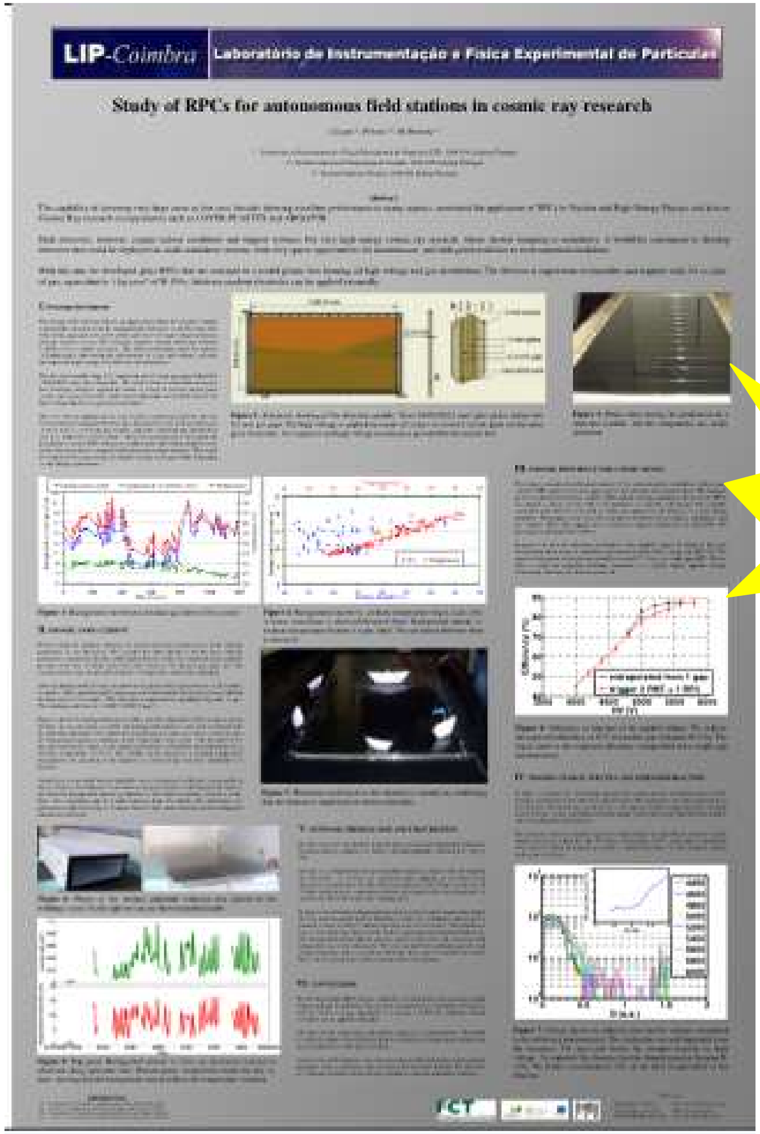
Outdoor Field experience with Autonomous Stations

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

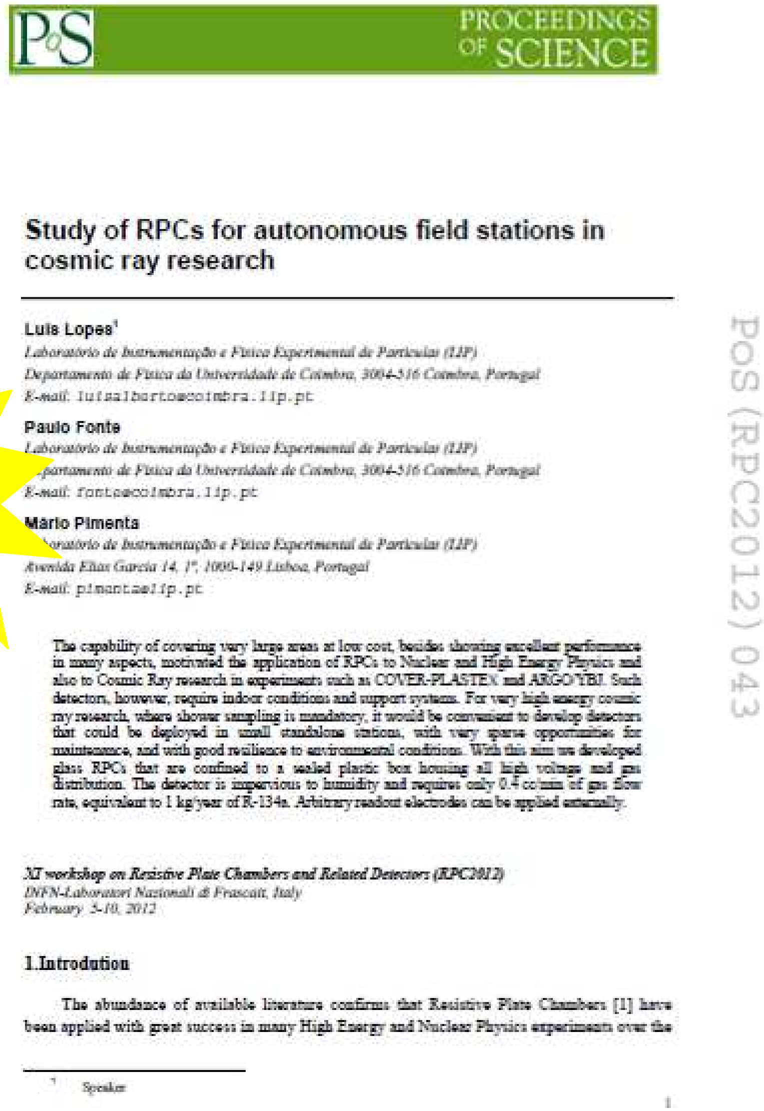
Cofinanciado por:

The begin - Outdoor

11th Workshop on Resistive Plate Chambers and Related Detectors (RPC2012)



Validate the design


PoS PROCEEDINGS OF SCIENCE

Study of RPCs for autonomous field stations in cosmic ray research

Luis Lopes[1]
Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Departamento de Física da Universidade de Coimbra, 3004-516 Coimbra, Portugal
E-mail: luisalberto@coimbra.lip.pt

Paulo Fonte
Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Departamento de Física da Universidade de Coimbra, 3004-516 Coimbra, Portugal
E-mail: fonte@coimbra.lip.pt

Mário Pimenta
Laboratório de Instrumentação e Física Experimental de Partículas (LIP)
Avenida Elias Garcia 14, 1º, 1000-149 Lisboa, Portugal
E-mail: pimenta@lip.pt

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

1

PoS (RPC2012) 043

The begin - Outdoor

12th Workshop on Resistive Plate Chambers and Related Detectors (RPC2014)

Resistive Plate Chambers for the Pierre Auger array upgrade

P. Assis, A. Blanco, N. Carolino, O. Cunha, M. Ferreira, P. Fonte, L. Lopes, L. Mendes, M. Palka, A. Pereira, M. Pimenta, B. Tomé

Confirm Indoor performance

Detector description here

JINST — Published by IOP Publishing for Sissa Medialab

Received: July 10, 2014
Revised: August 20, 2014
Accepted: September 2, 2014
Published: October 16, 2014

12th Workshop on Resistive Plate Chambers and Related Detectors,
23–28 February 2014,
Tsinghua University, Beijing, China

Resistive Plate Chambers for the Pierre Auger array upgrade

L. Lopes,[b,1] P. Assis,[a] A. Blanco,[b] M.A. Cerda,[c,f] N. Carolino,[b] O. Cunha,[b] M. Ferreira,[a] P. Fonte,[b,d] L. Mendes,[a] M. Palka,[e] A. Pereira,[a] M. Pimenta[a] and B. Tomé[a]

[a] Laboratório de Instrumentação e Física Experimental de Partículas (LIP), Avenida Elias Garcia 14, 1º, 1000-149 Lisboa, Portugal
[b] Laboratório de Instrumentação e Física Experimental de Partículas (LIP), Departamento de Física da Universidade de Coimbra, 3004-516 Coimbra, Portugal
[c] Observatorio Pierre Auger, Malargüe, Argentina
[d] Instituto Superior de Engenharia de Coimbra (ISEC), Instituto Politécnico de Coimbra, Rua Pedro Nunes, 3030-199 Coimbra, Portugal
[e] Smoluchowski Institute of Physics, Jagellonian University of Cracow, Cracow, Poland
[f] Istituto Nazionale di Fisica Nucleare sezione di Roma Tor Vergata, Roma, Italy

E-mail: luisalberto@coimbra.lip.pt

Abstract: In the framework of the Pierre Auger Observatory upgrade, Resistive Plate Chambers (RPCs) have been proposed as a dedicated detector to better estimate the muonic component of Extensive Air Showers (EAS), further constraining the nature of the cosmic rays and hadronic interactions that take place in Extensive Air Showers development. RPCs are a very interesting option to fulfill the requirements: to cover large areas at low cost; particle counting from one to thousands of particles; few ns time resolution and outdoor standalone operation with very low maintenance. The present work refers to the latest advances and outcomes in order to ensure the capability of RPCs to fulfill the totality of the Auger upgrade requirements.

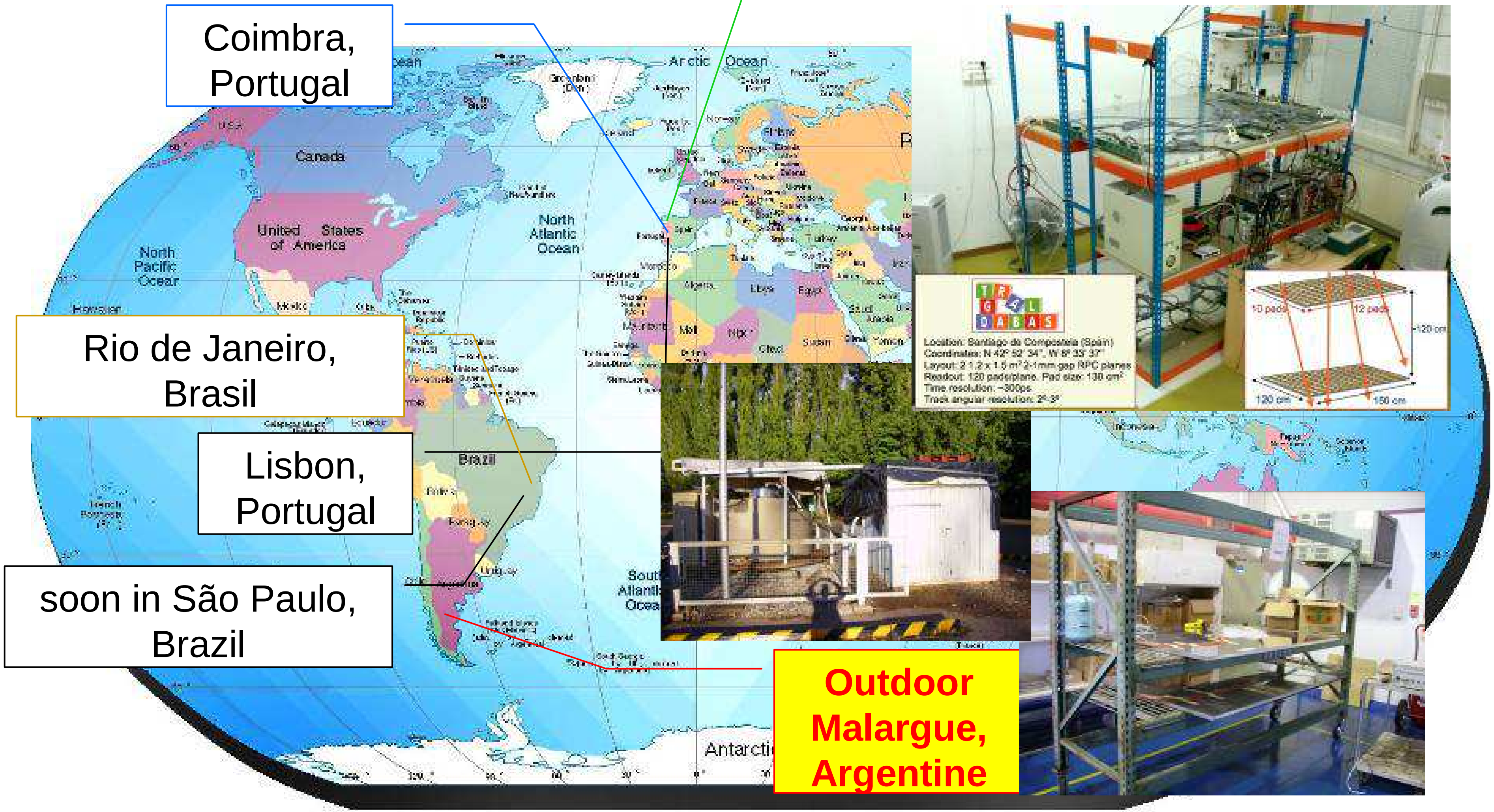
Keywords: Large detector systems for particle and astroparticle physics; Particle tracking detectors (Gaseous detectors); Timing detectors; Particle detectors

[1] Corresponding author.

doi:10.1088/1748-0221/9/10/C10023

2014 JINST 9 C10023

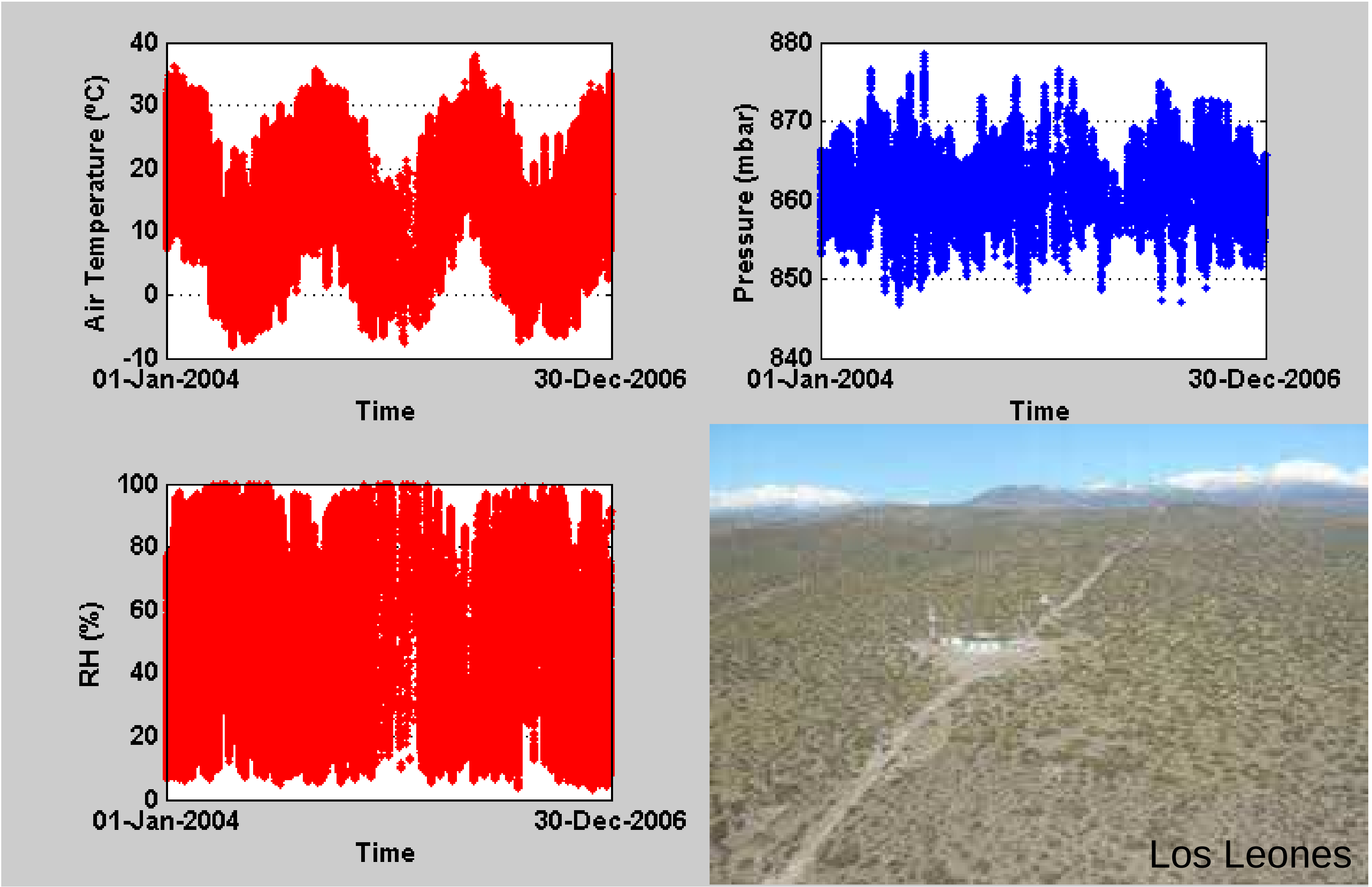
RPC - where they are?



AUGER Site – Malargue, Argentine

Situated close to the Andes at an average altitude of 1400 m above sea level, climate is dry and relatively cold. In Summer it could reach air temperatures above 35 ºC and in Winter below -15 ºC, wild daily fluctuations in temperature can occur very often. Strong winds and thunderstorms are frequent.

AUGER Site – Malargue, Argentine



AUGER Site – Malargue, Argentine

- What we should take care when "opening the door"
  - Large temperature gradients
    - Along the year
    - But mostly the daily excursions, which will affect efficiency plateau
    - Increase condensation risk
  - Humidity
    - Will be our strongest enemy… High voltage connections need to be very well protected, mostly due to condensation
  - Pressure
    - The smoother variable!! Just be aware that at lower pressure we just need to lower HV. Daily excursions equal to the ones observed in lab
    - Lower pressure implies also lower gas density inside the gap, this could led to a reduction of the available ion-electron pairs to start the avalanche. At the end this could have some influence on the width of the efficiency plateau, or even in the difficulty of observing such plateau when operating in avalanche mode…
  - Sun
    - Direct sunlight on the detectors should also be avoided, as inner temperature could reach easily 50 ºC during Summer.

Close the door and return to the Lab

Close the door and return to the Lab

- Design goals (after many attempts to work at the Pampas)
  - Monitor Temperature, Pressure and Relative Humidity
    - Temperature sensors should be in contact with the detector
    - Humidity sensors should monitor both the sensitive volume and the shielding case humidity
    - Pressure could be measure at any point close by
  - Monitor gas flow rate (need to be sure there is gas in the gaps)
  - In outdoor in remote sites, redundancy is of main importance.
  - Operate at the efficiency plateau or at least at a “constant” gain (constant E/N will be the goal)
    - Automatic HV adjustment, depending on the site, at a rate of tens of minutes.
  - Mechanically robust, easy to transport and install.
    - Most times we will not be at the site and the local staff may not have the necessary care when performing simple operations

Close the door and return to the Lab

“Inside” the detector

- 7 Temperature
- 2 Relative Humidity
- 1 Ambient Pressure

Outside the detector

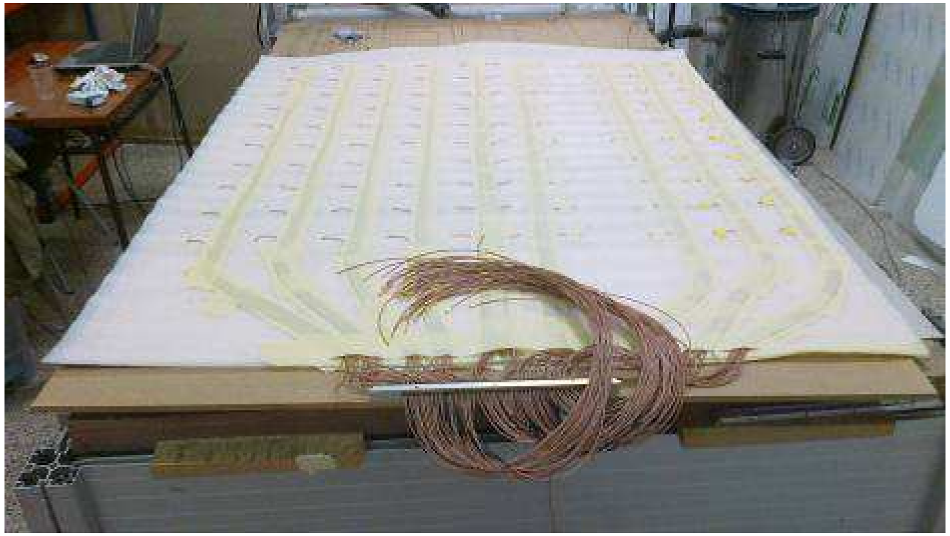
- 3 Temperature
- 1 Relative Humidity
- 1 Ambient Pressure

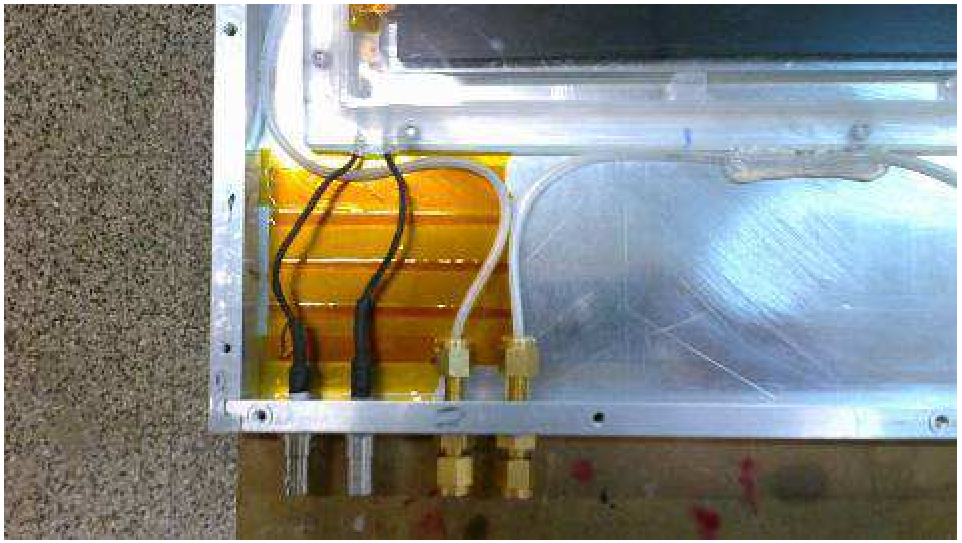
I2C bus

- Gas monitoring unit:
  - 1-Safety Colum
  - 2-Sensitive volume output
    - RH sensor
    - Bubbles counting
      - Optical sensor
      - Pressure sensor
  - 3-Trap, between sensitive volume output and Aluminum case input
  - 4-Aluminum case output
    - RH sensor
    - Bubbles counting
      - Optical Sensor
      - Pressure sensor

Close the door and return to the Lab

Assembly

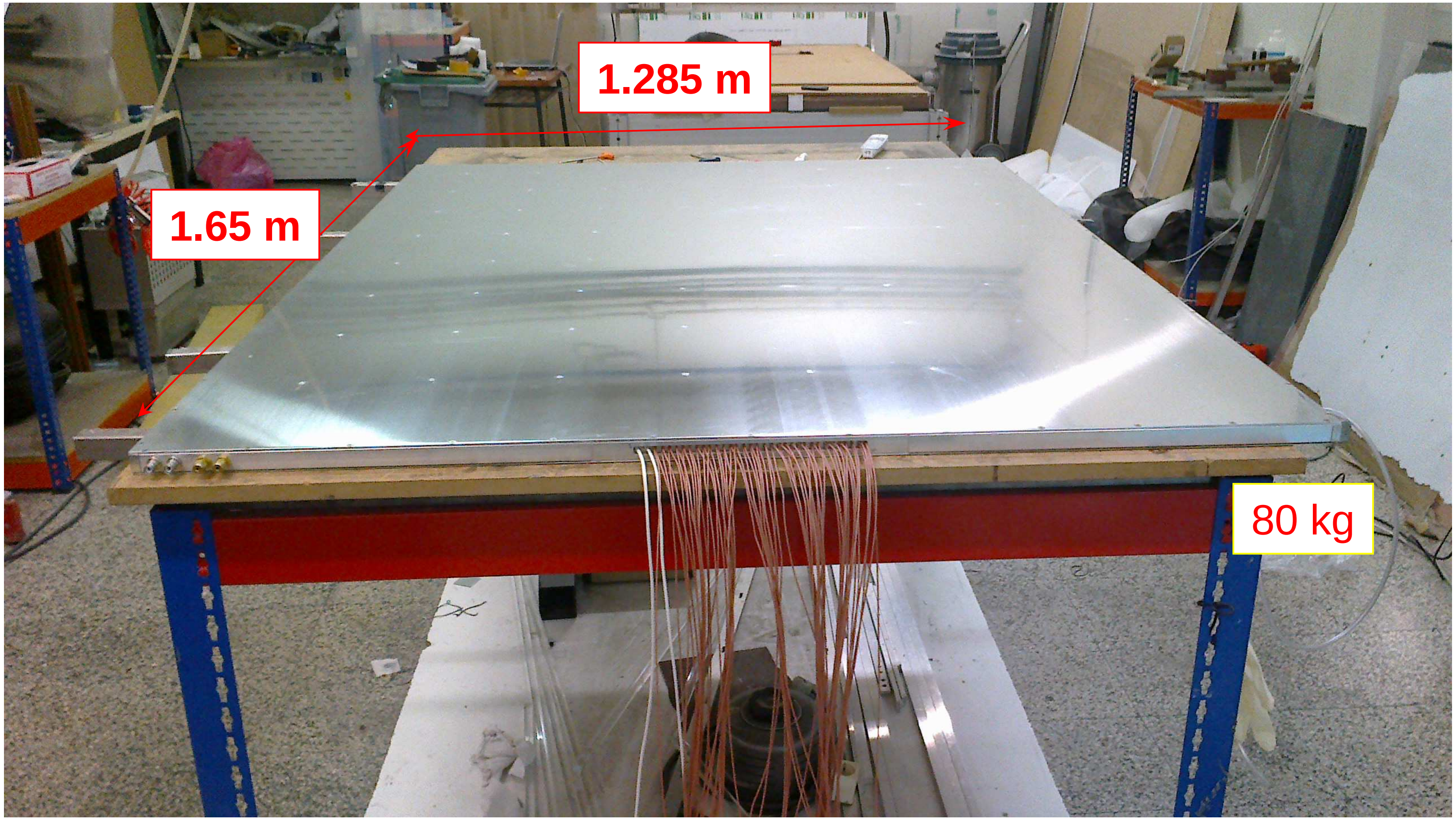




Close the door and return to the Lab

Ready to “run”

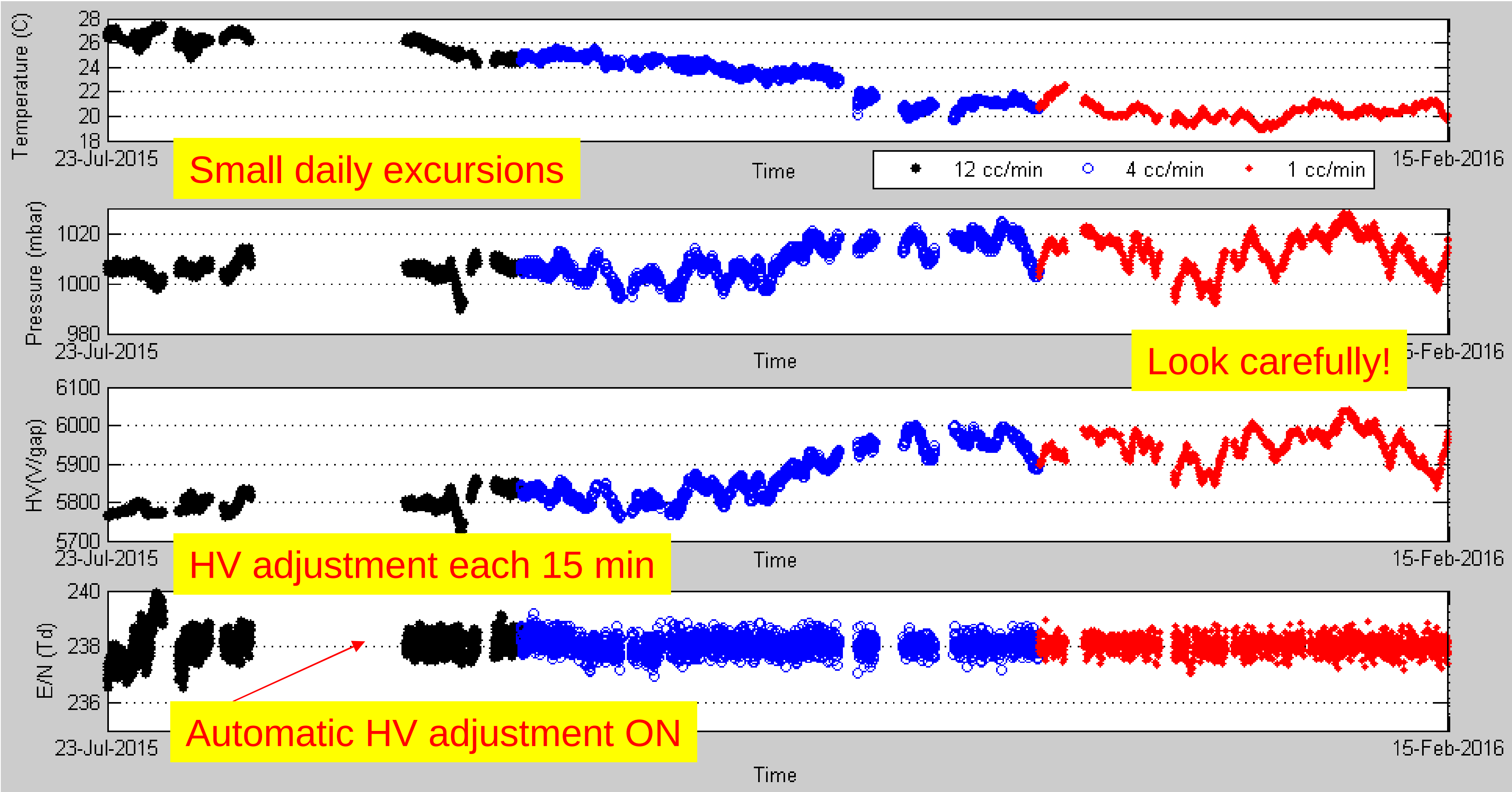
Aluminum case almost 100% sealed



Close the door and return to the Lab

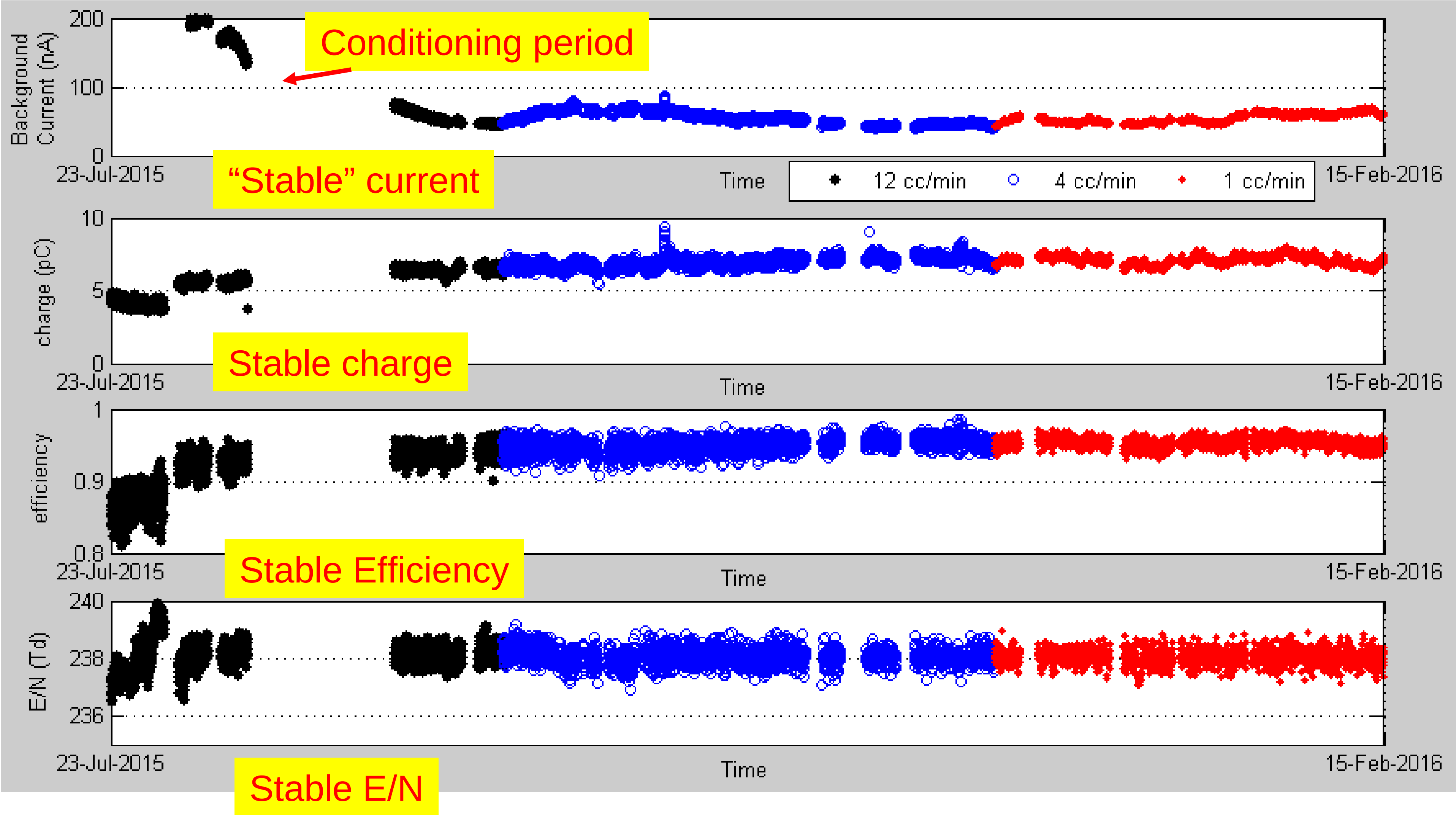
Automatic HV adjustment to operate at a "constant" E/N

$$V_{eff} = V_{ref} \times \frac{T_{ref}}{T_{measured}} \times \frac{P_{measured}}{P_{ref}}, \quad [V(V), T(^{o}C), P(mbar)] \qquad \frac{E}{N} = 0.0138068748 \times \frac{V_{eff,Volts}}{d_{cm}} \frac{(T_{^{o}C} + 273.15)}{P_{mbar}}, \quad [Td]$$

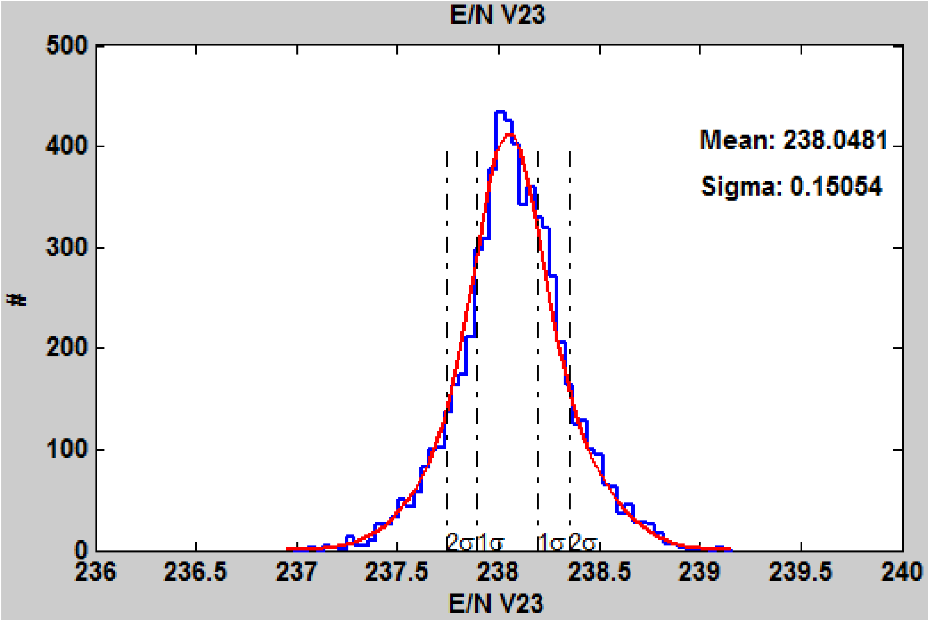


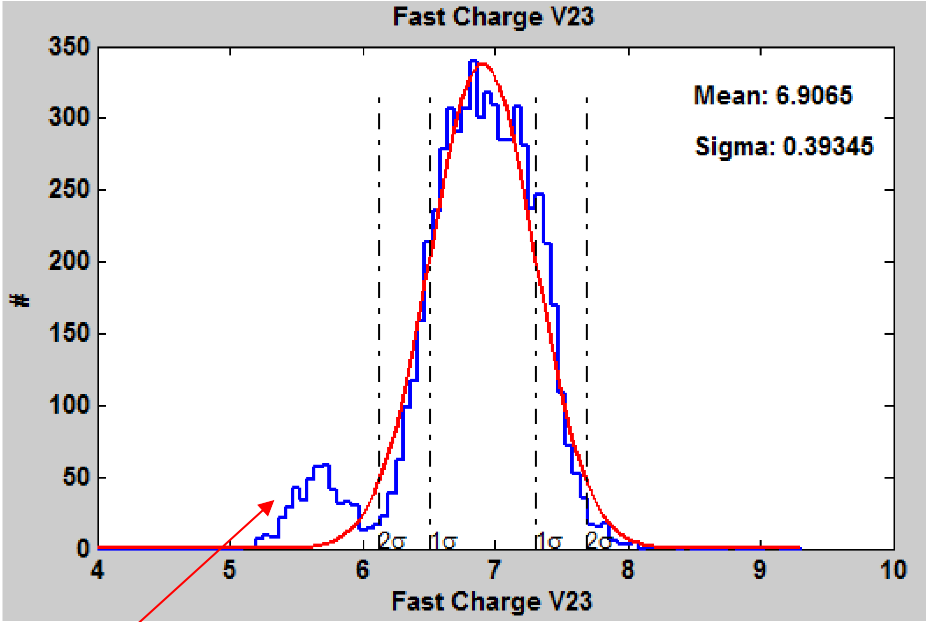
Close the door and return to the Lab

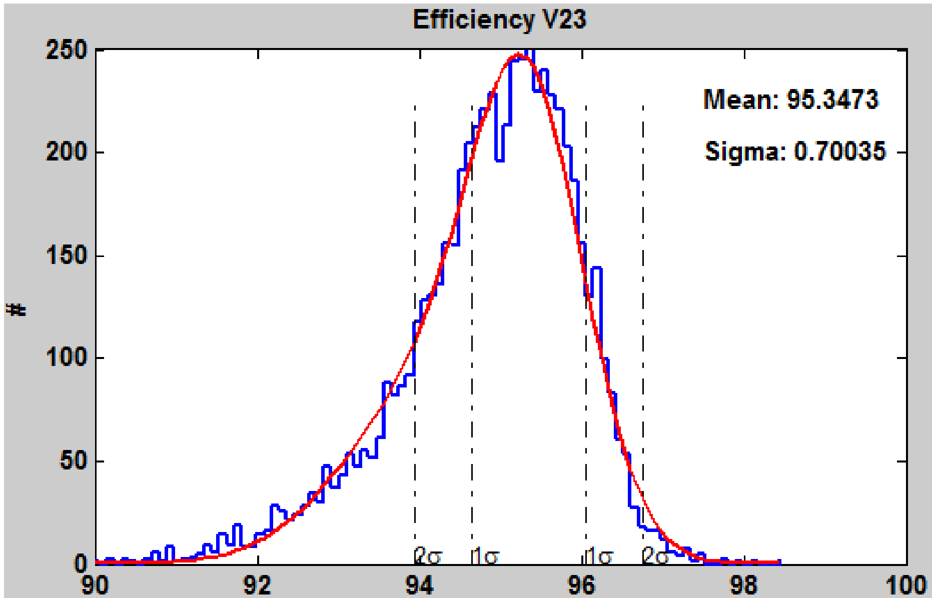
Automatic HV adjustment to operate at a “constant” E/N



Close the door and return to the Lab







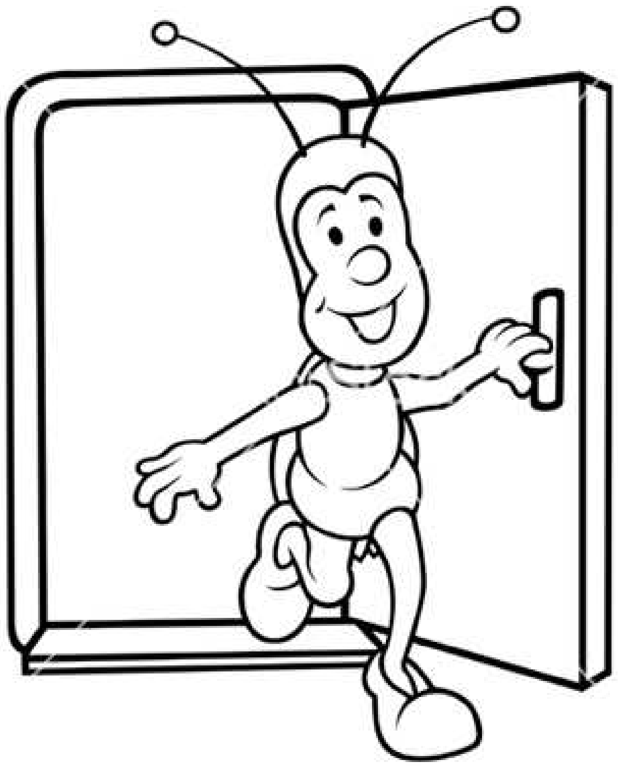
Mechanical “defects” that affect pad induced charge, it was corrected

Automatic HV adjustment each 15 min, should keep E/N stable allowing chamber to operate within efficiency plateau.

INDOOR

expected Geometric efficiency 90 %

Open the door and return to the field



Gianni Navarra setup @ Auger Observatory

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.

Gianni Navarra setup @ Auger Observatory

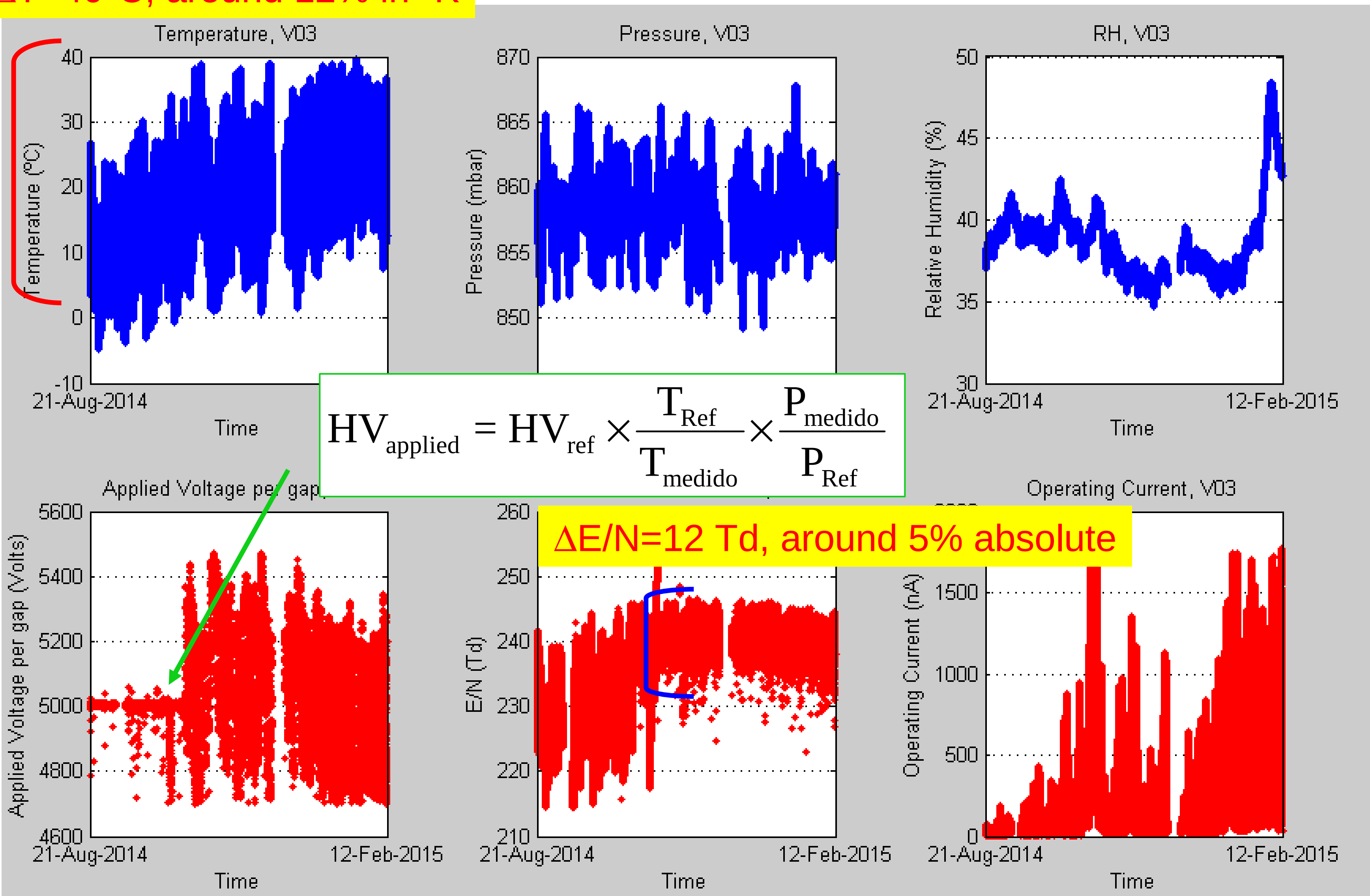
Really harsh conditions

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.

Gianni Navarra setup @ Auger Observatory

Top chamber

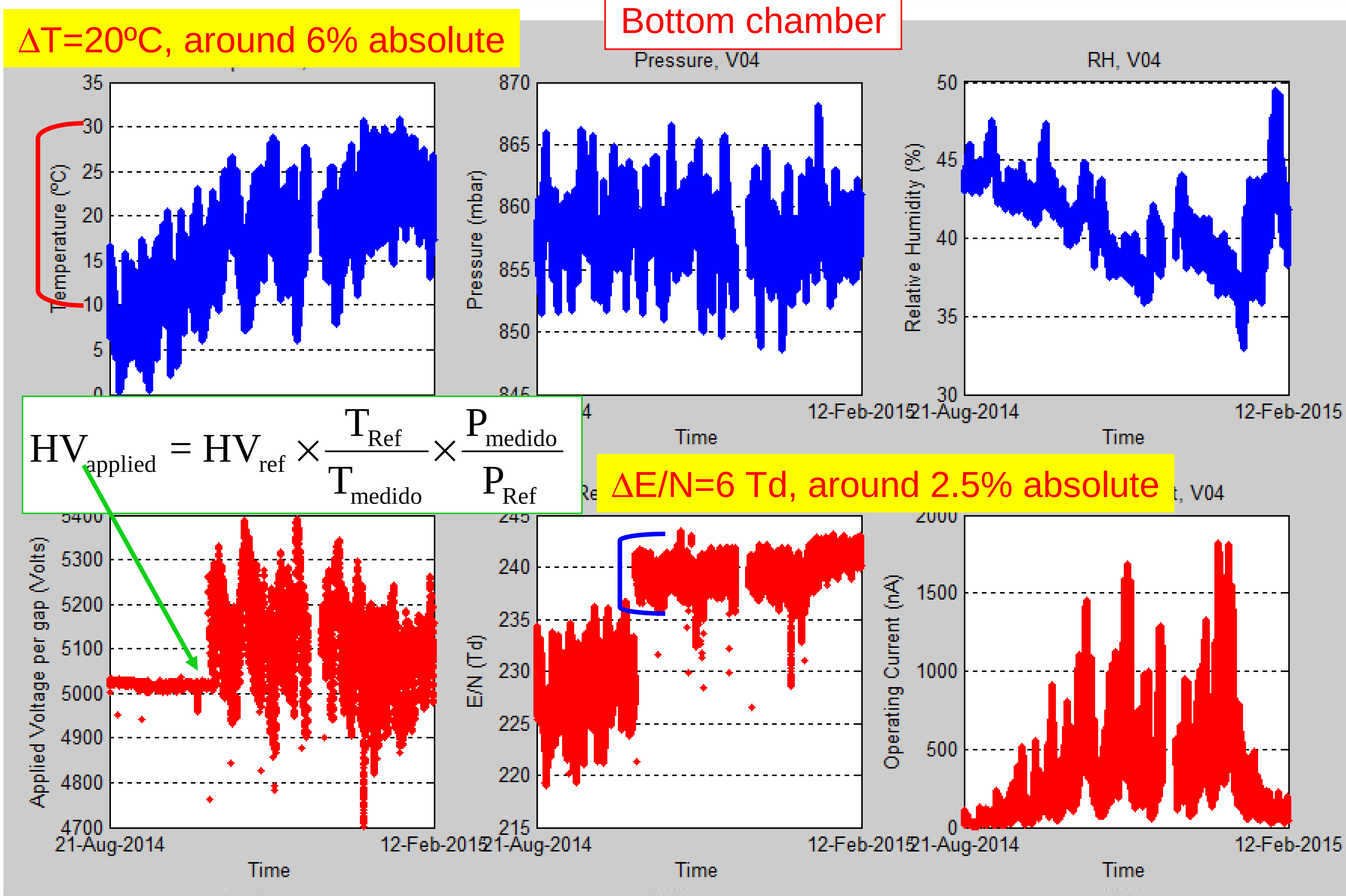
ΔT=40ºC, around 12% in ºK



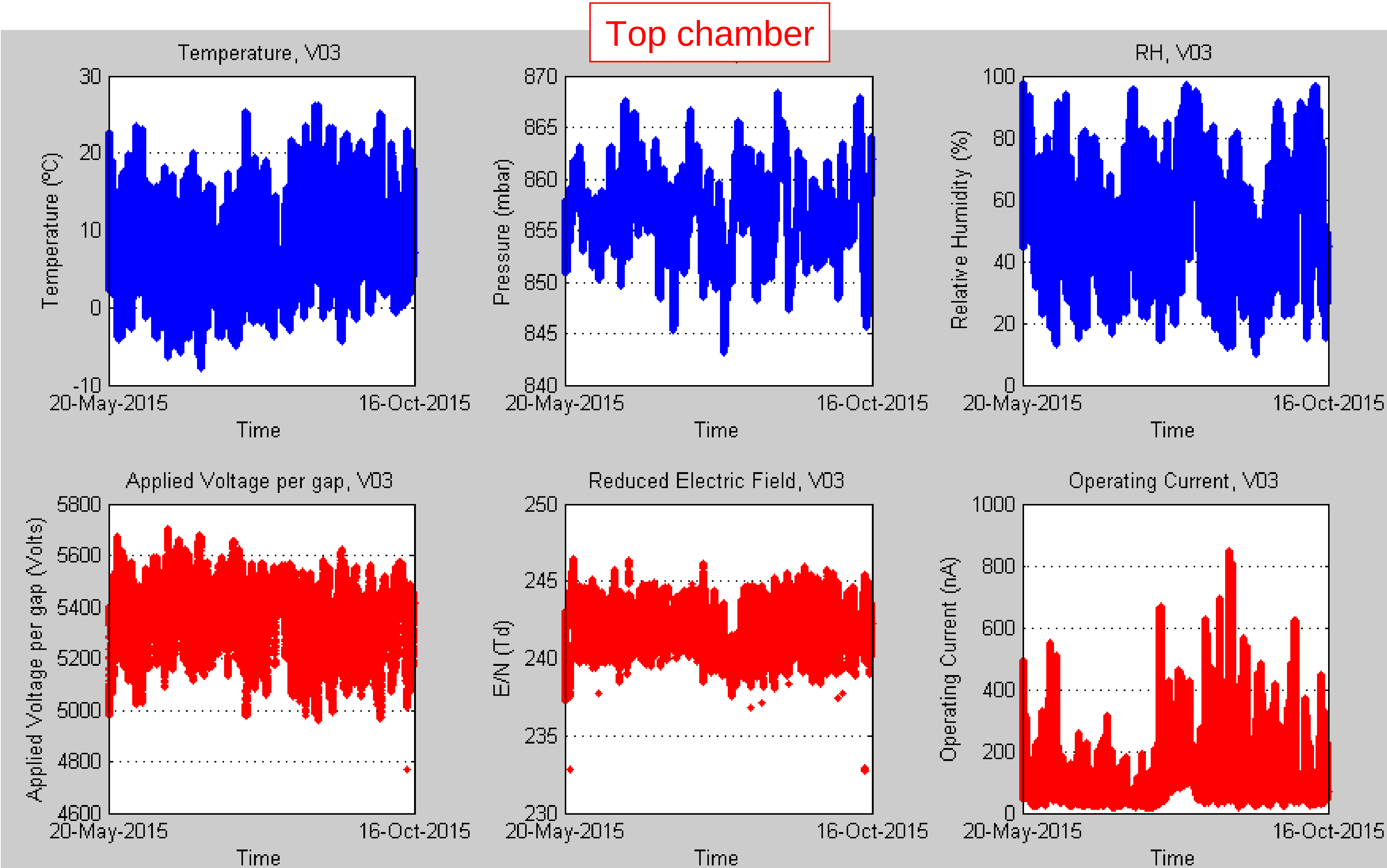
$$HV_{applied} = HV_{ref} \times \frac{T_{Ref}}{T_{medido}} \times \frac{P_{medido}}{P_{Ref}}$$

ΔE/N=12 Td, around 5% absolute

Gianni Navarra setup @ Auger Observatory



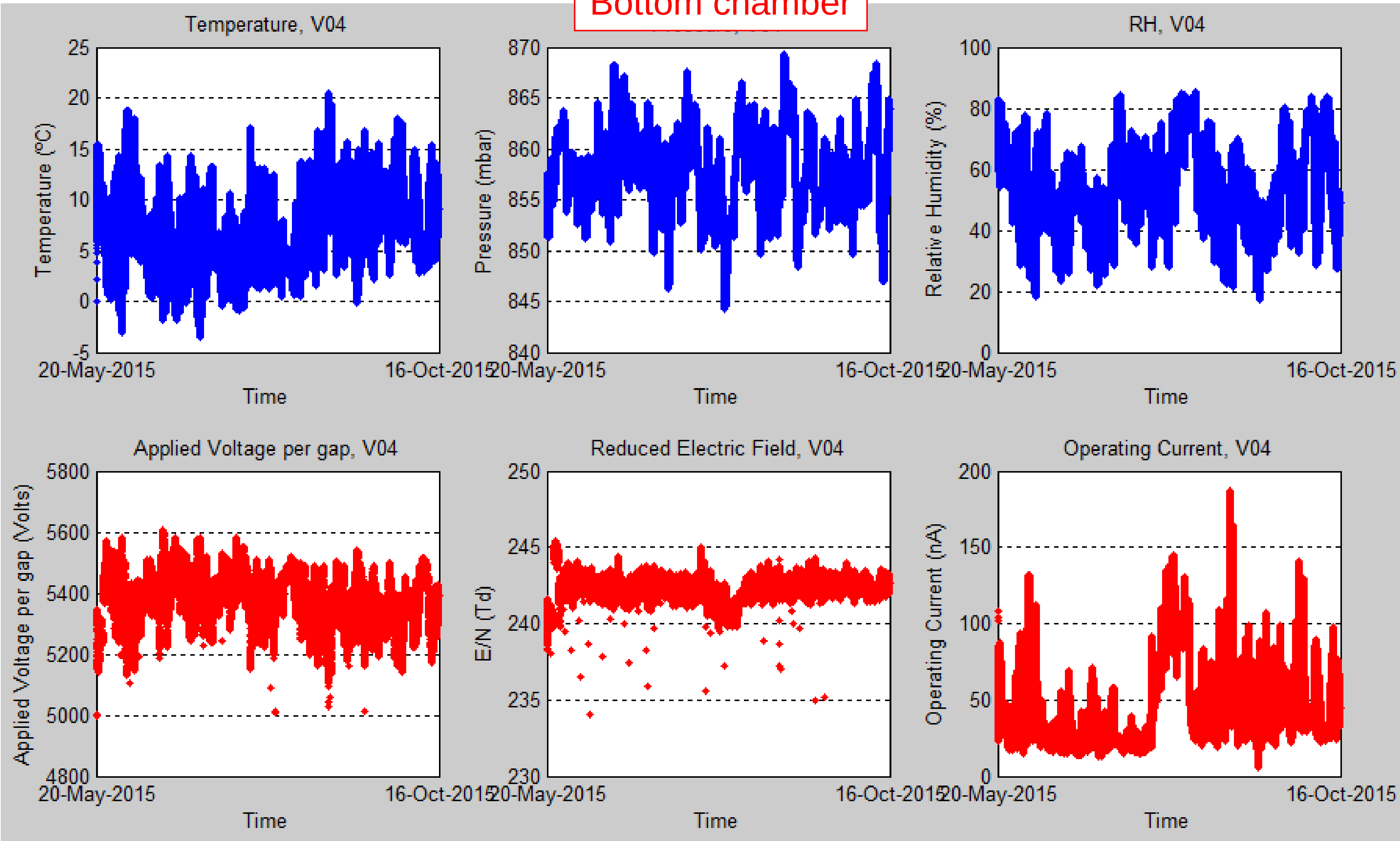
$$HV_{applied} = HV_{ref} \times \frac{T_{Ref}}{T_{medido}} \times \frac{P_{medido}}{P_{Ref}}$$



Top chamber
Temperature, V03
Temperature (ºC)
30
20
10
0
-10
20-May-2015
16-Oct-2015
Time
870
865
860
855
850
845
840
Pressure (mbar)
RH, V03
Relative Humidity (%)
100
80
60
40
20
0
Applied Voltage per gap, V03
Applied Voltage per gap (Volts)
5800
5600
5400
5200
5000
4800
4600
Reduced Electric Field, V03
E/N (Td)
250
245
240
235
230
Operating Current, V03
Operating Current (nA)
1000
800
600
400
200
0

Gianni Navarra setup @ Auger Observatory

Bottom chamber

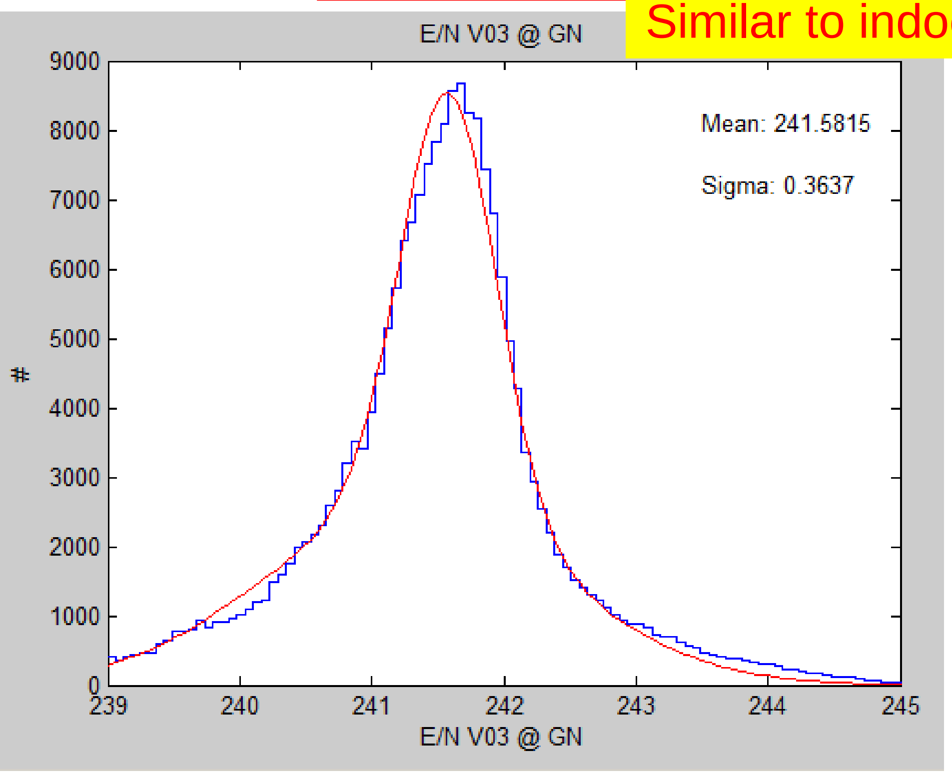


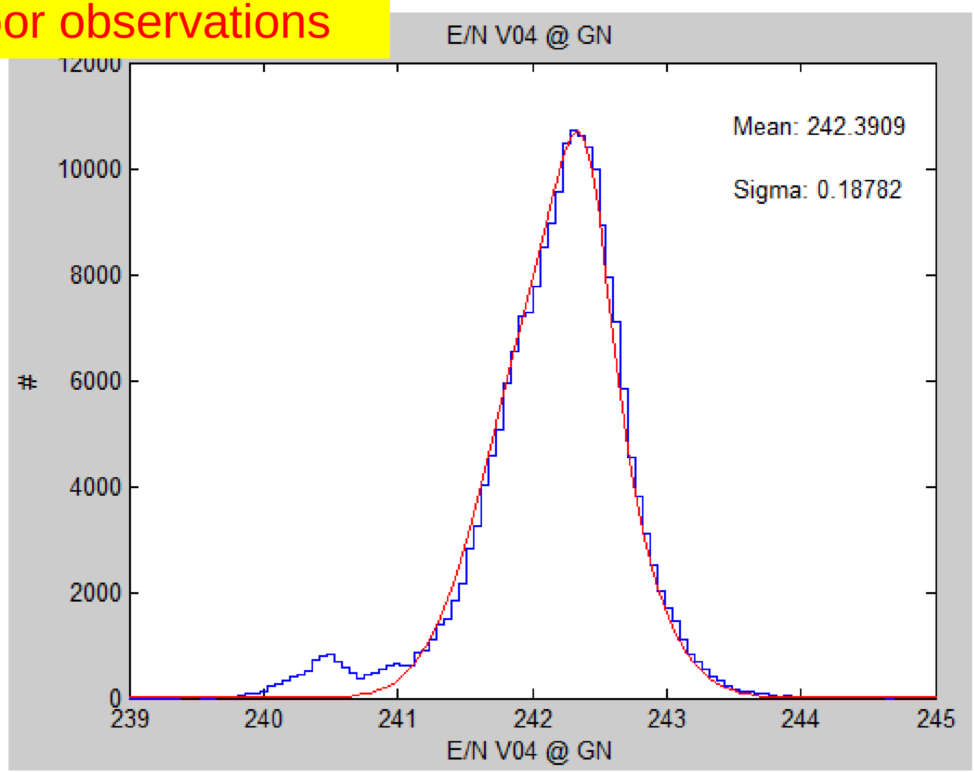
Gianni Navarra setup @ Auger Observatory

Top chamber

Bottom chamber

Similar to indoor observations



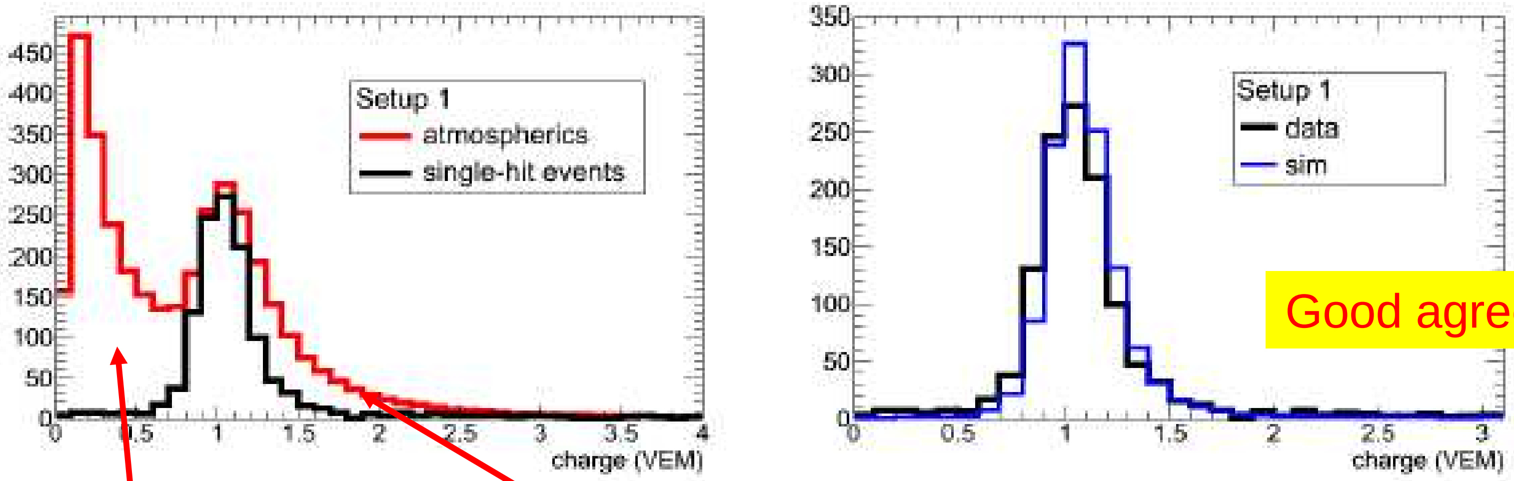


Wider daily temperature excursions result in wider E/N distributions

- Maybe we need to increase the HV adjustment frequency, to minimize this effect
- It could be difficult to operate at a stable efficiency in this setup. Not so important for the current application (calibrate the tank to single muons).

Gianni Navarra setup @ Auger Observatory

First result on tank calibration for single-hit muons, The event selection criteria require one and only one hit in the top RPC and one and only one hit in the bottom RPC



Good agreement

Figure 4: Left: charge distribution in data, before and after selecting single hit events; Right: charge distributions for single hit events in data and simulation. The number of simulated events was normalized to the number of acquired events.

Due to the single-hit cut the atmospheric particle flux component is severely reduced, leading to the disappearance of the first, low energy peak, confirming the selection of muons

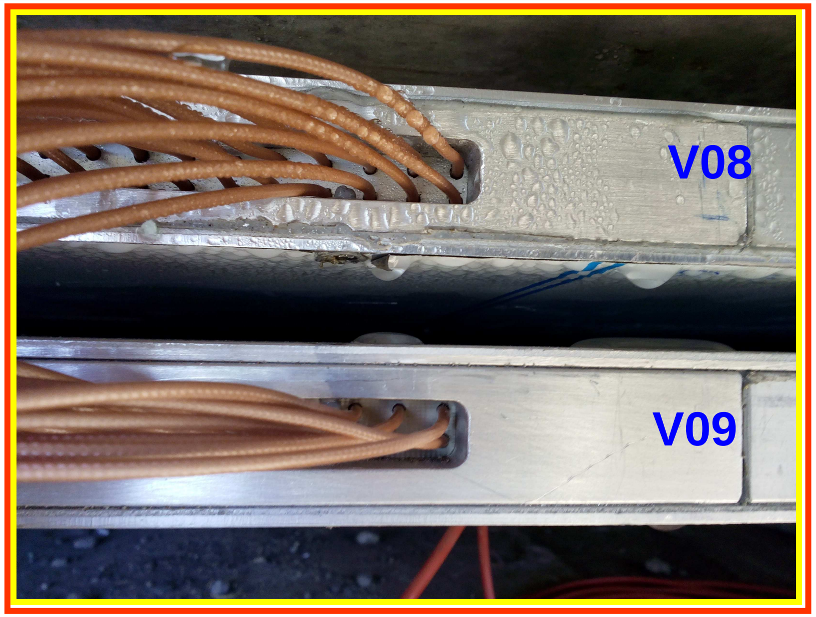
High charge events are characterized by having large tracklengths or/and high multiplicity. Since RPCs configuration limits the maximum tracklength, and we require multiplicity 1 the tail at the right is also reduced

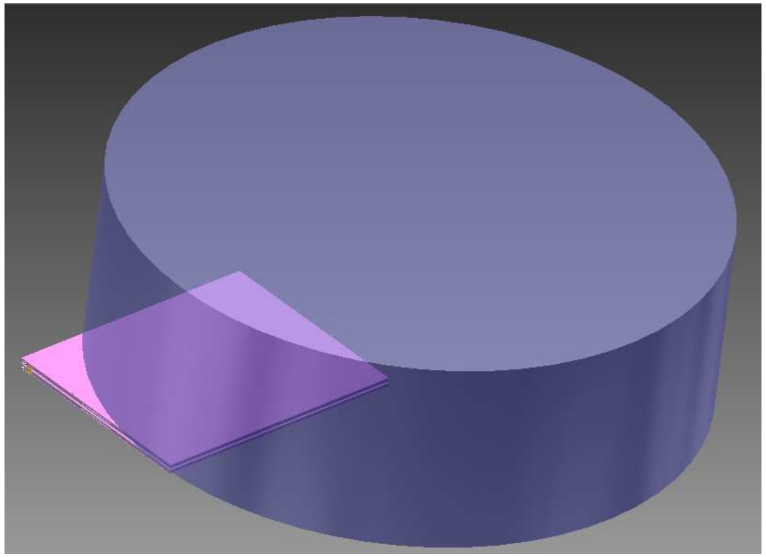
CONCLUSIONS from GN setup

- **14 months of operation at 12 cc/min and at 4 cc/min**
  - **Some problems related with humidity in the HV connectors. Understood the cause and solved.**
  - **The setup is not protected against ambient conditions. This gave us very good indications about the robustness of the detectors.**
  - **To assure a stable efficiency the automatic adjustment of HV each 15 minutes seems to be enough when daily temperature excursions are within 20 ºC, for wider excursions we need to test a higher frequency adjustment**
  - **The setup reveals to be useful for the calibration of the Water Cherenkov Tank response to single muon events.**
  - **Data taking is ongoing.**

Tierra del Fuego setup @ BATATA site, AUGER

Tierra del Fuego setup @ BATATA site, AUGER

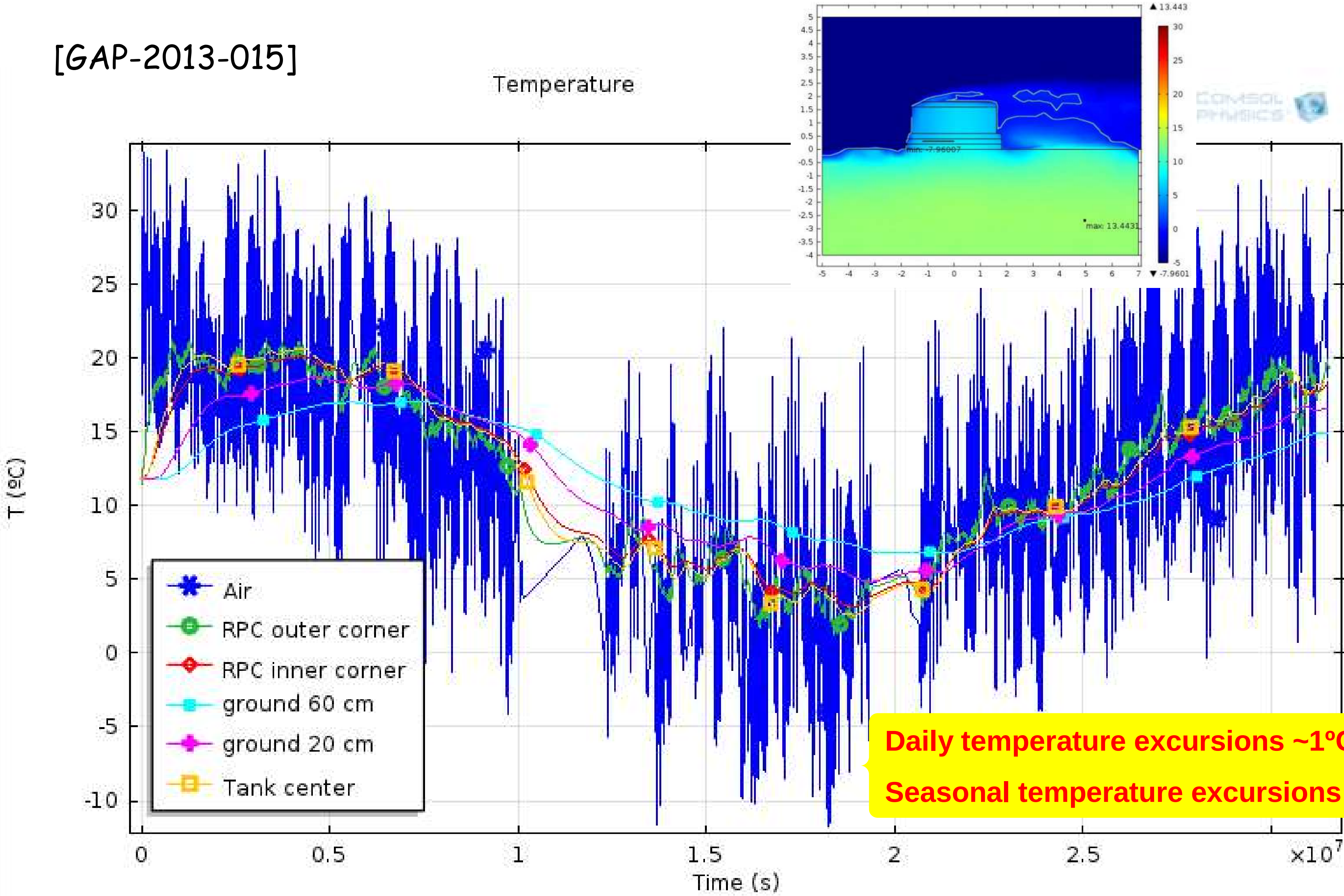




A concrete precast structure is needed to support the tank, filter the electromagnetic component of the shower and act as a protecting house for the RPCs.
Two overlapping RPCs underneath the tank.
This way we can use the tank and one RPC to define the trigger and measure the efficiency in the other RPC

Tierra del Fuego setup @ BATATA site, AUGER

[GAP-2013-015]



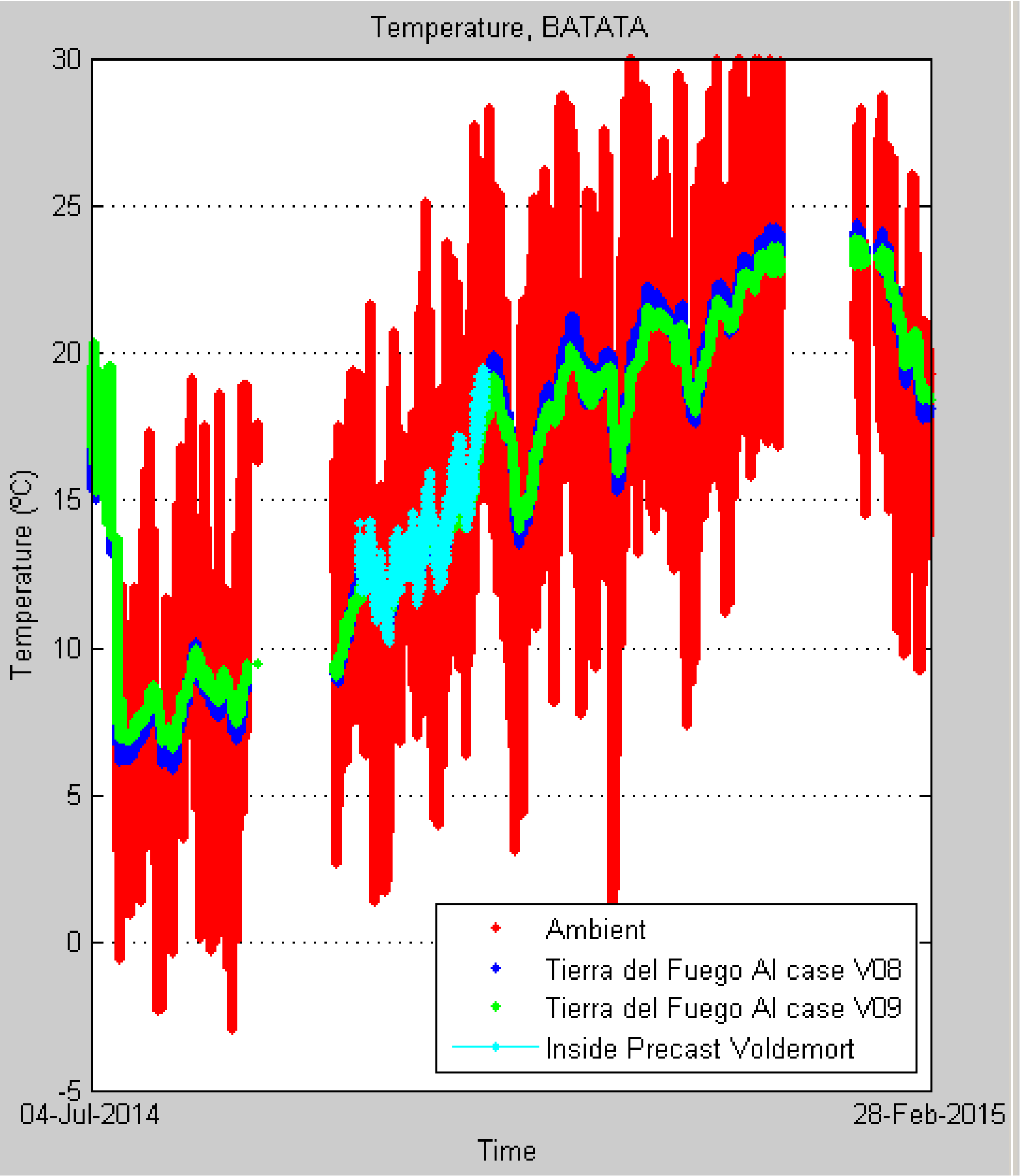
Daily temperature excursions ~1ºC

Seasonal temperature excursions ~20ºC

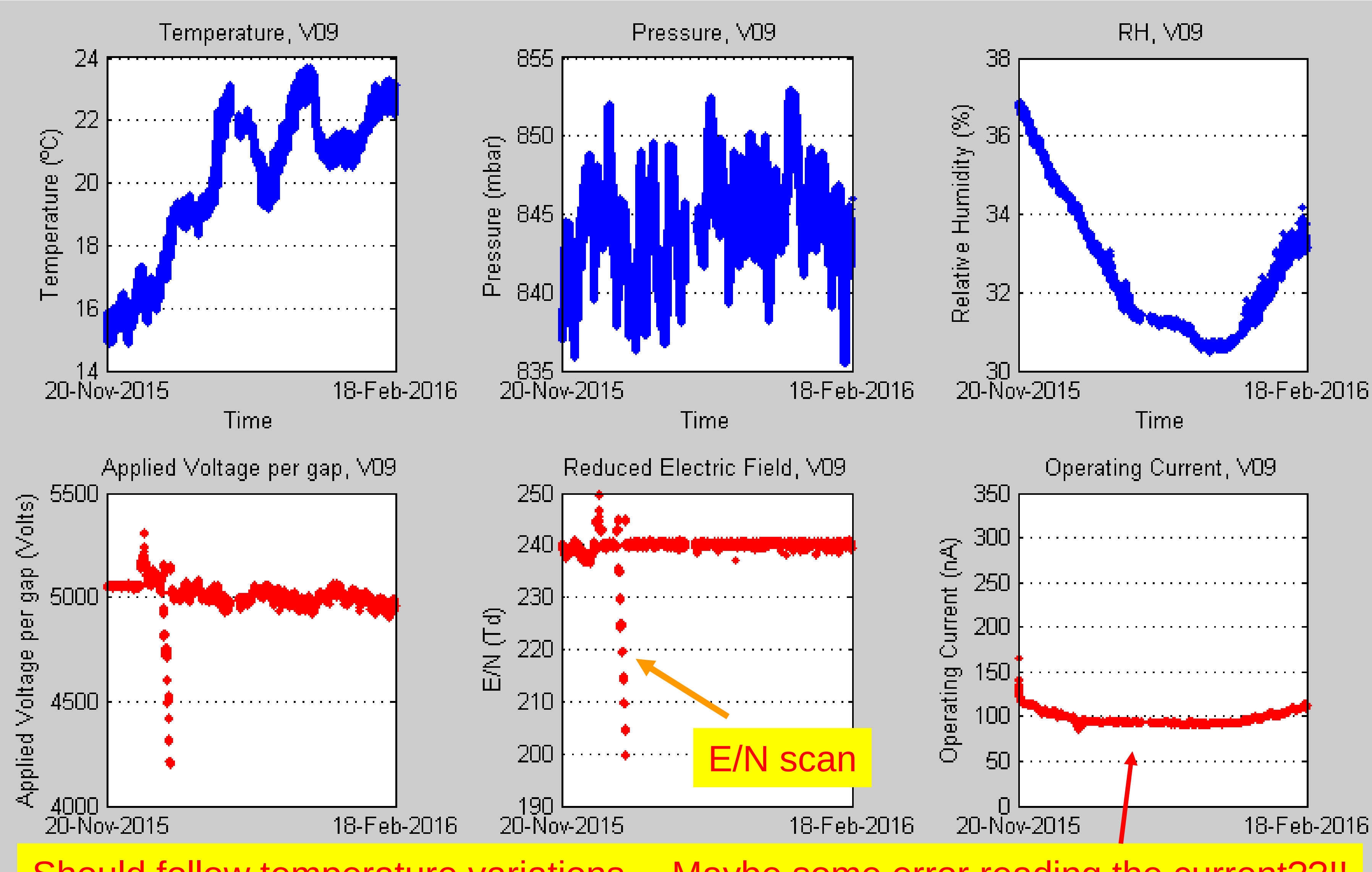
Tierra del Fuego setup @ BATATA site, AUGER

Daily air temperature excursions around 25 ºC

Chambers daily temperature excursions below 3 ºC

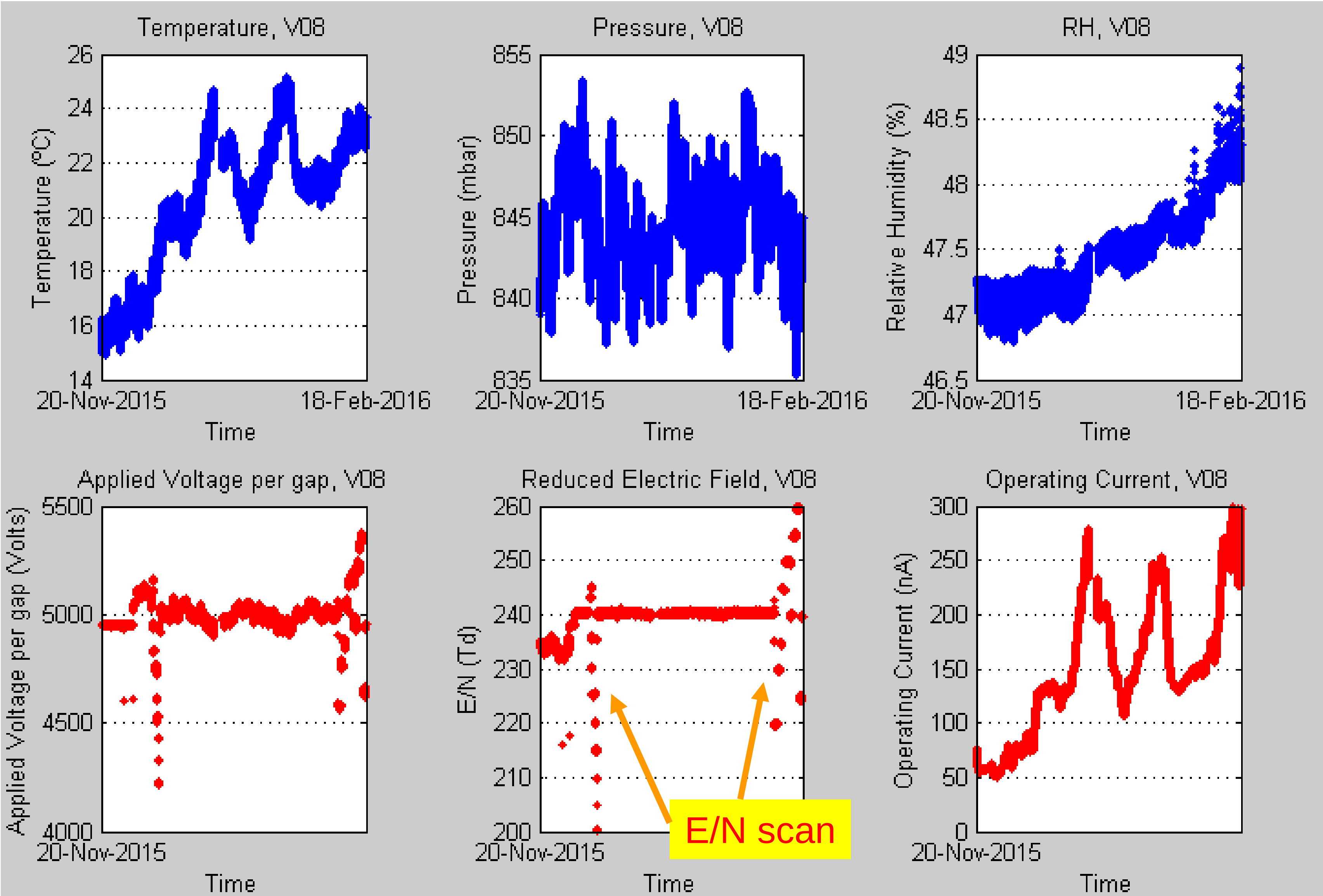


Tierra del Fuego setup @ BATATA site, AUGER

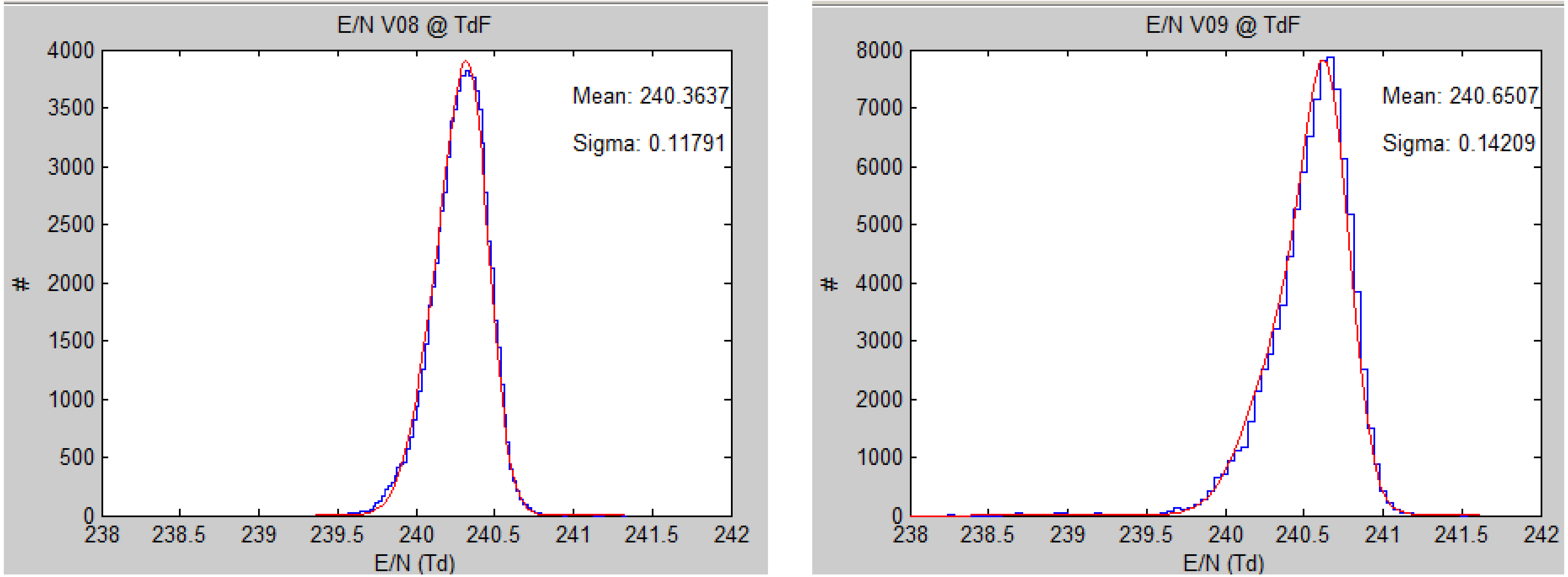


Should follow temperature variations… Maybe some error reading the current??!!

Tierra del Fuego setup @ BATATA site, AUGER

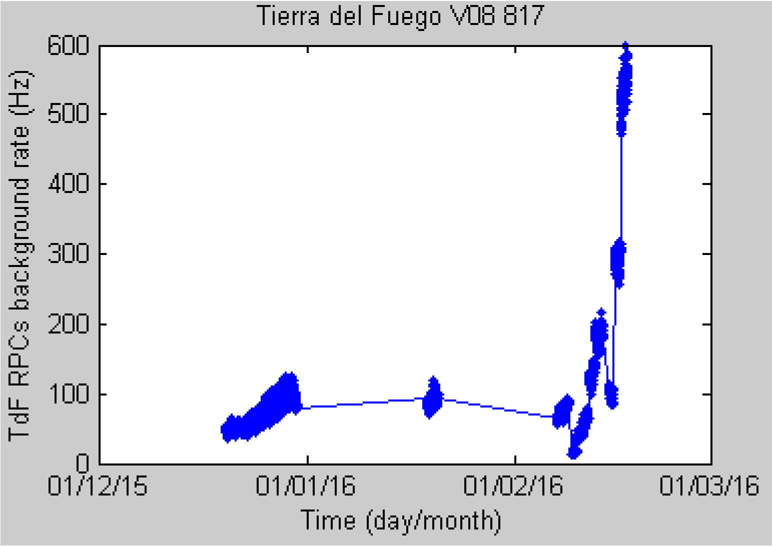


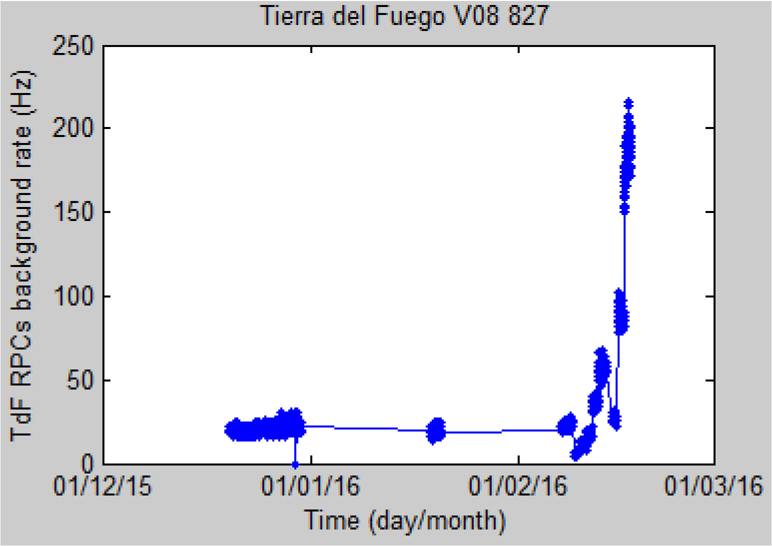
Tierra del Fuego setup @ BATATA site, AUGER

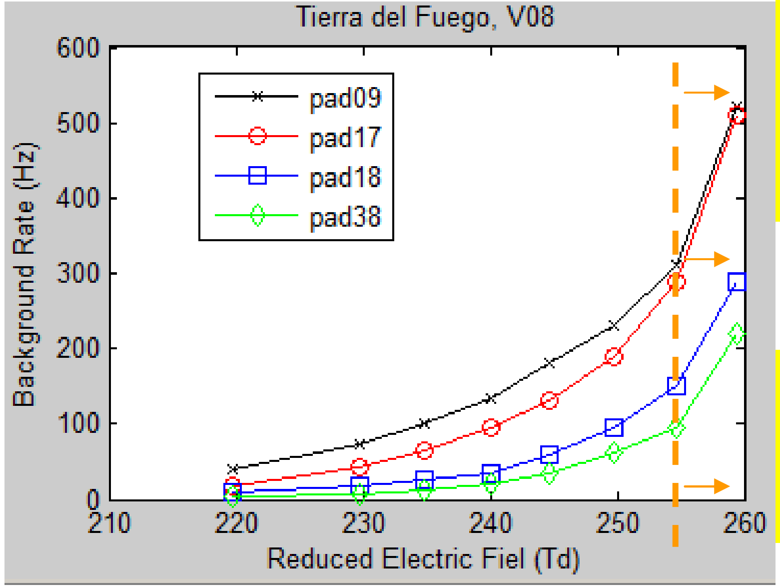


Narrow E/N distributions when comparing to the GN setup, confirming that wider temperature daily excursions plays a major role on E/N stability. Precast structure, tank and soil gives enough inertia, reducing the effect of air temperature in the detectors. This way we have very similar conditions to ones in the lab with respect to temperature daily variations.

Tierra del Fuego setup @ BATATA site, AUGER





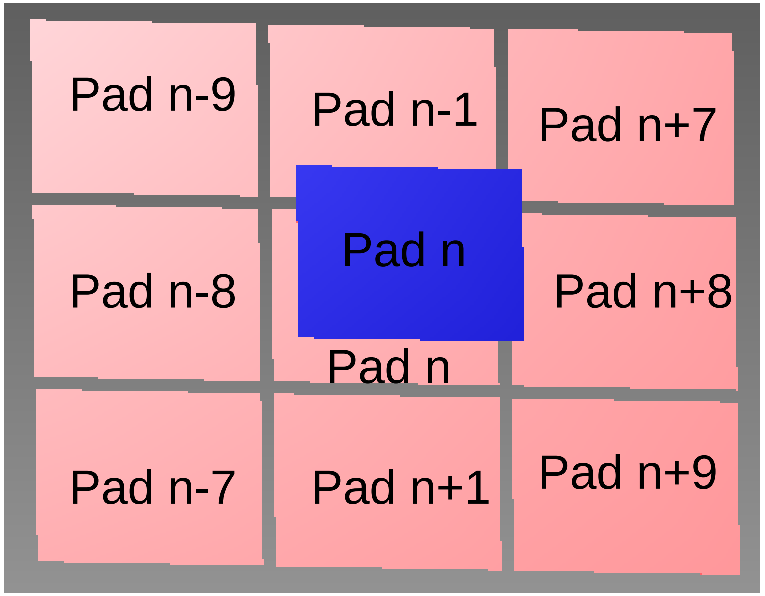


Background rates similar to the ones observed in the lab. Border pads show higher rates, but it's a mechanical issue already understood and corrected in new RPCs.

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

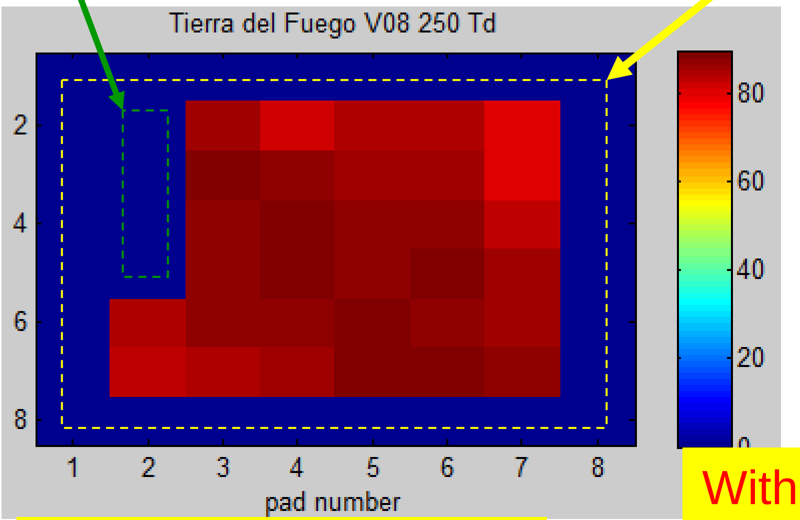
Tierra del Fuego setup @ BATATA site, AUGER

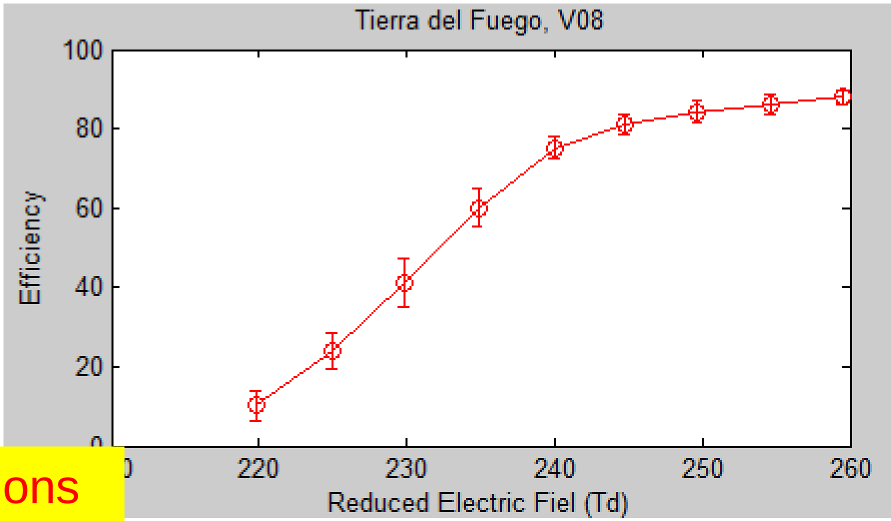
Trigger is defined by a coincidence between tank and chamber 9.
Efficient event is when we have a hit in a pad in chamber 9 and one hit in the same pad of chamber 8 or in any neighbor pad



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

Dead channels

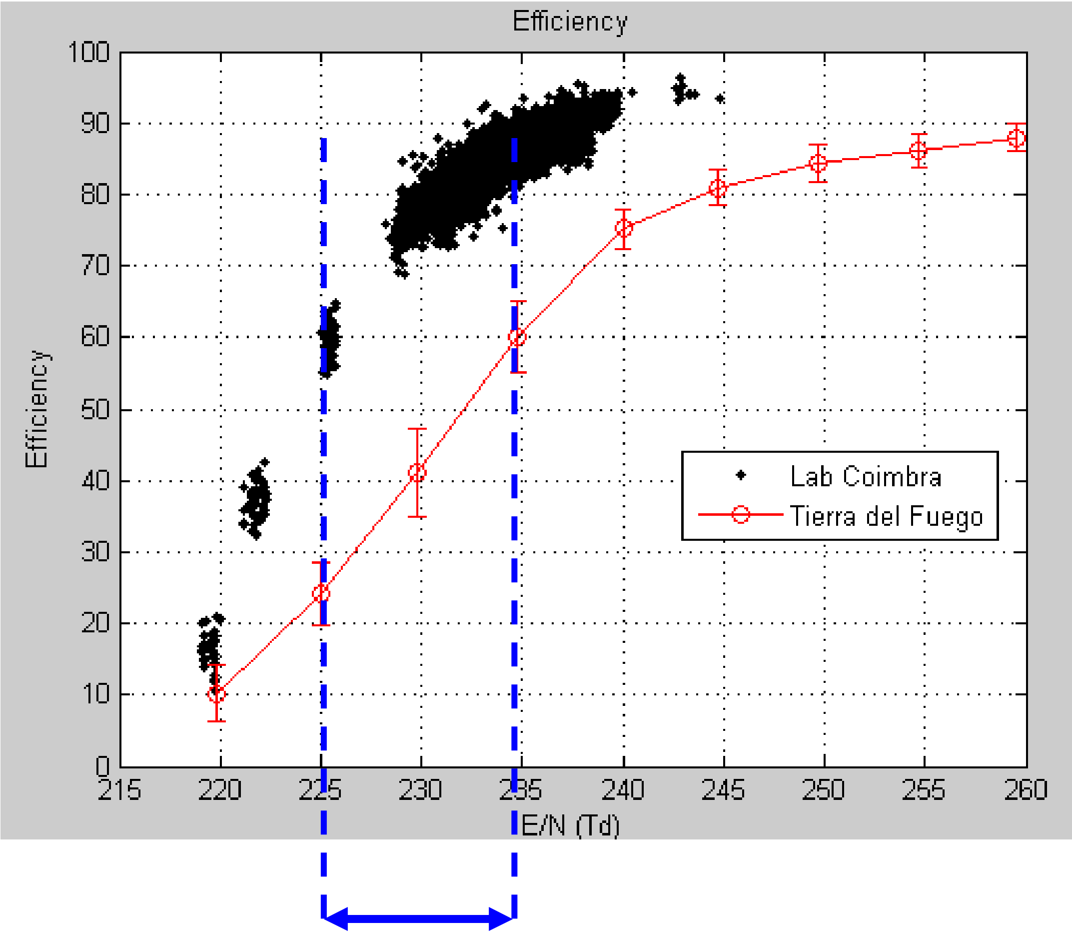




Uniform over all area

With muons
1 day / point

Tierra del Fuego setup @ BATATA site, AUGER



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.!!

Tierra del Fuego setup @ BATATA site, AUGER

Streamer mode

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

ELSEVIER

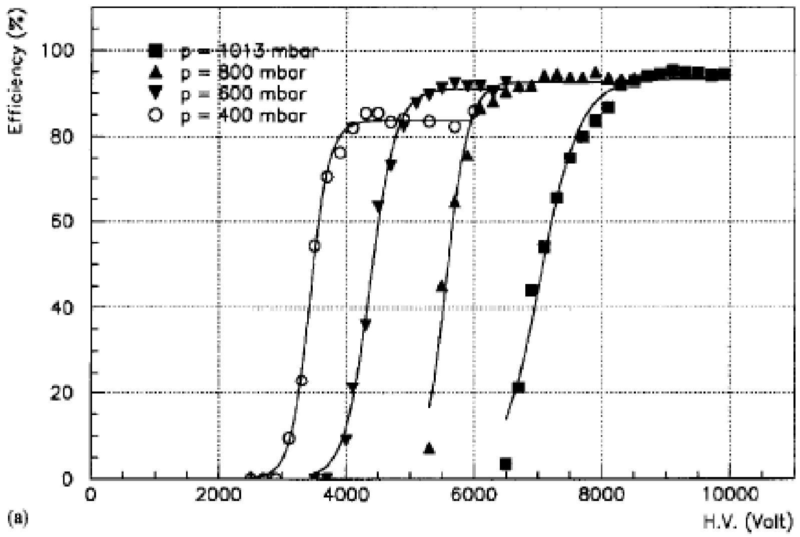
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Resistive plate chambers performances at low pressure

M. Abbrescia*, E. Bisceglie, G. Iaselli, S. Natali, G. Pugliese, F. Romano

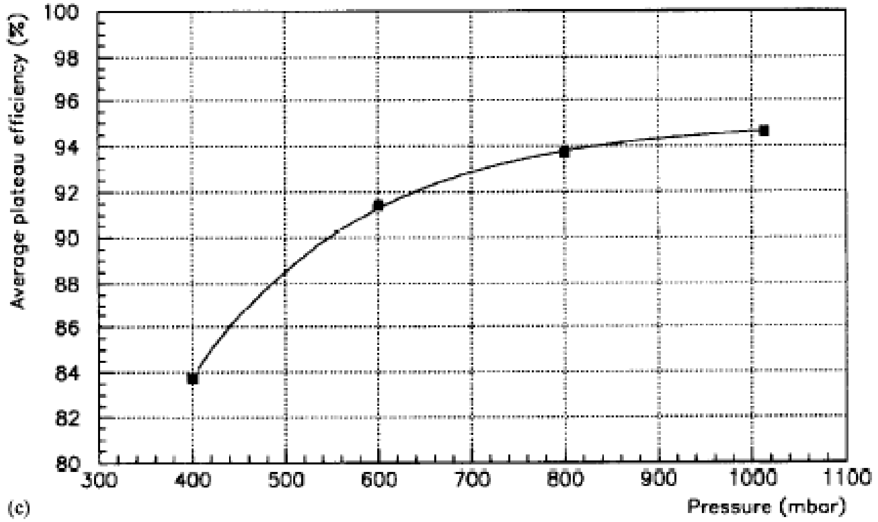
Dipartimento di Fisica e Sezione INFN, Via G. Amendola 173, 70126 Bari, Italy

Received 30 December 1996

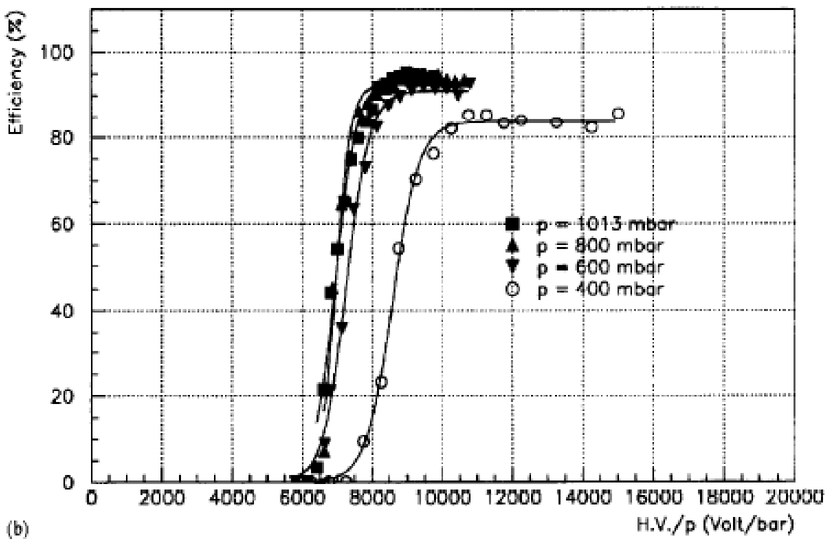


(a)

Lower pressure ⇒ Lower efficiency plateau



(c)



(b)

Tierra del Fuego setup @ BATATA site, AUGER

Interpreting the observed data!!!

α and η depend directly on E/N that depends on the pressure
Decreasing pressure we decrease α. How to "correct"?

$G = e^{\alpha^* g}$ is the average cathode-to-anode gas gain

$\nu = r\lambda/\alpha^*$,

$r = 1 - \frac{\eta}{\alpha}$

inefficiency

$$\mathcal{E}_{\mathcal{A}+\mathcal{C}+\mathcal{D}} \underset{\mathcal{E}\approx 1}{\cong} 1 - \left[G^{-\nu} + (1 - G^{-\nu}) \frac{1}{\nu \Gamma(\nu)} \left(\frac{\mathcal{N}_{eth}}{G/r} \right)^{\nu} \right], \quad (5.22)$$

High efficiencies

$$\frac{\mathcal{N}_{eth}}{G/r} \lll 1$$

So to decrease inefficiency we mainly can:
- Increase gain, increasing HV and consequently E/N
- Decrease threshold
- Increase ν, via wider gaps reducing α^* for the same Gain or increasing the number of gaps change from λ to N λ.
- Change gas, not easy since we want mono-component "mixture"

CONCLUSIONS from TdF setup

- **In real field conditions, operating standalone for months**
  - **More than 12 months of smooth operation. Some problems in HV connectors due to condensation inside precast. Solved and smooth operation since then.**
  - **The precast structure together with tank and soil proximity makes temperature daily excursions similar to the indoor ones, which is good concerning E/N stability.**
  - **First measurements of background rates and efficiency agrees with the ones observed indoor, although we observe a shift of 10 Td/gap (200 V/gap) in E/N towards higher fields, expected!!**
  - **Field measurements will continue (charge spectra) trying to clarify last observations.**
  - **Indoor setup will be constructed to study chamber's performance at pressures below atmospheric.**