Title of the thesis: Indirect searches for new physics via flavour violation observables

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Summary:
The completeness of the Standard Model (SM) as a description of fundamental interactions has entered a new era since the discovery of the Brout-Englert-Higgs boson in 2012. As of today the phenomena for which the SM most clearly fails to provide an understanding are neutrino masses, the baryon asymmetry of the Universe and the dark matter problem. While there are well motivated SM extensions explaining each of these phenomena, none have received direct experimental support allowing to discriminate among the various possibilities. Independently, anomalies in b-quark decays, violating the SM lepton flavour universality (LFUV), started emerging with a remarkably persistent (albeit not very high) significance $(\sim 3\sigma)$. These appeared in measurements, mostly reported by LHCb, of $b \to s\mu\bar{\mu}$ exclusive observables like the ratio $R_{K^{(*)}} = \mathrm{Br}(B \to K^{(*)}\mu\bar{\mu})/\mathrm{Br}(B \to K^{(*)}e\bar{e})$ or the angular distributions of the decay products, and of $b \to cl\bar{\nu}$ observables like $R_{D^{(*)}} = \mathrm{Br}(B \to D^{(*)}\tau\bar{\nu})/\mathrm{Br}(B \to K^{(*)}l\bar{\nu})$.

After reviewing these observables, and the significance of their deviations to the SM, the project will start by studying and comparing the SM extensions that could accommodate such deviations, with particular focus on the minimal renormalisable models adding a single leptoquark, of spin 0 or 1. Starting from such models, the possibility of addressing dark matter, neutrino masses, and possibly the baryon asymmetry problems by minimal further extensions will be explored. More specifically, the requirements on the Yukawa couplings of leptoquarks imposed by flavour anomalies (either $b \to s$, or $b \to c$, or possibly both) will be compared to those arising from the requirements of satisfying the observed dark matter relic density, and accounting for neutrino oscillation data. An important aspect of the PhD will be to confront the impact of such extensions on the experimental searches for other flavour-related observables occurring in many fronts: other than numerous neutrino-dedicated experiments, many high-intensity facilities (such as MEG, Mu3e, Mu2e and COMET) are exploring several low-energy lepton observables (violation of lepton flavour and number), while others will push the limits on anomalous magnetic moment of muons, and electric dipole moments; the LHCb experiment, as well as the upcoming SuperKEKB facility and NA62 are pursuing hadron flavour physics.

This PhD in particle phenomenology will require and develop knowledge in analytic and numerical computation of observables in SM extensions, as well as abilities to grasp and synthesize data and concepts ranging from dark matter to neutrino and flavour physics.