ATLAS Muon Drift-Tube Chamber Operation in Magnetic Fields and at High Background Rates

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on behalf of the ATLAS muon groups
at LMU and MPI Munich

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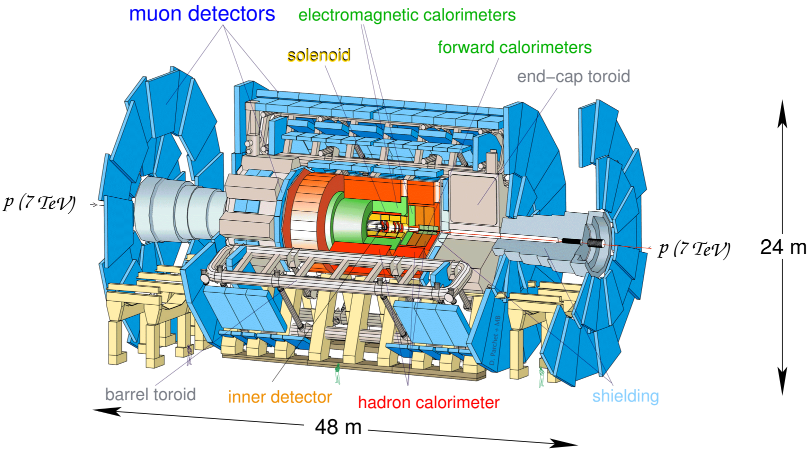
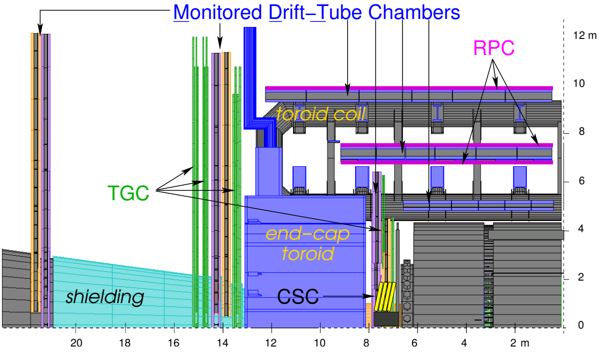
Outline

1. The ATLAS muon spectrometer.
2. Autocalibration using muon tracks.
3. Magnetic field dependence of the tube response.
4. High background rates in the muon spectrometer:
   - Spatial resolution at high background.
   - Efficiency at high background.
5. Summary.

The ATLAS Detector



The ATLAS Muon Spectrometer

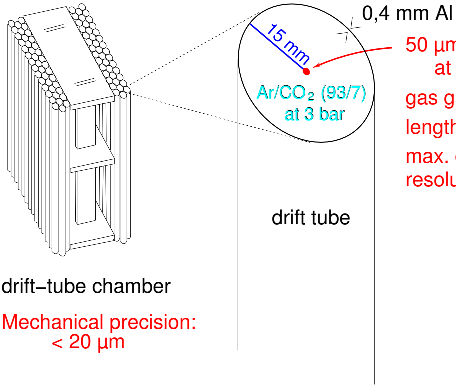


<B>=0.4 T
Large variations within chambers: up to 0.4 T

- Fast trigger chambers: TGC, RPC.
- High resolution tracking detectors: CSC, MDT.

★ Accurate μ momentum reconstruction (3% accuracy).

Monitored Drift-Tube Chambers



50 µm W–Re wire at 3080 V,
gas gain: $2 \cdot 10^4$,
length: 1m – 6m,
max. drift time: 700 ns,
resolution: <100 µm.

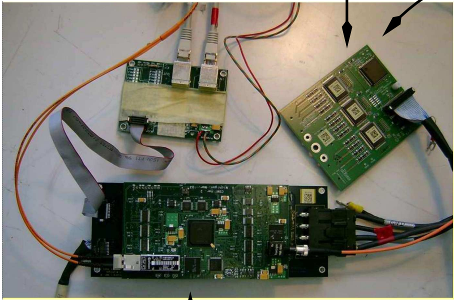
drift–tube chamber

Mechanical precision: < 20 µm

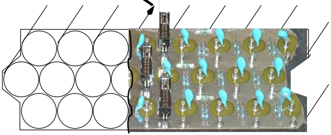
1194 chambers (380 000 tubes) built for ATLAS at 14 sites.

Muon Chamber Read-out

amplifier–shaper–discriminator card
with 24–channel TDC and ADC



chamber service module



24 tubes connected
to a shielded passive
read–out card

discriminator threshold:
set to the 16th p.e.

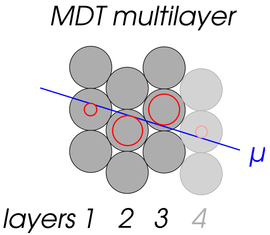
adjustable dead time:
200–790 ns

Autocalibration Using Muon Tracks

Space-to-drift-time relationship $r(t)$

- changes with operating conditions, mainly temperature and background rate
- must be recalibrated frequently with 20 μm accuracy using muon tracks
- strong dependence on B field: $\Delta t_{max} \approx 60$ ns T^{-1}
- size of autocalibration zones: 2 m^2
- μ rate per zone: ≈2000 h^{-1} with $p_T > 20$ GeV
  at $L = 10^{34}$ cm^{-2} s^{-1}

Autocalibration Procedure



- The muon tracks are straight within a multilayer of an MDT chamber.
- The initial $r(t)$ allows us to reconstruct muon tracks.

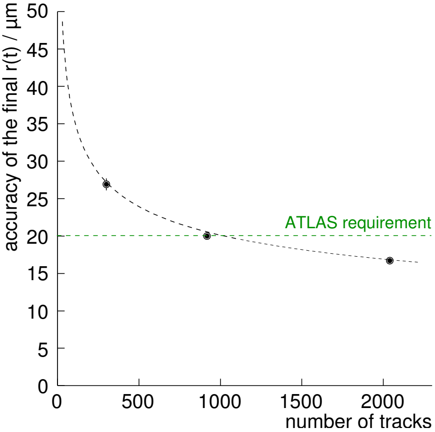
- d_k := track distance from the k-th anode wire hit, $r(t_k)$:= drift radius of the k-th hit.
  The residuals

$$\Delta(t_k) := r(t_k) - d_k$$

  contain information about the accuracy of $r(t)$.

Autocalibration Performance

Development of reliable $r(t)$ calibration algorithms

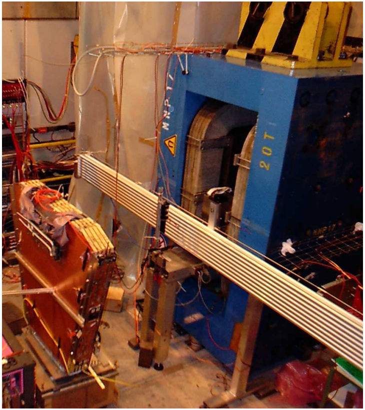


ATLAS requirement achieved with 1000 tracks.

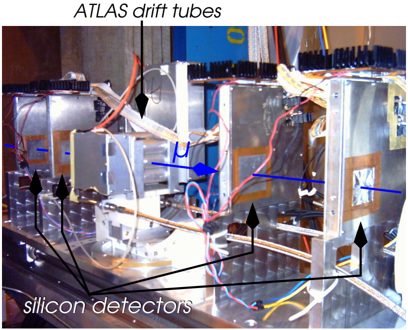
Recalibration once an hour is feasible.

Essential: make use of how Δ depends on $r(t)$.

Beam Test for the B Dependence of $r(t)$

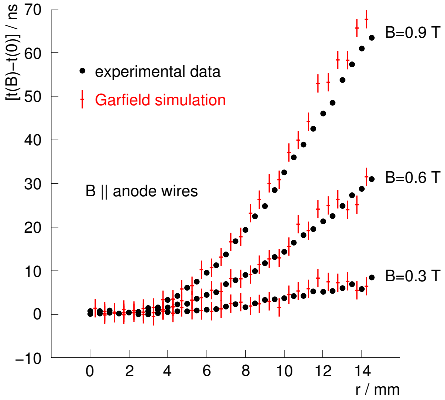


Dipole magnet inside the experimental area



Drift tubes with silicon detectors as external tracker inside the magnet (10 μm accuracy)

B-Field Dependence of $r(t)$ – Results



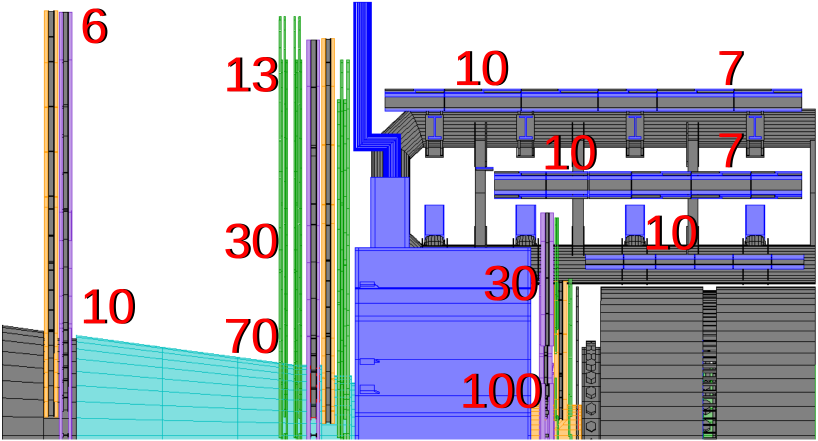
Agreement of simulation and experiment: $\leq$3 ns.

Required accuracy for calibration: 0.5 ns.

Data will be used to refine the simulation.

Neutron and Gamma Background

Background count rate in Hz/cm^2

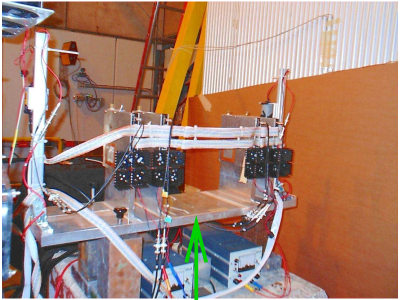


Test-Beam Measurements

MDT chamber
with 4 m long tubes

664 GBq
Cs137 source

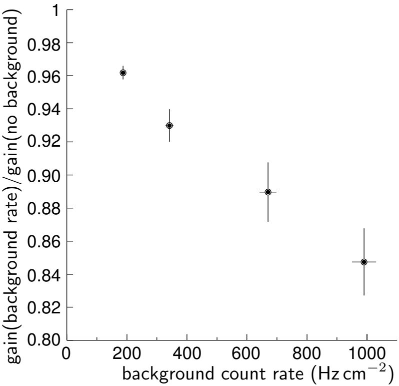
movable lead filters
for rate adjustment



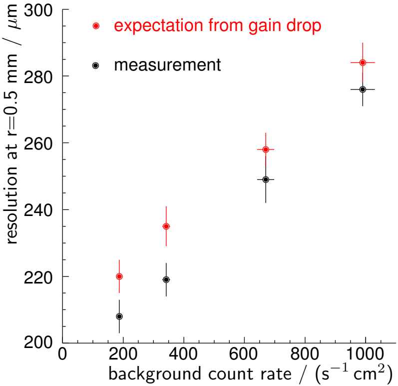
four–layer silicon tracking detector

Impact on the Tube Performance

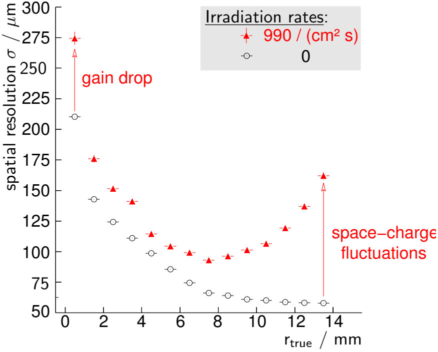
Gain drop



Resolution degradation for $r \to 0$

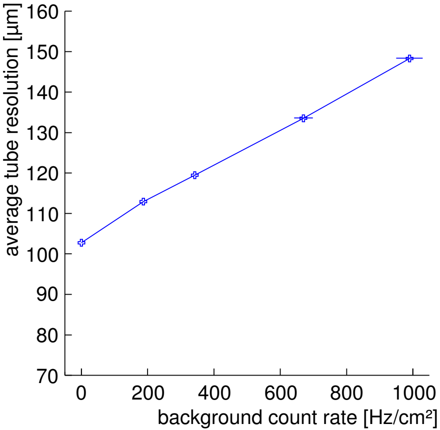


Impact on the Spatial Resolution

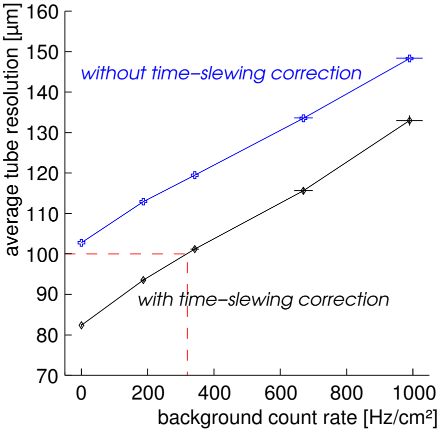


Resolution degradation under high background due to gain drop and space-charge fluctations.

Average Spatial Resolution

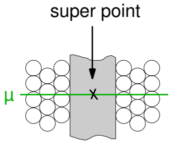


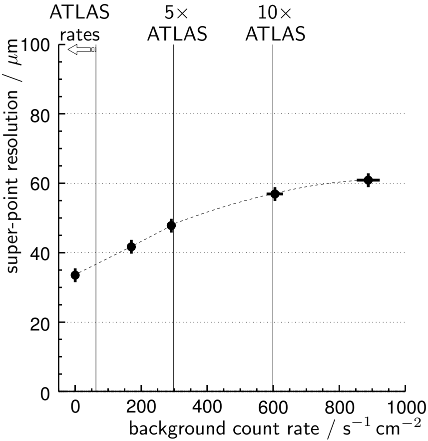
Average Spatial Resolution



Resolution $< 100\ \mu$m up to 3× the maximum ATLAS rate.

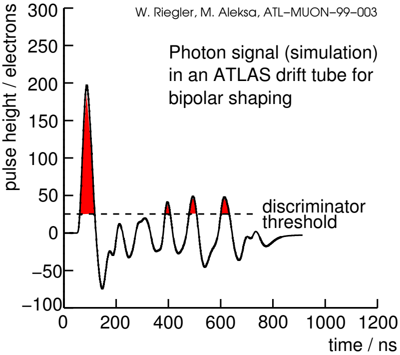
Chamber Resolution





High chamber resolution up to highest rates.

Photon Signals in ATLAS Drift Tubes



Several threshold crossings of the photon signal within 790 ns (measured: 1.5 on average at 200 ns dead-time)

⇓

High count rate!

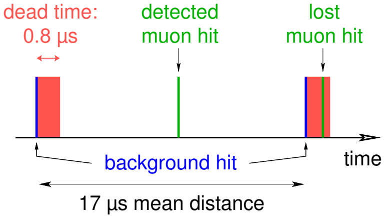
↓

Solution:

Dead time setting: 790 ns.

Impact of the Background on Efficiencies

Example: maximum background rate, i.e.
$100\ \mathrm{Hz\,cm^{-2}}$ for 2 m long tubes $\widehat{=}$ 60 kHz per tube.

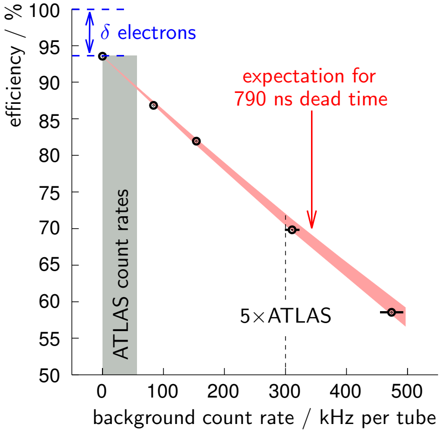


Outside the dead-time window:
muon hits are detected.

Inside the dead-time window:
muon hits are lost.

Decreasing detection efficiency with increasing background!

Single-Tube Efficiency

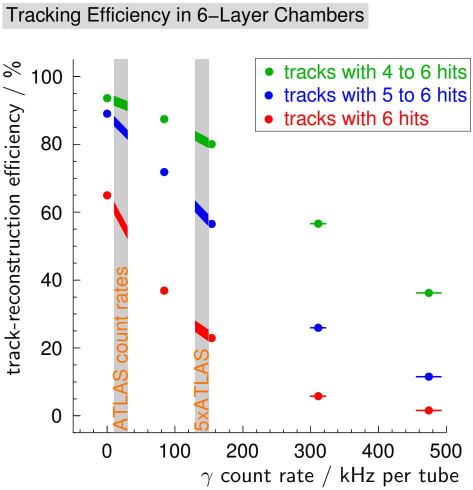


Present ATLAS strategy:
Operation with 790 ns artificial dead time to limit the data rate.

Efficiency>90% at ATLAS count rates!

Significantly lower efficiency at higher rates!

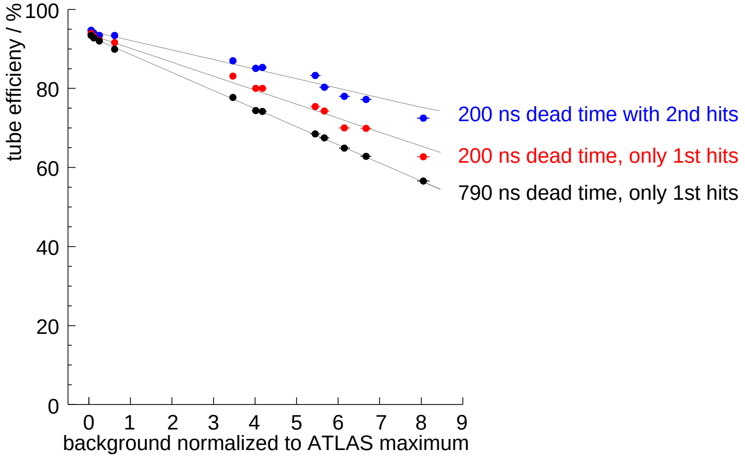
Tracking Efficiency at High γ Background



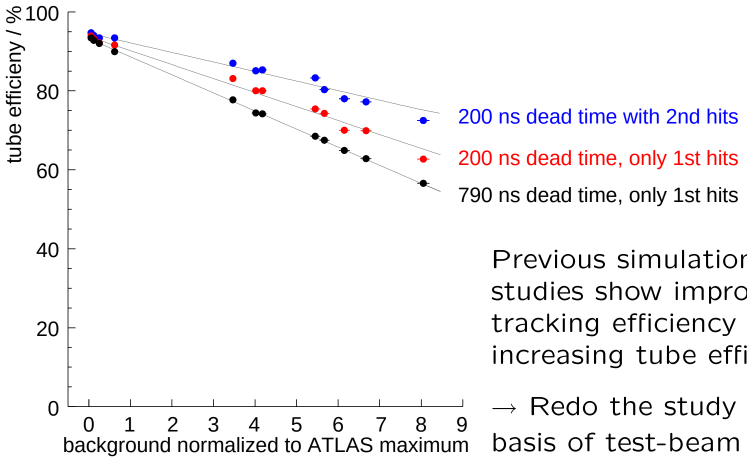
High reconstruction efficiency at ATLAS rates!

Significantly reduced efficiency at even higher rates!

Perspectives for Improving the Efficiency



Perspectives for Improving the Efficiency



Previous simulations studies show improving tracking efficiency with increasing tube efficiency.

→ Redo the study on the basis of test-beam data.

Summary

- Drift-tube chambers are the precision tracking detectors of the ATLAS muon spectrometer.
- Their $r(t)$ relationship can be calibrated with muon tracks with 20 μm accuracy once an hour.
- Measured B-field dependence of $r(t)$ will be used for correcting $r(t)$.
- High neutron and γ background in the muon spectrometer: up to 100 Hz cm^{-2}.
  - Chamber resolution: 38-44 μm.
  - Chamber tracking efficiency: 90-95% with 790 ns artificial dead time.
  - Potential improvement for LHC luminosity upgrade by lowering the dead-time and using second hits.