First top quark physics with ATLAS : a prospect
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Summary

At the CERN laboratory, located on the border between France and Switzerland, the LHC is soon to become operational. This accelerator will be the largest and most energetic hadron collider ever constructed. In an underground circular tunnel it will collide protons on protons at a maximum center-of-mass energy of 14 TeV. Detectors at four different locations will study the collisions, which are also known as “events”. One of the two general purpose detectors is the ATLAS experiment.

The purpose of the ATLAS detector is, among other things, to search for particles with masses up to several TeV. The greatest expectations lie in the discovery of the Higgs boson, the last of the fundamental particles in the Standard Model to remain undiscovered. Also, in different theorized extensions of the Standard Model new particles are predicted which might be produced at the LHC. The searches for these particles are far from easy: in the collisions they are swamped by the production of ‘uninteresting’ low mass particles. Furthermore, even before the searches can begin, the detector has to be commissioned and calibrated.

This thesis covers three subjects: the commissioning of the Inner Detector of ATLAS, a calibration scheme for the energy scales of the detector and finally an experimental setup for the measurement of the rate of production of W bosons and top quarks in first data.

First, the final steps of the installation and commissioning of the ATLAS detector are described. The data collected during the cosmic ray runs in the fall of 2008 have been used to study the performance of the SCT detector, the second most inner sub-detector in ATLAS. The SCT has been shown to perform in agreement with the design specifications. Extra attention is given to the commissioning of the evaporative cooling system of the SCT, which is to keep the temperature of the sensors at around -7°C. The system also cools the pixel detector, the most inner sub-detector in ATLAS, to around 0°C. Several problems occurred during the installation and commissioning of the system, notably with the heaters responsible for the evaporation of the remaining cooling fluid in the last steps of the cooling cycle. The problems are solved partly by adjusting the controls and partly by redesigning the cooling system.

As a second subject, an analysis is presented for the energy scale calibration of the detector, fine-tuned for the study of the top quark. The top quark is the heaviest of all six quarks known in the Standard Model and its large mass gives it a special role in the interaction between the Standard Model particles. Also the properties of undiscovered particles predicted by (yet) unproven theories such as supersymmetry are dependent on the top quark mass.

Using a kinematic fit with constraints for a semi-leptonic top quark pair decay, the jet energy scale and the missing transverse energy scale are determined on events simulated with Monte Carlo generators. A sample with integrated luminosity of \( L = 160 \, \text{pb}^{-1} \) at a center-of-mass energy of 14 TeV is used to show the feasibility of this procedure for first data calibration. Scanning over large ranges of the energy scales, with offsets up to 20%, it is shown that the
two correlated energy scales can be determined independently: first the jet energy scale by
minimization of the $\chi^2$ function and subsequently the missing transverse energy scale by using
as estimator the transverse momentum difference between the two top quarks, as reconstructed
with the kinematic fit.

Finally, an analysis is described to measure the rate of production of top quarks and $W$
bosons in proton-proton collisions with ATLAS. The signal of a $W$ boson production event can
resemble the signal of a top quark pair event; for the study of the latter, $W$ boson production
thus constitute a background channel. A second background channel to top quark pair events
is single top quark production. A first step in the identification of these backgrounds is the
determination of their rate of production.

Events with between two and four jets are studied; jets are the observable objects in the
ATLAS detector originating from either quarks or gluons. Using b-tagging algorithms, i.e.
special reconstruction tools for the identification of b-quarks, the number of jets tagged as
originating from a b-quark is measured as a function of the total number of jets in the event.
A likelihood method is applied to fit the composition of a sample of top quark and $W$ boson
events. The method is shown not only to be independent of the cuts applied in the b-tagging
algorithm, but also to be able to determine its efficiency on data. Applying the JetProb b-
tagging algorithm on a simulated sample of events with integrated luminosity of 50 pb$^{-1}$ at
a center-of-mass energy of 10 TeV, the $W$ boson production rate can be measured, together
with the combined production rate of the single and pair produced top quark events.

With both of these analyses the impact of supersymmetric events as predicted by two
models is studied. The kinematic fit is shown to possibly result in information on the mass
scale of the supersymmetric events. The likelihood method is shown to be sensitive to the
b-quark content in one of the supersymmetric models.