EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN-PPE/96-201
18 November, 1996

STUDY OF AGEING AND GAIN LIMITS OF MICROSTRIP GAS CHAMBERS AT HIGH RATES

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ABSTRACT

The CMS experiment comprises MSGCs as one of the key detection elements for high luminosity tracking at LHC. In addition to the high dose rate of 10 mC/year per cm of strip, these detectors have to survive the hostile presence of highly ionizing particles, neutrons low energy gammas and hadrons. In this report we present the results of systematic tests on maximum safe operational gain limits in MSGCs before the discharge. Long term ageing tests performed on prototype open 'banana' modules envisaged to be arranged around the interaction region in the forward part of the CMS tracker show no evidence of gain drop up to equivalent ~ 10 years of LHC operation. A comparison is made between argon and neon gas mixtures with DME in equal proportions by investigating long term irradiation effects on chamber operation by introducing controlled and reproducible pollution in the gas lines.

Invited Paper presented by A. Sharma at the

Study of ageing and gain limits of Microstrip Gas Chambers at high rates

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Abstract

The CMS experiment comprises MSGCs as one of the key detection elements for high luminosity tracking at LHC. In addition to the high dose rate of 10 mC/year per cm of strip, these detectors have to survive the hostile presence of highly ionizing particles, neutrons low energy gammas and hadrons. In this report we present the results of systematic tests on maximum safe operational gain limits in MSGCs before the discharge. Long term ageing tests performed on prototype open 'banana' modules envisaged to be arranged around the interaction region in the forward part of the CMS tracker show no evidence of gain drop up to equivalent ~ 10 years of LHC operation. A comparison is made between argon and neon gas mixtures with DME in equal proportions by investigating long term irradiation effects on chamber operation by introducing controlled and reproducible pollution in the gas lines.

1. INTRODUCTION

Microstrip Gas Chambers (MSGCs) [1,2] have been planned to be one of major tracking devices in the CMS experiment for high luminosity environment of the LHC collider at CERN. With the implementation of a diamond-like coating+ , either under or over the metal strips, these devices have been shown to have a high rate capability and long term stability of operation [3]. These features are however, very sensitive to the various parameters involved, therefore demands on quality of artwork, cleanliness conditions in the mechanical assembly as well as gas lines among others are rather rigorous. Moreover, the technology and metal used for manufacturing such a device is also a delicate issue considering the copious rate of thermal neutrons, low energy hadrons and gammas. Simulating these highly ionizing tracks by α-particles, discharge limits have been investigated on diamond coated chambers.

Further, in the forward and backward part of the tracker, MSGCs which will be arranged around the interaction region in modular 'bananas' containing many substrates in the gas volume along with readout and service electronics. The expected integrated dose rate of 10 mC/year per cm of strip may be foreseen to modify their operation [4]. Given these conditions, we have made systematic tests of long term operation of a prototype 'banana' and the ageing results are reported here.

Another ageing test has been performed to compare the effects of long term irradiation on the operation of an MSGC with different gas mixtures with the introduction of controlled pollution in each case.

2. EXPERIMENTAL PROCEDURES

2.1 Discharge limit tests

The discharge limits were investigated for three chambers one over-coated (DOC) and two under-coated (DUC1 and DUC2) with the usual geometry of 7 µm anodes, 100 µm cathodes and 200 µm pitch. The strips for all chambers were made of chromium, and a gold plated 100 µm glass was used as drift electrode. It may be mentioned that the three plates were of excellent quality* and could withstand very high voltages in the absence of radiation. A schematic description of the experimental set up used is shown in fig. 1. Alpha particles depositing typically few 100 keV in the active gas volume were introduced by means of a special 3 µm Hostaphan film glued on a 1 mm thin slit in the window. Maximum gain limits were determined with an

+ SURMET Corp. Burlington MA, USA

* IMT Masken und Teilungen AG, Greifensee, Switzerland

Fe^{55} source and then repeated with alphas. Due to the larger amount of ionization the trip voltage was lower in the latter case; thus simulating the presence of highly ionizing particles. Gain calibrations were performed and the same electronics chain was maintained for the tests. These measurements suffer from two limitations: first, the alphas are introduced in a very local position of the active area, and second they were performedin the absence of any other source of radiation. To overcome this, another set up was prepared for DUC2, in which it was possible to illuminate the whole active surface (10 x10 cm2) of the chamber, and in addition α-active gas Rn^{220} could be introduced as shown in fig. 2. This set up was used to determine the maximal safe voltage, thus limiting gain for chamber operation with the whole active area of the chamber connected.

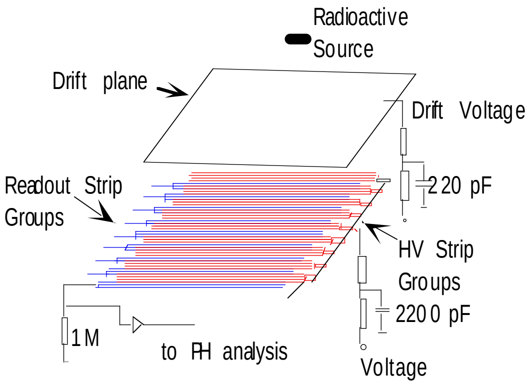

Fig. 1

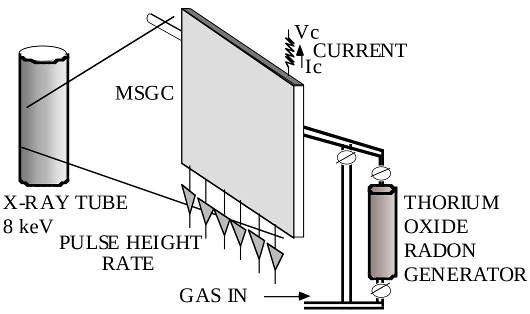

Fig. 2

2.2 Prototype ‘banana’ ageing tests

For the ageing studies of the prototype ‘banana’ module of the forward tracking, the set up used is the RD-10 lab at CERN [4]. Two

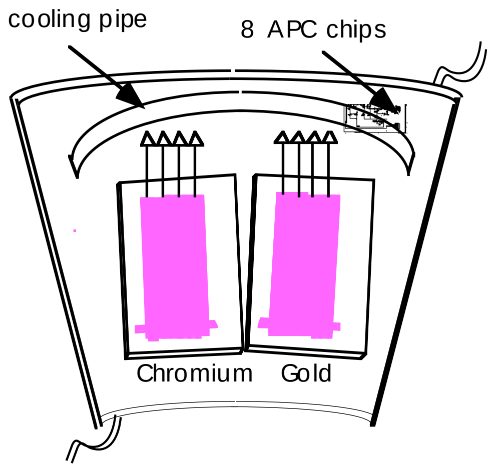

Fig. 3

MSGC plates were mounted inside the banana, one with gold and the other with chromium strips on diamond coated D263. The banana contained powered readout electronics [5] to simulate the 2 mW/channel heat dissipation expected out of the PreMux front end chips envisaged to be mounted inside the gas volume. A piece of cooling pipe was also included. The gold chamber was irradiated in both the tests, along with a single wire proportional counter for monitoring gas quality as well as variations of the gain with respect to temperature and pressure, which are also recorded separately. Both the tests were performed with an exposure spot size of 2 mm diameter, gain ~ 900 in the chamber, and a drift field of 3.3 kV/cm, which was increased subsequently in the low gas flow test to 6.7 kV/cm the anode voltage was consequently adjusted to have the same gain as before. The current density was ~ 9 nA/mm^2. The two tests lasted for 64 and 40 days, over which the charge accumulated per cm of strip of 85 and 73 mC respectively.

2.3 Controlled Pollution ageing tests

The third investigation reported here was performed in the GDD lab at CERN. The MSGC was assembled by mounting in a regular ‘wire chamber style’ (see fig. 4) a C85-1 glass plate

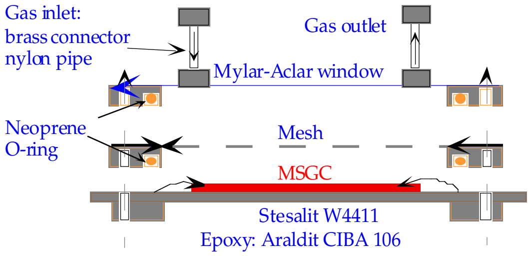

Fig. 4

with gold electrodes: 5 µm anodes, 100 µm cathodes and 200 µm pitch with a resistivity of 10^{11} Ω.cm. Two kinds of reproducible controlled pollution conditions were introduced. First a fresh 4 m stainless steel line cleaned with alcohol and heated in the oven at 80 degrees for 24 hours was placed at the gas inlet of the MSGC. Secondly, a Si-oil bubbler was connected immediately at the exhaust to allow for some controlled back diffusion. Tests with argon and neon mixed with DME in equal proportions were performed to have a comparative evaluation of the long term chamber operation with the above mentioned polluted conditions.

3. RESULTS AND DISCUSSION

3.1 Discharge Limit Tests

The first tests was performed on the DUC1 and DOC which had an average resistivity of 2.10^{14} and 2.10^{13} Ω/sq. using the set up of fig. 1. Pulse height spectra were made with Fe^{55} and the Gaussian fits were made to obtain the peak position and hence the gain. For the alpha spectra however, an exponential fit at the tail of the spectrum was taken to represent the maximal energy loss. Precursors or large signals are observed when the chamber's were exposed to α's [6]. Figs. 5 and 6 show the gains as a function of voltage for the different gas mixtures studied for the under- and over- coated chambers respectively. A drop of maximum safe voltage and thus the limiting operational gain in the presence of alphas is shown by the respective arrows marked on the plot.

From these results it is clear that there is only a small advantage using neon, ineffective because of the reduced ionization. The margins of voltage for safe operation are similar. Gains in excess of 10^4 could be achieved in pure DME both with Fe^{55} and α's. The gains were higher for the undercoated chamber; the required higher voltage, however, can have adverse consequences in case of a discharge since the energy is about twice than the corresponding energy for the overcoated chambers.

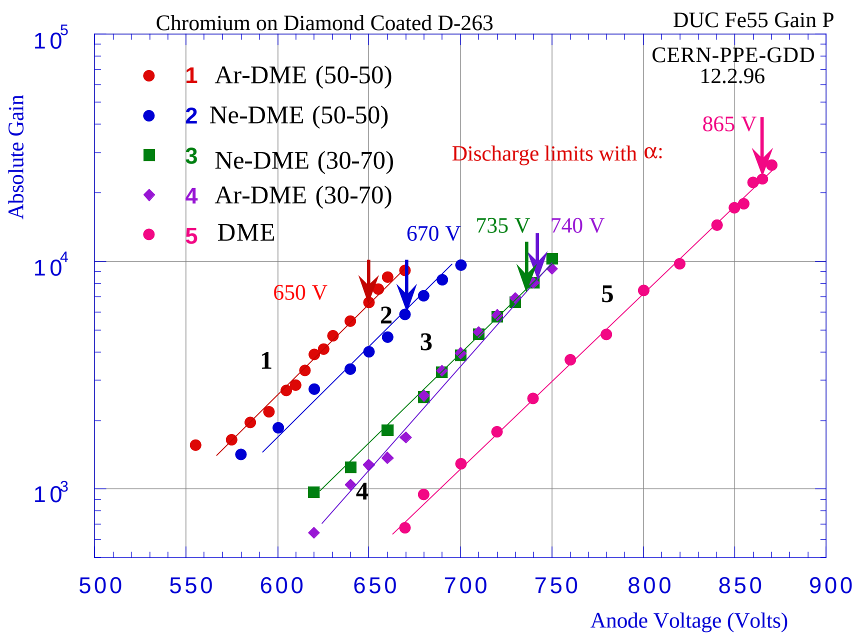

Fig. 5

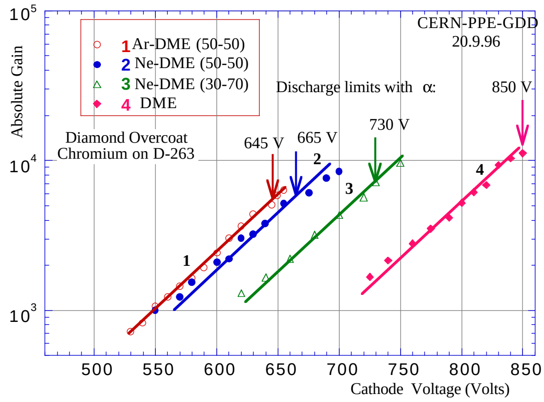

Fig. 6

These measurements however suffer from the following limitation: they are obtained by irradiating a small part of the active surface of the chamber to radiation, and are performed without a high rate of ionizing particles. With the improved set up shown in the previous section (fig. 2), measurements with a high X-ray flux exposure in the presence of heavily ionizing particles obtained from Radon were realized.

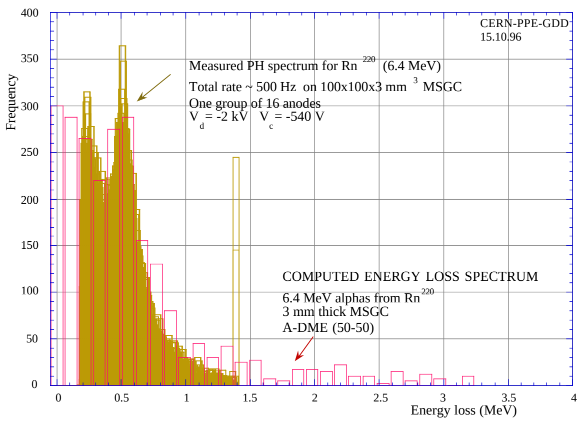

Fig. 7

Radon (Rn^{220}) emits α's of 6.4 MeV and we have measured in the thin chambers (3 mm gap) an energy loss spectrum with a peak at a few 100 keV and a maximum ~1.2 MeV as shown in fig. 7. The solid histogram is the measured spectrum, while the bars represent results of simulations performed with an estimated range of 28 mm for the 6.4 MeV α's in the gas. The peak occurs at a few 100 keV since the most probable energy loss is the one arising from perpendicular tracks. Fig. 8 summarizes the results of measurements of discharge limits of DUC2. In this chamber, which had an average resistivity of 1.2 10^{14} Ω/sq., anodes were connected in groups of 16 (32 groups in total) and each group could be accessed individually. When there is no source of radiation, one can reach voltages as high as 685 V on the cathodes connecting each group of the anodes one by one to ground (stopping for safety reasons). This corresponds to the top dashed line in the figure equivalent to ~ few 10^4 in gain. With an X-ray flux of ~10^4/mm^{2}s^{-1} this limit is reduced to values ranging 620-660 V over the groups thus lowering the gain achievable as is shown by the curve marked A. A single anode group will be responsible for lowering of the operational voltage of the whole chamber. The discharge limiting current in each case was set ~ 10 % above the total (leakage + radiation) current. When the radon generator is switched on, this safe voltage is further reduced to 605-635 V over all the groups (curve B) reducing the maximum attainable gain limit in the presence of highly ionizing particles to be ~ 3500 which is quite marginal for operating in a high flux of MIPs with full efficiency governed by the signal/noise of the readout electronics.

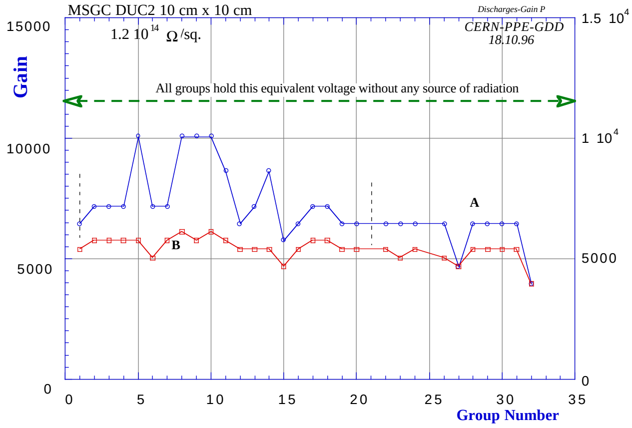

Fig. 8

3.2 Prototype 'banana' ageing tests

These tests were performed with the prototype CMS forward 'banana' chamber shown in fig. 3 of section 2.2. For the first tests performed with a gas volume exchange five times per hour, the chamber had accumulated an integrated charge of 85 mC/cm. Fig. 9 shows the relative current as the run progressed. Gain fluctuations due to daily variations in pressure and temperature were corrected for. An initial drop of ~ 5% was observed and a gas analysis performed at the same time showed some outgassing presumably from the electronics which was sitting powered inside the banana. A vertical scan at low rate after completion of the test, along the anode strips showed no drop of relative gain in the irradiated position. For the second test with a volume exchange each two hours, the relative current as a function of accumulated charge is shown in fig. 10. Note that the drift field was increased after reaching ~ 9mC/cm keeping all other conditions the same. No gain drop is seen throughout the run accumulating 73 mC/cm; this is corroborated by a low rate pulse height scan along the anodes.

3.3 Long term tests with controlled pollution

For these tests the chamber shown in fig. 4 was used. The semiconducting plate had a measured resistivity of 10^{11} Ω.cm. Table 1 summarizes the chronologic order and the results of the tests. The first tests that were performed with Ar-DME (50-50) and Ne-DME (50-50) accumulated more than 10 mC/cm per strip with no degradation of gain. Fig. 11 shows the results obtained with the first attempts of polluting the gas system with a stainless steel line. The gas

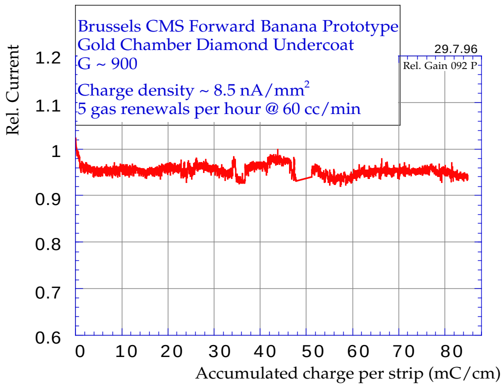

Fig. 9

rack seems to have been obviously cleaned by the action of DME in a few weeks. A 10 % drop of gain with the initial Ar-DME (50-50) run was not reproduced when the test was repeated after the Ne-DME (50-50) run which also showed no signs of deterioration. With the introduction of a new stainless steel line this drop was not observed either, proving that the pollution was irreproducible.

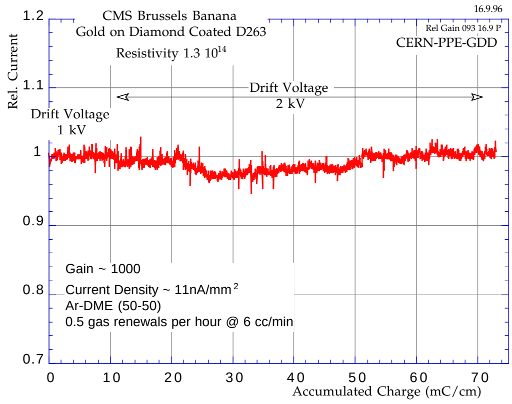

Fig. 10

The second attempt to pollute the system with the Si-oil bubbler was more dramatic. Fig. 12 shows the results of three successive ageing tests performed in different regions of the plate respectively neon, argon and again neon with DME (50-50) as operational gas mixture. Gain drops were observed in each of these tests albeit faster in neon mixtures. An optical investigation of the plate revealed the three irradiated spots distinctly, wider than the (2 mm) diameter of the collimator of the X-rays. This increment of spot size was distinctly correlated with the accumulated charge per irradiated spot. The sort of degradation in the Si-Oil bubbler runs is different from that observed in the former stainless steel gas line case, where a fluid covers the anodes and cathodes in the degraded areas.

4. Conclusions

We have shown that operation of MSGCs in a high flux of radiation is more delicate in the presence of highly ionizing radiation, limiting the operational gains of these devices. The reduction factor is correlated to many parameters of the MSGCs namely artwork, metalization, gas purity etc. The apparent advantage of a ~10 % increased gain in neon mixtures at discharge limit is compensated by large primary ionization in argon mixtures. More

Run No.	Gas mixture (50-50)	Attempted Pollution	Result
1	Ne-DME	None	OK
2	Ar-DME	None	OK
3	Ar-DME	SS Line 1	10% Gain drop @14 mC/cm
4	Ne-DME	SS Line I	OK
5	Ar-DME	SS Line I	OK
6	Ne-DME	SS Line II	OK
7	Ne-DME	SS Line III	OK
8	Ne-DME	Si-Oil bubbler	10% Gain drop @12 mC/cm
9	Ar-DME	Si-Oil bubbler	OK
10	Ne-DME	Si-Oil bubbler	20 % Gain drop @ 22 mC/cm
11	Ar-DME	Si-Oil bubbler	20 % Gain drop @ 25 mC/cm

Table 1

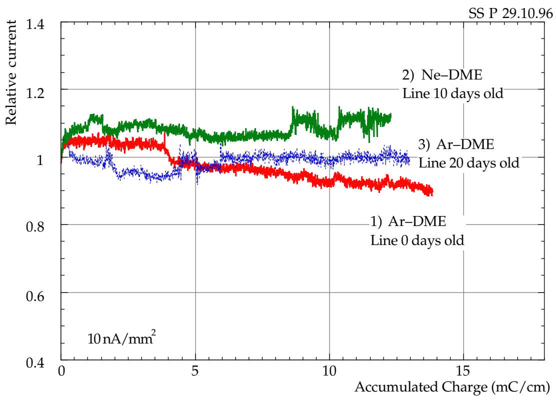

Fig. 11

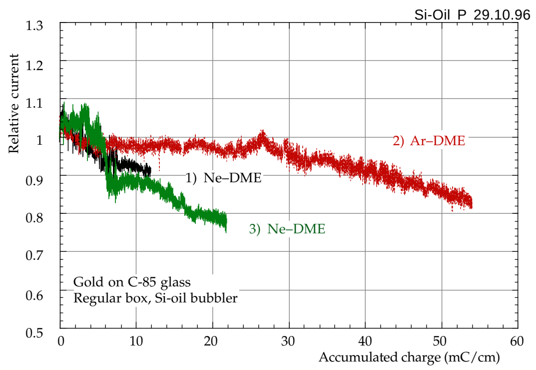

Fig. 12

work is needed to clearly disentangle these effects. Ageing tests of the forward ‘banana’ prototype have shown no gain drop till ~ 7-8 years of equivalent LHC operation. No clear cut effects to differentiate argon and neon mixtures affecting the long term behavior of an MSGC made on semiconducting glass could be established due to irreproducibility of the pollution conditions.

REFERENCES:

[1]. A. Oed, Position-sensitive Detector with Microstrip Anode for Electron Multiplication with Gases. Nucl. Instr. and Methods **A263** (1988)351.
[2]. RD28 Status Report 1996 CERN/LHCC 96-18.
[3]. R. Bouclier et al, Proceedings IEEE Nuclear Science Symposium and Medical Imaging Conference, San Francisco, Oct 21-28, 1995.
[4]. R. Bouclier et al CERN-PPE/96-33.
[5]. F. Angellini et al., NIM **A362** (1995) 273.
[6]. F. Angellini et al., Proc. Int. Workshop on MSGCs, Lyon, (1995) 307.
[7]. RD10 Status Report CERN DRDC 92-50.
[8]. APC chips used in the HERMES and H1 experiment.
[9]. R. Bouclier et al CMS TN/96-018.