Operation of the ATLAS Muon Drift-Tube Chambers at High Background Rates and in Magnetic Fields

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For the muon spectrometer of the ATLAS detector at the Large Hadron Collider (LHC), large drift tube chambers, the Monitored Drift Tube (MDT) chambers, are used for precision tracking in the toroidal field of superconducting air core magnets. The MDT chambers consist of two triple- or quadruple-layers of aluminum drift tubes with 30 mm diameter and 0.4 mm wall thickness mounted on either side of an aluminum space frame containing optical deformation monitoring systems. In order to achieve a momentum resolution of better than 10% up to muon momenta of 1 TeV, the chambers have to provide a spatial resolution of 40 μm. With a positioning accuracy of 20 μm of the sense wires within a chamber, the spatial resolution of a drift tube has to be better than 100 μm using an Ar:CO_2 (93:7) gas mixture at 3 bar and a gas gain of $2 \cdot 10^4$.

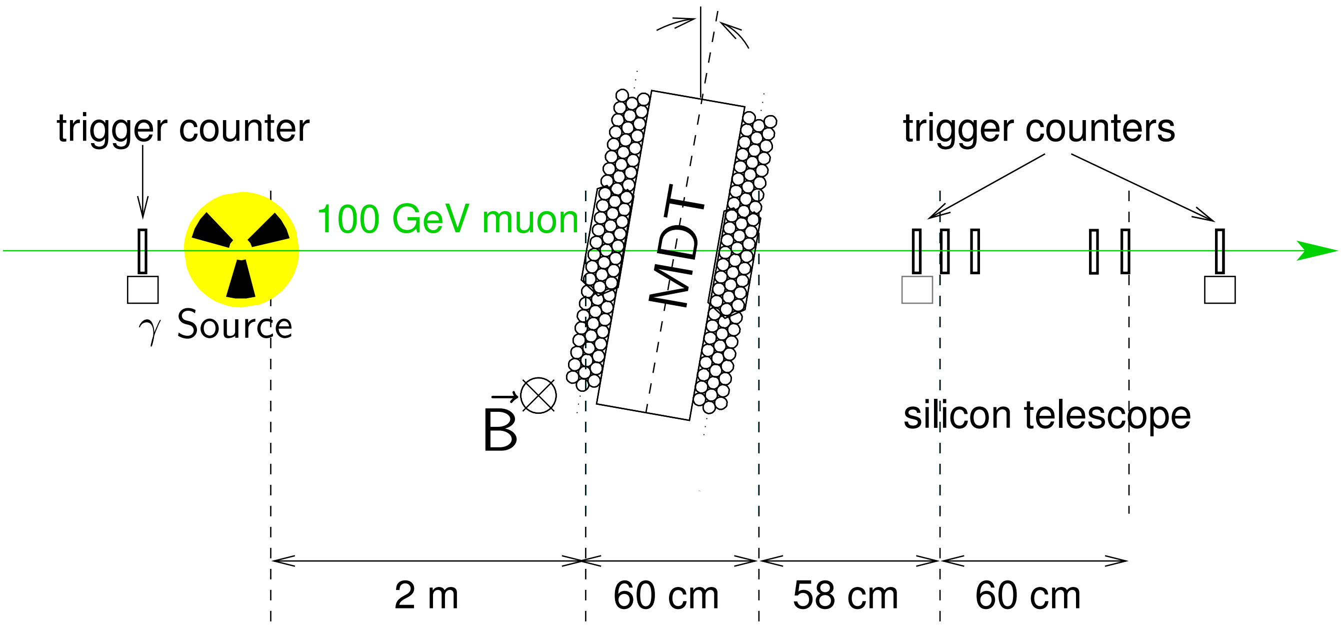

Figure 1: The experimental setup at the Gamma Irradiation Facility at CERN with a 740 GBq ^{137}Cs γ source and with a MDT chamber and a silicon strip detector telescope in the 100 GeV muon beam. The magnetic field of up to 1 T is oriented parallel to the drift tubes.

In the ATLAS experiment, the muon chambers will experience unprecedentedly high neutron and photon background count rates which have a significant impact on their performance. At the LHC design luminosity of 10^{34} cm^{-2}s^{-1}, count rates of up to 500 Hz/cm^2 have to be expected in the inner forward layers of the muon spectrometer. Variations of the magnetic field strength across chambers close to the toroid coils can be up to 0.4 T. The space-to-drift time relationship

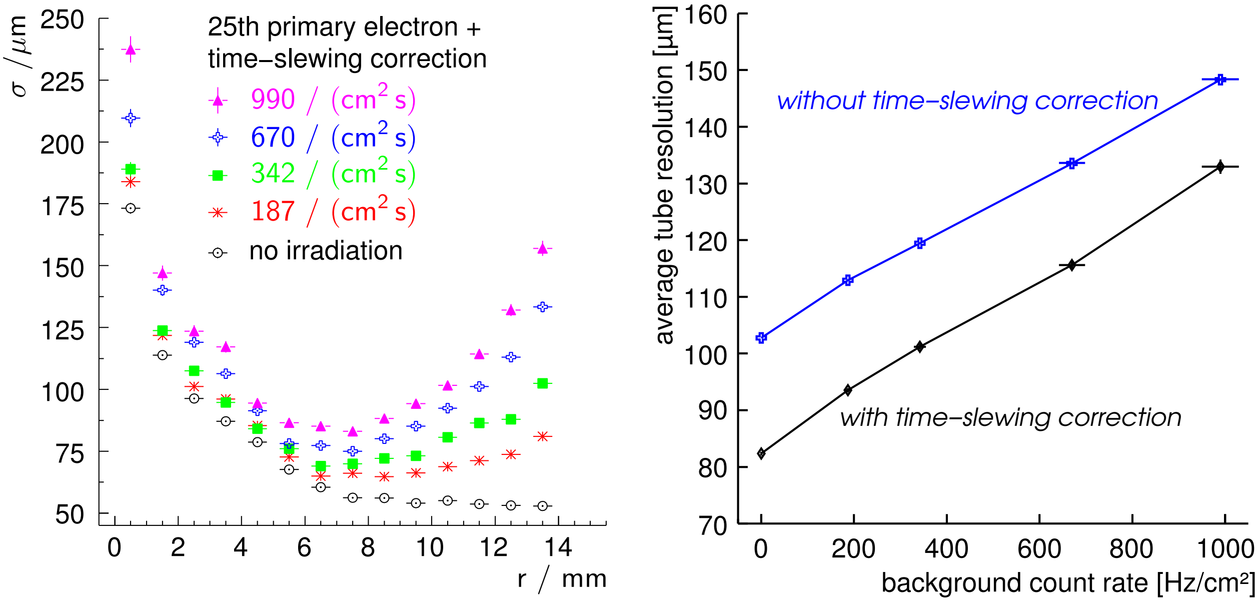

Figure 2: Left: Spatial resolution of the driftc tubes as a function of the impact radius r of the muon track for different photon irradiation rates. Right: Average drift tube resolution as a function of the irradiation rate with and without time slewing corrections.

of the drift tubes varies not only with temperature and magnetic field strength, but also with the background count rate. It has to be recalibrated in short time intervals with the required accuracy of better than 20 μm using muon tracks (autocalibration).

The resolution and efficiency of the MDT chambers with the final readout electronics, using bipolar shaping and a fixed deadtime of 800 ns, has been studied in a 100 GeV muon beam at the Gamma Irradiation Facility at CERN for varying magnetic fields and photon irradiation rates of up to 990 Hz/cm^2 (see Figure 1). A silicon strip detector telescope at a distance of 60 cm from the chamber was used as external reference in the beam. Efficient autocalibration algorithms have been developed and tested under the high background conditions.

The drift tube resolution as a function of the impact radius of the muon extrapolated from the silicon detector telescope is shown in Figure 2 (left) for increasing photon irradiation rates. The photon irradiation induces a space charge in the drift tubes which alters the electric field and the drift velocity in the Ar:CO_2 gas. Fluctuations of the space charge cause a deterioration of the spatial resolution which is most pronounced at large impact radii.

Without photon irradiation, an average drift tube resolution of 80 μm is achieved by employing time-slewing corrections based on the pulse height measurement provided by the readout electronics (see Figure 2, right). The spatial resolution of the drift tubes is found to deteriorate linearly with increasing background count rate. At the maximum expected rate in ATLAS of 500 Hz/cm^2, the resolution is degraded by not more than 25 μm which is compatible with the design goals. The probability of a drift tube to detect a muon hit decreases linearly with increasing count rate as expected from the fixed deadtime. At the maximum rate, the efficiency loss amounts to 25%.

The results are reproduced by detailed simulations of the drift tube response. The consequences and possible improvements for the operation of the chambers at even higher LHC luminosities and background rates have been investigated.