

Abstract

In the the Standard Model of Elementary Interactions (SM) there is only one scalar particle, a Higgs boson. In this thesis various models of elementary interactions with extended scalar sectors were discussed: the $O(N)$ Model, Two-Component Dark Matter Model (2CDMM), Two-Higgs Doublet Model (2HDM) and Two-Higgs Doublet Model with Scalar Singlet Dark Matter candidate (2HDMS). In the framework of these models, we discussed various theoretical issues: perturbative unitarity, vacuum stability of the scalar potential, electroweak symmetry breaking, triviality and little hierarchy problem. Various experimental constraints were imposed on the models:

- electroweak precision constraints on S, T, U parameters
- b physics constraints on charged Higgs boson in 2HDM and 2HDMS
- fit to the LHC signal strenghts from ~ 125 GeV scalar
- limits on Higgs invisible decays
- Dark Matter relic density limits from WMAP/Planck
- Dark Matter direct detection limits

The $O(N)$ Model contains extra N scalar particles, that are singlets of the $SU(3) \times SU(2) \times U(1)$ gauge group. The model provides multiple Dark Matter (DM) candidates. We discussed DM density evolution in scenarios with and without thermalization in the very early Universe. The parameter space of the model was constrained also with limits from direct detection experiments.

We also discussed a model with one scalar and one fermion DM candidates (2CDMM). The dynamics of evolution of DM density in the Universe was discussed and solutions to a set of Boltzmann equations were shown. The parameter space of the model was severely constrained by cosmological data.

The Two-Higgs Doublet Model was introduced to explain the enhancement in the $\gamma\gamma$ decay mode of the ~ 125 GeV boson observed at the LHC. Possibilities of such enhancement and consequences for the parameter space of the model were studied in various scenarios of mass hierarchy of the Higgs bosons present in the theory.

We also discussed a Two-Higgs Doublet Model with a Scalar Singlet Dark Matter candidate (2HDMS). All applicable constraints on this model were discussed, together with a fit to the LHC ~ 125 GeV signal strengths. We discussed a possibility of isospin-violation in DM - nucleon interaction, that may help to reconcile the results from xenon-based direct detection experiment with CDMS Si and COSENT.