University of Zurich[UZH]

Physik-Institut
Universität Zürich

Prof. Dr. Nicola Serra

Nicola Serra
Department of Physics
Winterthurerstrasse 190
8057 Zürich
Phone: +41 (0) 44 635 5725
E-mail: nicola.serra@cern.ch

Subject: Evaluation letter for the Ph.D. thesis of Andrea Mauri with title: ¨**Direct and indirect searches for New Physics in $b \to sll$ Decays**¨

Dear Colleagues,

I write this letter to evaluate the work described in the Ph.D. thesis of Mr. Andrea Mauri, with title "**Direct and indirect searches for New Physics in $b \to sll$ Decays**”. The work of Mr. Mauri is in the context of experimental particle physics, in particular of the LHCb experiment. LHCb is one of the four large experiments taking data at CERN in Geneva, and it has been designed and optimised to perform precise measurements of decays of particles containing b or c quarks. The thesis describes searches for physics beyond the Standard Model with two complementary strategies in $b \to sll$ transitions (where l indicates either an electron or a muon). The two strategies are described in Chapter 1 of the thesis. The first approach aims to search for new hidden sector particles that might mix with the Higgs boson, so called Dark Scalars. The experimental signature of such Dark Scalar would consist of a resonance in the dimuon invariant mass spectrum of $B \to K^{(*)}\mu\mu$ decays. In models where the Dark Scalars does not couple with Dark Matter, the dimuon resonance is displaced with respect to the B-meson decay vertex. In particular, Andrea discusses a model where a light inflaton mixes with the Higgs boson.

The second approach consists of searching from deviations with respect to the Standard Model due to the contribution of heavy (with respect to the B-meson mass) new particles. Chapter 2 of the thesis describes the status of the field, concentrating on the rare decays flavour anomalies. These anomalies consist of measurements of angular observables in the decay $B^0 \to K^*\mu\mu$ (in particular in the observable P_5') and the ratios of branching ratios $R(K^{(*)}) = \frac{\mathcal{B}(B\to K^{(*)}\mu\mu)}{\mathcal{B}(B\to K^{(*)}ee)}$. In this Chapter, the formalism of the effective Hamiltonian, used for the indirect search of New Physics, is also discussed. This formalism describes short distance interactions in $b \to sll$ decays in terms of effective operators and Wilson Coefficients, while long distance interactions are described by Form-factors. The Lepton Flavour Universality observables $R(K^{(*)})$ have negligible theory uncertainties, instead the observables P_5', and more in general all observables depending on the Wilson coefficient C_9^l, are affected by theory uncertainties due to non-local hadron operators, so-called charm loop.

In Chapter 3 a new strategy to search for heavy new particles in $B^0 \to K^* ll$ decays is proposed. Andrea studied systematically the impact of the charm loop effect directly in the experimental fit to data. Following recent developments in the literature, the non-local hadronic contributions are parametrised via a polynomial expansion in a conformal variable “z”. This amplitude fits has several advantages compared to traditional fit to the observables, in particular when applied simultaneously to the electron and muon modes $B^0 \to K^* ll$. The simultaneous LFU fit allows to determine the difference in Wilson coefficients $C_9^\mu - C_9^e$ and $C_{10}^\mu - C_{10}^e$. This strategy is completely free from theory uncertainties, not only from non-local hadronic operators, but also from form-factors. Andrea studied the sensitivity of this approach at LHCb for different scenarios.

The LHCb detector is described in Chapter 4. In particular, Andrea discusses studies of the performance of the Silicon Tracker conducted by him with data collected at LHCb. These studies will be part of a performance paper of the Silicon Tracker which is at present in preparation.

Chapter 5 and 6 describe the data analysis for the direct search for light Dark Scalars in $B^+ \to K^+ \chi(\to \mu\mu)$. This analysis consists of a peak search in the dimuon invariant mass spectrum and a search for displaced dimuon vertexes. The constraints that Andrea set on light scalars are the world’s best to date and allow to exclude almost the full parameter space for the light inflaton model, with masses below 5GeV.

The last session of the thesis (Chapter 7) describes sensitivity studies with realistic conditions to direct fits of Wilson coefficients in the decay $B^0 \to K^* \mu\mu$. This work includes realistic backgrounds as well as the $K\pi$ S-wave contribution and resolution as simulated by the LHCb official full simulation. This last section is part of the ongoing amplitude analysis of the decay $B^0 \to K^* \mu\mu$ for which Andrea is having a leading contribution and for which LHCb data are still blind.

In summary, the thesis of Andrea Mauri describes searches for physics beyond the Standard Model in $b \to sll$ transitions in different and complementary ways. Andrea was the leading force for the world’s best constraints on light Inflaton that can be produced in B-meson decays. He gave important phenomenology contributions to set a new and optimised strategy for the measurement of Wilson coefficients in $b \to sll$ transitions. He studied the performance of the silicon tracker of LHCb. Finally, he made realistic sensitivity studies for an amplitude analysis of the decay $B^0 \to K^* \mu\mu$ in LHCb, which is part of an ongoing effort led by Andrea. The thesis is well written and describes all the work with enough details. The work presented in the thesis represents an important addition to the field of searches for New Physics in rare B-meson decays, it is original and novel in its scope and methods and warrants the award of a Ph.D. degree in Physics. I therefore highly recommend that the Thesis is accepted.

Sincerely,

Prof. Dr. Nicola Serra