Construction of New Precision Drift-tube Chambers for the Upgrade of the ATLAS Muon Spectrometer in 2014

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FSP 101
ATLAS

Improving the ATLAS Muon-Spectrometer

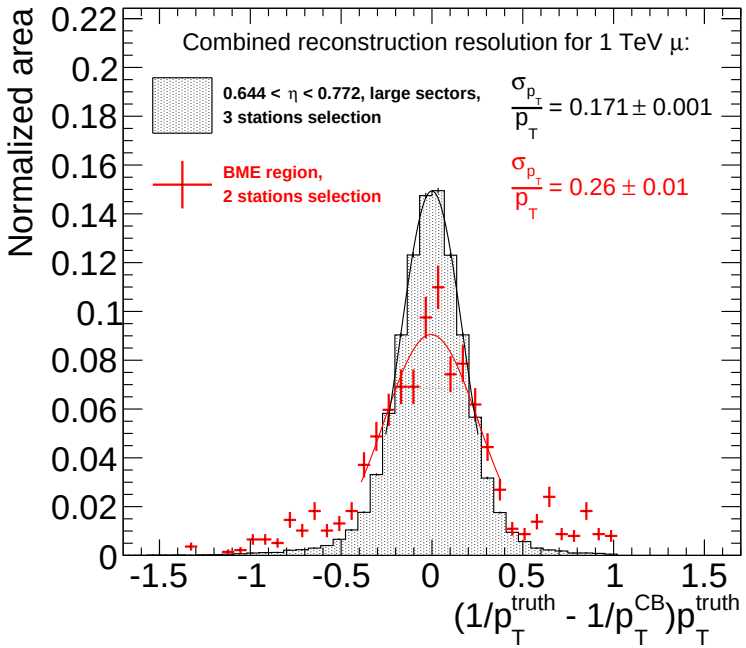
The ATLAS Muon-Spectrometer (MS):

- Instrumented with Monitored Drift-Tube (MDT) chambers in toroidal magnetic field
- Each MDT built of 2 $\times$ 3 layers of 30 mm diameter drift-tubes
- Muon track reconstruction uses 3 stations (Inner, Medium, Outer) of MDT chambers

Single muon performances:

- Resolution of $15 - 20\%$ for p_T =1 TeV
- Two station tracking would degrade resolution by 50%!
- Coverage with 3 MDT stations not always possible because of services or support structures

Can we improve this?



1 TeV single Muon resolution

MS upgrade during 2013-2014 LHC shutdown

The problem:

- Inner detector access with elevator shafts on both detector barrel sides
- Resulting in $\eta - \phi$ regions equipped only with 2 MDT stations

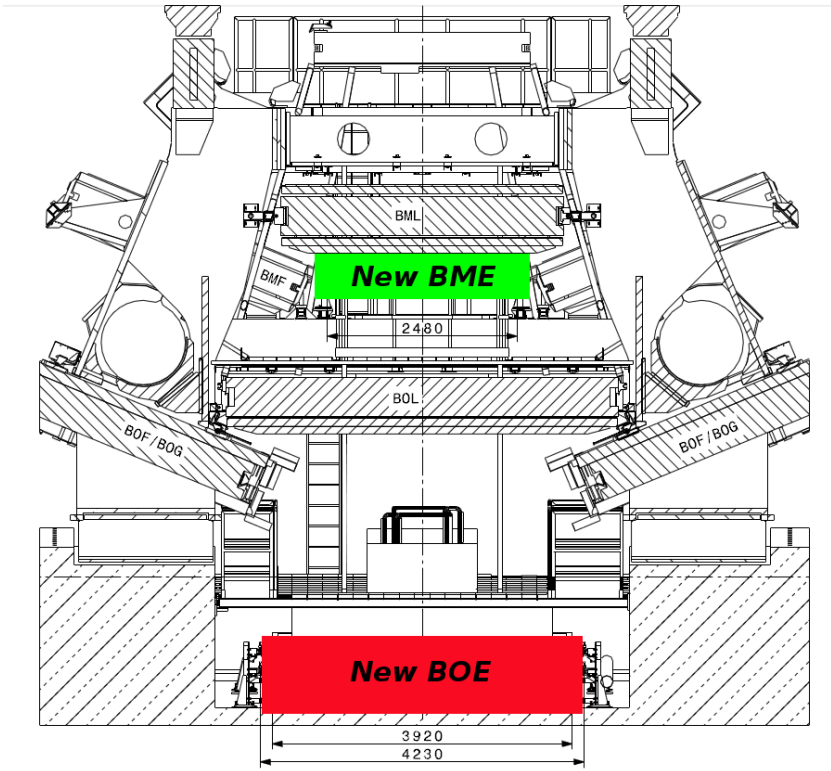
The upgrade:

Complete 3 station coverage by adding 2 MDT chambers for each side:

- Outer chamber station:
  - $\Rightarrow$ BOE, on detector cavern floor
- Middle chamber station:
  - $\Rightarrow$ BME, inside elevator shaft

Challenges:

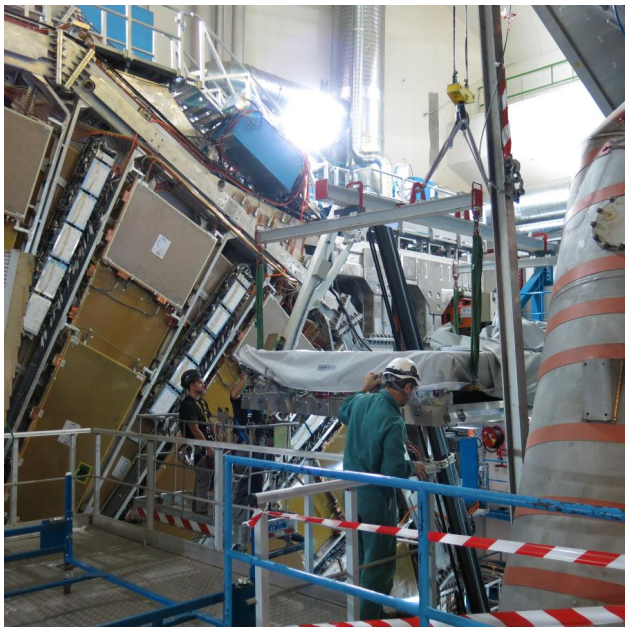
- *Accessibility must be maintained*
- *Integration with gas/electronic systems*
- *Compact geometry for BME chambers*
- *Possible technological improvement?*



New BME and BOE areas in ATLAS detector scheme

Outer Chambers (BOE) Installation

BOE chambers (standard MDT technology) installation:



First part of the upgrade completed in November 2013!

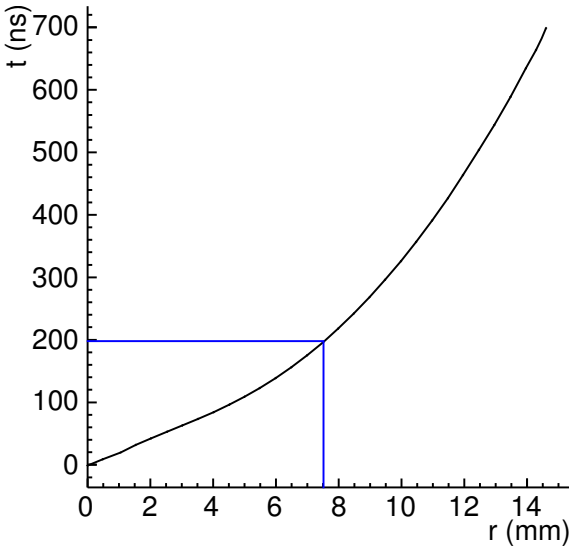
Middle chambers (BME) upgrade is more challenging:

- Tight geometry of installation area and need of movable supports for elevator access
- Development of new chamber with improved technology

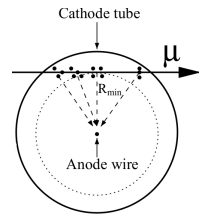
15 mm Diameter Drift-Tube Chambers

Concepts of new MDT with 15 mm diameter drift-tubes (sMDT):

- Smaller drift-tubes of 1/2 diameter w.r.t. *standard* ATLAS MDT
- Allow more compact geometry
- Fully compatible with present services: gas, electronic, readout
- Additional drift-tube layers can be used in each chamber $\Rightarrow$ *tracking redundancy*



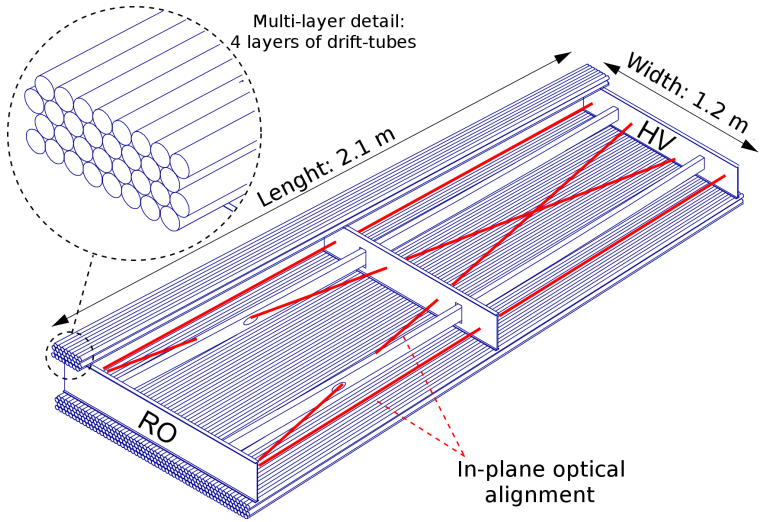
- Shorter drift time (< 200 ns) $\Rightarrow$ ⅓ of ATLAS standard MDTs
- Almost linear Drift-time/radius function $r(t)$
- New sMDT sustains $10\times$ higher γ and neutron background radiation rates
- More details and performance analysis in T 57.6 (P. Schwegler)

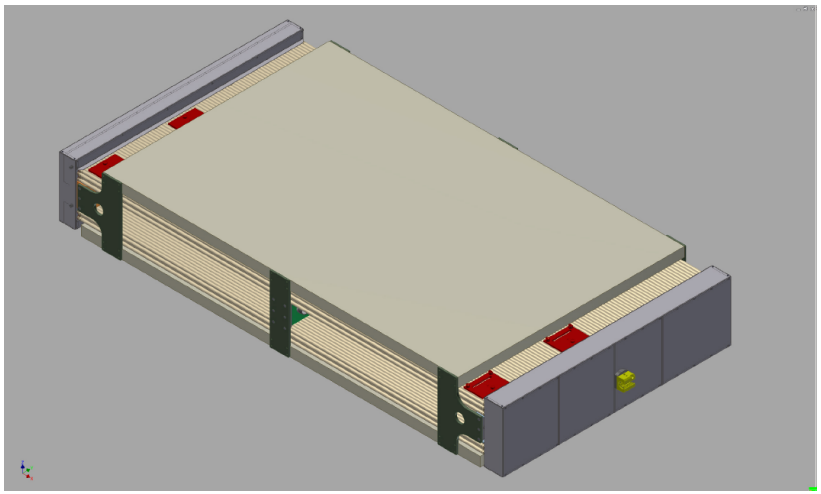


BME Chambers Details

New BME chambers design with sMDT technology:

- 2 multi-layers composed by 4 layers of 78 aluminium drift-tubes of 15 mm diameter
- Aluminium spacer frame equipped with 4 optical alignment lines to monitor deformations
- Ionizing medium: $Ar:CO_2$ gas at 3 bar pressure
- Anode wire voltage: 2730 V





⇒ 624 drift-tubes for each chamber

⇒ Chamber dimensions:

width ≈ 1.2 m, length ≈ 2.2 m

⇒ Chamber mount: 3-point rail guides (chamber can be moved in or out data-taking position)

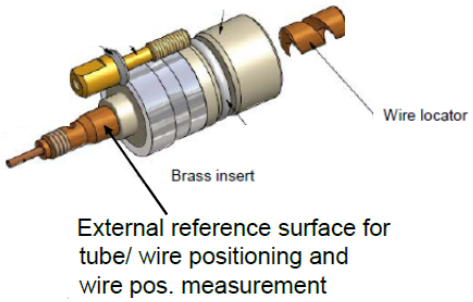
⇒ 4 platforms for mount of optical sensors

⇒ alignment w.r.t. MS with 30 µm accuracy

Drift-Tube Production Line

Each drift-tube is a multi-component device:

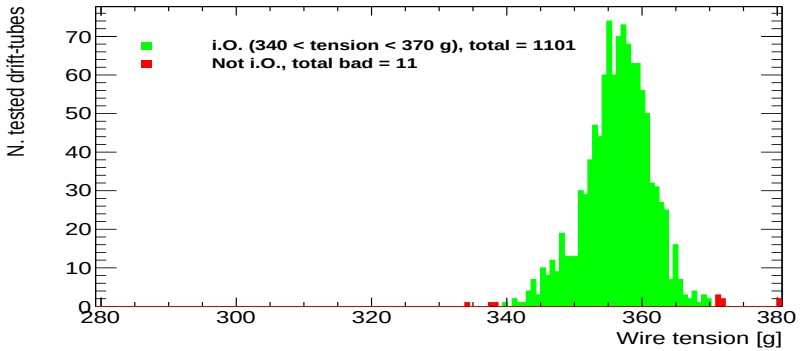
- 2 end-plugs
- 50 µm W-Re anode wire
- 2.15 m length, 15 mm ⌀ aluminum tube
- Wire-locator ensures precise wire positioning corresponding to external brass surface
- Wire crimped and tensioned to 3.5 ± 0.15 N



Production of several hundred drift-tubes with semi-automatic assembly line at MPI:

Tube wiring station

- **Steps: end-plug insertion, tube wiring, crimping**
- Wiring and crimping stations in clean and controlled environment
- Production rate capability of $>$ 50 tubes per day



Wire measurement tension after production (accounts for ≈7 g relaxation)

Quality Control

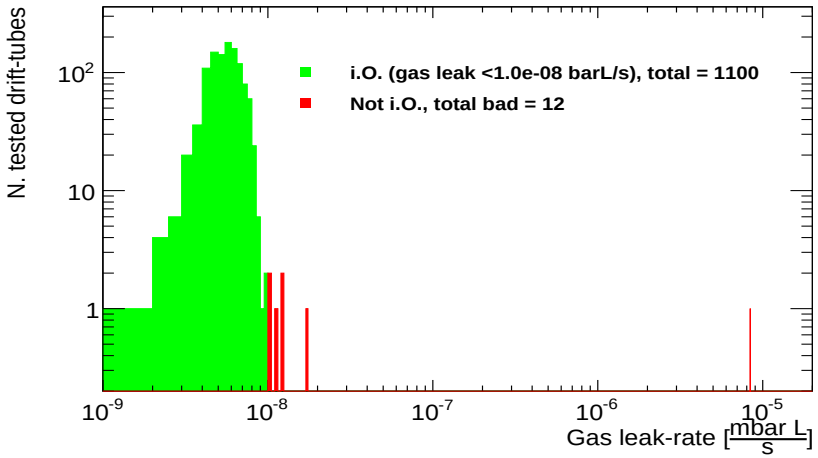
Tight quality criteria imposed on drift-tubes for ATLAS usage:

Testing station for multiple tubes

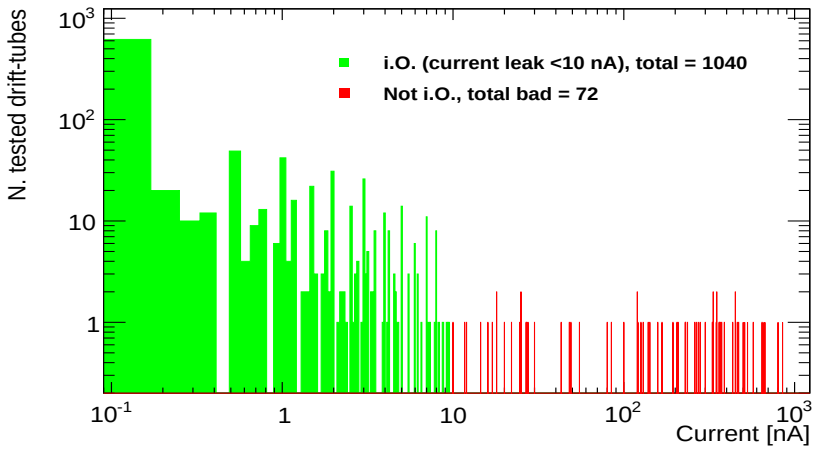
- Gas tightness, leak rate < 1 mbar L/s
- Leakage current < 10 nA at 3015 V
- Tube testing in clean environment immediately after production
- Drift tube parameters stored in SQL database

- Gas tightness failure rate $\approx 1\%$
- Leakage current failure rate $\approx 7\%$

Tube gas tightness test results:

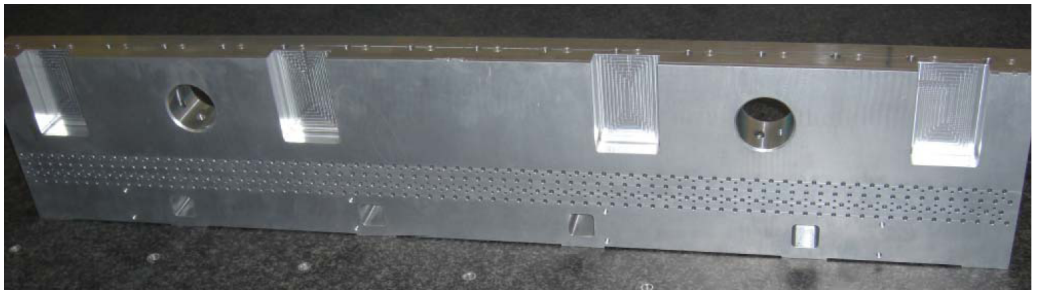


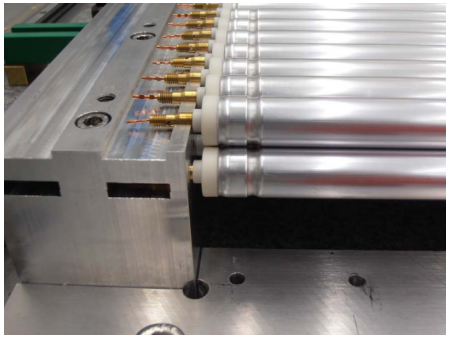
Tube leakage current test results:



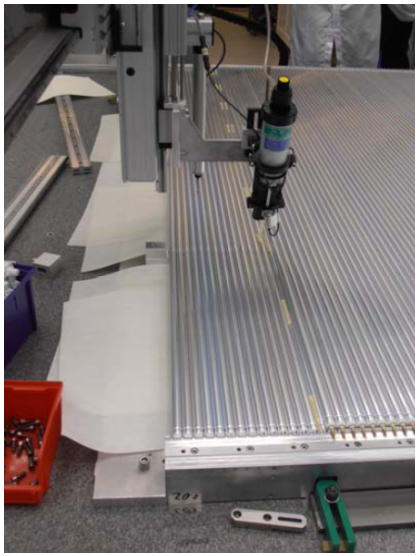
Chamber Construction

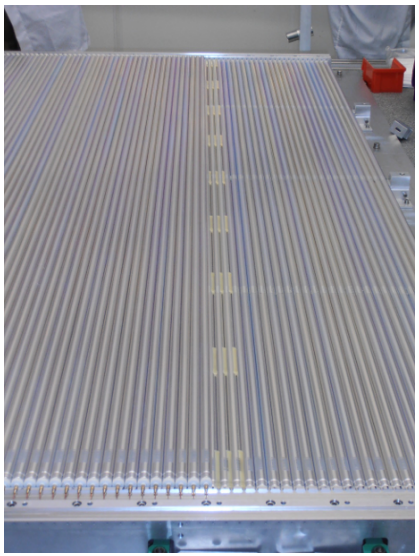
Jigging with precision surfaces and pin-supports used for tube/wire positioning:





Programmable gluing machine used in multilayer assembly:





The Complete Chambers

Assembly of one chamber in 5 working days:

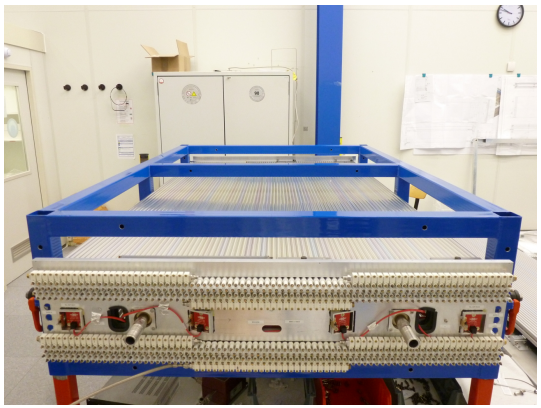
1. Positioning and gluing of first two drift-tube layers
2. Completion of 1^{st} multi-layer (4 layers). Alignment platforms gluing
3. Positioning and gluing of two drift-tube layers for 2^{nd} multi-layer
4. Completion 2^{nd} multi-layer. Test of optical alignment system on spacer frame
5. Positioning and gluing of spacer on top of 2^{nd} multi-layer, then 1^{st} multi-layer

Additional time needed for gas distribution and electronics mounting (less critical)

Three completed chambers:

BME-C1 Chamber:
first chamber (prototype) fully glued on precision jigging

BME-C2 Chamber:
mounting of the gas distribution system in clean environment



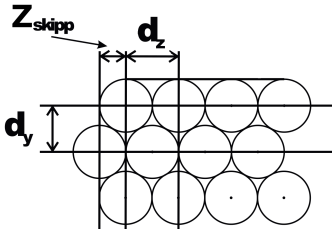
BME-A Chamber:
electronics mounted,
mock-up for ATLAS installation

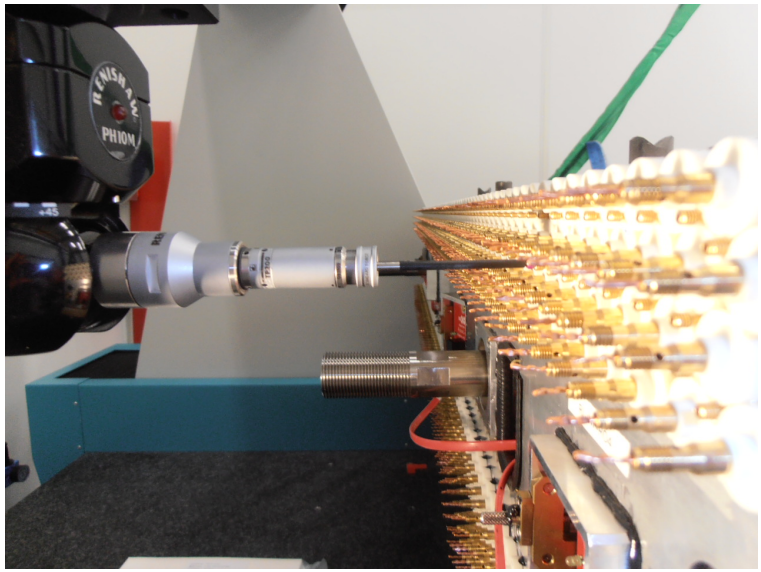
Characterizations of sMDT Chambers

- End-plug position measurement with 3D Coordinate Measuring Machine (CMM):

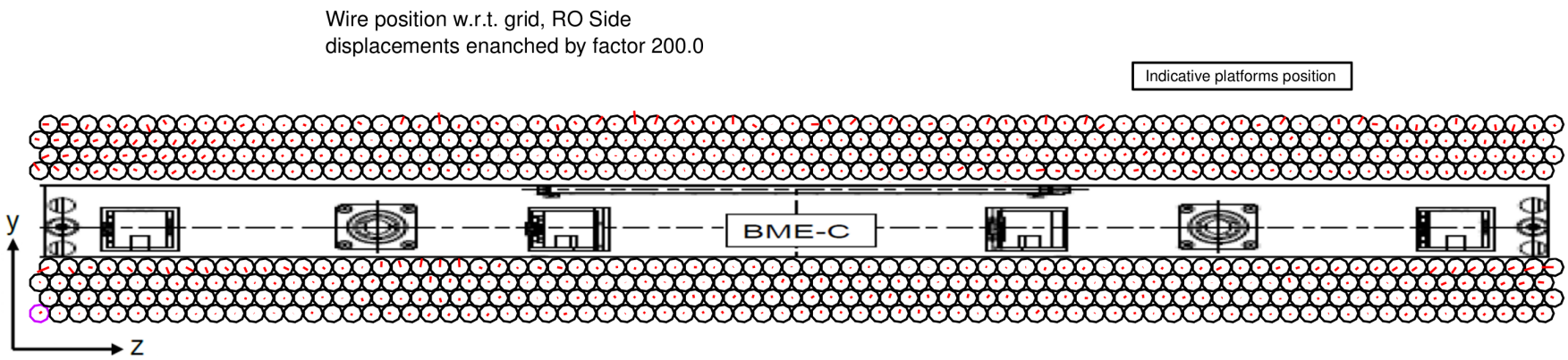
  $\Rightarrow$ wire position indirectly known to $\approx 4\,\mu$m precision

- Each sMDT chamber characterized by global geometrical parameters:



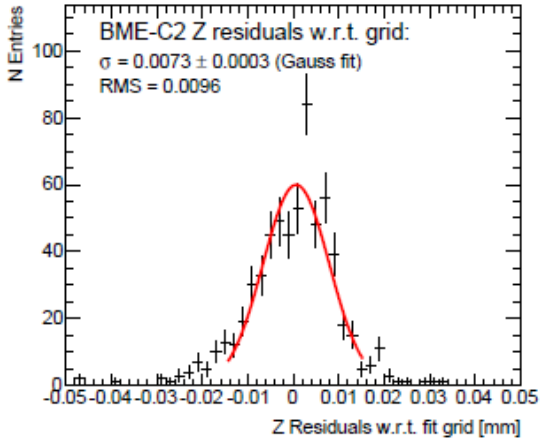


- Grid of wire positions and relative multi-layer position parameters extracted with minimum χ^2 fit

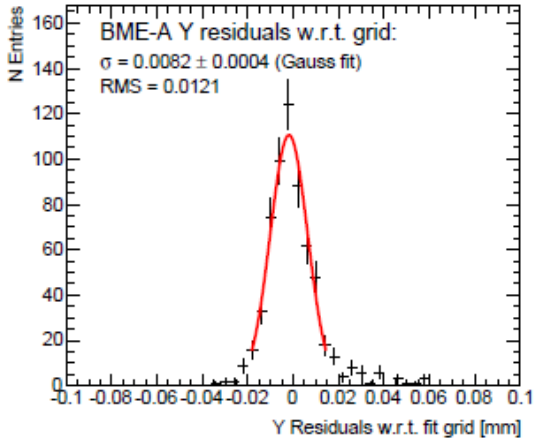


Summary of Chamber Parameters

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



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



Most precise large-size chambers ever built!

Conclusions and Next Steps in MS Upgrade

Conclusions:

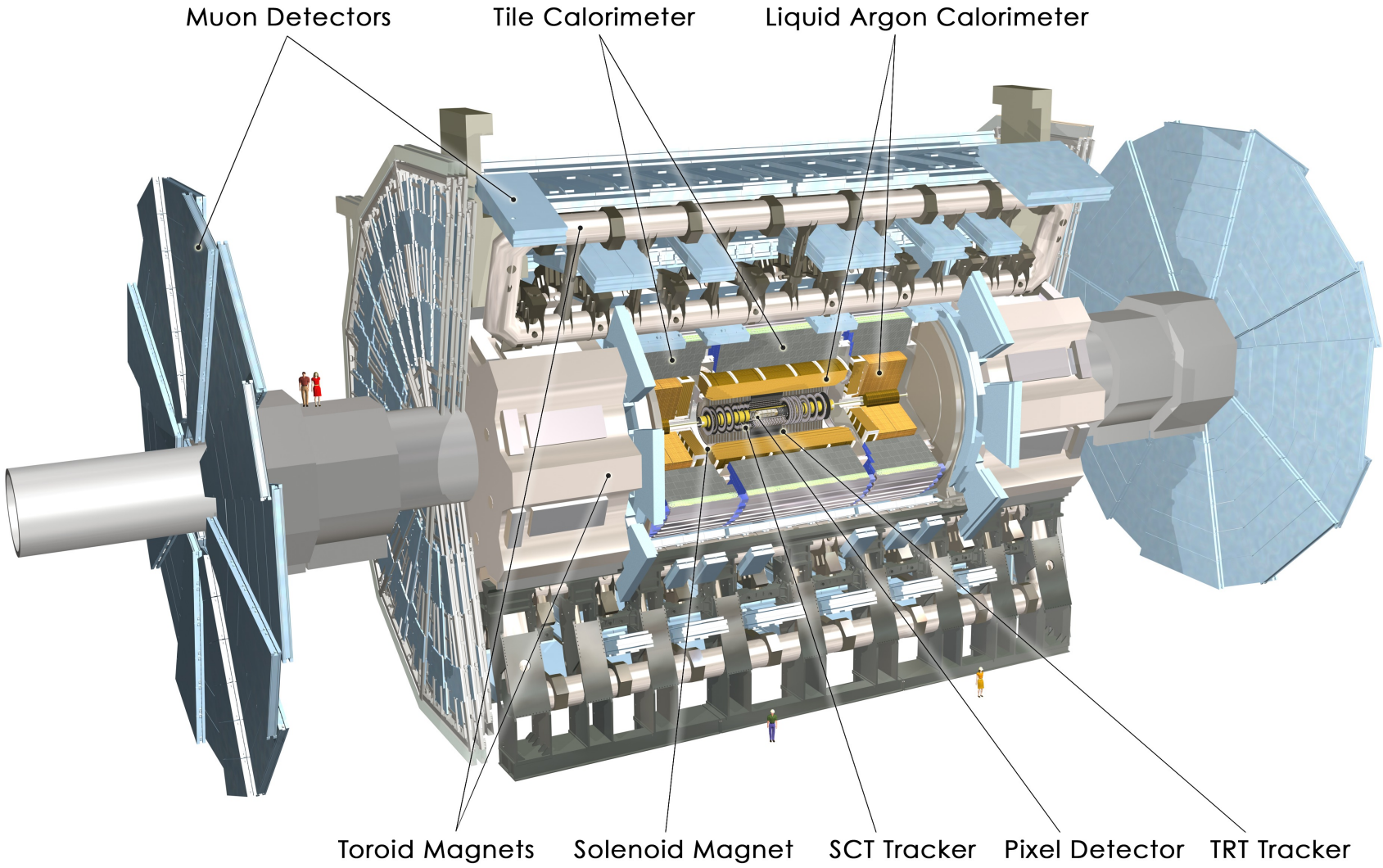
- Upgrade of the ATLAS MS is taking place during current LHC shutdown
- New MDT chambers with small (15 mm ⌀) drift-tube technology (sMDT) have been developed and produced at *MPI, Munich*:
  - ⇒ Automated production line
  - ⇒ Tight quality control and component testing
  - ⇒ Precision construction procedures
- The results are two of the most precise drift-tube chamber ever build!
- *Installation in ATLAS is in progress right now!*

THANKS FOR YOUR KIND ATTENTION!

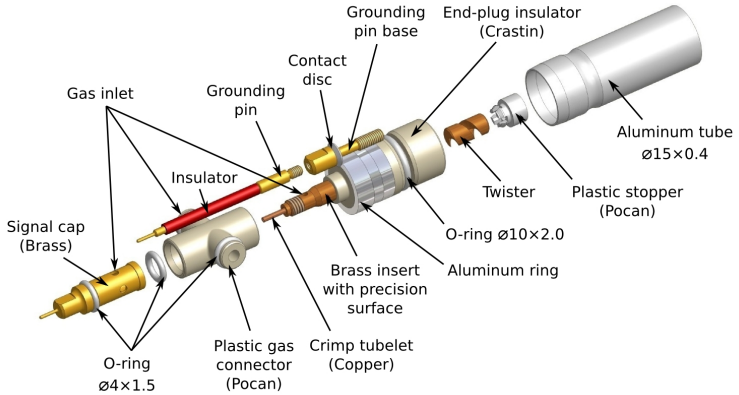
Questions?

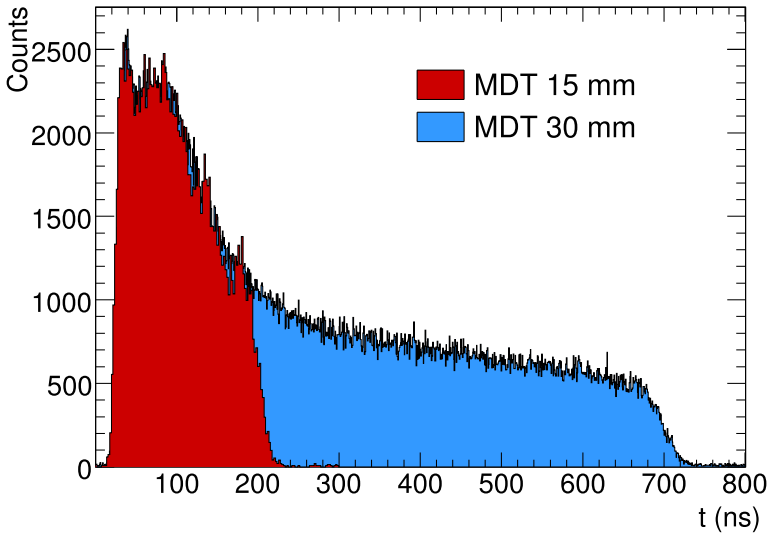
Back Up Slides

The Atlas Detector



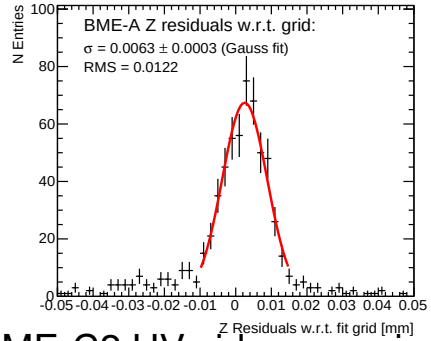
sMDT Miscellanea

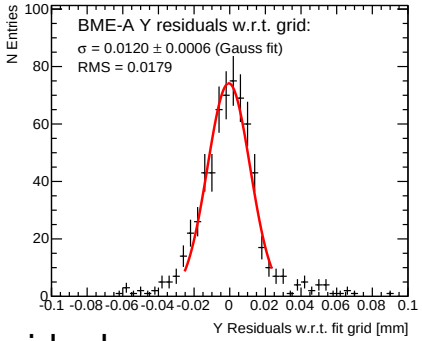




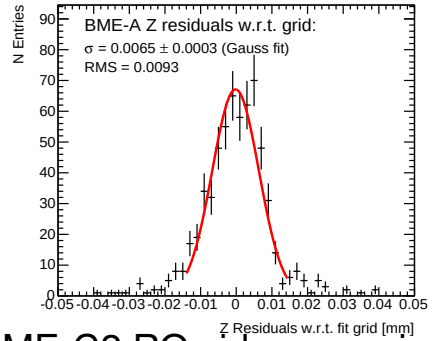
Chamber z, y Wire-Residuals

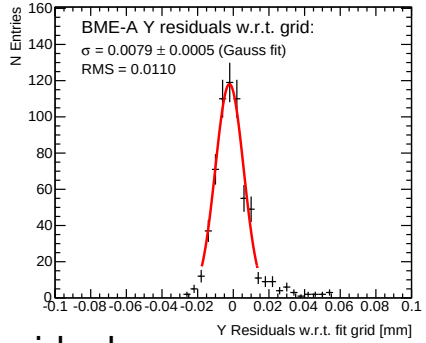
BME-A RO side: z, y wire-residuals



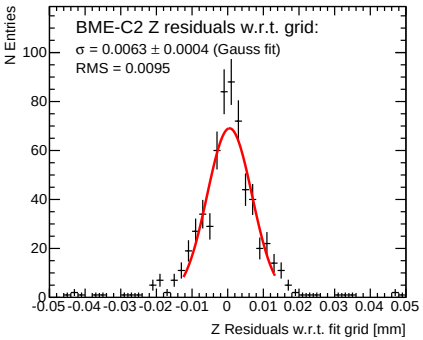


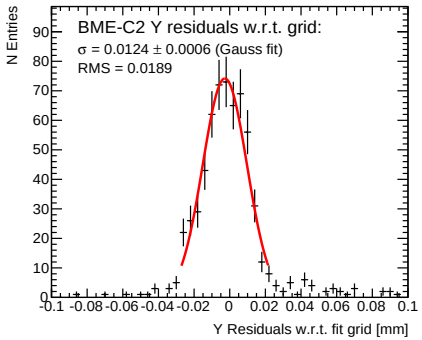
BME-A HV side: z, y wire-residuals





BME-C2 HV side: z, y wire-residuals





BME-C2 RO side: z, y wire-residuals