Some Aspects of Low Scale Seesaw Models

A thesis submitted in partial fulfilment of

the requirements for the degree of

Doctor of Philosophy

by

Vishnudath K. N.

(Roll No. 14330005)

Under the supervision of

Prof. Srubabati Goswami

Professor

Theoretical Physics Division

Physical Research Laboratory, Ahmedabad, India.

DISCIPLINE OF PHYSICS

INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR

2019

to

My Family

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Signature

Name: Vishnudath K. N.

(Roll No: 14330005)

Date:

CERTIFICATE

It is certified that the work contained in the thesis titled **" Some Aspects of Low Scale Seesaw Models"** by Mr. Vishnudath K. N. (Roll No. 14330005), has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

Prof. Srubabati Goswami
Theoretical Physics Division,
Physical Research Laboratory,
Ahmedabad, India.

(Thesis Supervisor)

Date:

Thesis Approval

The thesis entitled

Some Aspects of Low Scale Seesaw Models

by

Vishnudath K. N.

(Roll No. 14330005)

is approved for the degree of

Doctor of Philosophy

Examiner	Examiner
Supervisor	Chairman

Date: _____

Place: _____

Acknowledgments

The work presented in this thesis would not have been possible without the help and support that I received from many people. I take this opportunity to extend my sincere gratitude and appreciation to all those who made this Ph.D thesis possible.

First and foremost, I would like to extend my sincere gratitude to my supervisor Prof. Srubabati Goswami who introduced me to this exciting field of neutrino physics. I have benefited immensely from her expertise in the subject. She has instilled in me the intellectual curiosity which a researcher should always possess and showed me how one should question any piece of information or idea without taking it for granted. I am extremely grateful for her dedicated help, advice, inspiration, encouragement and the continuous support that she provided during the times of difficulty in both academic and personal life. I am positive that these things will go a long way in my life.

Besides my supervisor, I would like to thank my doctoral committee members Prof. Subhendra Mohanty and Dr. Partha Konar for their insightful comments and encouragement during the last four years, and also for the hard questions from which I learned a lot and which motivated me to widen my research from various perspectives.

I express my immense gratitude to my collaborators Prof. Sandhya Choubey, Dr. Najimuddin Khan, Dr. Arindam Das and Dr. Takaaki Nomura. It has been a very pleasent experience to work with them and I have learned a lot on different aspects of particle physics from them. A special thanks to Dr. Ila Garg, who has been a collaborator, a friend and a sister, for all the support that she has given me during the last six years.

I would also like to express my gratitude to the Director of PRL, the Dean, the Academic Committee members and the area chairman Prof. Hiranmaya Mishra for providing the necessary facilities to carry out the research work. I am also thankful to the head of the academic services Dr. Bhushit G. Vaishnav for his constant help.

I express my sincere gratitude to all the faculty members who had taught me during the course work including Prof. R. Rengarajan, Prof. J. Banerji, Prof. R. P. Singh, Prof. D. Angom, Dr. N. Mahajan, Dr. B. K. Sahoo, Dr. G. K. Samanta, Prof. R. Sekar, Dr. D. Chakrabarty, Dr. L. K. Sahu, Prof. P. Venkatakrishnan, Prof. N. Srivastava, Prof. S. K. Mathew, Dr. R. Bhattacharyya, Dr. B. Sivaraman and Dr. M. K. Srivastava. I would also like to thank Dr. S. Naik from astronomy division with whom I had done my project during the first semster of my coursework. I would also like to thank other professors from the theory division Prof. J. R. Bhatt, Dr. N. Singh and Dr. K. Patel for the useful physics discussions that we had during various seminars. I would also like to express my sincere gratitude to Prof. R. Mohanta and Dr. E. Harikumar from University of Hyderabad and Prof. V. Kodankandath from St. Thomas College, Thrissur, for all the support and motivation.

I am thankful to all the staff members of our division, library, computer center, administration, dispensary, canteen, workshop and maintenance section of PRL for their assistance and support. I also take this moment to express my gratitude to the academic and administrative staff members of IIT Gandhinagar for helping with the registration procedures. Thanks

to Praggya for all those small talks and the useful suggestions that she had given at various occasions.

I thank my seniors Monojit, Gulab, Newton and Chandan, my juniors Kaustav and Tanmay and the postdoctoral fellows Dr. Lakshmi, Dr. Biswajit and Dr. Ananya for various useful discussions. A special thanks to Dr. K. N. Deepthi for the continuous support that she has been giving in both academic and non-academic matters.

Thanks to Nijil for always being there ever since we boarded our train from Kerala to take admission in PRL. I would also like to thank my friend Aman, with whom I have been sharing my office in the last four years, for all the field theory discussions and for putting up with me all this while. I express my thanks to my friends and batch-mates Bhavesh, Bharti, Soumik, Niharika, Kiran, Anil and Pradeep for all the science discussions and the great times that we had together.

I would like to thank Chithra, Swapna, Jimbalu, Lekshmy, Bivin, Amala, Bhavya, Apoorv, Anju, Jabir, Ali, Hajira, Aravind, Subith, and Deva for making me feel at home and for all the delicious Kerala food.

I am also grateful to all the fellow researchers from PRL for the numerous helps and the support that they have given at various times. Especially, I would like to mention Rukmani, Akanksha, Balbeer, Arpan, Suchismita, Alekha, Tripurari, Ashish, Arvind, Richa, Avdhesh, Tanmoy, Abhaya, Lata, Girish, Chandan, Ikshu, Shradha, Manu, Venkatesh, Nidhi, Soumya, Selva, Arun, Prasanna, Archita, Aarthy, Navpreet, Rupa, Kuldeep, Prahlad, Ashim, Oindrila, Sukanya, Surya, Ayon, Priyank, Anshika, Vishal, Deepak, Sudipta, Pravin and Hrushikesh. Kindly forgive if I have left out anyone's name and please know that I am thankful to all of you.

I would also like to thank my friends Manjula, Vishnu, Jayaram, Alex, Saranya, Sameer, Thasni, Vishnu K., Kartavya and Aditya for all the support and care and for the wonderful times that I had spent with them.

Above all, I am immensely grateful to my parents and brother for everything that they have done for me.

Vishnudath K. N.

Abstract

The Standard Model (SM) of particle physics has been very successful in explaining a wide range of experimental observations and the discovery of the Higgs boson at the Large Hadron Collider has confirmed the mode of generation of the masses of the fundamental particles via the mechanism of electroweak symmetry breaking. This has put the SM on a solid foundation. However, despite its success in explaining most of the experimental data, the SM can not address certain issues, of which two of the most important are non-zero neutrino mass and the existence of dark matter.

The most plausible way to generate small neutrino masses is the seesaw mechanism which implies neutrinos to be lepton number violating Majorana particles. This Majorana nature of the neutrinos can give rise to the neutrino-less double beta decay process in which the total lepton number is violated by two units. It is well known that the canonical high scale seesaw models are not testable in the colliders and there are various low scale seesaw models proposed in the literature motivated by their testability. Such models can have various phenomenological as well as theoretical consequences. For example, the heavy seesaw particles can lead to enhanced rates of various charged lepton flavor violating decays and the new couplings associated with the seesaw can alter the stability/metastability of the electroweak vacuum. In addition, these heavy particles can have interesting signatures in the collider experiments. In this thesis, we study various phenomenological and theoretical implications of massive neutrinos in the context of various low scale seesaw models. We also explore the possibilities of having viable candidates for dark matter in the context of seesaw models.

First, we explore the implications of the Dark-LMA (DLMA) solution to the solar neutrino problem for neutrino-less double beta decay ($0\nu\beta\beta$). The standard Large Mixing Angle (LMA) solution corresponds to standard neutrino oscillations with $\Delta m^2_{21} \simeq 7.5 \times 10^{-5}$ eV^2 and $\sin^2\theta_{12} \simeq 0.3$, and satisfies the solar neutrino data at high significance. The DLMA solution appears as a nearly-degenerate solution to the solar neutrino problem for $\Delta m^2_{21} \simeq 7.5 \times 10^{-5}$ eV^2 and $\sin^2\theta_{12} \simeq 0.7$, once we allow for the existence of large non-standard neutrino interactions in addition to standard oscillations. We show that while the predictions for the effective mass governing $0\nu\beta\beta$ remains unchanged for the inverted hierarchy, that for normal hierarchy becomes higher

for the Dark-LMA parameter space and moves into the "desert region" between the two. This sets a new goal for sensitvity reach for the next generation experiments if no signal is found for the inverted hierarchy by the future search programmes. We also obtain the sensitivity for the DLMA region in the future ^{136}Xe experiments.

In the next part of the thesis, we study the minimal type-III seesaw model in which we extend the SM by adding two $SU(2)_L$ triplet fermions with zero hypercharge to explain the origin of the non-zero neutrino masses. The lightest active neutrino will be massless in this case. We use the Casas-Ibarra parametrization for the neutrino Yukawa coupling matrix and by choosing the two triplets to be degenerate, we have only three independent real parameters, namely the mass of the triplet fermions and a complex angle. The parametrization used allows us to have low masses of the triplet fermions and large Yukawa couplings at the same time. We show that the naturalness conditions and the limits from lepton flavor violating decays provide very stringent bounds on the model parameters along with the constraints from the stability/metastability of the electroweak vacuum. We perform a detailed analysis of the model parameter space including all the constraints for both normal as well as inverted hierarchies of the light neutrino masses. We find that most of the region that is allowed by lepton flavor violating decays and naturalness falls is stable/metastable depending on the values of the SM parameters.

In addition to neutrino masses, the existence of the dark matter is another issue that points towards the need for an extension of the SM. Hence, it is important to study the implications of the models that can simultaneously address these two issues. From this point of view, we consider singlet extensions of the SM, both in the fermion and the scalar sector, to account for the generation of neutrino mass at the TeV scale and the existence of dark matter, respectively. For the neutrino sector we consider models with extra singlet fermions which can generate neutrino masses via the so called inverse or linear seesaw mechanism whereas a singlet scalar is introduced as the candidate for dark matter. The scalar particle is odd under a discrete Z_2 symmetry which ensures its stability. We show that although these two sectors are disconnected at low energy, the coupling constants of both the sectors get correlated at a high energy scale by the constraints coming from the perturbativity and stability/metastability of the electroweak

vacuum. The singlet fermions try to destabilize the electroweak vacuum while the singlet scalar aids the stability. As a consequence, the electroweak vacuum may attain absolute stability even up to the Planck scale for suitable values of the parameters. We delineate the parameter space for the singlet fermion and the scalar couplings for which the electroweak vacuum remains stable/metastable and at the same time giving the correct relic density and neutrino masses and mixing angles as observed.

In addition to the simple extensions of the particle content, we also consider a class of gauged $U(1)$ extensions of the SM, where active light neutrino masses are generated by an inverse seesaw mechanism. Along with the three right handed neutrinos needed for the cancellation of gauge anomalies, we add three singlet fermions. This allows us to consider large neutrino Yukawa couplings keeping the $U(1)'$ symmetry breaking scale to be of the order of $\sim\ O(1)$ TeV. Demanding an extra Z_2 symmetry under which, the third generations of both the electrically neutral fermions are odd gives us a stable dark matter candidate. We express the $U(1)$ charges of all the fermions in terms of the $U(1)$ charges of the SM Higgs and the new complex scalar. We perform a comprehensive study to find out the parameter space consistent with the low energy neutrino data, vacuum stability and perturbativity, dark matter bounds and constraints from the collider searches.

Keywords: Neutrino mass, Seesaw mechanism, Majorana neutrinos, Neutrino-less double beta decay, Vacuum stability, Metastability, Low scale seesaw, Dark matter, Naturalness, Lepton flavor violation.

Contents

List of Figures

Bibliography

[1] Wikipedia, *Standard Model — Wikipedia, the free encyclopedia,* http://en.wikipedia.org/w/index.php?title=Standard%20Model&oldid=916336382 (2019). [Online; accessed 22-September-2019].

[2] Wikipedia, *Dark matter — Wikipedia, the free encyclopedia,* http://en.wikipedia.org/w/index.php?title=Dark%20matter&oldid=916765182 (2019). [Online; accessed 22-September-2019].

[3] X. Cui *et al.*, *Dark Matter Results From 54-Ton-Day Exposure of PandaX-II Experiment,* Phys. Rev. Lett. **119**, 181302 (2017).

[4] E. Aprile *et al.*, *First Dark Matter Search Results from the XENON1T Experiment,* Phys. Rev. Lett. **119**, 181301 (2017).

[5] G. Aad *et al.*, *Search for high-mass dilepton resonances using 139 fb^{-1} of pp collision data collected at $\sqrt{s}$ =13 TeV with the ATLAS detector,* (2019).

[6] S. L. Glashow, *Partial Symmetries of Weak Interactions,* Nucl. Phys. **22**, 579–588 (1961).

[7] S. Weinberg, *A Model of Leptons,* Phys. Rev. Lett. **19**, 1264–1266 (1967).

[8] A. Salam, *Weak and Electromagnetic Interactions,* Conf. Proc. **C680519**, 367–377 (1968).

[9] S. Chatrchyan *et al.*, *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC,* Phys. Lett. **B716**, 30–61 (2012).

[10] G. Aad *et al.*, *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC,* Phys. Lett. **B716**, 1–29 (2012).

[11] P. W. Higgs, *Broken symmetries, massless particles and gauge fields,* Phys. Lett. **12**, 132–133 (1964).

[12] P. W. Higgs, *Broken Symmetries and the Masses of Gauge Bosons,* Phys. Rev. Lett. **13**, 508–509 (1964). [,160(1964)].

[13] F. Englert and R. Brout, *Broken Symmetry and the Mass of Gauge Vector Mesons,* Phys. Rev. Lett. **13**, 321–323 (1964). [,157(1964)].

[14] G. S. Guralnik, C. R. Hagen, and T. W. B. Kibble, *Global Conservation Laws and Massless Particles,* Phys. Rev. Lett. **13**, 585–587 (1964). [,162(1964)].

[15] M. Gell-Mann, *Isotopic Spin and New Unstable Particles,* Phys. Rev. **92**, 833–834 (1953).

[16] K. Nishijima, *Charge Independence Theory of V Particles,* Prog. Theor. Phys. **13**, 285–304 (1955).

[17] Y. Nambu, *Axial vector current conservation in weak interactions,* Phys. Rev. Lett. **4**, 380–382 (1960). [,107(1960)].

[18] Y. Nambu and G. Jona-Lasinio, *Dynamical Model of Elementary Particles Based on an Analogy with Superconductivity. 1.* Phys. Rev. **122**, 345–358 (1961). [,127(1961)].

[19] J. Goldstone, *Field Theories with Superconductor Solutions,* Nuovo Cim. **19**, 154–164 (1961).

[20] J. Goldstone, A. Salam, and S. Weinberg, *Broken Symmetries,* Phys. Rev. **127**, 965–970 (1962).

[21] C. Wu, E. Ambler, R. Hayward, D. Hoppes, and R. Hudson, *EXPERIMENTAL TEST OF PARITY CONSERVATION IN BETA DECAY,* Phys.Rev. **105**, 1413–1414 (1957).

[22] B. Pontecorvo, *Mesonium and anti-mesonium,* Sov. Phys. JETP **6**, 429 (1957). [Zh. Eksp. Teor. Fiz.33,549(1957)].

[23] B. Pontecorvo, *Inverse beta processes and nonconservation of lepton charge,* Sov. Phys. JETP **7**, 172–173 (1958). [Zh. Eksp. Teor. Fiz.34,247(1957)].

[24] Z. Maki, M. Nakagawa, and S. Sakata, *Remarks on the unified model of elementary particles,* Prog. Theor. Phys. **28**, 870–880 (1962). [,34(1962)].

[25] L. Wolfenstein, *Neutrino Oscillations in Matter,* Phys. Rev. **D17**, 2369–2374 (1978). [,294(1977)].

[26] S. P. Mikheyev and A. Yu. Smirnov, *Resonance Amplification of Oscillations in Matter and Spectroscopy of Solar Neutrinos,* Sov. J. Nucl. Phys. **42**, 913–917 (1985). [,305(1986)].

[27] S. P. Mikheev and A. Yu. Smirnov, *Resonant amplification of neutrino oscillations in matter and solar neutrino spectroscopy,* Nuovo Cim. **C9**, 17–26 (1986).

[28] B. T. Cleveland, T. Daily, R. Davis, Jr., J. R. Distel, K. Lande, C. K. Lee, P. S. Wildenhain, and J. Ullman, *Measurement of the solar electron neutrino flux with the Homestake chlorine detector,* Astrophys. J. **496**, 505–526 (1998).

[29] P. Anselmann *et al.*, *Solar neutrinos observed by GALLEX at Gran Sasso.* Phys. Lett. **B285**, 376–389 (1992).

[30] J. N. Abdurashitov *et al.*, *Results from SAGE,* Phys. Lett. **B328**, 234–248 (1994).

[31] M. Altmann *et al.*, *Complete results for five years of GNO solar neutrino observations,* Phys. Lett. **B616**, 174–190 (2005).

[32] Y. Fukuda *et al.*, *Solar neutrino data covering solar cycle 22,* Phys. Rev. Lett. **77**, 1683–1686 (1996).

[33] Y. Fukuda *et al.*, *Evidence for oscillation of atmospheric neutrinos,* Phys.Rev.Lett. **81**, 1562–1567 (1998).

[34] Y. Ashie *et al.*, *Evidence for an oscillatory signature in atmospheric neutrino oscillation,* Phys.Rev.Lett. **93**, 101801 (2004).

[35] Q. Ahmad *et al.*, *Direct evidence for neutrino flavor transformation from neutral current interactions in the Sudbury Neutrino Observatory,* Phys.Rev.Lett. **89**, 011301 (2002).

[36] B. Aharmim *et al.*, *Electron energy spectra, fluxes, and day-night asymmetries of B-8 solar neutrinos from measurements with NaCl dissolved in the heavy-water detector at the Sudbury Neutrino Observatory,* Phys. Rev. **C72**, 055502 (2005).

[37] J. N. Bahcall and M. H. Pinsonneault, *What do we (not) know theoretically about solar neutrino fluxes?* Phys. Rev. Lett. **92**, 121301 (2004).

[38] K. Eguchi *et al.*, *First results from KamLAND: Evidence for reactor anti-neutrino disappearance,* Phys.Rev.Lett. **90**, 021802 (2003).

[39] T. Araki *et al.*, *Measurement of neutrino oscillation with KamLAND: Evidence of spectral distortion,* Phys. Rev. Lett. **94**, 081801 (2005).

[40] D. Casper *et al.*, *Measurement of atmospheric neutrino composition with IMB-3,* Phys. Rev. Lett. **66**, 2561–2564 (1991).

[41] R. Becker-Szendy *et al.*, *The Electron-neutrino and muon-neutrino content of the atmospheric flux,* Phys. Rev. **D46**, 3720–3724 (1992).

[42] M. H. Ahn *et al.*, *Measurement of Neutrino Oscillation by the K2K Experiment,* Phys. Rev. **D74**, 072003 (2006).

[43] D. Michael *et al.*, *Observation of muon neutrino disappearance with the MINOS detectors and the NuMI neutrino beam,* Phys.Rev.Lett. **97**, 191801 (2006).

[44] P. Adamson *et al.*, *Measurement of Neutrino Oscillations with the MINOS Detectors in the NuMI Beam,* Phys.Rev.Lett. **101**, 131802 (2008).

[45] P. Adamson *et al.*, *Measurement of the Neutrino Mass Splitting and Flavor Mixing by MINOS,* Phys. Rev. Lett. **106**, 181801 (2011).

[46] K. Abe *et al.*, *First Muon-Neutrino Disappearance Study with an Off-Axis Beam,* Phys.Rev. **D85**, 031103 (2012).

[47] K. Abe *et al.*, *Measurement of Neutrino Oscillation Parameters from Muon Neutrino Disappearance with an Off-axis Beam,* Phys. Rev. Lett. **111**, 211803 (2013).

[48] I. Esteban, M. C. Gonzalez-Garcia, A. Hernandez-Cabezudo, M. Maltoni, and T. Schwetz, *Global analysis of three-flavour neutrino oscillations: synergies and tensions in the determination of* θ_23, δ_CP*, and the mass ordering,* JHEP **01**, 106 (2019).

[49] P. F. de Salas, D. V. Forero, C. A. Ternes, M. Tortola, and J. W. F. Valle, *Status of neutrino oscillations 2018: 3*σ *hint for normal mass ordering and improved CP sensitivity,* Phys. Lett. **B782**, 633–640 (2018).

[50] F. Capozzi, E. Di Valentino, E. Lisi, A. Marrone, A. Melchiorri, and A. Palazzo, *Global constraints on absolute neutrino masses and their ordering,* Phys. Rev. **D95**, 096014 (2017).

[51] M. Tanabashi *et al.*, *Review of Particle Physics,* Phys. Rev. **D98**, 030001 (2018).

[52] W. Furry, *On transition probabilities in double beta-disintegration,* Phys.Rev. **56**, 1184–1193 (1939).

[53] V. N. Aseev *et al.*, *An upper limit on electron antineutrino mass from Troitsk experiment,* Phys. Rev. **D84**, 112003 (2011).

[54] C. Kraus *et al.*, *Final results from phase II of the Mainz neutrino mass search in tritium beta decay,* Eur. Phys. J. **C40**, 447–468 (2005).

[55] A. Osipowicz *et al.*, *KATRIN: A Next generation tritium beta decay experiment with sub-eV sensitivity for the electron neutrino mass. Letter of intent,* (2001).

[56] F. Frankle, *KATRIN: An experiment to determine the neutrino mass,* PoS **EPS-HEP2009**, 271 (2009).

[57] N. Aghanim *et al.*, *Planck 2018 results. VI. Cosmological parameters,* (2018).

[58] K. Garrett and G. Duda, *Dark Matter: A Primer,* Adv. Astron. **2011**, 968283 (2011).

[59] M. Lisanti, *Lectures on Dark Matter Physics,* in "Proceedings, Theoretical Advanced Study Institute in Elementary Particle Physics: New Frontiers in Fields and Strings (TASI 2015): Boulder, CO, USA, June 1-26, 2015," (2017), pp. 399–446.

[60] M. Bauer and T. Plehn, *Yet Another Introduction to Dark Matter,* (2017).

[61] I. Tkachev, *Cosmology and Dark Matter,* in "Proceedings, 2016 European School of High-Energy Physics (ESHEP2016): Skeikampen, Norway, June 15-28 2016," , vol. 5 (2017), vol. 5, pp. 259–294.

[62] J. H. Oort, *The force exerted by the stellar system in the direction perpendicular to the galactic plane and some related problems,* Bull. Astron. Inst. Netherlands **6**, 249–287 (1932).

[63] F. Zwicky, *On the Masses of Nebulae and of Clusters of Nebulae,* Astrophysical Journal **86**, 217 (1937).

[64] V. C. Rubin, *On the Masses of Nebulae and of Clusters of Nebulae,* Scientific American (ISSN 0036-8733) **248**, 96–106 (1983).

[65] D. Clowe, M. Bradac, A. H. Gonzalez, M. Markevitch, S. W. Randall, C. Jones, and D. Zaritsky, *A direct empirical proof of the existence of dark matter,* Astrophys. J. **648**, L109–L113 (2006).

[66] V. Silveira and A. Zee, *SCALAR PHANTOMS,* Phys. Lett. **B161**, 136–140 (1985).

[67] J. McDonald, *Gauge singlet scalars as cold dark matter,* Phys. Rev. **D50**, 3637–3649 (1994).

[68] C. P. Burgess, M. Pospelov, and T. ter Veldhuis, *The Minimal model of nonbaryonic dark matter: A Singlet scalar,* Nucl. Phys. **B619**, 709–728 (2001).

[69] G. Jungman, M. Kamionkowski, and K. Griest, *Supersymmetric dark matter,* Phys. Rept. **267**, 195–373 (1996).

[70] L. Delle Rose, S. Khalil, S. J. D. King, S. Kulkarni, C. Marzo, S. Moretti, and C. S. Un, *Sneutrino Dark Matter, Constraints and Perspectives,* (2018).

[71] W. Buchmuller, *Gravitino Dark Matter,* AIP Conf. Proc. **1200**, 155–164 (2010).

[72] J. L. Feng, *Dark Matter Candidates from Particle Physics and Methods of Detection,* Ann. Rev. Astron. Astrophys. **48**, 495–545 (2010).

[73] Y. Hochberg, E. Kuflik, T. Volansky, and J. G. Wacker, *Mechanism for Thermal Relic Dark Matter of Strongly Interacting Massive Particles,* Phys. Rev. Lett. **113**, 171301 (2014).

[74] L. D. Duffy and K. van Bibber, *Axions as Dark Matter Particles,* New J. Phys. **11**, 105008 (2009).

[75] T. D. Brandt, *Constraints on MACHO Dark Matter from Compact Stellar Systems in Ultra-Faint Dwarf Galaxies,* Astrophys. J. **824**, L31 (2016).

[76] H.-C. Cheng, J. L. Feng, and K. T. Matchev, *Kaluza-Klein dark matter,* Phys. Rev. Lett. **89**, 211301 (2002).

[77] V. A. Mitsou, *Dark matter: experimental and observational status,* in "15th Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Astrophysics, and Relativistic Field Theories (MG15) Rome, Italy, July 1-7, 2018," (2019).

[78] J. Liu, X. Chen, and X. Ji, *Current status of direct dark matter detection experiments,* Nature Phys. **13**, 212–216 (2017).

[79] M. Schumann, *Direct Detection of WIMP Dark Matter: Concepts and Status,* (2019).

[80] D. S. Akerib *et al.*, *Results from a search for dark matter in the complete LUX exposure,* Phys. Rev. Lett. **118**, 021303 (2017).

[81] R. Bernabei *et al.*, *First results from DAMA/LIBRA and the combined results with DAMA/NaI,* Eur. Phys. J. **C56**, 333–355 (2008).

[82] J. M. Gaskins, *A review of indirect searches for particle dark matter,* Contemp. Phys. **57**, 496–525 (2016).

[83] W. B. Atwood *et al.*, *The large area telescope on the fermi gamma-ray space telescope mission,* .

[84] M. G. Aartsen *et al.*, *Search for neutrinos from decaying dark matter with IceCube,* Eur. Phys. J. **C78**, 831 (2018).

[85] J. D. Bowman, A. E. E. Rogers, R. A. Monsalve, T. J. Mozdzen, and N. Mahesh, *An absorption profile centred at 78 megahertz in the sky-averaged spectrum,* Nature **555**, 67–70 (2018).

[86] V. A. Mitsou, *Shedding Light on Dark Matter at Colliders,* Int. J. Mod. Phys. **A28**, 1330052 (2013).

[87] V. A. Mitsou, *Overview of searches for dark matter at the LHC,* J. Phys. Conf. Ser. **651**, 012023 (2015).

[88] S. Weinberg, *Baryon- and lepton-nonconserving processes,* Phys. Rev. Lett. **43**, 1566–1570 (1979).

[89] P. Minkowski, *mu $\rightarrow$ e gamma at a Rate of One Out of 1-Billion Muon Decays?* Phys.Lett. **B67**, 421 (1977).

[90] M. Gell-Mann, P. Ramond, and R. Slansky, Proc.Supergravity Workshop pp. 315–318 (1979).

[91] T. Yanagida, Workshop on Unified Theory and Baryon Number in the Universe pp. 95–98 (1979).

[92] R. N. Mohapatra and G. Senjanovic, *Neutrino Mass and Spontaneous Parity Violation,* Phys.Rev.Lett. **44**, 912 (1980).

[93] J. Schechter and J. Valle, *Neutrino Masses in SU(2) x U(1) Theories,* Phys.Rev. **D22**, 2227 (1980).

[94] J. Schechter and J. Valle, *Neutrino Decay and Spontaneous Violation of Lepton Number,* Phys.Rev. **D25**, 774 (1982).

[95] G. Lazarides, Q. Shafi, and C. Wetterich, *Proton Lifetime and Fermion Masses in an SO(10) Model,* Nucl.Phys. **B181**, 287 (1981).

[96] R. N. Mohapatra and G. Senjanovic, *Neutrino Masses and Mixings in Gauge Models with Spontaneous Parity Violation,* Phys.Rev. **D23**, 165 (1981).

[97] R. Foot, H. Lew, X. He, and G. C. Joshi, *SEESAW NEUTRINO MASSES INDUCED BY A TRIPLET OF LEPTONS,* Z.Phys. **C44**, 441 (1989).

[98] G. Senjanovic, *Neutrino mass: From LHC to grand unification,* Riv. Nuovo Cim. **34**, 1–68 (2011).

[99] A. Broncano, M. Gavela, and E. E. Jenkins, *The Effective Lagrangian for the seesaw model of neutrino mass and leptogenesis,* Phys.Lett. **B552**, 177–184 (2003).

[100] Z.-z. Xing and S. Zhou, *Why is the 3 x 3 neutrino mixing matrix almost unitary in realistic seesaw models?* HEPNP **30**, 828–832 (2006).

[101] W. Grimus and L. Lavoura, *The Seesaw mechanism at arbitrary order: Disentangling the small scale from the large scale,* JHEP **0011**, 042 (2000).

[102] F. F. Freitas, C. A. de S. Pires, and P. S. Rodrigues da Silva, *Inverse type II seesaw mechanism and its signature at the LHC and ILC,* Phys. Lett. **B769**, 48–56 (2017).

[103] A. Abada, C. Biggio, F. Bonnet, M. B. Gavela, and T. Hambye, *mu —¿ e gamma and tau —¿ l gamma decays in the fermion triplet seesaw model,* Phys. Rev. **D78**, 033007 (2008).

[104] G. 't Hooft, C. Itzykson, A. Jaffe, H. Lehmann, P. K. Mitter, I. M. Singer, and R. Stora, *Recent Developments in Gauge Theories. Proceedings, Nato Advanced Study Institute, Cargese, France, August 26 - September 8, 1979,* NATO Sci. Ser. B **59**, pp.1–438 (1980).

[105] R. Mohapatra and J. Valle, *Neutrino Mass and Baryon Number Nonconservation in Superstring Models,* Phys.Rev. **D34**, 1642 (1986).

[106] P.-H. Gu and U. Sarkar, *Leptogenesis with Linear, Inverse or Double Seesaw,* Phys.Lett. **B694**, 226–232 (2010).

[107] H. Zhang and S. Zhou, *The Minimal Seesaw Model at the TeV Scale,* Phys.Lett. **B685**, 297–301 (2010).

[108] M. Hirsch, S. Morisi, and J. Valle, *A4-based tri-bimaximal mixing within inverse and linear seesaw schemes,* Phys.Lett. **B679**, 454–459 (2009).

[109] R. N. Mohapatra, *Mechanism for Understanding Small Neutrino Mass in Superstring Theories,* Phys. Rev. Lett. **56**, 561–563 (1986).

[110] S. K. Kang and C. Kim, *Extended double seesaw model for neutrino mass spectrum and low scale leptogenesis,* Phys.Lett. **B646**, 248–252 (2007).

[111] L.-J. Hu, S. Dulat, and A. Ablat, *Neutrino masses and flavor mixing in the Extended Double Seesaw Model with two texture zeros,* Eur.Phys.J. **C71**, 1772 (2011).

[112] P. B. Dev and A. Pilaftsis, *Minimal Radiative Neutrino Mass Mechanism for Inverse Seesaw Models,* Phys.Rev. **D86**, 113001 (2012).

[113] M. Goeppert-Mayer, *Double beta-disintegration,* Phys. Rev. **48**, 512–516 (1935).

[114] S. R. Elliott, A. A. Hahn, and M. K. Moe, *Direct Evidence for Two Neutrino Double Beta Decay in* ^{82}*Se,* Phys. Rev. Lett. **59**, 2020–2023 (1987). [,989(1987)].

[115] M. Doi, T. Kotani, and E. Takasugi, *Double beta Decay and Majorana Neutrino,* Prog. Theor. Phys. Suppl. **83**, 1 (1985).

[116] W. C. Haxton and G. J. Stephenson, *Double beta Decay,* Prog. Part. Nucl. Phys. **12**, 409–479 (1984).

[117] A. Gando *et al.*, *Search for Majorana Neutrinos near the Inverted Mass Hierarchy Region with KamLAND-Zen,* Phys. Rev. Lett. **117**, 082503 (2016). [Addendum: Phys. Rev. Lett.117,no.10,109903(2016)].

[118] S. T. Petcov, H. Sugiyama, and Y. Takanishi, *Neutrinoless Double Beta Decay and H+- +- —¿ l-prime+- l+- Decays in the Higgs Triplet Model,* Phys. Rev. **D80**, 015005 (2009).

[119] A. Ibarra, E. Molinaro, and S. Petcov, *TeV Scale See-Saw Mechanisms of Neutrino Mass Generation, the Majorana Nature of the Heavy Singlet Neutrinos and $(\beta\beta)_{0\nu}$-Decay,* JHEP **1009**, 108 (2010).

[120] M. Blennow, E. Fernandez-Martinez, J. Lopez-Pavon, and J. Menendez, *Neutrinoless double beta decay in seesaw models,* JHEP **07**, 096 (2010).

[121] S. M. Bilenky, A. Faessler, W. Potzel, and F. Simkovic, *Neutrinoless double-beta decay and seesaw mechanism,* Eur. Phys. J. **C71**, 1754 (2011).

[122] M. Mitra, G. Senjanovic, and F. Vissani, *Neutrinoless Double Beta Decay and Heavy Sterile Neutrinos,* Nucl.Phys. **B856**, 26–73 (2012).

[123] J. Lopez-Pavon, E. Molinaro, and S. T. Petcov, *Radiative Corrections to Light Neutrino Masses in Low Scale Type I Seesaw Scenarios and Neutrinoless Double Beta Decay,* JHEP **11**, 030 (2015).

[124] V. Tello, M. Nemevsek, F. Nesti, G. Senjanovic, and F. Vissani, *Left-Right Symmetry: from LHC to Neutrinoless Double Beta Decay,* Phys.Rev.Lett. **106**, 151801 (2011).

[125] J. Chakrabortty, H. Z. Devi, S. Goswami, and S. Patra, *Neutrinoless double-β decay in TeV scale Left-Right symmetric models,* JHEP **1208**, 008 (2012).

[126] J. Barry and W. Rodejohann, *Lepton number and flavour violation in TeV-scale left-right symmetric theories with large left-right mixing,* JHEP **09**, 153 (2013).

[127] P. S. Bhupal Dev, S. Goswami, and M. Mitra, *TeV Scale Left-Right Symmetry and Large Mixing Effects in Neutrinoless Double Beta Decay,* Phys. Rev. **D91**, 113004 (2015).

[128] R. L. Awasthi, P. S. B. Dev, and M. Mitra, *Implications of the Diboson Excess for Neutrinoless Double Beta Decay and Lepton Flavor Violation in TeV Scale Left Right Symmetric Model,* Phys. Rev. **D93**, 011701 (2016).

[129] G. Bambhaniya, P. S. B. Dev, S. Goswami, and M. Mitra, *The Scalar Triplet Contribution to Lepton Flavour Violation and Neutrinoless Double Beta Decay in Left-Right Symmetric Model,* JHEP **04**, 046 (2016).

[130] L. Calibbi and G. Signorelli, *Charged Lepton Flavour Violation: An Experimental and Theoretical Introduction,* Riv. Nuovo Cim. **41**, 71–174 (2018).

[131] R. Coy and M. Frigerio, *Effective approach to lepton observables: the seesaw case,* (2018).

[132] A. M. Baldini *et al.*, *Search for the Lepton Flavour Violating Decay $\mu^+ \to e^+\gamma$ with the Full Dataset of the MEG Experiment,* (2016).

[133] W. H. Bertl *et al.*, *Search for the Decay $\mu^+ \to e^+e^+e^-$,* Nucl. Phys. **B260**, 1–31 (1985).

[134] C. Dohmen *et al.*, *Test of lepton flavor conservation in mu —¿ e conversion on titanium,* Phys. Lett. **B317**, 631–636 (1993).

[135] W. H. Bertl *et al.*, *A Search for muon to electron conversion in muonic gold,* Eur. Phys. J. **C47**, 337–346 (2006).

[136] J. Casas, J. Espinosa, and M. Quiros, *Improved Higgs mass stability bound in the standard model and implications for supersymmetry,* Phys.Lett. **B342**, 171–179 (1995).

[137] J. Casas, J. Espinosa, and M. Quiros, *Standard model stability bounds for new physics within LHC reach,* Phys.Lett. **B382**, 374–382 (1996).

[138] S. Alekhin, A. Djouadi, and S. Moch, *The top quark and Higgs boson masses and the stability of the electroweak vacuum,* Phys.Lett. **B716**, 214–219 (2012).

[139] D. Buttazzo, G. Degrassi, P. P. Giardino, G. F. Giudice, F. Sala, A. Salvio, and A. Strumia, *Investigating the near-criticality of the Higgs boson,* JHEP **12**, 089 (2013).

[140] G. Isidori, G. Ridolfi, and A. Strumia, *On the metastability of the standard model vacuum,* Nucl.Phys. **B609**, 387–409 (2001).

[141] J. Espinosa, G. Giudice, and A. Riotto, *Cosmological implications of the Higgs mass measurement,* JCAP **0805**, 002 (2008).

[142] P. A. R. Ade *et al.*, *Planck 2015 results. XIII. Cosmological parameters,* Astron. Astrophys. **594**, A13 (2016).

[143] G. Isidori, V. S. Rychkov, A. Strumia, and N. Tetradis, *Gravitational corrections to standard model vacuum decay,* Phys. Rev. **D77**, 025034 (2008).

[144] N. Khan and S. Rakshit, *Study of electroweak vacuum metastability with a singlet scalar dark matter,* Phys. Rev. **D90**, 113008 (2014).

[145] J. A. Casas, V. Di Clemente, A. Ibarra, and M. Quiros, *Massive neutrinos and the Higgs mass window,* Phys. Rev. **D62**, 053005 (2000).

[146] S. Khan, S. Goswami, and S. Roy, *Vacuum Stability constraints on the minimal singlet TeV Seesaw Model,* Phys.Rev. **D89**, 073021 (2014).

[147] W. Rodejohann and H. Zhang, *Impact of massive neutrinos on the higgs self-coupling and electroweak vacuum stability,* Journal of High Energy Physics **2012**, 22 (2012).

[148] J. Chakrabortty, M. Das, and S. Mohanty, *Constraints on TeV scale Majorana neutrino phenomenology from the Vacuum Stability of the Higgs,* Mod. Phys. Lett. **A28**, 1350032 (2013).

[149] A. Datta, A. Elsayed, S. Khalil, and A. Moursy, *Higgs vacuum stability in the $B - L$ extended standard model,* Phys. Rev. **D88**, 053011 (2013).

[150] J. Chakrabortty, P. Konar, and T. Mondal, *Constraining a class of BL extended models from vacuum stability and perturbativity,* Phys. Rev. **D89**, 056014 (2014).

[151] A. Kobakhidze and A. Spencer-Smith, *Neutrino Masses and Higgs Vacuum Stability,* JHEP **08**, 036 (2013).

[152] L. Delle Rose, C. Marzo, and A. Urbano, *On the stability of the electroweak vacuum in the presence of low-scale seesaw models,* (2015).

[153] G. Bambhaniya, P. S. Bhupal Dev, S. Goswami, S. Khan, and W. Rodejohann, *Naturalness, Vacuum Stability and Leptogenesis in the Minimal Seesaw Model,* Phys. Rev. **D95**, 095016 (2017).

[154] G. Bambhaniya, S. Khan, P. Konar, and T. Mondal, *Constraints on a seesaw model leading to quasidegenerate neutrinos and signatures at the LHC,* Phys. Rev. **D91**, 095007 (2015).

[155] M. Lindner, H. H. Patel, and B. Radovi, *Electroweak Absolute, Meta-, and Thermal Stability in Neutrino Mass Models,* (2015).

[156] F. F. Deppisch, P. S. Bhupal Dev, and A. Pilaftsis, *Neutrinos and Collider Physics,* New J. Phys. **17**, 075019 (2015).

[157] A. Pilaftsis, *Radiatively induced neutrino masses and large Higgs neutrino couplings in the standard model with Majorana fields,* Z.Phys. **C55**, 275–282 (1992).

[158] S. Bray, J. S. Lee, and A. Pilaftsis, *Resonant CP violation due to heavy neutrinos at the LHC,* Nucl.Phys. **B786**, 95–118 (2007).

[159] A. Atre, T. Han, S. Pascoli, and B. Zhang, *The Search for Heavy Majorana Neutrinos,* JHEP **0905**, 030 (2009).

[160] W.-Y. Keung and G. Senjanovic, *Majorana Neutrinos and the Production of the Right-handed Charged Gauge Boson,* Phys.Rev.Lett. **50**, 1427 (1983).

[161] A. Datta, M. Guchait, and A. Pilaftsis, *Probing lepton number violation via majorana neutrinos at hadron supercolliders,* Phys. Rev. **D50**, 3195–3203 (1994).

[162] F. M. L. Almeida, Jr., Y. do Amaral Coutinho, J. A. Martins Simoes, and M. A. B. do Vale, *On a signature for heavy Majorana neutrinos in hadronic collisions,* Phys. Rev. **D62**, 075004 (2000).

[163] O. Panella, M. Cannoni, C. Carimalo, and Y. N. Srivastava, *Signals of heavy Majorana neutrinos at hadron colliders,* Phys. Rev. **D65**, 035005 (2002).

[164] T. Han and B. Zhang, *Signatures for Majorana neutrinos at hadron colliders,* Phys.Rev.Lett. **97**, 171804 (2006).

[165] F. del Aguila, J. Aguilar-Saavedra, and R. Pittau, *Heavy neutrino signals at large hadron colliders,* JHEP **0710**, 047 (2007).

[166] F. del Aguila and J. Aguilar-Saavedra, *Distinguishing seesaw models at LHC with multi-lepton signals,* Nucl.Phys. **B813**, 22–90 (2009).

[167] A. Akeroyd and M. Aoki, *Single and pair production of doubly charged Higgs bosons at hadron colliders,* Phys.Rev. **D72**, 035011 (2005).

[168] T. Han, B. Mukhopadhyaya, Z. Si, and K. Wang, *Pair production of doubly-charged scalars: Neutrino mass constraints and signals at the LHC,* Phys.Rev. **D76**, 075013 (2007).

[169] A. Akeroyd, M. Aoki, and H. Sugiyama, *Probing Majorana Phases and Neutrino Mass Spectrum in the Higgs Triplet Model at the CERN LHC,* Phys.Rev. **D77**, 075010 (2008).

[170] P. Fileviez Perez, T. Han, G.-y. Huang, T. Li, and K. Wang, *Neutrino Masses and the CERN LHC: Testing Type II Seesaw,* Phys.Rev. **D78**, 015018 (2008).

[171] A. G. Akeroyd and C.-W. Chiang, *Doubly charged Higgs bosons and three-lepton signatures in the Higgs Triplet Model,* Phys. Rev. **D80**, 113010 (2009).

[172] A. G. Akeroyd, C.-W. Chiang, and N. Gaur, *Leptonic signatures of doubly charged Higgs boson production at the LHC,* JHEP **11**, 005 (2010).

[173] A. Melfo, M. Nemevsek, F. Nesti, G. Senjanovic, and Y. Zhang, *Type II Seesaw at LHC: The Roadmap,* Phys.Rev. **D85**, 055018 (2012).

[174] H. Sugiyama, K. Tsumura, and H. Yokoya, *Discrimination of models including doubly charged scalar bosons by using tau lepton decay distributions,* Phys. Lett. **B717**, 229–234 (2012).

[175] F. del guila and M. Chala, *LHC bounds on Lepton Number Violation mediated by doubly and singly-charged scalars,* JHEP **03**, 027 (2014).

[176] C.-H. Chen and T. Nomura, *Search for $\delta^{\pm\pm}$ with new decay patterns at the LHC,* Phys. Rev. **D91**, 035023 (2015).

[177] Z.-L. Han, R. Ding, and Y. Liao, *LHC Phenomenology of Type II Seesaw: Non-degenerate Case,* Phys. Rev. **D91**, 093006 (2015).

[178] B. Bajc and G. Senjanovic, *Seesaw at LHC,* JHEP **0708**, 014 (2007).

[179] B. Bajc, M. Nemevsek, and G. Senjanovic, *Probing seesaw at LHC,* Phys.Rev. **D76**, 055011 (2007).

[180] R. Franceschini, T. Hambye, and A. Strumia, *Type-III see-saw at LHC,* Phys.Rev. **D78**, 033002 (2008).

[181] T. Li and X.-G. He, *Neutrino Masses and Heavy Triplet Leptons at the LHC: Testability of Type III Seesaw,* Phys. Rev. **D80**, 093003 (2009).

[182] P. Bandyopadhyay, S. Choi, E. J. Chun, and K. Min, *Probing Higgs bosons via the type III seesaw mechanism at the LHC,* Phys. Rev. **D85**, 073013 (2012).

[183] O. J. P. Eboli, J. Gonzalez-Fraile, and M. C. Gonzalez-Garcia, *Neutrino Masses at LHC: Minimal Lepton Flavour Violation in Type-III See-saw,* JHEP **12**, 009 (2011).

[184] F. von der Pahlen, G. Palacio, D. Restrepo, and O. Zapata, *Radiative Type III Seesaw Model and its collider phenomenology,* Phys. Rev. **D94**, 033005 (2016).

[185] R. Ruiz, *QCD Corrections to Pair Production of Type III Seesaw Leptons at Hadron Colliders,* JHEP **12**, 165 (2015).

[186] G. Bambhaniya, S. Goswami, S. Khan, P. Konar, and T. Mondal, *Looking for hints of a reconstructible seesaw model at the Large Hadron Collider,* Phys.Rev. **D91**, 075007 (2015).

[187] N. Haba, S. Matsumoto, and K. Yoshioka, *Observable Seesaw and its Collider Signatures,* Phys. Lett. **B677**, 291–295 (2009).

[188] C.-Y. Chen and P. S. B. Dev, *Multi-Lepton Collider Signatures of Heavy Dirac and Majorana Neutrinos,* Phys. Rev. **D85**, 093018 (2012).

[189] A. Das and N. Okada, *Inverse seesaw neutrino signatures at the LHC and ILC,* Phys. Rev. **D88**, 113001 (2013).

[190] P. Bandyopadhyay, E. J. Chun, H. Okada, and J.-C. Park, *Higgs Signatures in Inverse Seesaw Model at the LHC,* JHEP **01**, 079 (2013).

[191] A. Das, P. S. Bhupal Dev, and N. Okada, *Direct bounds on electroweak scale pseudo-Dirac neutrinos from* $\sqrt{s} = 8$ *TeV LHC data,* Phys. Lett. **B735**, 364–370 (2014).

[192] A. Das and N. Okada, *Improved bounds on the heavy neutrino productions at the LHC,* Phys. Rev. **D93**, 033003 (2016).

[193] S. Mondal and S. K. Rai, *Probing the Heavy Neutrinos of Inverse Seesaw Model at the LHeC,* Phys. Rev. **D94**, 033008 (2016).

[194] A. Das, P. Konar, and S. Majhi, *Production of Heavy neutrino in next-to-leading order QCD at the LHC and beyond,* JHEP **06**, 019 (2016).

[195] A. S. Barabash, *Double Beta Decay: Historical Review of 75 Years of Research,* Phys. Atom. Nucl. **74**, 603–613 (2011).

[196] O. G. Miranda, M. A. Tortola, and J. W. F. Valle, *Are solar neutrino oscillations robust?* JHEP **10**, 008 (2006).

[197] F. J. Escrihuela, O. G. Miranda, M. A. Tortola, and J. W. F. Valle, *Constraining nonstandard neutrino-quark interactions with solar, reactor and accelerator data,* Phys. Rev. **D80**, 105009 (2009). [Erratum: Phys. Rev.D80,129908(2009)].

[198] Y. Farzan and M. Tortola, *Neutrino oscillations and Non-Standard Interactions,* Front.in Phys. **6**, 10 (2018).

[199] P. Bakhti and Y. Farzan, *Shedding light on LMA-Dark solar neutrino solution by medium baseline reactor experiments: JUNO and RENO-50,* JHEP **07**, 064 (2014).

[200] P. Coloma and T. Schwetz, *Generalized mass ordering degeneracy in neutrino oscillation experiments,* Phys. Rev. **D94**, 055005 (2016).

[201] K. N. Deepthi, S. Goswami, and N. Nath, *Can nonstandard interactions jeopardize the hierarchy sensitivity of DUNE?* Phys. Rev. **D96**, 075023 (2017).

[202] M. C. Gonzalez-Garcia and M. Maltoni, *Determination of matter potential from global analysis of neutrino oscillation data,* JHEP **09**, 152 (2013).

[203] P. Coloma, P. B. Denton, M. C. Gonzalez-Garcia, M. Maltoni, and T. Schwetz, *Curtailing the Dark Side in Non-Standard Neutrino Interactions,* JHEP **04**, 116 (2017).

[204] P. Coloma, M. C. Gonzalez-Garcia, M. Maltoni, and T. Schwetz, *COHERENT Enlightenment of the Neutrino Dark Side,* Phys. Rev. **D96**, 115007 (2017).

[205] P. B. Denton, Y. Farzan, and I. M. Shoemaker, *Testing large non-standard neutrino interactions with arbitrary mediator mass after COHERENT data,* JHEP **07**, 037 (2018).

[206] I. Esteban, M. C. Gonzalez-Garcia, M. Maltoni, I. Martinez-Soler, and J. Salvado, *Updated Constraints on Non-Standard Interactions from Global Analysis of Oscillation Data,* JHEP **08**, 180 (2018).

[207] L. Cardani, *Neutrinoless Double Beta Decay Overview,* SciPost Phys. Proc. **1**, 024 (2019).

[208] M. Agostini *et al.*, *Improved Limit on Neutrinoless Double-β Decay of ^{76}Ge from GERDA Phase II,* Phys. Rev. Lett. **120**, 132503 (2018).

[209] S. A. Kharusi *et al.*, *nEXO Pre-Conceptual Design Report,* (2018).

[210] C. Alduino *et al.*, *First Results from CUORE: A Search for Lepton Number Violation via $0\nu\beta\beta$ Decay of ^{130}Te,* Phys. Rev. Lett. **120**, 132501 (2018).

[211] R. Arnold *et al.*, *Probing New Physics Models of Neutrinoless Double Beta Decay with SuperNEMO,* Eur. Phys. J. **C70**, 927–943 (2010).

[212] P. P. Povinec, *Background constrains of the SuperNEMO experiment for neutrinoless double beta-decay searches,* Nucl. Instrum. Meth. **A845**, 398–403 (2017).

[213] M. Agostini, G. Benato, and J. Detwiler, *Discovery probability of next-generation neutrinoless double- decay experiments,* Phys. Rev. **D96**, 053001 (2017).

[214] J. Engel and J. Menndez, *Status and Future of Nuclear Matrix Elements for Neutrinoless Double-Beta Decay: A Review,* Rept. Prog. Phys. **80**, 046301 (2017).

[215] J. Kotila and F. Iachello, *Phase space factors for double-β decay,* Phys. Rev. **C85**, 034316 (2012).

[216] S. Pascoli and S. T. Petcov, *The SNO solar neutrino data, neutrinoless double beta decay and neutrino mass spectrum,* Phys. Lett. **B544**, 239–250 (2002).

[217] S. Goswami and W. Rodejohann, *Constraining mass spectra with sterile neutrinos from neutrinoless double beta decay, tritium beta decay and cosmology,* Phys. Rev. **D73**, 113003 (2006).

[218] J. Barry, W. Rodejohann, and H. Zhang, *Light Sterile Neutrinos: Models and Phenomenology,* JHEP **07**, 091 (2011).

[219] J. T. Penedo and S. T. Petcov, *The 10^3 eV frontier in neutrinoless double beta decay,* Phys. Lett. **B786**, 410–417 (2018).

[220] F. Vissani, *Do experiments suggest a hierarchy problem?* Phys. Rev. **D57**, 7027–7030 (1998).

[221] J. A. Casas, J. R. Espinosa, and I. Hidalgo, *Implications for new physics from fine-tuning arguments. 1. Application to SUSY and seesaw cases,* JHEP **11**, 057 (2004).

[222] A. Abada, C. Biggio, F. Bonnet, M. Gavela, and T. Hambye, *Low energy effects of neutrino masses,* JHEP **0712**, 061 (2007).

[223] M. Farina, D. Pappadopulo, and A. Strumia, *A modified naturalness principle and its experimental tests,* JHEP **08**, 022 (2013).

[224] J. D. Clarke, R. Foot, and R. R. Volkas, *Electroweak naturalness in the three-flavor type I seesaw model and implications for leptogenesis,* Phys.Rev. **D91**, 073009 (2015).

[225] M. Fabbrichesi and A. Urbano, *Naturalness redux: The case of the neutrino seesaw mechanism,* Phys. Rev. **D92**, 015028 (2015).

[226] J. D. Clarke, R. Foot, and R. R. Volkas, *Natural leptogenesis and neutrino masses with two Higgs doublets,* Phys. Rev. **D92**, 033006 (2015).

[227] M. Chabab, M. C. Peyranre, and L. Rahili, *Naturalness in a type II seesaw model and implications for physical scalars,* Phys. Rev. **D93**, 115021 (2016).

[228] N. Haba, H. Ishida, N. Okada, and Y. Yamaguchi, *Vacuum stability and naturalness in type-II seesaw,* Eur. Phys. J. **C76**, 333 (2016).

[229] P. S. B. Dev, C. M. Vila, and W. Rodejohann, *Naturalness in testable type II seesaw scenarios,* Nucl. Phys. **B921**, 436–453 (2017).

[230] J. N. Ng and A. de la Puente, *Electroweak Vacuum Stability and the Seesaw Mechanism Revisited,* Eur. Phys. J. **C76**, 122 (2016).

[231] A. Das, N. Okada, and N. Papapietro, *Electroweak vacuum stability in classically conformal B-L extension of the Standard Model,* Eur. Phys. J. **C77**, 122 (2017).

[232] A. Das, S. Oda, N. Okada, and D.-s. Takahashi, *Classically conformal U(1) extended standard model, electroweak vacuum stability, and LHC Run-2 bounds,* Phys. Rev. **D93**, 115038 (2016).

[233] S. Bhattacharya, P. Ghosh, T. N. Maity, and T. S. Ray, *Mitigating Direct Detection Bounds in Non-minimal Higgs Portal Scalar Dark Matter Models,* (2017).

[234] I. Garg, S. Goswami, V. K. N., and N. Khan, *Electroweak vacuum stability in presence of singlet scalar dark matter in TeV scale seesaw models,* Phys. Rev. **D96**, 055020 (2017).

[235] B. He, N. Okada, and Q. Shafi, *125 GeV Higgs, type III seesaw and gaugeHiggs unification,* Phys. Lett. **B716**, 197–202 (2012).

[236] S. Goswami, K. N. Vishnudath, and N. Khan, *Constraining the minimal type-III seesaw model with naturalness, lepton flavor violation, and electroweak vacuum stability,* Phys. Rev. **D99**, 075012 (2019).

[237] J. Casas and A. Ibarra, *Oscillating neutrinos and muon —¿ e, gamma,* Nucl.Phys. **B618**, 171–204 (2001).

[238] A. Ibarra and G. G. Ross, *Neutrino phenomenology: The Case of two right-handed neutrinos,* Phys.Lett. **B591**, 285–296 (2004).

[239] C. Collaboration, *Search for Type-III Seesaw Heavy Fermions with Multilepton Final States using 2.3/fb of 13 TeV proton-proton Collision Data,* (2016).

[240] G. Aad *et al.*, *Search for type-III Seesaw heavy leptons in* pp *collisions at* $\sqrt{s} = 8$ *TeV with the ATLAS Detector,* Phys. Rev. **D92**, 032001 (2015).

[241] G. Altarelli and G. Isidori, *Lower limit on the Higgs mass in the standard model: An Update,* Phys. Lett. **B337**, 141–144 (1994).

[242] J. A. Casas, J. R. Espinosa, M. Quiros, and A. Riotto, *The Lightest Higgs boson mass in the minimal supersymmetric standard model,* Nucl. Phys. **B436**, 3–29 (1995). [Erratum: Nucl. Phys.B439,466(1995)].

[243] M. Quiros, *Constraints on the Higgs boson properties from the effective potential,* (1997).

[244] C. Ford, D. Jones, P. Stephenson, and M. Einhorn, *The Effective potential and the renormalization group,* Nucl.Phys. **B395**, 17–34 (1993).

[245] A. Sirlin and R. Zucchini, *Dependence of the Quartic Coupling H(m) on M(H) and the Possible Onset of New Physics in the Higgs Sector of the Standard Model,* Nucl.Phys. **B266**, 389 (1986).

[246] F. Bezrukov, M. Y. Kalmykov, B. A. Kniehl, and M. Shaposhnikov, *Higgs Boson Mass and New Physics,* JHEP **1210**, 140 (2012).

[247] G. Degrassi, S. Di Vita, J. Elias-Miro, J. R. Espinosa, G. F. Giudice *et al.*, *Higgs mass and vacuum stability in the Standard Model at NNLO,* JHEP **1208**, 098 (2012).

[248] K. Melnikov and T. v. Ritbergen, *The Three loop relation between the MS-bar and the pole quark masses,* Phys.Lett. **B482**, 99–108 (2000).

[249] R. Hempfling and B. A. Kniehl, *On the relation between the fermion pole mass and MS Yukawa coupling in the standard model,* Phys.Rev. **D51**, 1386–1394 (1995).

[250] B. Schrempp and M. Wimmer, *Top quark and Higgs boson masses: Interplay between infrared and ultraviolet physics,* Prog.Part.Nucl.Phys. **37**, 1–90 (1996).

[251] F. Jegerlehner and M. Y. Kalmykov, *O(alpha alpha(s)) correction to the pole mass of the t quark within the standard model,* Nucl.Phys. **B676**, 365–389 (2004).

[252] K. Chetyrkin and M. Zoller, *Three-loop β-functions for top-Yukawa and the Higgs self-interaction in the Standard Model,* JHEP **1206**, 033 (2012).

[253] M. F. Zoller, *Vacuum stability in the SM and the three-loop β-function for the Higgs self-interaction,* Subnucl. Ser. **50**, 557–566 (2014).

[254] K. G. Chetyrkin and M. F. Zoller, *β-function for the Higgs self-interaction in the Standard Model at three-loop level,* JHEP **04**, 091 (2013). [Erratum: JHEP09,155(2013)].

[255] M. Zoller, *Beta-function for the Higgs self-interaction in the Standard Model at three-loop level,* PoS **EPS-HEP2013**, 322 (2013).

[256] J. Chakrabortty, A. Dighe, S. Goswami, and S. Ray, *Renormalization group evolution of neutrino masses and mixing in the Type-III seesaw mechanism,* Nucl.Phys. **B820**, 116–147 (2009).

[257] N. Khan and S. Rakshit, *Constraints on inert dark matter from the metastability of the electroweak vacuum,* Phys. Rev. **D92**, 055006 (2015).

[258] N. Khan, *Exploring Hyperchargeless Higgs Triplet Model up to the Planck Scale,* (2016).

[259] G. Belanger, B. Dumont, U. Ellwanger, J. F. Gunion, and S. Kraml, *Global fit to Higgs signal strengths and couplings and implications for extended Higgs sectors,* Phys. Rev. **D88**, 075008 (2013).

[260] G. Aad *et al.*, *Constraints on new phenomena via Higgs boson couplings and invisible decays with the ATLAS detector,* JHEP **11**, 206 (2015).

[261] V. Khachatryan *et al.*, *Searches for invisible decays of the Higgs boson in pp collisions at sqrt(s) = 7, 8, and 13 TeV,* JHEP **02**, 135 (2017).

[262] R. Dick, R. B. Mann, and K. E. Wunderle, *Cosmic rays through the Higgs portal,* Nucl. Phys. **B805**, 207–230 (2008).

[263] C. E. Yaguna, *Gamma rays from the annihilation of singlet scalar dark matter,* JCAP **0903**, 003 (2009).

[264] Y. Cai, X.-G. He, and B. Ren, *Low Mass Dark Matter and Invisible Higgs Width In Darkon Models,* Phys. Rev. **D83**, 083524 (2011).

[265] A. Urbano and W. Xue, *Constraining the Higgs portal with antiprotons,* JHEP **03**, 133 (2015).

[266] A. Cuoco, B. Eiteneuer, J. Heisig, and M. Krmer, *A global fit of the γ-ray galactic center excess within the scalar singlet Higgs portal model,* JCAP **1606**, 050 (2016).

[267] V. Barger, P. Langacker, M. McCaskey, M. J. Ramsey-Musolf, and G. Shaughnessy, *LHC Phenomenology of an Extended Standard Model with a Real Scalar Singlet,* Phys. Rev. **D77**, 035005 (2008).

[268] K. Cheung, P. Ko, J. S. Lee, and P.-Y. Tseng, *Bounds on Higgs-Portal models from the LHC Higgs data,* JHEP **10**, 057 (2015).

[269] A. Djouadi, O. Lebedev, Y. Mambrini, and J. Quevillon, *Implications of LHC searches for Higgs–portal dark matter,* Phys. Lett. **B709**, 65–69 (2012).

[270] M. Endo and Y. Takaesu, *Heavy WIMP through Higgs portal at the LHC,* Phys. Lett. **B743**, 228–234 (2015).

[271] H. Han, J. M. Yang, Y. Zhang, and S. Zheng, *Collider Signatures of Higgs-portal Scalar Dark Matter,* Phys. Lett. **B756**, 109–112 (2016).

[272] P. Ko and H. Yokoya, *Search for Higgs portal DM at the ILC,* JHEP **08**, 109 (2016).

[273] Y. Mambrini, *Higgs searches and singlet scalar dark matter: Combined constraints from XENON 100 and the LHC,* Phys. Rev. **D84**, 115017 (2011).

[274] K. Cheung, Y.-L. S. Tsai, P.-Y. Tseng, T.-C. Yuan, and A. Zee, *Global Study of the Simplest Scalar Phantom Dark Matter Model,* JCAP **1210**, 042 (2012).

[275] J. M. Cline, K. Kainulainen, P. Scott, and C. Weniger, *Update on scalar singlet dark matter,* Phys. Rev. **D88**, 055025 (2013). [Erratum: Phys. Rev.D92,no.3,039906(2015)].

[276] F. S. Queiroz, K. Sinha, and A. Strumia, *Leptoquarks, Dark Matter, and Anomalous LHC Events,* Phys. Rev. **D91**, 035006 (2015).

[277] F. S. Queiroz and K. Sinha, *The Poker Face of the Majoron Dark Matter Model: LUX to keV Line,* Phys. Lett. **B735**, 69–74 (2014).

[278] P. Athron *et al.*, *Status of the scalar singlet dark matter model,* (2017).

[279] M. Gonderinger, Y. Li, H. Patel, and M. J. Ramsey-Musolf, *Vacuum Stability, Perturbativity, and Scalar Singlet Dark Matter,* JHEP **01**, 053 (2010).

[280] J. Elias-Miro, J. R. Espinosa, G. F. Giudice, H. M. Lee, and A. Strumia, *Stabilization of the Electroweak Vacuum by a Scalar Threshold Effect,* JHEP **06**, 031 (2012).

[281] C.-S. Chen and Y. Tang, *Vacuum stability, neutrinos, and dark matter,* JHEP **04**, 019 (2012).

[282] N. Haba, K. Kaneta, and R. Takahashi, *Planck scale boundary conditions in the standard model with singlet scalar dark matter,* JHEP **04**, 029 (2014).

[283] S. Ghosh, A. Kundu, and S. Ray, *Potential of a singlet scalar enhanced Standard Model,* Phys. Rev. **D93**, 115034 (2016).

[284] H. Davoudiasl, R. Kitano, T. Li, and H. Murayama, *The New minimal standard model,* Phys. Lett. **B609**, 117–123 (2005).

[285] W. Chao, M. Gonderinger, and M. J. Ramsey-Musolf, *Higgs Vacuum Stability, Neutrino Mass, and Dark Matter,* Phys. Rev. **D86**, 113017 (2012).

[286] S. Bhattacharya, S. Jana, and S. Nandi, *Neutrino Masses and Scalar Singlet Dark Matter,* Phys. Rev. **D95**, 055003 (2017).

[287] P. Ghosh, A. K. Saha, and A. Sil, *Study of Electroweak Vacuum Stability from Extended Higgs Portal of Dark Matter and Neutrinos,* (2017).

[288] M. Gavela, T. Hambye, D. Hernandez, and P. Hernandez, *Minimal Flavour Seesaw Models,* JHEP **0909**, 038 (2009).

[289] R. N. Lerner and J. McDonald, *Gauge singlet scalar as inflaton and thermal relic dark matter,* Phys. Rev. **D80**, 123507 (2009).

[290] M. Gonderinger, H. Lim, and M. J. Ramsey-Musolf, *Complex Scalar Singlet Dark Matter: Vacuum Stability and Phenomenology,* Phys. Rev. **D86**, 043511 (2012).

[291] M. Holthausen, K. S. Lim, and M. Lindner, *Planck scale Boundary Conditions and the Higgs Mass,* JHEP **1202**, 037 (2012).

[292] L. N. Mihaila, J. Salomon, and M. Steinhauser, *Gauge Coupling Beta Functions in the Standard Model to Three Loops,* Phys.Rev.Lett. **108**, 151602 (2012).

[293] T. E. Clark, B. Liu, S. T. Love, and T. ter Veldhuis, *The Standard Model Higgs Boson-Inflaton and Dark Matter,* Phys. Rev. **D80**, 075019 (2009).

[294] S. Antusch, J. Kersten, M. Lindner, and M. Ratz, *Neutrino mass matrix running for nondegenerate seesaw scales,* Phys.Lett. **B538**, 87–95 (2002).

[295] F. Staub, *SARAH 4 : A tool for (not only SUSY) model builders,* Comput. Phys. Commun. **185**, 1773–1790 (2014).

[296] S. Antusch and O. Fischer, *Probing the nonunitarity of the leptonic mixing matrix at the CEPC,* Int. J. Mod. Phys. **A31**, 1644006 (2016).

[297] P. Achard *et al.*, *Search for heavy isosinglet neutrino in e^+e^- annihilation at LEP,* Phys.Lett. **B517**, 67–74 (2001).

[298] O. Adriani *et al.*, *Search for isosinglet neutral heavy leptons in Z0 decays,* Phys.Lett. **B295**, 371–382 (1992).

[299] P. Abreu *et al.*, *Search for neutral heavy leptons produced in Z decays,* Z.Phys. **C74**, 57–71 (1997).

[300] M. Z. Akrawy *et al.*, *Limits on neutral heavy lepton production from Z0 decay,* Phys. Lett. **B247**, 448–457 (1990).

[301] A. M. Sirunyan *et al.*, *Search for heavy neutral leptons in events with three charged leptons in proton-proton collisions at $\sqrt{s}$ = 13 TeV,* Phys. Rev. Lett. **120**, 221801 (2018).

[302] G. Cynolter, E. Lendvai, and G. Pocsik, *Note on unitarity constraints in a model for a singlet scalar dark matter candidate,* Acta Phys. Polon. **B36**, 827–832 (2005).

[303] B. W. Lee, C. Quigg, and H. B. Thacker, *Weak Interactions at Very High-Energies: The Role of the Higgs Boson Mass,* Phys. Rev. **D16**, 1519 (1977).

[304] Y. Y. P. and Y. C. P., *Modification of the Equivalence Theorem Due to Loop Corrections,* Phys. Rev. **D38**, 2237 (1988).

[305] V. H. G. J., *The Equivalence Theorem,* Phys. Rev. **D41**, 2294 (1990).

[306] H. H. J., *On the precise formulation of equivalence theorem,* Phys. Rev. **D69**, 2619 (1992).

[307] M. Ajello *et al.*, *Fermi-LAT Observations of High-Energy γ-Ray Emission Toward the Galactic Center,* Astrophys. J. **819**, 44 (2016).

[308] A. Alloul, N. D. Christensen, C. Degrande, C. Duhr, and B. Fuks, *FeynRules 2.0 - A complete toolbox for tree-level phenomenology,* Comput. Phys. Commun. **185**, 2250–2300 (2014).

[309] G. Belanger, F. Boudjema, P. Brun, A. Pukhov, S. Rosier-Lees, P. Salati, and A. Semenov, *Indirect search for dark matter with micrOMEGAs2.4,* Comput. Phys. Commun. **182**, 842–856 (2011).

[310] G. Belanger, F. Boudjema, A. Pukhov, and A. Semenov, $micrOMEGAs_3$*: A program for calculating dark matter observables,* Comput. Phys. Commun. **185**, 960–985 (2014).

[311] W. T. V. W. H. Press, S. A. Teukolsky and B. P. Flannery, *Numerical Recipes in Fortran 90, Second Edition* (Cambridge Univ, 1996).

[312] C. Coriano, L. Delle Rose, and C. Marzo, *Vacuum Stability in U(1)-Prime Extensions of the Standard Model with TeV Scale Right Handed Neutrinos,* Phys. Lett. **B738**, 13–19 (2014).

[313] C. Coriano, L. Delle Rose, and C. Marzo, *Constraints on abelian extensions of the Standard Model from two-loop vacuum stability and* $U(1)_{B-L}$*,* JHEP **02**, 135 (2016).

[314] E. Accomando, C. Coriano, L. Delle Rose, J. Fiaschi, C. Marzo, and S. Moretti, *Z, Higgses and heavy neutrinos in U(1) models: from the LHC to the GUT scale,* JHEP **07**, 086 (2016).

[315] S. Oda, N. Okada, and D.-s. Takahashi, *Classically conformal U(1) extended standard model and Higgs vacuum stability,* Phys. Rev. **D92**, 015026 (2015).

[316] T. Basak and T. Mondal, *Constraining Minimal* $U(1)_{B-L}$ *model from Dark Matter Observations,* Phys. Rev. **D89**, 063527 (2014).

[317] S. Oda, N. Okada, and D.-s. Takahashi, *Right-handed neutrino dark matter in the classically conformal U(1) extended standard model,* Phys. Rev. **D96**, 095032 (2017).

[318] W. Rodejohann and C. E. Yaguna, *Scalar dark matter in the BL model,* JCAP **1512**, 032 (2015).

[319] J. Cao, L. Feng, X. Guo, L. Shang, F. Wang, and P. Wu, *Scalar dark matter interpretation of the DAMPE data with U(1) gauge interactions,* Phys. Rev. **D97**, 095011 (2018).

[320] S. Singirala, R. Mohanta, and S. Patra, *Singlet scalar Dark matter in $U(1)_{B-L}$ models without right-handed neutrinos,* Eur. Phys. J. Plus **133**, 477 (2018).

[321] P. Langacker, *Grand Unified Theories and Proton Decay,* Phys.Rept. **72**, 185 (1981).

[322] J. L. Hewett and T. G. Rizzo, *Low-Energy Phenomenology of Superstring Inspired E(6) Models,* Phys. Rept. **183**, 193 (1989).

[323] L. Basso, A. Belyaev, S. Moretti, and C. H. Shepherd-Themistocleous, *Phenomenology of the minimal B-L extension of the Standard model: Z' and neutrinos,* Phys. Rev. **D80**, 055030 (2009).

[324] E. Accomando, L. Delle Rose, S. Moretti, E. Olaiya, and C. H. Shepherd-Themistocleous, *Extra Higgs boson and Z as portals to signatures of heavy neutrinos at the LHC,* JHEP **02**, 109 (2018).

[325] M. Aaboud *et al.*, *Search for high-mass new phenomena in the dilepton final state using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector,* Phys. Lett. **B761**, 372–392 (2016).

[326] V. Khachatryan *et al.*, *Search for narrow resonances in dilepton mass spectra in proton-proton collisions at $\sqrt{s}$ = 13 TeV and combination with 8 TeV data,* Phys. Lett. **B768**, 57–80 (2017).

[327] A. Das, S. Goswami, V. K. N., and T. Nomura, *Constraining a general U(1)$'$ inverse seesaw model from vacuum stability, dark matter and collider,* (2019).

[328] J. Chakrabortty, P. Konar, and T. Mondal, *Copositive Criteria and Boundedness of the Scalar Potential,* Phys. Rev. **D89**, 095008 (2014).

[329] H. Huffel and G. Pocsik, *Unitarity Bounds on Higgs Boson Masses in the Weinberg-Salam Model With Two Higgs Doublets,* Z. Phys. **C8**, 13 (1981).

[330] M. Duerr, F. Kahlhoefer, K. Schmidt-Hoberg, T. Schwetz, and S. Vogl, *How to save the WIMP: global analysis of a dark matter model with two s-channel mediators,* JHEP **09**, 042 (2016).

[331] G. Blanger, F. Boudjema, A. Pukhov, and A. Semenov, *micrOMEGAs4.1: two dark matter candidates,* Comput. Phys. Commun. **192**, 322–329 (2015).

[332] P. Langacker, *The Physics of Heavy Z' Gauge Bosons,* Rev. Mod. Phys. **81**, 1199–1228 (2009).

[333] S. R. Coleman and E. J. Weinberg, *Radiative Corrections as the Origin of Spontaneous Symmetry Breaking,* Phys. Rev. **D7**, 1888–1910 (1973).

[334] A. Zee, *Quantum field theory in a nutshell* (2003).

List of Publications

Thesis related Publications

1. I. Garg, S. Goswami,**Vishnudath K. N.** and N. Khan,
   Electroweak vacuum stability in presence of singlet scalar dark matter in TeV scale seesaw models
   Phys. Rev. D **96**, 055020 (2017). arXiv:1706.08851

2. S. Goswami,**Vishnudath K. N.** and N. Khan,
   Constraining the minimal type-III seesaw model with naturalness, lepton flavor violation, and electroweak vacuum stability
   Phys. Rev. D **99**, 075012 (2019). arXiv:1810.11687

3. **Vishnudath K. N.**, S. Choubey and S. Goswami,
   A New Sensitivity Goal for Neutrino-less Double Beta Decay Experiments
   arXiv:1901.04313 (Accepted for publication in Phys. Rev. D)

4. Arindam Das, Srubabati Goswami, **Vishnudath K. N.** and Takaaki Nomura,
   Constraining a general $U(1)$ inverse seesaw model from vacuum stability, dark matter and collider
   arXiv:1905.00201 (Submitted to Phys. Rev. D)