Effects of Variations of SUSY Breaking Scale on Neutrino Parameters At Low Scale Under Radiative Corrections

Khumanthem Helensana Devi[1] , K. Sashikanta Singh [2] , N.Nimai Singh[3]
Department of Physics , Manipur University,
Imphal, 795003, India

Abstract:- **Radiative stability of neutrino parameters for inverted hierarchy is studied using renormalisation group analysis for different seesaw scales and varying susy breasking scale. We adopt the top-down approach starting from the grand unified scale which leads to the electroweak scale values of the neutrino parameters. We proposed the possibility of a Self-Complementary relation among three mixing angles, $\theta_{23} \approx \theta_{13} + \theta_{12}$, and also its radiative evolution under the same framework.**

Keywords— IH , SS scale, m_s scale, RGE, neutrino parameters

1. INTRODUCTION

Neutrino is evident when considering the fact that neutrino masses require physics beyond the standard theory . Till date we do not have a clear picture of such new physics and its energy scale. Hence we need more studies regarding these. The phenomenology of SUSY [1] is to a large extent determined by the SUSY breaking mechanism and the SUSY breaking scale (m_s) which determined the SUSY particle masses , the field contents of physical particles , the mass hierarchy and their particle contents.

Supersymmetry (SUSY) is a transformation relating fermions to bosons and vice-versa. It ensures the stability of hierarchy between the weak and Planck scales. It can provide a natural mechanism for understanding electroweak symmetry breaking (EWSB)[2] and Higgs Physics . SUSY at TeV scale is not a necessary consequence but is motivated by the possible cancellation of quadratic divergences [3] in radiative correction to the Higgs boson mass. Minimal Supersymmetric Standard Model (MSSM)[4] is a straight-forward symmetrization of the SM with minimal number of new parameters . Due to lack of evidence for superpartners in Large Hadron Collider [1, 5] simplest SUSY scenarios is forced towards region of parameter space unnatured for the Higgs sector. Supersymmetric particles are ruled out upto 2.4TeV (Gluinos)[3]. The discovery of Higgs boson with a mass around 125 GeV imposes constraints on SUSY models[6]. LHC has reached almost its
maximum energy of about 14TeV.

The tightest 95 % confidence level upper bound [7] for sum of neutrino masses , Σm_ν is $\Sigma m_\nu < 0.146$ eV (NH) , $\Sigma m_\nu < 0.172$ eV (IH) and $\Sigma m_\nu <$ 0.121 eV (degenerate) . Running of RGE [9, 10, 11] can be divided into two regions governed by different RG eqns as:

(a)from Λ_{GUT} down to the seesaw scale

(b)from seesaw scale down to Λ_{EW} .

From Model building point of view , we can observe that neutrino oscillation experiments hint not only for neutrino masses but the study of individual parameters and how they evolve carry physical insight.

In his paper, section 2 includes inputs of top-down approach . Section 3 includes tables and graphs. Section 4 includes results and analysis.

2. INPUTS FOR TOP DOWN APPROACH

In this paper, we try to confine SUSY and m_s scales . We used values of yukawa and guage couplings as initial inputs by studying the radiative evolution of the three gauge, yukawa and Higgs couplings using bottom-up approach with the change of m_s scale which is not mentioned here . Using all necessary mathematical frameworks, we analyzed the radiative nature of neutrino parameters using top-down approach. We proposed a phenomenological motivated relation known as Self Complementarity relation (SC) , $\theta_{23}=q(\theta_{13} + \theta_{12})$, q=1.1. It is like QLC relation which connects the quark and lepton sectors. It bears signature of certain hidden symmetry. In order to check the stability of SC relation against radiative evolution we have to vary SS and ms scales.

3. Tables and graphs

Input parameters	GUT scale 10^{16} GeV	Seesaw Scale (tan 40) 10^{15} GeV	10^{14} GeV	10^{13}GeV
m_1 (eV)	0.0512	0.0517	0.0508	0.0502
m_2 (eV)	0.0513	0.0518	0.0509	0.0503
m_3 (eV)	0	0	0	0
θ_{12} /^{0}	33.77	33.55	33.20	33.95
θ_{13} /^{0}	8.32	8. 40	8.44	8.22
ψ	180	180	180	180
δ	240	240	240	240

Table 1 : Input set for IH case (m_3=0) at tan40. θ_{23} is used from SC relation

m_s scale (TeV)	Δm^2_{31} (10^{-3} eV^2)	Δm^2_{21} (10^{-5} eV^2)	θ_{13} ($/^0$)	θ_{12} ($/^0$)	θ_{23} ($/^0$)	δ ($/^0$)
2	2.526	5.875	8.40	33.59	46.21	240.00
4	2.501	6.452	8.40	33.60	46.23	240.00
6	2.482	6.914	8.40	33.60	46.24	240.00
8	2.473	7.111	8.40	33.61	46.25	240.00
10	2.464	7.300	8.40	33.61	46.25	240.00
12	2.454	7.555	8.40	33.61	46.26	240.00
14	2.451	7.634	8.40	33.61	46.26	240.00

Table 2 : Variation of neutrino parameters on changing m_s for IH case (m_3=0) at SS scale of 10^{15} GeV for tan40 .

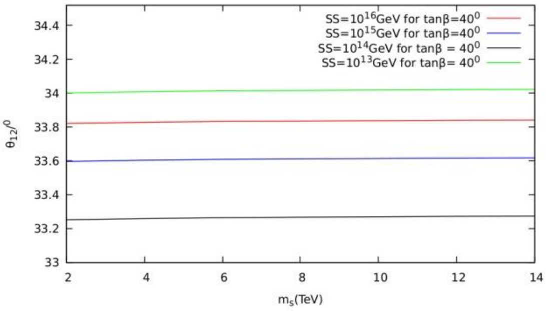

Fig1. Variation of θ_{12} with increasing m_s scale at tan40.

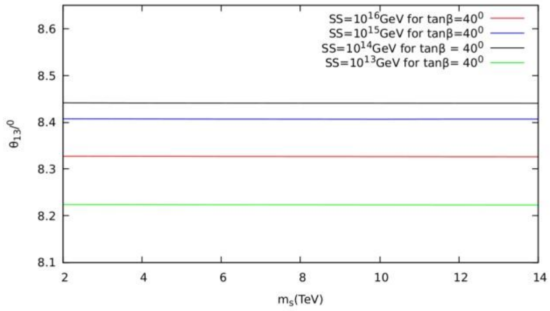

Fig2. Variation of θ_{13} with increasing m_s scale at tan40.

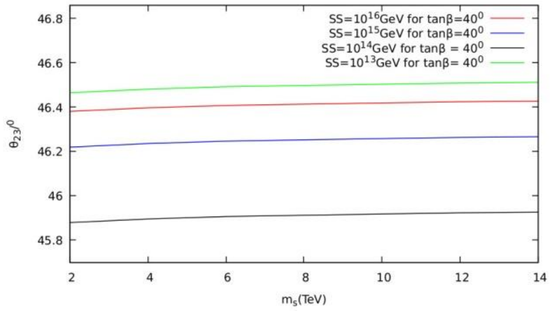

Fig3. Variation of θ_{23} with increasing m_s scale at tan40.

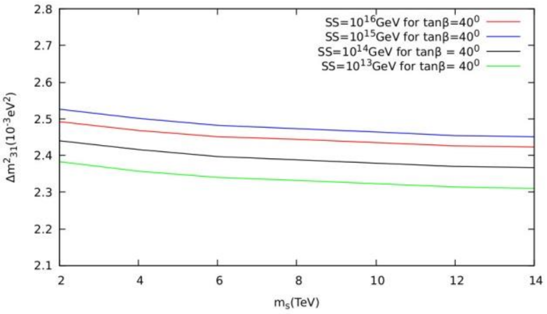

Fig4. Variation of Δm^2_{31} with increasing m_s scale at tan40.

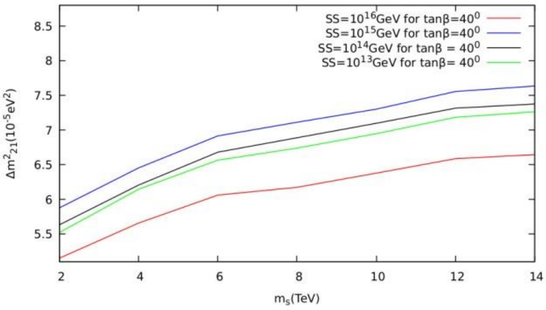

Fig5. Variation of Δm^2_{21} with increasing m_s scale at tan40.

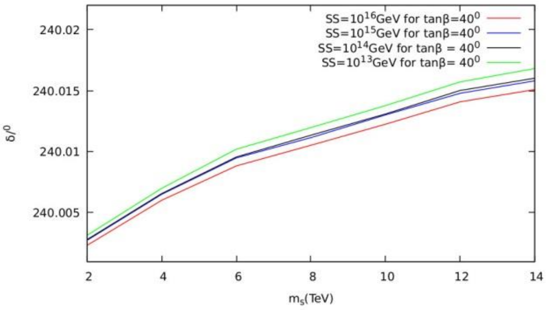

Fig6. Variation of δ with increasing m_s scale at tan40.

4. RESULT AND ANALYSIS

In this work, stability of neutrino parameters for inverted hierarchy case(m_3 = 0) is studied on changing m_s scale for different SS scale at tan 40 using top-down approach. With increasing m_s scale , Δm^2_{31} decreases while other neutrino parameters increases except θ_{13} which is stable throughout . We observed from the output data that neutrino parameters were affected on changing m_s scale from 2TeV to 14TeV with SS scale of values between 10^{13} GeV to 10^{15} GeV. Higher m_s scales (12 TeV and 14 TeV) are preferred . SS scale of 10^{15} GeV is preferred among other SS scales . Outputs of neutrino parameters are within 2σ range. SC relation is invariant against radiative evolution.

The evolutions of the leptonic mixing angles are insignificant because of small Yukawa couplings of charged leptons in the SM.

REFERENCES

[1] H. Menjo et al., “Status and Prospects of the LHCf and RHICf experiments,” PoS, vol. ICRC2021, p. 301, 2021.

[2] S. Dawson, “Introduction to electroweak symmetry breaking,” 1999.

[3] G. Aad et al., “Search for R-parity-violating supersymmetry in a final state containing leptons and many jets with the ATLAS experiment √s = 13TeV proton–proton collision data,” Eur. Phys. J. C, vol. 81, no. 11, p. 1023, 2021.

[4] M. A. Daz, M. A. Rivera, and N. Rojas, “On neutrino masses in the mssm with brpv,” Nuclear Physics B, vol. 887, p. 338357, Oct 2014.

[5] S. C. İnan and A. V. Kisselev, “Search for noncommutative interactions in γγ → γγ process at the LHC,” 3 2022.

[6] A. Tumasyan et al., “Search for higgsinos decaying to two Higgs bosons and missing transverse momentum in proton-proton collisions at √s = 13TeV eV ,” 1 2022.

[7] A. Loureiro, A. Cuceu, F. B. Abdalla, B. Moraes, L.Whiteway, M. McLeod, S. T. Balan, O. Lahav, A. Benoit-Lévy, M. Manera, R. P.Rollins, and H. S. Xavier, “Upper bound of neutrino masses from combined cosmological observations and particle physics experiments,”Phys. Rev. Lett., vol. 123, p. 081301, Aug 2019.

[8] S. Antusch, J. Kersten, M. Lindner, and M. Ratz, “Running neutrinomasses, mixings and CP phases: Analytical results and phenomenological consequences,” Nucl. Phys., vol. B674, pp. 401–433, 2003.

[9] V. Barger, M. S. Berger, and P. Ohmann, “Supersymmetric grand unified theories: Two-loop evolution of gauge and yukawa couplings,” Phys.Rev. D, vol. 47, pp. 1093–1113, Feb 1993.

[10] K. S. Singh, S. Roy, and N. N. Singh, “Stability of neutrino parametersand self-complementarity relation with varying SUSY breaking scale,”Phys. Rev. D, vol. 97, no. 5, p. 055038, 2018.

[11] R. N. Mohapatra, S. Antusch, K. S. Babu, G. Barenboim, M.-C. Chen,A. de Gouva, P. de Holanda, B. Dutta, Y. Grossman, A. Joshipura, andet al., “Theory of neutrinos: a white paper,” Reports on Progress in Physics, vol. 70, p. 17571867, Oct 2007.

[12] P. F. de Salas, D. V. Forero, S. Gariazzo, P. Martnez-Mirav, O. Mena, C. A. Ternes, M. Trtola, and J. W. F. Valle, “2020 global reassessment of the neutrino oscillation picture,” Journal of High Energy Physics, vol. 2021, Feb 2021.

[13] N. K. Francis and N. N. Singh, “Quasi-degenerate neutrino masses with normal and inverted hierarchy,” Journal of Modern Physics, vol. 02,no. 11, p. 12801284, 2011.