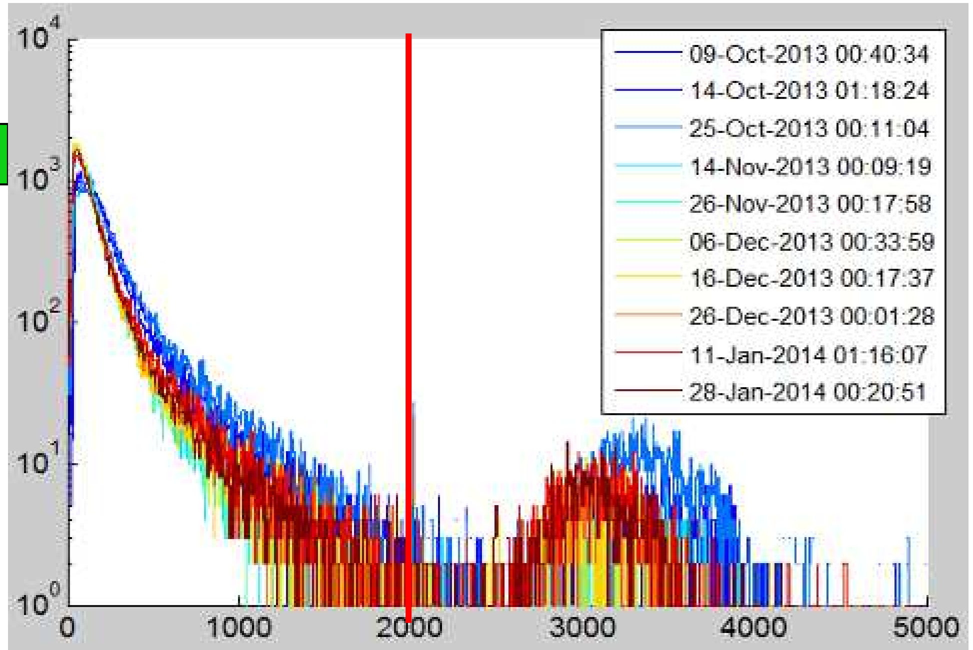
Analysis - Signal

RPC under test

Hit, is valid trigger that gives signal in the region cover by the RPC under test

Valid trigger ⇔ valid signal in the 4 planes





$$Streamer\ Fraction = \frac{\#hits\ Q > 2000}{\#hits} \times 100$$

$$real\ eff = 1 - \frac{1 - mean\ eff}{1 - mean\ dark\ eff}$$

Analysis – Reduced Electric Field

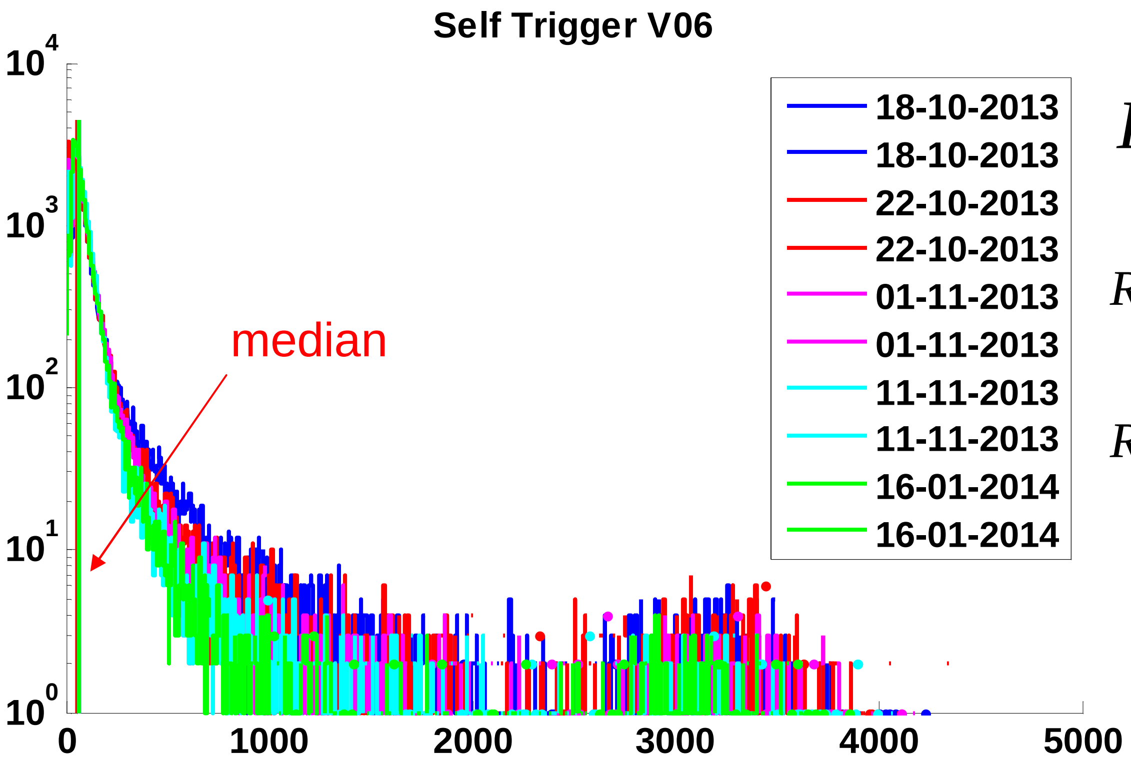
$$\frac{E}{N} = 0.0138068748 \times \frac{V_{eff,Volts}}{d_{cm}} \frac{\left(T_{°C} + 273.15\right)}{P_{mbar}}, \quad [Td]$$

$$V_{eff} = V_{applied} - R_{cm^2} I_{cm^2}$$

$$I_{cm^2} = r_{cm^2}^{background} \times Q_{median}^{background}$$

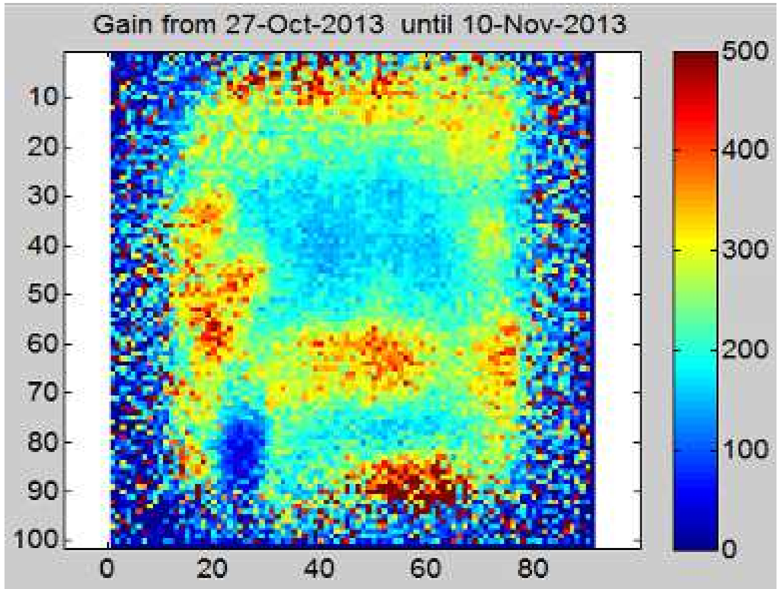
$$R_{cm^2} = \rho \times \frac{l}{S} \Leftrightarrow$$

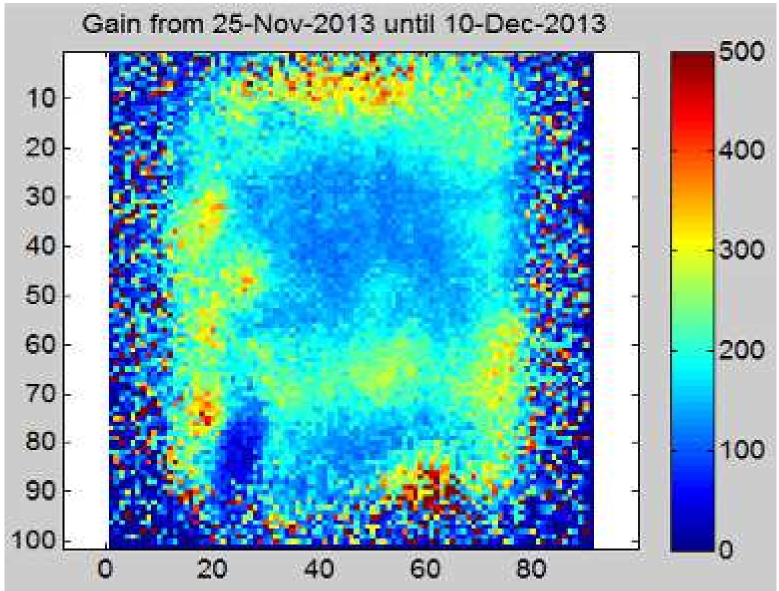
$$R_{cm^2} = \underbrace{10.5 \times 10^{12} \times 10^{\left(\frac{20 - T_{°C}}{24.3}\right)}}\times \frac{1.5 \times 0.19}{1}$$



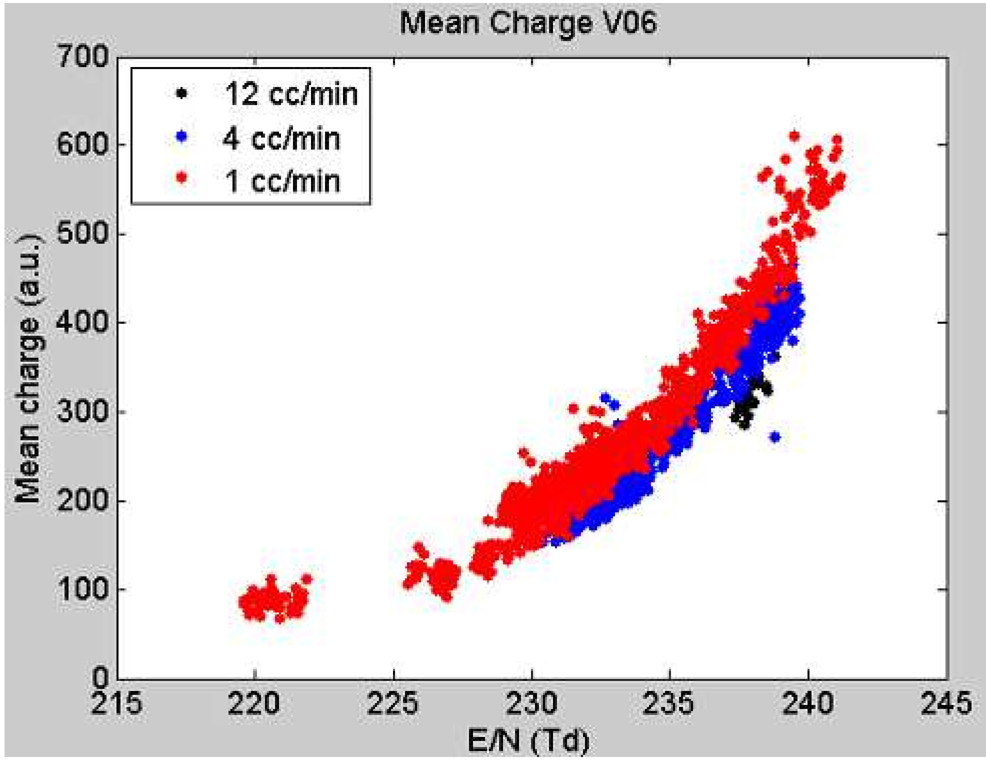
D. González-Díaz et al., Nuclear Instruments and Methods in Physics Research A 555 (2005) 72–79

Analysis - Charge

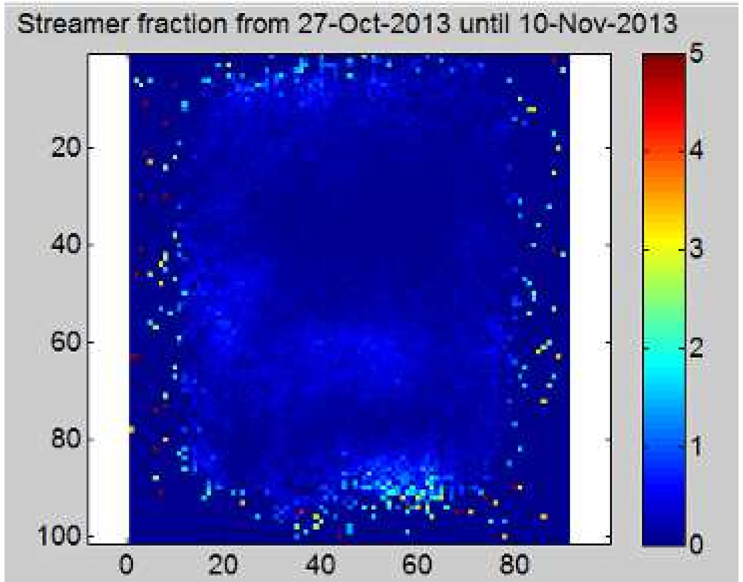


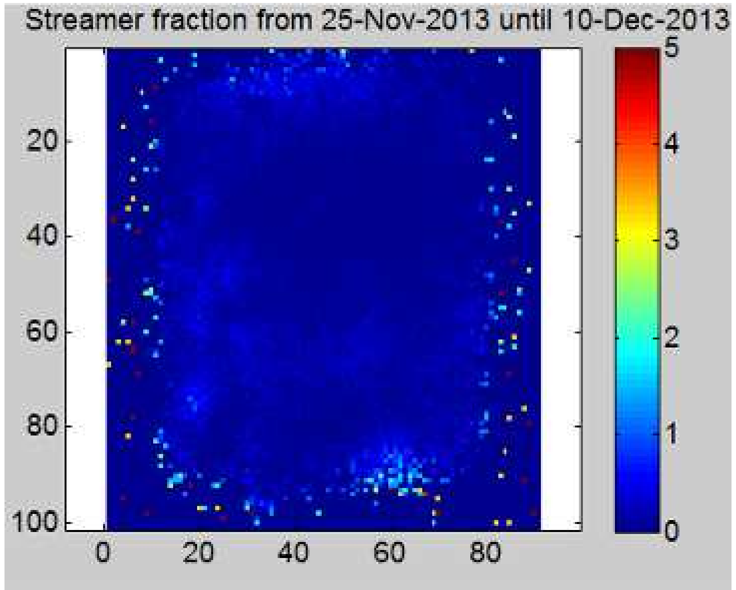


Charge well correlated with E/N

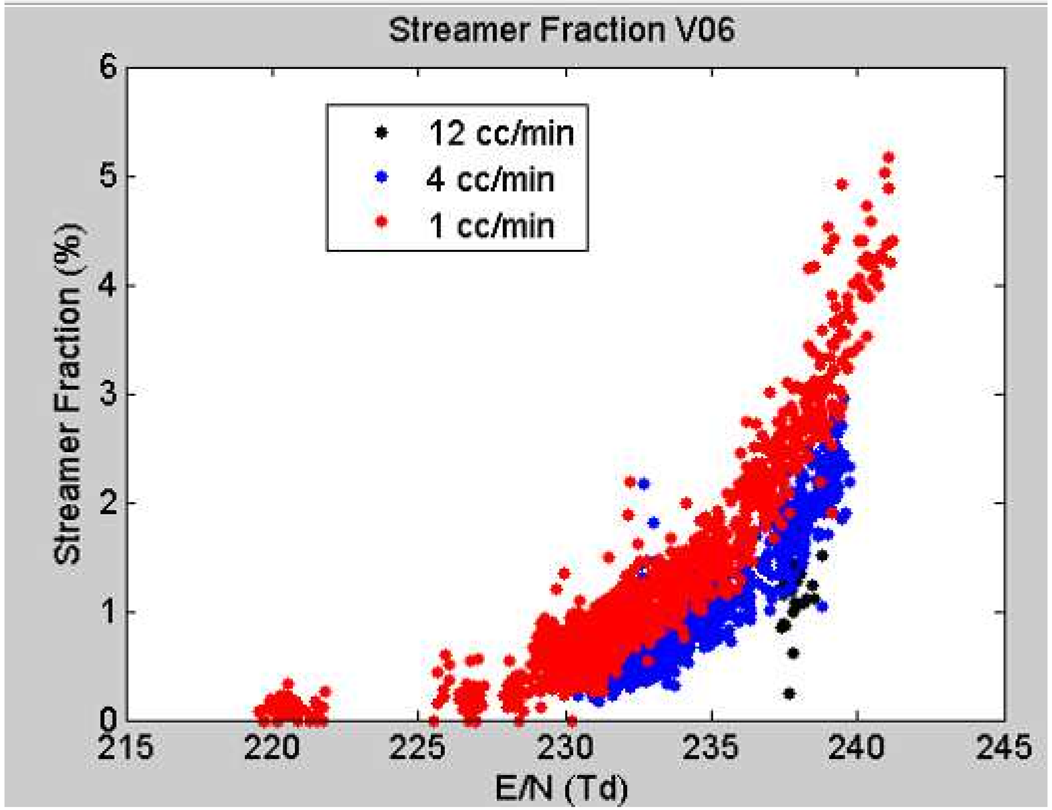


Analysis – Streamer Fraction

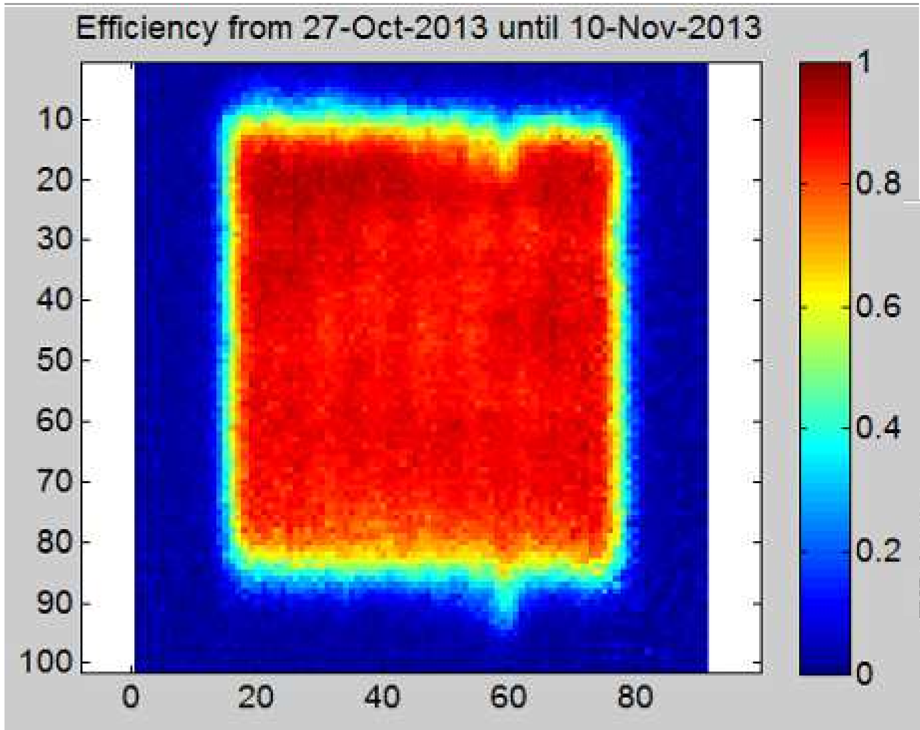




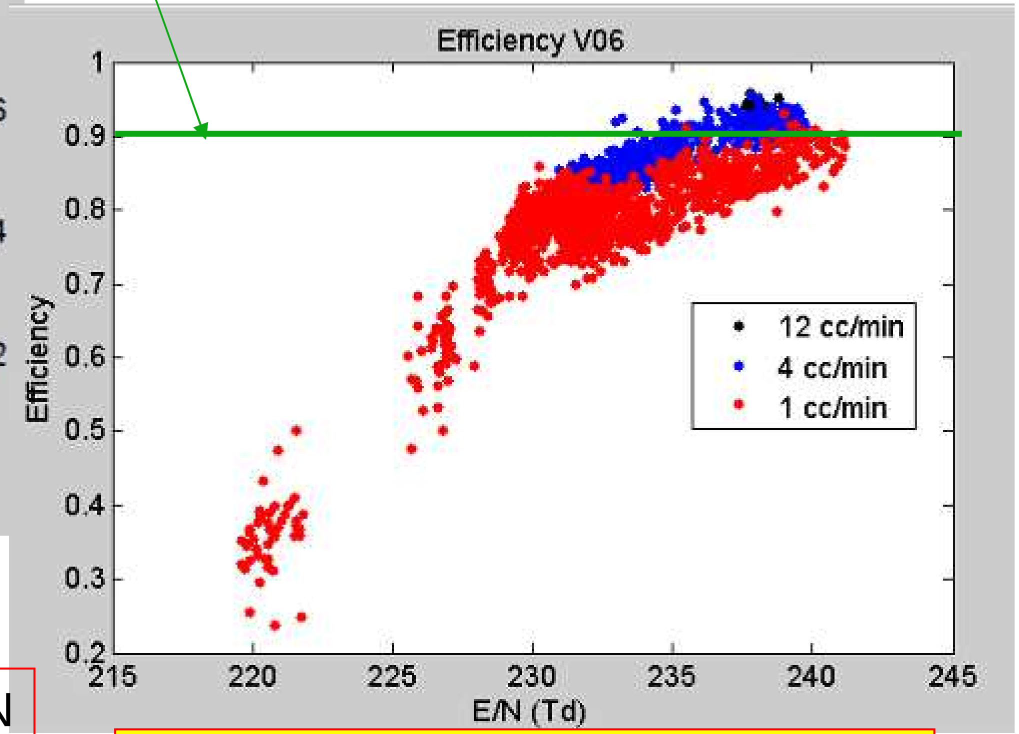
Streamer Fraction well correlated with E/N



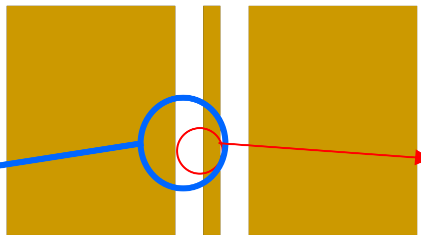
Analysis - Efficiency



Active Pad area fraction



High E/N

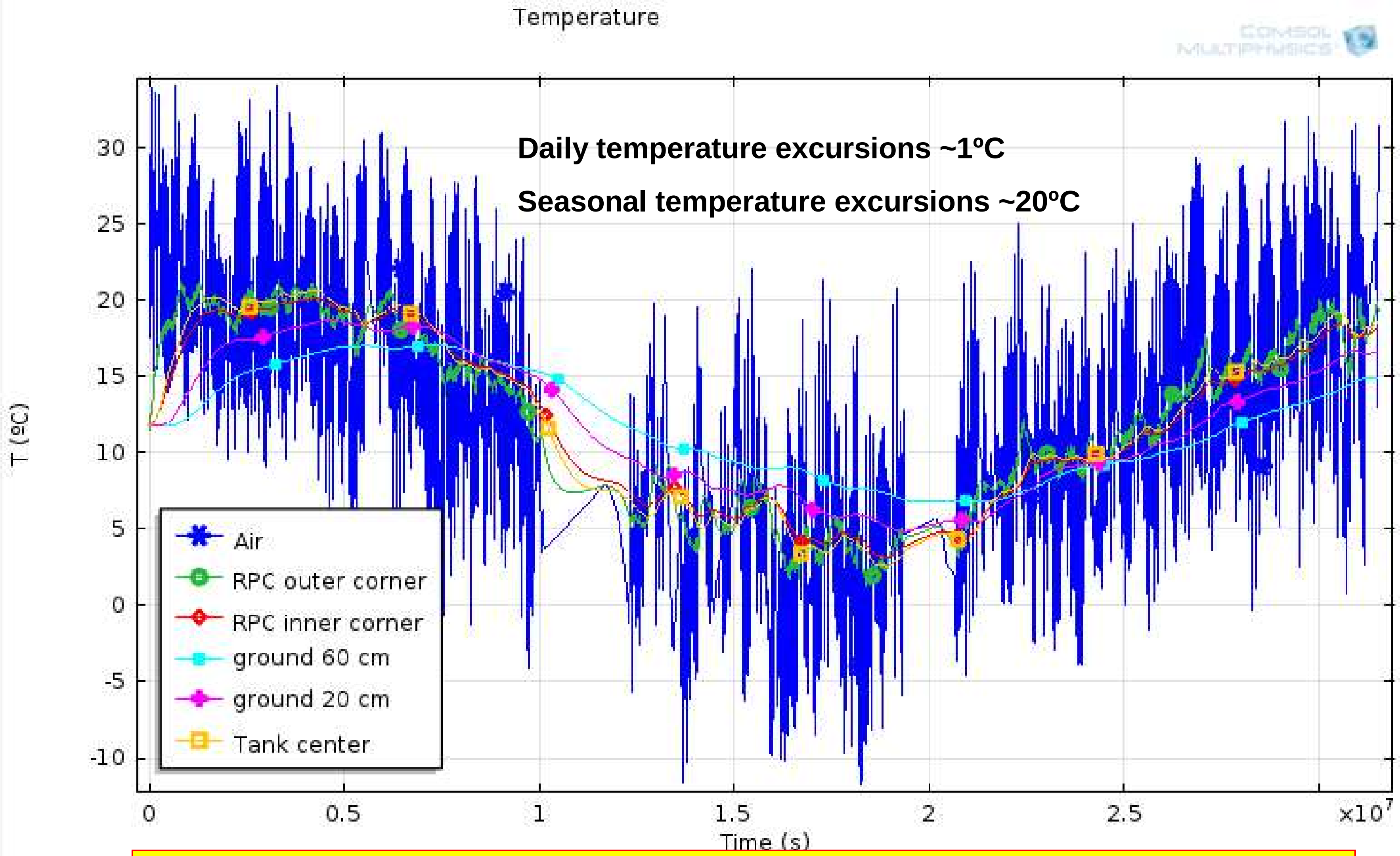


Low E/N

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.

Analysis – Thermal Simulation



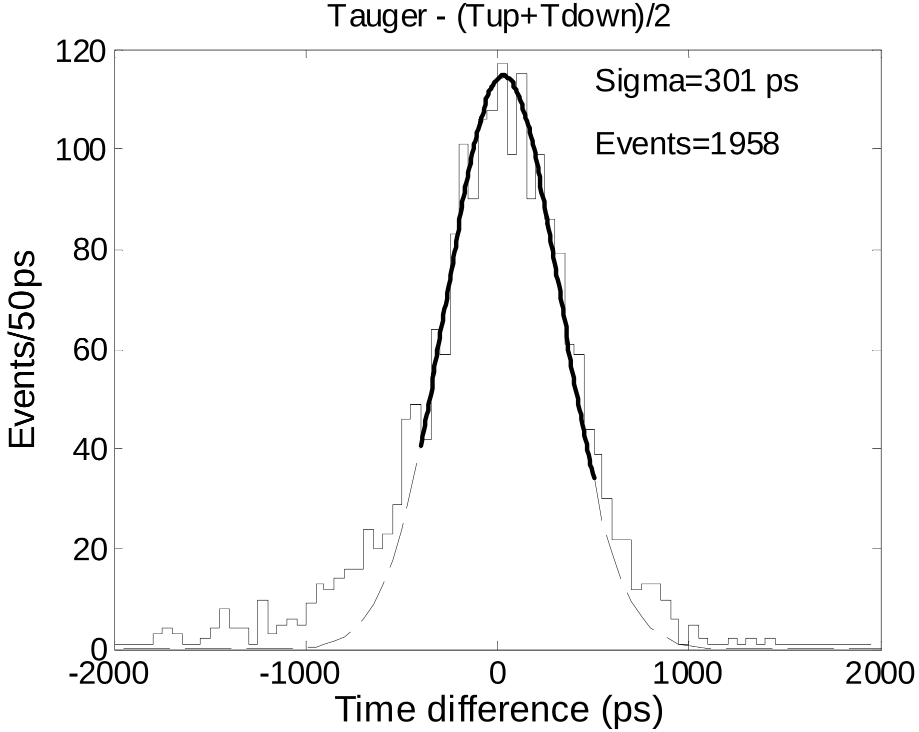
Small daily variations keep E/N "stable" over large time periods

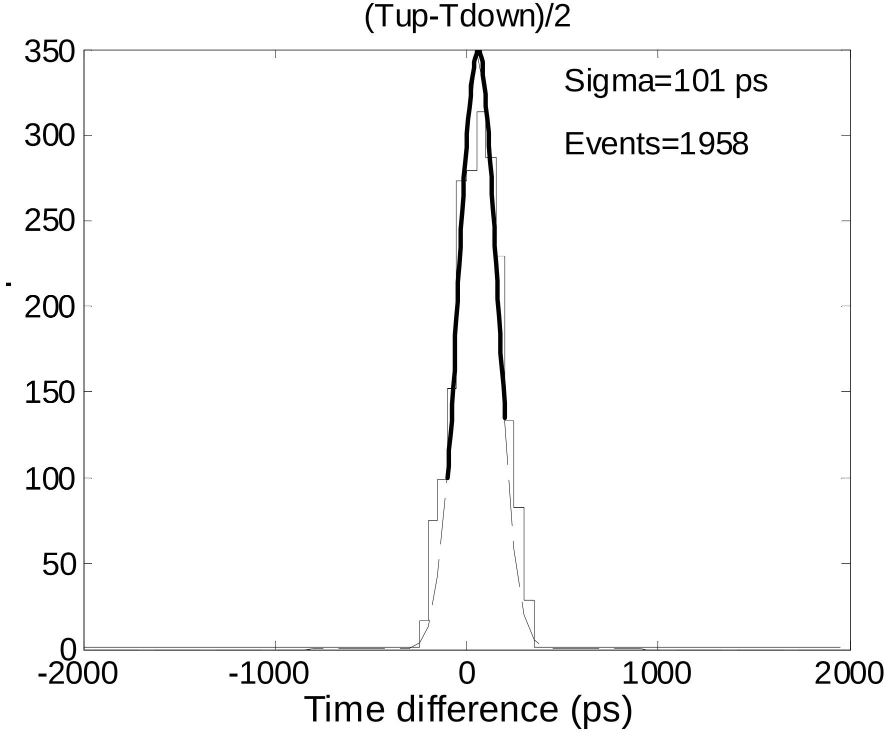
Analysis – Time Resolution

RPC-telescope

Measure in one pad

Telescope





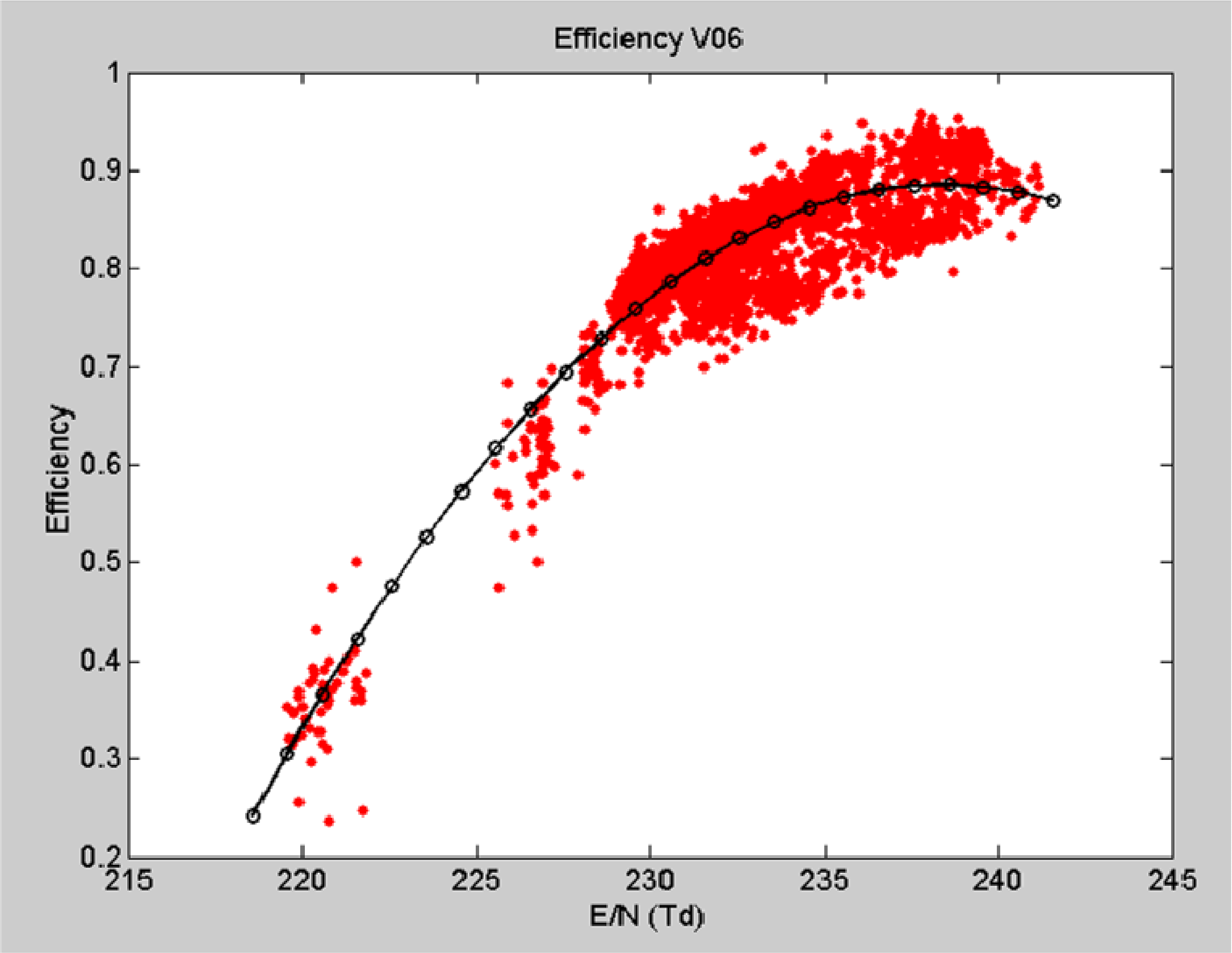
$$\sigma_{auger} = \sqrt{301^2 - 101^2} = 283\,\text{ps}$$

Some dependencies (longitudinal position p, ex) remain uncorrected

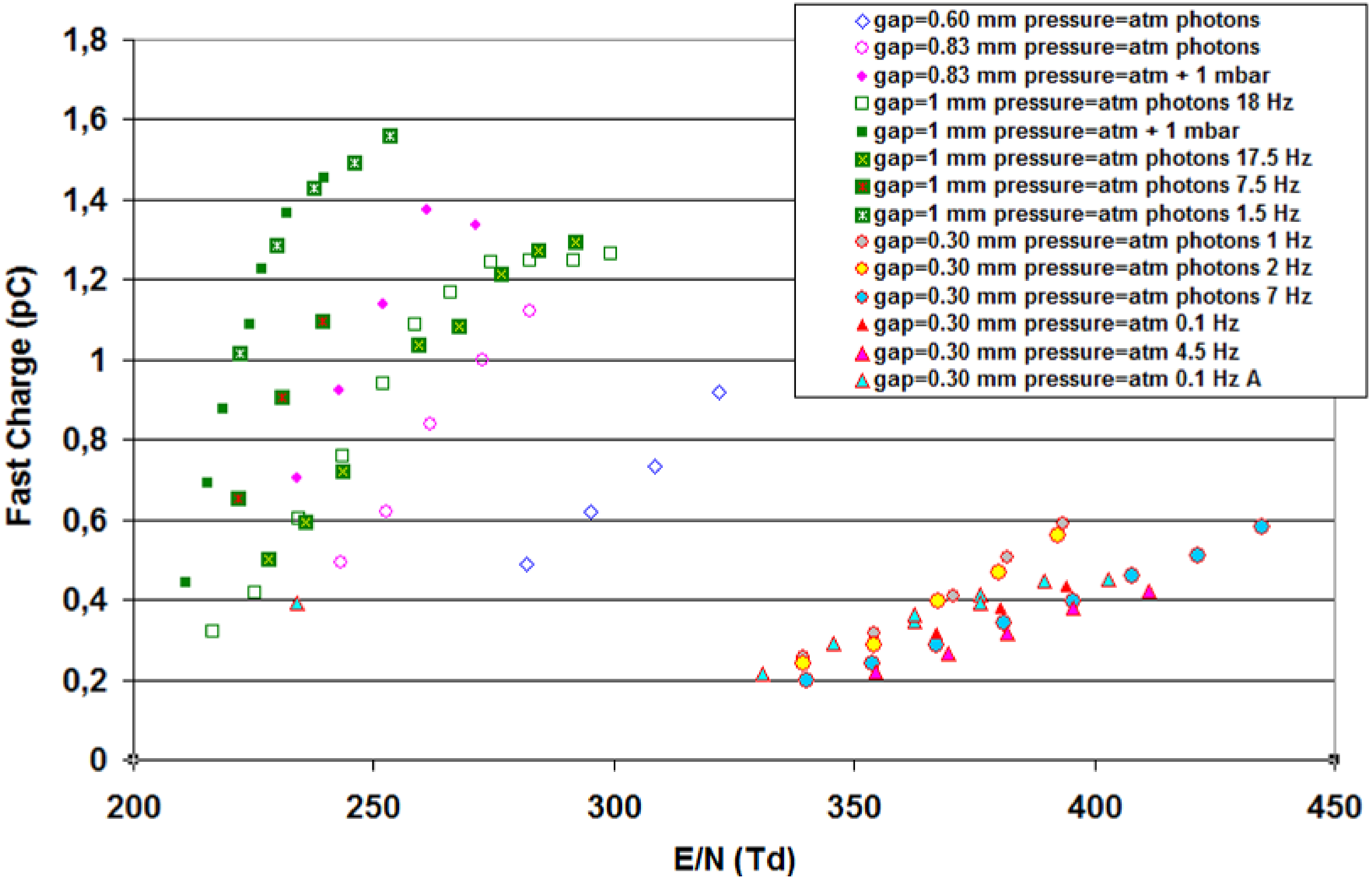
CONCLUSIONS

- After 3 months operating at 1 cc/min none undesirable effects were observed in the chamber performance, when compared with larger gas flow rates
- Charge, streamer fraction and efficiency “only” depends on E/N (reduced electric field).
- Time resolution below 300 ps σ.
- Efficiency levels uniform over all detector area.
- More than 10 RPC units already construct and in operation in 4 (2 continents) different places. Proving the robustness and easy operation…
- Once the practical quantities are well correlated with E/N, we can control them monitoring environment and adjusting the High Voltage, keep the efficiency at stable values over time.

Backup

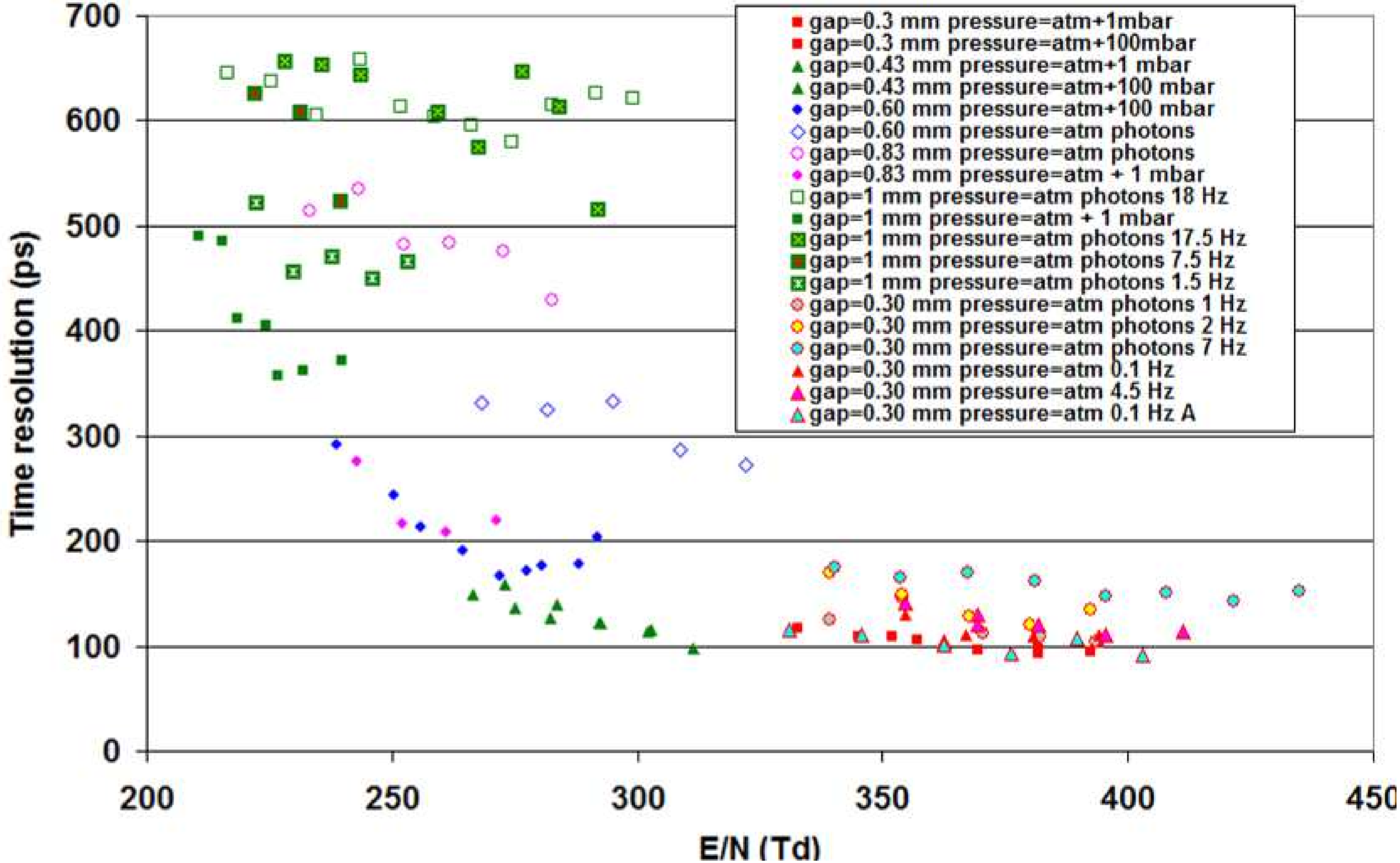

Efficiency V06
Efficiency
E/N (Td)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
215
220
225
230
235
240
245

Backup



gap=0.60 mm pressure=atm photons
gap=0.83 mm pressure=atm photons
gap=0.83 mm pressure=atm + 1 mbar
gap=1 mm pressure=atm photons 18 Hz
gap=1 mm pressure=atm + 1 mbar
gap=1 mm pressure=atm photons 17.5 Hz
gap=1 mm pressure=atm photons 7.5 Hz
gap=1 mm pressure=atm photons 1.5 Hz
gap=0.30 mm pressure=atm photons 1 Hz
gap=0.30 mm pressure=atm photons 2 Hz
gap=0.30 mm pressure=atm photons 7 Hz
gap=0.30 mm pressure=atm 0.1 Hz
gap=0.30 mm pressure=atm 4.5 Hz
gap=0.30 mm pressure=atm 0.1 Hz A
Fast Charge (pC)
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
200
250
300
350
400
450
E/N (Td)

Backup



Time resolution (ps)
E/N (Td)
700
600
500
400
300
200
100
0
200
250
300
350
400
450
gap=0.3 mm pressure=atm+1mbar
gap=0.3 mm pressure=atm+100mbar
gap=0.43 mm pressure=atm+1 mbar
gap=0.43 mm pressure=atm+100 mbar
gap=0.60 mm pressure=atm+100 mbar
gap=0.60 mm pressure=atm photons
gap=0.83 mm pressure=atm photons
gap=0.83 mm pressure=atm + 1 mbar
gap=1 mm pressure=atm photons 18 Hz
gap=1 mm pressure=atm + 1 mbar
gap=1 mm pressure=atm photons 17.5 Hz
gap=1 mm pressure=atm photons 7.5 Hz
gap=1 mm pressure=atm photons 1.5 Hz
gap=0.30 mm pressure=atm photons 1 Hz
gap=0.30 mm pressure=atm photons 2 Hz
gap=0.30 mm pressure=atm photons 7 Hz
gap=0.30 mm pressure=atm 0.1 Hz
gap=0.30 mm pressure=atm 4.5 Hz
gap=0.30 mm pressure=atm 0.1 Hz A