Sandra Horvat
Max-Planck-Institut für Physik

Status of MDT Production and Testing

September 13-19, 2003 // ATLAS Overview Week // Praha, Czech Republic
Outline

- Introduction: MDT Chambers (Monitored Drift Tube)
- Chamber Production and Quality Control
  - assembly monitoring at production sites
  - X-ray tomograph at CERN
  - cosmic-ray tests
- Plans for the preassembly at CERN
- Testbeam
  - full system test in the H8 facility at CERN
  - tests at the γ-irradiation facility (X5/GIF) at CERN
- Summary
MDT Chamber

1194 MDT tracking chambers covering 5500 m²; 370 000 drift tubes

Drift Tube, Ar:CO₂ (93:7), gas gain 2·10^4

Requirements - chamber resolution of 40 µm ⇒

* single tube resolution: better than 100 µm
* positioning of the sense wires within the chamber: 20 µm rms
Chamber Production
and quality control
- precision assembly, monitored using various techniques

- wires centered within the tube; X-ray verification

- tubes (1 layer) positioned into the precision combs; position measured with feeler gauges

- layers glued successively, attached to the support frame; deformations and displacements monitored by optical systems
Production line: chamber assembly → gas system → front-end electronics

• assembly monitoring

Quality control of each produced drift tube: information stored in the global production database

- 75% of 370,000 tubes produced
- Total rejection of only 2.6%
Reconstruction of the wire positions within the chamber:

![Graph showing deviation from the nominal grid and rms of deviations from the nominal grid.](image)

- wire positioning accuracy within the required $20 \mu m$ rms
Production line: chamber assembly $\rightarrow$ gas system $\rightarrow$ front-end electronics

- sample of chambers measured with an X-ray Tomograph at CERN
- wire measurement precision: $2 \mu m \text{ (stat.)} + 2 \mu m \text{ (syst.)}$

- certification of the site construction procedure
- check 15% of the chambers for consistency
- capacity:
  - present - 1.6 ch/week
  - from 2004 on - 2 ch/week

measurement of the intensity along the chamber
Production line: chamber assembly → gas system → front-end electronics

- assembly monitoring
- X-Tomograph

Entries 79
RMS of 76/79 chambers = 18 µm
including outliers = 25 µm

- 79 of 739 produced chambers measured
- 11 production sites certified
- average rms of measured chambers: 18 µm
Production line: chamber assembly → chamber services

- assembly monitoring
- X-Tomograph

1. preparation of gas tubelets
2. mounting on the chamber
3. HV and signal hedgehog cards (HV distribution, signal decoupling)

4. mezzanine cards (Amplifier/Shaper/Discriminator, Time-to-Digital Converter)
5. Chamber Service Module (interface between the chamber and the DAQ system)
Production line: chamber assembly $\rightarrow$ gas system $\rightarrow$ front-end electronics

- assembly monitoring
- X-Tomograph

Serious problem spotted for the **MDT gas tubelets**!

$\rightarrow$ corrosion of the brass tubelets by the cleaning agent through small cracks

Action:

★ replacing all brass tubelets with stainless steel

★ exception are most of the equipped end-cap chambers, after being certified
Chambers (brass tbl.) certified in US and shipped to CERN:

☆ under gas pressure for 5-11 months: showing no leaks
☆ epoxy applied to the critical parts of the tubelets, for additional safety

![EMS Long Term Leak Rate](chart1)

![EML Long Term Leak Rate](chart2)

Chamber ID

Leak Rate (mbar/day)

EML1
EML2

No epoxy

3 multi-layers leak, due to loose ETs

epoxy applied
Production line:
- chamber assembly
  - assembly monitoring
  - X-Tomograph
→ gas system
  - leak tests
→ front-end electronics

MDT chamber

Faraday Cage (FC)

HV hedgehog cards
under production, 40%

signal hedgehogs
mezzanine cards
under production, 30%

production starting

Chamber Service Module
1st prototype working
2nd in preparation
(FDR November 2003)

MROD
1st prototype working
2nd in preparation
(FDR November 2003)

- for more information see the talk of R.Richter
Quality control of the chamber performance, for all chambers:
(leak test, HV stability, noise, efficiency, drift-time spectra, resolution)
- for some chambers: wire positioning accuracy (LMU)
Production line:

- chamber assembly → gas system → front-end electronics
- assembly monitoring
- leak tests
- X-Tomograph
- cosmic ray stands

★ uniformity of the chamber response to muons:

![Drift-time spectrum](image)

Table:

<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>11124</td>
<td>28114</td>
</tr>
</tbody>
</table>

χ²/ndf = 593.6 / 521

| P1 | 0.1539 ± 0.169E-01 |
| P2 | 28.24 ± 2.487 |
| P3 | 6.030 ± 0.4632 |
| P4 | 196.5 ± 15.14 |
| P5 | 185.5 ± 11.04 |
| P6 | 2163 ± 2.058 |
| P7 | 8.100 ± 0.6913 |
| P8 | 11.88 ± 0.9989 |

Sigma (1.81±0.07) ns

![Sigma Distribution](image)
Production line:
chamber assembly $\rightarrow$ gas system $\rightarrow$ front-end electronics
- assembly monitoring
- leak tests
- cosmic ray stands

LMU-Munich:

★ measurement of the wire coordinates
(achieved precision: $\text{rms}_z = 9 \ \mu\text{m}; \text{rms}_y = 27 \ \mu\text{m}$)

reconstruction of the geometrical chamber parameters
### Production Status: 31.08.2003.

<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>total/site</th>
<th>Bare MDT/Plan</th>
<th>MDT with FC/Plan</th>
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</thead>
<tbody>
<tr>
<td>Boston</td>
<td>EI, EM</td>
<td>80</td>
<td>65/62</td>
<td>49/46</td>
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<tr>
<td>Univ.Washington</td>
<td>EI, EM</td>
<td>80</td>
<td>74/67</td>
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<td>Univ.Michigan</td>
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<td>80</td>
<td>79/69</td>
<td>78/62</td>
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<td>Protvino</td>
<td>EO</td>
<td>192</td>
<td>107/95</td>
<td>24/28</td>
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<tr>
<td>Beijing</td>
<td>BEE</td>
<td>32</td>
<td>0/0</td>
<td>0/0</td>
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<tr>
<td>Greece</td>
<td>BIS</td>
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<td>90/87</td>
<td>0/0</td>
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<tr>
<td>Cosenza/Roma</td>
<td>BIL/BIR</td>
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<td>40/41</td>
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<td>Cosenza/Pavia</td>
<td>BIL/BIR</td>
<td>56</td>
<td>29/35</td>
<td>3/2</td>
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<td>Dubna</td>
<td>BMS</td>
<td>84</td>
<td>62/52</td>
<td>0/0</td>
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<td>Frascati</td>
<td>BML</td>
<td>94</td>
<td>76/64</td>
<td>13/7</td>
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<td>Munich/Dubna</td>
<td>BOS/BOF</td>
<td>88</td>
<td>70/52</td>
<td>8/8</td>
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<td>Freiburg</td>
<td>BOG</td>
<td>18</td>
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<td>NIKHEF</td>
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<td><strong>All sites</strong></td>
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Production Status

- stable production of the bare chambers
- assembly of services compatible with installation schedule (needs a strong effort from the production sites)
Preassembly at CERN
Preassembly tasks at CERN

Preparation of the chambers for the installation into ATLAS detector:

- completion with gas distribution, electronics, DCS (if not yet done)
- assembly of the barrel MDTs with RPCs
- assembly of end-cap MDTs and TGCs on Big and Small Wheel
- certification of the chambers and assemblies
- storage until installation

Chambers and assemblies have to be ready four months before the installation date.
Preassembly areas and schedules: barrel

**B283: BIS/L (chambers without RPC), Jan. - Nov. 2004**

<table>
<thead>
<tr>
<th>Chamber</th>
<th>days/ch</th>
<th>Total days</th>
<th>Work description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIS</td>
<td>2.5</td>
<td>78</td>
<td>195 Preparation of MDT, mounting of electronics, tests, cosmic test</td>
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<td></td>
<td>1</td>
<td>50</td>
<td>50 Test of all components, cosmic test</td>
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<td>BIL/BIM/BIR</td>
<td>1</td>
<td>128</td>
<td>Preparation of gas components (Done in Greece in three labs)</td>
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<tr>
<td></td>
<td>1</td>
<td>116</td>
<td>116 Preparation of MDT, test of all components, cosmic test</td>
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<table>
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<tr>
<th>Assembly line</th>
<th>2003</th>
<th>2004</th>
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<tr>
<td></td>
<td>Jul</td>
<td>Aug</td>
<td>Sep</td>
</tr>
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<td>Clean area/283</td>
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<td>16</td>
<td>16</td>
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<tr>
<td>BIL</td>
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<td>20</td>
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<td>RFI [A]</td>
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<tr>
<td>RFI [C]</td>
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<tr>
<td>Cosmic stand *)</td>
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<tr>
<td>No. of ch/day</td>
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</tbody>
</table>

*) Cosmic stand assumed to accommodate 3 BIS and/or BIL chambers in parallel;
Preassembly areas and schedules: barrel

* **B283**: BIS/L (chambers without RPC), Jan. - Nov. 2004
* **BB5**: BMS/L and BOS/L, Oct. 2003 - end 2004

<table>
<thead>
<tr>
<th>Chamber</th>
<th>ch/day/line</th>
<th>Work description</th>
<th>2003</th>
<th>2004</th>
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<td>Oct</td>
<td>Nov</td>
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<td>BML</td>
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<td>Assembly of RPCs and MDT on Common support + cabling of RPC + cosmic test of RPCs + MDT (2 days/RPC)</td>
<td>BML 10</td>
<td>BML 15</td>
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<td>BML</td>
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<td>BOS/F/G</td>
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<td>BML 10</td>
<td>BML 15</td>
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<tr>
<td>BOL</td>
<td>1</td>
<td>Assembly of RPCs and MDT on Common support + cabling of RPC; cosmic test of RPCs + MDT (2 days/RPC)</td>
<td>BML 10</td>
<td>BML 15</td>
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Assembly line

<table>
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Cosmic stand *)

<table>
<thead>
<tr>
<th>No. of ch/day</th>
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<td>BMS 1</td>
</tr>
<tr>
<td></td>
<td>BMS 1</td>
<td>BMS 1</td>
</tr>
</tbody>
</table>

*) Cosmic stand assumed to accommodate three assembled stations at a time
A complete MDT - RPC station
Preassembly areas and schedules: end-cap

Installation tests:

★ **B184**: MDT testing, Mar. 2004 - end 2005

★ **B180**: integration on the Big Wheel, mid 2004 - end 2005

★ **B191**: integration on the Small Wheel, from 2005
Testbeam Program
H8 Testbeam

Full system test:
12 MDT chambers, trigger system (RPC, TGC), alignment system

end-cap sector
barrel sector
muon beam

EO  EM  EI  BOL  BML  BIL
**H8 Testbeam**

Full system test:
12 MDT chambers, trigger system (RPC, TGC), alignment system

*event display with MDT and RPC hits*
H8 System Test

Extensive program:

- chamber installation with prototype installation tools
- performance and long-term stability of the final electronics and DAQ system
- test of the barrel and end-cap alignment system with controlled chamber displacements
- test and development of the ATLAS-like software
- integration test of tracking and trigger chambers
- test of the trigger with the 25 ns beam
H8 System Test

Extensive program:

★ chamber installation with prototype installation tools

★ performance and long-term stability of the final electronics and DAQ system
  initial problems with DAQ identified and solved,
  12 MDT (3744 channels) running smoothly for two months

★ test of the barrel and end-cap alignment system with controlled chamber displacements

★ test and development of the ATLAS-like software

★ integration test of tracking and trigger chambers

★ test of the trigger with the 25 ns beam
H8 System Test

Extensive program:

★ chamber installation with prototype installation tools

★ performance and long-term stability of the final electronics and DAQ system

★ test of the barrel and end-cap alignment system with controlled chamber displacements
  (for more details on the alignment system see the talk of J.Bensinger)

★ test and development of the ATLAS-like software

★ integration test of tracking and trigger chambers

★ test of the trigger with the 25 ns beam
H8 System Test

Extensive program:

- Chamber installation with prototype installation tools
- Performance and long-term stability of the final electronics and DAQ system
- Test of the barrel and end-cap alignment system with controlled chamber displacements
- Test and development of the ATLAS-like software DAQ, Data Monitoring, tracking, Condition Database, Alignment
- Integration test of tracking and trigger chambers
- Test of the trigger with the 25 ns beam
H8 System Test

Extensive program:

★ chamber installation with prototype installation tools
★ performance and long-term stability of the final electronics and DAQ system
★ test of the barrel and end-cap alignment system with controlled chamber displacements
★ test and development of the ATLAS-like software
★ integration test of tracking and trigger chambers
★ test of the trigger with the 25 ns beam to be completed this month
H8 System Test

Example of an interplay of various systems:

set of controlled chamber displacements:
H8 System Test

Example of an interplay of various systems:
Condition database describes the conditions in which the experiment runs at any given moment.

- alignment data applied to correct for the chamber displacement
X5 Testbeam (Gamma Irradiation Facility)

- influence of the $\gamma$-irradiation on the resolution and efficiency
- time-slewing corrections
- threshold optimisation

Simulates irradiation rates up to 4 times the maximum ATLAS rate

($400 \text{ Hz/cm}^2 = 440 \text{ kHz/tube}$)
X5/GIF Testbeam

Single tube resolution:

- threshold: $-44$ mV
- background count-rates:
  - $427$ kHz/ tube
  - $287$ kHz/ tube
  - $146$ kHz/ tube
  - $88$ kHz/ tube
  - $0$

- degradation of the resolution for large drift radii due to increasing effect of the space charge fluctuations

- average degradation of $\sim10 \, \mu$m at the maximum nominal ATLAS rate

- price to be paid for using Ar:CO$_2$ (chosen to avoid the aging)
X5/GIF Testbeam

Final version of the read-out electronics:
measures the accumulated charge in a 15.5 ns time gate
after the threshold crossing

ADC information can be used for time-slewing corrections
Chamber Performance Test in X5/GIF

- Maximum nominal irradiation in ATLAS
- 4*maximum nominal irradiation in ATLAS

Average resolution (µm) vs. count rate (Hz cm$^{-2}$)

- 44 mV, no time-slew. correction
Chamber Performance Test in X5/GIF

- Maximum nominal irradiation in ATLAS
- 4*maximum nominal irradiation in ATLAS

**Average Resolution (µm)**
- 44 mV, no time-slew. correction
- 44 mV, with time-slew. correction
- 34 mV, with time-slew. correction

**Count Rate (Hz cm²)**
Without irradiation, the design resolution of $80 \mu m$ is achieved.

Even at the maximum nominal ATLAS irradiation rates, this degrades by only $10 \mu m$. 
Aging studies at X5/GIF

- for the first time the recirculating gas system was used in long-term irradiation studies

Setup:

\[ \text{BIS multilayer 1} \rightarrow \text{aged region} \]
\[ \text{recirculation, 1 or 2 volumes/day, 10\% fresh gas rate} \]
\[ \text{BIS multilayer 2} \rightarrow \text{flushing mode, 1 volume/day} \]

\[ \implies \text{strong decrease in the pulse height close to the gas inlet of ML-1, no such effect seen in ML-2} \]

Where does the aging come from? Detailed investigation.
Aging studies at X5/GIF

Electron microscopy of the wire surface:
silicone deposits close to the gas inlet

\[ L = 30 \, \text{cm} \text{ from the gas inlet} \]

Cause: silicone grease decontamination was found in gas system components!

\* Unprecedentedly strict quality control needed for the installation of ATLAS MDT gas system
Summary
Status of MDT Production...

- production of the bare chambers proceeding according to schedule
- mounting of the chamber services delayed, but soon to ramp up
- infrastructure for the preassembly at CERN in preparation, chamber assembly and tests already started
...and Testing

- aging effects in a recirculating gas system
  rigorous cleanliness control

- functionality of the final read-out electronics verified
  resolution of better than 100 µm achieved even at the highest
  γ-irradiation rates

- full system test in H8
  integrating MDT, RPC, TGC, and alignment
Status of MDT Production...

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...and Testing

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   rigorous cleanliness control
★ functionality of the final read-out electronics verified
   resolution of better than 100 $\mu$m achieved even at the highest $\gamma$-irradiation rates
★ full system test in H8
   integrating MDT, RPC, TGC, and alignment

// September 15$^{th}$, 2003. //