Construction and Test of High Precision Drift-Tube (sMDT) Chambers for the ATLAS Muon Spectrometer

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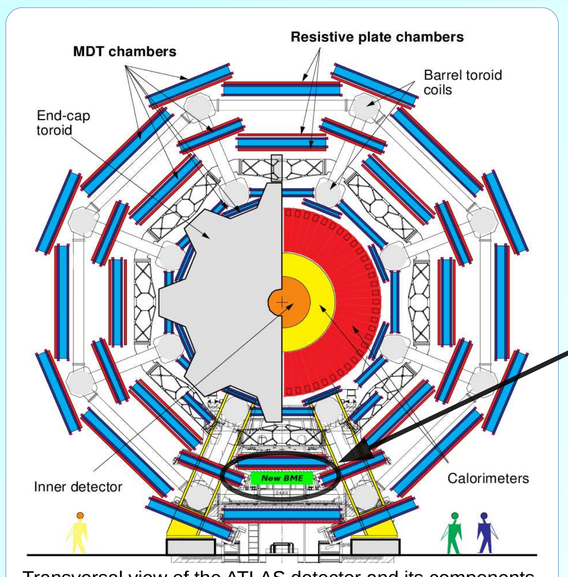
ABSTRACT: For the upgrade of the ATLAS muon spectrometer in March 2014 new muon tracking chambers (sMDT) with drift-tubes of 15 mm diameter, half of the value of the standard ATLAS Monitored Drift-Tubes (MDT) chambers, and 10 µm positioning accuracy of the sense wires have been constructed. The new chambers are designed to be fully compatible with the present ATLAS services but, with respect to the previously installed ATLAS MDT chambers, they are assembled in a more compact geometry and they deploy two additional tube layers that provide redundant track information. The chambers are composed of 8 layers of in total 624 aluminium drift-tubes. The assembly of a chamber is completed within a week. A semi-automatized production line is used for the assembly of the drift-tubes prior to the chamber assembly. The production procedures and the quality control tests of the single components and of the complete chambers will be discussed. The wire position in the completed chambers have been measured by using a coordinate measuring machine and cosmic ray muons tracks in a test stand with two MDT reference chambers.

ATLAS EXPERIMENT
http://atlas.ch

Improving the ATLAS Muon-Spectrometer



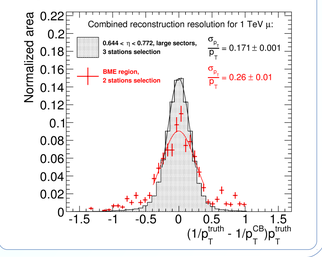
Transversal view of the ATLAS detector and its components, the muon spectrometer upgrade region is specified in green

- The ATLAS Muon-Spectrometer is instrumented with Monitored Drift-Tube (MDT) chambers in a toroidal magnetic field.
- Each MDT chamber is built of 2x3 or 2x4 layers of 30 mm diameter drift-tubes
- Standard muon track reconstruction is performed with 3 stations (Inner, Medium, Outer) of MDT chambers
- 2 stations coverage (due to presence of services) significantly worsens muon momentum resolution

The BME Upgrade

- sMDT technology allows compact chamber design
- Installation in before unaccessible areas
- elevator shaft area (used for inner detector access)
- Movable supports use to maintain accessibility

1 TeV muon expected resolution in regions with 2 or 3 MDT stations

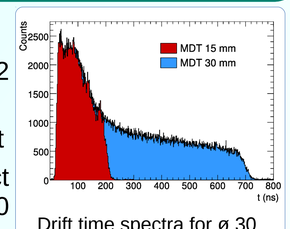


Small Tubes Drift-Chambers (sMDT)


Comparison between ATLAS standard ø 30 mm tubes and ø 15 mm ones

Small Tube Technology

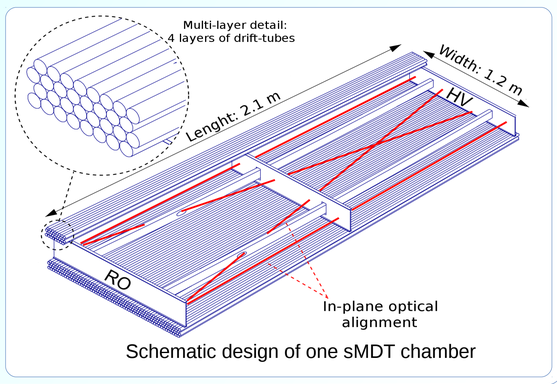
- Smaller aluminum drift tubes with 1/2 diameter with respect to ATLAS standard
- Compatible services: gas, electronic, readout
- Shorter drift time (<200 ns), 1/3 with respect to ATLAS standard, allows to sustain x10 higher γ and neutron background rates



Drift time spectra for ø 30 and ø 15 mm tubes

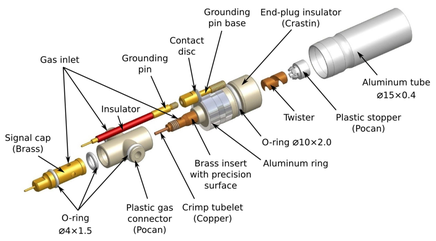
sMDT Chamber Design

- 2 multi-layers composed by 4 layers of 78 small tubes
- 624 tubes needed to build one chamber of 1.2 m width and 2.2 m length
- Aluminum spacer frame equipped with 4 optical alignment lines to monitor deformations
- Ionizing medium: Ar:CO_2 (93:7) gas at 3 bar pressure
- Anode wire voltage 2730 V
- Chamber aligned to the rest of the MS with 4 optical sensors (nominal precision of 30 µm)



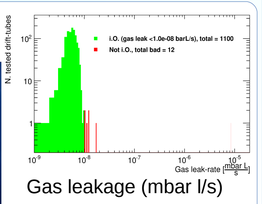
Schematic design of one sMDT chamber

Tube Production & Quality Testing

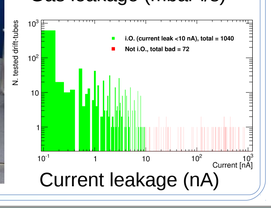


- Each drift-tube is a multi component device that must satisfy tight precision and quality criteria
- Large scale tube production is also a challenge
- Semi-automated wiring and testing stations in clean environment
- Wire tension (3.5+/-0.15 N), gas leakage (>1 mbar l/s), current leakage (>10 nA) stored in MySQL database
- Production rate capability > 50 tubes per day

Setup of gas and leakage current testing station for parallel analysis of multiple tubes

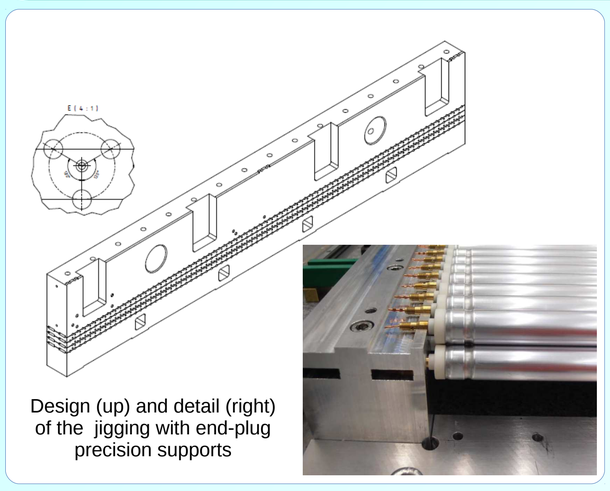


Gas leakage (mbar l/s)



Current leakage (nA)

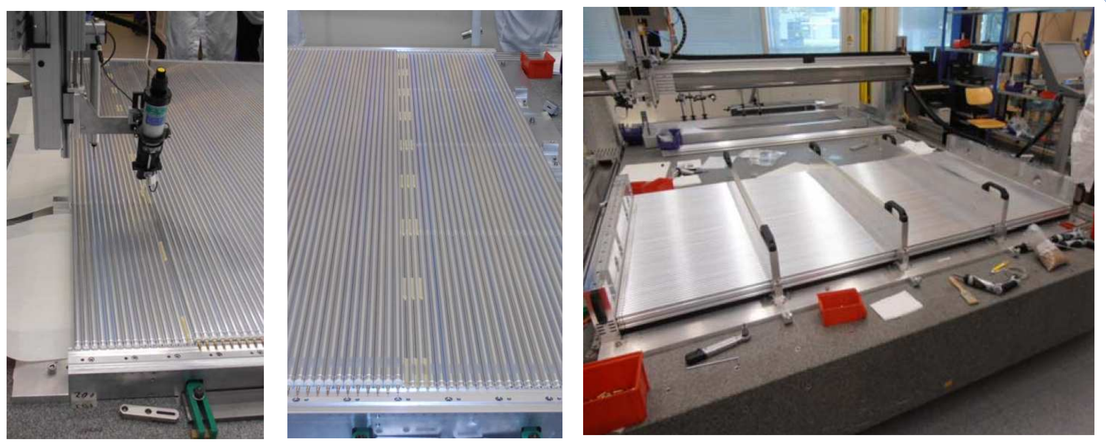
High Precision Chamber Assembly


Design (up) and detail (right) of the jigging with end-plug precision supports

- Jigging with precision surfaces and pin support used for tube/wire positioning
- Programmable gluing machine used for fast assembly of each multi-layer

Five Days Mounting Procedure

- Position and gluing of the first two drift-tube layers
- Completion of first multilayer, first multi-layer removed from jigging
- Position and gluing of the first two drift-tube layers of second multi-layer
- Completion of second, test of optical alignment and frame support
- Gluing of the two multi-layers and frame


Glue positioning using programmable gluing machine, the position of each tube is registered (using a barcode) on a MySQL DB

Gas Distribution & Electronic

- Mounting of the gas distribution system in clean environment
- Time consuming because of the high number of components (es. 624 x2 end-plugs).
- Reached leak rate of 4 mbar/h

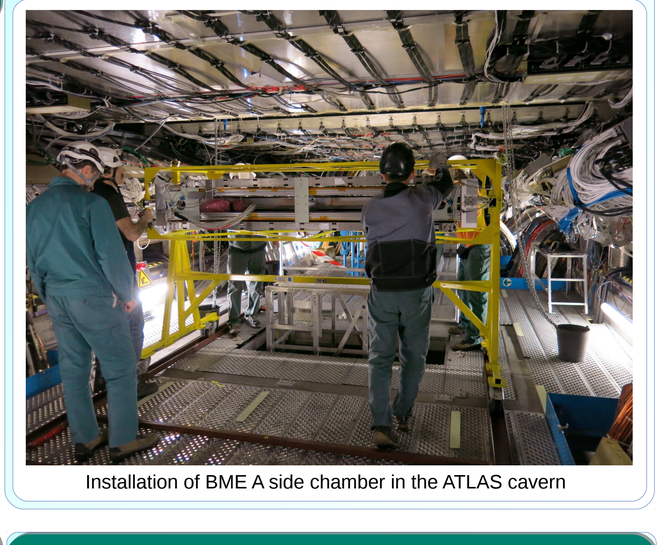

View of complete mount of the gas distribution system

- Electronic boards, readout, and trigger system are fully compatible with ATLAS standards
- Larger number of channels with respect to similar MDT chambers: track hit redundancy

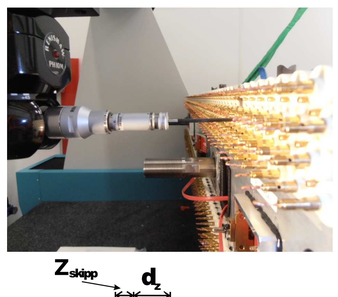
The Chamber Installation

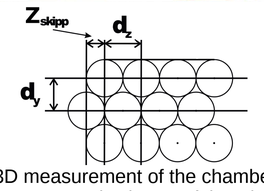
- The BME upgrade is comprised of two sMDT chambers together with the corresponding RPC trigger chambers. One for each side (A and C) of the ATLAS detector

The installation of BME-A and BME-C completed successfully in April 2014


Installation of BME A side chamber in the ATLAS cavern

Evaluation of Chamber Geometry and Precision





3D measurement of the chamber components and scheme of the wire-grid

- Geometrical characteristics of a chamber are defined by a wire-grid: 2 pitches (along y and z coordinates), z displacement of the first layer, z and y distance between the two multi-layers
- End-plug positions (corresponding to wire positions) are measured with a 3D coordinate measuring machine
- Grid parameters are extracted with a minimum χ^2 fit
- The geometrical precision of the wire grid depends by the spread of the end-plug position around the fitted best-values: this is obtained looking at the RMS of the distribution and at the sigma of a Gaussian fit

The two sMDT chambers produced result as the most precise chambers of this size

BME-A	RO side	HV side	Nominal
z-pitch [mm]	15.0995 ± 0.00001	15.0990 ± 0.00001	15.100
y-pitch [mm]	13.0956 ± 0.0001	13.0857 ± 0.0001	13.095 / 13.085
z-offset layers [mm]	7.5529 ± 0.0003	7.5509 ± 0.0003	7.550
z-distance ML [mm]	0.0089 ± 0.0003	0.0283 ± 0.0003	0
y-distance ML [mm]	135.3417 ± 0.0005	135.2815 ± 0.0005	135.347 / 135.271
σ wire pos. z	6 µm	7 µm	20 µm
σ wire pos. y	12 µm	8 µm	20 µm

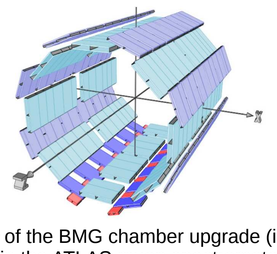
BME-C	HV side	RO side	Nominal
z-pitch [mm]	15.0993 ± 0.00001	15.0988 ± 0.00001	15.100
y-pitch [mm]	13.0972 ± 0.0001	13.0851 ± 0.0001	13.095 / 13.085
z-offset layers [mm]	7.5511 ± 0.0003	7.5461 ± 0.0003	7.550
z-distance ML [mm]	- 0.0073 ± 0.0003	0.0095 ± 0.0003	0
y-distance ML [mm]	135.3562 ± 0.0005	135.2996 ± 0.0005	135.347 / 135.271
σ wire pos. z	6 µm	7 µm	20 µm
σ wire pos. y	13 µm	8 µm	20 µm

Conclusion and Future Muon-Spectrometer Upgrades

- New MDT chambers with small (15 mm ø) drift-tube technology have been developed and produced at MPI, Munich
- Semi-automated assembly and testing stations are used to produce and test more than 50 drift-tubes each day
- Precision construction procedures and tools allow the assembly of a complete sMDT chamber in 5 working days
- The geometry analysis of the chambers revealed a construction precision below 10 µm:

The highest precision reached for chambers of this dimensions

- The BME-A and BME-C chambers have been installed in April 2014 in the ATLAS cavern
- The production of new chambers is foreseen for the upgrade of other sectors (BMG) of the ATLAS muon spectrometer


View of the BMG chamber upgrade (in red) in the ATLAS muon spectrometer

Bibliography

- B. Bittner et al. Performance of drift-tube detectors at high counting rates for high-luminosity LHC upgrades, NIM A 732 (2013), p. 250
- B. Bittner et al. Development of fast high-resolution muon drift-tube detectors for high counting rates, NIM A 628 (2011), p. 154

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