PROCEEDINGS OF SCIENCE

Testing the neutrino mass generation mechanism at the colliders

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The neutrino mass generation mechanism is a mystery so far which explains the possible origin of the tiny observed neutrino masses and the flavor mixings over the decades- which indicates the existence of the beyond the Standard Model (BSM) physics, however, there is no observation of such BSM physics so far. Among the plethora of scenarios, the simple tree level mass generation mechanism with heavy fermions are the interesting ones which are tested at the Large Hadron Collider for the years. In this talk we will discuss briefly about the current status of these models and their prospects in the near future.

**** The European Physical Society Conference on High Energy Physics (EPS-HEP2021), ****
**** 26-30 July 2021 ****
**** Online conference, jointly organized by Universität Hamburg and the research center DESY ****

[*]Speaker

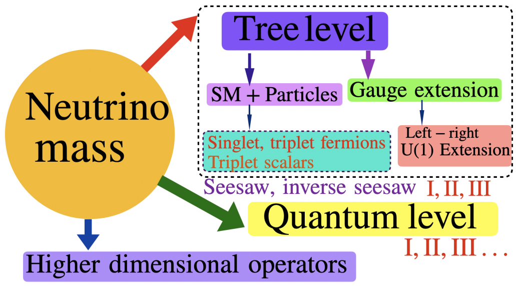

Figure 1: A graphic representation of the neutrino mass generation scenarios.

1. Introduction

The experimental evidence for neutrino oscillations and lepton flavor mixings, from the various experiments, motivate extensions of the SM incorporating non-zero neutrino masses and mixings. After the pioneering realization of the unique d=5 Weinberg operator within the SM with $\Delta L = 2$ lepton number violation (L = Lepton number), it was realized that the very well known Seesaw mechanism could be the simplest idea to explain the smallness of the neutrino masses and flavor mixings. In many of these models, SM is extended by gauge singlet, Majorana type, heavy right handed neutrinos (RHNs). After electroweak (EW) symmetry breaking, the light Majorana neutrino masses are generated by, for instance, the so called type-I seesaw mechanism. Apart from the seesaw mechanism the SM can be extended using $\mathrm{SU}(2)_L$ triplet scalar, triplet fermions which are called the type-II and type-III seesaw scenarios. Apart from the tree level neutrino mass generation mechanism there is an alternative way of generating the neutrino mass at the quantum level where the neutrino masses can be explained from the one, two, three or more loop generated processes. Besides these $\mathrm{U}(1)$ gauge extended and Left-Right scenarios are interesting aspects where neutrino mass can be generated at the tree level and quantum level. Depending on the choice of the neutrino mass generation models LHC has started searching the heavy fermions. Firstly they considered the seesaw scenario which is extended by SM singlet heavy right handed neutrinos. A graphic representation of the possible aspects of the neutrino mass generation mechanism has been shown in Fig. 1. A variety of heavy neutrino and heavy triplet productions have been studied in [1–23] which investigate the limits on the heavy fermion mass and mixing plane.

2. Results

A variety of RHN production mechanism including the photon mediated/ initiated process, we have checked that photon mediated signature is always weak (M_N < 700 GeV-900 GeV) and strongly dependent on the p_T (jets/ photons) cuts [2, 3] using the MLM matching procedure to produce the RHNs and used the corresponding ATLAL/ CMS cross sections (SSDL and/or trilepton) to constrain them in the mass mixing plane. We have also shown the component cross sections where different initial states have been considered (using the MLM matching) using the Matched cross section from the 'results.html' file of the generated events. Which shows us the effect of p_T cuts and that is which is roughly safe between 300 GeV to 400 GeV of the RNN mass when p_T

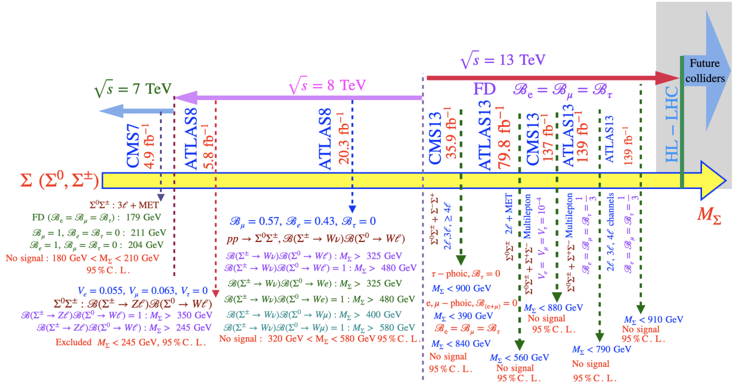

Figure 2: The mass scale of the triplet fermion and the different bounds on the triplet fermion from the LHC at $\sqrt{s}$ = 7 TeV, 8 TeV and 13 TeV respectively [22].

(jets) > 30 GeV. Note that it has been reflected in our mass mixing plane where we could probe the RHN mass (around 300 GeV) with p_T (jets) > 30 GeV below electroweak precision bounds even at HL-LHC. We claimed that at 14 TeV, p_T^j > 30 GeV will help to probe the RHNs up to 300 GeV even if the jet initiated processes are included. We have also studied the NLO-QCD production of the RHNs at the LHC and beyond where the SSDL and 3 ℓ final states have been explored with varied renormalization and factorization scales [4] followed by the fat jets at LHC in association with SSDL [15] and single lepton plus a fat jet at the e^-e^+ collider[14]. The corresponding limits on the mass mixing plane are given in the upper panel of Fig. 3. We have studied the $H \to N\nu$ process at the LHC from the Higgs production channel and calculated the bound on the light heavy mixing from the $2\ell 2\nu$ final state [12, 13]. We study the triplet fermion production at the e^-e^+ collider where final state is $\Sigma^+ e^- (\Sigma^0 \nu)$ at the s channel and t channel respectively. We consider the triplet fermion at the 1 TeV which will boost the decay product like SM W boson into a fat jet. Hence $e\nu$+ fat jet signal can be probed from the triplet fermions. This process can probe the light-heavy mixing with respect to the triplet mass [21] and the corresponding limits are shown in the lower panel of the Fig. 3. The mass scale of the triplet fermion and the different bounds on the triplet fermion from the LHC at $\sqrt{s}$ = 7 TeV, 8 TeV and 13 TeV respectively [22] in Fig. 2.

3. Conclusion

We study the models with the heavy fermions under the simple extensions of the SM where the neutrino mass is generated by the seesaw mechanism at the tree level to reproduce the neutrino oscillation data. We find that such heavy fermions can be tested at the underground experiments- at the proton-proton, electron-positron and electron-proton colliders in the near future. We have calculated the bounds on the light-heavy mixings for the electron-positron collider which could be probed in the near future.

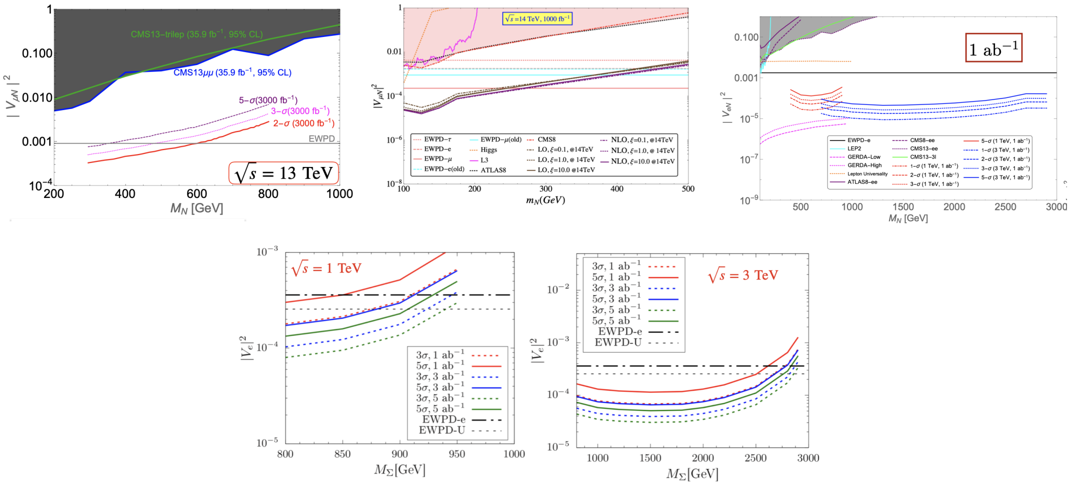

Figure 3: Upper panel: The limits on the mass mixing plane from the SSDL+ fat jet at the LHC, scale dependent NLO-QCD production of the RHNs and single lepton in association with fat jet at the e^-e^+ collider from left to right. Lower panel: Limits on the mixing angle from the $e\nu$+ fat jet signal in type-III seesaw scenario.

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