Physicists at the Large Hadron Collider, or LHC, in Geneva, investigate the deepest constituents of matter. They accelerate bunches of protons (the hydrogen atom nucleus) to nearly the speed of light and have them collide head-on. When two protons collide with very high energy they shatter and their constituents interact among themselves to produce electrons, muons, photons, and jets of various particles that fly out in all directions and are finally gathered in sophisticated detectors positioned on a few strategic points along the beam ring. Experimental physicists perform the difficult task of analyzing their properties: what is the precise number of gathered particles, their energy, charge, and quantum numbers. They finally publish the results of their analyses.

Even before looking at those results, theoretical physicists know for the most part what will come out of the proton collisions: how many electrons, muons, or photons they should expect and what will be their energy and spatial distribution. This is because the protons are made of quarks and gluons, the particles holding those quarks together through the strong force. The interactions of these fundamental constituents among themselves and other particles are very well known: they follow the predictions of the Standard Model, a model so accurate that it has provided the "gold standard" for predictions in particle physics since the early 1970s. The particles of the Standard Model have all been observed. The last to be found was the Higgs boson, discovered at the LHC in July 2012.

Despite the Standard Model's success, though, theoretical physicists know that it cannot be the end of the story, as there exist some phenomena in Nature that are not predicted in its framework. The dark matter of the Universe, the mass of neutrinos, the reason for a different number of particles and antiparticles in the Universe, and other more technical issues are not explained by the Standard Model. Nobody knows for sure how the new physics "beyond" the Standard Model, or BSM, looks like. There are many hypotheses in the literature, each of which is potentially valid, but in order to be considered the true story a new theory must find experimental confirmation. If BSM physics were to appear at the LHC, it would be first in the form of an "anomaly," a discrepancy between the measured number of certain detected particles and the Standard Model expectation.

In a collider, anomalies are often due to statistical fluctuations, so that they come and go all the time. Some of them, however, which were recently observed in LHCb, the detector built to measure precisely the decay rate of particles made of "beauty" quarks, have caught the attention of many theorists. They have appeared in "flavor-changing" transitions and, when investigated collectively, they seem to bring out a coherent picture of new physics that, among other things, would involve unexplained differences in the way possible new particles interact with electrons and muons.

In this project I propose to perform a systematic analysis of BSM models that can provide an explanation for these so-called flavor anomalies and, at the same time, be endowed with a viable candidate for the dark matter of the Universe. The models are roughly divided in two classes: those featuring "heavy" particles, of mass larger than the mass of the Higgs boson; and those whose particles are "lighter" than the beauty quark.

I will construct and analyze models according to some of the symmetries that theorists believe should buttress the structure of any BSM framework, in an attempt to derive a picture as self-consistent as possible from the mathematical point of view. Additionally, in order to ascertain the validity of this picture, the models will be confronted with a large amount of data from BSM collider and dark matter searches.

To achieve my goal I will use state-of-the-art numerical programs and statistical techniques to to construct a set of likelihood functions, numerical functions that present a peak when the model's predictions are close to the signals observed, while they smoothly decrease in value as the model's expectations differ more and more from what is detected. The numerical value of the likelihood function for each model is related to the probability of the model being the real theory. The results of my analyses will help point future financial and intellectual resources in the right direction.