Upgrade of the ATLAS Muon Spectrometer with sMDT Chambers

Upgrade with small-diameter Muon Drift Tube (sMDT) chambers:
- Half drift-tube diameter of the “standard” MDT
- > 10 times higher rate capability
- Same resolution/efficiency

- Improves rate capability in the high-background regions for Super-LHC
- Increases acceptance for precision \( p_T \) measurement & triggering

- Two sMDT installed in 2014 in Muon Spectrometer barrel region
- Construction of 12 chambers for the feet regions underway

Parameters

<table>
<thead>
<tr>
<th>Diameter</th>
<th>15 mm</th>
<th>30 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Ar:CO(_2) (93:7) at 3 bar</td>
<td></td>
</tr>
<tr>
<td>Wire</td>
<td>50 µm W-Re</td>
<td></td>
</tr>
<tr>
<td>Tube Wall</td>
<td>400 µm</td>
<td></td>
</tr>
<tr>
<td>High Voltage</td>
<td>2760V</td>
<td>3080V</td>
</tr>
<tr>
<td>Gain</td>
<td>( 2 \times 10^4 )</td>
<td></td>
</tr>
<tr>
<td>Max Drift-Time</td>
<td>200 ns</td>
<td>750 ns</td>
</tr>
</tbody>
</table>

Chamber Construction

New chamber design similar to the current ATLAS MDT. Main challenge: four times denser tube gas and electrical connections
- insulate the wire from the tube wall,
- center the wire with an accuracy ~10 µm
- connect to the gas manifold (in HV-safe way)
- connect with HV and RO electronics

Tube wire tension 3.5±0.15 N; leakage current < 1 nA; gas leak rate <10\(^{-8}\) bar l/s.
Semi-automatic wiring & testing of tubes → three people can prepare 50-60 tubes/day.
A chamber of 8 layers of 78 tubes/layer glued together with high precision in just 5 days.

The 3D-survey of the two sMDT chambers (2.2 m long x 1.2 m wide) installed in the ATLAS detector has shown a construction precision of ~10 µm.

Resolution and Efficiency Degradation at High Rate Background

Increasing flux of background radiation (rate n/γ up to 14 kHz/cm\(^2\)), degrades spatial resolution:
- at small radii: reduced gain from space charge around the wire
  \( \text{Gain} \approx \left( \frac{r_{\text{wire}}}{r_{\text{tube}}} \right)^3 \rightarrow \text{factor 8} \)
- at large radii: space charge density fluctuations of ions modifies the E-field & \( v_{\text{drift}} \)

Smaller diameter → performance degradation vs radiation reduced by more than one order of magnitude

Spatial Resolution Without Background

- Similar Resolution MDT and sMDT

Further Advantages

- Increasing tracking redundancy and efficiency by packing a double number of tubes in the same volume as a standard MDT
- Replacement of a MDT with a sandwich of sMDT and RPC to extend the trigger acceptance and reduce the trigger fake rate in regions where it is not possible to introduce any new trigger chamber (BIS7/8), without loosing tracking resolution.
- Much shorter drift time helps the project of including MDT hits information in Level 1 trigger: improved accuracy of \( p_T \) measurement of muon candidates sharpens the trigger \( p_T \)-threshold reducing the trigger rate.
- R-T function almost linear for drift radii < 7 mm: reduced sensitivity of the position measurement to gas composition and pressure, irradiation rates, temperature, magnetic field, …