Test and Calibration of Large Drift Tube Chambers

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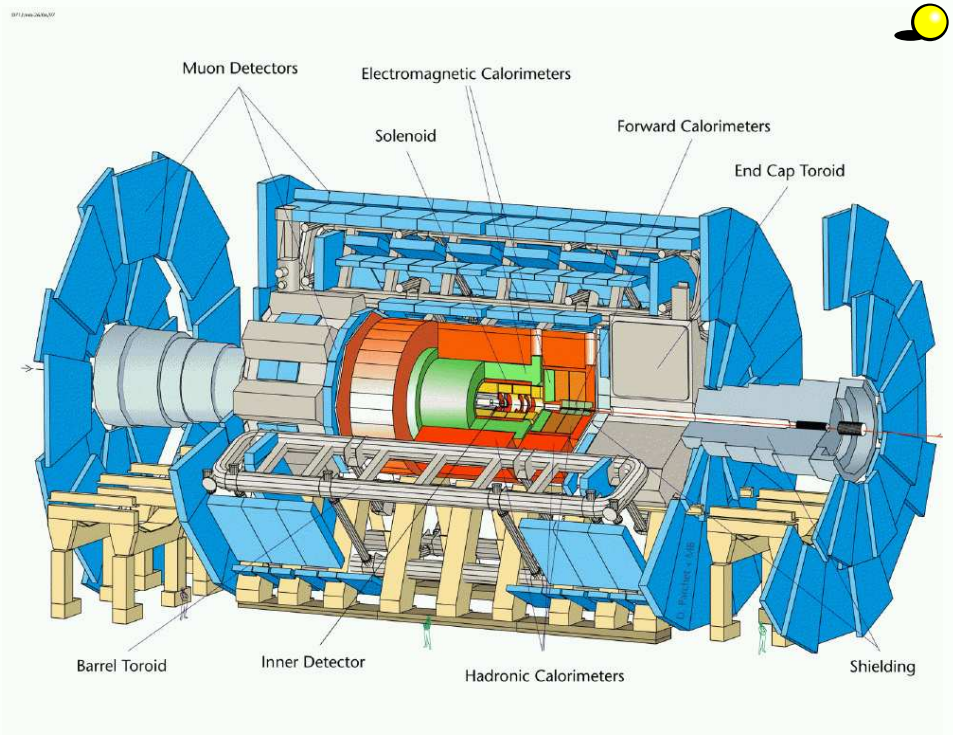
Outline

- Introduction
- The LMU Cosmic Ray Facility
- Chamber Commissioning
- Chamber Calibration
- Summary

Introduction

Introduction (1)

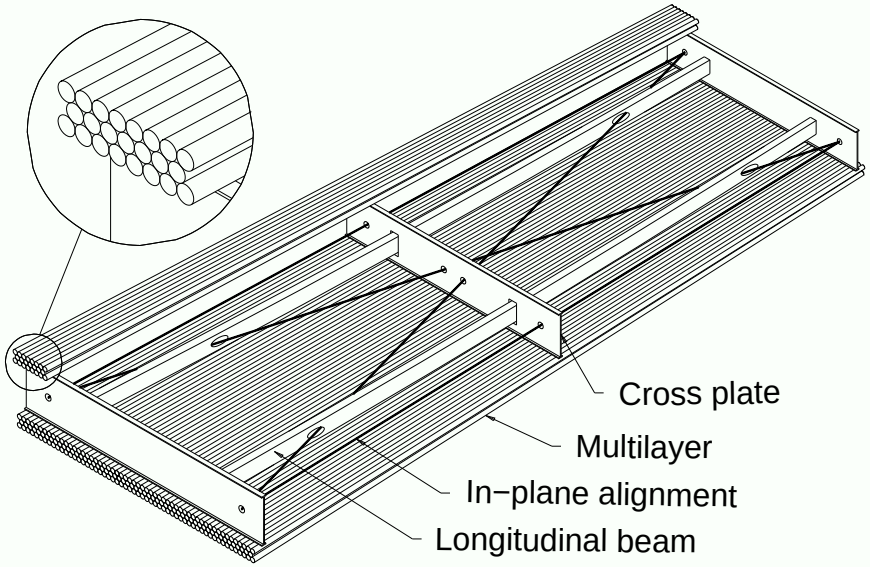
ATLAS Muon Spectrometer



- Air Core Toroid Magnet System
- Area: $> 5500\ m^2$
- 788 Trigger Chambers
- 1226 Precision Chambers
- 32 Cathode Strip Chambers (CSC)
- **1194 Monitored Drift Tube (MDT) Chambers**

Introduction (2)

Monitored Drift Tube Chambers



- Drift tubes
  - Aluminum tubes, 3 cm outer diameter, 400 μm wall thickness
  - Centered anode wire, 50 μm diameter
  - Gas mixture: Ar/CO_2 = 93/7
  - Pressure: 3 bar
  - Gas gain: 2×10^4
  - Max. drift time: $\approx$ 700 ns
  - Averaged resolution: 100 μm
- 2 multilayer of 3 (or 4) tube layer
- Support frame of aluminum
- Optical (RasNik) systems to monitor chamber deformations
- Chamber size: 1-11 m^2
- Optical chamber to chamber alignment

Introduction (3)

Physics requirements: - $\Delta p_T / p_T < 10\%$ up to 1 TeV

- Stand-alone operation

Sagitta measurement with 3 MDT stations

$\longrightarrow$ 50 μm point resolution needed

$\longrightarrow$ 20-30 μm RMS on wire positions needed

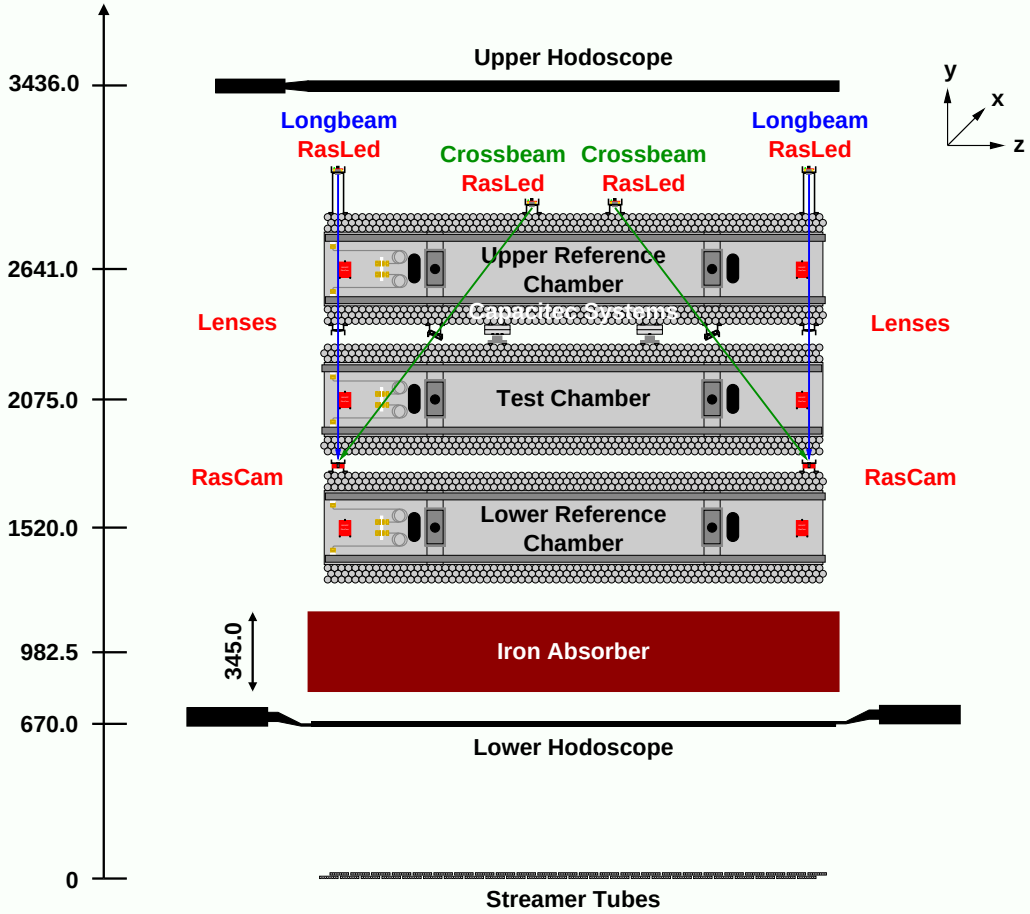
Guaranteed by chamber design and monitoring

. . .

The LMU Cosmic Ray Facility

Setup (1)

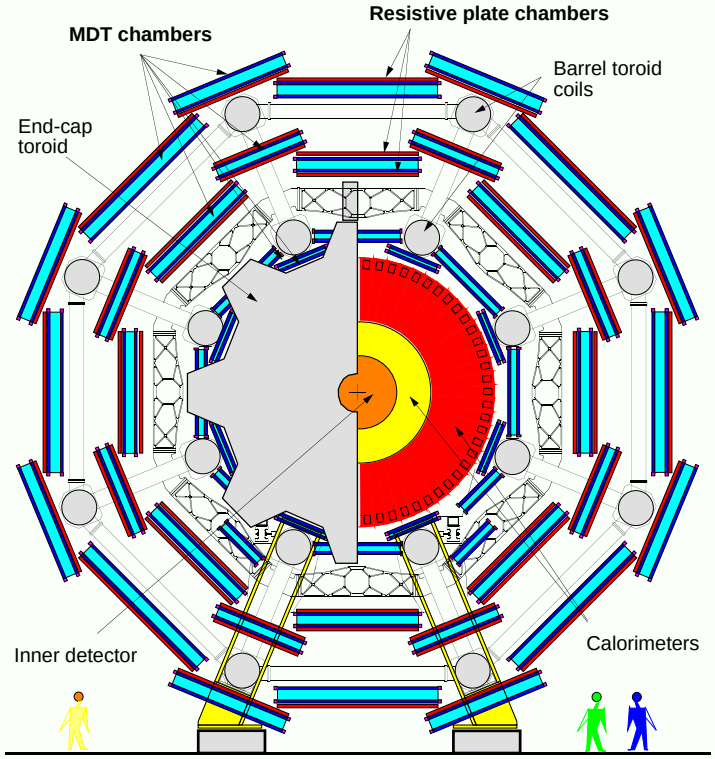
- Chamber size: 3.8 m $\times$ 2.2 m
  2 $\times$ 3 layers, 72 tubes per layer



- 2 Scintillator hodoscopes
  - Full chamber coverage (8.7 m^2)
  - 5 segments along tubes
  - $<$ 800 ps time resolution
  - 7.5 cm track resolution along tube
- Iron Absorber ($\Rightarrow$ E$_\mu$ $>$ 600 MeV)
- Streamer tubes (energy cut based on multiple scattering)
- 2 Reference chambers certified by X-Ray tomograph
- Optical and capacitive alignment monitors ($<$ 5 μm precision)
- 80 Hz trigger rate
  15-25 M events / chamber
- Test chamber can be shifted

Programme

Commission and calibrate 88 BOS/BOF MDT chambers built at the Max-Planck-Institut für Physik



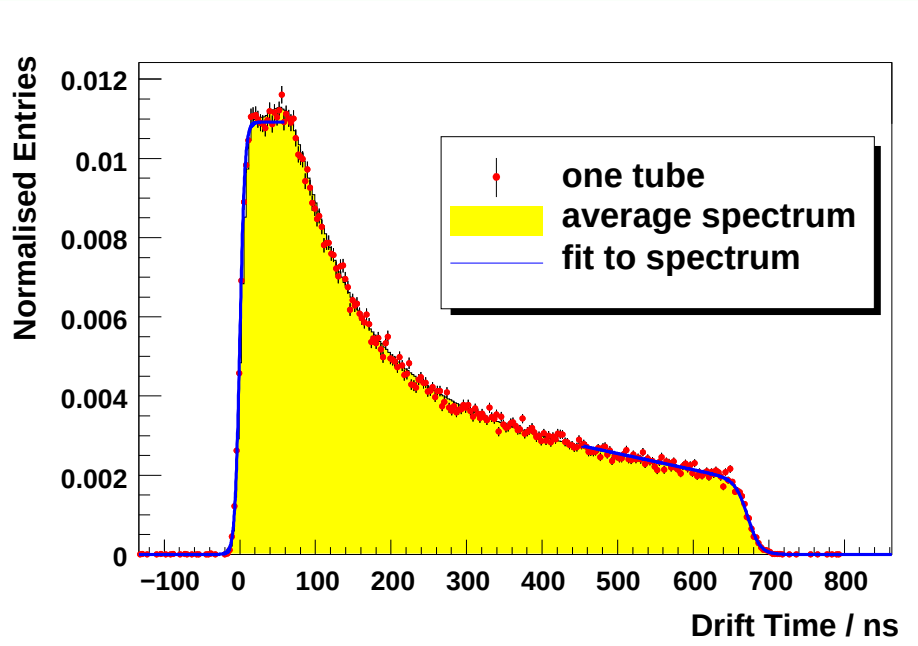
- Fix leaks / Measure leak rate
- Complete chamber
- Equip with & test front-end electronics
- HV test
- Commission chamber (tube response, homogeneity)
- Calibrate chamber (wire positions, geometry)

Goal: MDTs ready for installation and operation in ATLAS

Commissioning

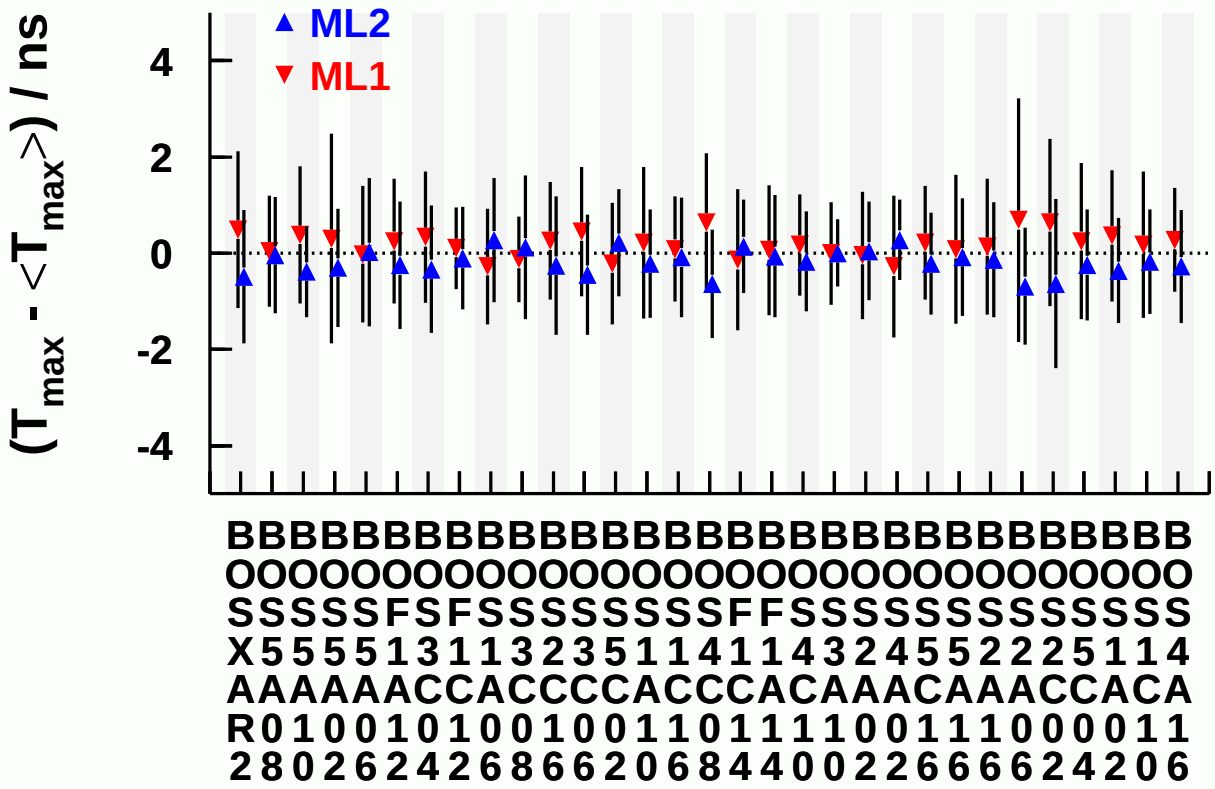
Tube Response

- Measure drift time spectra
- Fit analytic functions at beginning and end
- Parameter set
  - Maximum drift time
  - Rise time
  - Noise level
  - . . .



Chamber Homogeneity

Maximum Drift Time



Very good agreement between multilayers

N.B.: Error bars denote single tube RMS spread

Calibration

Motivation

Physics requirements: . . .

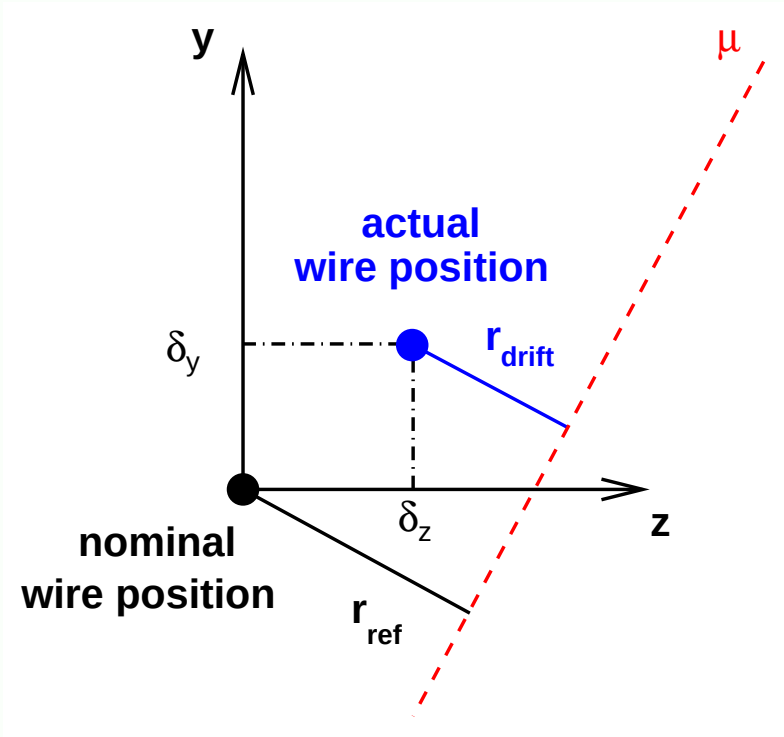
$\longrightarrow$ 20-30 μm RMS on wire positions needed

Guaranteed by chamber design and monitoring

but. . .

- Some geometry parameters difficult to control during production (e.g. layer distances)
- Longterm stability (chamber production started end of 2000)
- Anchor points for calibration / reconstruction at LHC

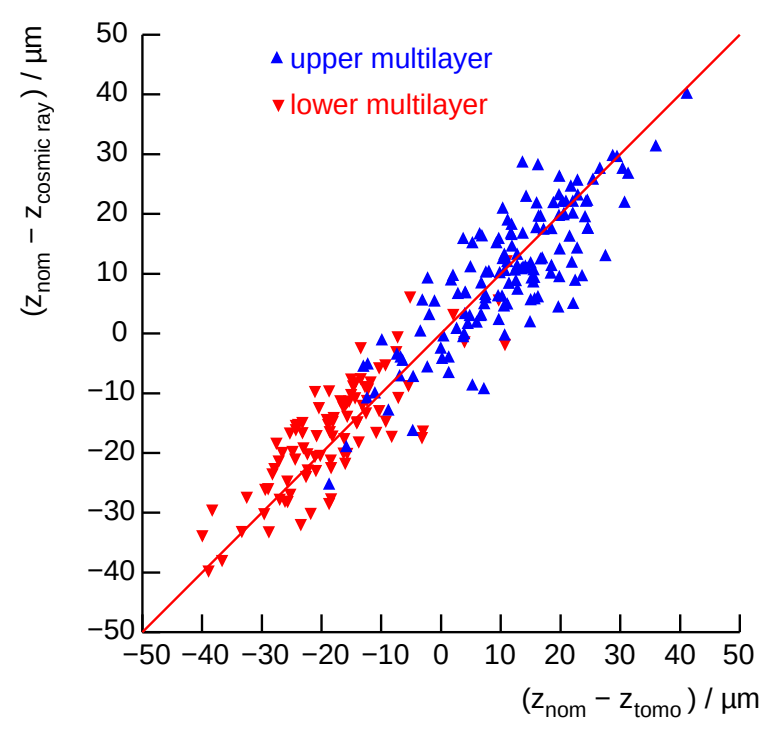
Method



$$y = y_0 + m^{-1} \cdot z$$

- Wire positions derived from comparison of predicted drift radius r_{ref} (weighted average reference tracks) and measured drift radius r_{drift} in the test chamber
  $\Delta r = r_{drift} - r_{ref} \approx \delta_z - m \cdot \delta_y$
- δ_y from linear fit of Δr vs. m
- δ_z from $\langle \Delta r' \rangle = \delta_z - \langle m \rangle \cdot \delta'_y \approx \delta_z$ ($\Delta r'$ with corrected y pos.)
- Grid scaling factor γ:
  $z(n) = z_0 + \gamma \cdot g_{nom} \cdot n$

Performance

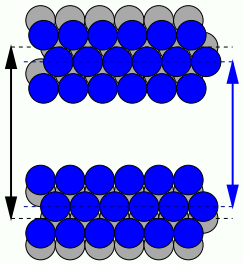


BOS5A08
(Exceptional chamber with known production error)

Comparison of measurements of Cosmic Ray Facility with X-Ray Tomograph gives accuracy

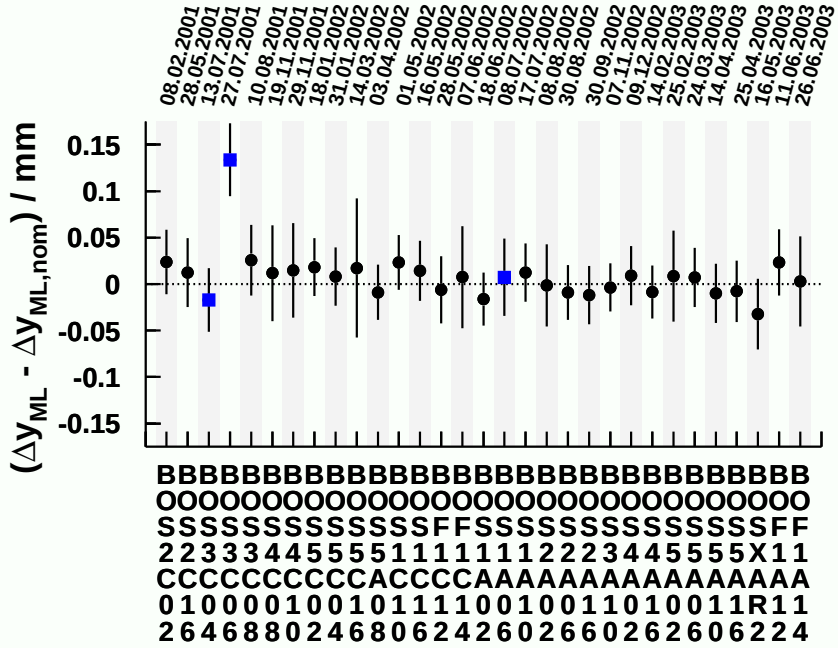
- Perpend. to chamber plane
  - δ_y: 25 μm
  - $\delta_{y,\ Layer}$: 4.5 μm
  - $\alpha_{x,\ Layer}$: 17 μrad
- In chamber plane
  - δ_z: 8 μm
  - $\delta_{z,\ Layer}$: 2 μm
  - g: 0.15 μm
- Agreement with Monte Carlo

Preliminary Results (1)



Multilayer y-Distance

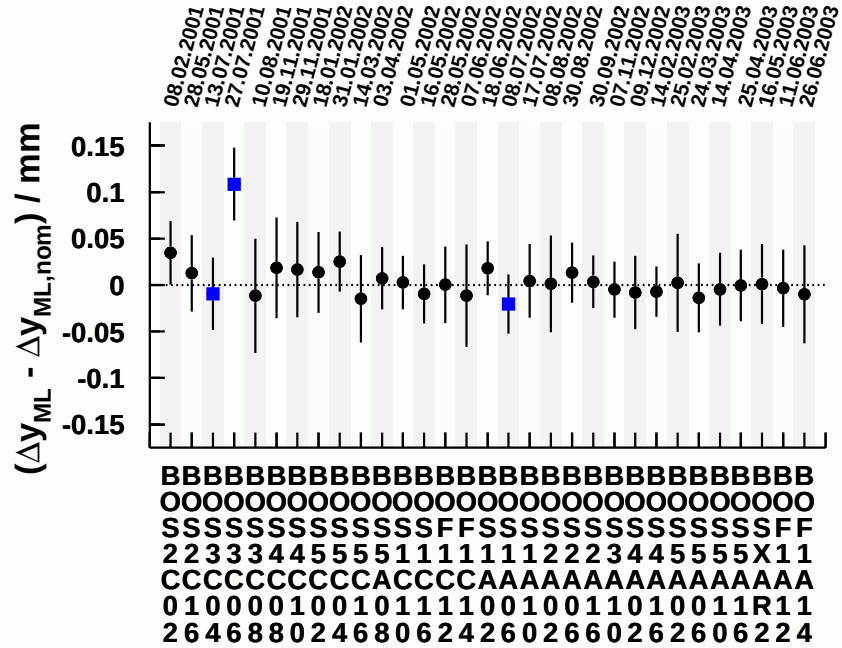
RO Side



Mean: 8.0 (3.7) μm

RMS: 26.8 (13.8) μm

HV Side



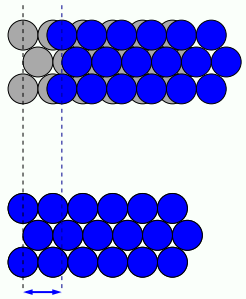
Mean: 5.0 (1.5) μm

RMS: 22.7 (10.8) μm

N.B.: Blue circles mark repaired chambers, values given in parentheses are without these MDTs

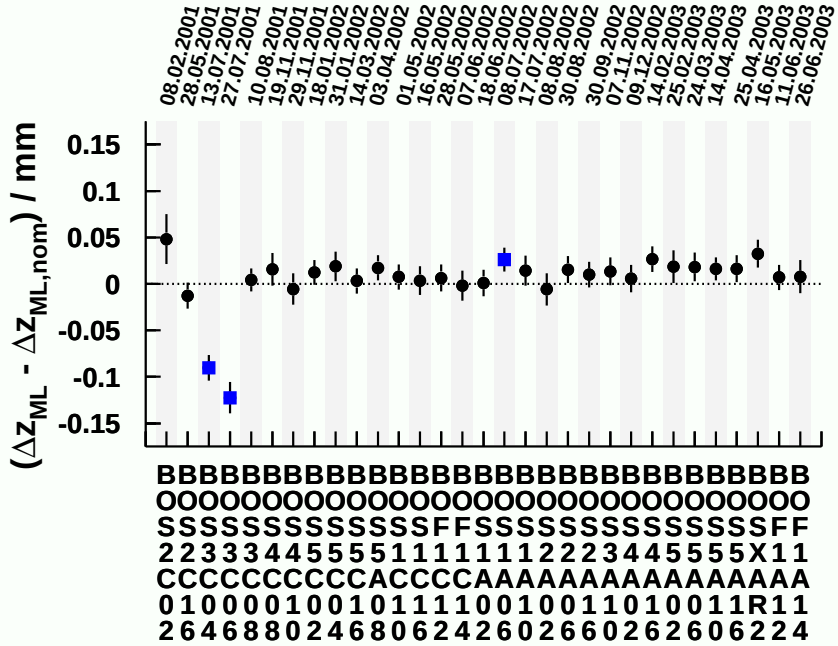
Error bars denote RMS spread of single tube deviation from linear fi t to multilayer data

Preliminary Results (2)

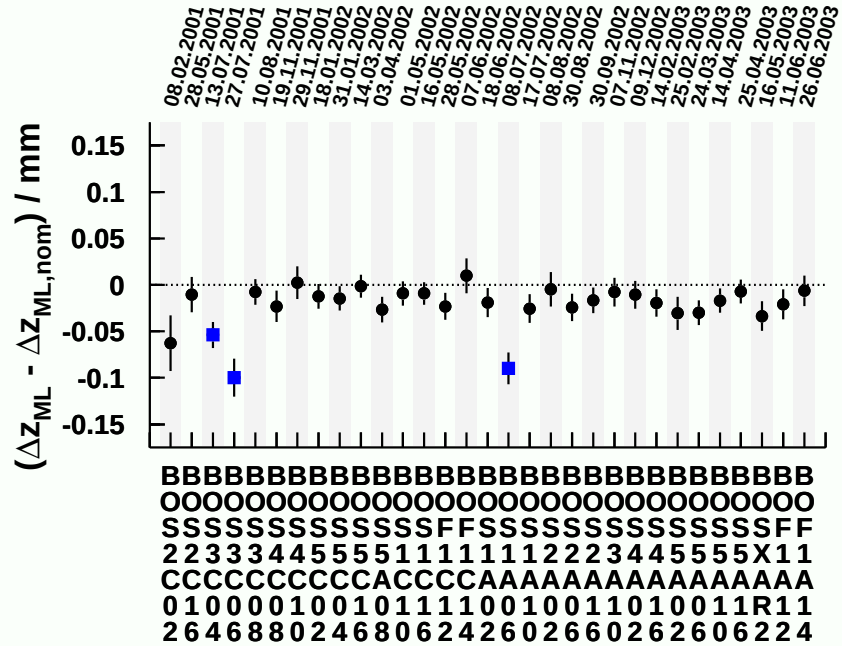


Multilayer z-Displacement

RO Side



HV Side



Mean: 4.1 (9.8) μm

RMS: 31.5 (9.9) μm

Mean: -22.8 (-14.8) μm

RMS: 23.9 (10.4) μm

N.B.: Blue circles mark repaired chambers, values given in parentheses are without these MDTs

Error bars denote RMS spread of single tube deviation from linear fi t to multilayer data

SUMMARY

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  - $\mathcal{O}(10\ \mu\mathrm{m})$ on wire positions
  - Few μm on chamber geometry

  Valuable anchor points for the calibration with LHC data

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  Valuable anchor points for the calibration with LHC data
- 31 BOS/BOF MDT chambers analyzed so far
  - ATLAS leak rate limit fulfilled
  - Very good homogeneity of tube response
  - Consistent chamber geometry throughout production time

Additional Slides

Leak Rate Meas. (1)

- Max. allowed leak rate: $2 \times N_{Tubes} \times 10^{-8}$ bar l/s
  $\longrightarrow$ 0.68 mbar / d
- 3460 O-ring seals in each chamber
- Leak test with He leak detector in sniffer mode, Ar/He mixture at 3 bar (2.6 bar Ar, 0.4 bar He)
- Precision absolute pressure measurement for each multilayer separately (0.1 mbar accuracy)
- $\delta T = 0.1\,^{\circ}C \longrightarrow \delta p = 1$ mbar
  $\Rightarrow$ need good temperature measurement / stabilization

  Difficult for a chamber of this size!

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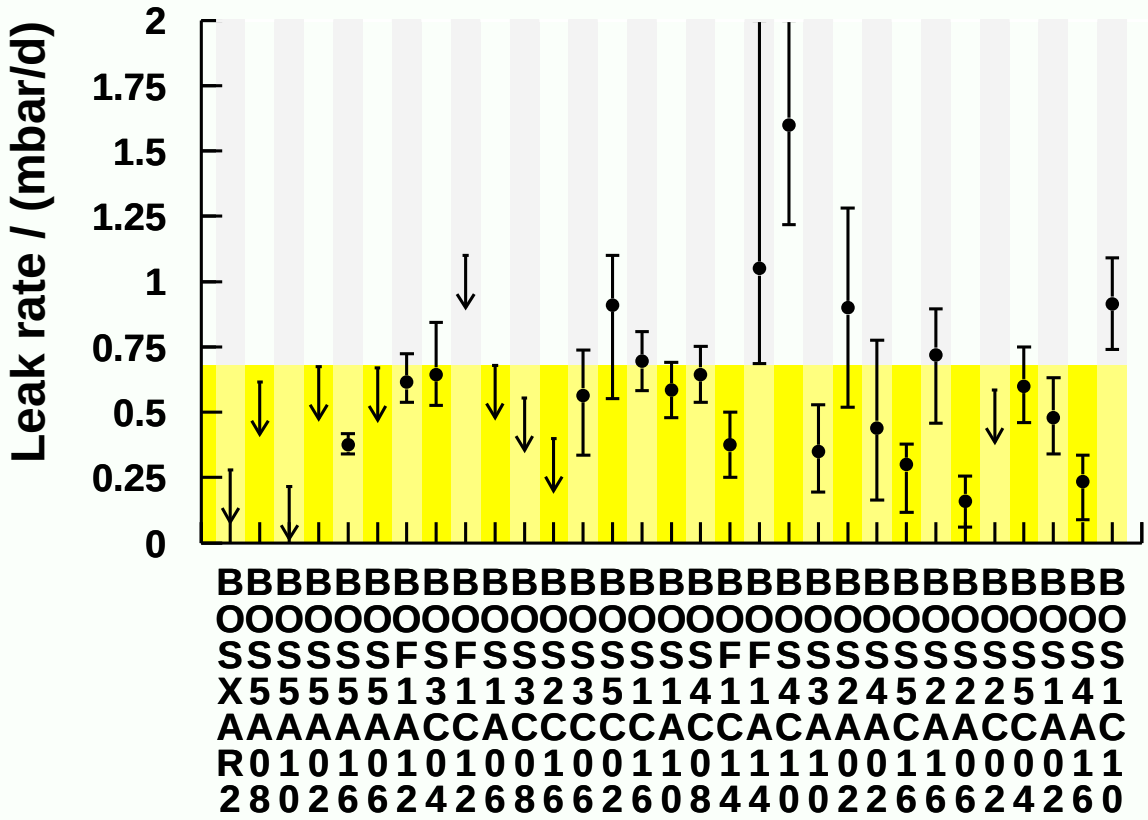
Leak Rate Meas. (2)

Max. allowed leak rate: 0.68 mbar/d



Chambers meet ATLAS requirements

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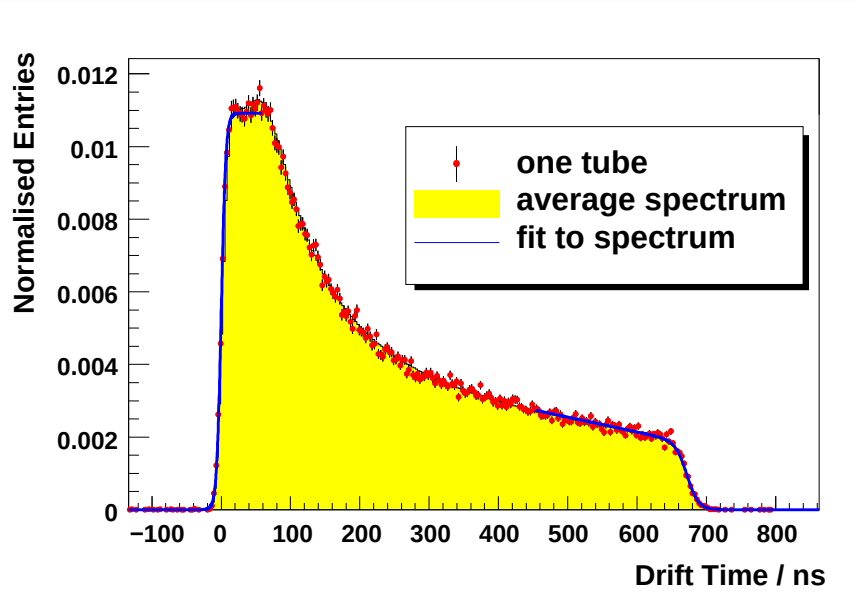
Fit Functions



Leading edge

$$F(t) = p_0 + \frac{A_0}{1 + \exp\left(\frac{t_0 - t}{T_0}\right)}$$

Trailing edge

$$G(t) = p_m + \frac{\alpha_m \cdot t + A_m}{1 + \exp\left(\frac{t - t_m}{T_m}\right)}$$

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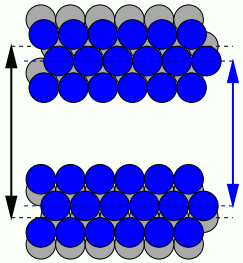
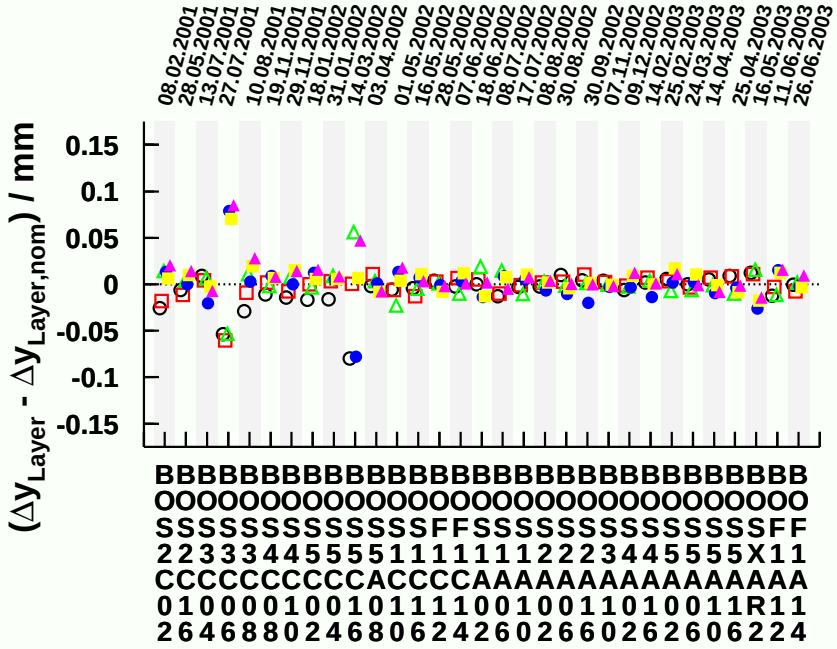
Preliminary Results (3)

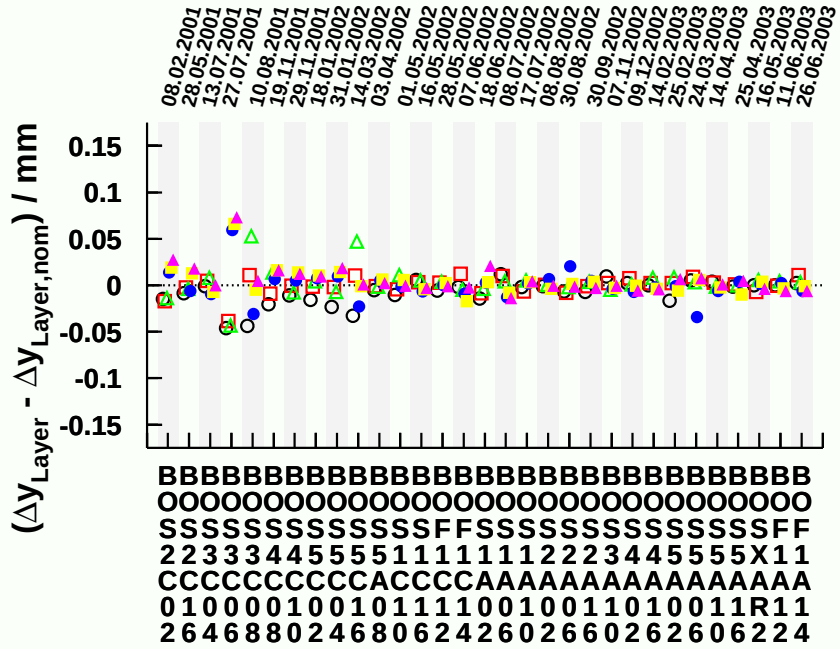


Layer y-Distance

RO Side



HV Side



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