Long Term Irradiation Study of sMDT Drift Tubes Using Beta-Electrons From a Sr90 Source Accumulating 60 C Per Wire

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ATLAS MDT Drift Tubes $D = 30$ mm: Precision Muon Tracking

MDT 30 mm: Monitored Drift Tube chambers are used for precision tracking in the ATLAS muon system

2010: proposal to build NSWs from sMDT for HL-LHC: $7.5 \times 10^{34} \text{1/cm}^2 \text{s}$
Ar:CO2 93:7 3 bar
2730 V GG: 20000
Basic Idea of Improvement: Drift Tubes D=15mm <-> D=30mm

occupancy improvement:
- 3.8 x shorter drift-time
- 2 x smaller cross section
=> 7.6 x reduction

less gain loss by space charge:
- 8.7 x smaller gain loss

=> new long term stability test using $^{90}$Sr with $Q_{acq} > 6$ C/cm
Observed Ageing Phenomena at ATLAS MDT Drift Tubes D=3cm

Freiburg group (LS Herten):
M. Kollefrath NIM A 419 (1998) p351

Ar:CH4:N2 91:5:4 Vol% aging after \(80\) mC/cm hydro-carbonic deposits on the anode wire steady deterioration of detector performance

Ar:CH4:N2:CO2 94:3:2:1 Vol% no reduction in performance up to \(0.6\) C/cm with water or ethanol addition

Ar:CO2 80:20 Vol% no ageing observed up to \(0.6\) C/cm

S. Zimmermann PHD Thesis 2004

ageing introduced by silicone pollution in the drift gas
the anode wire acts as pollution filter
the silicone is trapped within the first 50 cm of the anode wire
=> build-up of whiskers

no aging using clean Ar:CO2 93:7 Vol%
=> requirement: no pollutions!
no aging of 3 cm MDT tubes was observed using Ar:CO2 gas mixtures
93:7 Vol% and
80:20 Vol% 

at accumulated charges up to few C/cm
legacy requirement for ATLAS: 0.6 C/cm (2000)

the requirement for the inner radius of the New Small Wheel (2010) was a factor 10 higher (HL-LHC)

this drove the new study of the Ar:CO2 gas mixture

Ar:CO2 93:7 Vol%

to a factor 10 higher accumulated charges: 6 C/cm
ATLAS sMDT Muon-Drift-Chamber

no aging is expected from the material cocktail

- D=15mm aluminum drift tubes
- insulating endcaps

- D=50µm gold-plated tungsten wire

- capacitive hedgehog cards
- ASD amplifier shaper discriminator board
- TDC board
- gold plated signal and grounding pins

- gas inlet distribution
- o-ring sealed
ATLAS sMDT Muon-Drift-Tube

- **PBTP**: Polybutylenterephtalat
  - endplug: 20% fibreglas reinforcement
  - no cracks
  - no outgassing
  - used as gas inlet at MDT chambers

- **brass, copper**: non ageing materials
  - wire: gold plated tungsten wire D=50µm
  - signal-cap: brass, gold plated signal pin
  - o-rings: EPDM, no grease or sealant

- **Aluminum**: etched and Surtec coated protective coating
  - => cleaning conductive surfaces

- **PBTP stopper (PBTP)**

- **D=15mm**
  - 0.4mm wall thickness
  - drift-tube ø15x0.4 (aluminum)

- **o-rings**: EPDM, no grease or sealant

- **no aging (outgasing) is expected to be created by these materials ✔**
90Sr Beta Source Characteristics

<table>
<thead>
<tr>
<th>Decay</th>
<th>β- endp. energy</th>
<th>Half life</th>
<th>Range</th>
<th>Energy loss [keV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>90Sr -&gt; 90Y</td>
<td>0.546 MeV e^-</td>
<td>28.8 a</td>
<td>R = 0.8 mm in Al</td>
<td>100 17.0 in Ar</td>
</tr>
<tr>
<td>90Y -&gt; 90Zr</td>
<td>2.282 MeV e^-</td>
<td>64.1 h</td>
<td>R = 5.1 mm in Al</td>
<td>200 11.7</td>
</tr>
<tr>
<td>90Y -&gt; 90Zr</td>
<td>0.3 MeV e^-</td>
<td>1000</td>
<td>R = 0.4 mm in Al</td>
<td>1500 8.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1500 8.2</td>
<td>2000 8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2000 8.5</td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta E(\text{Al}) \approx 180 \text{ keV} \]
\[ \Delta E(\text{Ar}) \approx 9 \text{ keV} \]

90Y betas contribute, most 90Sr betas stop in aluminum tube
**$^{90}\text{Sr}$ Irradiation Setup**

stainless steel gas inlet, 3cm plastic for insulation

3 periods of measurements:
- 2011 irradiation of 4 tubes
- 2012 irradiation of 2 tubes optimized
- 2013 irradiation of PBTP endplugs + tube

basic idea:
- keep HV, gas-flow and pressure const.
- HV: 2730 V  GG: 20000
- 1 year measurement
- monitor I and T
Anode Currents Induced by the Beta Irradiation 2011 and 2012

2730 V

- 2 tubes irradiated
- 2 tubes irradiated
- 4 tubes irradiated

no indication of decreasing currents, currents scale with T

Ar:CO2 93:7 Vol%
3 bar
4h ≈ 1 Vol

0.05 in/h

3 μA

20 C
Current – Temperature - Relation

A linear fit will be used to correct the T dependence.
Current Corrected by Temperature

- Temperature correction works => almost constant current
- No decline in current intensity

Temperature corrected

Not temperature corrected
$^{90}\text{Sr}$ Irradiation Setup

2013 irradiation of PBTP endplugs + tube
shift of source position in 2013
Anode Currents Induced by the Beta Irradiation in 2013

no indication of decreasing currents, currents scale with T
no irradiation induced outgassing of the endplug
## Accumulated Charges

<table>
<thead>
<tr>
<th>Year</th>
<th>Current (µA)</th>
<th>Accum. Q (C)</th>
<th>Q/cm</th>
<th>Location</th>
<th>Int. Act. Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1.4</td>
<td>10</td>
<td>3.1</td>
<td>tube</td>
<td>1 cm</td>
</tr>
<tr>
<td>2012</td>
<td>3.0</td>
<td>39</td>
<td>12.2</td>
<td>tube</td>
<td>1 cm</td>
</tr>
<tr>
<td>2013</td>
<td>1.3</td>
<td>13</td>
<td>2.0</td>
<td>tube</td>
<td>1 cm</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>62</td>
<td>19.3</td>
<td>tube</td>
<td></td>
</tr>
</tbody>
</table>

|                | 17           | ≈5.0         | endplug | (estimate) |

✔
Summary

- 2 sMDT tubes were irradiated using a 90Sr beta-source
- Ar:CO2 93:7 Vol% was used as counting gas
- more than 60 C were accumulated per tube
  this corresponds to almost 20 C/cm
  this is 3 * higher than the ATLAS HL-LHC requirement of 6 C/cm
- the endplug was irradiated by ≈ 5 C/cm
  no outgassing or deterioration of the gas was observed
  no cracks were observed
- no sign of deterioration in performance was observed
- the observed anode currents scale with temperature fluctuations as expected
  no decrease in performance was observed
**Difference Between Wire-Detectors and Planar Detectors**

**Wire**:
- All charges created in one tube diameter are concentrated along the wire on 0.05 mm.
- Inhomogeneous electric field.
- => Acceleration of electric dipoles.
- C-H mixtures show ageing.
- Ar:CO2 mixtures do not age.

**Planar Structure**:
- Each event covers only an area of ≈ 2 mm².
- No big concentration of long chain molecules.
- Homogeneous el. field, no acceleration of electric dipoles.
- No loss in performance at use of C4H10 @ 0.35 C/cm².
- A heavily discharging region was investigated using SEM, no aging was observed.
- No whiskers or hairs were observed on the surface of the resistive strips.
- A pretty rough surface by construction.

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**Figure**: Wire detector diagram with 2730 V, 0.05 mm, D=15 mm, Ar/CO₂ 93/7%.

**MM**: Ar:CO₂:C₄H₁₀ 93:5:2 Vol% 0.02 C/cm²

**SEM Image**: C-deposit on an anode wire after 0.12 C/cm.
- Ar:CH₄:N₂:CO₂ 94:3:2:1
- M. Kollefrath et al. NIMA 419 p351
Backup

Konfiguration 1

1.8 microA

Konfiguration 2

3.1 microA
Estimate of the Gas-Gain During the Irradiation

interacting fraction \( 0.093 \)

strength of the source: \( 244 \text{ Mbq, 5.6 y} = 213 \text{ MBq} \)

\[ 0.776 \text{ is part of the spectrum } > 300 \text{ keV} \]

\[ 0.776 \times 213 = 165 \text{ MBq} \]

beta electrons: \( 1.53 \times 10^7 \text{ betas/s} \) create \( 3 \mu\text{A} \) detector current

av. excitation energy: \( 27 \text{ eV} \)

9 keV average energy loss per beta, see estar/NIST

\[ 9000/27 = 333 \text{ e}^- \text{ produced by 1 beta} \]

\[ 1.9 \times 10^{13} \text{ e}^-/\text{s} / 5 \times 10^9 = 4000 \]

=> gas-gain of 4000 is factor 5 below 20000

Figure 1: \( \beta \) spectrum of \(^{90}\text{Sr}\) and the daughter nucleus \(^{90}\text{Y}\).