Alignment of the ATLAS Muon Spectrometer with Tracks and Muon Identification at High Luminosities

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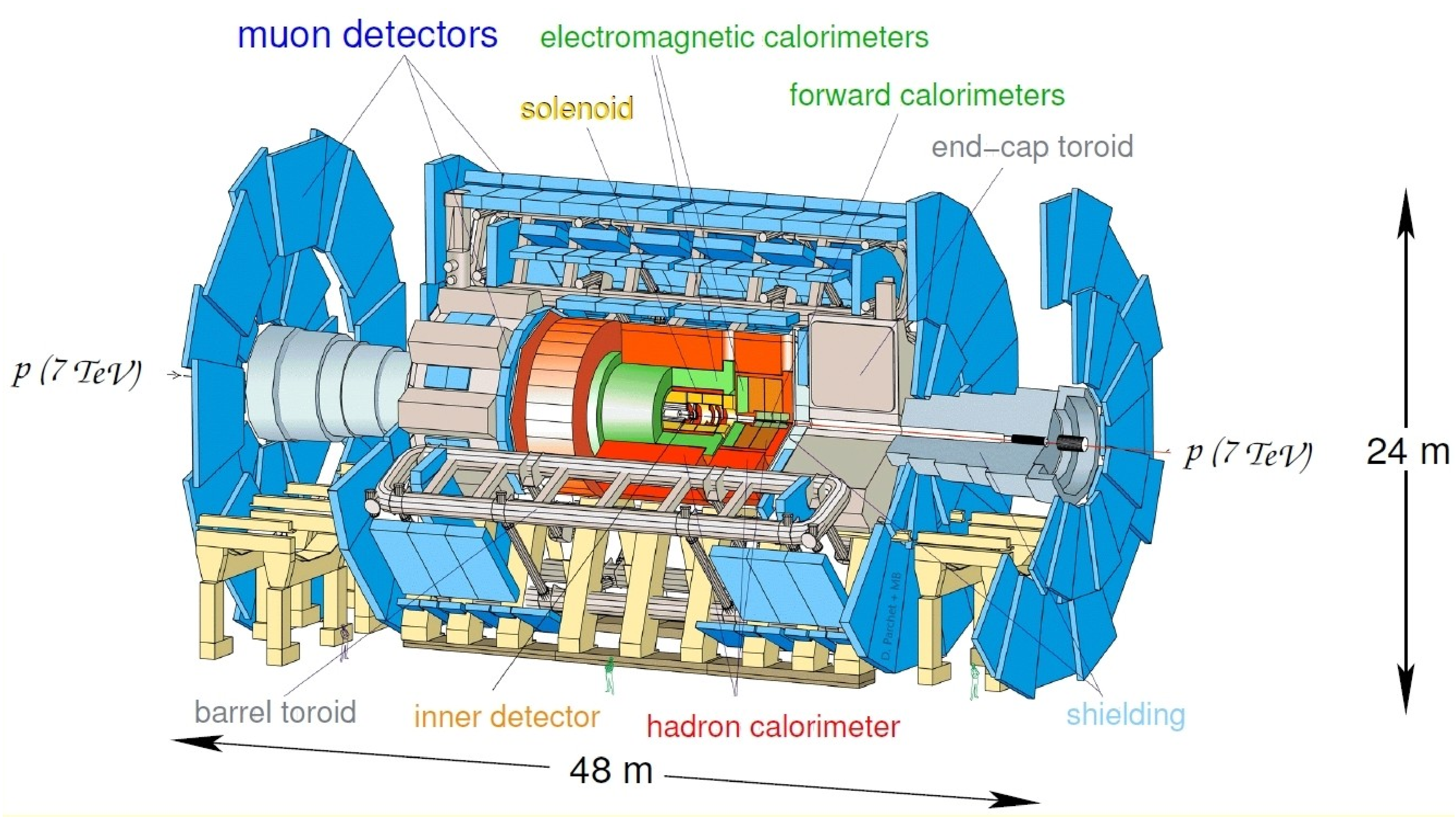
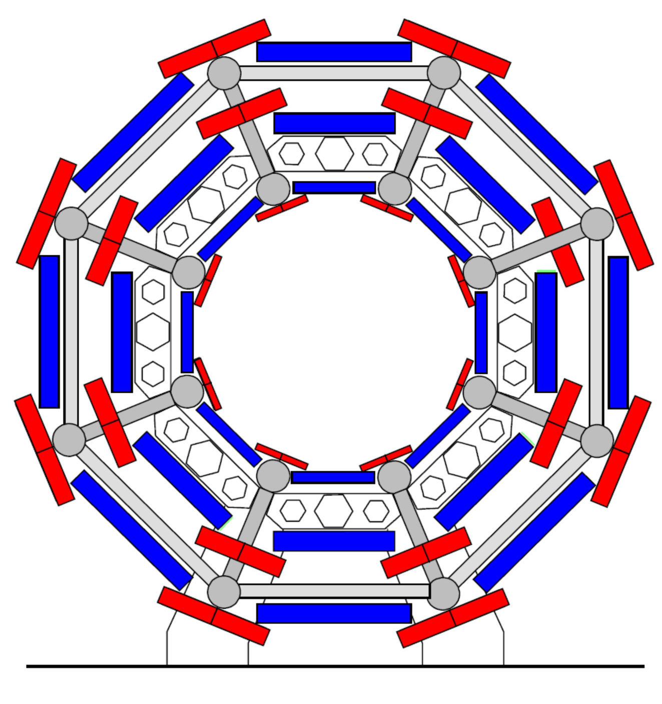


Abstract

The ATLAS muon spectrometer consists of three layers of precision drift-tube chambers in an air-core toroid magnet system with an average field of 0.4 T. The muon momenta are determined with high accuracy from the measurement of the sagitta of the muon tracks in the three chamber layers. In order to achieve the required momentum resolution of the muon spectrometer of better than 4% for transverse momenta below 400 GeV/c and of 10% at 1 TeV/c, the relative positions of the muon chambers are measured by a system of optical sensors with an accuracy of 30 µm. In order to verify the correctness of the optical alignment, a method has been developed to measure the relative chamber positions with muon tracks which are recorded during the operation of the experiment. For muons of p<40 GeV/c the momenta can be determined with high-enough precision independently of the relative misalignment of the chambers from the comparison of the local track direction measurements in the individual chamber layers. This method allows for monitoring of the chamber positions with an accuracy of about 30 µm in time intervals of a few hours during LHC operation.

During the operation of the experiment the chambers will be exposed to a high flux of neutrons and g rays which may lead to occupancies of up to 20%. Even higher occupancies are expected for a possible luminosity upgrade of the LHC. We investigated on test-beam measurements at the Gamma-Irradiation Facility at CERN and Monte-Carlo data how pattern recognition algorithms can cope with the increased hit rates.

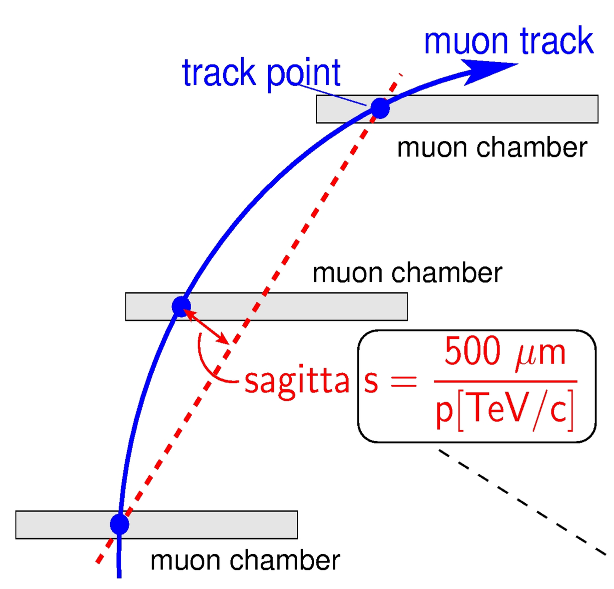
Alignment of the ATLAS Muon Spectrometer with Tracks



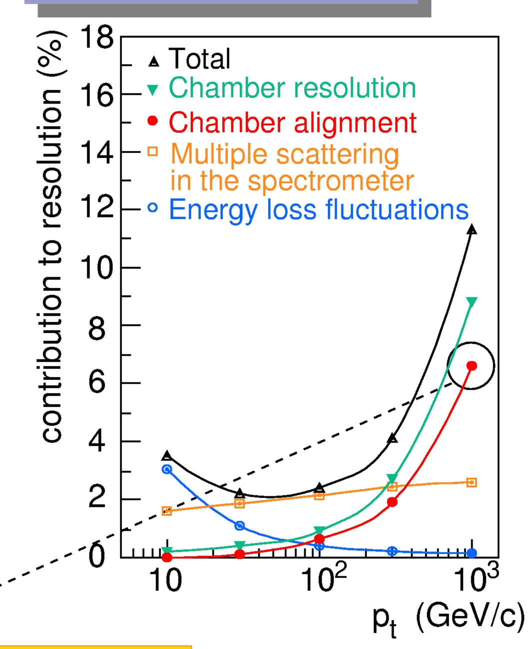
Schematic of the cross section of the barrel part of the muon spectrometer orthogonal to the *p* beams.

- Relative alignment of large barrel chamber with optical system.
- Missing optical precision alignment for small barrel chambers.
- Role of muon tracks:
  - Absolute alignment of large chambers.
  - Alignment of the small with respect to the large chambers by means of overlap tracks.
  - Monitoring of the alignment of the large towers.

Momentum measurement principle

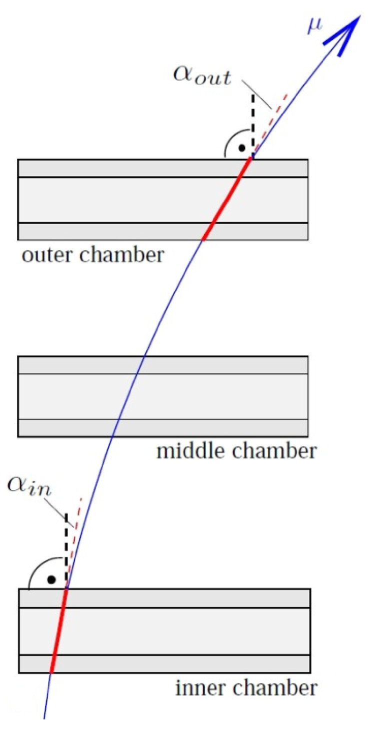


Momentum resolution



Muon chamber alignment accuracy: 6%·500 µm = 30 µm

Monitoring of the alignment of large barrel towers



Idea: Try to profit from the knowledge of the chamber geometry on the level <20 µm.

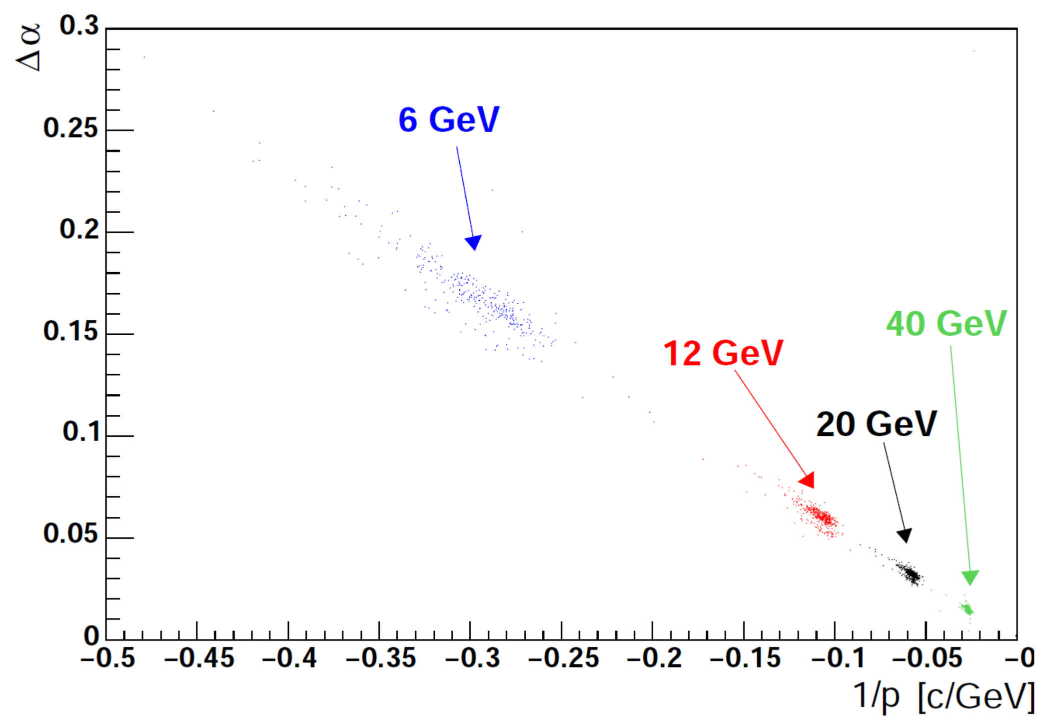
Method: Momentum from the deflection angle in the magnetic field:

$$\Delta\alpha = \alpha_{out} - \alpha_{in} = \frac{q}{p} \cdot \int_{\mathcal{P}} B\, dl.$$

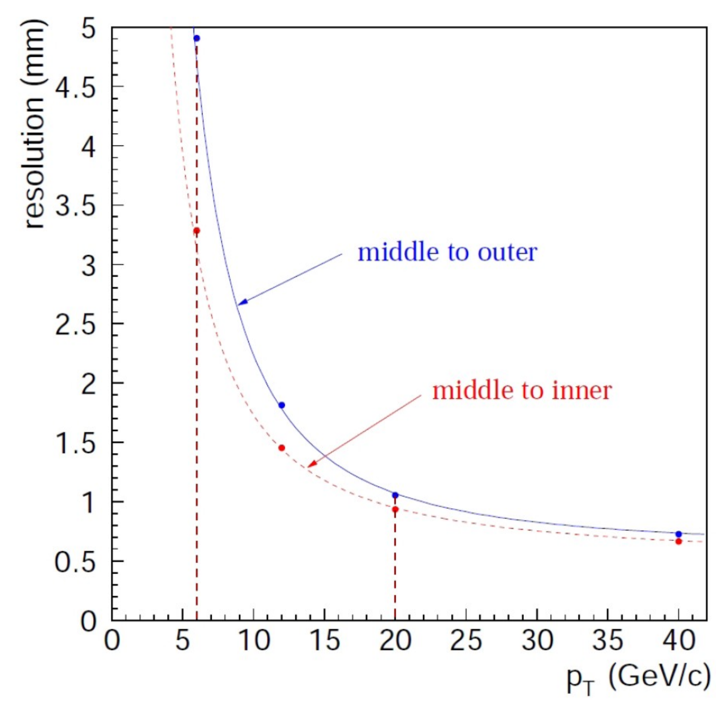
- The method uses the "direction capability" (segments) of muon chambers.
- It is independent of relative chambers shifts.
- Systematic error: rotation of a chamber gives wrong momentum.

→ The rotation can be determined by comparing the momentum measurement in the middle chamber with the deflection angle measurement.

Deflection angle as a function of the muon momentum



Position and misalignment measurement accuracy



Number of >6 GeV muons needed for 100 µm alignment accuracy:

- 10000 tracks to determine the rotation angle between the inner and outer chamber.
- 2500 tracks to achieve an alignment monitoring accuracy of 100 µm.

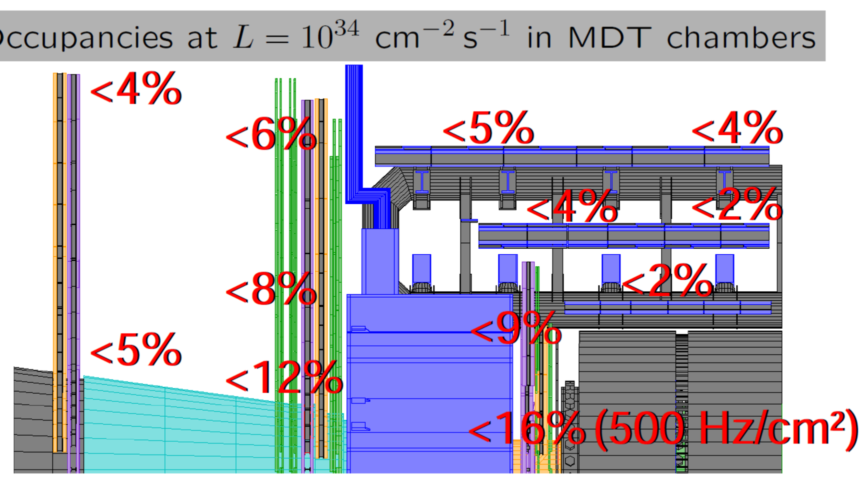
Muon Identification at High Luminosities

Radiation background in the ATLAS experiment

Difficulty in ATLAS: high $n-\gamma$ background.

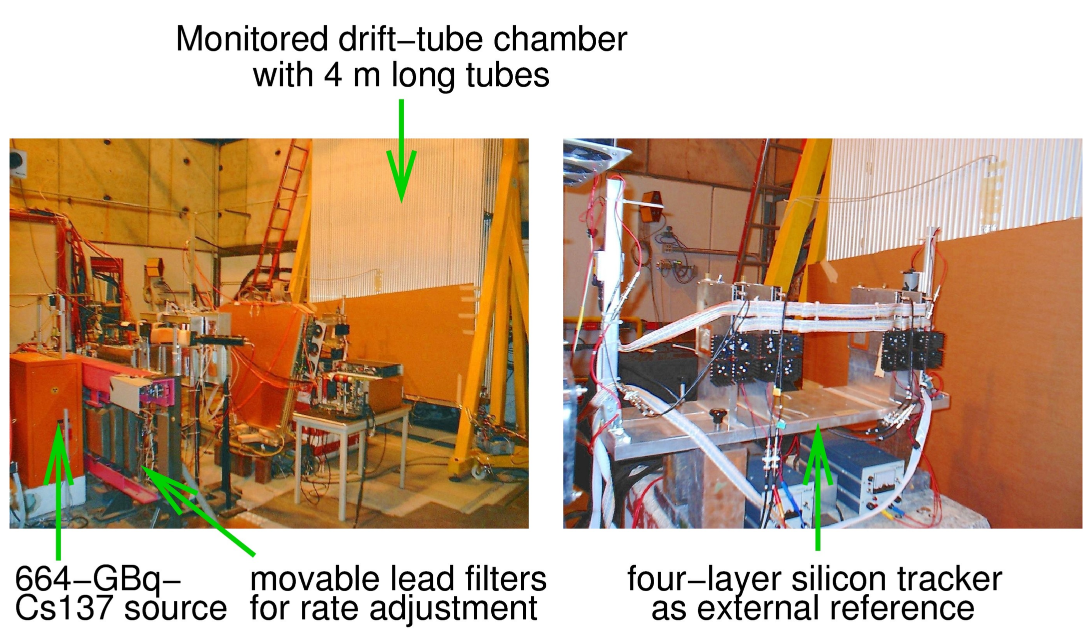
→ High occupancy ($\sim 10\times$ CMS).

Occupancies at $L = 10^{34}$ cm^{-2} s^{-1} in MDT chambers

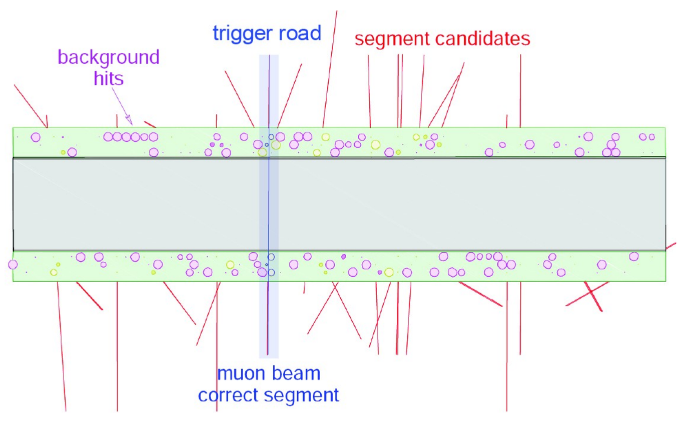


(Numbers include a safety factor of 5.)

Set-up at CERN's Gamma Irradiation Facility (GIF)

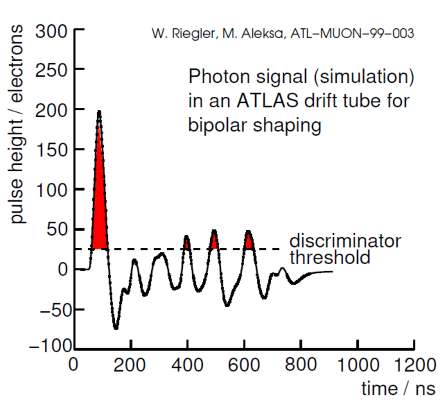


Test-Beam Event



- Muon chamber full of hits and segment candidates.
- Trigger road needed to reconstruct the correct track segment.

Photon hits in an ATLAS drift tube



Several threshold crossings of the photon signal within the $t_{drift,max}$ of $\approx$800 ns (measured: 1.5 on average at 200 ns dead-time)

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High count rate!

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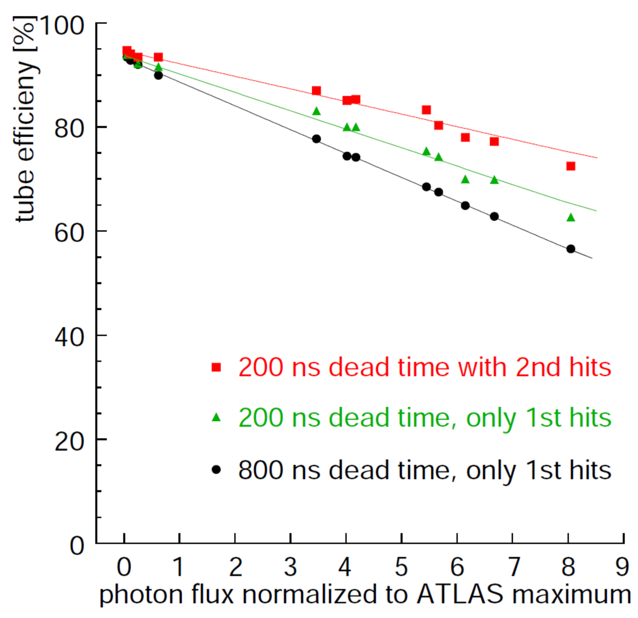
Solution for ATLAS:

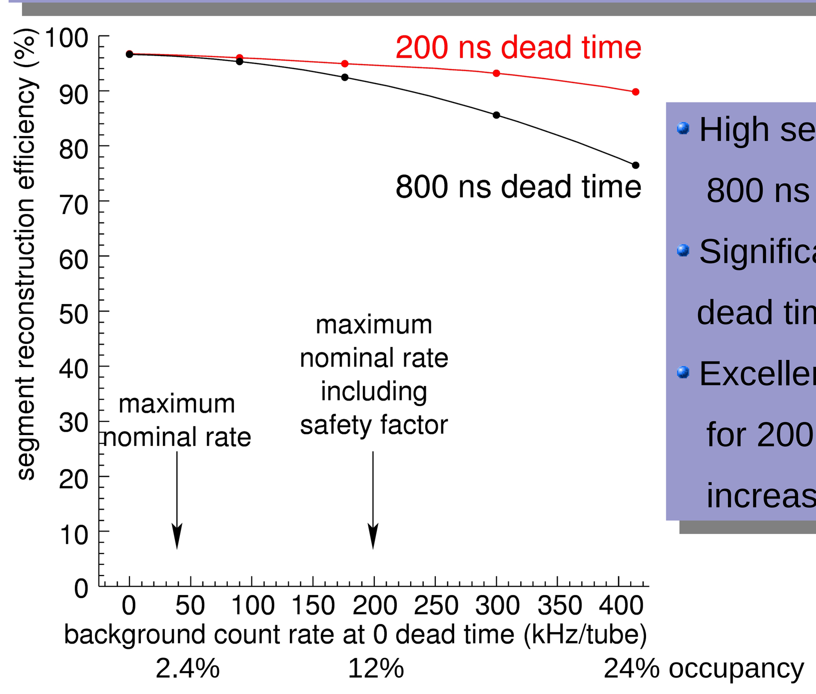
Dead time setting: 800 ns.

3σ single tube efficiencies



- High muon detection efficieny for ATLAS nominal background rates independently of the dead time.
- Highly improved efficiency with minimum dead time of 200 ns + second-hit recovery at very high background rates.

Segment reconstruction efficiencies



- High segment reconstruction efficiency for 800 ns dead time at nominal rates.
- Significant efficiency degradation for 800 ns dead time at very high rates.
- Excellent segment reconstruction efficiency for 200 ns at very high rates with no increase of the number of fake segments!