Quality Control in the Construction of new small-diameter Muon Drift Tube (sMDT) Chambers for the ATLAS Muon Spectrometer at the HL-LHC

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FSP ATLAS
Erforschung von Universum und Materie

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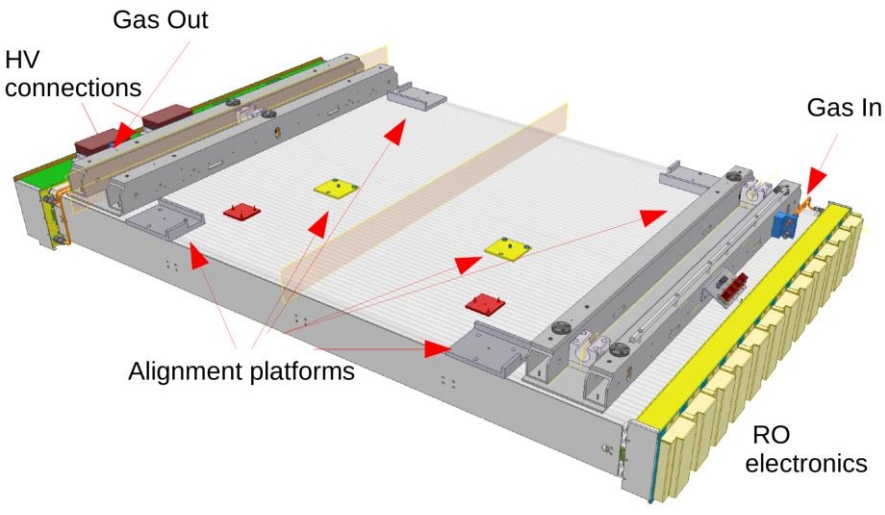
MAX PLANCK INSTITUTE FOR PHYSICS

Project Overview

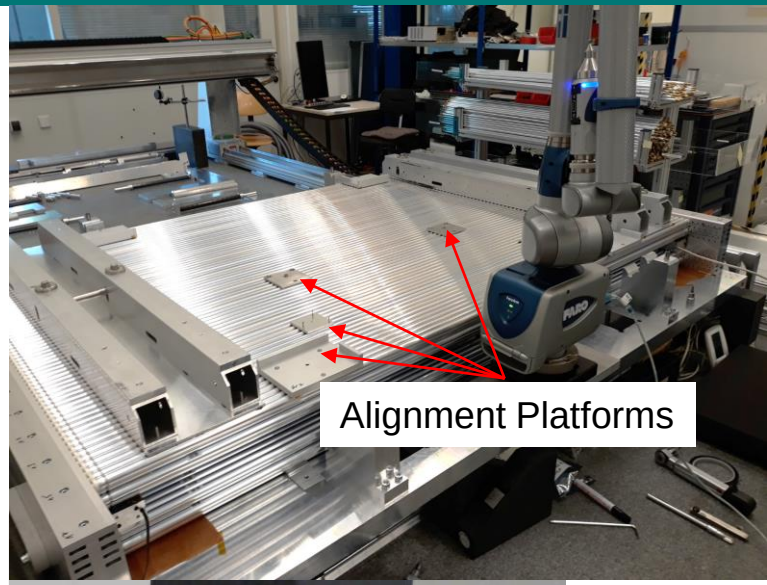
- Installation of 96 small-diameter Muon Drift Tube (sMDT) chambers + thin-gap RPCs during the ATLAS detector upgrade for the High-Luminosity LHC in the small barrel sector
- Goal: increase the trigger acceptance, rate capability, efficiency and selectivity
- sMDTs half the diameter of previous MDTs (30 mm → **15 mm**)
- 464 (BIS2-6) up to 560 (BIS1) sMDTs make up a chamber

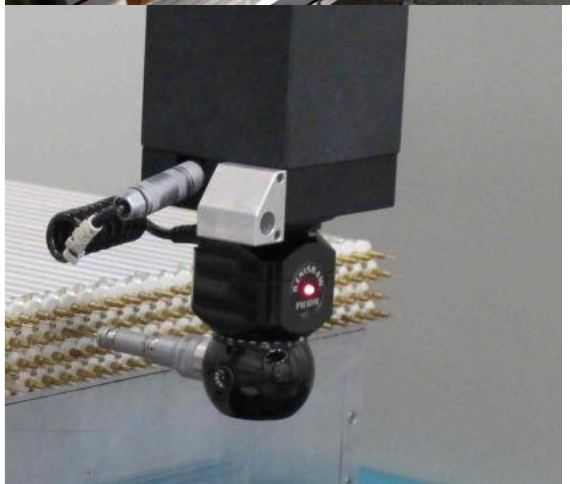


- Operated with Ar:CO2 (93:7) gas mixture at 3 bar absolute pressure and 2730 V operating voltage to provide a **single tube resolution of 100 microns**
- Sense **wire positioning accuracy of 20 microns** required to achieve desired momentum resolution
- 48+2 chambers built at MPI, 48+2 chambers built at University of Michigan

Quality Control Motivation

- High mechanical precision, high reliability and lifetime over >15 years of ATLAS operation at HL-LHC
- Stringent quality control and documentation of all components and at all steps of the chamber construction (see Alice's talk, T 23.5):
  - Tube production
  - Chamber and alignment sensor platform gluing
  - Wire position measurements
  - Gas system installation (covered by Alice)
  - Electronics installation (covered by Alice)
  - Cosmic ray tests (covered by Alice)





Drift Tube QC

Wiring and wire tensioning stations

Gas tightness and dark current tests

- Drift tube production under **class 1000 clean room** conditions to avoid any contamination
- Semi-automated assembly
- Up to 300 tubes can be produced + tested per week

Drift Tube QC:

- **Gas leakage rate**
  - Tube filled with Ar:He (95:5) gas mixture at 3 bar overpressure in evacuated cylinder
  - detecting leaking He, translate to leaking Ar
- **Dark current**
  - Dark current tested with nominal $ArCO_2$ gas mixture at the nominal voltage + 300 V
  - Measured and averaged over 10 minutes

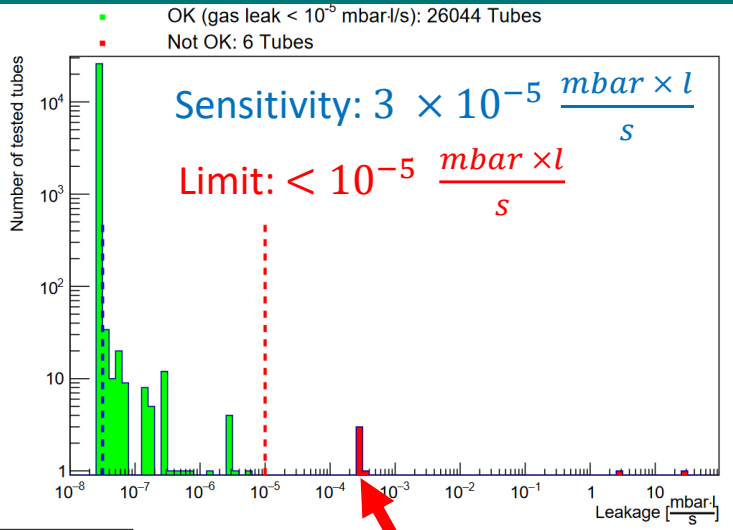
Drift Tube QC

- **Tube length**
  - Selection into 3 length categories
  - Tubes of similar lengths in the same multilayer to avoid problems during gas system installation
- **Wire tension**
  - Assures knowledge of wire position over whole tube length
  - 2 measurements with over 2 weeks delay → make sure wires don't slip out of the crimps
- Production **failure rate** ~5 %

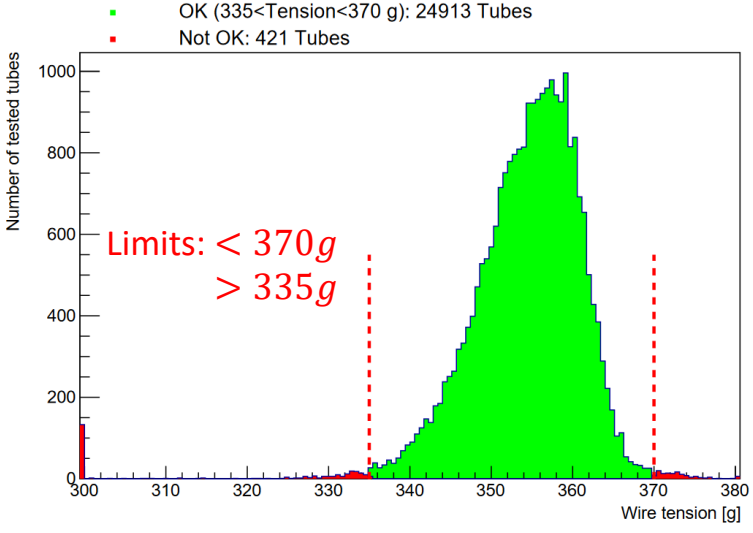
Drift Tube QC

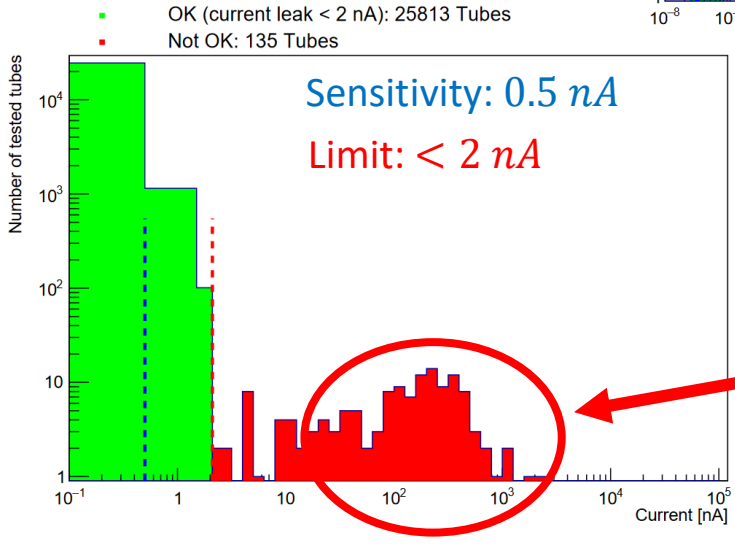
Tube certification:

- Each tube labeled and identified with a bar code in the QC database including its location in the chamber
- Tubes checked to be "**good**" according to the database **before gluing** them in the chamber



Nearly no rejections

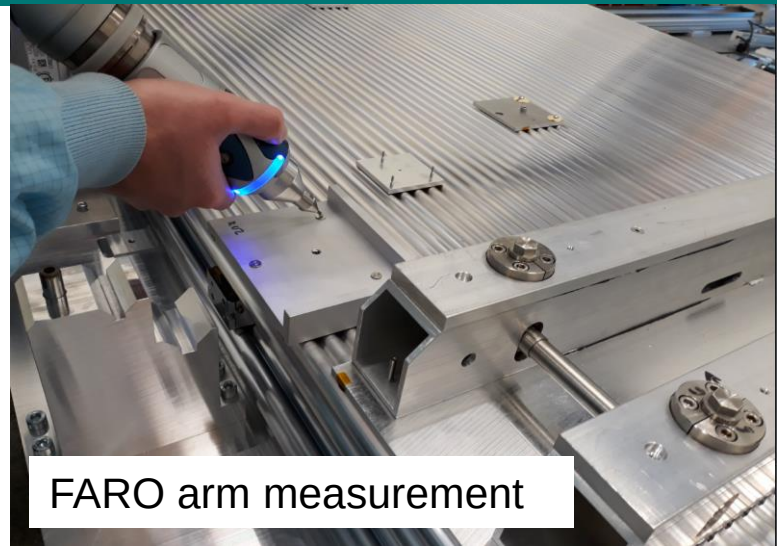




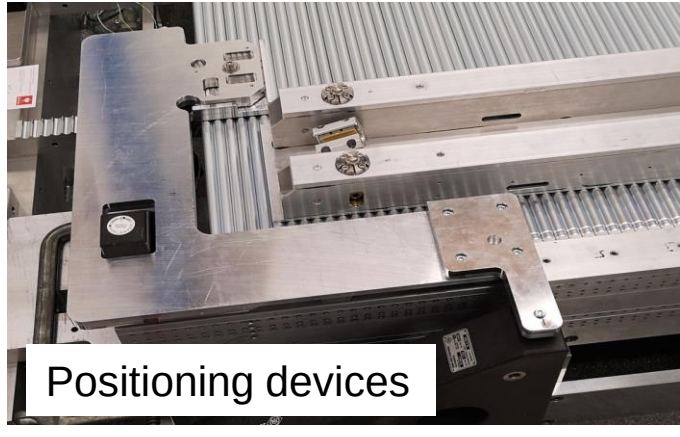
Dust contamination inside tubes for short time period

Alignment Platforms

- Chamber and platform gluing in temperature-controlled class 10000 clean room
- Platforms for mounting of optical sensors of the global chamber alignment monitoring system
- 3D electro-mechanical feeler (FARO arm) measures platform positions in each direction → **tolerance of 200 (500) µm** for AP and CCC (B-field) platforms
- Positions relative to the sense wire grid must be known with **at least 30 µm precision**
- FARO arm measurement **achieves 10 µm precision**



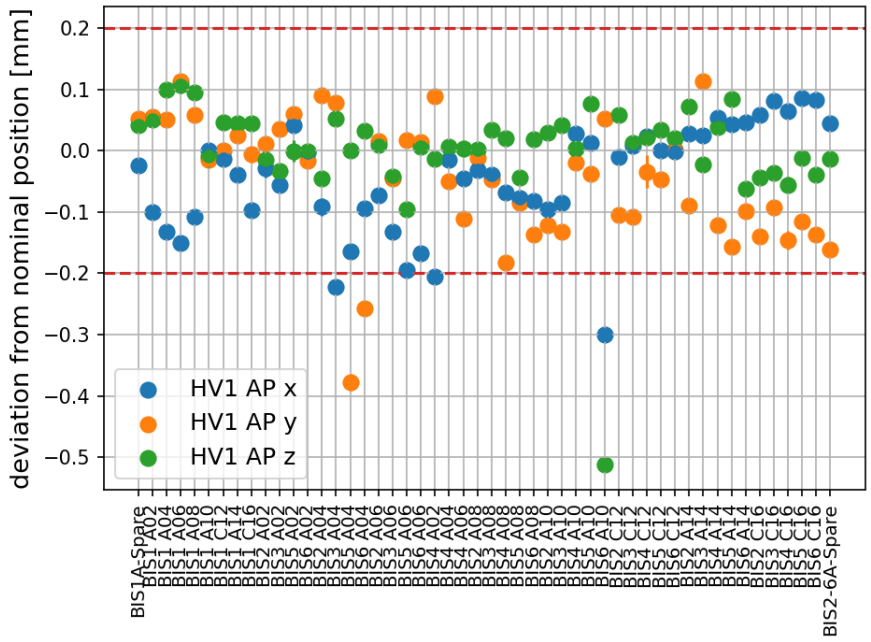
FARO arm measurement

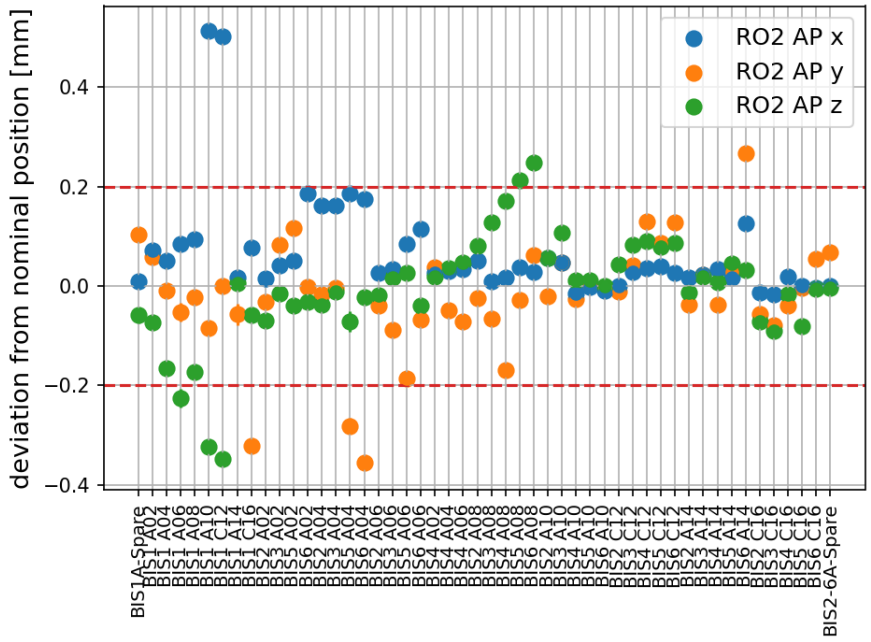


Positioning devices

Platform Positions

- E.g. AP platform position results:

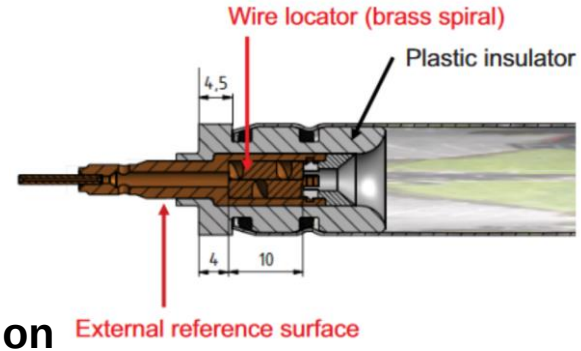


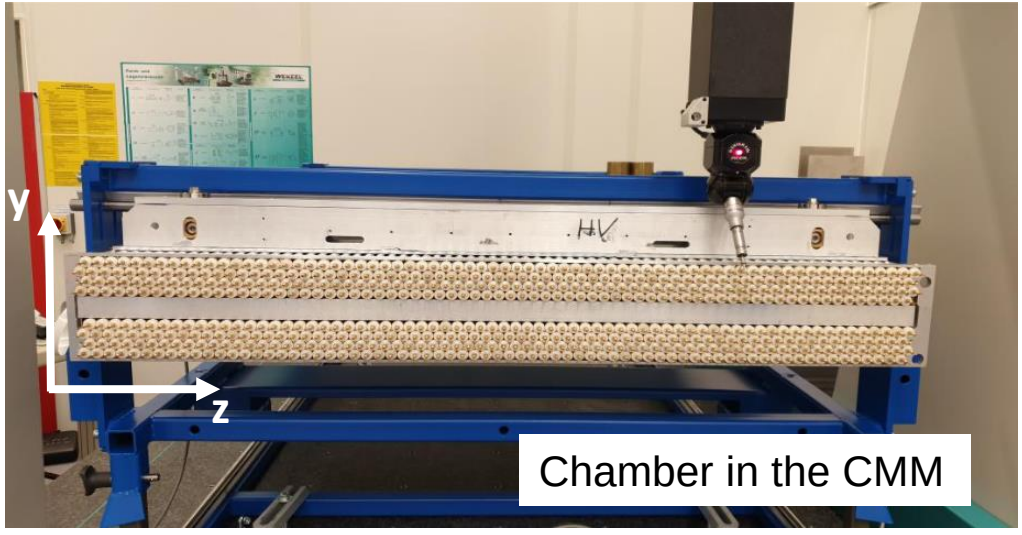


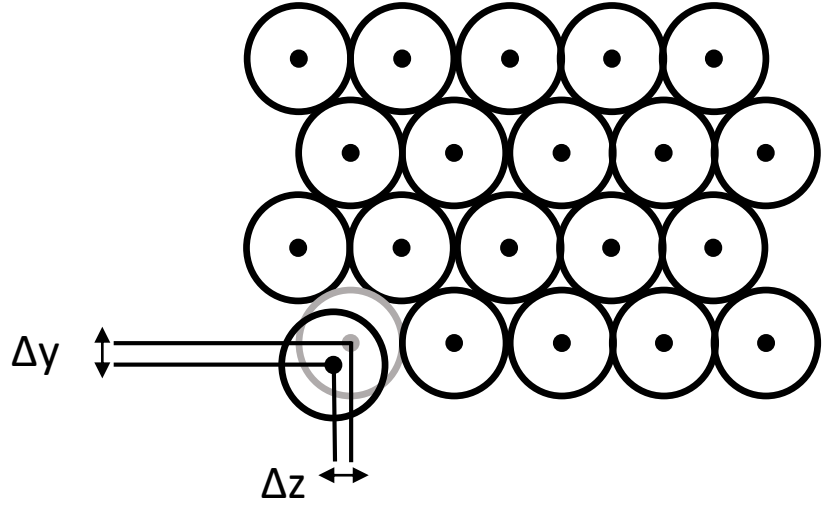
- All 3 angles are derived from measurements as well
- Platform positions **within specifications with few exceptions**

Wire Position Measurements

- Automated Coordinate Measurement Machine (CMM) used to measure position of each endplug
- Derive wire position accuracy w.r.t. fitted sense wire grid Δr ($r^2 = y^2 + z^2$)
- **20 µm precision required** to achieve desired momentum resolution
- Monitor further important quantities: layer distances, gravitational sag, **torsion**



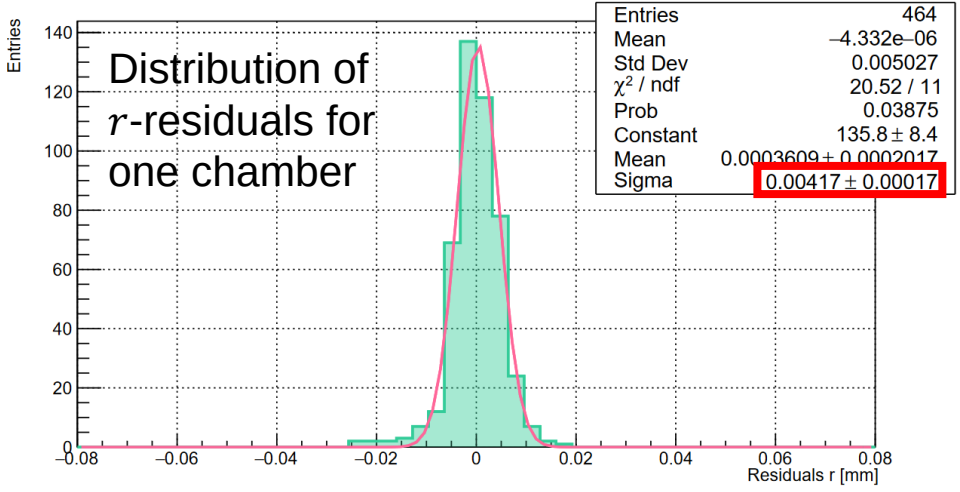


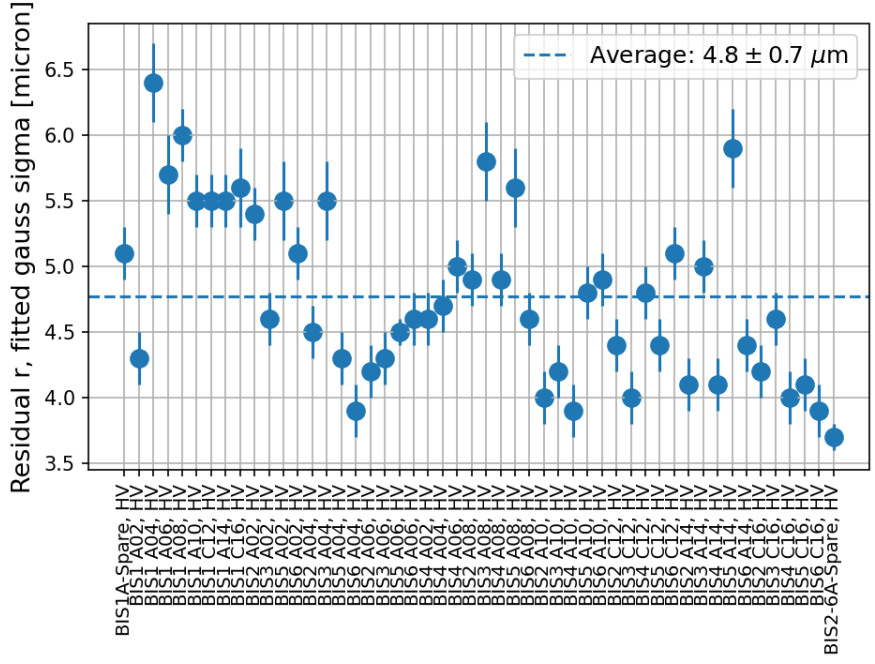


Wire Position Measurements

- Residual Δr (w.r.t. fitted wire grid) calculated for both sides (RO, HV) of each chamber
  - Wires positioned with around **5 µm precision** relative to the wire sense array

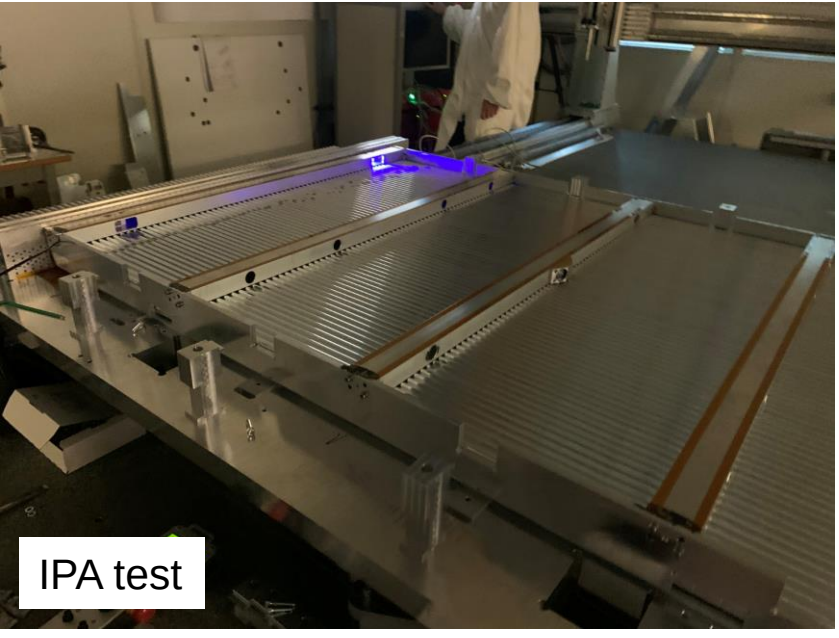
  → Well below the required 20 µm!





In-Plane Alignment System and Torsion

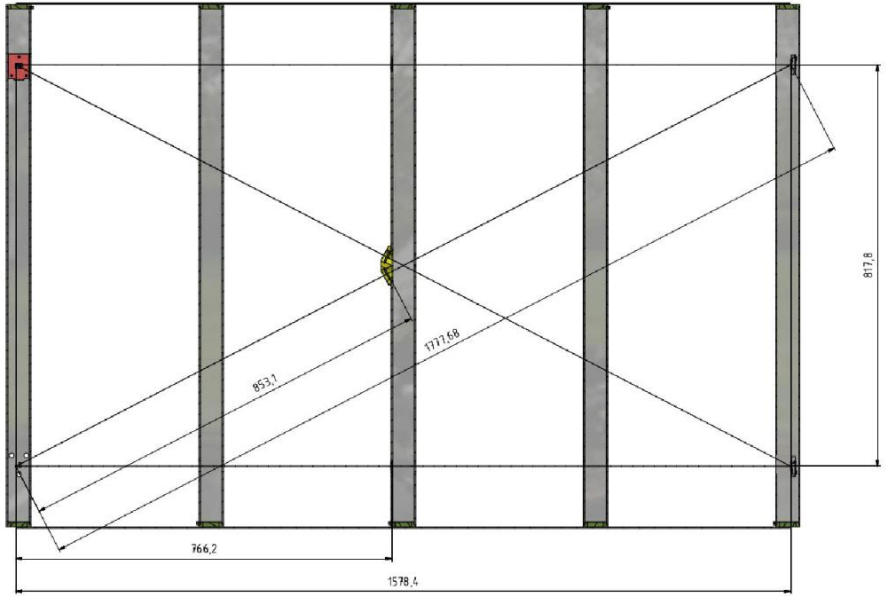
- In-Plane Alignment System (IPA) situated in the spacer between the multilayers
- Responsible for the monitoring of unstable **chamber torsion**
- Validate IPA configuration by comparing CMM and IPA torsion results



2 CCD Cameras

4 lenses

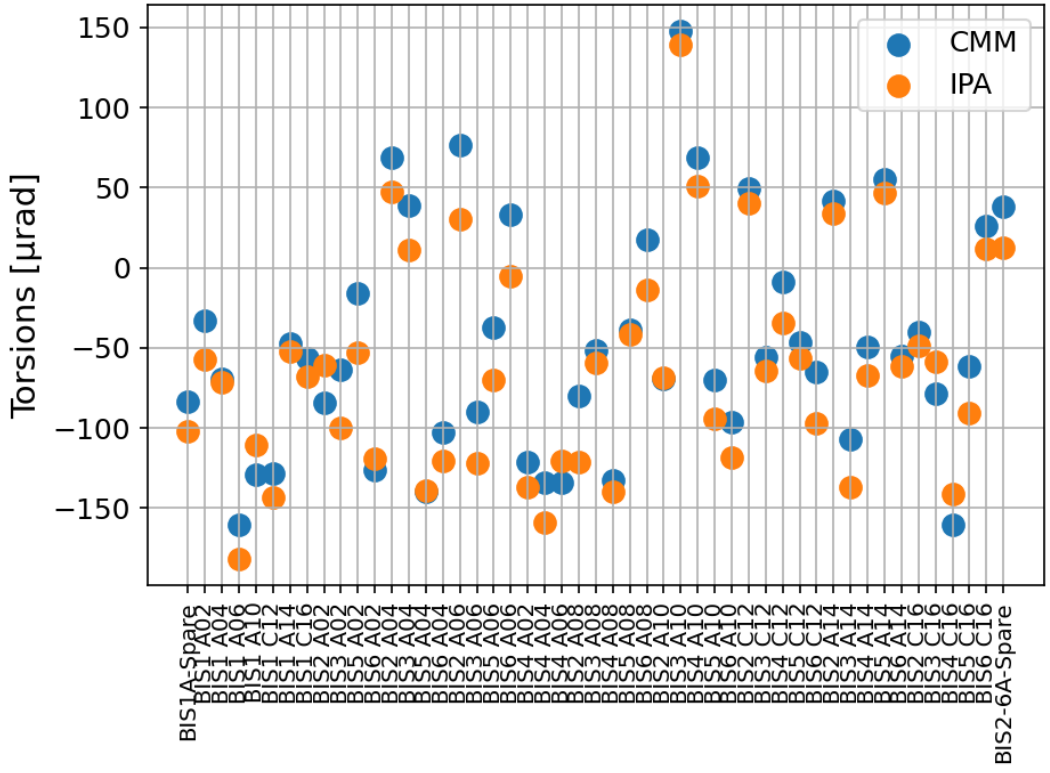
2 LEDs projecting chessboard-like patterns



In-Plane Alignment

- CMM and IPA torsion angles typically **within < 20 µrad** of each other

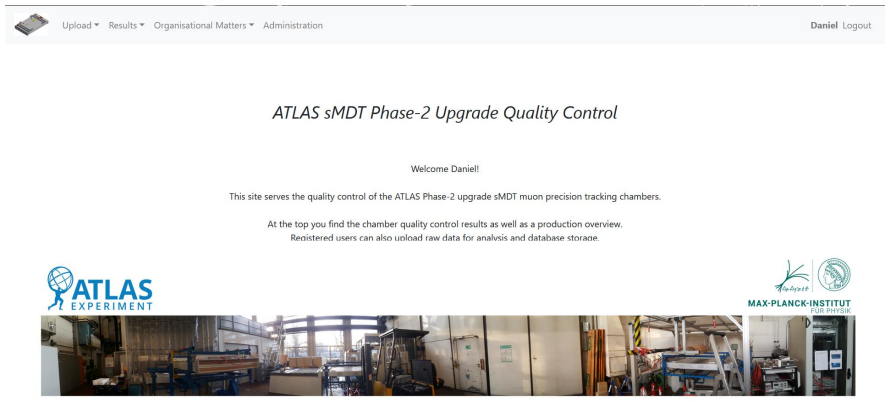
  → Negligible compared to overall torsion variation, validates IPA precision



Quality monitoring

- **Common QC database** for the two production sites at MPI Munich and Michigan, hosted at CERN
- Web-frontend, **upload raw data** from QC measurements
- **Automated analysis** of e.g. platform position or CMM wire position measurements
- Mechanical and electronics performance posted on webpage in real time
- **Automatic email notification** of experts about new results

  → fast feedback for the chamber construction
- **Storage of data** about each individual drift tube and chamber production steps

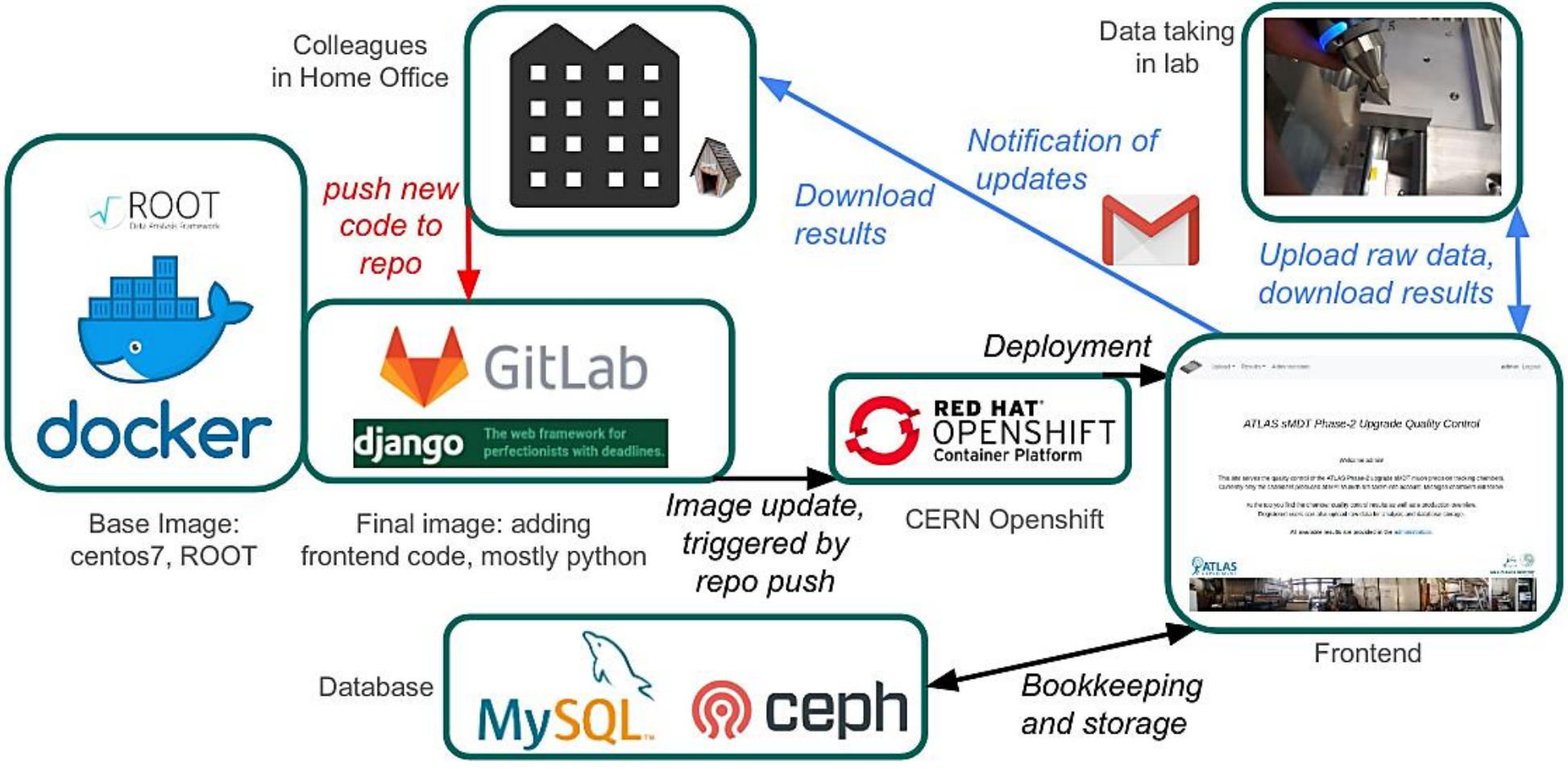


Summary

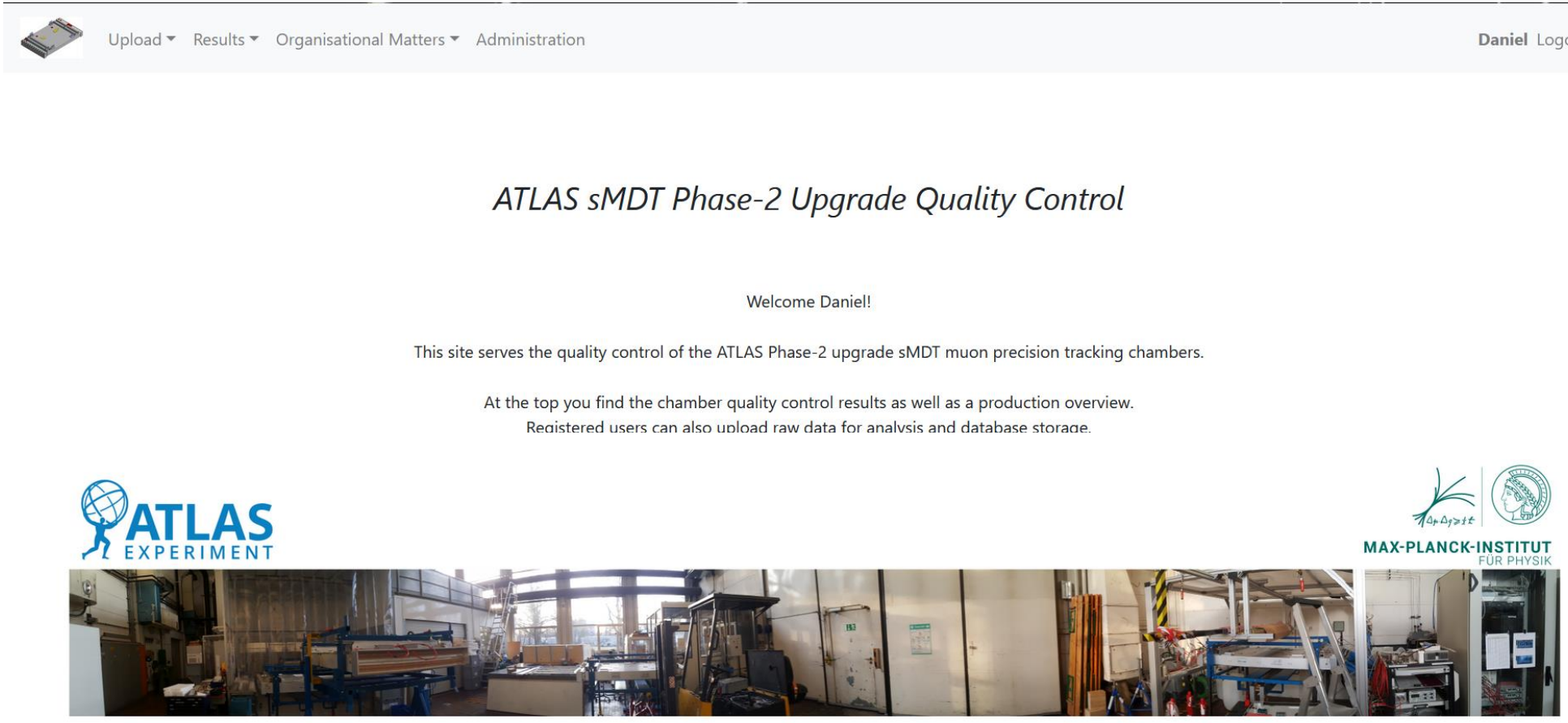
- Stringent and exhaustive QC program essential part of series production of new sMDT chambers for the ATLAS phase-2 upgrade
- Tube production finished with excess of tubes, multiple tests before certification for gluing
- Validation of chamber quality in every step of production
- Database with web-frontend to assure fast tracking of the quality measurements
- All 48+2 chambers constructed at MPI, 42+1 certified and 38 chambers shipped to CERN already
- QC continues at CERN!

BACKUP

How it works


Colleagues
in Home Office
Data taking
in lab
Notification of
updates
Download
results
Upload raw data,
download results
push new
code to
repo
ROOT
docker
GitLab
django
The web framework for
perfectionists with deadlines.
Deployment
RED HAT
OPENSHIFT
Container Platform
ATLAS sMDT Phase-2 Upgrade Quality Control
Base Image:
centos7, ROOT
Final image: adding
frontend code, mostly python
Image update,
triggered by
repo push
CERN Openshift
Frontend
Database
MySQL
ceph
Bookkeeping
and storage

QA/QC Webpage

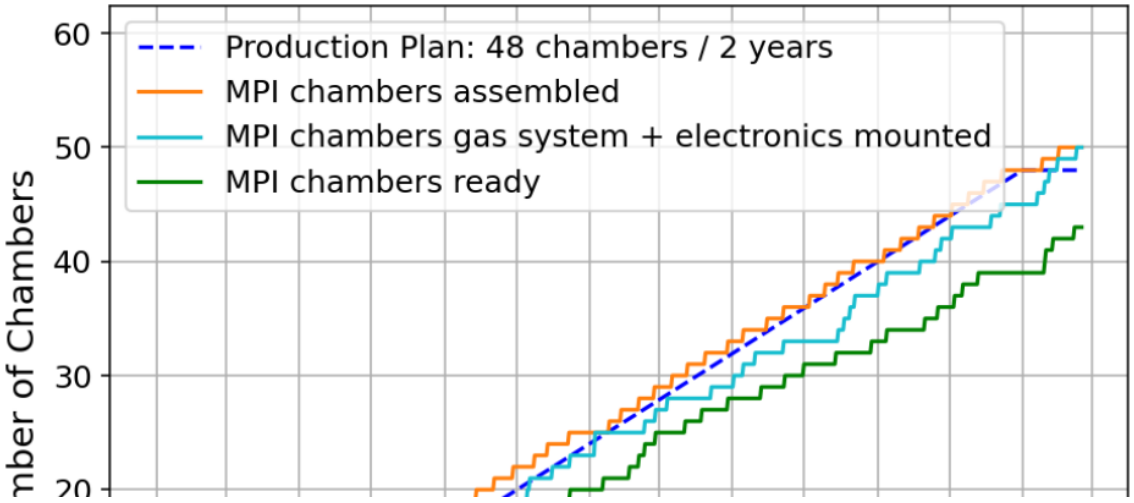


Production Overview

Chamber Production | Gas Leakage | AP Platform Positions | CCC/B Platform Positions | CMM | CMM Residuals | Torsion | Cosmic

MPI Overview

Chamber Production Progress



Camber Overview

Upload ▾ Results ▾ Organisational Matters ▾ Administration **Daniel** Logout

Overview | Tubes | Rasnik Reference Data | Rasnik Data | Platform Positions | CMM Data | Gas Tightness | Electronics

MPI Module 25: BIS3 A08

Electronics	No
Gas Tightness	Yes
CMM Data	Yes
Platform Positions	Yes
Rasnik Reference Data	Yes
Rasnik Data	Yes

Technical Drawing

Measurement Results

MPI Module 25: BIS3 A08

RO Axial-Praxial 1

Coordinate	Distance	Distance Stat. Error	Distance Nominal	Offset to Nominal
x	424.026	0.005	424.000	0.026
y	19.409	0.007	19.500	-0.091
z	90.482	0.005	90.450	0.032

HV Axial-Praxial 1

Coordinate	Distance	Distance Stat. Error	Distance Nominal	Offset to Nominal
x	1333.976	0.005	1334.000	-0.024
y	19.453	0.009	19.500	-0.047
z	90.488	0.009	90.450	0.038