**Abstract**

The landmark discovery of Higgs boson at the Large Hadron Collider (LHC) in 2012 has brought about the final constituent in the most successful Standard model (SM) of particle physics. Several experiments have verified the predictions of the SM with exquisite precision. Although this discovery unravels the properties and interactions of the charged fermions and their origin of mass, it fails to provide a basis for understanding the light neutral fermions, the most elusive neutrinos. The discovery of neutrino oscillation and the corresponding realization that they are massive and they mix during propagation which bagged the 2015 Nobel prize in Physics has brought about a severe crack in the model's elegant edifice thereby pointing out its incompleteness. That neutrinos have non-zero but tiny masses and large mixing has been well established by several neutrino experiments over the past few decades. Among these experiments, the relatively recent ones like T2K, Double Chooz, Daya Bay, RENO and MINOS experiments have not only confirmed the results from earlier experiments but also provided strong evidence for the non-zero reactor mixing angle $\theta_{13}$. The latest global fit shows that a few of the parameters of the light neutrinos are yet to be determined experimentally. They are namely, the Dirac CP phase, octant of atmospheric mixing angle and the ordering of light neutrinos: normal ordering (NO) or inverted ordering (IO). Also, the intrinsic nature of neutrinos ( whether Dirac or Majorana) remains unknown at oscillation experiments. If neutrinos are Majorana fermions, there arise two more CP phases known as Majorana CP phases, which are not sensitive to oscillation experiments and have to be probed at alternative experiments. Again, the neutrino sector is constrained by the data from cosmology as well. For example, the latest data from the Planck mission constrain the sum of absolute neutrino masses $\sum_i |m_i| < 0.12$ eV. Although we have significant experimental observations related to the neutrino sector except for the above-mentioned unknowns, the dynamical origin of light neutrino masses and their mixing is still a mystery. The SM is considered an insufficient theory, owing to the fact that besides the neutrino mass, it also fails to address some other vital questions like the Baryon Asymmetry of the universe (BAU), Dark matter (DM), Lepton Number Violation (LNV), Lepton Flavor Violation (LFV) and various other cosmological problems. Several beyond standard model (BSM) proposals have been put forward which can address these issues.

The simplest of the BSM frameworks is the seesaw mechanism where a seesaw between the electroweak scale and the scale of newly introduced fields decide the smallness of neutrino masses. Popular seesaw models can be categorized as type I seesaw, type II seesaw, type III seesaw, inverse seesaw etc.

Another very fascinating and modest frameworks in which neutrino mass and other unsolved queries can be addressed is the left-right symmetric model (LRSM) where the gauge symmetry of the SM is extended to $\mathrm{SU(3)_c \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}}$ so that the right-handed fermions (which are singlet in SM) can form doublets under the new $SU(2)_R$. In LRSM, the left and right-handed fermions are treated on equal footing. It provides a natural framework to understand the spontaneous breaking of parity and origin of small neutrino mass via seesaw mechanism. It has become a topic of interest since long back owing to its indomitable importance and has been studied in details by several groups in different contexts. Apart from this, another interesting motivation for this model is its verifiability. A TeV scale LRSM can have very interesting signatures which are being looked at colliders.

The RH neutrinos which exist in the seesaw mechanism, besides explaining the neutrino flavor oscillation and neutrino mass can also throw light on the matter-antimatter asymmetry of the universe, i.e, excess of baryons over anti baryons in the universe. As pointed out by Fukugita and Yanagida, these right-handed neutrinos can play a vital role in leptogenesis through the CP violating decay of the singlet fermion through which baryogenesis could be realized. Again, matter-antimatter asymmetry could be generated by a resonant baryogenesis mechanism with atleast two Quasi Degenerate RH neutrinos in TeV range with a mass difference comparable to their decay widths is widely studied in literature. Another important issue of discussion in collider is the relative values of mass of the RH gauge boson and heavy right-handed neutrinos. Keeping in mind the bounds of the RH gauge boson mass for successful baryogenesis from several earlier works, it would be interesting to see the consistency of those results as well as try to find a common parameter space where we can realize both baryogenesis and low energy phenomenon like neutrinoless double beta decay and lepton flavor violation. The possible observation of neutrinoless double beta decay (NDBD) would also play an important role in understanding the origin of BAU as it would imply that lepton number indeed is not conserved (one of the essential conditions for leptogenesis). Furthermore, the Majorana nature of neutrinos would also be established from

NDBD. Among the latest experiments, KamLAND-Zen imposes the best lower limit on the decay half-life using Xe-136 as $T^{0\nu}_{1/2} > 1.07 \times 10^{26}$ yr at 90% CL and the corresponding upper limit of effective Majorana mass in the range (0.061-0.165) eV. In LRSM, there are several contributions to NDBD that involve left and right-handed sectors individually as well as others that involve both sectors through left-right mixing accompanied by both light and heavy neutrinos. Furthermore, the LFV processes are seeking great interest in recent times as the experiments to detect them are becoming increasingly precise. The decay processes, ($\mu \rightarrow 3e$) and ($\mu \rightarrow e\gamma$) are simplest to detect with the current experimental limits for these low energy processes as $< 1.0 \times 10^{-12}$ and $< 4.2 \times 10^{-13}$ respectively.

Again one of the most important BSM framework to understand the origin of neutrino mass and large leptonic mixing is to identify the possible underlying symmetries. The neutrino oscillation data before the discovery of non zero $\theta_{13}$ were in perfect agreement with $\mu - \tau$ symmetry. But, after discovery of non zero $\theta_{13}$, one needs to go beyond these $\mu$-$\tau$ symmetric framework. Since the experimental value of $\theta_{13}$ is still much smaller than the other two mixing angles, $\mu$-$\tau$ symmetry can still be a valid approximation and the non zero $\theta_{13}$ can be accounted for by incorporating the presence of small perturbation to $\mu$-$\tau$ symmetry.Typical seesaw models in the absence of specific flavor symmetries usually predict a very general structure of light neutrino mass matrix which can always be fitted to the observed data due to the presence of many free parameters. The same is true in LRSM as well. However, if the theory has a well-motivated underlying symmetry that gives rise to a very specific structure of the neutrino mass matrix, the number of free parameters can be significantly reduced. One such possibility is the zero texture models. It has been shown that in the diagonal charged lepton basis, not more than two zeros are allowed in the light neutrino mass matrix. While all six possible one zero texture ($^6C_n, n = 1$) are allowed, among the fifteen possible two zero textures, only six were found to be allowed after incorporating both neutrinos as well as cosmology data. It would be interesting to find the correlations among light neutrino parameters and also find the new physics contribution to other interesting processes like neutrinoless double beta decay (NDBD) and charged lepton flavor violation (CLFV).

In this thesis, we attempt to study in this direction and present a phenomenological study of different neutrino mass mixing patterns to check their consistency with the stringent constraints from cosmology, with various processes like NDBD, LFV etc within the framework of LRSM. In NDBD, we discuss the different new physics contributions arising in the framework of LRSM that can contribute to the effective mass governing the process and identify the significant ones. Apart from the new physics contributions to NDBD in LRSM as available in the literature, we tried to study the linkage between baryogenesis and other low scale phenomena like NDBD, LFV etc keeping in mind the relevant collider bounds of the masses in LRSM. We also attempt to do a phenomenological study on the neutrino mass matrix $M_\nu$ favouring two zero texture in the framework of LRSM where type I and type II seesaw naturally occurs. The symmetry realizations of these texture zero structures have been realized using the discrete cyclic abelian ($Z8 \times Z2$) group in LRSM. We basically focused in the implications of these texture zero mass matrices in low energy phenomenon like NDBD and LFV in LRSM scenario. The mass of the extra gauge bosons and scalars has been considered to be of the order of TeV accessible at the colliders. As the processes, NDBD, LFV etc are being probed at several experiments, this study points out the possibility of probing such scenarios at those experiments. Such aspects of probing LRSM can be complementary to the ongoing collider searches. The thesis is structured as follows,

In **chapter 1**, starting with a brief history of the neutrinos, we present a literature survey of the current theoretical and experimental status of the neutrino sector. Then we discuss the Standard Model of Particle Physics along with its limitations for which we have to go for beyond standard model (BSM) frameworks. We also discuss the different BSM frameworks which can address the issues of the SM, mainly the neutrino mass and mixing, the different seesaw scenarios in brief which can explain the tiny neutrino mass. We mainly focus on the appealing BSM framework, left-right symmetric model and discuss the different phenomenology that could be addressed in its framework, mainly the neutrinoless double beta decay, lepton flavor violation, matter-antimatter asymmetry of the universe which we discuss in different sections. Finally, we discuss in brief the role of flavor symmetry in particle physics giving special emphasis on the discrete group $Z_n$ which we have implemented in this thesis.

In **chapter 2**, we have studied neutrinoless double beta decay and charged lepton flavor violation in broken $\mu - \tau$ symmetric neutrino masses in a generic left-right symmetric model (LRSM). The leading order $\mu - \tau$ symmetric mass matrix originates from the type I (II) seesaw mechanism, whereas the perturbations to $\mu-\tau$ symmetry in order to generate non-zero reactor mixing angle $\theta_{13}$, as required by latest neutrino oscillation data, originates from the type II (I) seesaw mechanism. In our work, we considered four different realizations of $\mu-\tau$ symmetry, viz. Tri-bimaximal Mixing (TBM), Bi-maximal Mixing (BM), Hexagonal Mixing (HM) and Golden Ratio Mixing (GRM). We then studied the new physics contributions to neutrinoless double beta decay (NDBD) ignoring the left-right gauge boson mixing and the heavy-light neutrino mixing within the framework of LRSM. We have considered the mass of the gauge bosons and scalars to be around TeV and studied the effects of the new physics contributions on the effective mass and the NDBD half-life and compared with the current experimental limit imposed by KamLAND-Zen. We further extended our analysis by correlating the lepton flavor violation of the decay processes, ($\mu \rightarrow 3e$) and ($\mu \rightarrow e\gamma$) with the lightest neutrino mass and atmospheric mixing angle $\theta_{23}$ respectively.

In **chapter 3**, we did a model-independent phenomenological study of baryogenesis via leptogenesis, neutrinoless double beta decay (NDBD) and charged lepton flavor violation (CLFV) in a generic left-right symmetric model (LRSM) where neutrino mass originates from the type I + type II seesaw mechanism. We studied the new physics contributions to NDBD coming from the left-right gauge boson mixing and the heavy neutrino contribution within the framework of LRSM. We have considered the mass of the RH gauge boson to be specifically 5 TeV, 10 TeV and 18 TeV and studied the effects of the new physics contributions on the effective mass and baryogenesis and compared with the current experimental limit. We tried to correlate the cosmological BAU from resonant leptogenesis with the low energy observables, notably, NDBD and LFV with a view to finding a common parameter space where they coexist.

In **chapter 4**, we studied baryogenesis via leptogenesis, neutrinoless double beta decay (NDBD) in the framework of LRSM where type I and type II seesaw terms arises naturally. The type I seesaw mass term is considered to be favouring $\mu-\tau$ symmetry, taking into account the widely studied realizations of $\mu-\tau$ symmetric neutrino mass models, viz. Tri-bimaximal Mixing (TBM), Hexagonal Mixing (HM) and Golden Ratio Mixing (GRM) respectively. The required correction to generate a non-vanishing reactor mixing angle $\theta_{13}$ is obtained from the perturbation matrix, type II seesaw mass term in our case. We studied the new physics contributions to NDBD and baryogenesis ignoring the left-right gauge boson mixing and the heavy-light neutrino mixing, keeping mass of the gauge bosons and scalars to be around TeV and studied the effects of the new physics contributions on the effective mass, NDBD half-life and cosmological BAU and compared with the values imposed by experiments. We basically tried to find the leading order contributions to NDBD and BAU, coming from the type I or type II seesaw in our work.

In **chapter 5**, we have done a phenomenological study on the neutrino mass matrix $M_\nu$ favoring two zero texture in the framework of the left-right symmetric model (LRSM) where type I and type II seesaw naturally occurs. The type I SS mass term is considered to be following a trimaximal mixing (TM) pattern. The symmetry realizations of these texture zero structures have been realized using the discrete cyclic abelian $Z8 \times Z2$ group in LRSM. We have studied six of the popular texture zero classes named as A1, A2, B1, B2, B3 and B4 favoured by neutrino oscillation data in our analysis. We basically focused on the implications of these texture zero mass matrices in low energy phenomenon like neutrinoless double beta decay (NDBD) and lepton flavor violation (LFV) in the LRSM scenario. For NDBD, we have considered only the dominant new physics contribution coming from the diagrams containing purely RH current and another from the charged Higgs scalar while ignoring the contributions coming from the left-right gauge boson mixing and heavy light neutrino mixing. The mass of the extra gauge bosons and scalars has been considered to be of the order of TeV scale which is accessible at the colliders.

In **chapter 6**, we consider the possibility of texture zeros in lepton mass matrices of the minimal left-right symmetric model (LRSM) where light neutrino mass arises from a combination of type I and type II seesaw mechanisms. Based on the allowed texture zeros in light neutrino mass matrix from neutrino and cosmology data, we make a list of all possible allowed and disallowed texture zeros in Dirac and heavy neutrino mass matrices which appear in type I and type II seesaw terms of LRSM. For the numerical analysis we consider those cases with maximum possible texture zeros in light neutrino mass matrix $M_\nu$, Dirac neutrino mass matrix $M_D$, heavy neutrino mass matrix $M_{RR}$ while keeping the determinant of $M_{RR}$ non-vanishing, in order to use the standard type I seesaw formula. The possibility of maximum zeros reduces the free parameters of the model making it more predictive. We then compute the new physics contributions to rare decay processes like neutrinoless double beta decay, charged lepton flavor violation. We find that even for a conservative lower limit on the left-right symmetry scale corresponding to heavy charged gauge boson mass 4.5 TeV, in agreement with collider bounds, for right-handed neutrino masses above 1 GeV, the new physics contributions to these rare decay processes can saturate the corresponding experimental bound.

In **chapter 7**, finally, we give a comprehensive summary of the work carried out in this thesis. We also discuss in brief the future scope of research in this direction or in neutrino physics in general.