RPCs and applications to the Particle Physics

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Lay out

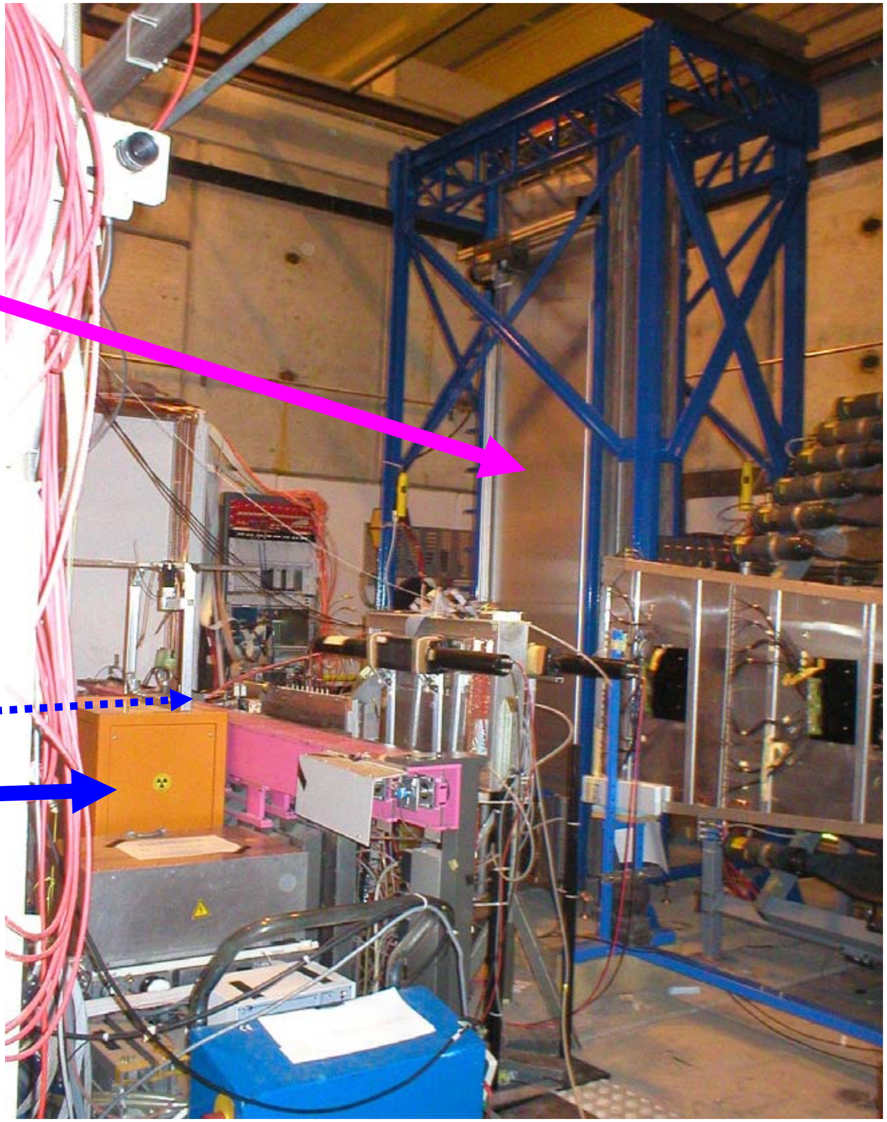
- Review of the ageing effects
- Ageing test at the GIF
- Measurement of the Fluorine production rate
- A method for improving space resolution

The GIF experimental setup

3 standard production chambers(BML-D) in the area.
6 gaps under ageing test.

Beam

^{137}Cs source (20 Ci);
660 keV photons

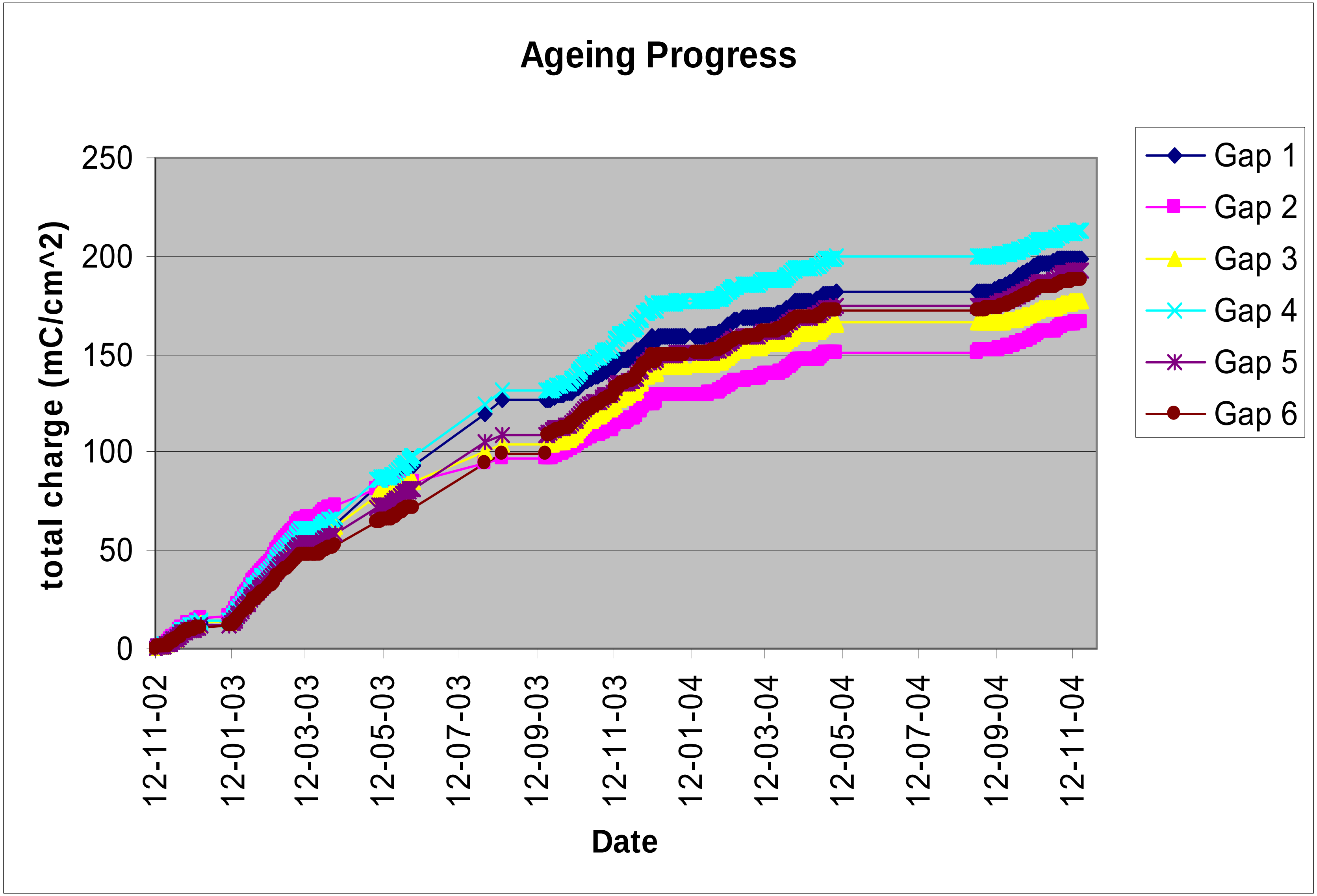


RPC ageing effects

- A several years test at the GIF allowed to understand two main ageing effects
  - the increase of the electrode plate resistivity which reduces the rate capability
  - the increase of the detector noise
- Both effects were studied on Atlas and CMS production chambers kept under intense irradiation in order to accelerate the ageing
- Rate requirements in the test for Atlas
  - expected rate for the RPCs in the Atlas barrel is 10-20 Hz/cm^2
  - Applied safety factor >5 → 100 Hz/cm^2.
  - 10 Atlas equivalent years simulated in 2 Years → 500 Hz/cm^2

RPC ageing effects (2)

- The above conditions, assuming a delivered charge of 30 pC/count for Atlas, require a total integrated charge in the course of the experiment of 0.3 C/cm^2
- The results clearly indicate how RPCs have to be treated to survive a long working time in a hostile environment
- A third ageing effect, consisting in the gradual deterioration of the graphite electrode, was studied in laboratory tests
- In the serial RPC production, the graphite was reinforced in order to survive up to abut 0.6-0.8 C/cm^2

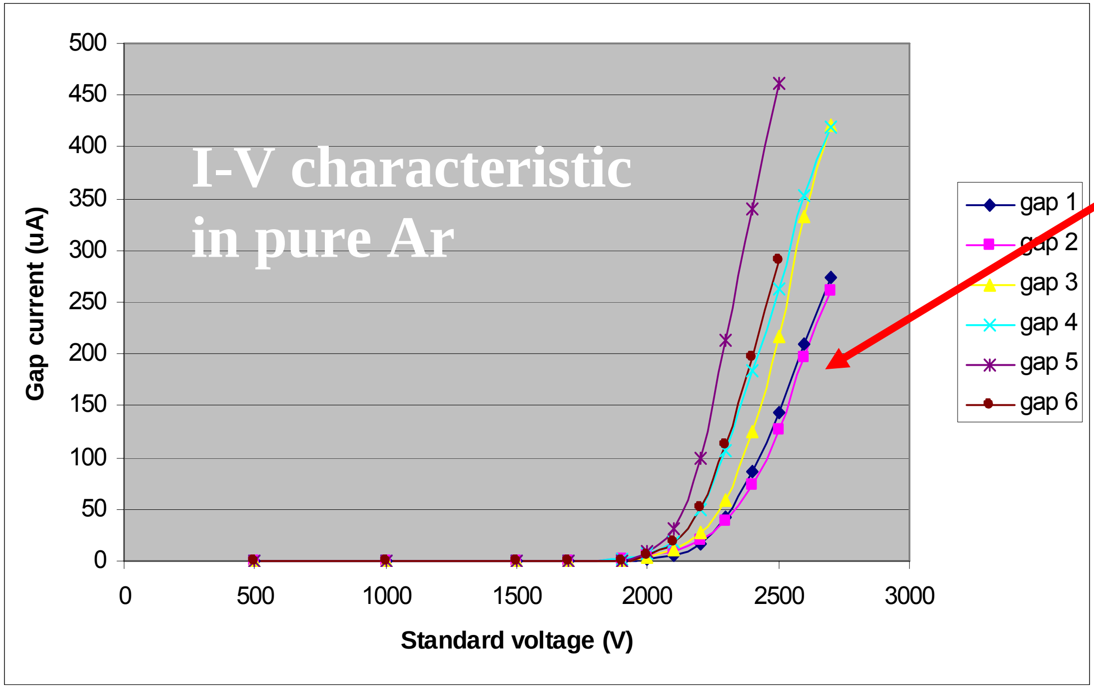


Specific Atlas ageing rules: 100 Hz/cm2 (including a safety factor of 5) for 10 LHC Years >>> total expected integarted charge 0.3 C/cm2

How to monitor the resistivity during the test?

We use two methods to measure the resistivity of the bakelite plates during the test

- The chambers are filled with Ar, and the HV is raised up to a value when the resistivity of the gas is negligible compared to the resistivity of the electrodes. Above this value, an I-V curve gives the value of the resistivity of the bakelite.

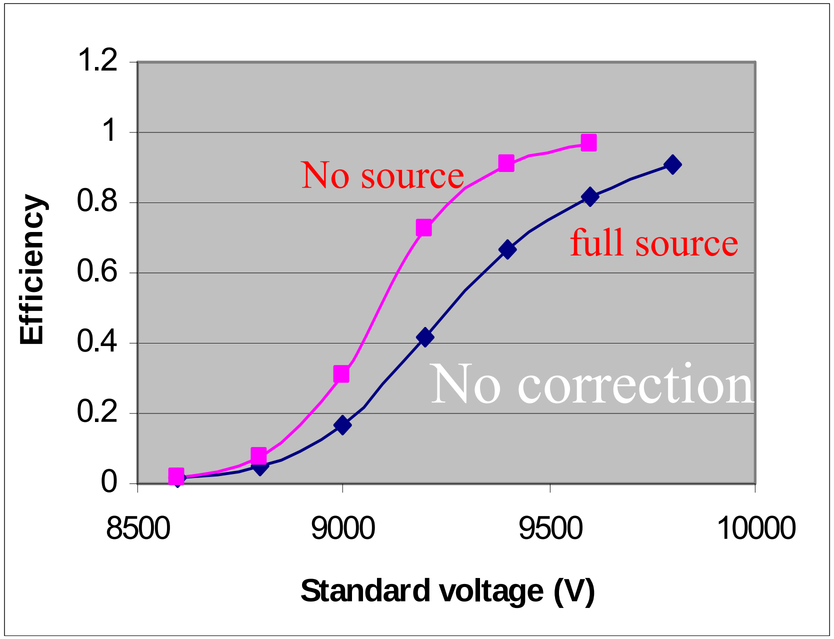


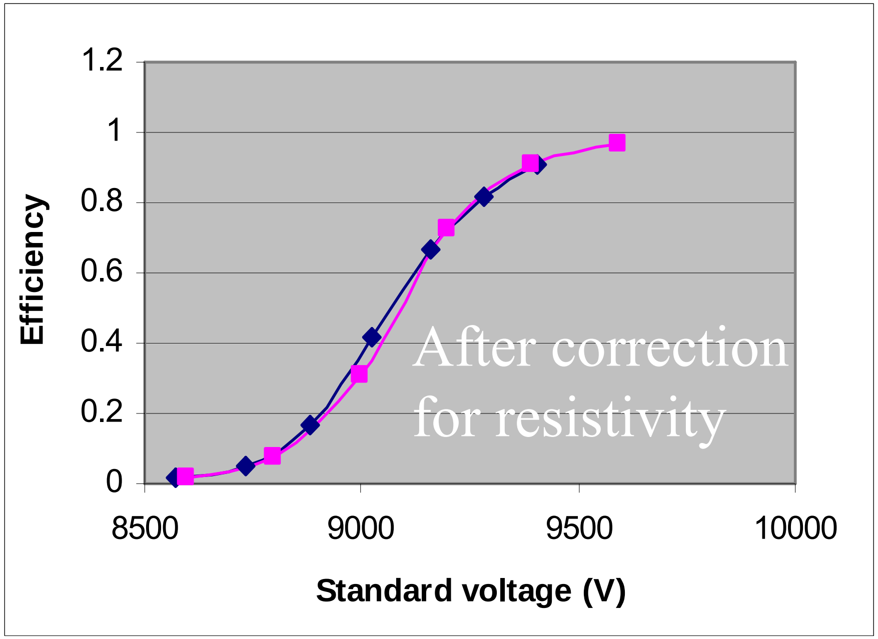
Linear increase dominated by bakelite resitivity

Resistivity measurements (2)

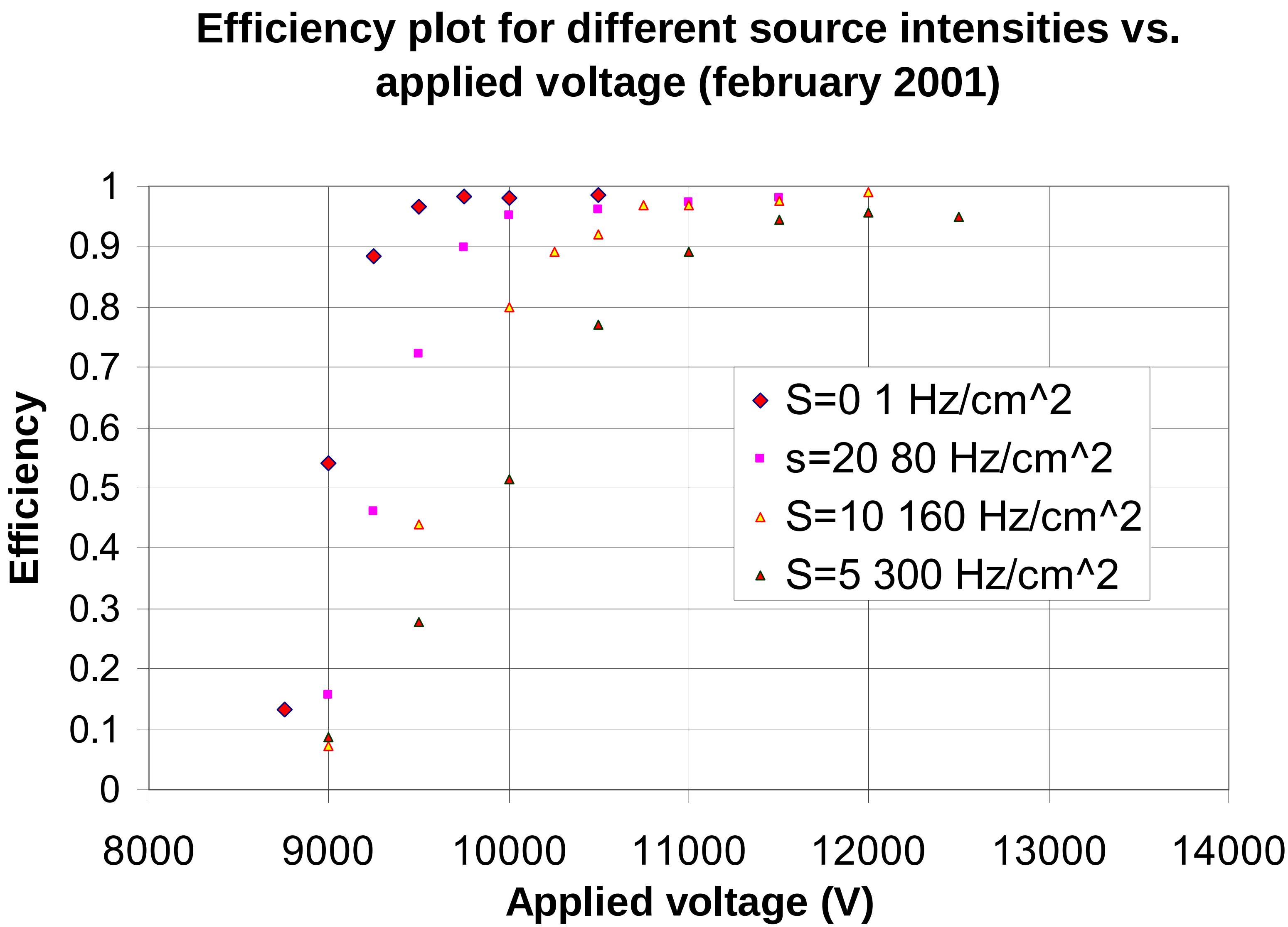
- The efficiency plateaus with full source and with source off are compared. The shift of the plateau with full source is due to the gap current, which produces a voltage drop across the bakelite plates. From the voltage drop and the current measured we calculate the plates r

$$\Delta V_{gas} = \Delta V_{gap} - R_{bak} I_{gap}$$

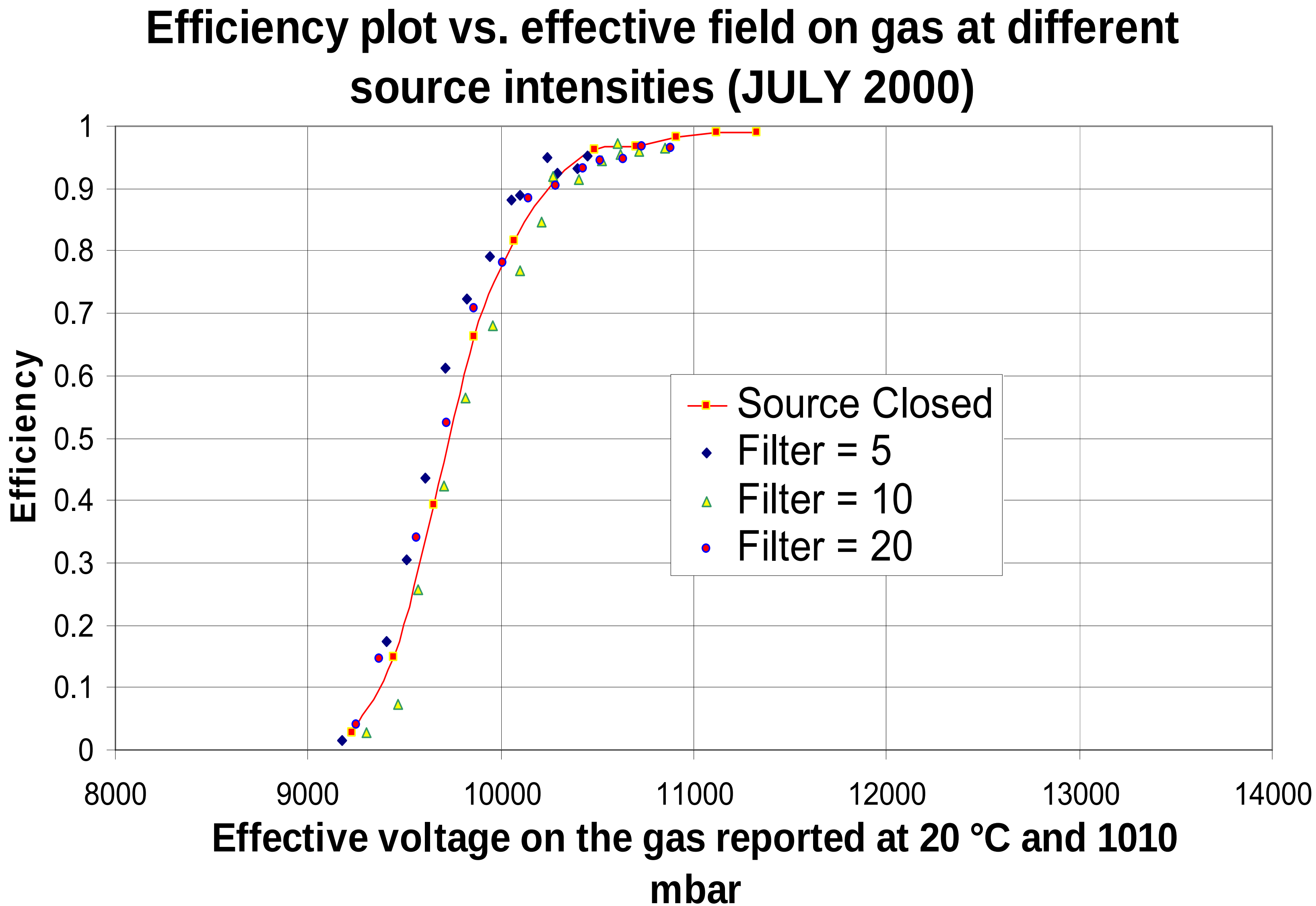




Final rate capability test for a pre-production prototype

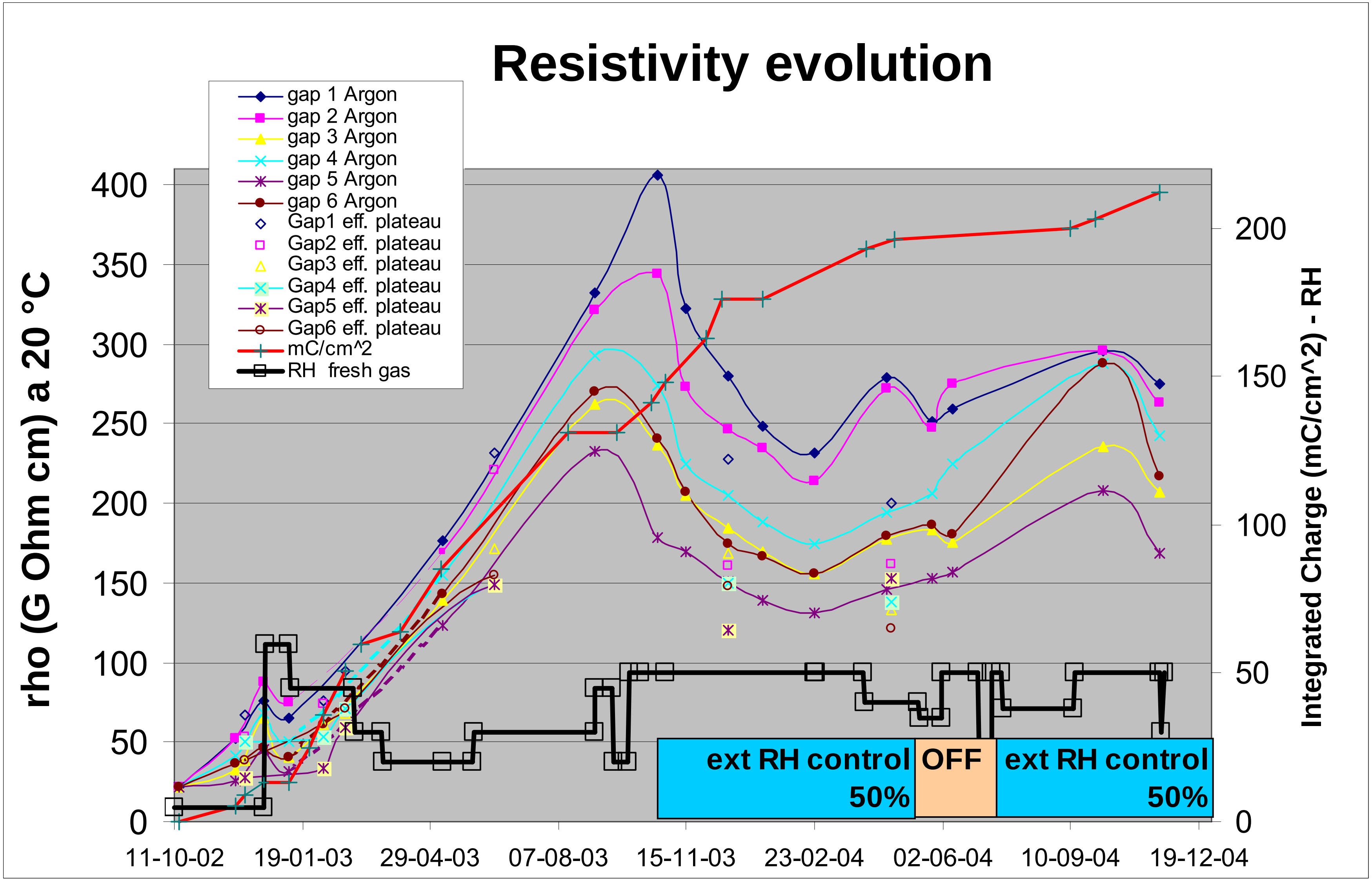


Vgas=Vapplied - IR



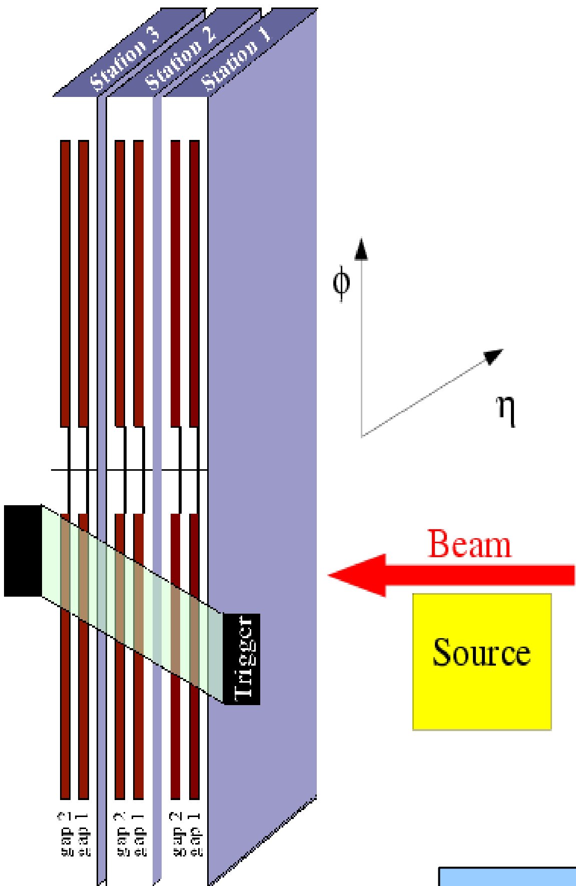
Specific ageing effects: the plate resistivity increase

- The gradual resistivity increase of phenolic-melaminic plates kept under intense currents is documented since a long time. The following results have been achieved at X5
- → The effect depends on the detector working current: non powered RPCs did not show any resistivity increase at X5
- → The effect depends on the humidity and is reduced (or disappears at all) when RPCs are operated at relatively high humidity
- → The humidity effect is relevant only if both the working gas and the environment are humidified
- → Possible explanation: the effect of water is polarity dependent (more effective on the anode side)



Resistivity evolution
gap 1 Argon
gap 2 Argon
gap 3 Argon
gap 4 Argon
gap 5 Argon
gap 6 Argon
Gap1 eff. plateau
Gap2 eff. plateau
Gap3 eff. plateau
Gap4 eff. plateau
Gap5 eff. plateau
Gap6 eff. plateau
mC/cm^2
RH fresh gas
rho (G Ohm cm) a 20 °C
Integrated Charge (mC/cm^2) - RH
0
50
100
150
200
250
300
350
400
0
50
100
150
200
11-10-02
19-01-03
29-04-03
07-08-03
15-11-03
23-02-04
02-06-04
10-09-04
19-12-04
ext RH control 50%
OFF
ext RH control 50%


Plate resistivity evolution (2)



- Each detector layer consist of two gas gaps with the gas flowing serially from the lower to the upper ones
- Only the 6 lower gaps were kept at the working point
- The upper ones are normally kept at HV=0
- After ~2 years of operation, the plate resistivities of the upper chambers are consistent with the initial values

The operating current is the primary cause of the observed increase in plate resistivity

Comparison of up and down gas volumes (Nov 03)

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Layer nr	gas vol up Ro Gohm * cm	gas vol down
1	168	410
2	82	340
3	43	230
4	38	270
5	36	180
6	41	240

- → Non powered gas volumes show resistivities compatible (a part one case) with the production specifications

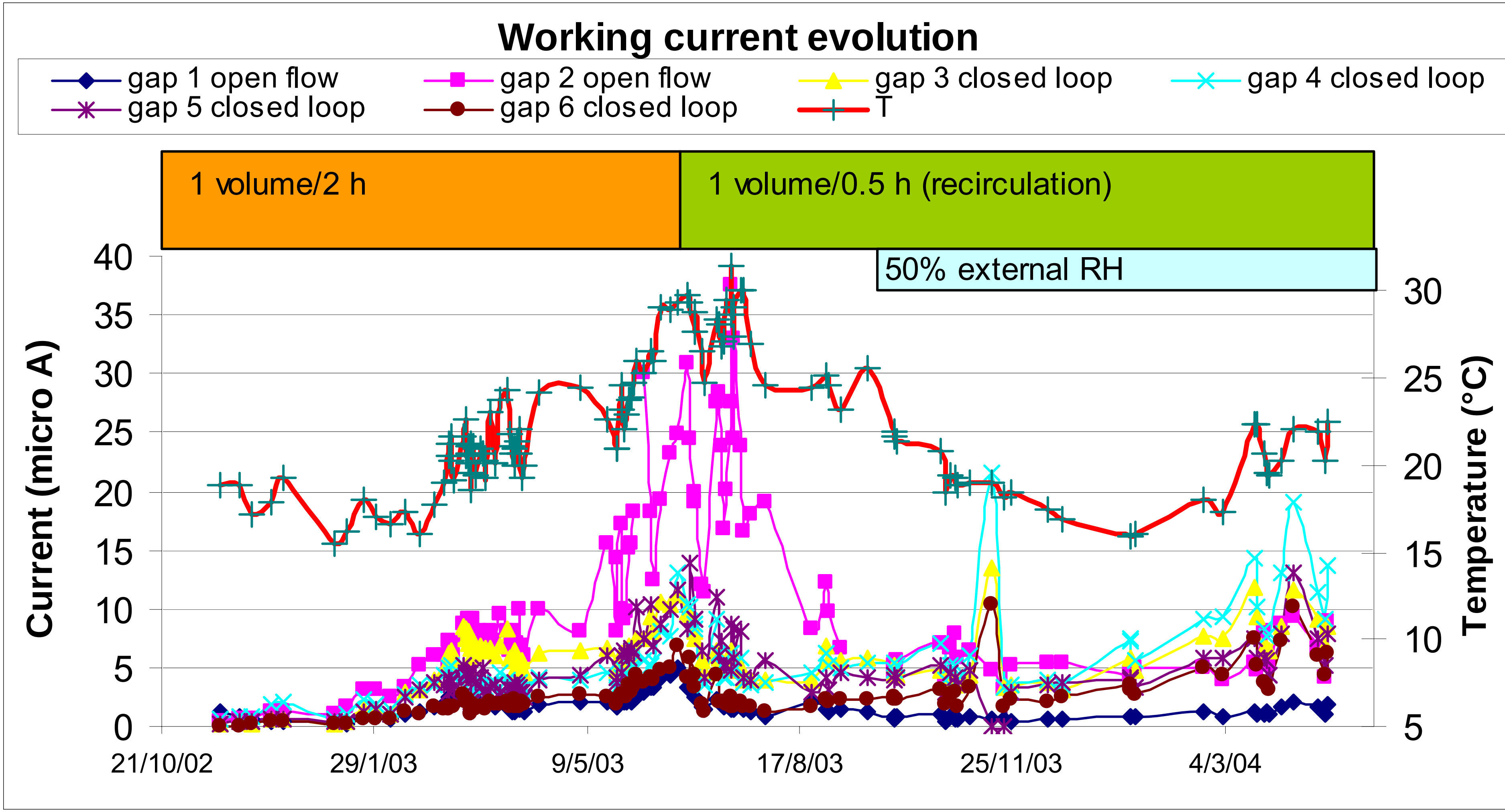
Specific ageing effects: the noise increase

- This effect is due to electrode surface damages producing an increase of the noise rate and noise current. We have shown that it is enhanced by:

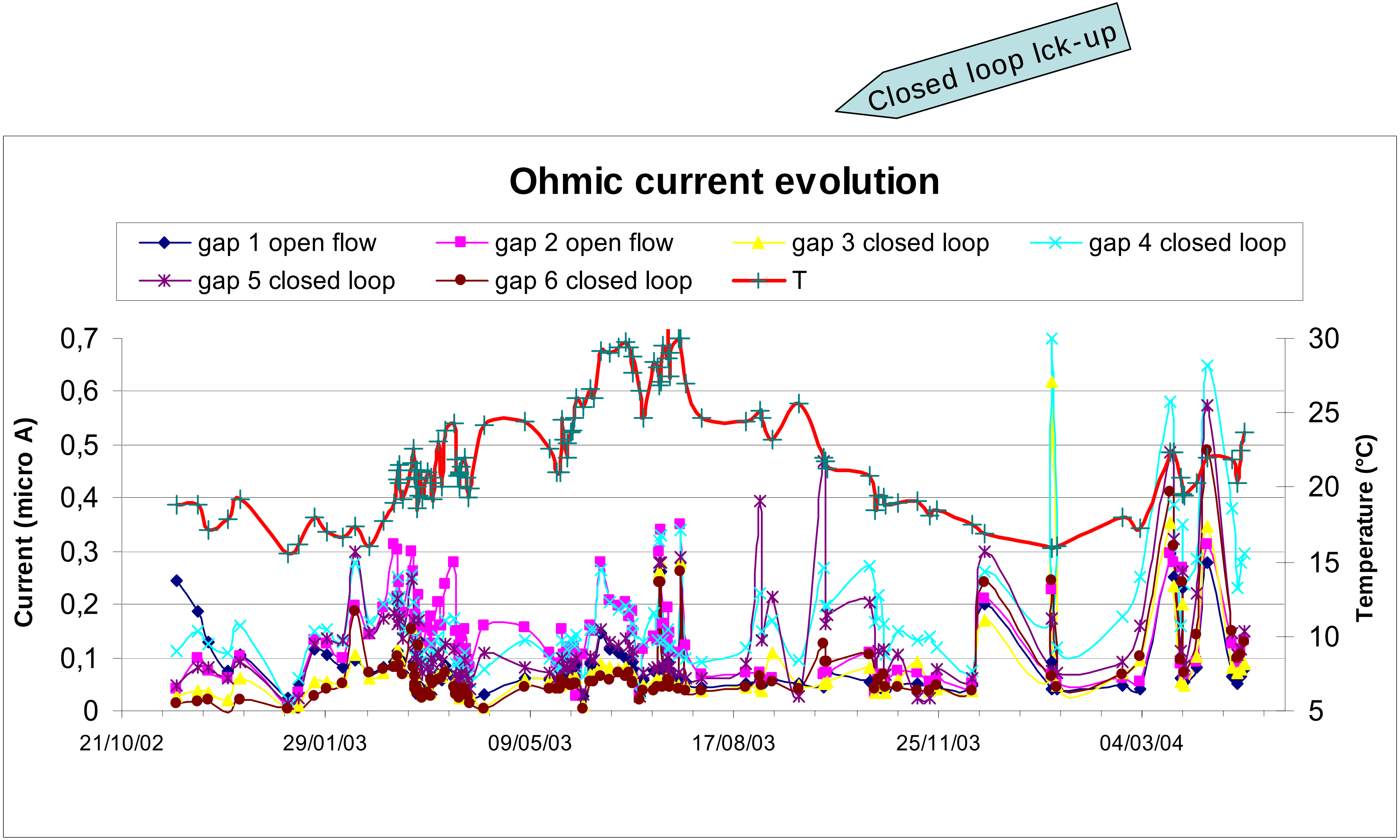
1. High temperature →a very stable RPC working in Atlas requires temperatures not exceeding 23-24 C
2. Insufficient gas flow rate, A number of accidents occurred in the gas system caused evident temporary increase of the noise → a flow rate up to 1 Vol/h is required in Atlas
3. Stress due to very high counting rate (1 kHz/cm2)
4. Already existing local defects of the surface

Specific ageing effects: the noise increase (2)

- X5 tests have also shown that this type of damages are to some extent reversible if the temperature and gas flow conditions are kept again at the correct values
- The production of HF (presumably) in the RPC working gas has been identified as one of the main causes of surface damage
- This observation triggered the search for a practical and reliable method for monitoring the Fluorine production in the gas
- We have also shown that the i-Butane has a strong effect in reducing the Fluorine production → this suggests to maximize the i-Butane concentration in the RPC gas (we are however already close to the flammability limits...)

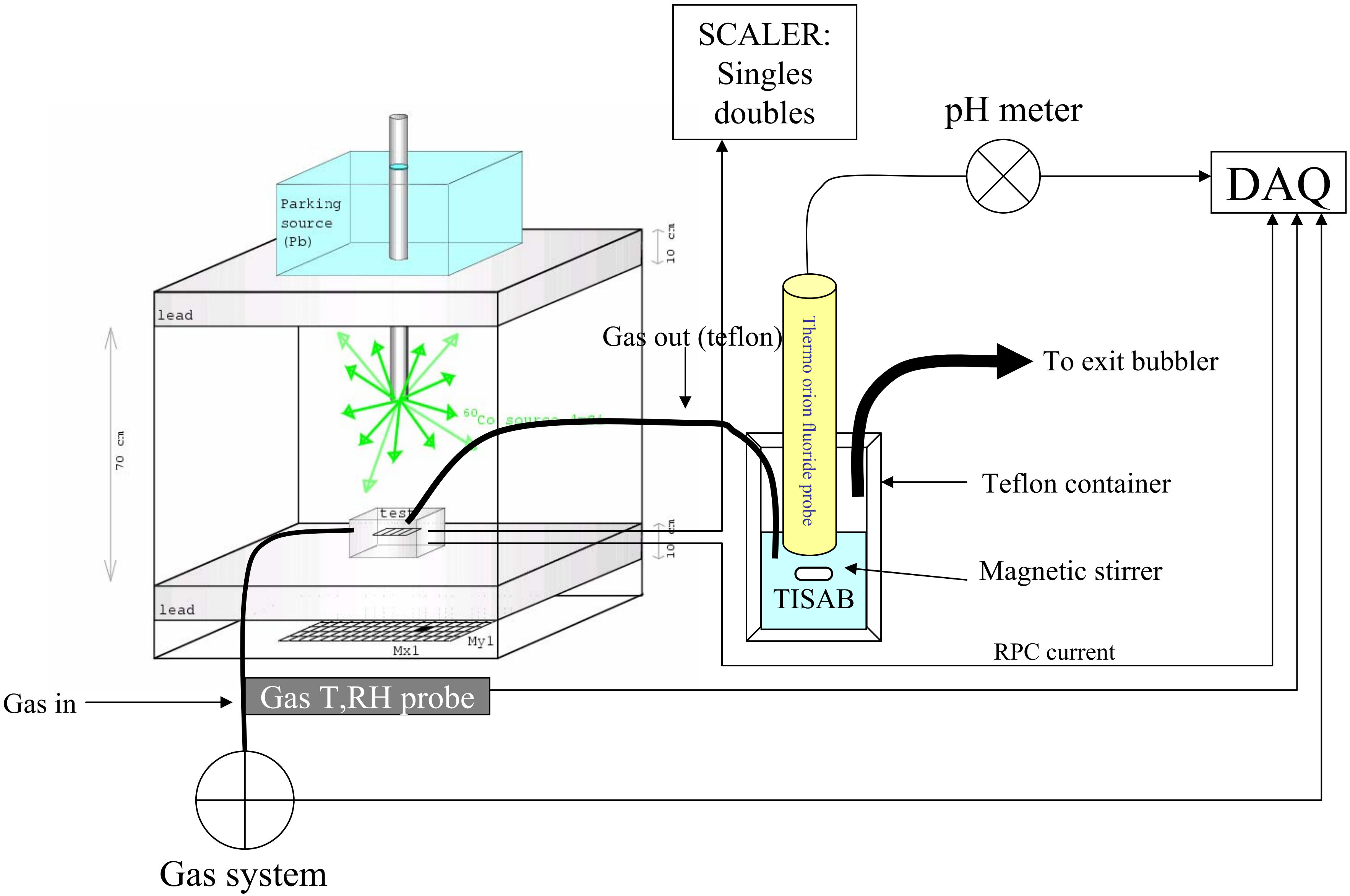


Working current evolution
gap 1 open flow
gap 2 open flow
gap 3 closed loop
gap 4 closed loop
gap 5 closed loop
gap 6 closed loop
T
1 volume/2 h
1 volume/0.5 h (recirculation)
50% external RH
Current (micro A)
Temperature (°C)
0
5
10
15
20
25
30
35
40
5
10
15
20
25
30
21/10/02
29/1/03
9/5/03
17/8/03
25/11/03
4/3/04

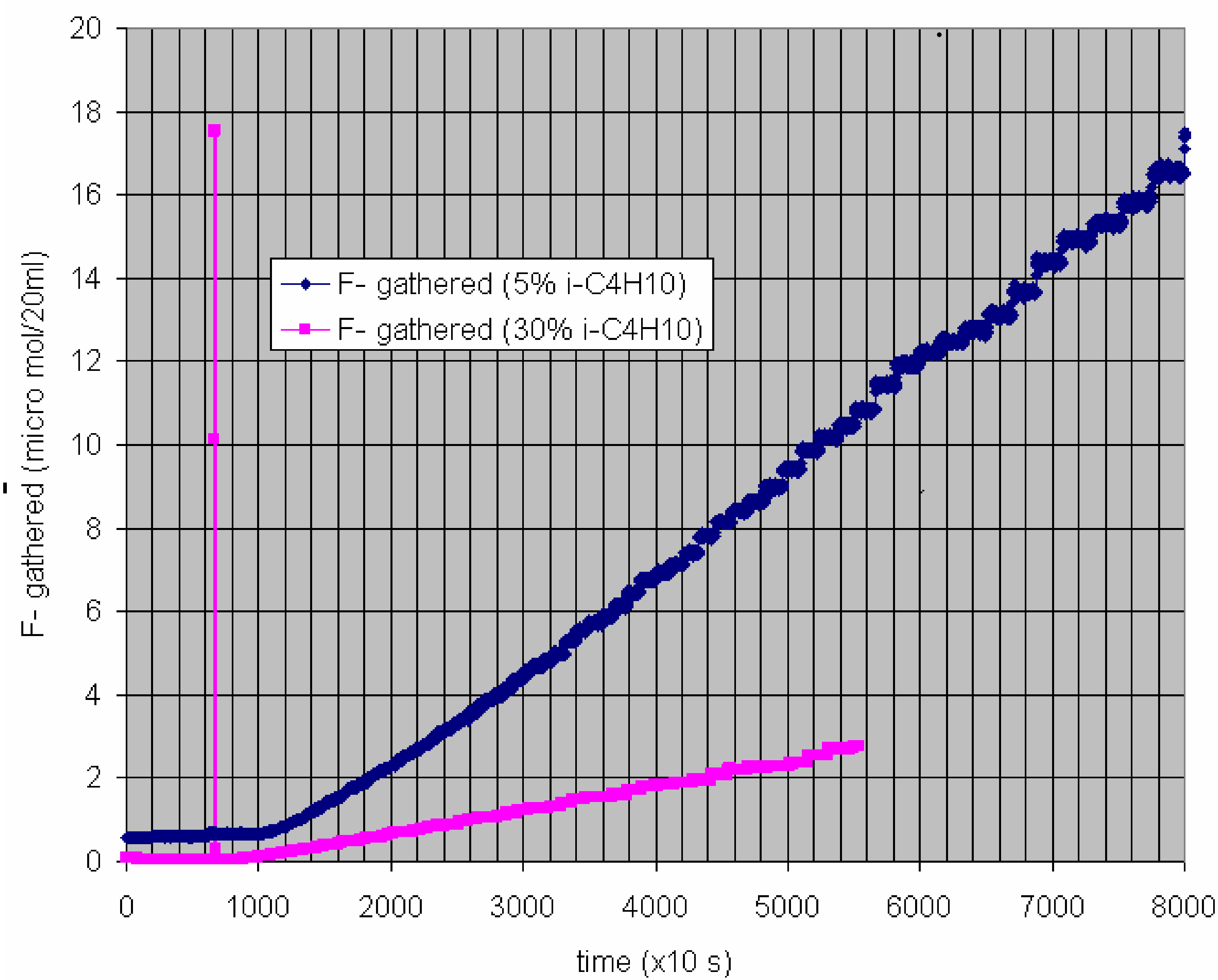


Closed loop lck-up
Ohmic current evolution
gap 1 open flow
gap 2 open flow
gap 3 closed loop
gap 4 closed loop
gap 5 closed loop
gap 6 closed loop
T
Current (micro A)
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Temperature (°C)
30
25
20
15
10
5
21/10/02
29/01/03
09/05/03
17/08/03
25/11/03
04/03/04

Experimental setup for Fluorine monitoring



Comparison of 2 different gas mixtures



How does the graphite electrode work ?

- Independently to the position measurement, to understand the behavior of the graphite electrode potential after the occurrence of a discharge in the gas, is itself an important aspect of the RPC detector physics that was not well focused so far

- It is also relevant for other detectors, like wire detectors using graphite resistive cathodes

➔ summarize therefore the basic formulas and focus the aspects that are relevant in view of the read-out of the signal propagating in the graphite.

Basic formulas

- In the limit of negligible inductive effects, that are justified by the very high graphite resistivity, about 100 k kΩ/■, the graphite electrode, coupled to the its ground reference, is a distributed capacitance-resistance system
- The potential distribution time behavior is regulated by the two dimensional diffusion equation

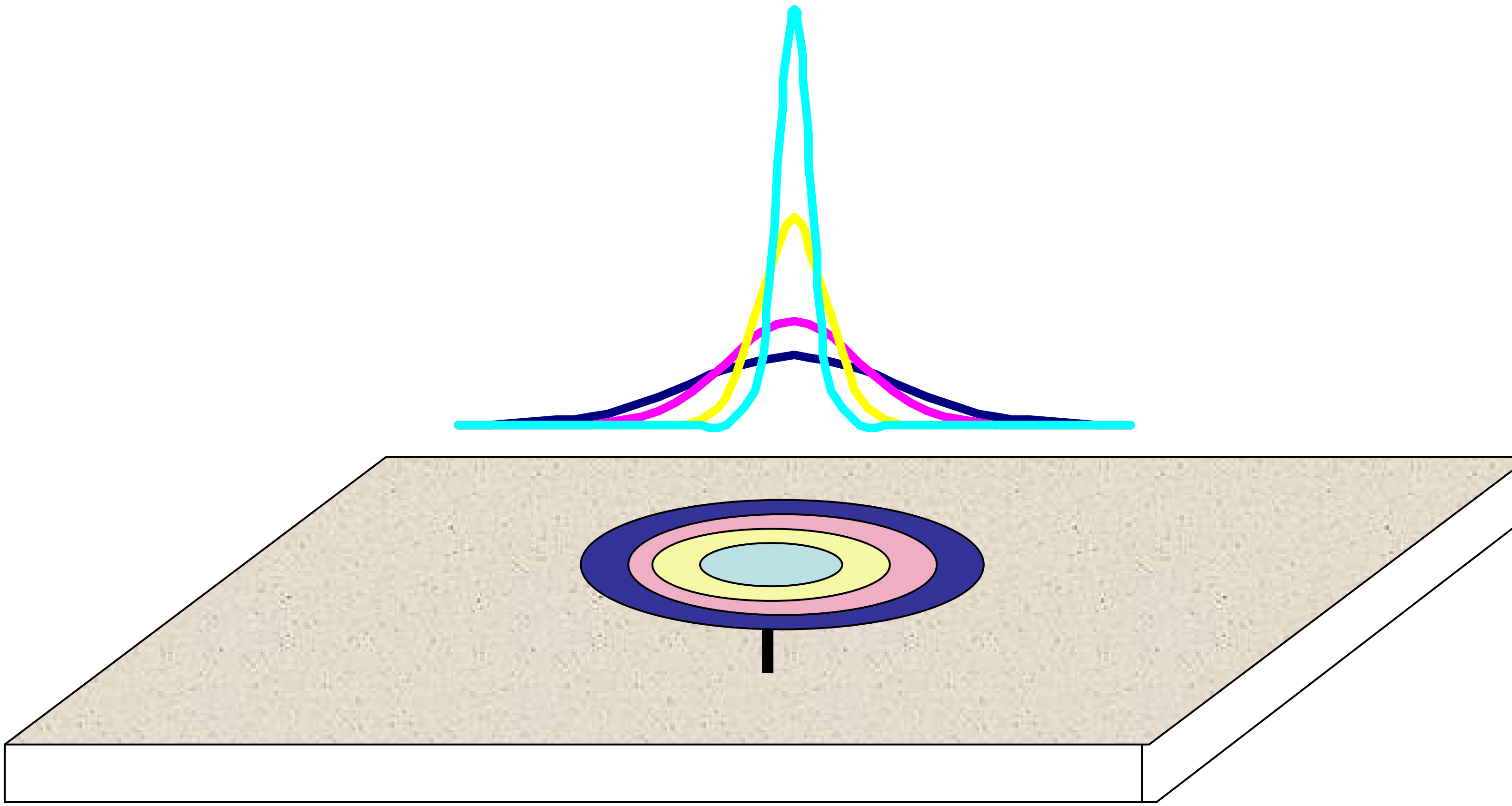
$$\partial V/\partial t = a^2 (\partial^2 V/\partial x^2 + \partial^2 V/\partial y^2) \quad \text{with} \quad a^2 = 1/\sigma C^*$$

σ = surface resistivity and
C^* = capacitance per unit surface

- The electrical discharge originated by a ionizing particle produces a “point-like” perturbation of the graphite potential which propagates to the whole electrode according to a gaussian function

$$V(r,t) = (1/4\,\pi\, a^2 t) \exp \{[(x-xo)^2 + (y-yo)^2]/4a^2 t\} \quad \text{o}$$
$$V(r,t) = (1/4\,\pi\, a^2 t) \exp \{r^2 /4a^2 t\}$$

where r is the distance from the discharge point



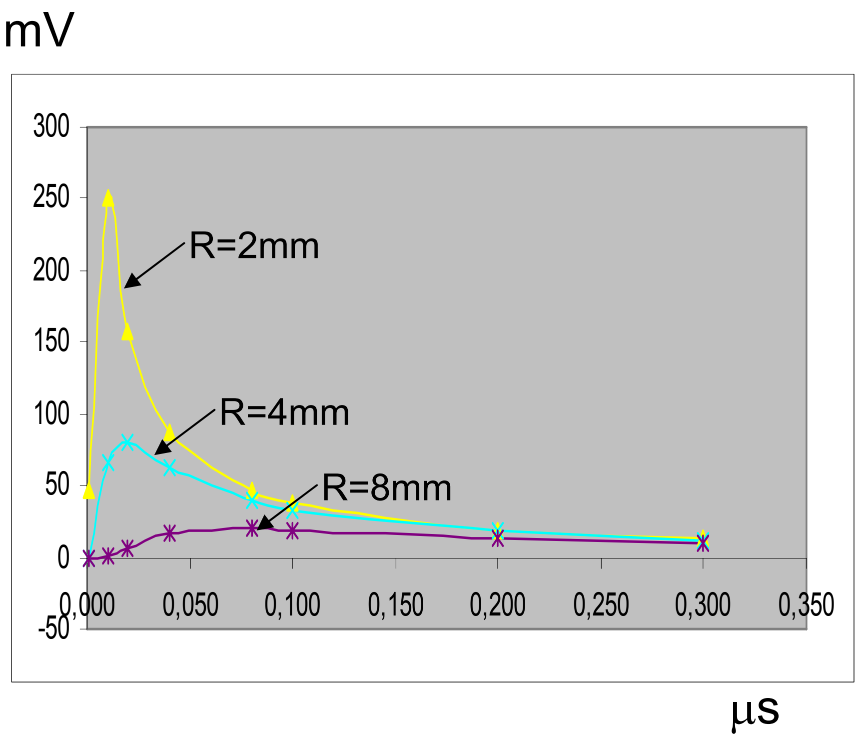
Basic formulas (2)

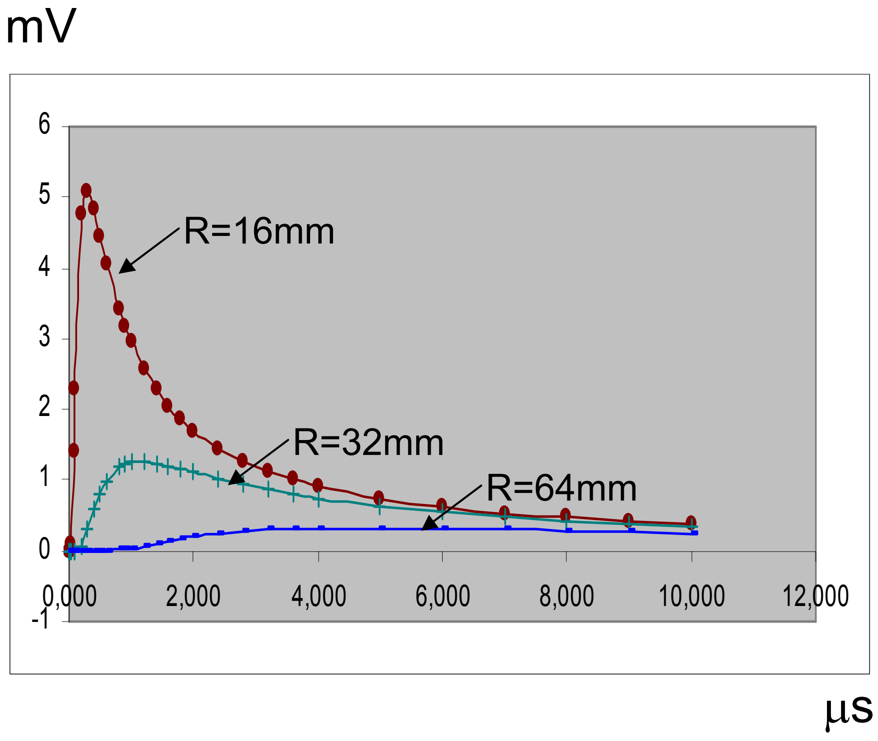
- This solution of the diffusion equation is valid for an unlimited electrode and disregard the effects of boundary conditions, i.e. the electrode edges
- By measuring the graphite potential at a fixed position we observe a waveform with a maximum at the time

$$t^* = r^2/4a^2$$

- This gives a quadratic r-t relationship
- However:
  - quadratic relationship
  - Extreme variability of the waveform with the distance
  - Adequate electronics required

Waveforms for various distances

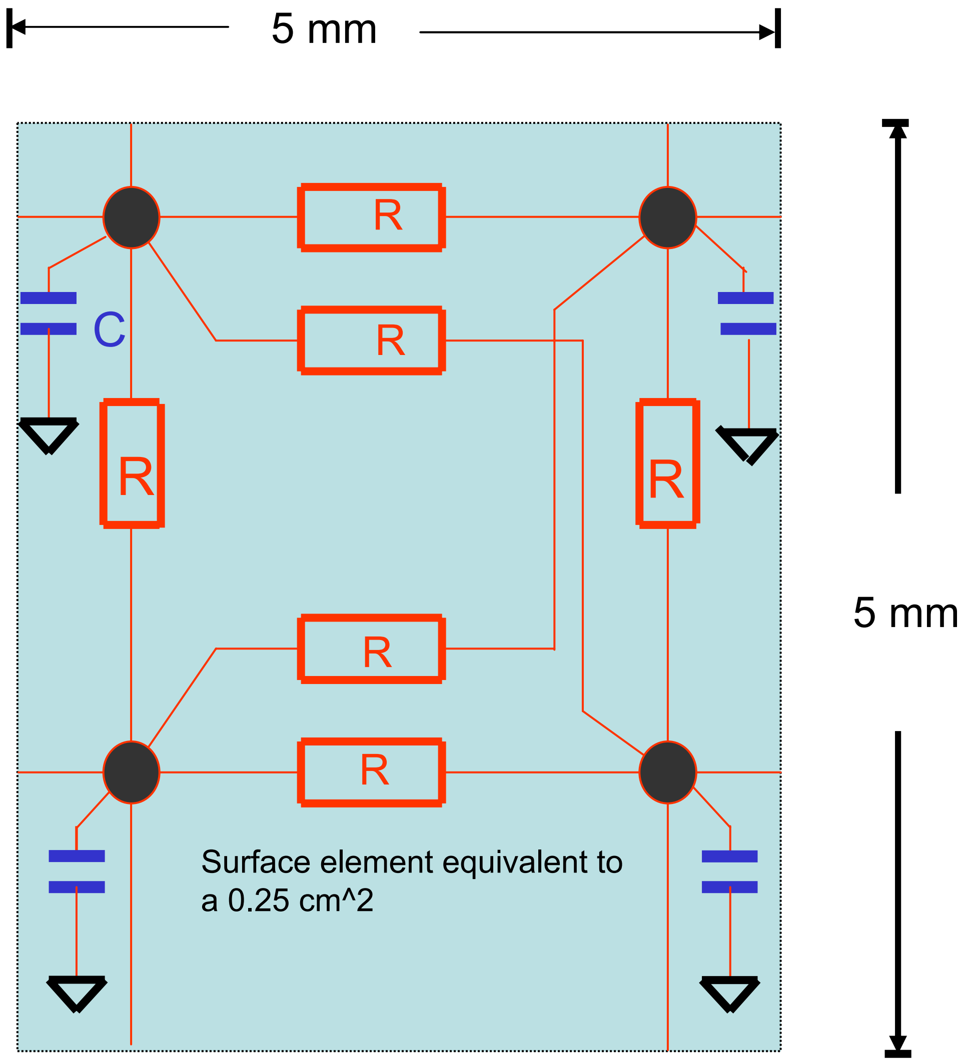




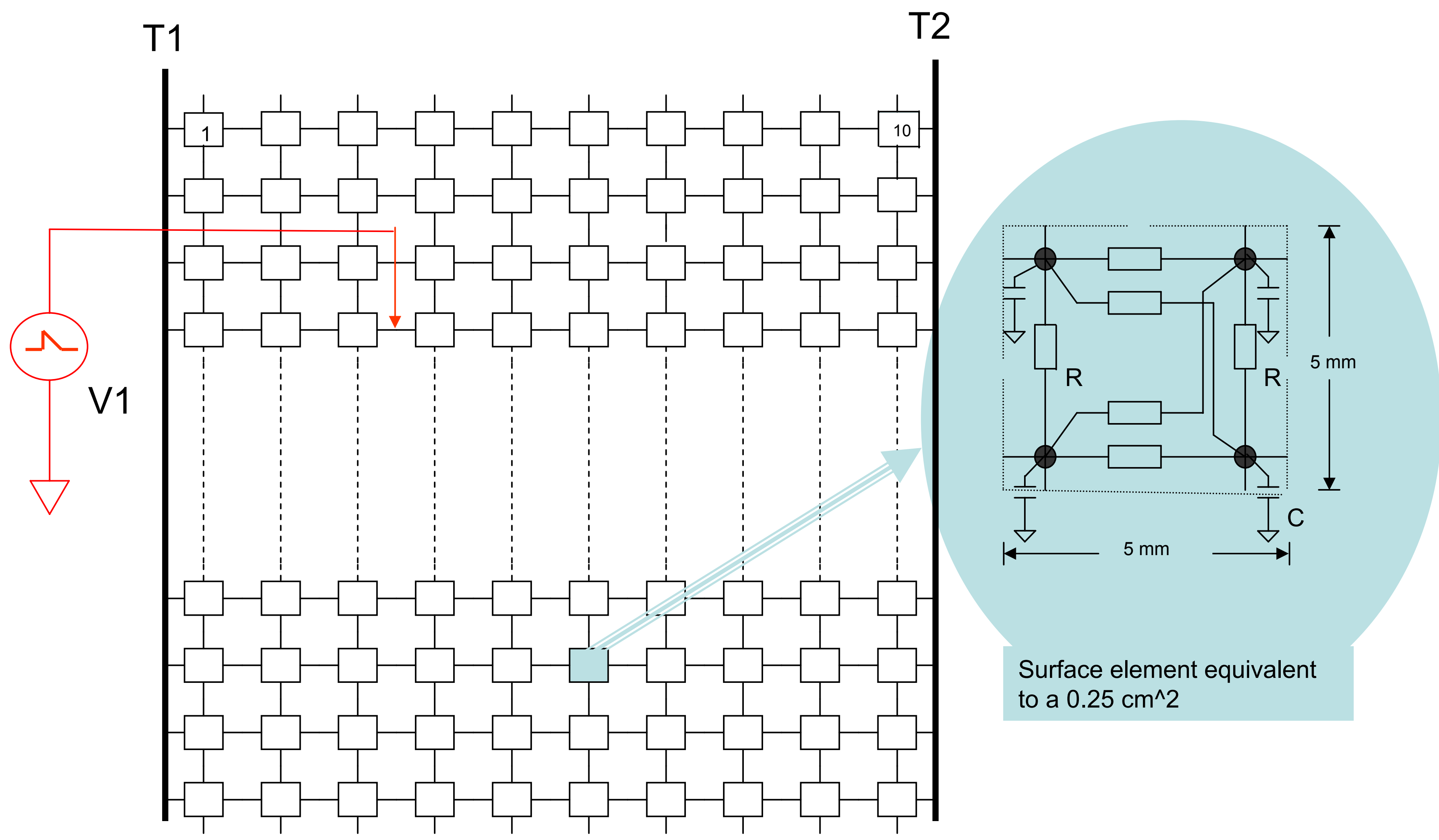
The strong variability with respect to the distance requires a dedicated electronic (σ=50 kΩ/■, C*=90 nF/m²)

SURFACE SIMULATION ELEMENT 5*5 MM^2

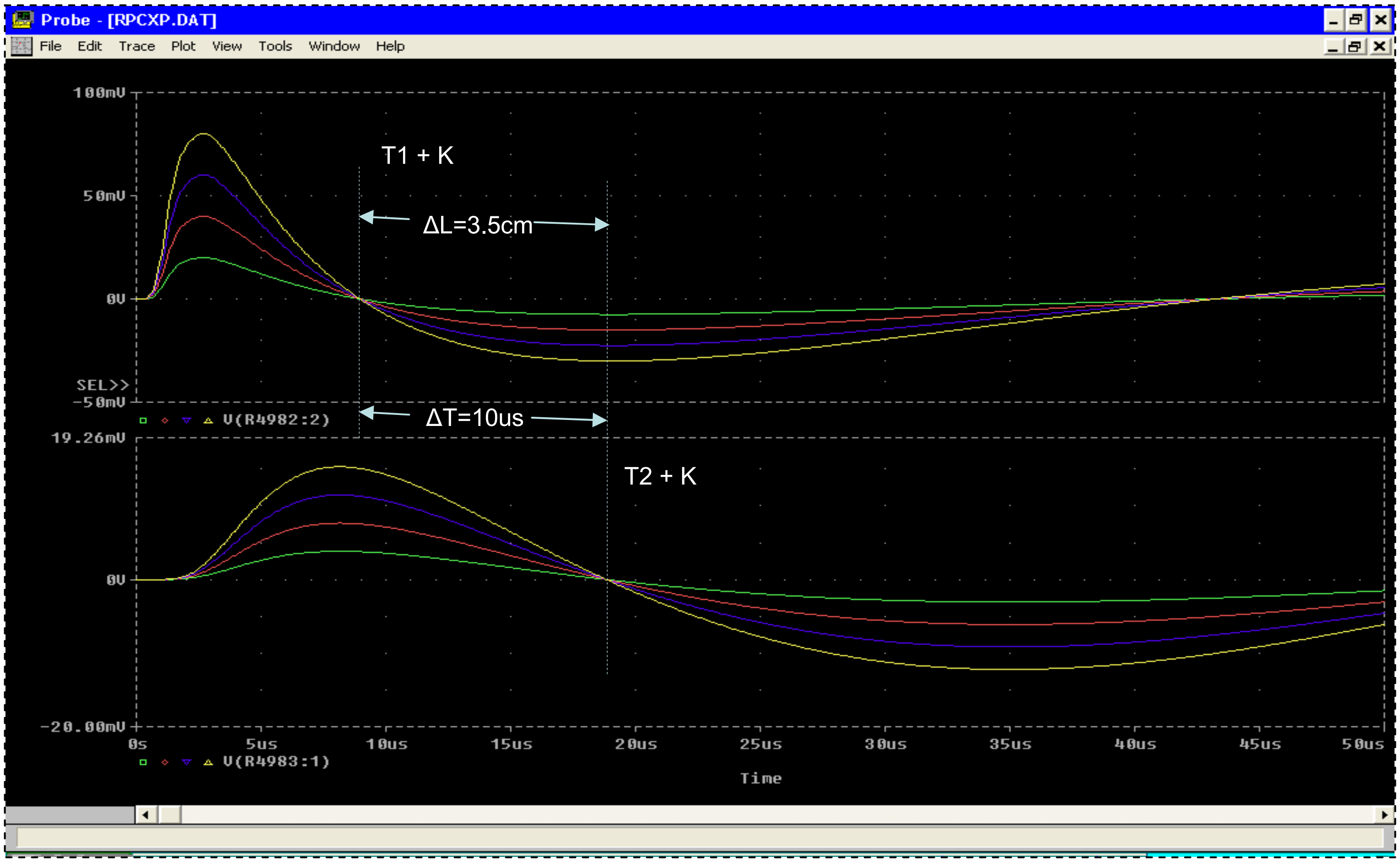
C=10pF AND R=100 Kohm



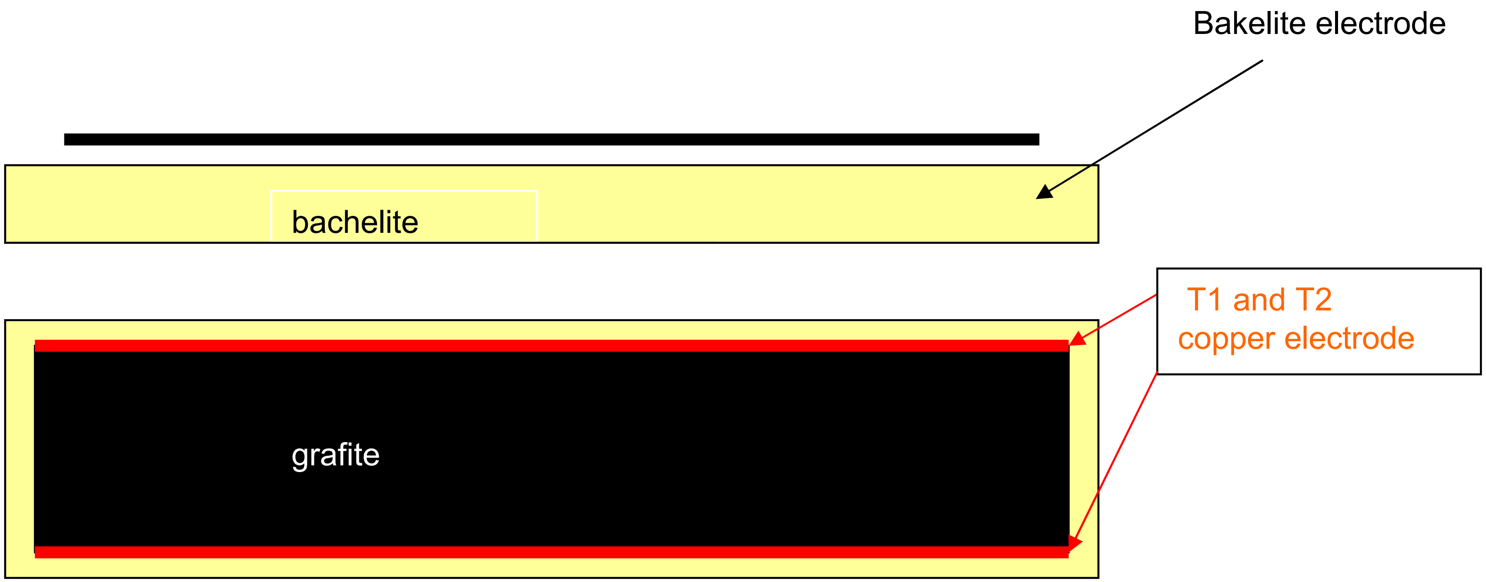
10*40 matrix of element equivalent to a surface of (5*20 cm^2)



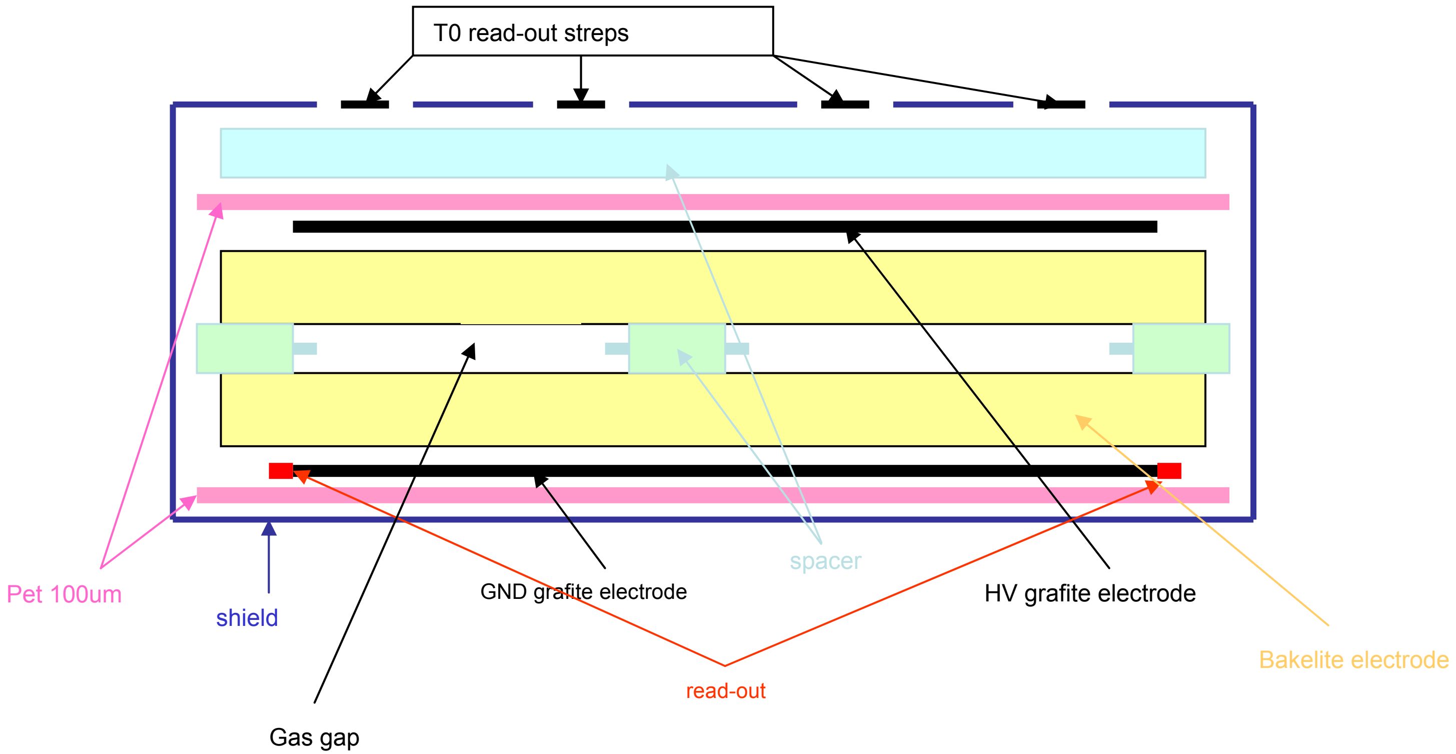
T1 and T2 simulated signal ΔL = 3,5cm


Probe - [RPCXP.DAT]
File Edit Trace Plot View Tools Window Help
100mV
50mV
0V
SEL>>
-50mV
T1 + K
ΔL=3.5cm
ΔT=10us
V(R4982:2)
19.26mV
0V
-20.00mV
T2 + K
0s
5us
10us
15us
20us
25us
30us
35us
40us
45us
50us
V(R4983:1)
Time

Proiection of RPC grafite graunde electrode



Section of RPC



Sperimental set-up

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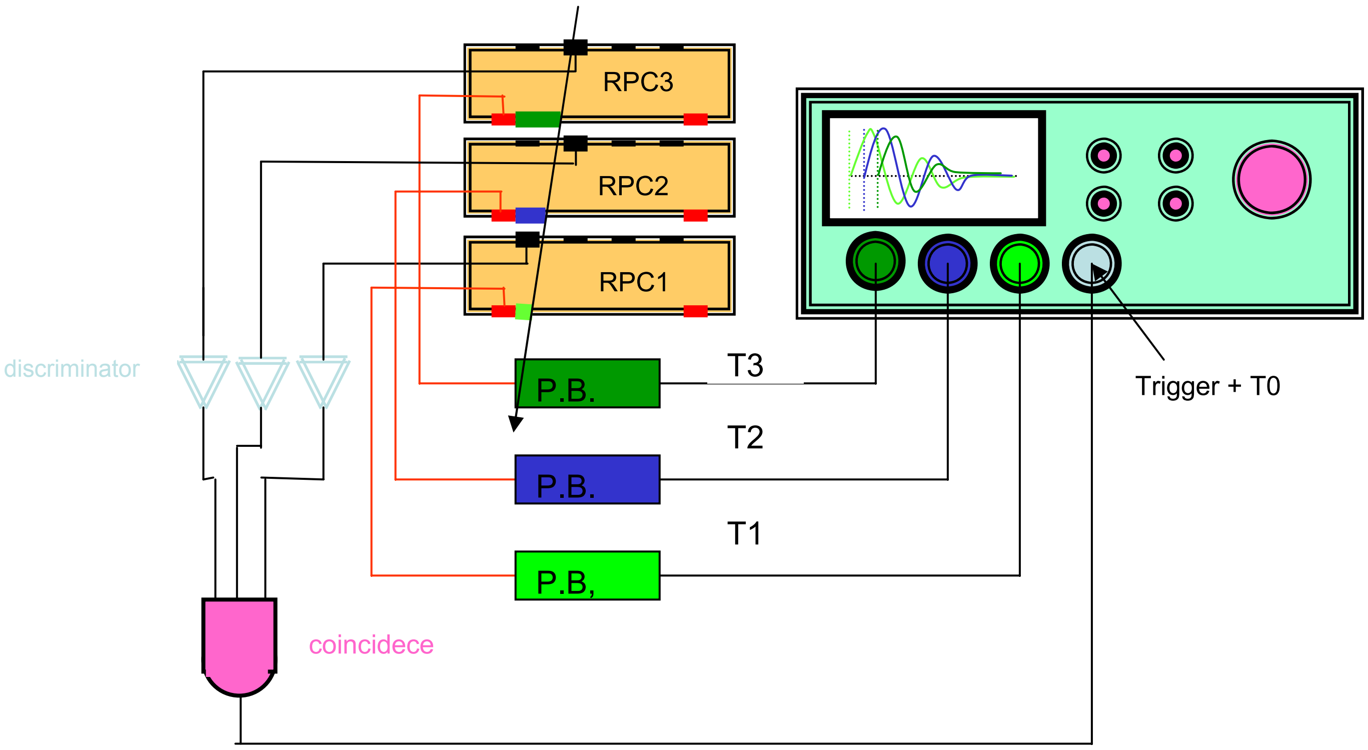

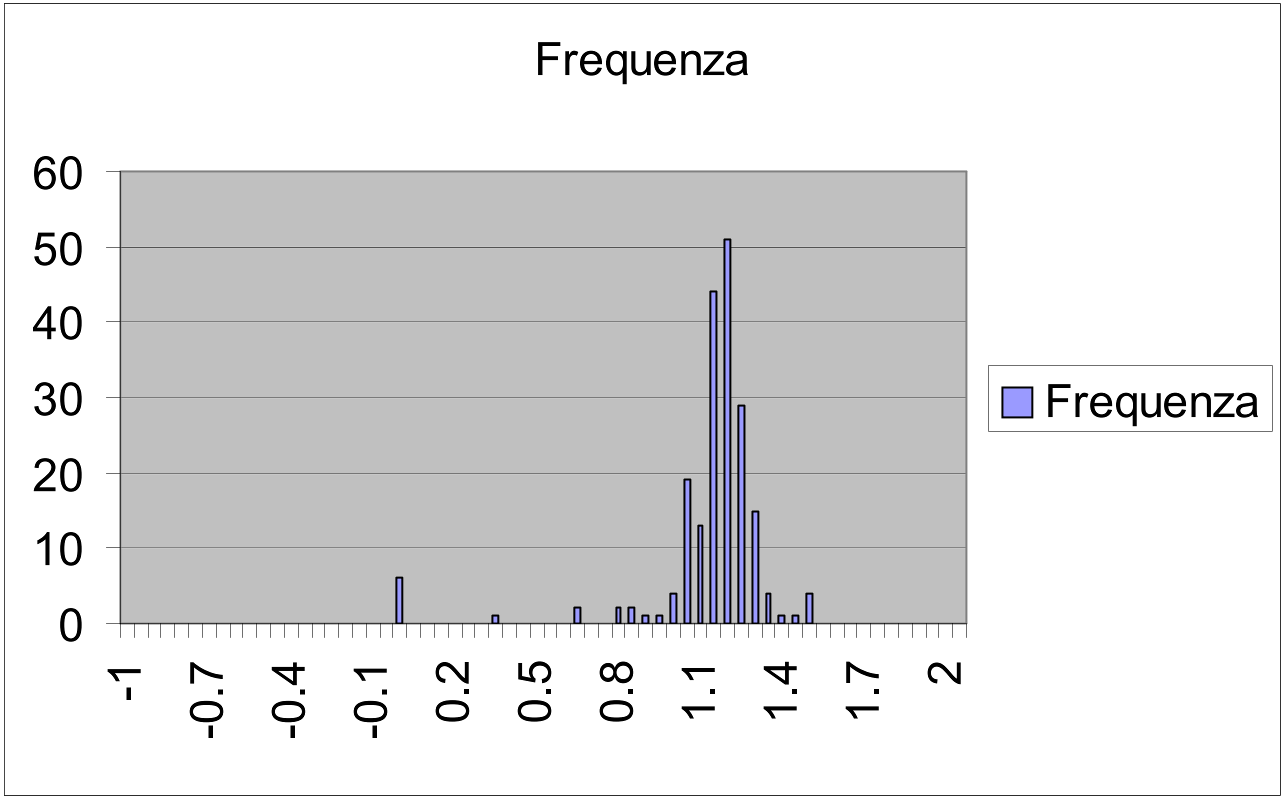

Frequenza
60
50
40
30
20
10
0
-1
-0.7
-0.4
-0.1
0.2
0.5
0.8
1.1
1.4
1.7
2
Frequenza