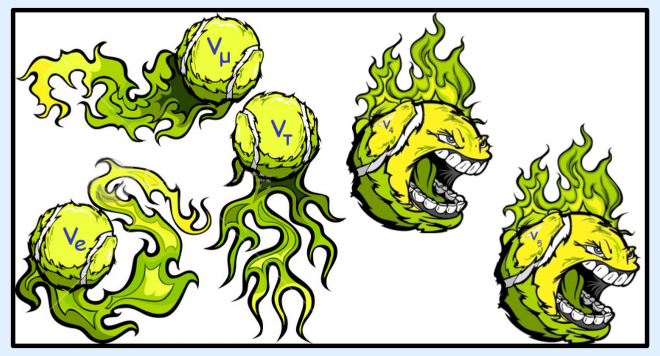
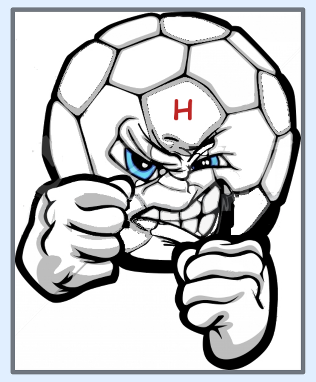


The minimal 3+2 neutrino model VS Higgs decays



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Introduction

The seesaw mechanism is generally invoked to explain the difference between neutrino masses and the rest of the fermions.

In this work, we study the minimal 3+2 neutrino model in scenarios where the singlets have masses at the GeV scale. This can lead to Higgs decays into heavy neutrinos, which would be observable at the LHC.

Why is this interesting?

- We would be observing new neutral fermions.
- The Higgs coupling to light and heavy neutrinos would suggest the seesaw mechanism is at work.
- The size of the couplings, along with the "lightness" of the heavy masses, would suggest the existence of an approximate lepton-number symmetry.
- This can be further correlated to future measurements of lepton flavour violating processes.

The minimal 3+2 neutrino model

We extend the SM by adding two Majorana singlets. The model is then described by 11 parameters [1]:

- Three mixing angles and two CPV phases, contained within the U_{PMNS} matrix.
- Two non-zero light neutrino masses.
- Two heavy neutrino masses.
- One complex angle participating in active-heavy neutrino mixing.

For the normal hierarchy, the 3x2 active-heavy mixing matrix U_{ah} is:

$$U_{ah} = i\,U'_{\rm PMNS}\begin{pmatrix} 0 \\ H\, m_\ell^{1/2} R^\dagger M_h^{-1/2} \end{pmatrix}$$

$$R = \begin{pmatrix} \cos(\theta_{45}+i\gamma_{45}) & \sin(\theta_{45}+i\gamma_{45}) \\ -\sin(\theta_{45}+i\gamma_{45}) & \cos(\theta_{45}+i\gamma_{45}) \end{pmatrix}$$

A large γ_{45} maximizes mixing!

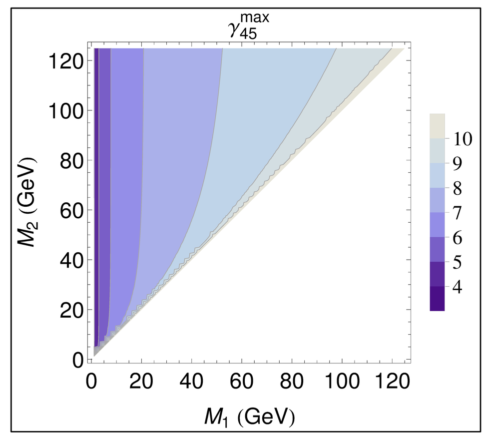
The 2x2 matrix H is a function of the other parameters. It is hermitian, and close to the identity.

Constraints

Among others, we find three important constraints on the parameter space.

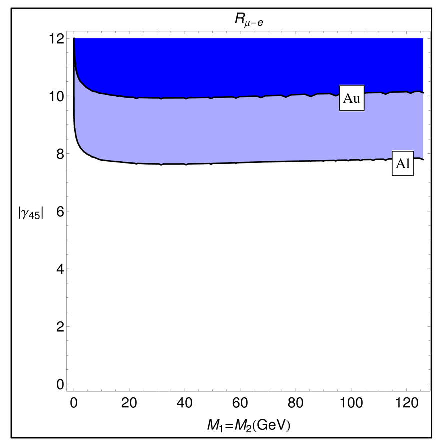
1. Neutrinoless Double Beta Decay (0νββ):

Strongly constrains active-heavy mixing, ruled by γ_{45}. Bound can be avoided by having degenerate heavy neutrinos, which brings a cancellation [2]. Such degeneracy can be justified by introducing an approximate lepton-number symmetry



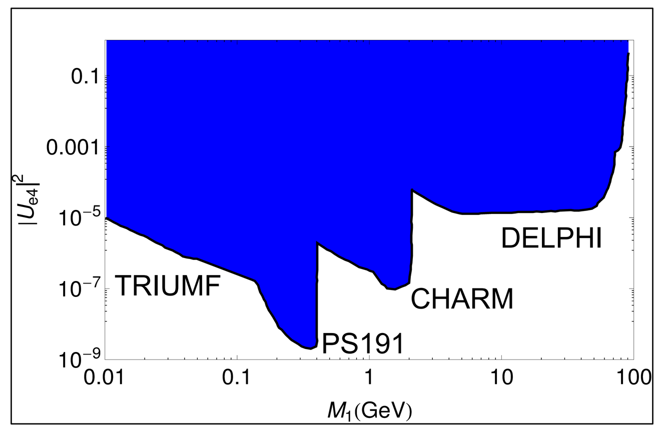
2. Lepton Flavour Violation (LFV):

Involves $\mu \to e\,\gamma$ decay and μ-e conversion in nuclei [3], the latter placing the strongest constraints. They give an upper bound on γ_{45}, even on the degenerate case. Here, dark blue zone is excluded, and light blue can be probed in the future.



3. Direct Search Bounds

Many experiments have tried to directly produce, and detect, heavy neutrinos. This provides upper bounds on active-heavy mixing. Here, the blue zone is excluded. Data taken from [4].



We find that the combined bounds heavily restrict the parameter space.

Higgs decays into heavy neutrinos

As the Higgs is coupled to one active and one sterile neutrino through the Yukawas, the Higgs can decay into one light and one heavy neutrino [5-7].

The branching ratio is obtained through:

$$\Gamma(h\to\nu_i N_j) = \frac{g^2}{32\pi}\frac{M_j^2}{m_W^2}m_h\left(1-\frac{M_j^2}{m_h^2}\right)^2|C_{ij}|^2$$

$$C_{ij} = i\begin{pmatrix} 0 \\ H^2 m_\ell^{1/2} R^\dagger M_h^{-1/2}\end{pmatrix}$$

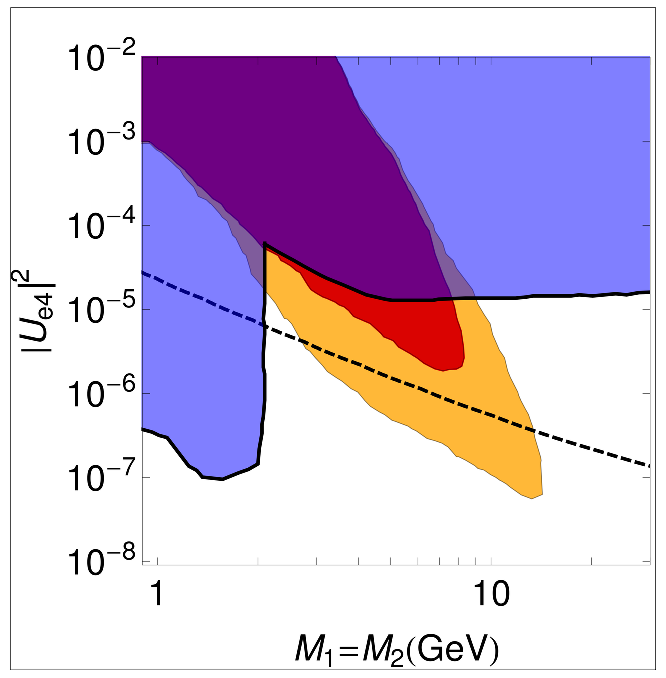
Again, process is enhanced by large γ_{45}.

We explore the possibility of having heavy neutrinos with large lifetimes, which would lead to displaced vertices at the LHC.

The following results are PRELIMINARY.

Using SusHi [8], we calculate the maximum area of the parameter space which can be probed by this process. We focus on Higgs production by gluon fusion, at 13 TeV. We require a transverse decay length larger than 1mm, and smaller than 1m. Results are consistent with those of [9], which follows a similar analysis.

Area of parameter space where displaced vertex is visible, and Higgs branching ratio is not too small. Blue area is excluded by direct search experiments. Dashed line indicates area that could be probed by future LFV experiments. Red area can be probed by a luminosity of 300 fb^{-1}, orange area can be probed by 3 000 fb^{-1}.



Full analysis to appear soon on arXiv.

STAY TUNED!

Conclusion

We have completed the first stage of a feasibility study for the observation of Higgs decays into heavy neutrinos. The study is done in the context of the minimal 3+2 neutrino model.

We have concentrated on decays where the heavy neutrino would generate a displaced vertex. After imposing constraints from other experiments, we find a small region where such decays could leave a signature. For this, we need a high luminosity LHC, with up to 3 000 fb^{-1}.

The region of interest consists of heavy neutrinos with masses between 2 - 10 GeV, and active-heavy mixing of order 10^{-5} – 10^{-7}. Note these results are preliminary, with the next stage of the study involving more detailed considerations of the displaced vertex signature.

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