# Abstract

The Standard Model of particle physics is the best theory we have for the description of the behavior of elementary particles. Most experimental results are consistent with this theory, which make it one of the best tested theories in human history. However, there are some experimental findings that call for an extension of this model. For example, the discovery of neutrino oscillations, i.e. the fact that neutrinos change their type ("flavor") while traveling, indicates that neutrinos are not massless, which they, however, have to be in the Standard Model. The model contains many parameters, which have to be fixed by experiments. The majority of them is associated with the flavor sector of the model, i.e. the masses of the elementary fermions and their mixing matrices that describe how strongly the different fermions couple in weak charged current interactions. These matrices also determine how the charge conjugation-parity (CP) symmetry is violated.

Experimental determinations of flavor mixing matrices in the quark and lepton sector have shown that they are very different in the two sectors. While the matrix in the quark sector is nearly diagonal, its lepton counterpart also has very large off-diagonal entries. There have been many attempts at explaining the observed mixing matrix patterns. Certain types of explanations link a symmetry (flavor symmetry), and the potential breaking thereof, to the form of the matrices.

In this thesis, such an explanation is attempted. We use the finite group $\Delta(384)$ as the flavor symmetry and combine it with a generalized CP transformation to make predictions for the mixing matrix parameters. This group is broken to distinct subgroups in the up-quark, down-quark, charged lepton, and neutrino sectors. The relative alignment of the different subgroups allows to make predictions for the form of the mixing matrices. After an introduction to the concepts of flavor groups and generalized CP transformations, the group $\Delta(384)$ with CP is analyzed for viable breaking patterns of a given type. The findings are categorized and their predictions are studied.

The second part of the first chapter presents a model which realizes one of the previously identified breaking patterns in a concrete quantum field theoretical model. It builds on the Minimal Supersymmetric Standard Model and three singlet neutrino superfields. On top of that, extra gauge-singlet fields (flavons) are introduced, whose vacuum expectation values are responsible for the spontaneous breaking of the flavor symmetry and the generation of the charged fermion mass hierarchies. The structure of the resulting mass- and mixing matrices are discussed in detail before the flavon vacuum alignment is presented. The model accommodates the experimental data very well and furthermore makes predictions for the CP violating phases in the lepton sector.

The second part of this thesis discusses phenomenological aspects of flavor in particle physics. The connection between lepton number violation and neutrino masses has been studied extensively in the past. Motivated by a study of effective operators that violate lepton number and their effects on neutrino masses, neutrinoless double beta decay, as well as muon to positron conversion in nuclei, we studied one particular operator in detail: $\mathcal{O}^s_{\alpha\beta} = \ell^c_\alpha\, \ell^c_\beta\, u^c\, u^c\, \overline{d^c}\, \overline{d^c}$. This operator is special because the estimates showed that it needs a very small effective scale to generate neutrino masses of relevant size. This raised the question if it is possible to find a renormalizable theory that only generates the operator $\mathcal{O}^s_{\alpha\beta}$ and therefore makes sizable rates for muon to positron conversion possible without being forbidden by neutrino mass- or neutrinoless double beta decay bounds. In the project we categorized possible tree-level ultraviolet completions of $\mathcal{O}^s_{\alpha\beta}$ and discussed phenomenological implications of processes induced by the new particles. The flavor structure has to be non-generic in order to evade bounds from neutrinoless double beta decay and charged lepton flavor violating processes. Also baryon number violating effects appear as well as collider bounds that restrict the size of the new parameters. We discussed that in order to bring muon to positron conversion within reach of next-generation experiments, non-trivial flavor structures and tuning of the parameters are necessary.