Precision Drift Tube Chambers for the ATLAS Muon Spectrometer at Super-LHC

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The ATLAS detector is one of the two general purpose detectors at the Large Hadron Collider (LHC) at CERN. One of the most challenging aspects of the ATLAS experiment is the measurement of muon momenta with very high precision. The ATLAS muon detector is equipped with three layers of tracking chambers in a toroidal magnetic field of 3–6 Tm bending power generated by a superconducting air-core magnet system. Over most of the pseudo-rapidity coverage of the experiment, measurements of the track sagitta are provided by precision drift-tube detectors, the Monitored Drift Tube (MDT) chambers[1]. The ATLAS muon spectrometer has to cope with high radiation background rates mainly caused by low-energy neutrons leaking out of the calorimeter and γ rays emitted from nuclei excited by the low energy neutrons. At the LHC design luminosity, Monte-Carlo simulations predict background counting rates of about 10 $cm^{-2}s^{-1}$ in the barrel part of the muon spectrometer, and of up to 100 $cm^{-2}s^{-1}$ in the end-caps [2]. The muon chambers are designed to cope with up to five times higher background rates. At the Super-LHC, the high luminosity upgrade of the LHC, ten times higher counting rates may be encountered assuming that the background rate scales with the accelerator luminosity.

The ATLAS MDT chambers consist of two triple or quadruple layers of aluminum drift tubes of 30 mm diameter and 0.4 mm wall thickness. The tubes are filled with a gas mixture of Argon and CO_2 in the ratio 93:7 at an absolute pressure of 3 bar. The drift tubes are operated at 3080 V corresponding to a gas gain of 2 x 10^4 chosen to prevent aging. Without background radiation, the average spatial resolution of individual drift tubes is about 80 μm.

It is known that high background counting rates lead to a degradation of the drift-tube spatial resolution due to space-charge fluctuations and to a reduction of the muon detection efficiency depending on the maximum drift time in the tubes[3, 4]. The efficiency loss can be significantly reduced by reducing the diameter of the drift tubes from 30 mm to 15 mm because of the shorter maximum drift distance and the higher drift velocity closer to the sense wire[5]. Furthermore, the background counting rate is reduced by an additional factor of two because of the smaller tube wall surface in which neutron conversions take place. A first detector prototype equipped with 15 mm diameter drift tubes was successfully tested in a cosmic-ray test stand[5].

The possibility of improving the muon detection efficiency at Super-LHC by reducing the diameter of the drift tubes to 15 mm has now been investigated in a high-intensity radiation environment at the Gamma Irradiation Facility (GIF) at CERN where a cosmic ray test stand has been setup. The GIF provides a 590 GBq ^{137}Cs source emitting photons of 662 keV energy which corresponds well with the ATLAS background photon energies. The test setup consists of a layer of 6 prototype drift tubes with 15 mm diameter and 1 m length in between two reference tracking chambers, each consisting of two triple layers of 8 standard ATLAS drift tubes with 30 mm diameter and of 50 cm length separated by a 30 cm high space frame (see Fig. 1).

All parameters of the prototype drift tubes except for the radius were the same as for the ATLAS MDT chambers. In order to maintain the same electric field strength as in the 30 mm diameter tubes for drift distances to the wire below 7.5 mm, the operating voltage has been set to 2760 V. The standard ATLAS MDT readout electronics can be used. The trigger for cosmic muons was provided by two layers of scintillation counters separated by an absorber.

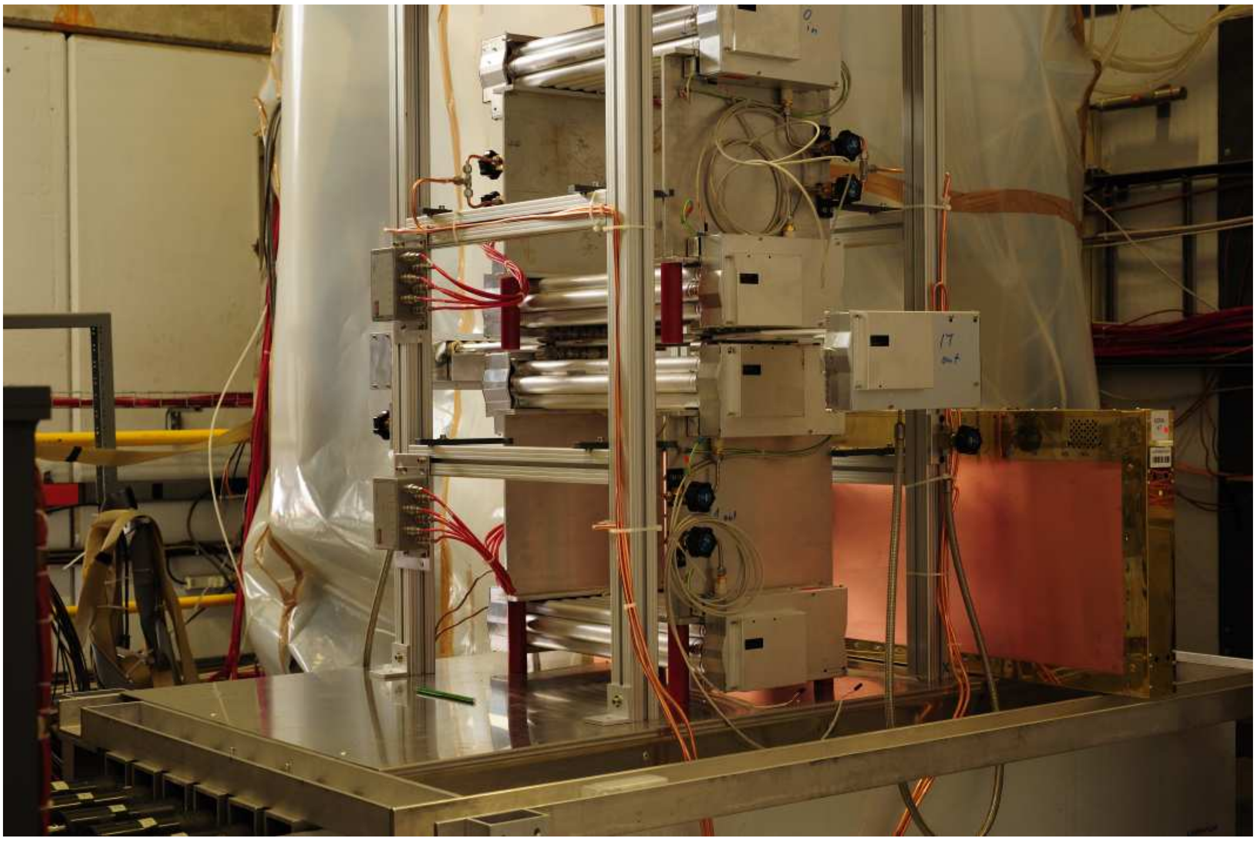

Figure 1: The cosmic ray test setup at the Gamma Irradiation Facility at CERN. The 15 mm diameter drift tubes are positioned between the two reference chambers with 30 mm diameter tubes with an accuracy of about 50 μm in the direction perpendicular to the tubes. One recognizes the Faraday cages with the readout electronics of the tube bundels. The trigger counters are mounted in the box underneath the drift tubes detectors. The ^{137}Cs source is located in front of the setup to the left.

We report on the performance of the prototype drift-tube detector with thin-walled aluminum tubes of 15 mm diameter at different counting rates up to 1.5 kHz/cm^2 and compare the results with simulations.

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