Contents

1. Introduction

The Standard Model (SM) of particle physics is a very successful theory in that it explains a vast range of phenomenons observed in nature. Its predictive powers exceeds those of any previous theory and its mathematical structure is well defined and organised. The SM describes the fundamental aspects of matter and energy by expressing matter particles (fermions) and particles that mediate interactions (bosons) in a unified theory. The newest result of particle physics was the discovery of the Higgs Boson by CMS [?] and ATLAS [?]. The Higgs Boson's existence had been predicted over forty years ago as inherent part of the SM.
Despite these achievements there are still questions unanswered by the SM. One open issue is the inclusion of gravity and the explanation of the hierarchy of the fundamental interactions. Another unexplained phenomenon is the discrepancy between the amount of matter and anti-matter observed in the universe. While the SM does implement the mechanism of charge-parity (CP) violation, the generated effects within the SM are not large enough to explain today's observations.
For this reason, many other theories – such as the supersymmetry (SUSY) or the Left-Right Symmetric Model (LRSM) – have been developed as extensions of the SM. These theories are designed so that their predictions agree with the SM at low energies but differ at higher energies. Usually new particles are introduced with heavier masses, changing the physics at high energy scales with respect to the SM.

All high energy physics experiments aim at performing precision measurements of SM parameters or at discovering physics beyond the SM. The LHC has introduced an optimal environment with an unprecedented center of mass energy and a high luminosity that provides the allocated experiments with a high amount of statistics. The experiments CMS and ATLAS – the so-called 'general purpose' detectors – aim at finding new particles through direct searches. The LHCb experiment however, performs indirect searches for new physics, for example by identifying deviations from SM predictions in loop-diagram processes. The LHCb experiment focusses on rare decays of B and D mesons and hadrons and also studies CP violation.
The $B^0 \to K^{*0}e^+e^-$ decay is of special interested, because it proceeds through a flavour changing neutral current (FCNC) and is therefore forbidden at tree-level in the SM. It has to proceed through penguin or loop diagrams and thus is particularly sensitive to new physics and particularly useful for testing the quantum structure of the underlying theory. Since relative contributions from new physics is greater for these processes than for tree-level processes it is more likely to be detectable through thorough analysis.
The main contribution to the $B^0 \to K^{*0}e^+e^-$ comes from the transition of $b \to s\gamma$ where the photon is virtual and decays into an electron-positron pair. While the

branching ratio for this transition has been found to be consistent with SM predictions (measurement via $B^0 \to K^{*0}\gamma$ [4]), new physics could still be detectable in details of the decay such as the photon polarisation. Due to the chirality structure of the weak interaction, the photons from the $b \to s\gamma$ transitions are dominantly left-handed. A measurement of a significant amount of right handed photons from this transitions would be an unambiguous sign of new physics beyond the SM. The photon polarisation can be probed by performing an angular analysis of the $B^0 \to K^{*0}e^+e^-$ decay. In this case, the photon from the $b \to s\gamma$ is virtual and the information about its polarisation is conserved in the kinematics of the electron-positron pair.

This master's thesis provides the fundamental basis for an angular analysis of the $B^0 \to K^{*0}e^+e^-$ decay. In the course of this work the reconstruction of the $B^0 \to K^{*0}e^+e^-$ candidates is studied and different reconstruction algorithms are evaluated. Hereby the focus is put on the reconstruction of bremsstrahlung emitted by the electrons and the reconstruction of the invariant mass of the electron-positron pair.
Furthermore a new selection procedure for the $B^0 \to K^{*0}e^+e^-$ events in $3\,\mathrm{fb}^{-1}$ of data collected by LHCb in 2011 and 2012 is developed. Therefore a method implementing two identical Boosted Decision Trees trained on different parts of the dataset is applied. The selection of the $B^0 \to K^{*0}e^+e^-$ events is optimised and the number of reconstructed and selected $B^0 \to K^{*0}e^+e^-$ events is extracted by fitting a probability density function – composed of a probability density function for the signal and the background respectively – to the dataset.

2. Conclusion

The $b \to s\gamma$ transition proceeds through a flavour changing neutral current and thus is particularly sensitive to the effects of new physics. These effects could be detectable in details of the decay such as the polarisation of the photon which is predicted by the SM to be predominantly left-handed. Certain extensions of the SM such as the Left-Right Symmetric Model (LRSM) can provide a significant right-handed photon amplitude. The photon amplitudes can be measured by performing an angular analysis of the $B^0 \to K^{*0}e^+e^-$ decays at low invariant dilepton mass.

The work in this master's thesis is the first step towards this angular analysis.
The comparison between the different reconstruction algorithms for the bremsstrahlung emitted by the electrons shows that the new reconstruction algorithm increases the resolution of the B^0 mass by 13%. By implementing the tool specially dedicated to reconstructing low dilepton mass pairs the B^0 mass resolution can be augmented by a total of 27%. Furthermore this tools shows an increased reconstruction efficiency for events with very low invariant dilepton mass which are the ones most important for the angular analysis. Thanks to the new reconstruction algorithms the lower cut on the invariant dilepton mass could be dropped from $30\,\mathrm{MeV}/c^2$ in the 2011 analysis to $20\,\mathrm{MeV}/c^2$ while keeping a high precision on the angles Φ, θ_l and θ_K.
The new stripping line used in the preselection of the $B^0 \to K^{*0}e^+e^-$ candidates in the 2011 and 2012 LHCb data features a selection efficiency which is increased by a factor 1.4 with respect to the previous stripping line. Furthermore the selection procedure developed in this work implementing two BDTs yields the biggest sample of $B^0 \to K^{*0}e^+e^-$ events ever selected. Summed over the three independent trigger categories for which the analysis was performed the signal yield is 130 $\pm$ 16 events which corresponds to a signal significance of 8.3 standard deviations. This signal yield is 40% more than the yield that would have been obtained by applying the selection developed in the 2011 analysis.

Continuing from this dataset of $B^0 \to K^{*0}e^+e^-$ candidates the angular analysis will be performed. Monte Carlo toy studies have shown that an accuracy on the parameter $A_T^{(2)}$ using 130 $B^0 \to K^{*0}e^+e^-$ events and assuming no contribution from background events of $\sigma(A_T^{(2)}) \approx 0.2$ can be achieved.

Bibliography

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