Further advances in Ageing Studies for RPCs

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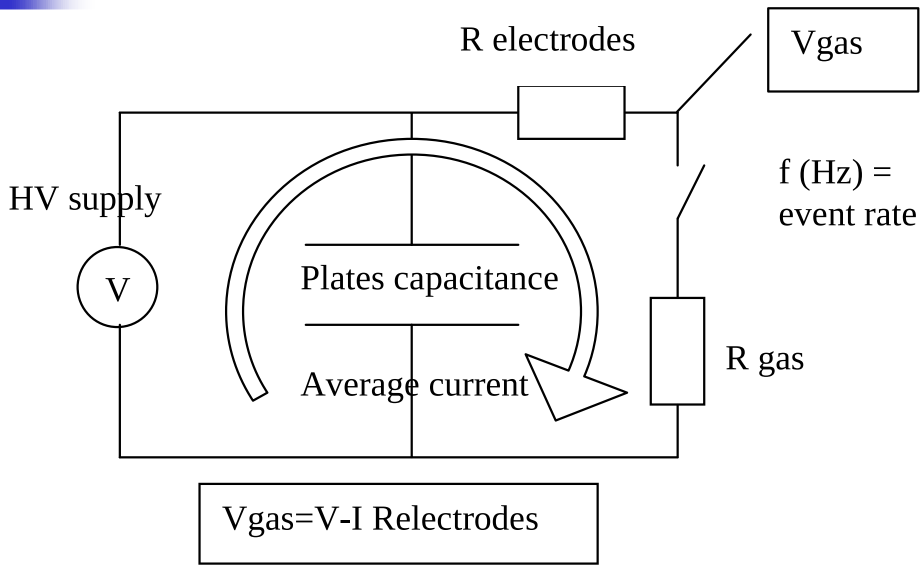
Introduction

Sistematic tests carried out, in the ATLAS framework, on RPCs of different sizes (from 100 cm^2 to 1.4 m^2) showed a decrease of the rate capability at fixed voltage as the only relevant ageing effect. It has been demonstrated that:

- This effect is due to an increase of the total plate resistance
- This amplifies the progressive displacement of the working point at higher rates
- The effect can be compensated within some limits
- All the other detector performances are left unchanged

An RPC thermodynamic model



Vgas is a well defined global parameter if:

- Uniform irradiation
- Field fluctuations small with respect to V-Vgas

- At high rate everything goes “as if” we supply Vgas instead of V in a low rate environment
- The detector working point is completely determined by Vgas
- An increase of Relectrodes reflects in an amplification of the rate effect

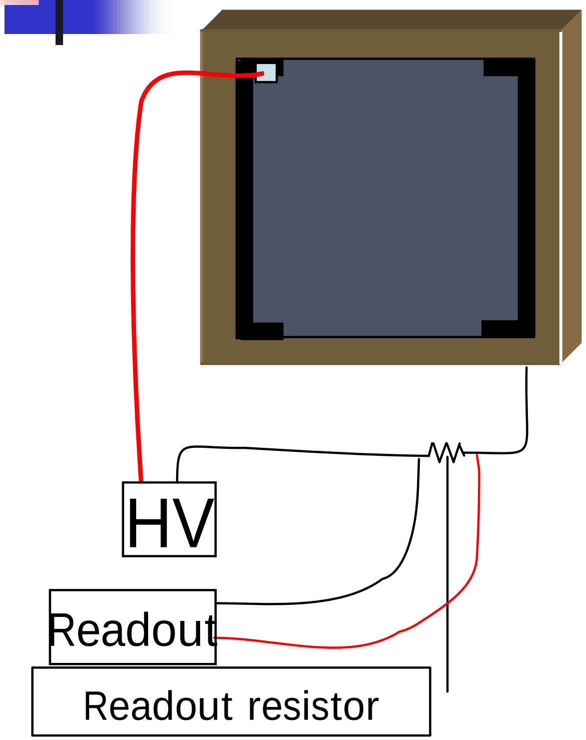
The resistance increase

It is due to two main components:

- a moderate increase of the bakelite resistance (interpreted as resistivity drift)
- A progressive increase of the <u>anodic</u> graphite coating resistivity. The <u>cathodic</u> layer remains almost unaffected

This increase, as a function of the integrated charge, after an initial exponential growth, reaches a “breakdown point” characterized by a faster than exponential behaviour, revealing a loss of connectivity of the graphite grains. <u>This is the dominant long term ageing effect</u>

Systematic test of the graphite



The graphite coating of RPCs is a paint constituted by graphite grains in a resin base:

•The surface resistivity is 100 KΩ/

•A heavy graphite string (100 KΩ/)is also painted on the coating edges for a uniform field distribution

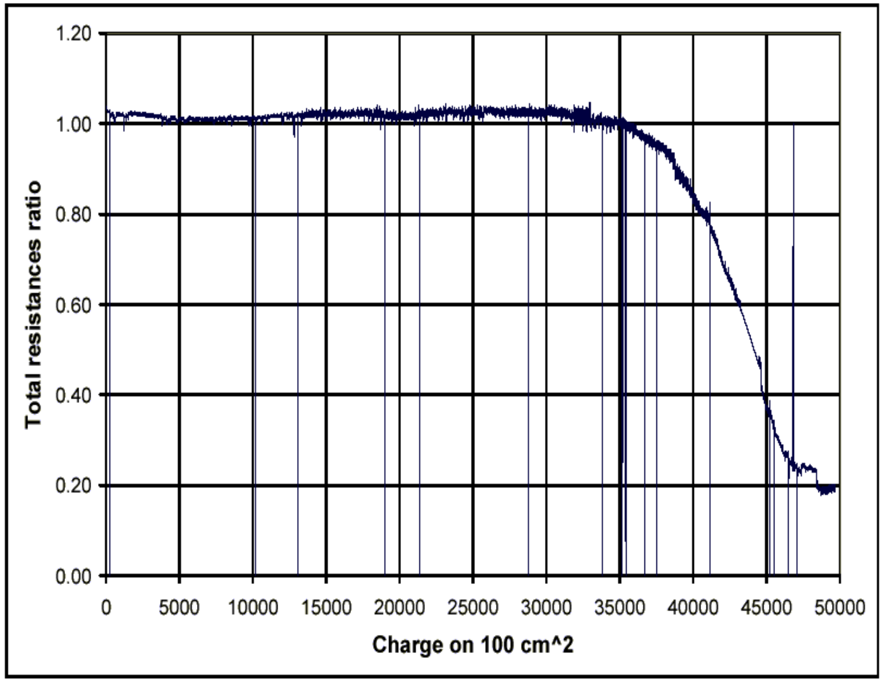
- We tested single 10X10 cm^2 bachelite plates 2 mm thick, coated on both sides, by applying a voltage across the electrode in order to simulate an ageing test
- The samples were protected by glued PET films and a glue ring, as in real RPCs.

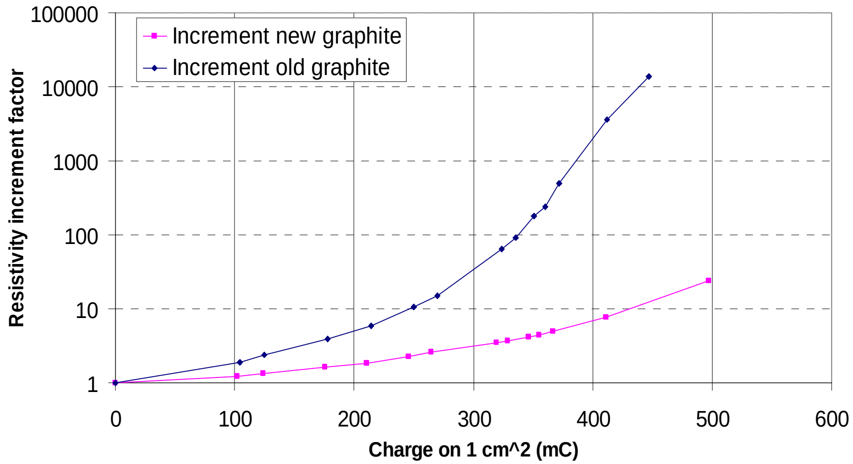
Test details

- The current was monitored along with the stablilized temperature (around 24 °C)
- Periodically the graphite surface resistivity was measured
- The test is performed on several samples, varying the bakelite resistivity (10^9 to 10^11 Ohm cm) and the applied voltage (400-800 V), to obtain different test speed
- Two types of graphite were tested by confrontation: the classical (OG) one and a new “enhanced” type (NG). This last has a double amount of graphite per cm^2 while keeping the same surface resistivity

Bakelite 4*10^10 @ 400 V

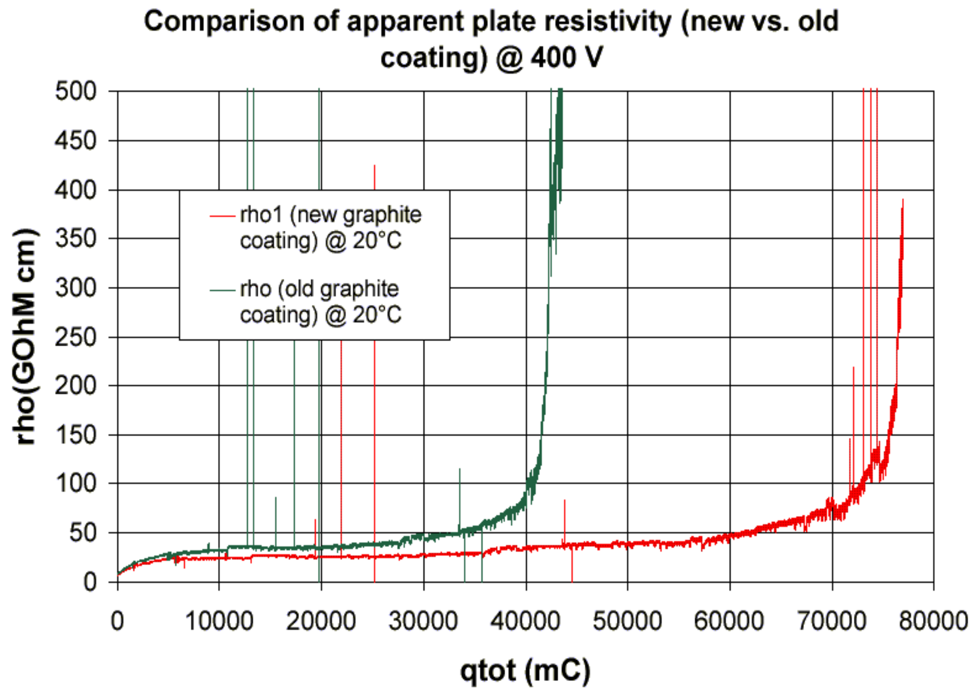
- Test on ATLAS like bakelite
- Duration:135 days (OG), 225 days (NG), still under test
- Above 300 mC/cm^2 the OG damage become apparent
- The resistance ratio finds a minimum because the area covered by the heavy string is not affected

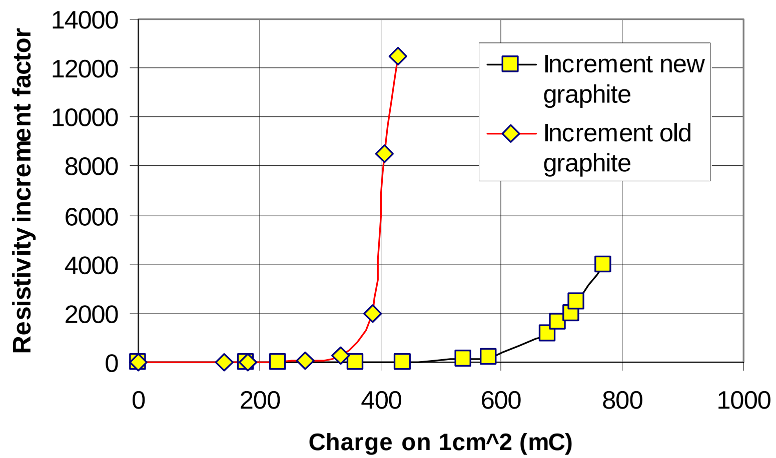




Bakelite 6*10^9 @400 V

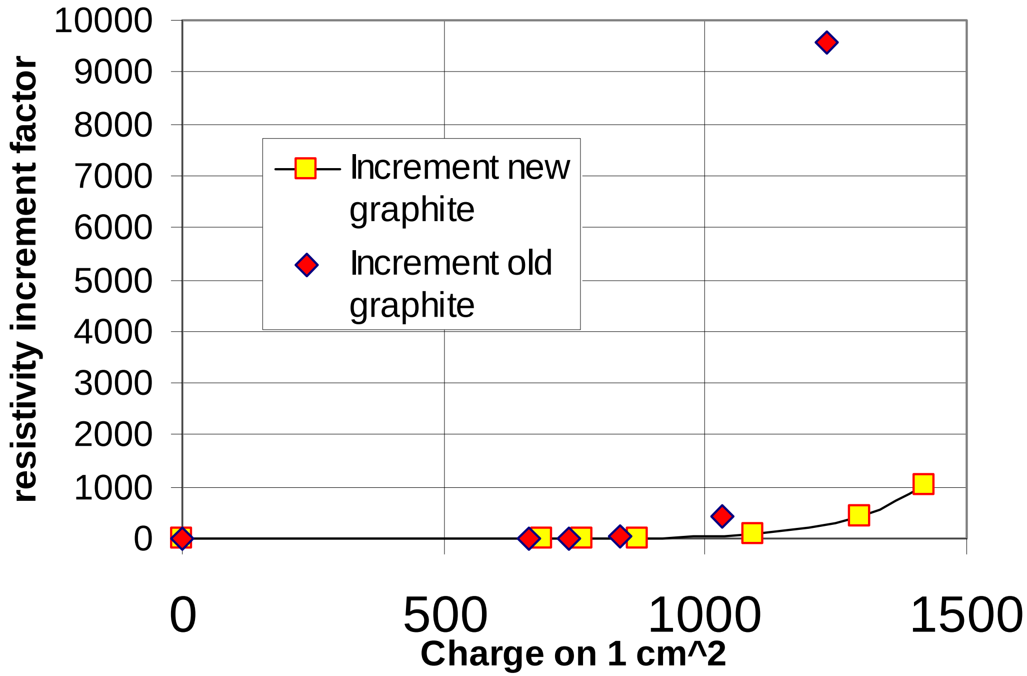
- Low resistivity (faster test)
- Duration:56 days (OG), 120 days(NG)
- The OG breakdown is lightly retarded
- A limit is found for the NG at about a double charge with respect to the OG





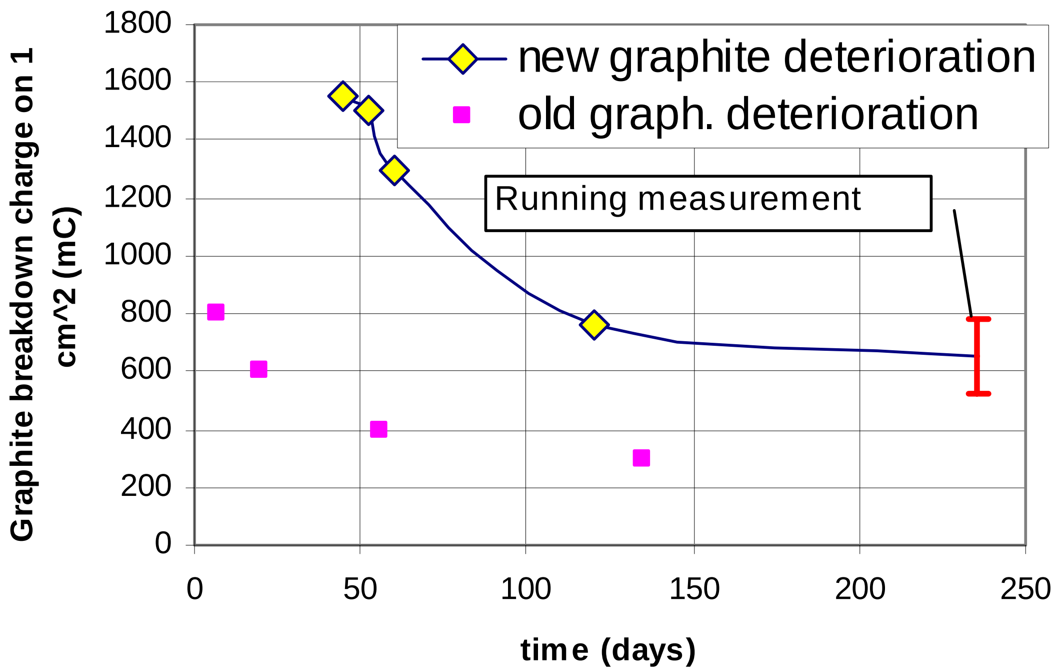
HI speed test

- Very low resistivity: 3*10^9 Ohm cm
- High voltage: 800V
- The breakdown points for both OG and NG are retarded in terms of charge
- The time for breakdown is short: 7 days (OG) 45 days (NG)



WHICH IS THE ROLE OF THE TIME IN THE GRAPHITE AGEING ?

The role of time



Notice that the time is relevant only if current is flowing. This is explainable thinking to the chemical nature of the damage:

The cathions (namely OH^-) reach the anodic graphite and reacts. If they are supplied too fast with respect to the reaction speed, a fraction of them doesn't take part in it and is "wasted"

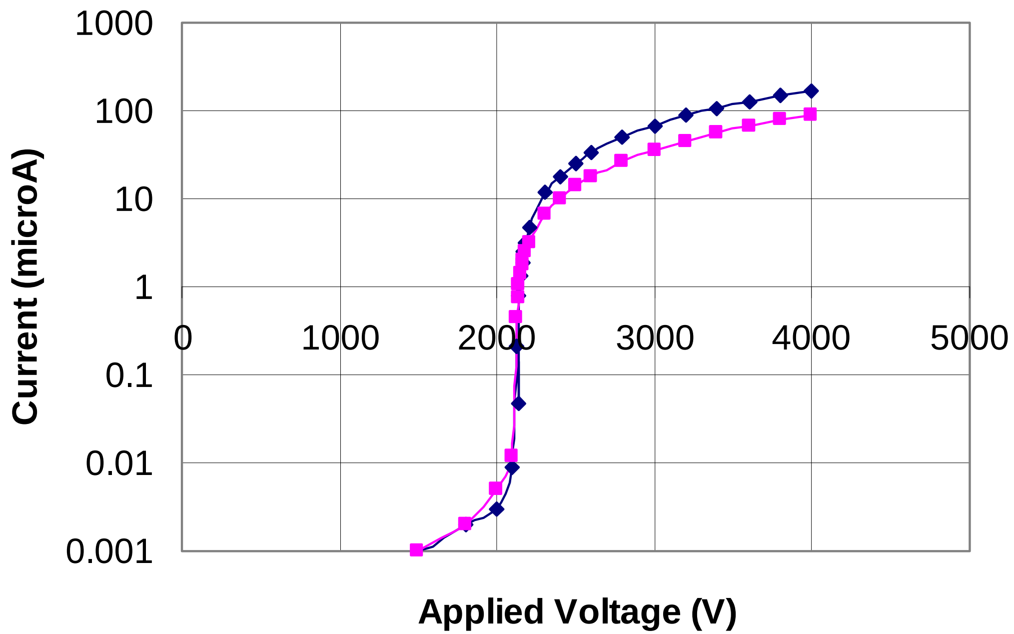
Which is the trend for real life ageing (10 Atlas Years)? We can hope for a plateau but only time can tell...

Pure Argon test: a new ageing techinque

•10x10 cm^2 detectors (NG & OG)

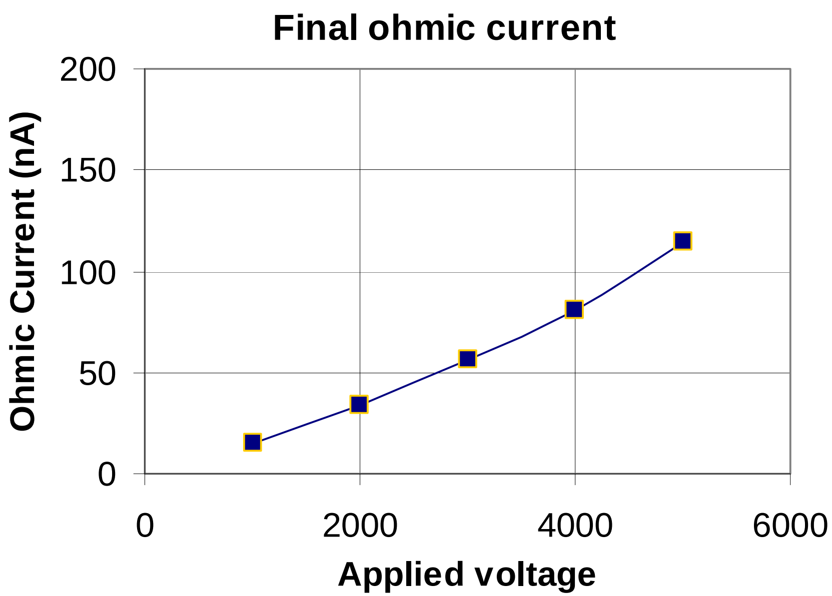
•Filled with pure Ar: self streamer regime. Streamers are produced in cascade untill the field decrease under a critical value. As the field is restored the process repeats

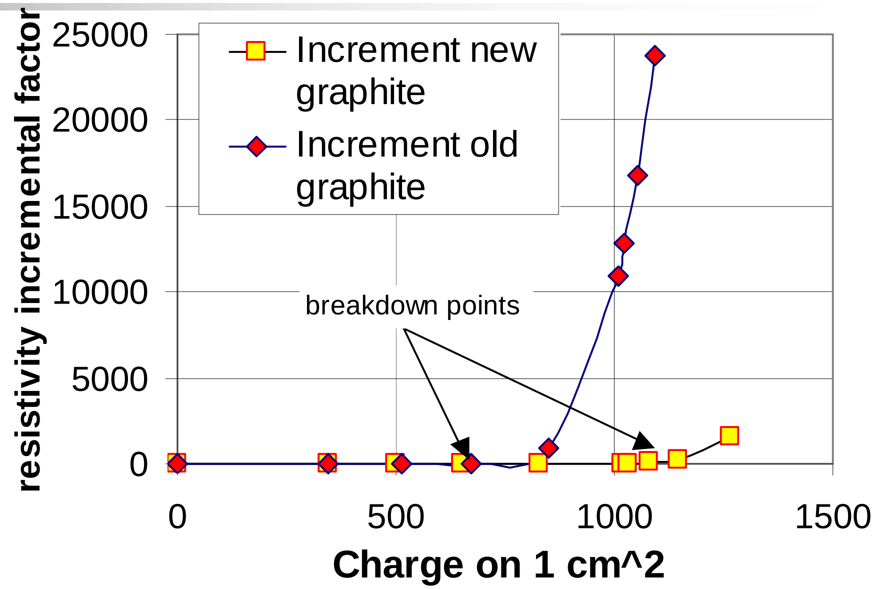
•Sparks are not produced because of the resistive nature of the electrodes.



- It is possible to age a detector without a source, without a complex gas system, with relatively low voltages and nearly at any desidered speed.

Test results for NG chamber in Ar



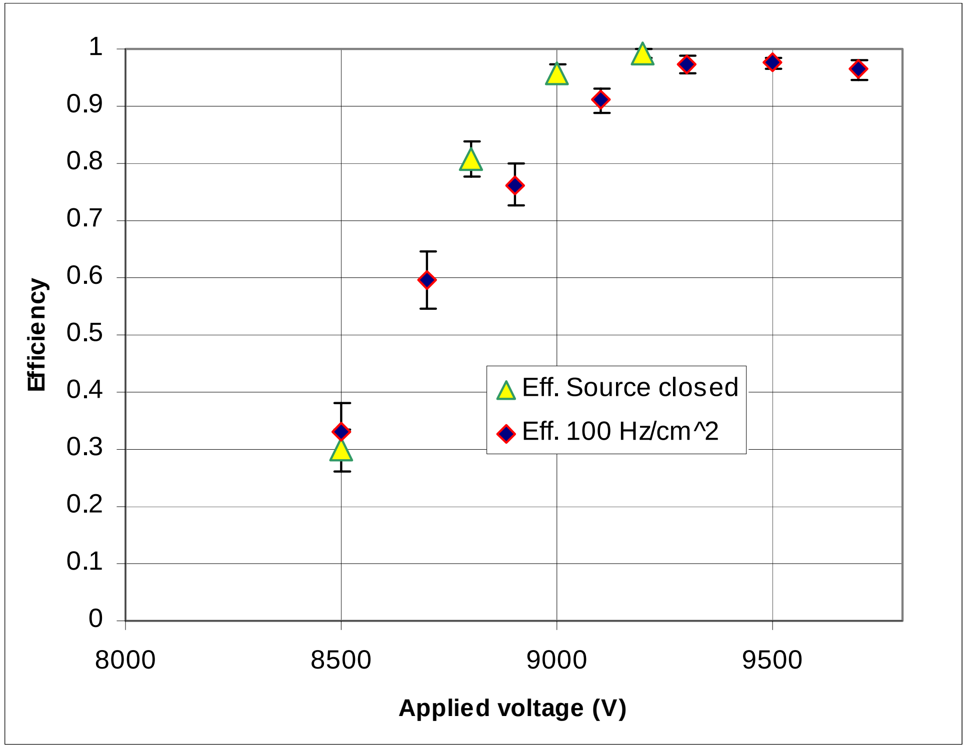


- Test duration (breakdown points):
  - 70 days 645 mC/cm^2 (OG)
  - 4.5 months 1100 mC/cm^2 (NG)
- Apparent resistivity:
  - Initial: 1.6*10^10 Ohm cm
  - Final: 4*10^11 Ohm cm (NG)

•The Ohmic current is the same as the beginning

•the test was performed in extreme conditions: I>100 microA on 100 cm^2 at the beginning!!

Further results for the Ar aged chamber



- The efficiency and resistance measurements are performed using:
  - the standard avalanche gas mixture
  - a ^{60}Co gamma source
  - RPC telescope to trigger on cosmic rays

The chamber survived the extreme test demonstrating that this method could be used for further ageing tests in less extreme and more realistic conditions

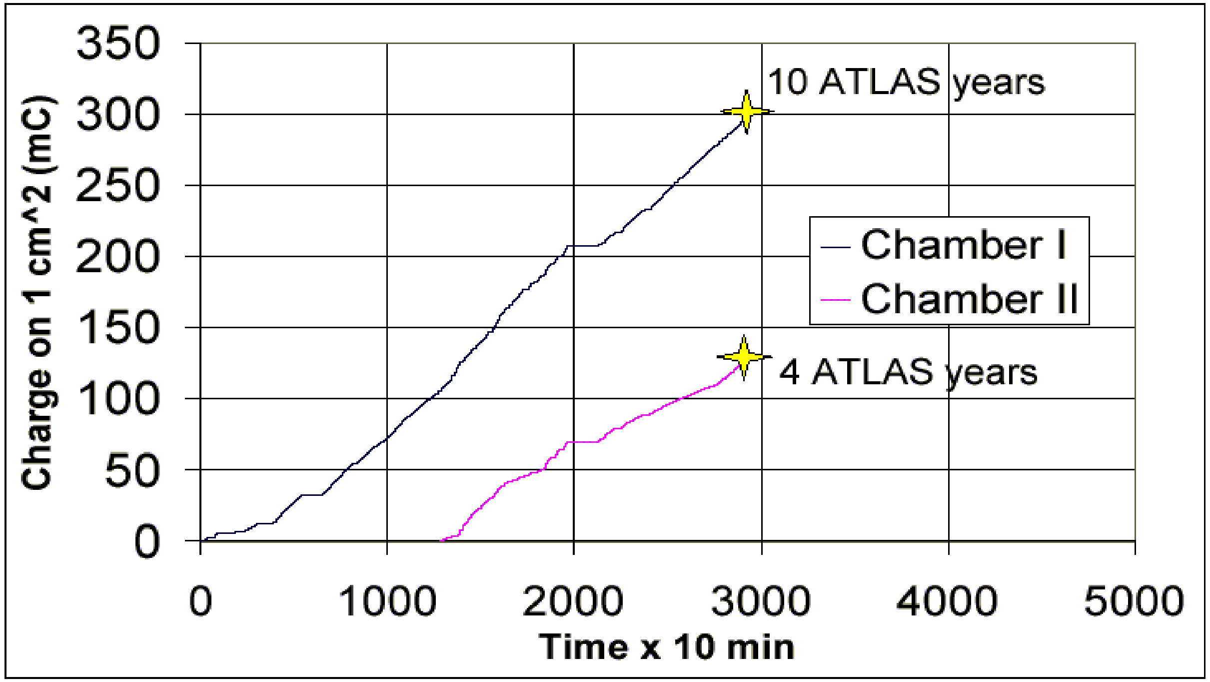
Test on 50x50 detectors at GIF

Four 50 x 50 NG detectors are under test at GIF:

- Already integrated 10 ATLAS years (0.3 C/cm^2)
- Already integrated 4 ATLAS years
- < 1AY
- < 1AY

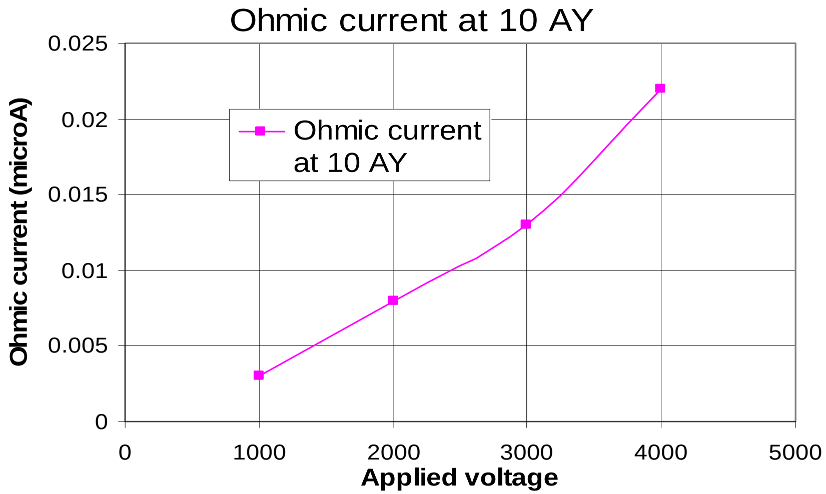
- resistivity of RPC I: 2.5*10^10 Ohm cm at the beginning, 10^11 Ohm cm after 10 ATLAS years

- All RPCs use NG so we don't expect strong graphite contributions at this stage of the ageing

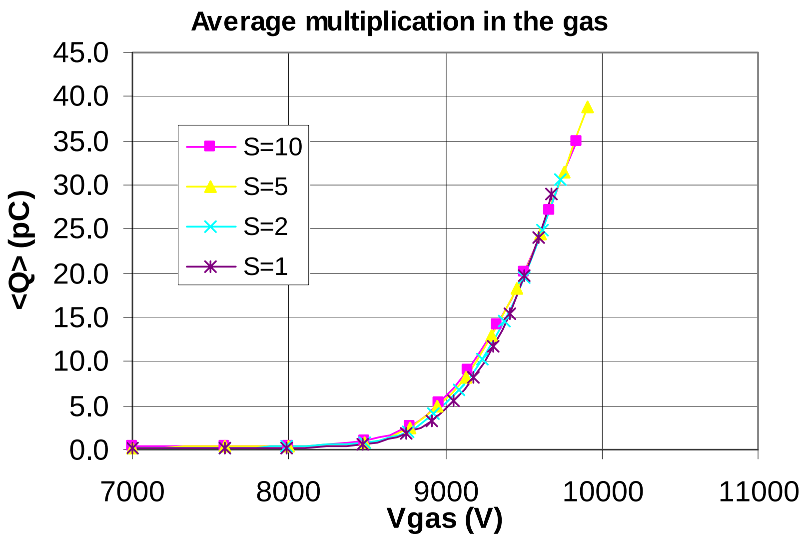


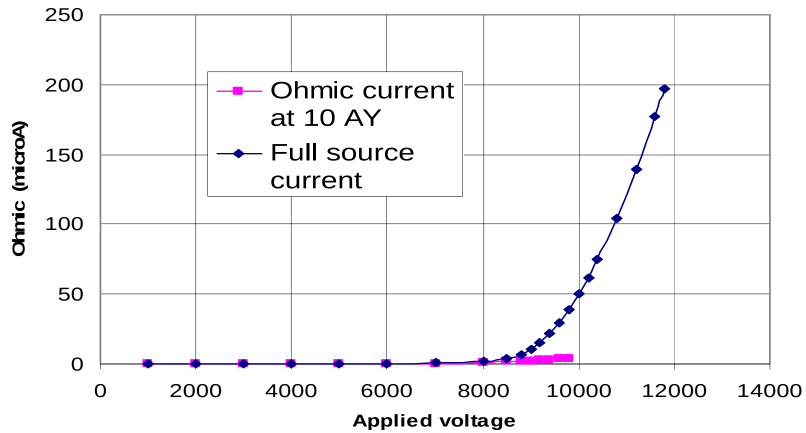
Final perfomances for RPC I

- The total electrode resistance is estimated as usual using the function <Q>(Vgas), measured for different source intensities.
- Vgas=V-IR, with R used as a free parameter, which is fixed by imposing the overlap of the previous curves: at a given Vgas one has always the same <Q>

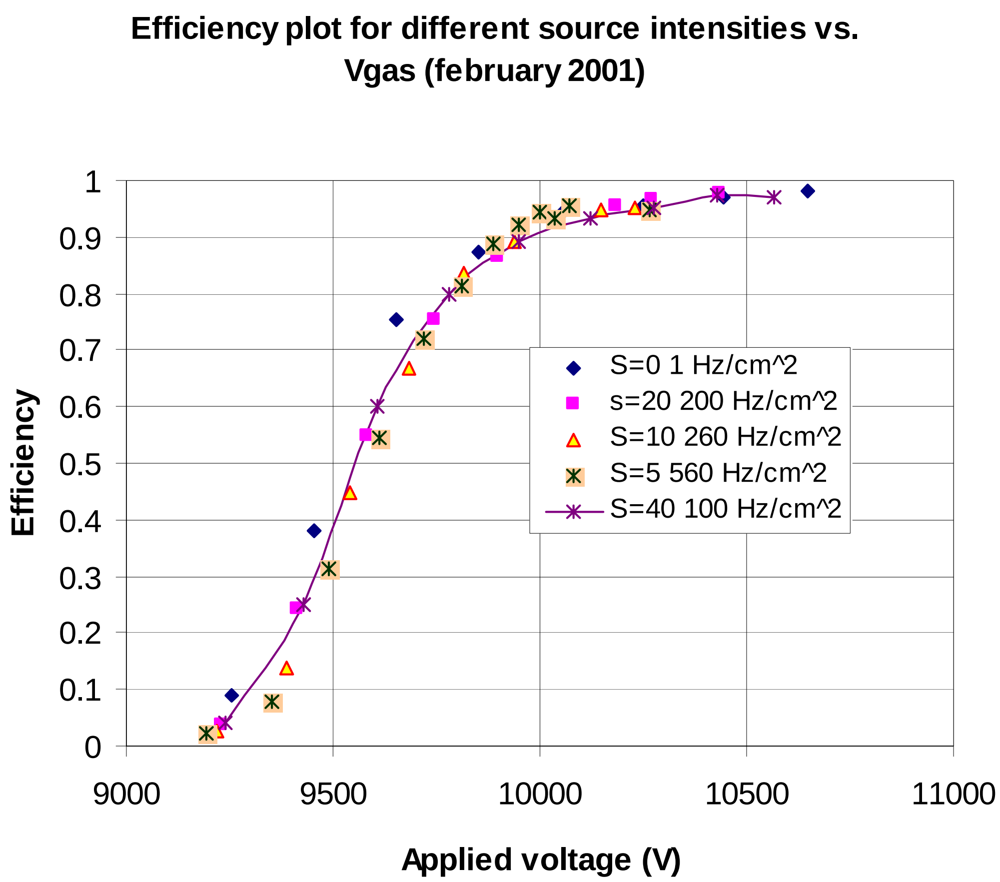


- Ohmic current remained negligible





Efficiency at high rate



- After 10 AY the chamber works up to 600 Hz/cm^2
- The efficiency is above 96%
- The right Vgas is obtained with the same value calculated with <Q>
- The test is still not significative for the NG at the present amount of integrated charge
- The test is still running

Conclusions

- We pointed out a macroscopic long term ageing effect, caused by the degradation of the graphite coating
- We proposed and tested sistematically an enhanced graphite coating extending by a factor of 2 the detector life.
- A new simple ageing technique for RPCs is proposed, based on pure Ar operation. The detector reacts compatibly with the ageing in standard conditions
- A traditional test on several chambers is running at GIF, one already reached 0.3 C/cm^2 that is not enough to put in evidence the breakdown of the new graphite layer