Title of the thesis :
Probing New Physics Beyond the Standard Model: Axions, Flavor, and Neutrinos

Summary of the thesis :
In this doctoral thesis, several phenomenological aspects related to the origin of neutrino masses, to flavor physics, as well as to the problem of the violation of CP symmetry by the strong interaction, have been studied. In chapter 2, after an introduction to the Standard Model (SM), we develop in more detail the experimental observations and the open theoretical questions requiring the presence of physics beyond the Standard Model. Chapter 3 focuses on the origin of neutrino masses and their mixing considering the hypothesis of the existence of heavy neutral leptons (HNLs). Particular attention is paid to the experimental research of HNLs, in particular to the constraints on their masses and their couplings deduced from the proton-proton collisions studied at the LHC. More specifically, through several processes researched at the LHC (ATLAS, CMS and LHCb), we point out that the bounds coming from collider searches are often based on overly simplistic assumptions. In this part of the thesis, we show how to reformulate these constraints in order to cover realistic models with several HNLs and more general couplings to the active sector. Chapter 4 is devoted to the physics of flavor as a means of exploring the physics beyond the Standard Model through low-energy experiments. Especially the rare decays of the meson B, notably $B o K^{(ast)} u u$, are studied and analyzed in detail. For these channels we provide the most successful theoretical predictions, which we have enriched with an analysis of the impact of new physics on the decay widths. The problematic point of this analysis remains the treatment of uncertainties related to non perturbative QCD. We show that a measure of the partial widths would make it possible to test the functional dependence of the form factors on the momentum transfer, q^2. In chapter 5, some phenomenological consequences of the solution to the strong CP problem are studied in terms of particles called axions. Particular emphasis is placed on the hypothesis that axions could form a population of hot dark matter (HDM). A new phenomenological

determination of the axion-pion scattering rate in the early Universe is provided in this thesis. This determination uses the $pi pi o pipi$ scattering data and the amplitudes calculated in chiral perturbation theory, the applicability of which is extended in the resonance region by a unitarization method named inverse amplitude method. The result thus obtained makes it possible to obtain a bound on the mass of the axion, also known as the HDM bound. A summary of the results obtained in this thesis is presented in chapter 6, where we also discuss some possible avenues to continue and further deepen the research addressed in this work.