Construction of New Small-diameter Muon Drift Tube (sMDT) Chambers for the HL-LHC Upgrade of the ATLAS Muon Spectrometer

Alice Reed

on behalf of the ATLAS muon working group at MPP Munich

Max Planck Institute for Physics, Munich

FSP ATLAS
Erforschung von Universum und Materie

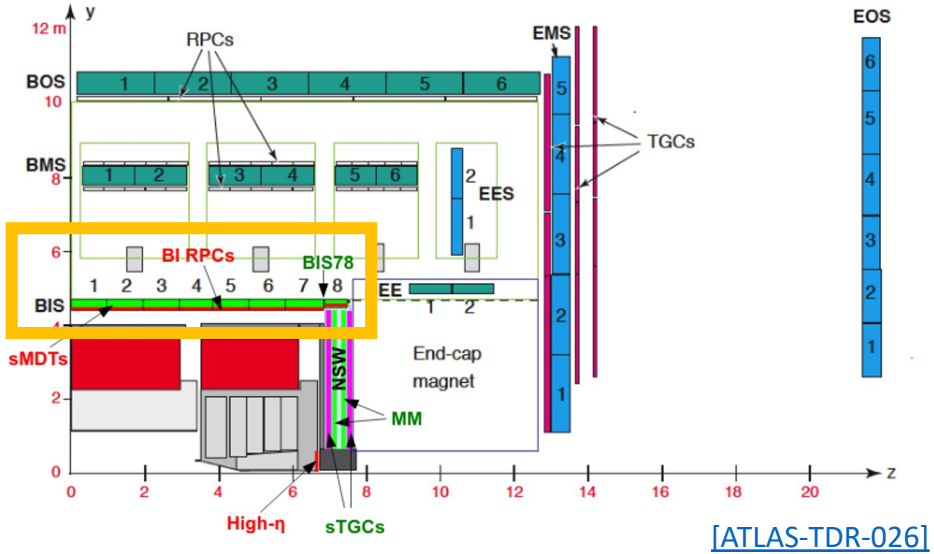
March, 2023

MAX PLANCK INSTITUTE FOR PHYSICS

Introduction

- The High-Luminosity LHC (HL-LHC), aims to deliver integrated luminosities at least 5x the current LHC nominal

- The ATLAS muon spectrometer will undergo major upgrades to cope with the increased background counting rate including:
  - New trigger and readout electronics
  - New thin-gap resistive plate chambers (RPCs) in the barrel inner layer



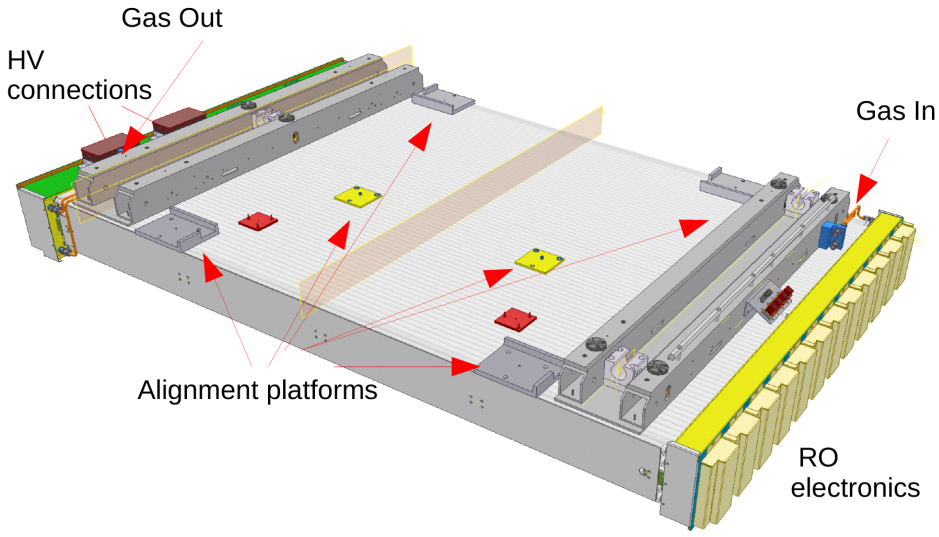
[ATLAS-TDR-026]

- Replacing the current muon drift tube chambers (MDT) in the small sectors of the inner layer with small-diameter muon drift tube chambers (sMDT)

- Aim of these upgrades: increase the trigger acceptance, efficiency and selectivity

sMDT Chamber Overview

- sMDT chambers consist of 464 (BIS2-6) or 576 (BIS1) small-diameter muon drift tubes
- Drift tubes arranged in 2 multilayers of 4 layers (8 layers total)
- High voltage side contains the HV electronics connections and the tubes are read out on the RO side

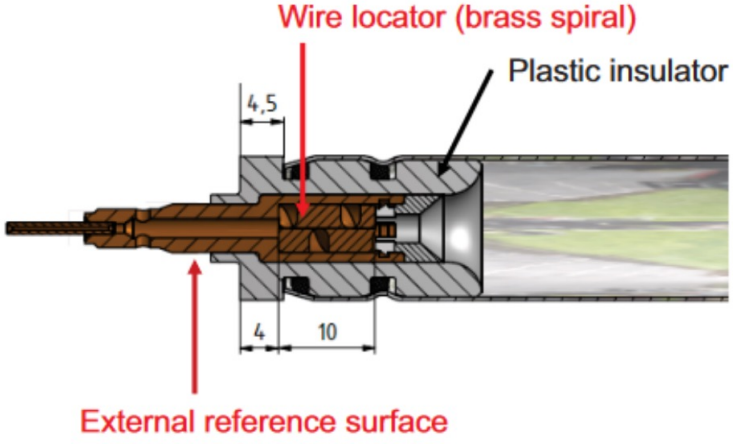


- Operated with Ar:CO_2 (93:7) gas mixture at 3 bar absolute pressure and 2735 V to provide a single tube resolution of 100μm
- 48 (+2 spare) chambers built at MPI Munich, 48 (+2 spare) chambers built at University of Michigan and Michigan State University
- Drift tube endplugs, chamber supports and transportation frames provided by Protvino for all MPI and Michigan chambers

sMDT Tubes

- sMDT chambers consist of drift tubes with a diameter of 15 mm, half the diameter of the drift tubes of the MDTs
- Background reduced by a factor of 2
- Maximum drift time reduced by a factor of 4

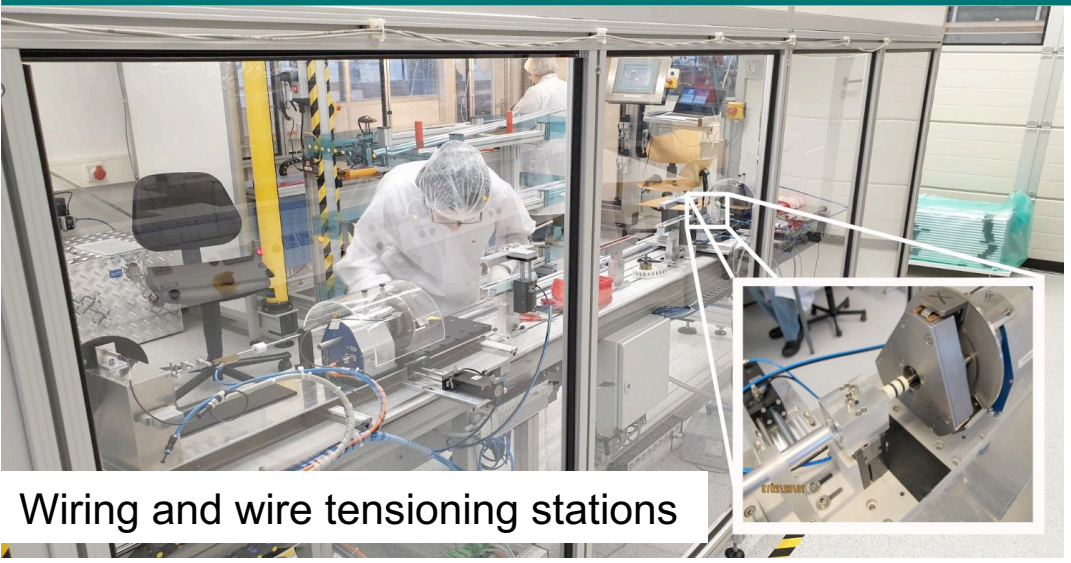
  → Occupancy reduced by a factor of 8



- Drift tube endplugs contain a brass insert (surrounded by an insulator) containing a spiral wire locator
- This spiral locator ensures the wire position is known relative to the external reference surface with a precision of 1µm

Figures: [ATLAS-TDR-026]

Drift Tube Production



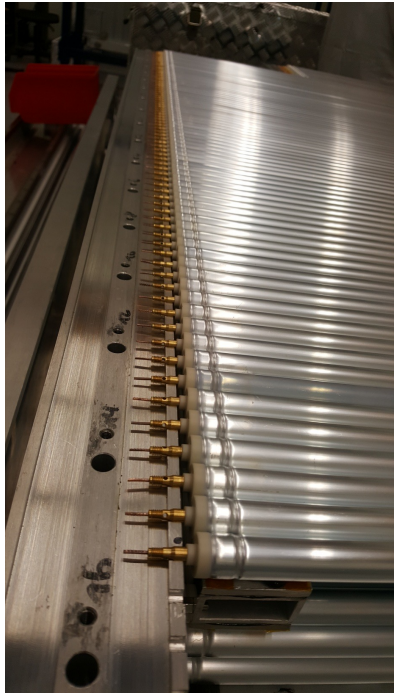
Wiring and wire tensioning stations

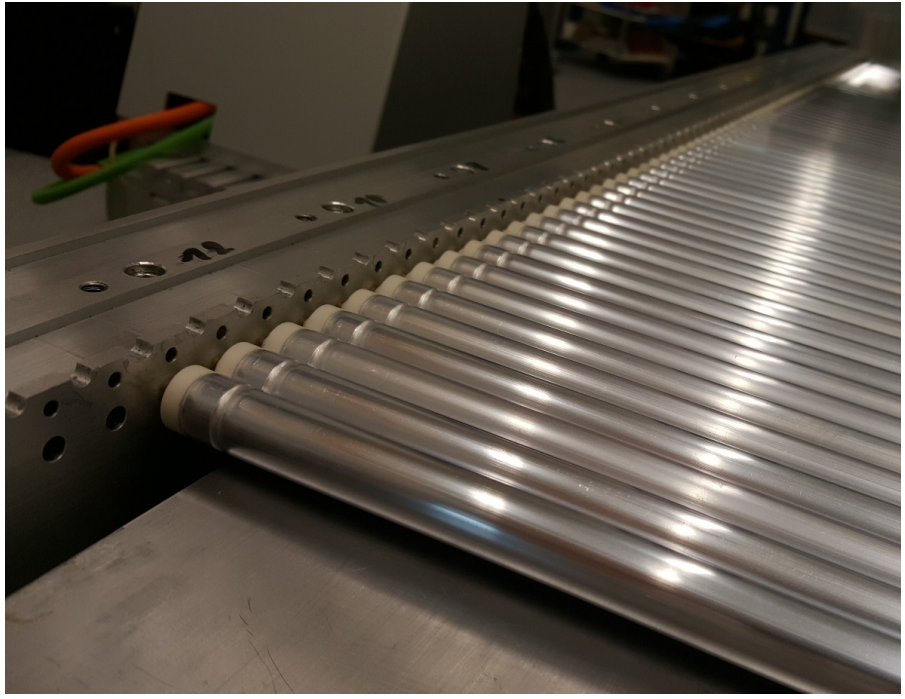
Gas tightness and dark current tests

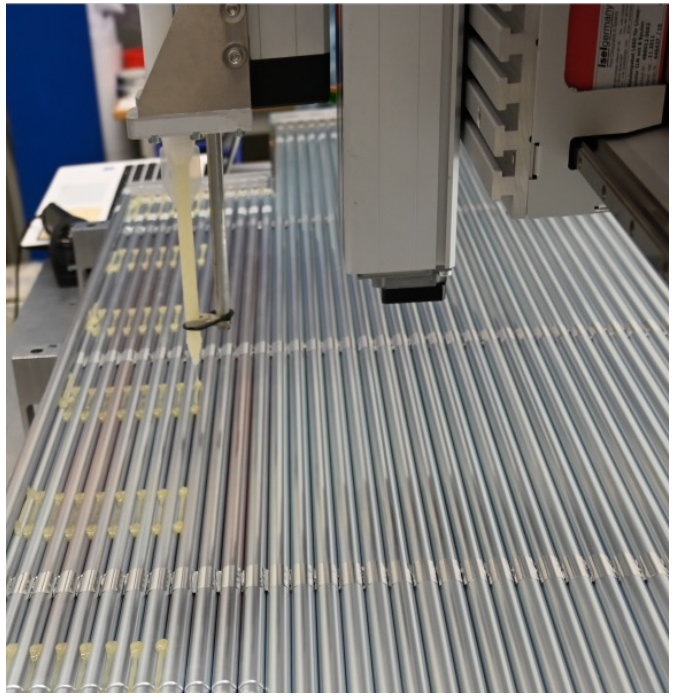
- Drift tube production under class 10000 clean room conditions to avoid any contamination
- 50μm sense wire passed through the raw Al tube using an air flow through the tube
- Sense wire is tensioned and endcaps fixed in place to maintain desired tension
- Semi-automated assembly to avoid direct contact with wire by hand
- Wire tension, dark current and gas leakage of each tube is measured during production
- More information on tube testing and certification can be found in Daniel's talk T23.4

Chamber Assembly

- 8 layers of drift tubes are glued into place on a granite table in a temperature controlled clean room in 2 multilayers (4 layers in each multilayer)
- Tubes positioned by placing the endplugs in combs during gluing

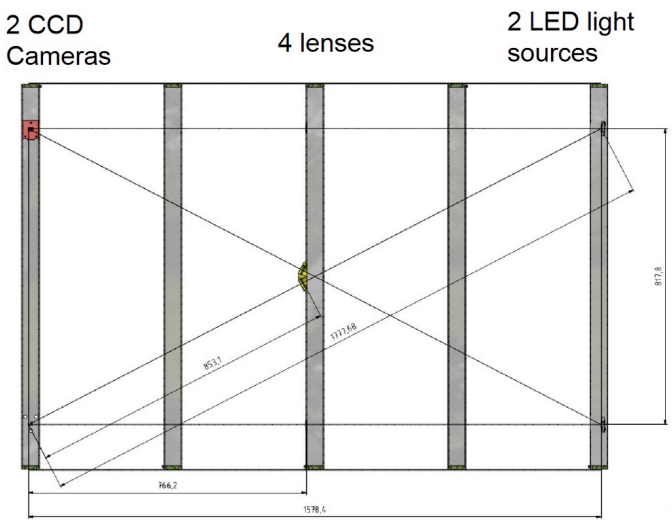


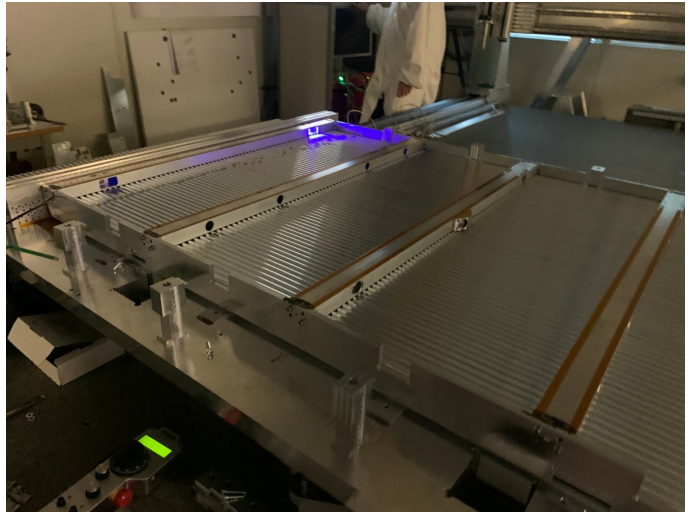




In-Plane Alignment System

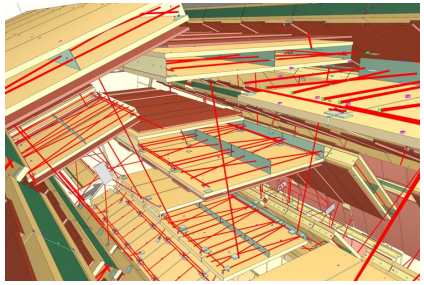
- In-Plane Alignment System (IPA), situated in the spacer, is glued between the 2 multilayers
- IPA consists of 2 LEDs and 2 CCDs – changes in the optical path length corresponds to torsion in the chamber
- Space for chambers is restricted so support between multilayers must be <5cm high
- Chamber torsion can occur and needs to be monitored after chamber installation

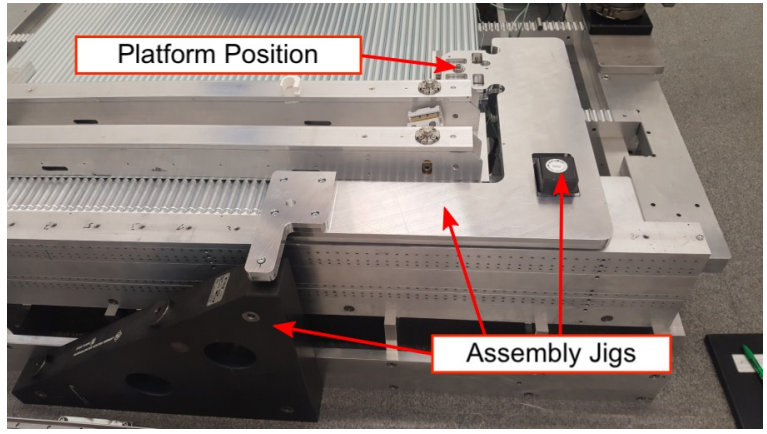




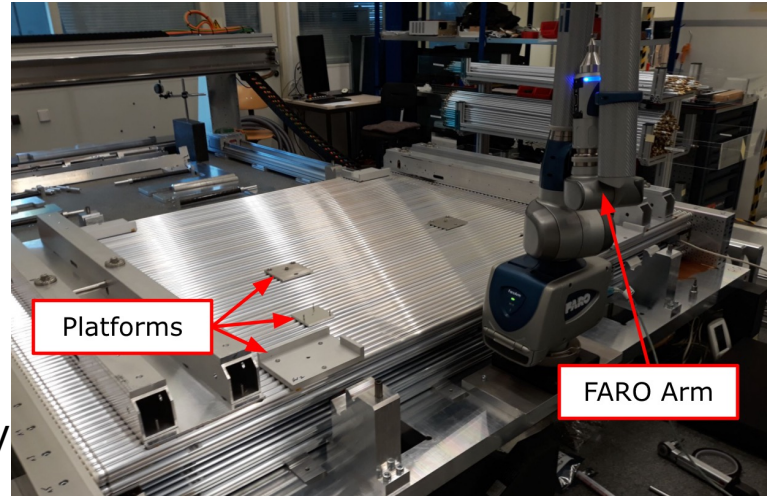
Alignment Platform Gluing

- Position of the chambers within the detector after installation is monitored by the global optical alignment system:



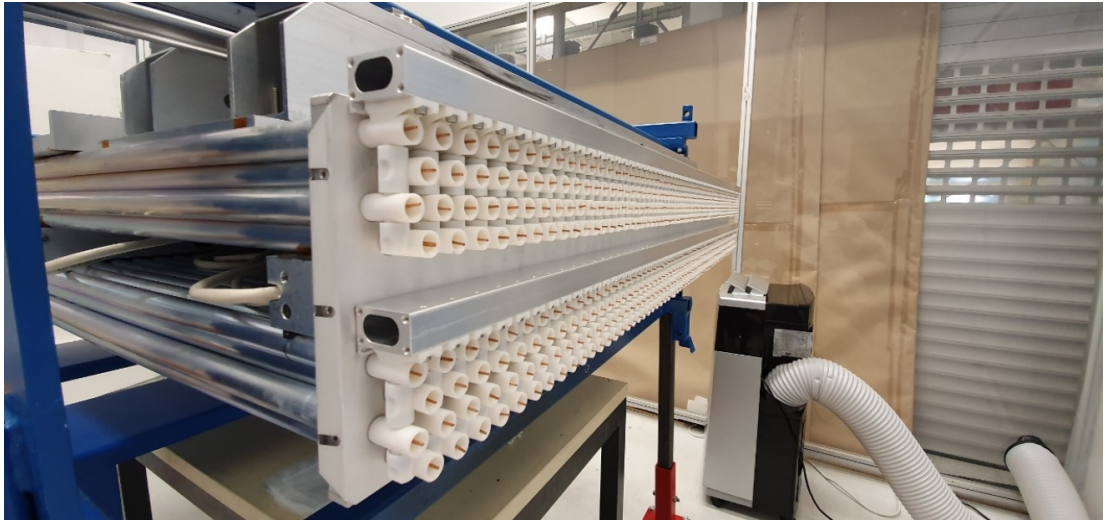


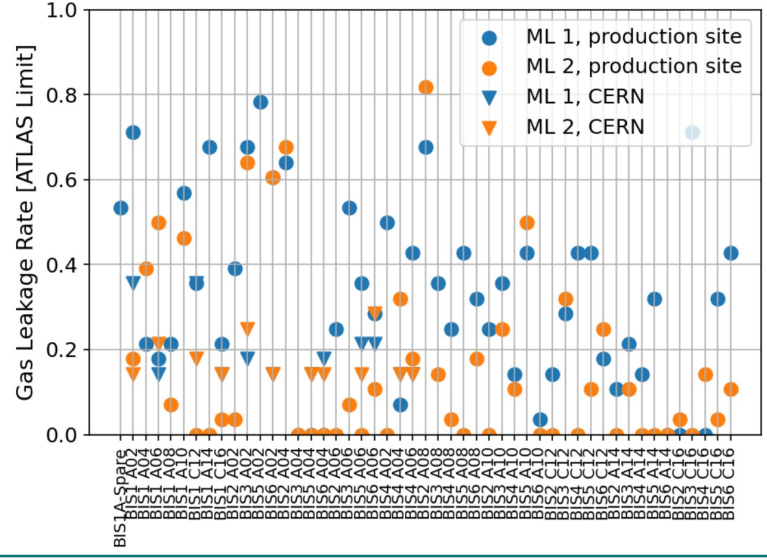
- Platforms for the optical sensors are glued in position on top of the chamber layer 8 using assembly jigs
- Platform positions then measured using a 3D electromechanical feeler arm (FARO arm)
- Position of platforms relative to the sense wire grid must be known with a precision of < 30 µm
- More information on platform position measurements and quality control can be found in Daniel's talk T23.4



Gas System

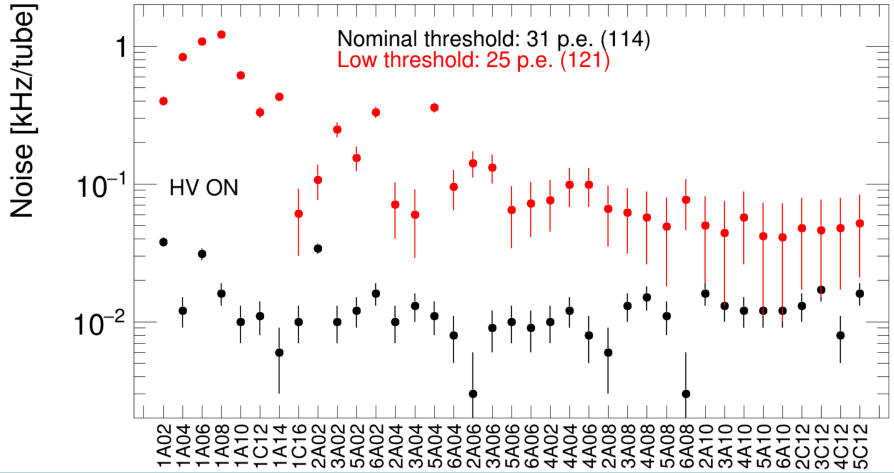
- Before a chamber can be certified, the gas system and electronics are installed and tested
- Gas system is mounted in a temperature controlled clean room
- Gas leak rates are measured after the gas system mounting, after the electronics are installed and again once the chambers have arrived at CERN
- Leak rates well below ATLAS limit (6.7 mbar in 24 h) for all chambers

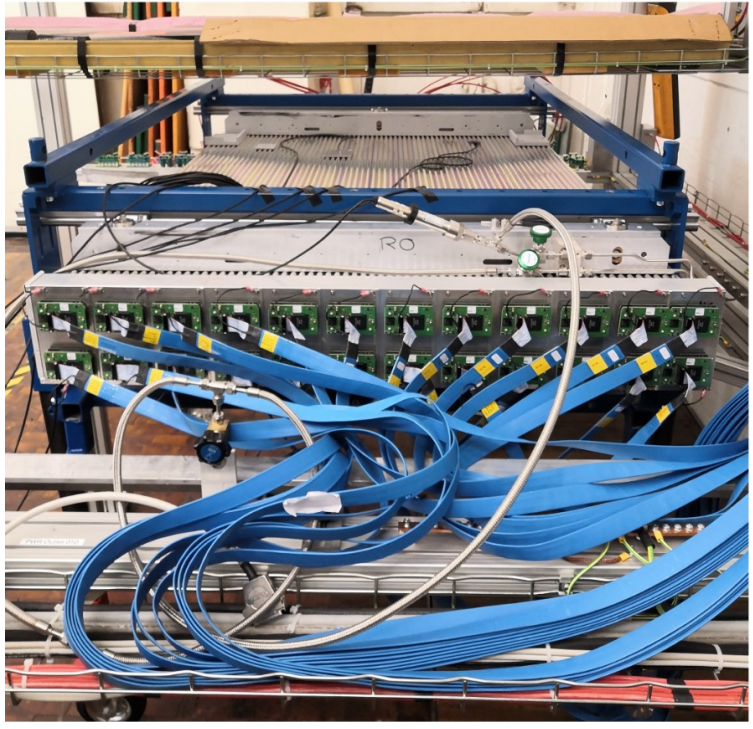




Electronics Installation

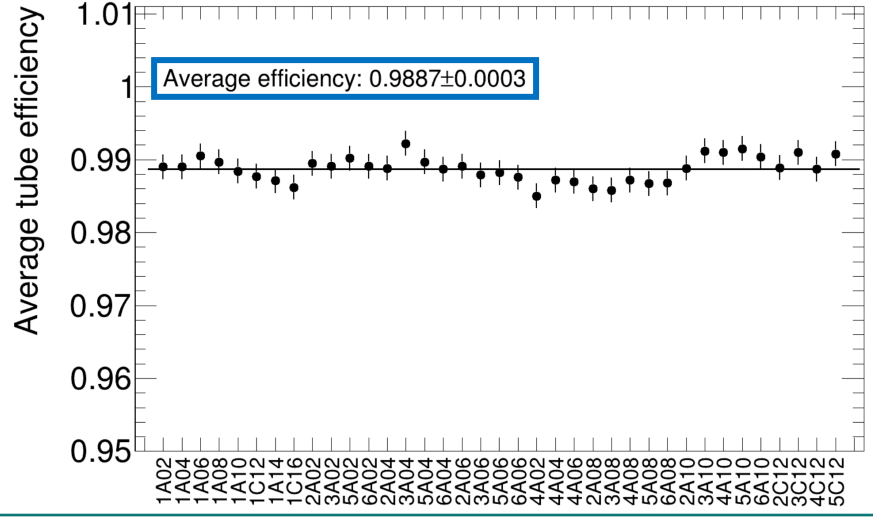
- Read-out electronics are installed and tested in a cosmic-ray test stand (43 chambers tested)
- Tube noise rates are measured with and without applied operating voltage (all tubes required to have noise < 1 kHz at nominal threshold)
- Chambers also tested at a low threshold to test performance in case of grounding
- Recent chambers have average noise <100Hz, even at the low threshold:

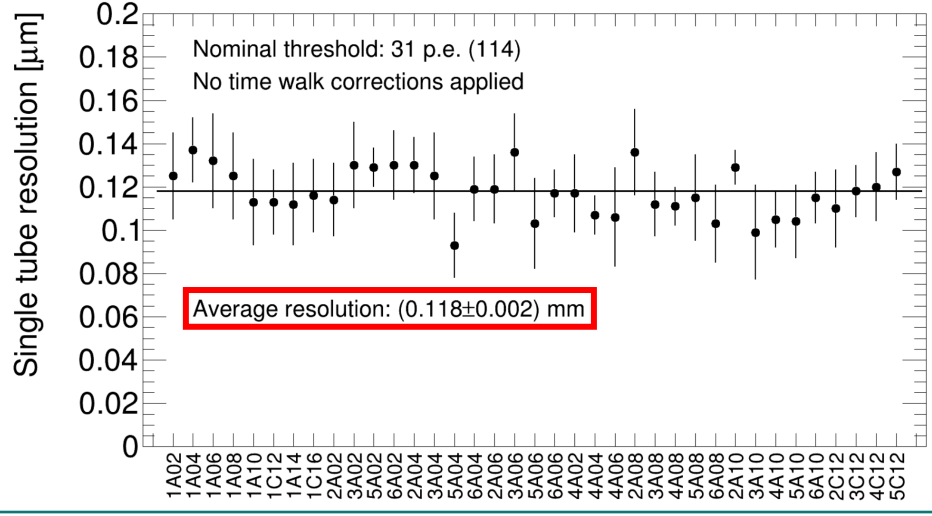




Chamber Performance and Testing

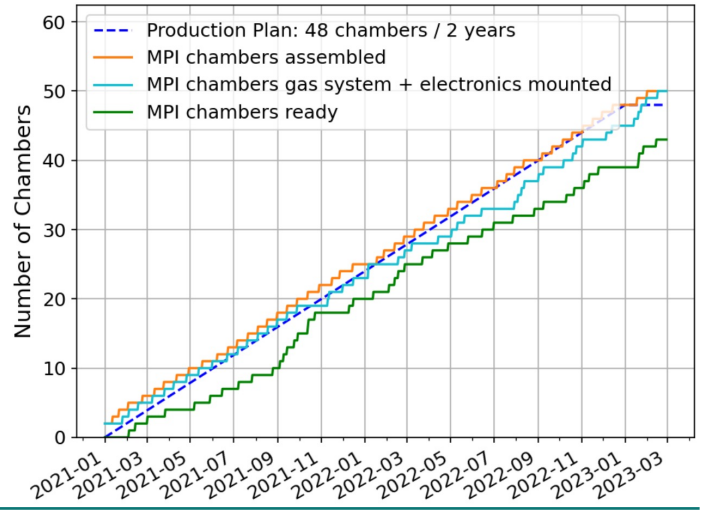
- Muon detection efficiencies and tube resolution measured for each tube during chamber performance testing in the cosmic ray stand
- Average tube efficiency ~ 99% consistently across all chambers
- Single tube resolution consistent across all chambers
- After time walk corrections are applied, average resolution improves by ~ 20 μm giving an average single tube resolution of < 100 μm



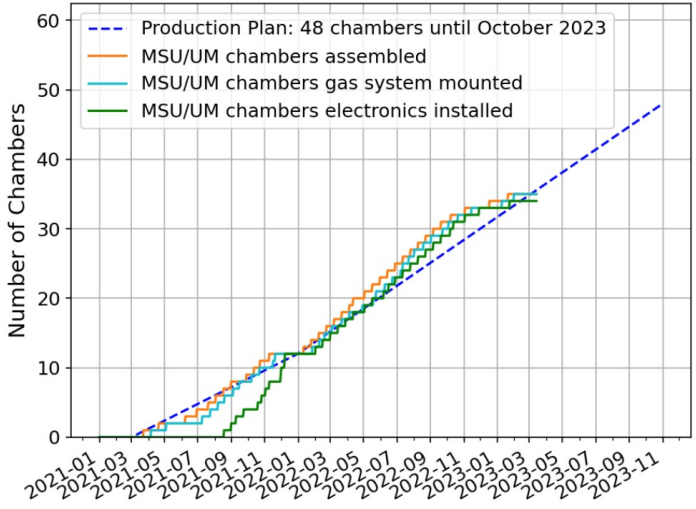


Chamber Production Status

- Series production at MPI began in December 2020
- 48 (+2 spare) chambers assembled
- 48 chambers with electronics and gas systems mounted
  - 🎉 MPI construction complete! 🎉
- 43 chambers tested in the cosmic-ray stand



- Series production in Michigan began in March 2021
- Chamber production proceeding well and on schedule to finish production this year:
  - 35 chambers assembled and have gas system mounted
  - 34 chambers with electronics installed



Conclusions

- As part of the ATLAS HL-LHC upgrade, the current MDT chambers in the small sectors of the inner layer will be replaced with sMDT chambers
- Production of 48 (+2 spare) sMDT chambers at MPI Munich complete! 🥳
- Completion of a chamber every two weeks allowed for production to remain on schedule
- 32 chambers have already been delivered to CERN
- Chamber performance and gas leak rates well within the ATLAS requirements for all chambers