

Standard Model extensions with vector-like fermions

(popular science summary)

One of the most fundamental questions that have been driving particle physicists for many years is whether the Standard Model, a theory that describes basic constituents of matter and their interactions, is complete. There are many good reasons to think it is not, and perhaps a whole new world of exotic matter and forces is hiding just around the corner, waiting to be discovered.

To answer this question, physicists must look at what happens in processes whose characteristic energy is much higher than the mass of Standard Model particles. To reach such an energy, experimental physicists use particle accelerators, or colliders, to bring bundles of protons (or electrons) up to almost the speed of light and make them collide with each other. The idea behind the process is the following: if there exist objects in nature that were not predicted by the Standard Model, they could be produced in the collider for a tiny fraction of a second, and then decay to the known particles, leaving a clear trace in the detector. At the same time, theoretical physicists try to extrapolate the guidelines for constructing truthful and predicting models of “new physics” from the details and structure of the Standard Model itself. In fact, some of the Standard Model predictions can be taken as indication that additional elementary particles must show up at the energies tested in a collider environment. The question remains what kind of particles they are.

Over the past decades, many models of new physics have been proposed. So far, none of them have found an experimental confirmation. Thus, the search keeps going on. The goal of the presented project is to systematically analyze a specific class of the Standard Model extensions containing *vector-like fermions*, particles that in many aspects resemble quarks and leptons (as them, they have a spin of one-half), but they can be much heavier and interact slightly differently with the gauge bosons (such as the photon). Interestingly, these are exactly the features which allow them to solve many of the problems of the Standard Model.

In the course of this project, the experimental predictions of selected models with vector-like fermions will be compared to data. Since the comparison must be performed for a large number of parameters and model configurations, defined for example by the mass of a vector-like fermion and the strength of its interaction with other particles, advanced numerical tools will be used for this purpose. If such a verification turns out successful, the model under study can be considered as a promising scenario of new physics. Conversely, if the model predictions do not coincide with what the experiments measure, the model must be rejected.

The results obtained during the implementation of the project will be important for the development of elementary particle physics. Not only will they indicate possible directions for future theoretical research, but they will also provide guidance to the experimental groups in their hunt for beyond the Standard Model particles.