

# Snowmass2021 - Letter of Interest

## *Complementary Heavy neutrino search in Rare Higgs Decays*

**Thematic Areas:** (check all that apply /■)

- (EF01) EW Physics: Higgs Boson properties and couplings
- (EF02) EW Physics: Higgs Boson as a portal to new physics
- (EF03) EW Physics: Heavy flavor and top quark physics
- (EF04) EW Precision Physics and constraining new physics
- (EF05) QCD and strong interactions: Precision QCD
- (EF06) QCD and strong interactions: Hadronic structure and forward QCD
- (EF07) QCD and strong interactions: Heavy Ions
- (EF08) BSM: Model specific explorations
- (EF09) BSM: More general explorations
- (EF10) BSM: Dark Matter at colliders
- (Other) *[Please specify frontier/topical group]*

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**Abstract:** The Higgs boson can mix with Beyond the Standard Model scalars which give mass to neutrinos. This mixing opens rare Higgs decay channels into heavy neutrinos, and subsequently a multi-lepton final state at the collider. Searching for heavy neutrinos via rare Higgs decay can test a small mixing between the Higgs boson and BSM ‘seesaw’ scalars, and it is complementary to  $|V_{lN}|^2$ -based heavy neutrino search channels. Performing the study for future lepton collider, like CEPC and FCC-ee, etc. will help learning the perspective of testing such mixings.

In BSM theories, ‘the Higgs’ can mix with extra scalars that generate neutrino masses. The Higgs boson thus acquire a coupling to heavy neutrinos proportional to the scalar mixing  $\theta_S$ , and this mixing governs the Higgs decay branching fraction into the heavy neutrinos whenever kinematically allowed. Noticeably this scalar mixing angle is generally independent from  $|V_{lN}|^2$ , or the effective heavy neutrino’s coupling to the active neutrino and the SM’s gauge bosons, thus serves as an a complementary search channel to  $|V_{lN}|^2$ -based Drell-Yan channels.

Higgs-mediated heavy neutrino search involves efficient Higgs production at collider and the Higgs boson’s prompt decay into one or two heavy neutrinos. The heavy neutrinos subsequently decay into a final state containing leptons and missing momentum. This search channel depends on  $\theta_S$ , it applies to seesaw scenarios with tiny  $|V_{lN}|$ , such as Type-I like models where  $|V_{lN}|^2$  can be suppressed. Due to a typically large multiplicity in leptons and potential lepton number violation, Higgs rare decay possesses unique final states, such as two pairs of same-sign, same-flavor dileptons<sup>1</sup>, that can be almost background-free and has good prospective sensitivity on small  $\theta_S$  values.

The Higgs mixing to extra seesaw scalar(s) is often a crucial part of a neutrino mass model as it connects the model to the electroweak sector. A model independent, high sensitivity search limit of  $\theta_S$  will be an important check for studying these seesaw scenarios.

I find it of interest to extend the existing  $\theta_S$  study<sup>1,2</sup> to future lepton collider projects, such as the CEPC, FCC-ee, where different (from pp-collision) signal and background channels will need to be studied.

## References

- [1] Y. Gao, M. Jin and K. Wang, JHEP **02**, 101 (2020) doi:10.1007/JHEP02(2020)101 [arXiv:1904.12325 [hep-ph]].
- [2] A. Das, Y. Gao and T. Kamon, Eur. Phys. J. C **79**, no.5, 424 (2019) doi:10.1140/epjc/s10052-019-6937-7 [arXiv:1704.00881 [hep-ph]].