The $\phi(1020)$-meson production cross section measured with the ATLAS detector at $\sqrt{s}=7$ TeV

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Introduction

“Whooooooooooohaaaaaaaaaaaaaa, the particles fly through the tunnel at enormous speed. When they collide they have so much energy they smash apart and make new particles!” The kids move forward in their chairs, they did not expect the “physicist” to actually tell an exciting story, but she does!

The start-up and the first three years of running of the Large Hadron Collider (LHC) at the CERN research complex in Geneva, Switzerland, have been exciting indeed. The LHC is the most powerful particle accelerator ever built and it has provided enough data already to announce the discovery of the Higgs boson on 4 July 2012. The Higgs boson interacts with the masses of the elementary particles of the Standard Model of particle physics, the theoretical model that describes these particles and the forces between them.

At four points along the LHC where the protons collide, detectors are recording the particles that emerge from the collisions. The ATLAS experiment is one of the two general-purpose experiments at the LHC and it is well-suited for searches for new physics. To operate a large and complex system like the ATLAS detector, a sophisticated framework of safety procedures and software packages is in place. To provide real time monitoring of the operational performance, the recorded data are processed online and the results are assessed by physicists who staff the control room.

When the LHC collides protons, the protons may break up and new particles are created, such that observed particle multiplicities at the LHC range up to a few hundred. With large energy transfers in the collision the interactions can be calculated by quantum chromo dynamics (QCD), the part of the Standard Model that describes the interactions between the constituents (quarks and gluons) of the colliding protons. But if the energy transfer is low QCD is no longer calculable, because the strength of the coupling constant increases with decreasing energy transfer, impeding the use of perturbation theory. At this regime the theory needs to be complemented with data.

In this thesis, a measurement of the differential $\phi$-meson cross section is presented. The $\phi$-meson is produced in the hard scatter of a proton-proton collision, as well as in the softer hadronisation processes that take place simultaneously. This makes the $\phi$-meson cross section a suitable variable to calibrate the non-perturbative models. On the other hand, the $\phi$-meson is measured in a low-momentum regime, that is not probed with most measurements, and the selection of $\phi$-mesons uses particularities of the experiment that can only be exploited with excellent understanding of the detector.
Thesis layout

Chapter 1 of this thesis introduces QCD and the phenomenological models that are used to predict the physics of the non-perturbative regime. The implementation of these models in the Monte Carlo event generators PYTHIA, HERWIG++, and EPOS is discussed in detail.

In chapter 2, the LHC and the ATLAS experiment are introduced, chapter 3 discusses the inner tracker of ATLAS in more detail, because it is most important for the measurement of the $\phi$-meson cross section and because I was responsible for a part of the online operation of the inner detector during my PhD project.

The reconstruction of the trajectories of charged particles and the usage of energy loss in the inner tracker for particle identification are discussed in chapter 4. The discriminating power between the different particle species is assessed using simulated data.

Chapter 5 describes the selections and selection efficiencies of the $\phi$-meson reconstruction, while the $\phi$-meson production cross section is presented and compared to different theoretical predictions in chapter 6.