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Parameter of MDT Ageing and Reanimation

S. Kircher, M. Kollefrath, G. Herten, W. Mohr

University of Freiburg
Fakultät für Physik
Hermann-Herder-Str. 3
79104 Freiburg i. Br.
Germany

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ABSTRACT

We present results of ageing tests performed in Ar-CH_4-N_2-CO_2-(94-3-2-1) and Ar-CO_2-(93-7). In the latter gas no sign of ageing has been observed under different operating parameters with the final design end plug. In Ar-CH_4-N_2-CO_2-(94-3-2-1) a strong dependence of the lifetime on the anode voltage, the counting rate, the irradiation length and the gas flow has been observed. This dependences imply that the lifetime of a drift tube can not be described solely by the charge per unit length (as has been assumed by many for a long time).
The potential of sputtering as a backup technique in case of unforeseen effects that lead to ageing of drift tubes has been investigated. The problem of cracks as a byproduct of this technique could be solved. Reanimation up to a level of $\approx 90\,\%$ could be achieved in Ar-O_2-(99-1) and Ar-CO_2-(93-7) each at atmospheric pressure and a current with reversed polarity of $1\,\mu$A/cm.

1 Introduction

Previous authors [2] have presented inconsistent results of ageing tests with Ar-CH_4-N_2-CO_2--(94-3-2-1). On one hand a set of tubes was operated at 3350 V and irradiated over a length of 2.5 cm. Another set of tubes had an active zone of ≈ 300 cm and a voltage of 3400 V. The first set showed almost no ageing whereas the tubes of the second set were dead after 80 mC/cm. Since, on the basis of these results, it was not possible to recommend the gas for the operation of the MDT's, we investigated the parameters of the ageing process systematically.

Even though Ar-CO_2-(90-10) did not show ageing, there were very few ageing tests with the present baseline gas of the MDT's and no ageing test with the final components of the gas system. Another crucial point is that an ageing resistent gas like Ar-CO_2-(93-7) could turn into a gas that does show ageing, if it is polluted with the constituents of air by backdiffusion through gas leaks or with any chemical that enters the drift tube by outgasing of components of the gas system (e.g. material of end plug or cleaning agent). Thus ageing tests with tubes with final components in Ar-CO_2-(93-7) were performed. In order to get a more reliable result of the influence of materials on the ageing process further tests in Ar-CH_4-N_2-CO_2-(94-3-2-1) were carried out. Since the later gas is known for its ageing, a possible influence of the material can be seen very soon.

Another important question was if MDT's show rapide ageing under the bombardment with hadrons, such as reported by [7]. We therefore performed ageing tests with α-particales in both gases.

Reanimation of drift tubes by means of sputtering could not be recommended so far as an assurance against unforeseen ageing of MDT's since a large number of end plugs became leaky after the treatment. In order to be able to safely recommend sputtering for the use in the MDT's the reson for the leaks was investigated.

This note is aimed to give an overview of the results. Any details of the setup and the method of analysis can be found in [1, 2, 3]. Nevertheless section 2 gives a very brief overview of the experimental method (not even meant to be complete) and explains the most important quantities. The results of the sputter and ageing experiments are presented in section 3 and 4 respectively.

2 Method

Apart from six so called α-tubes (section 4.3) all tests in the Freiburg Ageing Experiment were carried out with γ-radiation from a ^{241}Am-source. It's main lines are 16 keV and 60 keV. The gas system of the setup is made completely out of stainless steel and no grease was used for any valve. All tubes are serviced by a parallel gas system[1].

[1]when not explicitly stated otherwise.

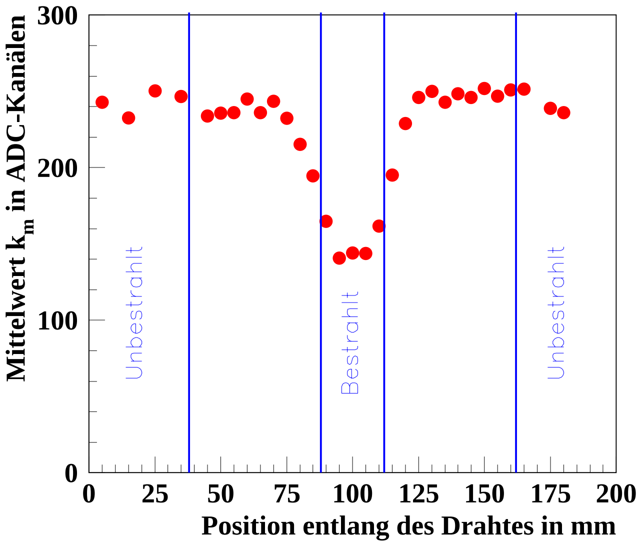


Figure 1: Example of a measurement of the mean pulse height as a function of the position along the wire. One can clearly see the pulse height drop in the irradiated zone (the gap between the lead absorbers in this example is 25 mm). From this data it is possible to calculate the pulse height ageing a_p using equation 1. For the given example the value is $a_p = 65.8\,\%$.

In the following some quantities necessary to understand the results are defined.

Lifetime Q of a drift tube :
The lifetime Q of a drift tube is defined as the charge per unit length that a tube has accumulated until the mean pulse height drops below 70 % of its initial value (the pulse height at the beginning of operation). The pulse height is determined at an operating voltage that corresponds to a gas gain of $2 \cdot 10^4$ and a counting rate that is low enough that space charge effects vanish. The error of Q can be estimated from the RMS of the lifetime of tubes that are operated under exactly the same conditions. If only one tube was operated an error of 45 % was assumed. (For details see [3].)

Anode voltage U_a (ageing voltage) :
The anode voltage U_a is the voltage at which the tube was aged. This is usually some 250 V to 500 V above the voltage where the mean pulse height was determined. On average a tube was operated 86 % of the time at U_a. In the remaining fraction either maintainance work or measurements were carried out.

Irraditaion length d_k of a drift tube :
The irraditaion length d_k is the length of the anode wire that was irradiated by the γ-source. Experimentally this quantity was realised with two lead absorbers that were mounted directly on the tube. Typical values in the Freiburg Ageing Experiment range from 1 cm to $\approx$ 8 cm.

Pulse height ageing a_p and counting rate ageing a_c :
In addition to the mean pulse height as a quantity to define the death of a drift tube another more sensitive method, called ageing a, was developed. The idea is to measure the mean pulse height at different positions along the wire (see figure 1). Since a measurement far away from the irradiated zone remains unchanged even if the tube is dead in the 'hot' zone, the ratio of

the mean pulse height in the 'hot' and 'cold' zone is a measure of the status of a tube:

$$a_p := \frac{\overline{ADC}(irradiated\ zone)}{\overline{ADC}(not\ irradiated\ zone)} \quad (1)$$

The advantage of this definition is that effects that affect the whole tube, such as temperature, pressure, (small) gas mixture changes, wrong anode voltage or an unstable front end electronics should cancel out in first order.
A similar quantity a_c can be defined for the counting rate.

Pulse height ageing a_p in α-tubes :
Since the electric field inside the tube is deteriorated by the α-source[2] the pulse height ageing a_p in an α-tube is not 100 % (like in a γ-tube). Empirically we found a value of $\approx$110 % for these tubes at the beginning of the irradiation.

3 Results of the sputter experiments

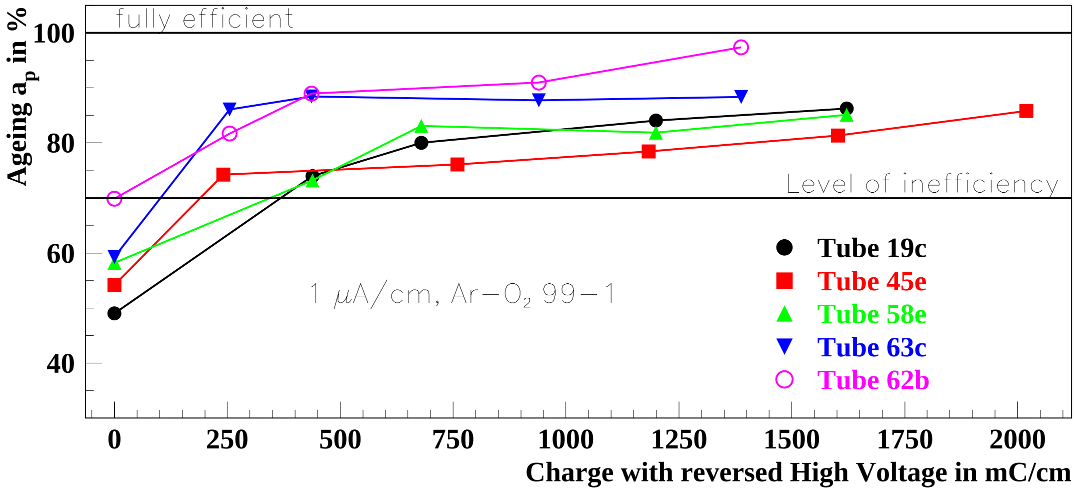
The first part of this section describes the reanimation potential of different gas mixtures. The remainder of the section is devoted to the problem (and its solution) of cracks that have been observed in the plastic parts of the end plug[3] after sputtering.

3.1 Reanimation potential of different gases

In this section we present the reanimation potential of all gases that were considered in the course of the Freiburg Ageing Experiment (including negative results). It should be pointed out, that the gas mixtures mentioned in this section refer to the mixture used for reanimation. All tubes were aged before in Ar-CH_4-N_2-CO_2-(94-3-2-1).

Reanimation in Ar-O_2-(99-1) :
The studies in this gas where performed at two different currents (1 μA/cm and 5 μA/cm). The idea behind that was to see if there is any current that turns out to be optimal for reanimation. The results are shown in figure 2. One can see that all tubes reached a pulse height ageing a_p above 70 % after approximatly 1.5 C/cm. Thus it could be demonstrated that reanimation is possible. In a few cases a pulse height ageing a_p above 95 % could be reached. This tubes can be regarded as almost fully reanimated.
Figure 2 does not take the history (the ageing process) and therefore the status of the tubes at the beginning of the reanimation into account. Nevertheless we are (so far) not able to explain the huge spread of the achieved pulse height ageing a_p between $\approx$ 75 % and 98 %.
The results appear to be independened of the current per unit length (1 μA/cm vs. 5 μA/cm).

[2]Actually the biggest contribution to the field deterioration comes from the shielding of the α-source (since a_p itself is, like for γ-tubes, determined with a γ-source.)
[3]Previously reported by [2].



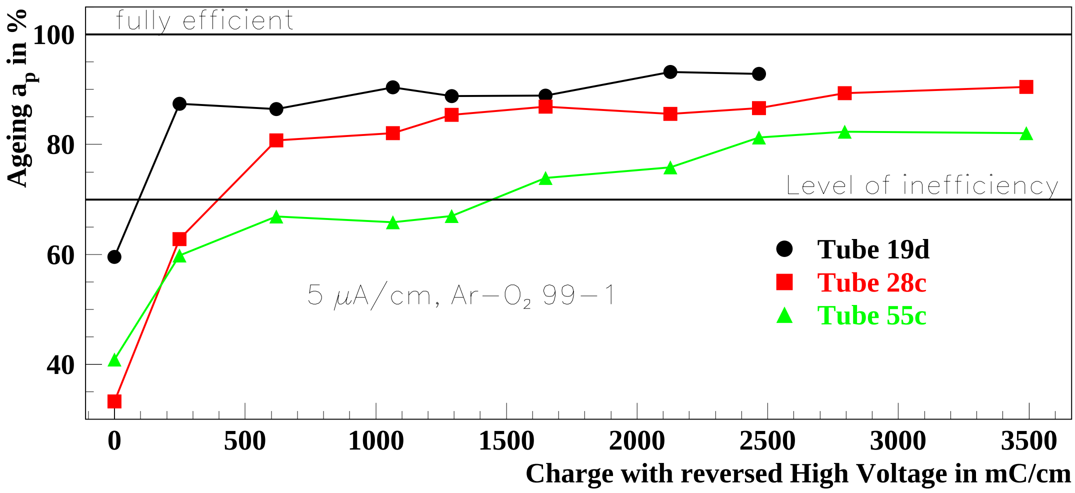


Figure 2: Pulse height ageing a_c as a function of the charge accumulated with reversed high voltage in SputterGas. The two graphs refer to a (sputter) current of $1\,\mu$A/cm and $5\,\mu$A/cm. Please note that currents with normal polarity (during an ageing experiment) are typically on the order of 100 nA/cm. Tube 62b was aged and reanimated again as tube 45e.

Since lower currents are more favourable for ATLAS (lower power consumption and therefore less heat) we recommend a current of $1\,\mu$A/cm if reanimation should turn out to be neccessary.

Reanimation in Ar-CO_2-(93-7) :
The studies in Ar-CO_2-(93-7) where performed with 2 tubes at a current of $2\,\mu$A/cm. The results are shown in figure 3. Since the figures 2 and 3 look very similar the, we conclude that Ar-O_2-(99-1) and Ar-CO_2-(93-7) are almost equally well suited for reanimation of drift tubes. Since the latter gas will most likely be used for the operation of the ATLAS-Muon Spectrometer it would be convenient to use this gas for reanimation as well.

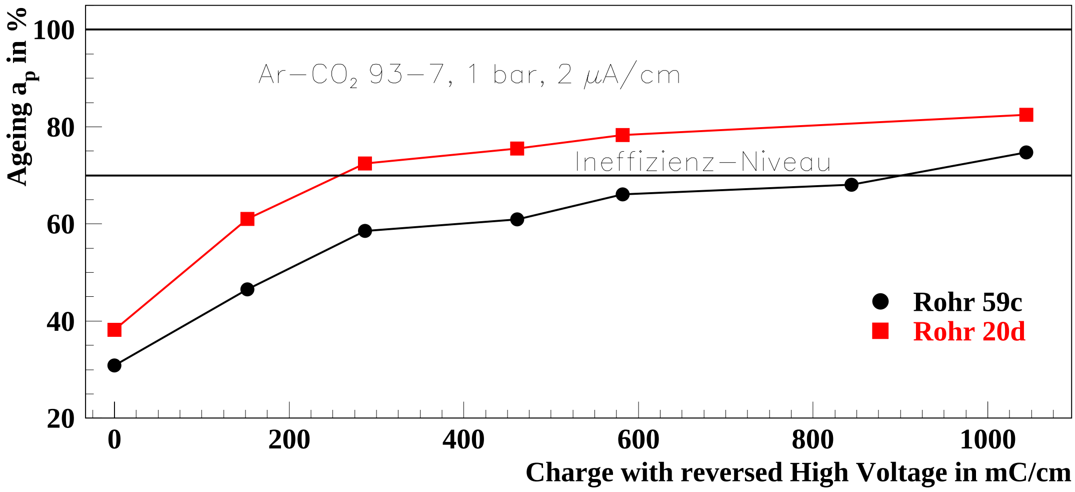


Figure 3: Pulse height ageing a_c as a function of the charge accumulated with reversed high voltage in Ar-CO_2-(93-7).

Reanimation in pure Argon :
Reanimation in pure Argon is possible but better results can be achieved in Ar-O_2-(99-1) or Ar-CO_2-(93-7).

Reanimation in Ar-CH_4-N_2-CO_2-(94-3-2-1) :
This gas is totally unsuitable for reanimation. Even worse it turned out to exhibited huge noise and enabled the growth of large, needle-like structures (200 μm) on the wire.

Reanimation in pure N_2 :
Reanimation in pure N_2 does not show any effect on the pulse height ageing a_p. But all tubes in a set of 12 exhibited huge noise after the treatment. It was not investigated if the same structures like in Ar-CH_4-N_2-CO_2-(94-3-2-1) have grown on the wire.

Since two gas mixtures (Ar-O_2-(99-1) and Ar-CO_2-(93-7)) have been found, that allow reanimation up to a level of $\approx 90\,\%$ and the problem of cracks in the end plug has been solved, we recommend sputtering as a backup solution for the ATLAS-Muon Spectrometer.

3.2 Cracks in the end plug

In order to investigate the reason for the cracks systematicly, a set of usually 5 to 10 identical tubes was built and operated with reversed high voltage. A current stablelising high power supply was used. After about 400 mC/cm the sputtering was stopped and a leak test was done. If a leak was found, the concerning tube was taken out of the setup. The remaining tubes where operated up to a maximum of 11 C/cm (in steps of about 400 mC/cm).
The parameters gas mixture, end plug design and end plug material have been changed in each set of tubes. This allowed us to draw the following conclusions (summarised in table 1):

Material	Design	Gas	Current μA/cm	Charge C/cm	Cracks HV	Cracks LV	Leaks HV	Leaks LV	# EP
PBT	FR-1	Ar-O_2	1	3.1 ± 1.5			0	0	20
PBT	FR-1	Ar-CO_2	1 & 10	4.5 ± 2.1			0	0	12
Noryl	FR-1	N_2	2	0.2 ± 0.0			0	0	24
Noryl	FR-1	Ar-O_2	1	1.1 ± 0.5	6	5	3	3	14
Noryl	FR-1	Ar-CO_2	1 & 10	5.3 ± 0.0			0	0	8
Noryl	NIEF-1	Ar-O_2	1 & 2.5 & 5	1.7 ± 0.9	8	8	8	2	16
Noryl	NIEF-2	Ar-O_2	5	11.2 ± 1.6	1	1	0	1	16
Noryl	NIEF-5	Ar-O_2	5	12.0 ± 0.9			0	0	10
Noryl	MPI	Ar-O_2	1 & 5	7.1 ± 3.1	?	?	0	0	10

Table 1: Mean sputter charge for different end plugs and sputter gas mixtures. The 'error' is the standard deviation of the distribution of charges. Note that the 'error' is zero if for example no crack was observed and the test was started and terminated in each tube of a set at the same time. Column 6 to 9 display the number of cracks and leaks on the readout (LV) and high voltage side (HV). The latter is the gas outlet. FR-1 is an end plug designed for the Freiburg ageing experiment at a time when no final design end plug was available.

- the proneness of an end plug to develop a crack and/or a leak clearly depends on the material used. Since PBT (Polybutylenterephthalat) is in comparison to Polyphenylenether (Noryl) known for its small ability to develop tension cracks, we argue that tension cracks in the plastic are the reason for the observed leaks. It is also known that the development of tension cracks can be enhanced by certain chemicals.
- Furthermore the proneness of an end plug to develop a crack depends on the gas mixture used for sputtering. No cracks were observed in Ar-CO_2-(93-7).
- It is possible to avoid cracks (and leaks) in the end plug by optimizing its production. In the case of the NIEF-end-plug all cracks were found on the welding nut, which is known to be a place where tension is likely to built up.

Encouraged by the promissing results with a PBT-end-plug it was investigate if it is possible to produce the final design end plug by using PBT. It turned out not to be possible since PBT is known for its large molding shrinkage. This would result in a large gab ($\approx 200\,\mu$m) between the aluminium and plastic part.
The results show that with the final design end plug (NIEF-5 and MPI) one does not expect cracks in an end plug after sputtering (for example for the purpose of reanimation or polarity therapy). Therefor this technique can be recommended for the application in the ATLAS-Muon Spectrometer in the case it is needed.

EP	Rate kHz/cm	U_a Volt	Charge in mC/cm $\bar{Q}$	Q_{max}	# tubes	d_{max} cm	Comment
MPI	14	3505	5209 ± 213	5209	1	5.6	
MPI	14	3400	2171 ± 631	2686	5	5.6	
MPI	4.5	3400	1588 ± 522	2183	6	8.6	
MPI	1.3	3400	1531 ± 291	1831	3	8.9	
MPI	0.9	3400	608 ± 382	1012	6	11.9	
FR	0.9	3600	2859 ± 169	2859	1	2.5	
FR	14	3400	916 ± 499	1269	2	5.6	sign for ageing
FR	1.3	3400	1396 ± 77	1396	1	8.9	
FR	0.9	3400	370 ± 90	370	1	11.9	

Table 2: Mean and maximum charge of tubes that where operated under identical conditions in Ar-CO_2-(93-7) with 600 ppm of water. No tube became inefficient according to the criteria introduced in section 2. Nevertheless two tubes with FR-end-plugs showed a sign for ageing ($a_p \approx 80\,\%$). Since no tube has died we do not distinguish different irradiation lengths d_k or d_{max} (e.g. in each line we find tubes with different d_k and d_{max}). The mean charge $\bar{Q}$ is just the average charge Q of the tubes on May 17th, 2001. The standard deviation therefor does not represent an uncertainty, but the spread over the charge Q of different tubes.

4 Results of the ageing experiments

In this section the latest results of the Freiburg Ageing Experiments are presented[4]. The first two subsections are devoted to ageing tests with a γ-source in Ar-CO_2-(93-7) and Ar-CH_4-N_2-CO_2-(94-3-2-1). The following subsection describes tests with an α-source in the same gases. In the last subsection the results of material tests (tests of materials that are in contact with the drift gas, such as Pocan, Apiezon etc.) are presented.

4.1 Ageing in Ar-CO_2-(93-7)

Ageing tests in Ar-CO_2-(93-7) with a water content of 600 ppm were carried out with 26 drift tubes. Due to the experience we got from ageing tests in Ar-CH_4-N_2-CO_2-(94-3-2-1) (see section 4.2) we tried to vary the operation conditions (anode voltage, collimator aperture and type of end plug) as much as reasonably possible.
Some key numbers of these tests are listed in table 2. We can summarize these and earlier tests [4] as follows:

- Some tubes accumulated a charge of more than 2 C/cm. But no sign of ageing was seen in tubes with the so called MPI-end-plug (end plug that is used for mass production in the ATLAS-Muon Spectrometer and ordered via MPI. They should be similar to the NIEF-end-plug used by other production sites.).

[4]Earlier results (cathode coating, influence of additives to the gas) can be found in [5] and [6].

- Two tubes with the so called Freiburg-end-plug (end plug that was designed in Freiburg at times when no end plug was available by the collaboration) showed a sign of ageing, but did not become inefficient according to the criteria introduced in section 2. It should be pointed out, that tubes with an MPI-end-plug and a similar charge showed no sign of ageing[5].

- The results in Ar-CO_2-(93-7) are consistent with earlier results in Ar-CO_2-(90-10) [4]. In these tests 48 tubes were operated under the following conditions: anode voltage U_a = 3500 V, irradiation length > 2.8 m and radioactive source: ^{137}Cs (740 GBq). All tubes showed no sign of ageing after 0.6 C/cm.

- Pure Ar-CO_2-(93-7) and probably pure Ar-CO_2-(90-10) seems to be absolutely ageing resistant. Nevertheless it is difficult to keep a drift gas in a huge gas system (like that of the ATLAS-Muon Spectrometer) pure over a long period of time. Reasons can be back diffusion of air through leaks or outgasing of components that are in contact with the gas system.

- It should be kept in mind that Ar-CO_2-(90-10) and probably Ar-CO_2-(93-7) is known to show noise [2]. For the reconstruction of a muon event it does not make a difference if the noise level of a single tube is too high or the tube is inefficient through ageing.

4.2 Ageing in Ar-CH_4-N_2-CO_2-(94-3-2-1)

For the motivation of the ageing tests in Ar-CH_4-N_2-CO_2-(94-3-2-1) with 1200 ppm water please refer to the introduction or [3]. The tests were repeated with different tubes under identical operation conditions (anode voltage, gas flow, irradiation length, counting rate, end plug etc.). The spread of the lifetimes (determined as described in section 2) of these tubes turned out to be in the range of 30 % to 45 % (for a single measurement, not the mean). The estimate of the error together with the large set of different operation conditions allowed us to investigate the dependence of the lifetime (in C/cm) on many different quantities. The results are displayed in figure 4 and summarized below:

- The MDT lifetime seems to depend exponentially on the anode voltage.

- Very surprisingly the MDT lifetime decreases with increasing collimator aperture (the length of the tube that was actually irradiated) significantly. This effect seems to saturate at around 80 mC/cm.

- An increasing gas flow in contrast also increases the lifetime significantly. (ten times the gas flow gives more than ten times the lifetime). One can speculate that this effect will be reduce if the collimator aperture will be wider.

[5] At present this effect is not fully understood but investigations are already going on in Freiburg. Candidates are Araldite and a vacuum oil used for the production of a tube with the Freiburg-end-plug.

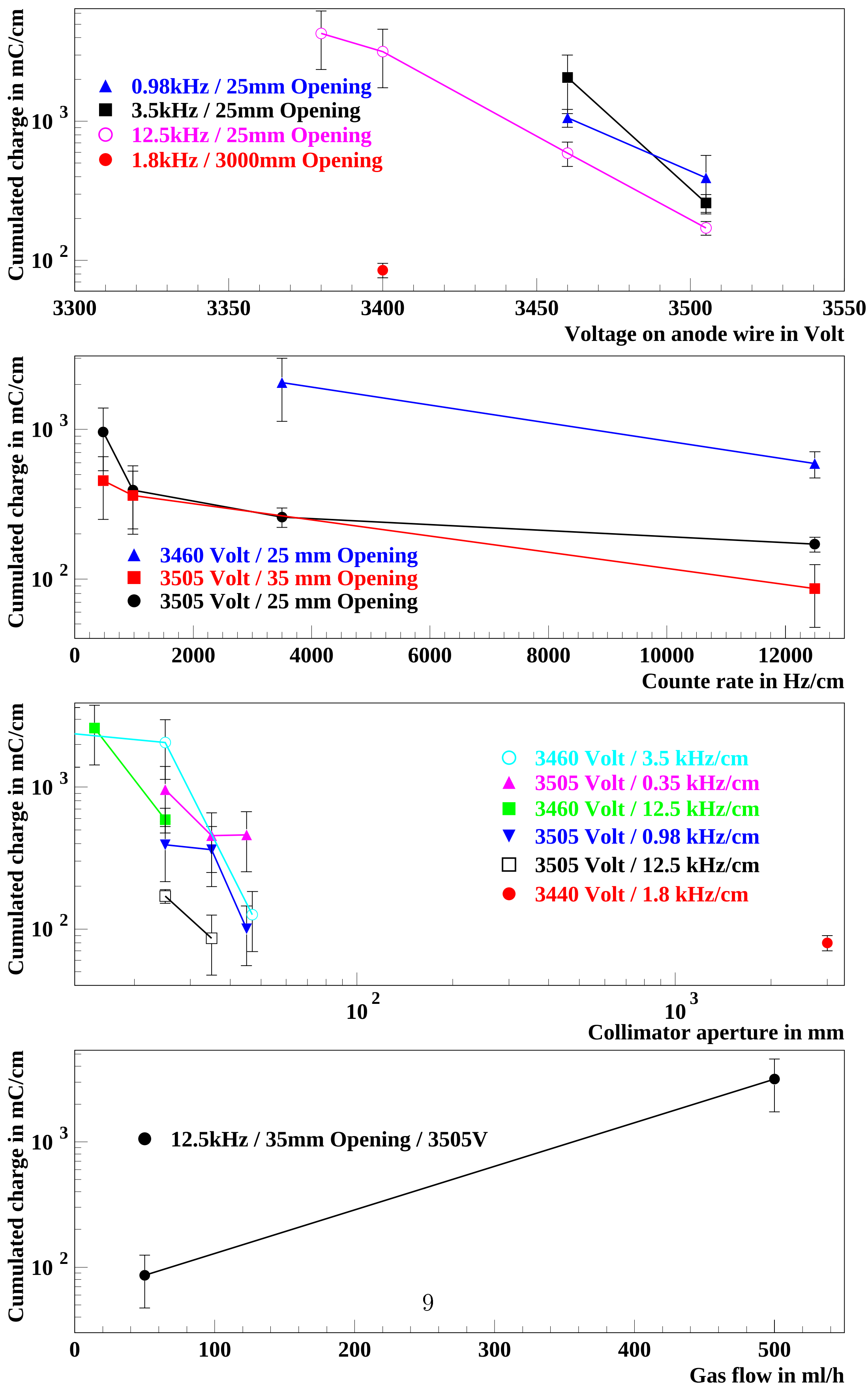


Figure 4: Dependence of the lifetime Q of tubes operated in Ar-CH_4-N_2-CO_2-(94-3-2-1) on the anode voltage U_a, the gas flow, the irradiation length d_k and irradiation rate R. Same symbols represent experiments with tubes that were carried out under identical conditions except the quantity on the abscissa.

- We observed a nearly exponential dependence of the lifetime on the counting rate in the experimentally investigated parameter range.

From these results we can draw a few conclusions:

- An extrapolation of the lifetime to the operation conditions of the ATLAS-Muon Spectrometer (d $\approx$ 400 cm, U = 3130 V, R = 300 Hz/cm, gas flow $\approx$ one volume exchange per day) is very difficult since it is not clear which of the four quantities dominates outside the experimentally investigated range. Therefore we can not recommend to use Ar-CH_4-N_2-CO_2-(94-3-2-1) to be used in the ATLAS-Muon Spectrometer.

- Nevertheless exactly this fact allows us to specify an optimized ageing test (that could be used for the next generation of detector development). The voltage and counting rate in this test should be higher than the operation conditions of the final detector. The length of the tube as well as the gas flow should have the values of the final experiment.

- From the results in figure 4 we can learn an important lesson for gases that are thought to be ageing resistant (like Ar-CO_2-(93-7)). Since it is not possible to guarantee that this gas will remain pure over a long period of time (leaks, outgasing, see 4.1) the above dependencies allows one to optimize the operation parameter in order to further protect the MDT's against unforeseen (ageing)-effects.
  One immediate consequence is that a parallel gas system gives more safety for the tubes.

4.3 Ageing under irradiation with α-particles

Ageing tests with an α-source were performed on 6 tubes all with a FR-end-plug. Half of them were operated in Ar-CH_4-N_2-CO_2-(94-3-2-1) + 1200 ppm H_2O the others in Ar-CO_2-(93-7) + 600 ppm H_2O. Since α-particles do not penetrate the aluminum wall the source (^{241}Am) was inserted into the drift tube and fixed with Araldite. The key numbers of these tests are listed in table 3.
On September 20th, 2001, two tubes have died and two others showed serious damage (last pulse height ageing measurement a_p in table 3).
It is interesting but difficult to compare these results with those of tests with γ-tubes. Typical pulse charges and counting rates of γ-tubes in the Freiburg Ageing Experiment are: q = 8 pC to 80 pC, R = 0.45 kHz to 12.5 kHz. For comparison: the charge per pulse of a muon event at 3080 V is 2.5 pC. At this voltage α-particles have a 60 times larger pulse charge.
At this point it is not possible to draw a clear picture of the dependence of the MDT-lifetime in an α-test on different quantities (like we were able to do in the γ-tests). It is noticeable that the tube that is in the direction of the gas flow behind another tube died much earlier than expected (lower anode voltage and counting rate). To fix the α-source inside the tube much more Araldite was used than usually necessary for a tube with FR-end-plug. Araldite is known to give bad ageing results [7, 8].

α-act.	R	U_a	Charge	Pulse charge in pC		Current	Last a_p	Gas
Bq/cm	Hz/cm	Volt	mC/cm	q_p	q	nA/cm	%	
107	160	3505	589	380	254	40.5	75	Ar-CH_4-N_2-CO_2
196	287	3300	424	203	138	39.7	100	Ar-CH_4-N_2-CO_2
490	674	3300	200*	138	101	67.8	58	Ar-CH_4-N_2-CO_2
113	1595	3505	3200	2177	175	246.4	109	Ar-CO_2
224	348	3080	280*	120	54	26.9	59	Ar-CO_2
440	647	3300	920	207	141	90.9	99	Ar-CO_2

Table 3: Operating parameters and efficiency of α-tubes on September 20th, 2001. The pulse height ageing a_p of a fully efficient tube is due to the α-source inside the tube $\approx 110\,\%$ (see section 2). The first column gives the α-activity of the source that is emitted into the drift gas (and not the aluminum wall). Due to afterpulsing the counting rate we measured with the readout electronics was much higher (second column). Column 5 and 6 are the pulse charges that refer to this two different event rates. The charges in column 4 marked with * are the charges that these tubes have accumulated until they have been declared dead.
The tube in the second last line (224 bq/cm) is in serial gas connection behind the tube in the last line (440 Bq/cm).

Since these tests represent an upper boundary of the damage caused by highly ionizing particles such as hadrons in the ATLAS-Muon Spectrometer and the observed lifetimes are higher than 0.2 C/cm in all (six) tubes, we conclude that unforeseen effects from hadrons are unlikely. Nevertheless the MDT's should survive a charge of 0.6 C/cm (this includes the safety factor of five). Therefore the goal is not reached and further investigations are necessary.

4.4 Tests of materials

The MDT drift gas is in contact with a few different materials. In order to demonstrate that none of these materials shortens the life time of a drift tube (for example by outgasing any substance that in turn leads to chemical reactions inside the tube) two types of ageing tests were performed:

In a bubbler test a volume suitable to place a huge amount of the material to be studied, was build on the gas inlet side of the tube. This volume was made with the same standard of cleanliness as the rest of the gas system. Usually more than one tube was served by one bubbler.

A mass test is nothing more than a test with exactly the same tubes and service components as that used for the MDT mass production[6].

[6] This might seem like a trivial point, but please keep in mind, that some tests were already done at a time when no final components were available.

Material	Used for	Gas	Type of test	# of tubes	Charge $\bar{Q}$ mC/cm	Observation
Pocan	Gas jumper	Ar-CH_4-N_2-CO_2	Bubbler	4	206	$Q \approx$ as expected
Pocan	Gas jumper	both gases	Mass t.	31	1219	none
Apiezon	Valves	Ar-CH_4-N_2-CO_2	Bubbler	3	203	$Q =$ as expected
Apiezon	Valves	Ar-CO_2	Bubbler	3	1361	none
EPDM	O-rings	Ar-CO_2	Bubbler	21	761	none
EPDM	O-rings	both gases	Mass t.	31	1219	none
URON	Cleaning	Ar-CO_2	URON	3	293	none
URON	Cleaning	Ar-CH_4-N_2-CO_2	URON	2	217	none

Table 4: Summary of material tests. The charge $\bar{Q}$ is the average over all tubes that are used for this test. Note that for the cleaning agent URON no classification into a mass or bubbler test is possible.

The test of the cleaning agent URON B3[7] can not be classified into any of the above categories. Instead the test was done by first cleaning the brass gas connectors in an ultrasonic bath and than flushing the tubes with URON and dry air. Immediately after this process the tubes were built into the ageing setup.
These test need another test to compare the results with. In all cases this was a test with tubes that were operated under identical conditions but other materials (no bubbler, FR-end-plug). The results are summarized in table 4. With the sensitivity and statistics of these tests no influence of Pocan, Apiezon, EPDM and URON on the lifetime of MDT's was found. Details of this tests can be found in [3].

5 Conclusion

The MDT base line gas Ar-CO_2-(93-7) did not show any sign of ageing under a lot of different operation conditions when the final-design-end-plug was used. To protect the tubes against unforeseen effects from outgasing of materials, it was demonstrated that Pocan, Apiezon, EPDM and URON do not have an influence on the ageing process. Ageing effects from highly ionizing particles like charged hadrons, were estimated through ageing tests with an α-source. The lifetime of these α-tubes was not lower than expected (when we took the high pulse charge into account). But further investigations are necessary.
Studies with the gas Ar-CH_4-N_2-CO_2-(94-3-2-1) helped to get a better understanding of the quantities that influence the ageing process. Surprisingly we discovered a strong dependence on the length of the tube (when the overall length is short). Also the assumption that the charge per unit length is constant under a variety of operation conditions could be demonstrated to be untrue.

[7]This is the cleaning agent used by the company that produces the brass gas connectors.

Reanimation of tubes by means of sputtering as a fall back solution against unforeseen ageing of MDT's could be demonstrated to work without the danger of destroying the plastic parts of the end plug. It was also possible to show that reanimation works best in Ar-O_2-(99-1) and Ar-CO_2-(93-7).

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