Second Year Report

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Abstract

My supervisors are Simone Marzani (Università di Genova) and James Ferrando (DESY Hamburg).

My PhD project takes place within the framework of high energy particle physics, in particular I am part of the ATLAS collaboration, one of the experiment situated at the Large Hadron Collider (LHC) at CERN. During the second year of my PhD my work focused on completing a task related to the performance studies of the ATLAS detector and in continuing a physics analysis that use the the proton-proton collision data collected by the ATLAS detector.

1 Inner Detector Alignment

This year I have qualified as an ATLAS author completing a project related to the performance studies of the ATLAS detector. The part of the detector under study was the innermost component, the so called Inner Detector, whose main role is to reconstruct the tracks, and consequently the momentum, of the outgoing charged particles from the proton collisions. This goal is achieved thanks to the magnetic field, within which the ID is situated, and the layered detector structure that allows it to collect various hits from the passing particles and to reconstruct the curvature of the tracks. The ID is mostly composed of silicon detectors elements, whose resolution is around $\sim 10\mu$m. One of the effects that can degrade the quality of the reconstructed tracks is when the position of the detector elements does not correspond to the nominal one because of some undetected movements of the detector. These movements are due to mechanical and thermal stress and can be of the same order of magnitude as the ID element resolution. The Inner Detector alignment consists of a track based procedure that aim to investigate and retrieve the real position of the detector elements. My work focused in developing a software that analyses possible residual misalignments of the detector. These misalignments are caused by collective movements of the detector elements that are not revealed by the standard procedure. To investigate them a system with further constraints is needed. In particular some resonance decays, such as the Z boson decay into two muons, are used. The mass of the Z boson ($m_Z = 91.2\,\text{GeV}$) is well known and the variation of the reconstructed mass from the nominal value can be related to misalignment effects and used to estimate them.

2 The Low Mass DY measurements at $\sqrt{s} = 13\,\text{TeV}$

The main project I have been working on this year is an analysis using the proton proton collision data collected with the ATLAS detector. The analysis in question regards the measurements of the Drell-Yan (DY) process in a low invariant mass range of the final state leptons. In high-energy proton-proton collisions the Drell-Yan process take place with the annihilation of a quark and an anti-quark into a vector boson that then decay into a lepton pair. The DY process is mediated by neutral vector bosons, photon and Z, and the final state considered in the analysis is the production of a muon anti-muon pair. The DY process is the primary source of on-shell Z boson production ($m_Z = 91.2\,\text{GeV}$) in collisions at the LHC. The invariant mass range of the outgoing muons explored in this analysis is below the Z boson resonance peak and down as low as allowed by the physics triggers. In particular the mass region analysed is between 7 GeV and 60 GeV. The aim of the analysis is to measure the single and double differential cross-section of the inclusive DY process in various kinematics variables of the di-muon pair. The difficulties of the measurement come from the high signal-to-background ratio. The biggest source of background comes from events with multiple jets containing muons in the final state that are misidentified as prompt muon, i.e. muons coming from the main interaction. A good understanding of the background components is necessary for the final result. The multi-jets background is poorly described by the Monte Carlo (MC) simulations and needs to be improved with a template fit of the MC distributions to the data. For the fit some kinematics quantities that are not related to the measured ones and that have a discriminating power between signal and background are used. In particular, a quantity related to the impact parameters of the particle, that are the longitudinal and transverse distance of the particle track from the interacting point, is used in the analysis. These quantities are useful because the muons coming from multi-jets are not prompt, and their production happen displaced from the the interaction point, that is with high values of the IPs.

My role in the analysis is that of continuing the work of the main analyzer performing new control studies and extending the measurement to new observable. In particular the measurement of the double differential cross-section as a function of the invariant mass and the transverse momentum of the dimuon pair has been included. This measurement is interesting because allows to investigate some non-perturbative terms of the theoretical prediction. The interest is enhanced by the good performance of the detector in reconstructing the muon momentum particularly in the low mass region. My work focused in studying the optimal binning for the measurement. This choice comes from the balance of two main aspects: a fine binning increases the physical information in the results, a larger bin size is needed in order to have enough data events in each bin and to trust the reconstructed track parameters. After that a study of the background estimation fit method applied to the measurement binning has been performed.

Another problem I am dealing with regards some controls studies of the impact parameter distributions. These are used, as mentioned before, in the background estimation method. A good description of these quantities is needed in order to trust the fit results and possible mis-modelling of the Monte Carlo simulations should be taken into account as a source of uncertainty. A misdescription of the data is indeed observed in the simulation and, in order to constrain the uncertainty, a data based correction is derived for the impact parameters quantities. The correction is evaluated looking at a data selection that is different from the one used in the analysis, but has similar kinematics properties. In particular two resonance decays, that are excluded from the analysis selection through a different mass window selection, are used: the Υ particle ($m_{\Upsilon} = 9.45\,\mathrm{GeV}$) and the Z boson. Muons produced in the decays of these particles span a wide range of muon transverse momentum.

The next steps in the work for the analysis are to finalize the measurement of the differential cross section assessing the effect of the IPs correction and to estimate the impact of the various uncertainty sources on the result. The analysis is currently in an ATLAS internal editorial board stage. After successfully concluding this passage, the analysis results will be circulated to the ATLAS collaboration to get the approval for an article submission.