7 CONCLUSION

In this chapter, we summarize the overall conclusions drawn from the phenomenological works carried out in each of the preceding chapters that mainly deals with the study of neutrino mass and its implications on phenomenon like neutrinoless double beta decay, lepton flavor violation, baryon asymmetry of the universe etc. We have implemented the appealing left-right symmetric model to explain the neutrino mass where it is a combination of both type I and type II seesaw mass terms. We have further studied the texture zeros in the neutrino mass which gives interesting results for the low energy phenomenon we have considered in this thesis. To realize the texture zeros, we used the discrete abelian group, $Z_8 \times Z_2$. The chapter wise significant conclusion have been presented in different sections. We also discuss in brief the possible scope of research in this direction that might be carried out in future.

7.1 Chapter 2

In **chapter 2**, we studied the implications of NDBD and LFV in LRSM framework. Out of different contributions for NDBD that could arise in the LRSM scenario, we considered the standard light neutrino contribution as well as the new physics contribution arising from heavy RH neutrino and the scalar triplet to NDBD while ignoring the left-right gauge boson mixing and heavy light neutrino mixing for simplicity and the lesser contributions. The masses of the extra gauge bosons and scalars are considered to be of the order of TeV. The leading order $\mu-\tau$ symmetric neutrino mass matrix originates from the type I (II) seesaw mechanism, whereas the perturbations to $\mu-\tau$ symmetry in order for generation of non-zero reactor mixing angle, θ_{13} as required by latest neutrino oscillation data from the type II (I) seesaw mechanism. The different realizations of the $\mu-\tau$ symmetric mass matrices we considered are namely, TBM, BM, HM and GRM matrices. We have also discussed the impacts of the lightest neutrino mass and not so precisely known atmospheric mixing angle, θ_{23} on the behaviour of LFV of the decay process, $\mu \rightarrow 3$e and $\mu \rightarrow$ eγ respectively. Interestingly, we have observed different results from the two approaches. In the standard contribution to NDBD, it is observed that for both NH and IH, the light neutrino contribution can saturate the KamLAND-Zen limit for lightest neutrino mass (m_1/m_3) for (NH/IH) of around 0.1 eV. From the new physics contributions to NDBD in type II as perturbation, for IH, TBM, HM and GRM shows results within the recent experimental bound for lightest mass varying from (0.001-0.1) eV. Whereas, for NH the effective mass lies within experimental limit for lightest mass in the range (0.01-0.1) eV. For type I perturbation, the values consistent with exp. bound are found for lightest mass (0.001-0.1) eV for TBM and (0.01-0.1 eV) for all other cases. It is observed from our analysis that the BR for the process $\mu \rightarrow 3$e depends on the neutrino mass spectrum. In case of IH, BR is spread over a wide range and lies even in the range of recently proposed limit with a sensitivity of 10^{-16}. For the process, $\mu \rightarrow$ eγ, the results for BR are found to be consistent with the experimental limit for all the mixing patterns, except for HM and BM (NH) in the 3σ range of θ_{23}. In this case, the dependence of LFV on the neutrino mass spectrum is not much significant.

7.2 Chapter 3

In **chapter 3** the main purpose of the work is to see if there is a common parameter space where we can establish a linkage between baryogenesis and the low scale phenomenon like NDBD and LFV, we have done a phenomenological study of these phenomenon at a TeV scale LRSM considering some specific values of RH Gauge boson mass, 5 TeV, 10 TeV and 18 TeV (as found separately in the earlier works) and check the consistency of the previous results. Based on our study, we could say that, for a low scale model independent seesaw model, one can account for successful leptogenesis and larger parameter space for BAU with the observed cosmological value is obtained for $M_{W_R} = 18$ TeV than for 5 TeV. New Physics contributions to NDBD in TeV scale LRSM for different M_{W_R} shows that dominant contribution comes from the exchange of RH gauge boson rather than the mixed, LH-RH gauge boson mixing contributions. The λ contributions to NDBD is a bit suppressed owing to the less Yukawa coupling and not so large left-right mixing in our analysis while η contribution is further suppressed by two orders of magnitude that the λ contribution. Again, it is possible to obtain a common parameter space for both NDBD and BAU. This corresponds to the NDBD contribution coming from the heavy RH neutrino for both NH and IH. However, in this case better results are obtained for 18 TeV RH gauge boson mass. Whereas, as far as the momentum dependent λ and η mechanisms are concerned, both NDBD and BAU can be simultaneously explained for M_{W_R} =5 TeV or $\leqslant$ 10 TeV and only for IH. Sizable implications for other low energy observable, charged LFV of the processes, $\mu \rightarrow$ 3e and $\mu \rightarrow$ eγ are obtained for a minimal TeV scale LRSM which simultaneously accounts for BAU and NDBD. For LFV, the BR prediction for $\mu \rightarrow$ eγ is not much dependent on the atmospheric mixing angle, θ_{23}. Having done an extensive study of several of the earlier works, we have found that our results are in accordance with the previous works where low scale phenomena are discussed.That successful leptogenesis can be found within the vicinity of the experimental limit for RH gauge boson mass as low as 5 TeV and is not much dependent on the mass hierachy, NH or IH. However, both low scale BAU and effective mass governing NDBD can be simultaneously obtained for only some parameter space that depends on the mass hierarchy and the W_R mass as mentioned in the above points.

7.3 Chapter 4

In **chapter 4**, we have done a phenomenological study of BAU and NDBD in the framework of TeV scale LRSM with the primary focus to see the contributions of type I and type II SS terms to the aforementioned phenomenon considering both normal and inverted mass hierarchy of neutrino mass spectrum. In particular, we have considered the type I SS mass term to be $\mu - \tau$ symmetric, namely, TBM, HM and GRM respectively whereas the perturbation to generate non zero θ_{13} has been obtained from the type II SS term. It would be enthralling to explore the situations where both the contributions from type I and type II SS are comparable in size or to speculate the dominance of either of the SS terms to study BSM phenomenon like, BAU and NDBD. Based on our study, we could say that successful leptogenesis can be accounted for, considering M_{W_R} as 10 TeV for a model independent analysis irrespective of different mixing patterns. The baryon asymmetry is found in the observable range in all the cases irrespective of the mass hierarchies and type I/II SS contribution. Most of the observed values are found in the lightest mass range from 0.05 to 0.1 eV. Variation of BAU with α and β shows almost similar results for all the mixing patterns, but there is a correlation between the phases which is different for NH and IH. In case of IH, greater parameter space is obtained for α satisfying the experimental bound of BAU for leading type I contribution. In new Physics contributions to NDBD in TeV scale LRSM, TBM, HM, GRM shows results within experimental bound for a wide range of lightest neutrino mass varying from 10^{-4} to 10^{-1}. However the results are not much dependent on the mixing patterns. From a careful observation of all the plots, we can say that IH is more consistent with the experimental results. Variation of NDBD with both the Majorana phases α and β shows that there is a dependence on the phases irrespective of the mixing patterns and for IH, the parameter space seems to be for constrained for α satisfying the experimental bounds.

In brief, we can state that regarding the leading order contribution, not much can be concluded in case of baryogenesis from our analysis. Whereas NDBD is more consistent with type I leading contribution. And regarding the mass hierarchy after a careful observation of all the results, we may conclude that IH gives better predictions in explaining both BAU and NDBD. Further detailed analysis is to be pursued considering some discrete groups in analyzing the structures of the mass matrices we have considered in our analysis and also the variation with the other neutrino parameters to give a rather strong conclusion which we leave for our future study.

7.4 Chapter 5

In **chapter 5** We have performed a systematic study of the Majorana neutrino mass matrix with two independent zeros. As has been pointed out in several earlier works that seven out of fifteen patterns namely (A1, A2, B1-B4, C1) can survive the current experimental data at 3σ level. We tried to study the constraints of the allowed patterns of texture zero neutrino mass matrices in the framework of LRSM from low energy phenomenon like NDBD and LFV. We have shown that one can obtain the desired two zero texture mass matrices by implementing a abelian discrete symmetric group $Z8 \times Z2$ in the framework of left-right symmetric model. The two zero textured neutrino mass matrix in our case is able to explain NDBD with the effective Majorana mass within the experimental limit propounded by experiment (KamLAND-Zen). However all the different allowed classes of two zero textures shows different results for different neutrino mass hierarchies. Based on our results, having done a careful comparison of the plots obtained for different classes of two zero textures, it is seen that none of the cases totally disallows NDBD as far as the KamLAND-Zen limit is concerned irrespective of the mass hierarchies. However the allowed range of the parameter space is constrained for the allowed experimental bounds of effective Majorana neutrino mass. We have considered the type I seesaw mass term in LRSM to be satisfying TM mixing in our case. Again we have done an analysis of the model parameters (W, X, Y, Z) in our case which are heavily constrained for a very limited parameter space for some classes, specifically for the class B2 (NH/IH). Thus we can say that the contributions from the type II SS in NDBD is relatively less for this class. Interestingly the present results ruled out all the classes except A2(IH) in explaining the experimentally allowed regions of charged lepton flavour violation. Again, the Majorana phases α and β are also constrained from both NDBD and LFV point of view. However, the sensitivity of NDBD experiments to the effective mass governing NDBD will probably reach around 0.05 eV in future experiments which might exclude or marginally allow some of the two zero texture patterns in nearby future. However, here we have considered some random structures of the Dirac and Majorana mass matrix that leads to the two zero texture neutrino mass matrix. It would be interesting to study an indepth analysis for all the texture structures the Dirac and Majorana mass matrix that might lead to the zero textures in the neutrino mass matrix. We have left this study of the texture zero classes considering all the model parameters and its implications for all contributions of NDBD and LFV in the framework of LRSM for the next chapter that could lead to a more strong conclusion.

7.5 Chapter 6

In **chapter 6** we have studied the possibility of texture zeros in lepton mass matrices of the minimal left-right symmetric model where light neutrino mass arises from a combination of type I and type II seesaw mechanism. Considering the allowed texture zeros in light neutrino mass matrix, we list out all possible texture zero possibilities in Dirac and heavy neutrino mass matrices which play a role in type I and type II seesaw mechanism. After making this exhaustive list in table 6.1, we consider, for our numerical studies, the possibility with a maximum allowed zeros in M_ν, M_D and M_{RR} while keeping the rank of the latter three. After finding the allowed parameter space for two zero textures in light neutrino mass matrix M_ν, we then evaluate the elements of M_D, M_{RR} by choosing an optimistic $M_{W_R} = 4.5$ TeV while keeping the right-handed neutrino masses above 1 GeV. We then evaluate the contributions to NDBD half-life as well as CLFV decays $\mu \to e\gamma, \mu \to 3e$ and constrain the texture zero mass matrices from the relevant experimental bounds. It is seen that out of all the cases considered with 5-0 M_D and $4-0$ M_{RR}, only A1 (NO), B1 (NO/IO), B2 (NO), B3 (NO/IO), B4 (NO) are allowed from both NDBD and CLFV constraints while the others are disallowed by at least one of the constraints. We further show the allowed cases pointing out the individual contributions to NDBD and total contributions to CLFV which can saturate the current experimental upper bound, keeping them sensitive to ongoing and future experiments. It is interesting to note that even for the most conservative lower bound on left-right symmetry scale that is $M_{W_R} = 4.5$ TeV from collider experiment, the complementary bounds from rare decay experiments can rule out several texture possibilities while keeping the allowed ones sensitive to upcoming experiments. We performed our study from a phenomenological point of view keeping the framework as minimal as the minimal LRSM. We leave a more detailed study of these interesting texture zero scenarios within additional flavour symmetry for an upcoming work.

7.6 Future Prospects

The works implemented in this thesis can be further extended taking into account the left-right symmetric model (LRSM) with some additional symmetries and see the consequences in neutrino sector as well in cosmology like dark matter or the baryon asymmetry of the universe. We can further study the phenomenological implications on neutrinoless double beta decay, lepton flavor violation and the constraints on the scale of the new physics. TeV scale LRSM can have many interesting implications in collider phenomenology which can be further explored. Furthermore, LRSM with discrete non-abelian groups like A4 and its phenomenological consequences in type I as well as type II seesaw can be studied in more details which we have left for future works.