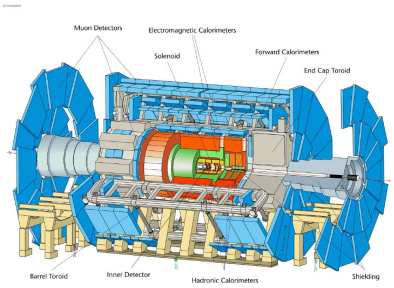
B-Field Dependence of the Space-Drift-Time Relation of ATLAS MDT Chambers

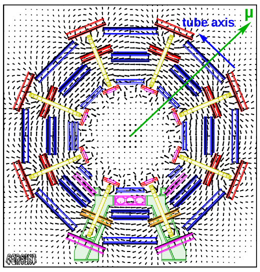


J. Dubbert[a,b], M. Groh[a], S. Horvat[a], D. Khartchenko[a], S. Kotov[a], O. Kortner[a], H. Kroha[a], K. Nikolaev[a], F. Rauscher[b], R. Richter[a], A. Staude[a], and C. Valderanis[a]

[a]*Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany*
[b]*Ludwig-Maximilians-Universität München, Am Coulombwall 1, D-85748 Garching, Germany*

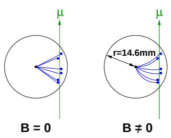
Abstract

The ATLAS muon spectrometer consists of an air-core toroid magnet system instrumented with 3 layers of Monitored Drift Tube (MDT) stations. 8 superconducting coils generate an average magnetic field of 0.4 T over a distance of 6 m. To achieve the desired momentum resolution of less than 10% for muon energies up to 1 TeV with the 3-point sagitta measurement, the resolution of a single muon station has to be better than 50 μm. About a third of the barrel MDT chambers will be installed on the outer side of the magnet coils and therefore experience a highly non-uniform magnetic field with field variations of up to 0.4 T. The dependence of the space-to-drift-time relationship r(t) of the drift tubes on the magnitude and the orientation of the magnetic field with respect to the anode wires and the muon incident angle was measured in a test-beam. These measurements allow for a parameterization of the magnetic-field dependence of r(t) with the required accuracy of 1 ns.



Field map of the ATLAS barrel muon spectrometer at η = 0

Principle of Drift Tube Operation



Drift paths of electrons in the absence and presence of a magnetic field

- Hit radius determined from measured electron drift time
- r-t relation sensitive to operating parameters (gas mixture, density, HV) and environment (background rate, B-field)

Theoretical Model

Magnetic field has components parallel to anode wire and muon direction, i.e. $\vec{B} = (B_1, 0, B_2) = B(\cos\phi, 0, \sin\phi)$

Differential Equation for the Electron Drift

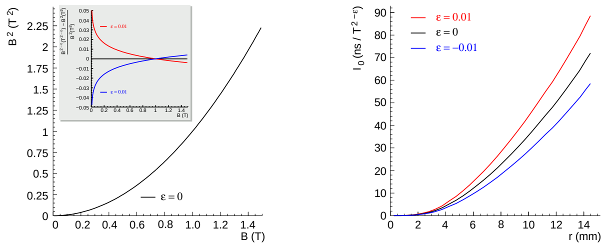
$$\ddot{\vec{x}} = -\left(\frac{\dot{\vec{x}}}{\tau}\right)^{1+\varepsilon} - \frac{e}{m}\vec{E} - \frac{e}{m}\dot{\vec{x}} \times \vec{B}$$

Solution of Differential Equation

$$t(r,\vec{B}) = t(r,\vec{B}=0) + B^{2-\varepsilon}\underbrace{\cdot 1}_{=:A(\phi)} \cdot \underbrace{\int_{25\,\mu m}^{r} \frac{v_{B=0}^{1+\varepsilon}(r')}{E^{2-\varepsilon}(r')}\,dr'}_{=:I_0(r)}$$

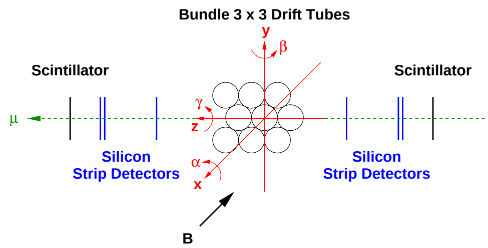
Factorization into a part, $B^{2-\varepsilon}A(\phi)$, depending on the magnetic field configuration and a part, $I_0(r)$, only depending on the drift properties at $B = 0$

Visualization of Magnetic Field Factors



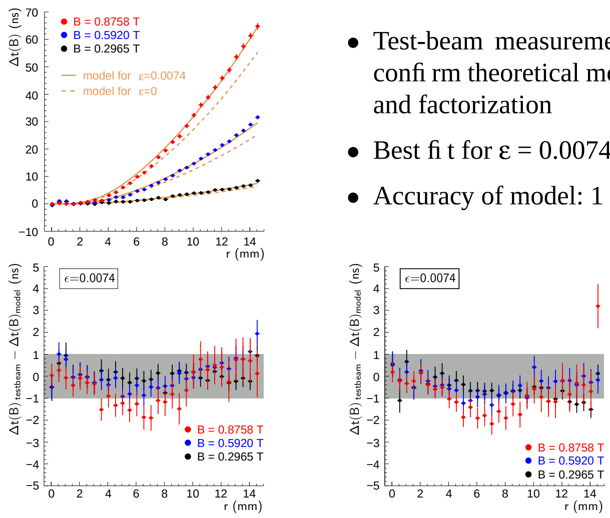
Test-beam Measurements

Setup



- 3 × 3 tubes (same as one MDT multilayer)
- Fully rotatable on all three axes
- Magnetic field 0 - 0.9 T
- Reference tracking with 6 silicon detectors

Results and Conclusion



β = 0°   β = 24°

- Test-beam measurements confirm theoretical model and factorization
- Best fit for ε = 0.0074
- Accuracy of model: 1 ns

Contact: kortner@mppmu.mpg.de, valdera@mppmu.mpg.de