# Temperature dependence of the MDT gas gain


Gabriella Gaudio *INFN Pavia, Italy*
Carsten Noeding *University of Mainz, Germany*
Michael Treichel *CERN/EP, Geneva, Switzerland*



Abstract

This note describes the measurements taken in the Gamma Irradiation Facility (GIF) in the X5 test beam area at CERN to investigate the temperature dependence of the MDT drift gas ($Ar / CO_2$ - 90:10). Spectra were taken with an Americium-241 source during the aging studies. We analysed the effects of temperature changes on the pulse height spectrum.


## 1 Introduction

Performance deterioration of the MDT chambers during long-term LHC operation is a serious concern. This aging is due to changes in the cathode and anode surfaces, which directly affect the tube lifetime. Pollutants introduced by inadequate cleaning of the construction elements can accelerate the aging significantly. In order to evaluate this effect before the start of production a number of tubes are irradiated in the X5 GIF facility at CERN which houses a 740 GBq $^{137}$Cs source, and pulse height spectra are taken at regular intervals. As the experimental zone is close to a large door, the temperature strongly varies in relative short time lapses. This translates into pulse height variations which affect the precision of the aging measurements but can also be exploited to directly study the temperature dependence of the pulse height.

## 2 Experimental setup

Six tubes of 150 cm length were installed in the X5 test beam area at CERN. They were placed in a vertical position on an aluminium support frame at a distance of 1 m in front of a $^{137}$Cs source. Electronic cards for high voltage power supply were soldered on the bottom side of each tube. Preamplifier hybrids were mounted on the readout cards which were soldered to the other side. The shapers were implemented on an electronic module which was placed outside the area. A Faraday cage mounted on each tube end minimized noise and pick-up. The signals were digitized by a standard ADC module, and the gate was generated by the signal itself.

In order to accumulate the charge per unit wire length specified for the aging procedure (see [1]) in a reasonably short time, a 740 GBq $^{137}$Cs source with a Pb absorber was used. Lead filters can be chosen to adjust the actual gamma rate. The source gives a rather flat spectrum up to 660 keV with peaks at 660 keV and at around 80 keV. Reference spectra for testing the tube performance were taken with a 37 MBq $^{241}$Am source with a Molybdenum foil in front of it.

The gas mixture was $Ar / CO_2$ - 90:10 at 3 bar absolute pressure flowing at ten times the rate foreseen for ATLAS. The HV power supply was 3.4 kV during $^{137}$Cs irradiation which corresponds to a gas gain of $6\times10^4$, while it was 3 kV during spectra acquisition (gas gain $1.2\times10^4$).

# 3 Aging studies

Deterioration of the performance of the MDT yields a significant decrease of the signal. For a given reference spectrum this leads to a downward shift and deformation of the pulse height distribution.

## 3.1 Reference spectra

The reference spectra are taken with the $^{241}$Am source with a Mo foil. The spectra (see figure [1]) are calibrated using the expected peak positions at 17 keV (which arises from Molybdenum fluorescence X-rays) and 60 keV. In each histogram, the position of the two peaks and of the pedestal (which is the first peak in the spectrum) are determined by fitting them with a Gaussian function. For a cross check, spectra are acquired without the foil. The 17 keV peak does not show in these spectra, as expected. To determine the aging of the drift tubes it is necessary to take spectra at regular time intervals and to determine the relative change.

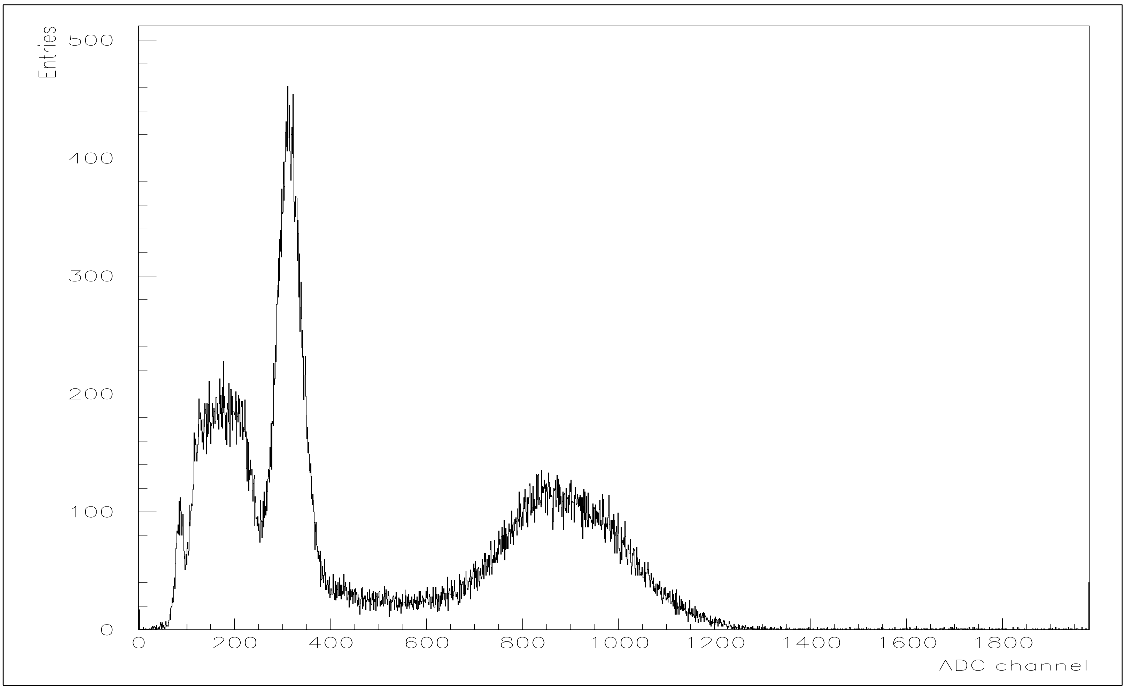


**Figure 1:** Reference spectrum taken before beginning of irradiation

### 3.2 Accumulated charge

Under the operating parameters described above and without a filter in front of the Cs-source the current is $46\mu A$ and is very stable. This leads to an accumulated charge per unit length of

$$Q_{total} = \frac{46\mu A}{6tubes \cdot 150cm} \cdot 86400s = 4.4mC\frac{1}{tube \cdot cm \cdot day}$$

Former aging tests have shown that it is possible to extrapolate to the expected charge deposit of 0.6 C/cm from an accumulated charge of about 100 mC/cm. Therefore we can expect first results from this aging test after about one month of running.

## 4 Measurements of temperature effects

As described in Section 3.1, the progressive degradation of the MDT's performance can be seen by a shift in the ADC spectrum to lower energies. Nevertheless, a change in the peak position can also be observed as an effect due to different environmental conditions such as temperature. These variations also influence the drift properties of the gas.

### 4.1 Theory

Gain variations can be understood in terms of the Diethorn formula [3]:

$$\ln G = \frac{\ln 2}{\ln(b/a)} \cdot \frac{V}{\Delta V} \cdot \ln\left[\frac{V}{\ln(b/a)aE_{min}(\rho_0)(\rho/\rho_0)}\right]$$

where $a$ and $b$ are the wire and inner tube radii, respectively, $V$ the wire potential, $\Delta V$ the ionization potential, and $E_{min}$ the electrical field at the start of the avalanche. The linear dependence of $E_{min}$ on the density is a consequence of the well known $E/p$ scaling. Second order effects such as the direct temperature dependence, due to the increase of the collision rate at increasing temperature, have been neglected. The derivative with respect to the density yields the relative gain variation:

$$\frac{\partial \ln G}{\partial \rho} = \frac{1}{G}\frac{\partial G}{\partial \rho} = -\left(\frac{\ln 2}{\ln(b/a)} \cdot \frac{V}{\Delta V}\right) \cdot \frac{1}{\rho} \Rightarrow \frac{\Delta G}{G} = -\left(\frac{\ln 2}{\ln(b/a)} \cdot \frac{V}{\Delta V}\right) \cdot \frac{\Delta\rho}{\rho}$$

Thus, a measurement of the density dependence of the gain yields the Diethorn parameter $\Delta V$, while the other parameter $E_{min}$ can be determined from the absolute value of the gain.

For Argon dominated mixtures we expect $\Delta V \cong 40\ \mathrm{V}$ [2][4], hence we obtain

$$\frac{\Delta G}{G} = -8 \cdot \frac{V}{3\ \mathrm{kV}} \cdot \frac{40\ \mathrm{V}}{\Delta V} \cdot \frac{\Delta\rho}{\rho} \cong 8 \cdot \frac{V}{3\ \mathrm{kV}} \cdot \frac{40\ \mathrm{V}}{\Delta V} \cdot \frac{\Delta T}{T} \text{ at constant pressure}$$

and

$$\ln G \cong 8 \cdot \frac{V}{3\ \mathrm{kV}} \cdot \frac{40\ \mathrm{V}}{\Delta V} \cdot \ln\left[2.8 \cdot \frac{20\ \mathrm{kV/cm}}{E_{min}(1\ \mathrm{bar})} \cdot \frac{V}{3\ \mathrm{kV}} \cdot \frac{\rho_0}{\rho}\right]$$

for the ATLAS drift tubes, where $\rho_0$ is the density at 3 bar.

### 4.2 Measurements

In order to measure the peak position as function of temperature one tube has been chosen. The spectra were taken using the $^{241}$Am source with Mo foil during one morning exploiting the daily thermal excursion as varying environmental conditions.

In the first cycle of measurements the temperature was monitored by a digital thermometer of sensitivity $\pm 0.1°$ C placed at the entrance of the experimental area while in the second cycle the thermometer was placed onto the support near the tubes. Therefore the two data sets must be analysed separately. We have determined the peak position of the 60 keV peak as described in Section 3.1. By plotting $\log[A(T)/A(T_0)]$ against $\log[T/T_0]$ and performing a linear fit we were able to derive a value for the Diethorn parameter $\Delta V$. Taking into account a systematic error of $\pm 3$ channels due to fluctuations of the fitted ADC pedestal we obtain $\Delta V = (35 \pm 2)$ V in the first case (thermometer near entrance) and $\Delta V = (39 \pm 1)$ V in the second (thermometer near tubes). As a cross check, the same analysis is done with the 17 keV peak yielding compatible values. Figure [2] displays the results.

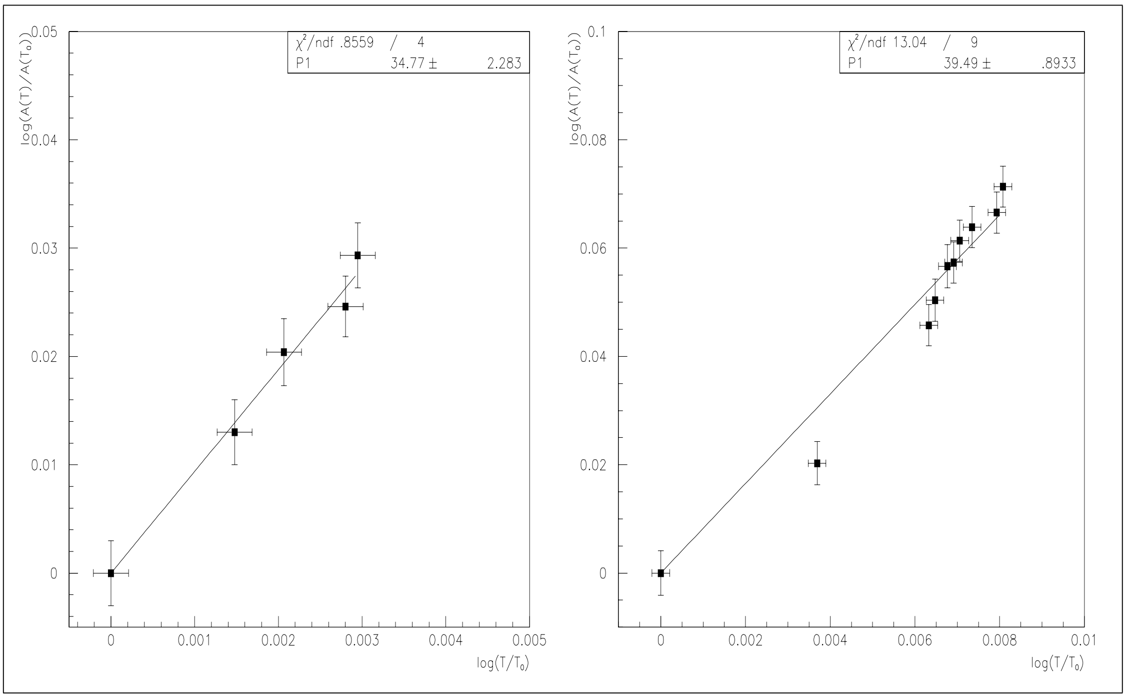


**Figure 2:** Linear fit for temperature dependence measurement: thermometer placed near entrance (left) and near tubes (right)

## 5 Conclusions

The extracted Diethorn parameter ΔV agrees well with the one determined from the high voltage dependence [2], and the small difference between the values obtained by two different methods gives us further confidence that the dependence of the MDT gas gain on external parameters is well understood. To reduce the remaining systematics it would be desirable to repeat these simple measurements with a direct measurement of the gas temperature. For the operation of the ATLAS chambers, however, the present results are more consequential.

## Acknowledgments

We want to thank Adrian Fabich for helping us in managing the data acquisition software and Martin Aleksa for numerous discussions and clarifications on his measurements.

## References

1 ATLAS Muon Collaboration: *Technical Design Report*, CERN / LHCC 97-22, June 1997, available on the WWW-page: `http://atlasinfo.cern.ch/Atlas/GROUPS/MUON/TDR/Web/TDR.html`

2 M. Aleksa, W. Riegler: *Non-Linear MDT Drift Gases like AR/*$CO_2$, ATLAS Muon Note 98-268, 18. December 1998

3 W. Diethorn, USAEC Report NY06628 (1956), as cited in [4]

4 W. Blum, L. Rolandi, *Particle Detection with Drift Chambers*, Springer-Verlag, 1993