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CMS NOTE 1996/017

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

October 10, 1996

Results of Ageing Tests on the Forward MSGC Banana Prototype

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Abstract

The forward tracker of the CMS experiment at CERN will consist of a large number of MicroStrip Gas Chambers (MSGCs), expected to operate for several years in the high luminosity environment of LHC with an accumulated dose rate of ~ 10 mC/yr per cm of strip. They are planned to be arranged around the interaction point in modular wheels which contain several MSGCs. The ‘open’ option of a forward CMS ‘banana’ module includes the electronics inside the gas volume. Long term tests of one such prototype containing two plates, one with gold and the other with chromium strips on diamond-like coated D263 glass with representative electronics and surface mount components inside the gas volume have been performed; the satisfactory results are reported here. A first test has been made with a gas flow rate of 60 cc/min in the prototype (corresponding to 5 gas renewals per hour) and has shown no gain drop up to 85 mC/cm of accumulated charge per strip. A second test has been performed with a gas flow rate of 6 cc/min corresponding to 1 renewal every two hours, with no gain drop till 73 mC/cm when the experiment was suspended.

1. Introduction

The CMS experiment at CERN is aiming for high resolution and fast tracking of charged particles at a bunch crossing interval of 25 ns. The recently developed MicroStrip Gas Chambers (MSGCs) [1,2] are envisaged for a large part of the tracking in the forward-backward and barrel part of the CMS tracker [3,4].The experimental conditions are stringent for detecting new physics at the TeV scale with interaction rates of ~ 10^9/s, high multiplicities and a severe radiation environment with doses up to ~ 4 MGy/r^2 (r in cm) for the innermost MSGCs. This translates into an accumulated dose rate per cm of strip of 10 mC/ yr. In addition, a total neutron rate of 5-15 10^{12} n/cm^2.yr is expected. In the forward and backward regions, wedge shaped MSGCs will be arranged in 3 concentric rings on the front face of a supporting wheel and 3 concentric rings on the backside. Front and back rings are staggered along the radius R to avoid any dead space in R for high P_T particles. Each MSGC detector ring consists of adjacent 'banana' shaped modules, containing several (up to 8) individual counters. Essentially, two designs are under investigation; the open geometry where the front-end and service electronics lie inside the gas volume, and the closed solution, where they are outside the gas. These detectors have not only to be made with radiation resistant materials, but also perform without degradation in this environment. Long term tests are being performed in several laboratories, and systematic investigations are underway in the GDD-RD10 lab at CERN. In the present paper we report on recent results from ageing studies being performed with a prototype of the open solution where in the actual design [2], the wedge shaped MSGCs are assembled side by side in a common gas box.

2. Experimental details

Fig 1 shows a photograph of the prototype and Fig. 2 a schematic description of the assembly. The carbon fiber support plate contains two substrates: one with gold strips (manufactured by lift off)[+] and the other with chromium strips produced by wet etching on diamond coated[*] Desag D263 glass of 300 μm thickness. The drift electrode is a 100 μm thick gold plated glass sheet. The technology for manufacturing the MSGCs with the diamond undercoat has been verified both for artwork and operation and stable functioning has been demonstrated up to high rates ~ 10^6 Hz/mm^2 and without ageing up to 100 mC/cm of strip in clean conditions [5]. The prototype has been operated with powered front-end chips used for the H1 silicon [6] (since MSGC chips were unavailable), mounted on a 5 x 4 cm^2 ceramic support equipped with remote service electronics. All gluing was done with Epotecny E505.SIT which has been demonstrated not to outgas [7]. The lightweight gas box consists of a carbon fiber-honeycomb bottom plate, covered on both sides with a 15 μm thick aluminum foil. The substrate supports and the drift gap spacers consist of VECTRA [8]. High voltage and signal feedthroughs have been manufactured of PEEK [9]. Both these polymers were proven not to pollute the detector gas [7].The side walls of the box consist of thin wall (100μm) aluminium tubes of rectangular cross section of 3x10 mm^2. They also serve as integrated input and output manifolds for gas distribution via laser drilled holes. The same aluminium tubes will also be used for the coolant flow evacuating the 2 mW/channel heat produced by the front end chips; in the tests presented here however, no coolant was flown through the pipes. The gas box in finally closed by an aluminium clad (9μm) polyester foil (12 μm).

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The prototype was placed in the GDD-RD10 laboratory which has a clean gas system and gas quality monitoring system (see fig. 3). Great care has been taken to have stainless steel tubing, filters for water and oxygen, and the absence of any polluting agent

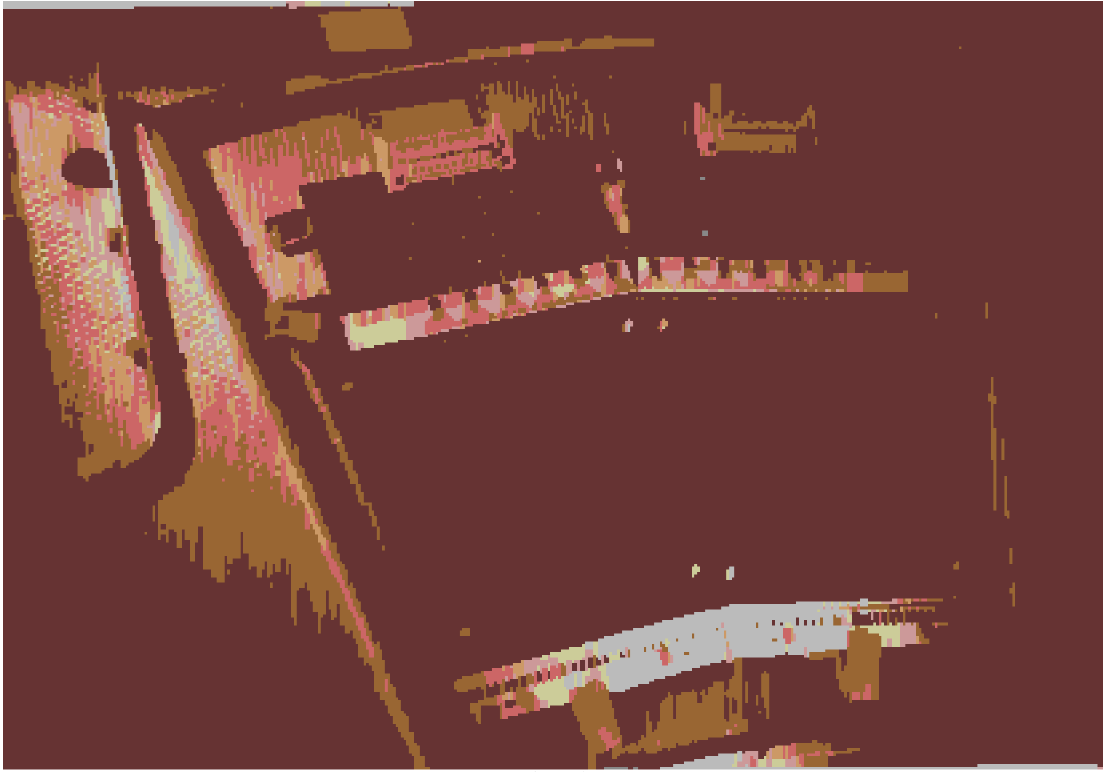
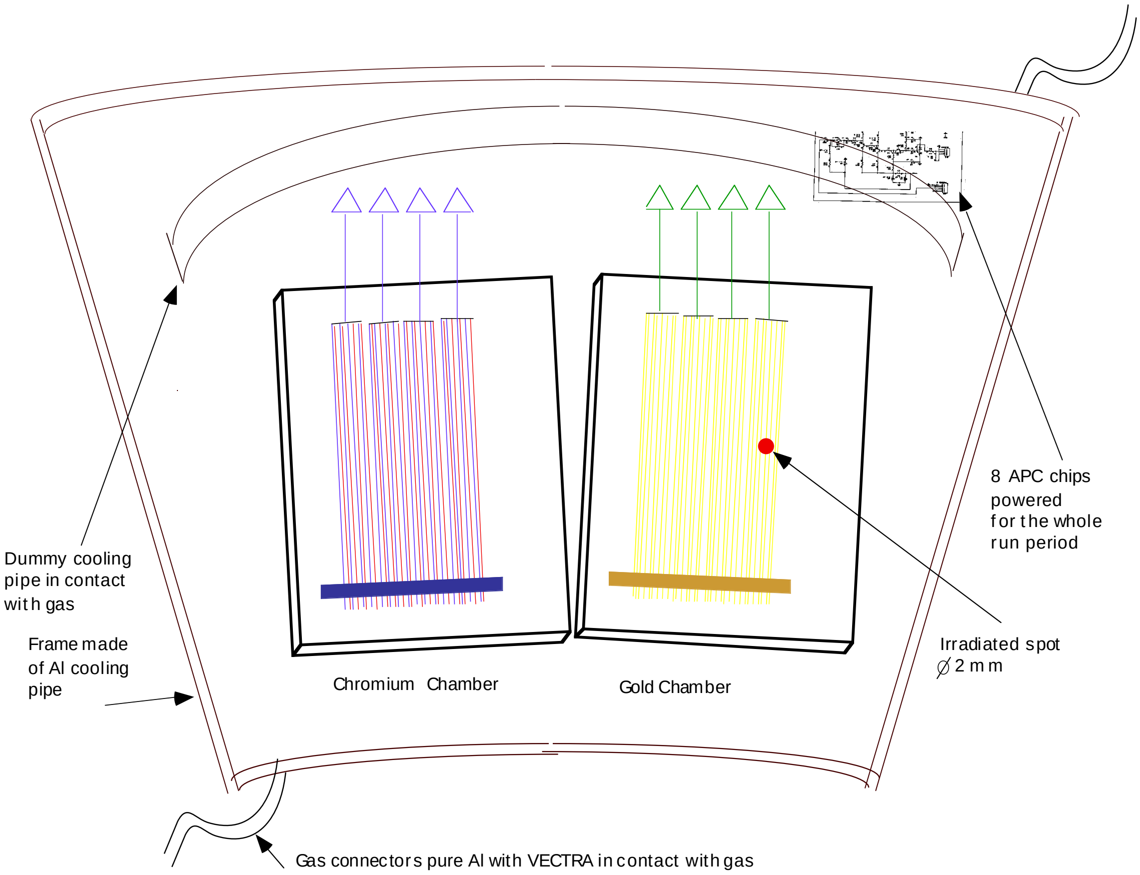


Fig. 1



Dummy cooling pipe in contact with gas

Frame made of Al cooling pipe

8 APC chips powered for the whole run period

Irradiated spot ∅ 2 mm

Gas connectors pure Al with VECTRA in contact with gas

Fig. 2

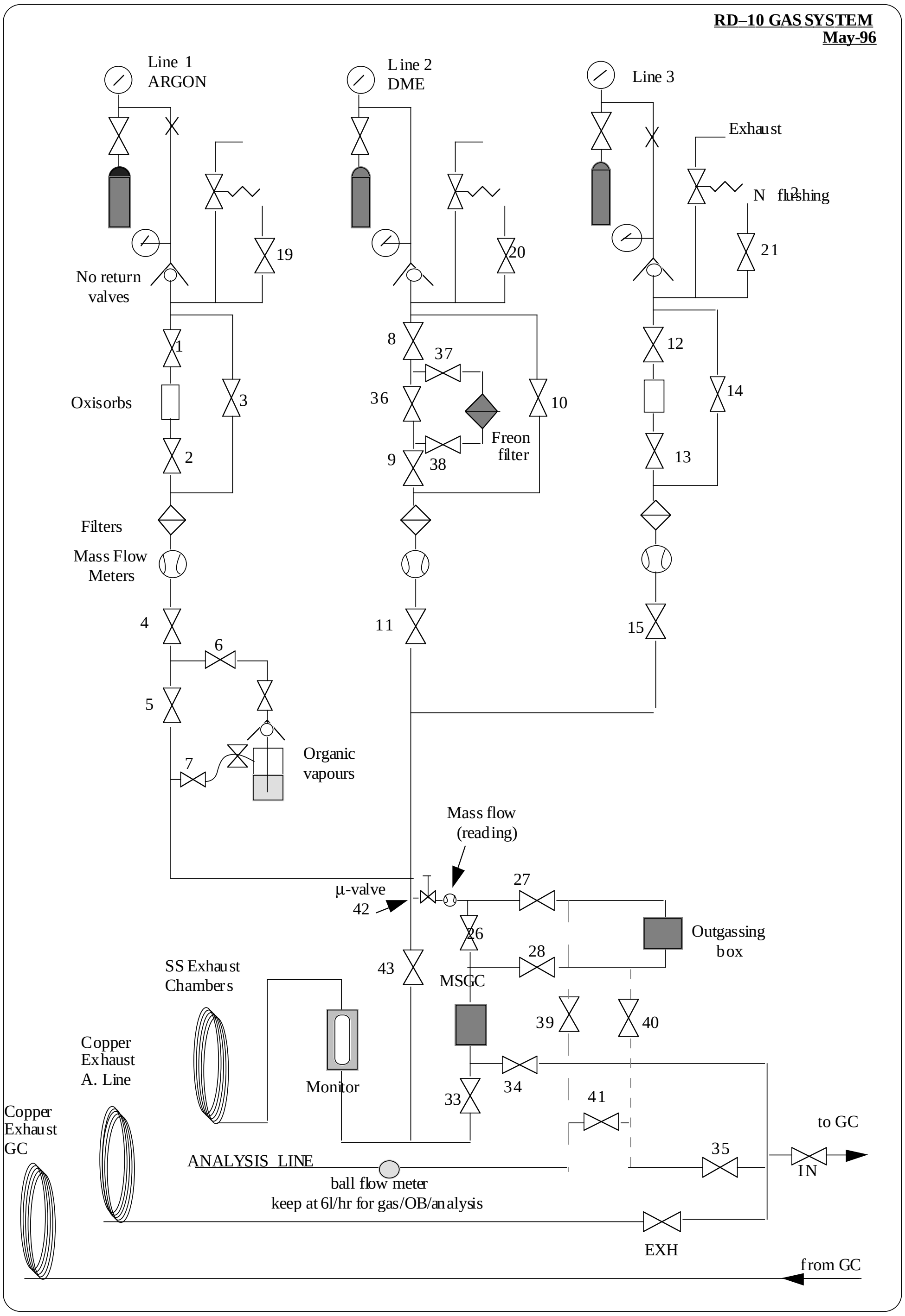


Fig. 3

and suspicious materials soluble in or reactive with DME. With the help of a gas chromatograph and its two associated detectors, an ECD (electron capture device) and a MSD (mass selective device), the gas downstream the MSGC can be sampled and the appearance of any pollution or impurity can be identified and in some cases quantified. The gas can be made to flow, after mixing argon and DME in equal proportions, via the MSGC banana to the monitor chamber and then to a long exhaust. This configuration was used for tests performed at a gas flow rate of 60 cc/min which corresponds roughly to 5 volume exchanges per hour for the prototype. It is also possible, by using a bypass, to have only a fraction of the gas sent to the MSGC and the rest being directed to the monitor counter. This scheme enables us to reduce the flow in the MSGC prototype without affecting gas composition. A renewal every two hours requiring a gas flow rate of 6 cc/min was set for the second ageing test. This was done in order to estimate the chamber's long term performance with realistic gas flow rates. The SMC [10] and HERMES [11] experiments have their MSGC tracking chambers running with similar gas renewal rates.

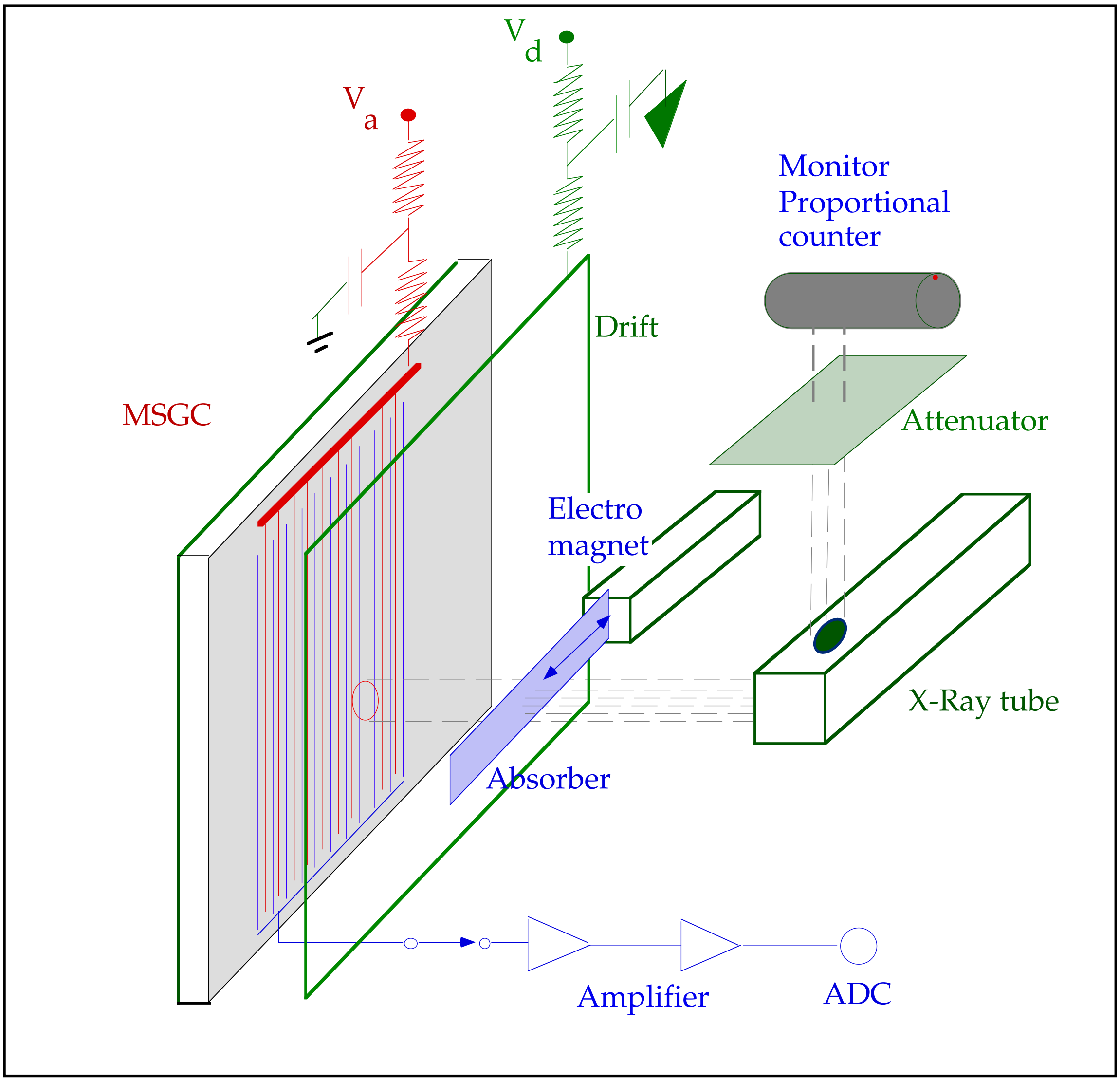


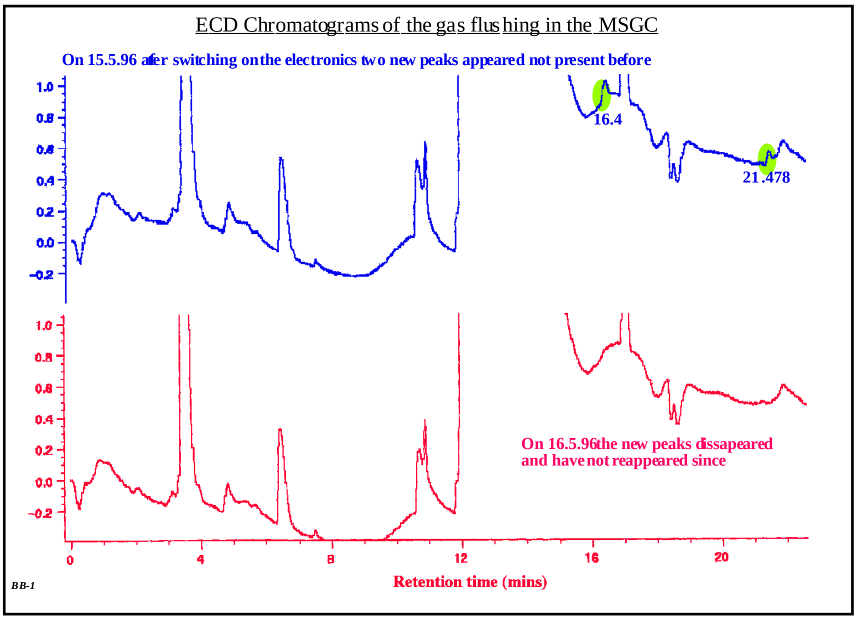
Fig. 4

Fig. 4 shows the schematic of the setup. It includes an X-ray generator for providing a high flux of photons for accelerated ageing tests and a single wire proportional counter for monitoring the gas quality as well variations of gain with respect to temperature and pressure. These ambient parameters are also recorded separately. Details of data analysis may be found in [12]. Four sectors of ten cathodes each are connected together and grounded via the preamplifier; the anodes are biased. The return current of the anodes from the high voltage power supply is measured in the presence and absence of radiation giving a measure of the gain in the chamber. We have used two algorithms of corrections: the first arising from the response of gain due to change of T/P, T being the temperature and P the pressure. From the behavior of proportional counter it has long been known [13] that the gain increases as E/p increases. The exact relationship however is non-trivial. The correction based on this surmise would therefore be justified if it accounts for the gain of the MSGC assuming similar response to T/p as the monitor counter The assumption fails when the difference in the electric field of the two detectors, being uniform in the proportional counter while quite non-uniform in the MSGC especially near the amplification region, is considered. Hence this is only an approximation and is not valid in case of a dramatic change of ambient conditions. The second correction stems from the response to temperature of the MSGC substrate, the resistivity of which changes appreciably with this parameter. The details of normalization procedures may be found in [6].

A central part of one sector in the gold chamber (see fig. 2) was irradiated with a collimated spot size 2 mm in diameter. The other cathode sectors were floating. The chamber was set up for a gain of ~ 900 at an anode voltage of 590 V, and a drift field of 3.3 kV/cm which was later increased to 6.7 kV/cm, corresponding to an avalanche size of ~ 2.10^5, nominal for MIPs at LHC in the forward region. A current density of ~ 9 nA/mm^2 was chosen for the long term irradiation, to be as close as possible to the realistic charge density of 0.1 nA/mm^2 permitting us to accomplish the test in a reasonable time. The first test was performed over a period of 64 days during which the MSGC accumulated a charge of 85 mC/cm of strip with a gas flow of 60 cc/min, and a second test at 6 cc/min has reached 73 mC/cm after 40 days.

3. Results and Discussion

i) Tests at 60 cc/min


ECD Chromatograms of the gas flushing in the MSGC

On 15.5.96 after switching on the electronics two new peaks appeared not present before

On 16.5.96 the new peaks dissapeared and have not reappeared since

Fig. 5

ECD chromatograms of the gas samples were taken both before and just after starting the long term irradiation. The electronics inside the banana was powered a couple of hours before starting the run. Fig. 5 shows the results. Two small peaks appeared immediately after switching on the electronics, and disappeared in about 16-17 hours indicating some initial outgassing, which also resulted in a drop of gain in the same period. A typical pulse height spectrum from the MSGC is shown in fig. 6.

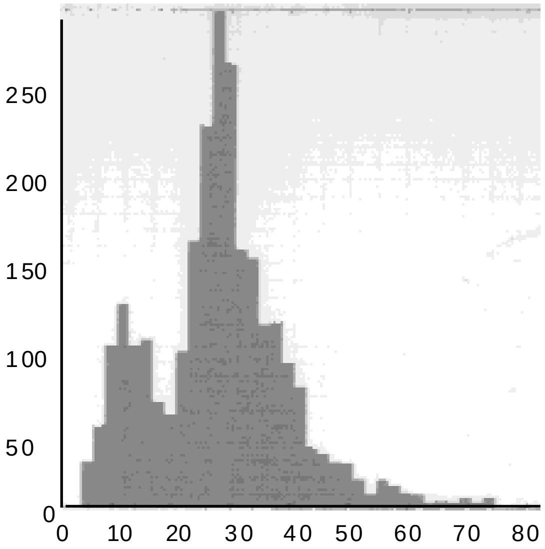


Fig. 6

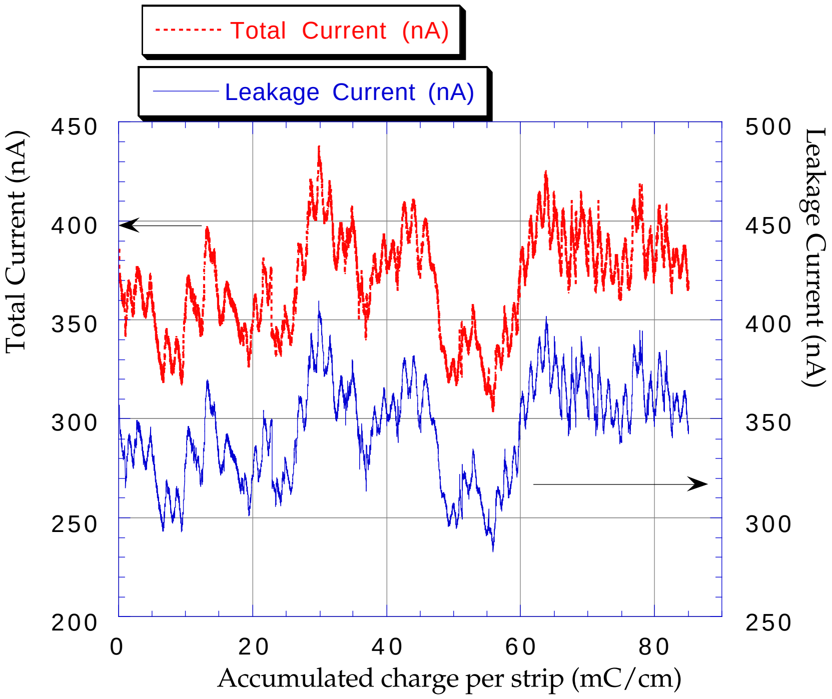


Fig. 7

Fig. 7 shows the raw leakage current (lower curve) and the total current observed with radiation for the total period of the run as a function of accumulated charge per strip. The average leakage current of the group was 340 nA, corresponding to an average surface resistivity of 1.2.10^{14} Ω/square. The regular oscillations correspond to regular day and night temperature and pressure variations. Fig. 8 shows the peak of the monitor counter and the current from radiation for the same period.

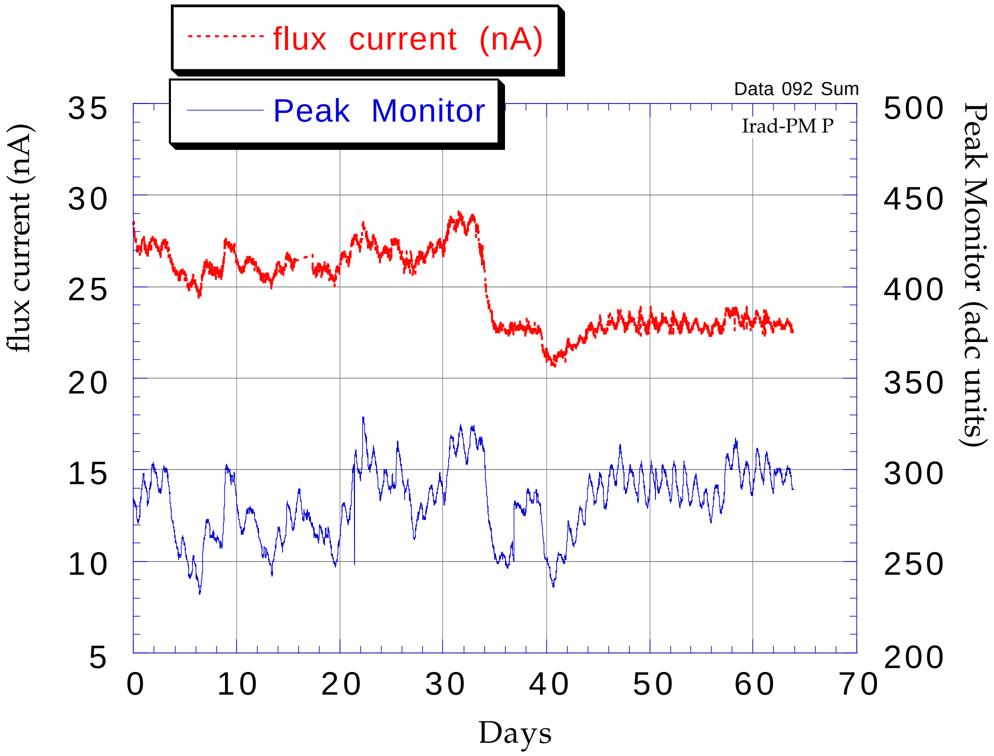


Fig. 8

The sharp drop of gain both in the monitor counter and the MSGC is due to a sudden change of ambient conditions (thunderstorm) as seen in figs. 9 and 10 which show the two parameters as function of T/P in arbitrary units.

From these data it is seen that both the gain in the monitor counter and the MSGC follow closely the parameter (T/P) and at ~ 48 mC/cm the gain of the MSGC has dropped by 10 %. This drop is not real in terms of ageing, but is a systematic shift in our run conditions. Indeed, following the dramatic change in ambient conditions and the gain drop in both chambers, a leak was suspected, eventually detected and fixed.

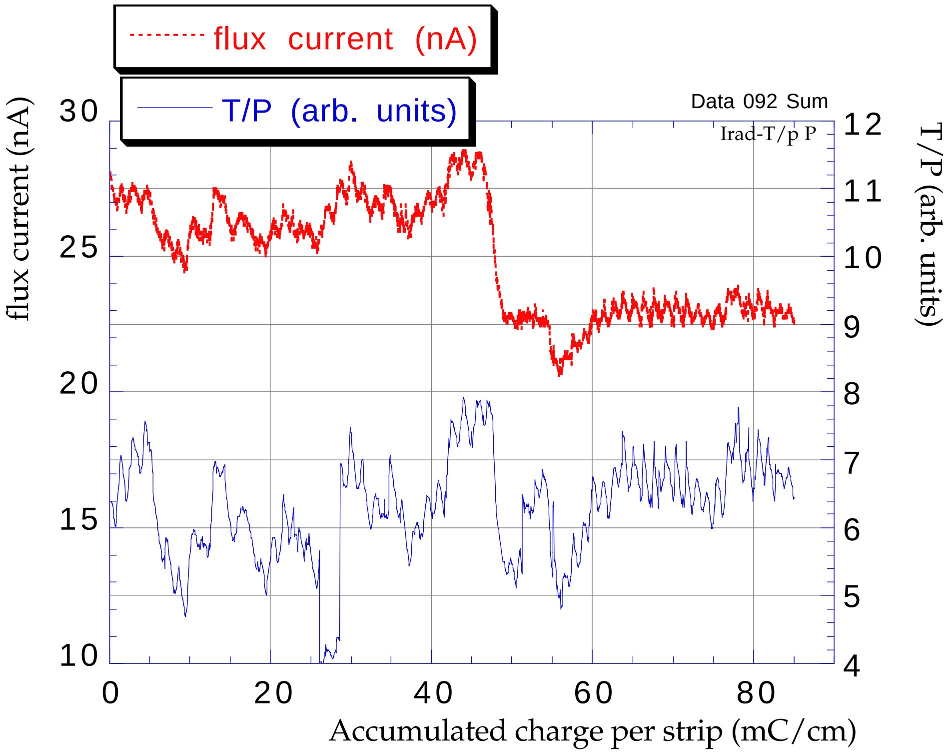


Fig. 9

For control a low rate vertical scan (i.e. along the anodes) for pulse height was made and no difference was found in the irradiated and unirradiated positions. A high rate scan has also been performed by measuring the current as a function of vertical distance along the anode. The result of such a scan is shown in fig. 10, which shows that the current at the top of the anode group is half that of the maximum current in the central region, while at the bottom the current drops by 30 % of the maximum value due to the fact that the substrates are not completely vertical inside in the ‘banana’.

Another observation is that the slope of the current is quite sharp at the position of irradiation (40 mm), therefore after the vertical scan, the collimator was not exactly set back to its original position, the accuracy of such a reading is given by eye reading off a graduated mm scale. This explains the non recovery of current to its nominal value after restarting the run, due to manipulations for fixing the leak. Since the run continued uninterrupted after that, and the gain did not drop from this value it is concluded that the above hypothesis of reading the current off a smaller number of cathodes is correct.

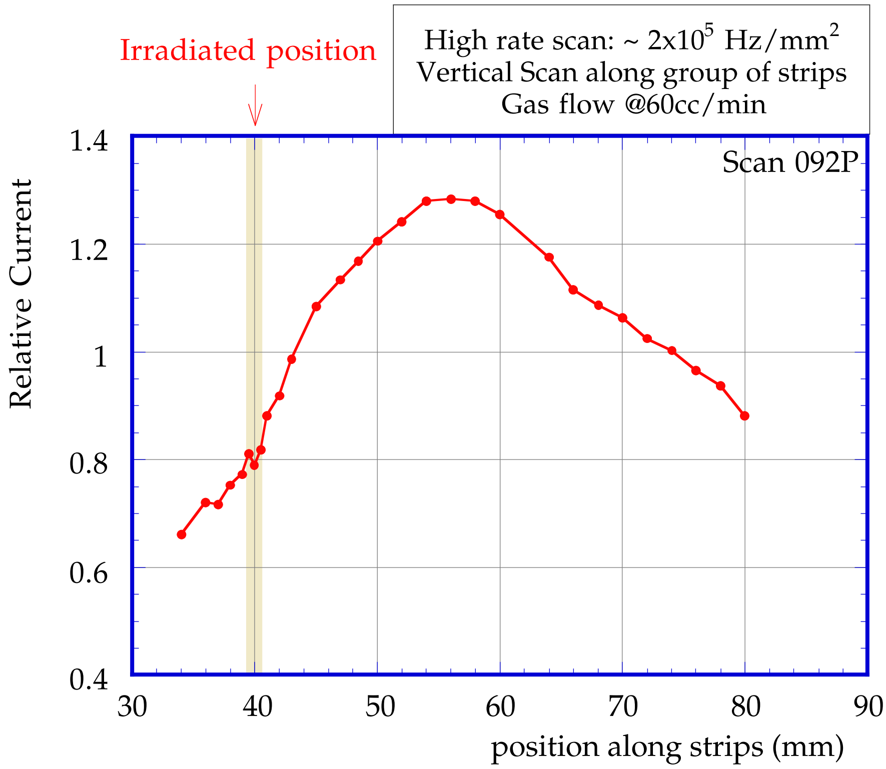


Fig. 10

Fig. 11 shows the relative gain from the current measurement at high rate as a function of the accumulated charge per cm of strip for the total period of the run.

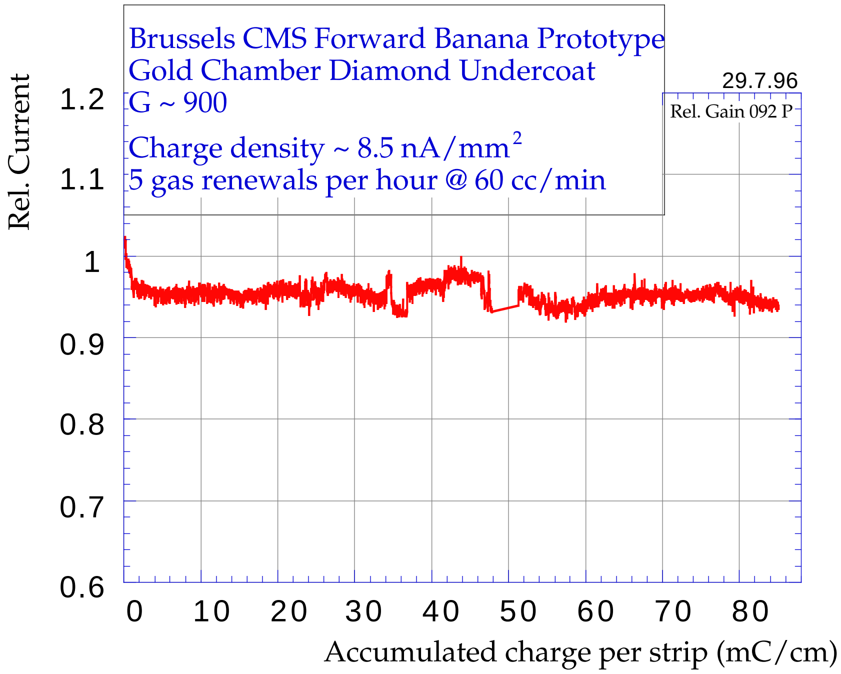


Fig. 11

No gain drop was observed within ±3% in the whole period of the run after the initial 5 % drop presumably due to the aforesaid outgassing from the electronics inside the gas volume.

ii) Run at 6cc/min

Following results of vertical and horizontal scans the position of maximum current was chosen to be the spot for irradiation for this run. Following previous work [7] an increase in the quantity of air was anticipated at this low rate of gas flow through the system. Other conditions remaining the same, this run was set up with the same voltages i.e. 1 kV on the drift and 590 V on the anodes giving a gain of 10^3, and a current density of 11 nA/mm^2. The measured values of air in this run are ~ 1250 ppm. No discharges have been observed and the chamber has been remarkably stable. The relative gain upto 9 mC/cm accumulated charge is shown in fig. 12.

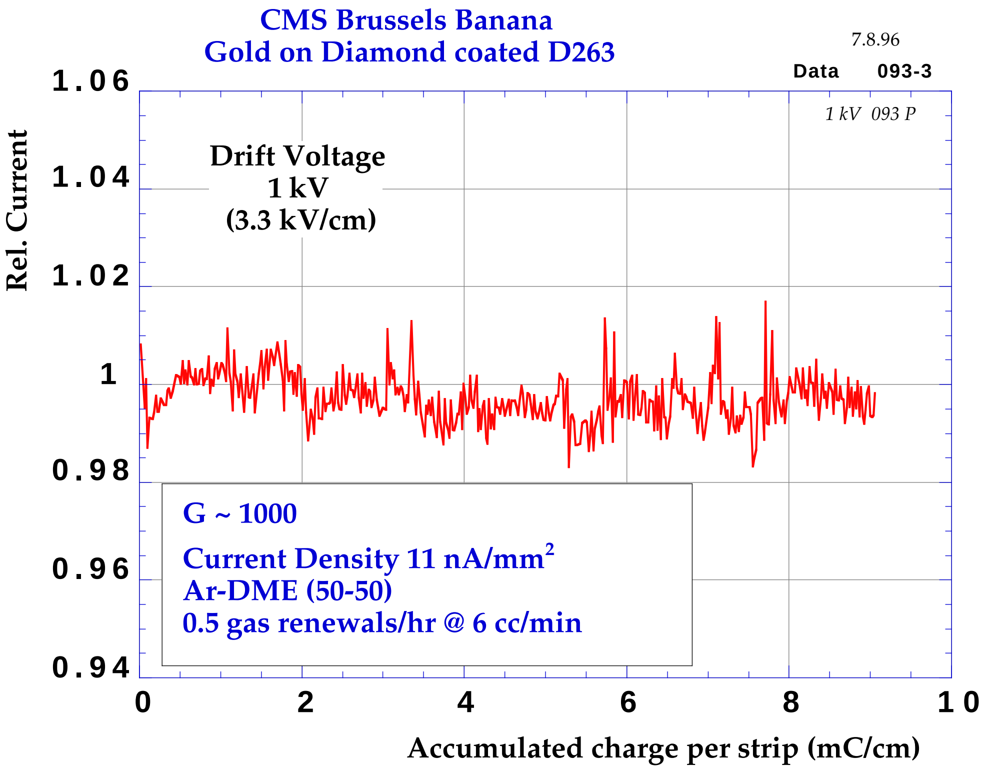


Fig. 12

Observing the stable operation in these conditions, the drift voltage was increased to 2 kV, and the anode voltage was adjusted to 556 V in order to have the same gain namely ~ 10^3. Fig. 13 shows the final relative current plot. Here the first 9 mC/cm were accumulated with the lower drift voltage, and the rest at the higher drift field of 6.7 kV/cm. The small drop of 2 % at 21 mC/cm is due to our interventions in attempts to reduce the air level in the gas flow. After this level settled to 1200 ppm ~ 28 mC/cm, the current has been going up slightly and continued to do so till about 50 mC/cm when the gas mixture stabilized and we are back to the same gain as at the start of the experiment.

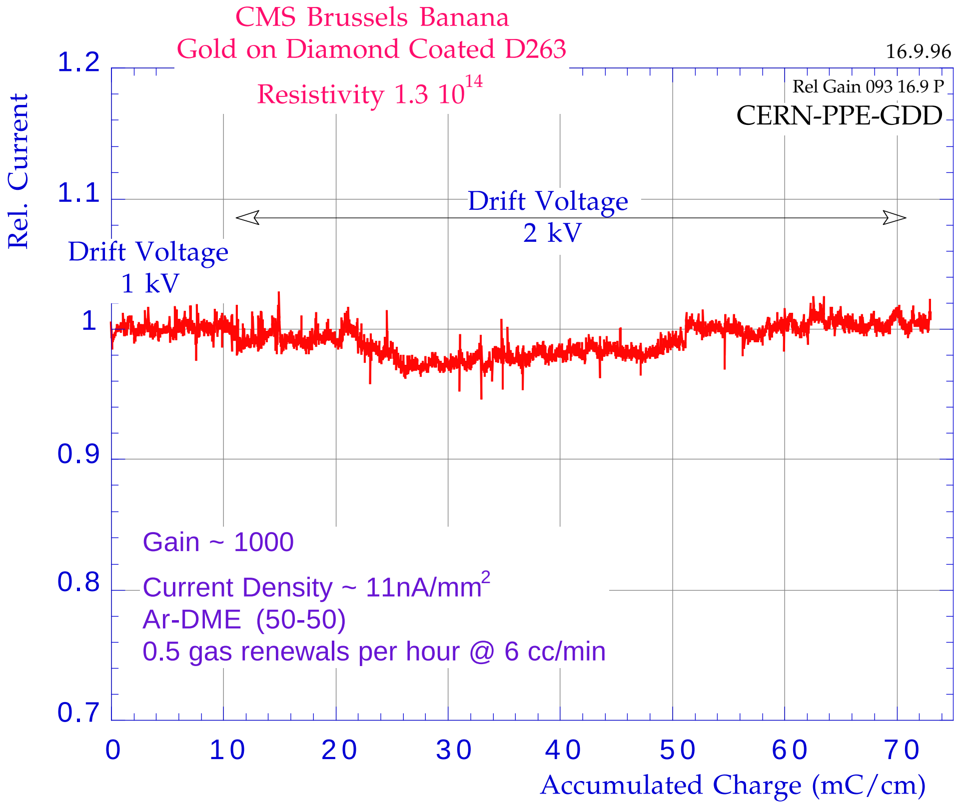

CMS Brussels Banana
Gold on Diamond Coated D263
Resistivity 1.3 10^14
16.9.96
Rel Gain 093 16.9 P
CERN-PPE-GDD
Rel. Current
1.2
1.1
1
0.9
0.8
0.7
Drift Voltage
2 kV
Drift Voltage
1 kV
Gain ~ 1000
Current Density ~ 11nA/mm^2
Ar-DME (50-50)
0.5 gas renewals per hour @ 6 cc/min
0
10
20
30
40
50
60
70
Accumulated Charge (mC/cm)

Fig. 13

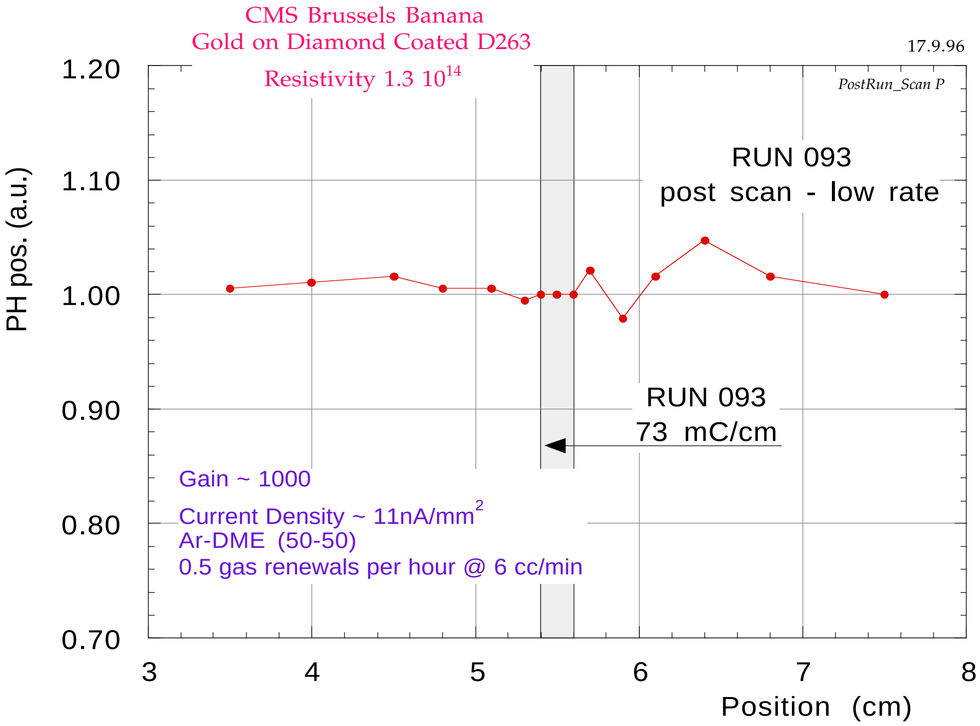

CMS Brussels Banana
Gold on Diamond Coated D263
Resistivity 1.3 10^14
17.9.96
PostRun_Scan P
RUN 093
post scan - low rate
RUN 093
73 mC/cm
PH pos. (a.u.)
1.20
1.10
1.00
0.90
0.80
0.70
Gain ~ 1000
Current Density ~ 11nA/mm^2
Ar-DME (50-50)
0.5 gas renewals per hour @ 6 cc/min
3
4
5
6
7
8
Position (cm)

Fig. 14

A low rate gain scan along the anodes showed no gain drop at the irradiated position as seen from fig. 14, hence this run was concluded with no gain drop after accumulated an integrated charge of 73 mC/cm of strip.

4. Conclusions

From the results of the two tests described above, we conclude that no ageing has been observed up to 80 and 73 mC/cm of strip. The open geometry solution for the forward 'bananas' seems quite promising with a gold on diamond coated D263 chamber. However, this has to be proved for chambers built with other substrates or metallizations Aluminium, for instance which is our next step.

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