Why going beyond the Standard Model

The Standard Model (SM) of elementary particles is an extremely successful description of what we observe at colliders. Neutrino oscillations and properties of the Universe show that SM is not the ultimate theory. The SM does not contain the masses of neutrinos and their mixing. The SM does not explain almost 5/6 of matter in the Universe. Neutrino masses and mixing is subject of the RGE running. The parameters of the effective Standard Model are completely determined. The parameters of the Standard Model are translated into boundary conditions at the condensation scale. All three Higgs fields acquire vacuum expectation values that generate the neutrino mass matrix elements.

Leptogenesis

The baryon abundance from sphaleron conversion of the lepton abundance.

Two types of right-handed neutrinos (electroweakinos, sneutrinos) are introduced in a way that the lepton number is respected by \( M_R > M_D > M_L > M_T \), and \( \nu_l > \nu_R \).

Neutrino mass is generated by the SM neutrino attraction.

\[ m_\nu = \frac{1}{2 \Lambda} \left( M_R^2 - M_D^2 \right) \]

Effective lagrangian description – 2 Higgs doublet + 1 Higgs singlet model

to describe the low-energy phenomenology of the model

Higgs boson particle spectrum

Higgs boson particle spectrum

10 degrees of freedom

\[ v_1, v_2, v_3 \] electroweak bosons

\[ v_1, v_2 \] Higgs-Goldstone bosons

\[ h, H \] charged and pseudo-scalar Higgs bosons

\[ \Lambda, H \] scalar Higgs bosons

Hierarchy of scales

\[ \Lambda > M_R > M_W > M_H > m_\nu \]

A key result dictated by phenomenology, as it is shown in the following.

Parameter fixing from lepton number conservation

To be specific we choose

\[ M_\nu = 10^{-3} \text{ GeV} \]

The heavy neutrino mass splitting is given by the inverse seesaw mass parameter which is given by the RGE running.

\[ m_\nu = \frac{1}{2 \Lambda} \left( M_R^2 - M_D^2 \right) \]

The Yukawa couplings constants corresponding to two strongest decays are the following:

1. The SM-like Higgs boson channel gives

\[ y_{\nu_{\text{SM}}} \approx 10^{-3} \]

2. The heavy Higgs boson (\( \nu_{\text{SM}} \)) channel has to be forbidden kinematically due to \( M_H > M_D > 2 M_\nu \).

\[ y_{\nu_{\text{SM}}} \approx 10^{-3} \]

The light neutrino mass is

\[ m_\nu = \frac{1}{2 \Lambda} \left( M_R^2 - M_D^2 \right) \]

Model predictions

Candidate for dark matter candidate

Dark matter candidates should be a particle which is massive, stable and sterile enough. Stability = lifetime longer than the age of the Universe.

In our model the candidate is the \( \nu_\chi \) Higgs boson.

The mass is \( m_{\nu_\chi} \approx 10^{-1} \text{ keV} \), and it is a warm dark matter candidate.

\[ \gamma_{\nu_\chi} \approx 10^{-1} \text{ keV} \]

Light neutrino mass

\[ m_\nu = \frac{1}{2 \Lambda} \left( M_R^2 - M_D^2 \right) \]

ABSTRACT

We propose an extension of the Standard Model (SM) where neutrino mass is generated within the low-scale seesaw scenario via the lepton number violating condensation of neutrinos. To prove the concept we elaborate a model of just single neutrino generation and provide an order-of-magnitude test of its phenomenology.

Leptogenesis completes fixing of the model parameters. Properties of a dark matter (DM) candidate and light neutrino mass are then completely determined.

Despite a small room for parameter tuning and without ordering it, surprisingly, we get the decay rate of our DM close to what is needed. Neutrino mass turns out to be extremely small. That should not be seen as a problem if it will be the case solely of the lightest neutrino within the future realistic three-generational model.