Searching for the N-Naturalness tower of neutrinos

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The Standard Model of Particle Physics has achieved extraordinary success in describing the fundamental particles and their interactions. Its predictions have been confirmed by a wide range of experiments; however, several experimental observations and theoretical considerations indicate that it cannot represent the ultimate description of nature. A framework beyond the Standard Model (BSM) is required to address some of the most prominent open questions in particle physics, such as the hierarchy problem, the nature of dark matter, and the origin of neutrino masses.
The observation of neutrino oscillations has demonstrated that at least two neutrino species possess non-zero masses and, since the Standard Model predicts massless neutrinos, this phenomenon provides direct evidence for physics beyond the Standard Model. Neutrino experiments therefore represent an important laboratory for testing BSM scenarios.
Over the past decades, an extensive experimental program has been developed to measure neutrino properties with increasing precision. Oscillation experiments have determined several of the mixing parameters with high accuracy, while direct kinematic measurements probe the absolute neutrino mass scale. Searches for neutrinoless double beta decay aim to determine whether neutrinos are Majorana particles, and several upcoming facilities are expected to significantly improve the sensitivity of these measurements.
The growing amount of experimental data provides an increasingly powerful testing ground for theoretical extensions of the Standard Model and confronting BSM models with the full set of experimental results requires a consistent analysis strategy capable of combining multiple datasets simultaneously.

In this work, such a global analysis approach is employed to investigate one particular realisation of the $Many\ Species$ mechanism, which proposes a solution to the electroweak hierarchy problem [1] and a mechanism that can generate suppressed neutrino masses [2], by postulating the existence of N quantum field species situated, for example in multiple copies of the Standard Model.
We focus on the N-Naturalness model [3], which introduces multiple sectors hosting copies of the Standard Model, each with a different Higgs mass parameter. The additional N sectors provide the suppression to the Higgs mass parameter and, at the same time, when equipped with a right-handed neutrino which can couple all the other sectors, can provide a mechanism to generate neutrino masses and match their observed value without requiring a very small Yukawa coupling [4].
The presence of additional sectors and therefore additional neutrinos (namely, a tower of neutrinos with increasing masses) modifies oscillation probabilities and effective neutrino mass, allowing for testing the theory against observations.

The analysis compares the predictions of the model with publicly available data from the Daya Bay and GERDA experiments, together with projected sensitivities from JUNO and the LEGEND experiments. In particular, the analysis aims at constraining two key parameters of the theory: N, the number of sectors, and r, the measure of fine-tuning of the theory.
We report exclusion limits on the parameter space (r, N), for normal and inverted ordering and in the case the neutrino is Majorana or Dirac. In the case of a Majorana neutrino, we can rule out $N \leq 10^4$ sectors with $r \geq 0.1$. This is particularly exciting as it shows that a gauge and gravitational unification around M_{GUT}, which is a benchmark scenario of the N-Naturalness framework with $N = 10^4$ without fine-tuning, is ruled out by neutrino experiments. Overall, this analysis provides the first constraints from terrestrial neutrino experiments on the parameter space of the N-Naturalness model [5].

Literatur

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