Identification of muons in ATLAS
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Summary

The Standard Model of Elementary Particles is an elegant theory which describes the fundamental building blocks of matter: particles and their interactions. In over twenty years of experimenting, the predictions of the Standard Model have been extensively tested and shown to accurately match the experimental observations, often to astounding precision. The only particle predicted by the Standard Model that has not been observed yet is the Higgs boson.

To produce the (heavy) Higgs boson, particle collisions at a high center of mass energy are needed. The Large Hadron Collider (LHC) at the CERN laboratory in Geneva, Switzerland, provides proton-proton collisions at an unprecedented center of mass energy of 14 TeV and will produce the Higgs boson, if it exists. If the Higgs boson is not found at the LHC, particle masses in the Standard Model cannot be explained.

The Higgs boson is unstable and will decay into lighter particles. By measuring these decay products one can reconstruct the Higgs boson from these particles. One of the cleanest decay modes of the Higgs boson is its decay into four muons.

The ATLAS detector, one of the LHC general purpose detectors, is designed to discover the Higgs boson. It consists of an Inner Detector tracker, mounted close around the interaction point to measure particle tracks. Around the Inner Detector, massive detectors are placed which are designed to measure particle energies: the Calorimeters. Finally, ATLAS is equipped with a Muon Spectrometer for measuring with high precision muon tracks.

The focus of this thesis is the identification of muons in the ATLAS detector. Before one can accurately identify muons, both the detector parts as well as the reconstruction software should be commissioned. A chapter in this thesis is devoted to the hardware commissioning of a part of the Muon Spectrometer: the monitored drift tube (MDT) chambers, constructed at the Nikhef institute in Amsterdam, The Netherlands.

Muons are reconstructed in a series of steps. First, the electrical signals from the muon detectors are used to make hits in space. A pattern recognition algorithm groups these hits into patterns. These patterns are used as seeds for the reconstruction of track segments, which in turn are combined into a Muon Spectrometer track. These muon tracks can be combined with tracks in the Inner Detector to reconstruct a muon track with an even better precision.

This thesis focuses on the development and performance of a particular muon identification algorithm, MuTagIMO. This algorithm identifies Inner Detector tracks as muons, using track segments reconstructed in the Muon Spectrometer. This method has several advantages. First of all, muons are identified efficiently, also the muons with very
low transverse momenta. Secondly, the algorithm is capable of tagging Inner Detector tracks even in regions where the Muon Spectrometer registers only a few hits. Finally, this method is proven to be robust. It has a high efficiency even when parts of the Muon Spectrometer are not operational. A disadvantage of this method is the increased rate of mis-identified tracks: some Inner Detector tracks which did not come from a muon are wrongly identified as muons.

In order to successfully identify muons, the detector systems should be well calibrated and aligned. The magnetic field and the amount of material traversed by the muons should be known to high precision. During the start up of the LHC and ATLAS, these requirements will not be met. This makes muon tagging a valuable addition to the muon identification programme.

At the time of writing of this thesis, LHC collision data was not yet available. The performance of the identification algorithm is therefore evaluated using cosmic ray muons. The results of cosmic ray muon data are compared with simulated cosmic ray events. The results are consistent and show a 98.6% identification efficiency. The inefficiency is due to the lack coverage in certain regions of the Muon Spectrometer. This effect is observed in both data and simulation, giving confidence that the ATLAS detector is properly modeled.

Cosmic muon events have a different topology than collision events. The performance of the algorithm is evaluated with muons from simulated collision events as well. The algorithm is shown to be very efficient, also for muons with low momenta. The algorithm has a high efficiency, even in the regions where the Muon Spectrometer has lower coverage. The algorithm is robust against exclusion of part of the MDT chambers from the detector. The mis-identification rate is shown to be understood and well under control.

The MuTagIMO algorithm will be extremely useful for identification of muons during the start-up phase of the LHC.