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Planck scale effect in a supersymmetric E_6 model

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Abstract. We propose a Supersymmetric E_6 model with intermediate Left-right symmetry as a result of spontaneous compactification of E_8 theory in a ten dimensional space. We show that much lower value of Left-right symmetry breaking scale and consistent unification scale can be achieved by gravity induced correction mediated by spontaneous compactification of higher dimensions at the Planck scale. In the model we could successfully lower the intermediate Left-right symmetry breaking scale M_R up to 10^4 GeV. With such a lower value of M_R, we can easily accommodate low scale leptogenesis specifically the resonant leptogenesis in tune with gravitino constraint. The model can also predict desired value of neutrino mass that can be tested at LHC.

Keywords: Exceptional groups, Renormalization group equation, Supersymmetry.

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1. Introduction

The Exceptional group E_6 [1] offers a best challenge of unification with several desirable features like, a natural anomaly-free choice for a Grand Unification Theory (GUT), and presence of a single representation {27} covering the matter and Higgs sectors. The fundamental representation allows an entire generation of standard model fermions, a right handed neutrino and two Higgs doublet.The model based on E_6 also keeps most of the nice features of the well known GUT groups like SU(5), SU(6) and SO(10). Further its Super-symmetric (SUSY) version is inspired by ten dimensional $E_8 \otimes E'_8$ string theory [2], which is a paramount candidate for the unification of all fundamental gauge interactions including gravity. Since compactification of this $E_8 \otimes E'_8$ string theory on a Calabi–Yau manifold with an SU(3) holonomy results in the breaking of E_8 to E_6, it inspires the current interests in E_6 GUT and to examine the spontaneous compactification effect in the model. It is needless to mention that E_6 is the only exceptional Lie group that has complex representations and therefore the only exceptional group that can be used as a GUT in effective four dimensions. In the present paper, we shall investigate the spontaneous compactification effect in a supersymmetric E_6 gauge model as it is the most viable candidate in the effective four dimension. It has been shown by many authors that presence of non-renormalisable five dimensional operators, originating from compactification of extra dimension, can modify the usual prediction of GUTs in case of SU(5) [3] and SO(10) [4] and E_6 models [5]. In the present case, we show that a low scale Left-right symmetry breaking scale can be obtained through this non-renormalisable operators induced by gravitational correction. This observation can then be correlated with the well-known cosmological problem of matter-antimatter asymmetry through the possibility of Leptogenesis [6] consistent with the gravitino constraint [7]. In tune with the above requirements, the present paper, with low Left-right symmetry breaking scale, can have a nice phenomenological implication. The paper is organized as follows. In the next section, we discuss the model along with the pattern of symmetry breaking. Section–III is devoted to obtain the mass scales at different stages through the Renormalization Group calculations including one-loop beta function and gravity induced correction. We shall then conclude in the last section with a remark on the possibility of a light neutrino.

2. The Model

In the present model, we take an E_6 gauge theory coupled with N = 1 SUSY in four dimension. This E_6 gauge model may be viewed as a remnant of supersymmetric E_8 group in a ten dimensional theory with compact six dimensional coset space ($G_2/SU(3)$). It has been shown in [8] that, as a result of Coset Space Dimensional Reduction one can obtain a E_6 model with Higgs $\{27+\overline{27}+650\}$. We may note here that, in the conventional superstring inspired E_6 models, the Higgs sector is confined to only $27+\overline{27}$. In the present case, the additional Higgs belonging to {650} representation of E_6 allows non-renormalisable five dimensional operators $F_{\mu\nu}\phi_{\langle 650\rangle}F^{\mu\nu}$ that can induce gravitational correction for the gauge couplings, which can drastically modify the usual GUT predictions. This operator may be an effect of quantum gravity at the Planck scale.

We now consider the symmetry breaking pattern from E_6 to low energy as given by,

$$\boldsymbol{E_6 \otimes SUSY}$$
$$\xrightarrow{M_U} \boldsymbol{SU(2)_L \otimes SU(2)_R \otimes SU(3)_C \otimes U(1)_{B-L} \otimes U(1)_\Psi (G_{22311}) \otimes SUSY}$$
$$\xrightarrow{M_R} \boldsymbol{SU(2)_L \otimes SU(3)_C \otimes U(1)_y \otimes U(1)_\chi\ (G_{2311}) \otimes SUSY}$$
$$\xrightarrow{M_\chi} \boldsymbol{SU(2)_L \otimes SU(3)_C \otimes U(1)_y\ (G_{231}) \otimes SUSY}$$
$$\xrightarrow{M_S = M_Z} \boldsymbol{SU(3)_C \otimes U(1)_Q (G_{31})} \quad (1)$$

In the above breaking channel, the exceptional gauge group E_6 is broken to the Left–right symmetric group extended by an additional U(1), i.e. $SU(2)_L \otimes SU(2)_R \otimes SU(3)_C \otimes U(1)_{B-L} \otimes U(1)_\Psi$ (G_{22311}) by the vacuum expectation value (VeV) of $(1,1,15)_0(G_{2241}) \subset 210_0$ ($SO(10) \otimes U(1)_\Psi) \subset 650$ of E_6 near the GUT scale M_U. In the next step the $SU(2)_R \otimes U(1)_\Psi \otimes U(1)_{B-L}$ symmetry is spontaneously broken to $U(1)_y \otimes U(1)_\chi$ symmetry at the M_R scale, by the VeV of $(1,2,1)_{-1/2,1/2} + (1,2,1)_{1/2,-1/2}$ (G_{22311}) $\subset 16_{1/2} + \overline{16}_{-1/2}$ ($SO(10) \otimes U(1)_\Psi$) $\subset 27 + \overline{27}$ representation of E_6. Here, $Y = T_R^3 + \frac{B-L}{2}$ is the standard hypercharge. The other U(1) charge is orthogonal to $U(1)_y$ and its quantum number is given by [9],

$$\chi = T_\Psi + T_R^3 - C_{12}^2 Y \quad (2)$$

Here, T_Ψ and T_R^3 are the generators for $U(1)_\Psi$ and $SU(2)_R$ respectively and C_{12}^2 depends on the couplings for $SU(2)_R$ and $U(1)_{B-L}$ at the M_R scale. Thus unlike the conventional U(1) charge, this $U(1)_\chi$ is model dependant. This $U(1)_\chi$ symmetry is broken spontaneously at M_χ close to TeV scale by the G_{22311} multiplet $(1,1,1)_{0,2}$ contained in the {27} representation. This may provide a heavy neutral Z-boson along with the conventional Z-boson. Finally the electro-weak symmetry breaking is achieved by the VeV of the bi-doublet $(2,2,1)_{-1}(G_{2241}) \subset 10_{-1}$ ($G_{10,1}$) $\subset$ 27, at (M_Z). For simplicity, we consider that the Supersymmetry scale (M_{SUSY}) lies at the electroweak symmetry breaking scale (M_Z).

We now include the non-renormalizable d=5 operator to the conventional Lagrangian and then study the modifications induced by the operator. The total gauge Lagrangian is given by,

$$\mathcal{L} = \mathcal{L}_{NR} + \mathcal{L}_R,$$

$$\text{where, } \mathcal{L}_{NR} = -\frac{\eta}{4M_G} Tr(F_{\mu\nu}\phi_{\langle 650\rangle}F^{\mu\nu}),\ \mathcal{L}_R = \frac{1}{4} Tr\, F_{\mu\nu}F^{\mu\nu} \tag{3}$$

Here η is a dimensionless parameter, M_G is the compactification scale close to the Planck scale, $\phi_{\langle 650\rangle}$ is the Higgs belonging to {650} of E_6, $F_{\mu\nu}$ is the E_6 gauge field strength, which contains the coupling constants g_i's. Now in order to break E_6 to left-right symmetric G_{22311}, we take the VeV of $(1,1,15)_0$ (in the G_{2241} space) $\subset 210_0$ of $SO(10) \subset 650$ multiplet [10], as has been mentioned before. The vacuum expectation value is given as,

$$\langle\phi_{\langle 650\rangle}\rangle = \frac{\phi_0}{\sqrt{29/3}} diag\{-\frac{3}{2}, -\frac{3}{2}, -\frac{3}{2}, -\frac{3}{2}, 1,1,1,4,-1, \underbrace{0 \ldots 0}_{18}\} \tag{4}$$

Using this normalized VeV in (3), the total Lagrangian can be decomposed into kinetic energy of the $SU(2)_L, SU(2)_R, SU(3)_C, U(1)_{B-L}, U(1)_\Psi$ gauge fields. i.e.

$$\mathcal{L} = -\left(\frac{1}{4}\right)[(1+\epsilon_{2L})Tr(F_{\mu\nu}{}^{2L}F^{\mu\gamma\, 2L}) + (1+\epsilon_{2R})Tr(F_{\mu\nu}{}^{2R}F^{\mu\gamma\, 2R}) + (1+\epsilon_{3C})Tr(F_{\mu\nu}{}^{3C}F^{\mu\gamma\, 3C}) + (1+\epsilon_{B-L})Tr(F_{\mu\nu}{}^{B-L}F^{\mu\gamma\, B-L}) + (1+\epsilon_\psi)Tr(F_{\mu\nu}{}^{\Psi}F^{\mu\gamma\, \Psi})]\ ) \tag{5}$$

Here the parameters ϵ_i, with i= 2L, 2R, 3C, $U(1)_{B-L}$, $U(1)_\Psi$, are related to the non-renormalizable E_6 lagrangian ($\mathcal{L}_{NR}$) through the non vanishing VEV of {650} in (4), given by,

$$\epsilon_{2L} = \epsilon_{2R} = -\left(\frac{3}{2}\right)\epsilon;\ \epsilon_{3c} = \epsilon;\ \epsilon_{B-L} = 4\epsilon;\ \epsilon_\psi = -\epsilon \text{, with } \epsilon = \sqrt{\frac{3}{29}}\frac{\eta\phi_0}{M_G} \tag{6}$$

Thus the gauge coupling constants at the unification point get modified. At the unification scale M_U, the GUT boundary condition is expressed as

$$\alpha_{2L}(M_U)(1+\epsilon_{2L}) = \alpha_{2R}(M_U)(1+\epsilon_{2R}) = \alpha_{3C}(M_U)(1+\epsilon_{3C}) = \alpha_{B-L}(M_U)(1+\epsilon_{B-L}) = \alpha_\Psi(M_U)(1+\epsilon_\Psi) = \alpha_G \tag{7}$$

Where $\alpha_i = (g_i^2/4\pi)$ with i = 2L, 2R, 3C, $U(1)_{B-L}$, $U(1)_\Psi$ and $\alpha_G = (g_0^2/4\pi)$, g_0 being the gauge coupling at the unification scale. These boundary conditions lead to the corresponding gravitational corrections for the four gauge couplings. In the next section, we show that a low intermediate scale can be achieved through this gravity induced gauge coupling corrections.

3. Renormalization group equations:

We now discuss the Renormalization Group equations including one-loop beta function contributions, to calculate the corresponding mass scales at different stages of the breaking channel-(1). In the minimal super symmetric model it has been observed that, the inter mediate scale M_R is very close to the Grand Unification scale M_U ~10^{16} GeV, at the one-loop level, which is inconsistent with the accommodation of leptogenesis in the model. In the present case, we show that the result can be modified and consistent with leptogenesis if d=5 operators are taken into account. The effect of gravity induced correction will be visible through renormalization group equation from M_R to M_U.

We now write down the Renormalization Group (R.G.) equations at different mass scales involved in the symmetry breaking channel (1). Between the mass scales M_Z and $M\chi$ the R.G. equations run as,

$$\alpha_i^{-1}(M_Z) = \alpha_i^{-1}(M\chi)+ \frac{bi}{2\pi}\{\ln(M_\chi/M_Z)\},\ i= 3c,2L,Y \quad (8)$$

Since supersymmetry is being preserved between the mass scales M_Z and M_χ, the one loop beta function values b_i s for SU(N), are given by

$$b_i = -3N + 2N_g + \Sigma\, Ti, \text{ (for i=SU(3)}_C\text{, SU(2)}_L\text{,U(1)}_y) \quad (9)$$

Here we are confined to three fermion generations, i.e. N_g = 3. Using the Higgs scalars $(2,1)_{\pm 1/2}(G_{231Y}) \subset 10_{-1} \subset 27$ for electro-weak symmetry breaking, the one-loop beta function coefficients , are given as:

$$\begin{pmatrix} b_y \\ b_{2l} \\ b_{3c} \end{pmatrix} = \begin{pmatrix} \frac{33}{5} \\ 1 \\ -3 \end{pmatrix} \quad (10)$$

Using the input values of the Standard Model couplings measured on the Z-pole at LEP as $\alpha_1(M_Z) = 0.016947$, $\alpha_2(M_Z) = 0.033813$ and $\alpha_3(M_Z) = 0.1187$ and $M\chi = 10^3$ GeV, we obtain the values of $\alpha_i^{-1}(M\chi)$. Then at $M\chi$, the $U(1)\chi$ symmetry is broken down spontaneously by the VeV of the singlet $(1,1)_{0,2}$ $(G_{2311}) \subset\{27\}$. Hence between the mass scales $M\chi$ and M_R the R.G. equations run as,

$$\alpha_i^{-1}(M\chi) = \alpha_i^{-1}(M_R)+ \frac{bi}{2\pi}\{\ln(M_R/M_\chi)\},\ i = 3C,2L,Y \text{ and } \chi \quad (11)$$

Thus the one loop beta function values *bi* for i=3C, 2L,Y remain unchanged as given in Eqn. (10). Hence $\alpha_i^{-1}(M_R)$ for i = 3c,2L,Y can be predicted. Here we note that, the value of coupling constant for $U(1)_\chi$ at M_χ ($\alpha_\chi^{-1}(M_\chi)$), is not known. Since $U(1)_\chi$ symmetry is broken at M_χ, its low energy memory at M_Z is lost.

However, the value of α_{χ}^{-1}(M_R) at M_R is dependent on the values of coupling constants of $SU(2)_R$, $U(1)_\Psi$ and $U(1)_{B-L}$, as is evident from (2). Therefore we have to borrow its value from M_R where the above symmetries are broken.

Then in the next stage from M_R to M_U, the effect of gravity becomes visible. Therefore the R.G. equations between the mass scales M_R and M_U, with the boundary condition (7), are written as,

$$\alpha_i^{-1}(M_R) = \alpha_i^{-1}(M_U) + \frac{b_i'}{2\pi}[\ln(M_U/M_R)]+\Delta_i^{gr}, \qquad (12)$$

Here i=2L,2R,3C,$U(1)_{B-L}$,$U(1)_\Psi$ and $\Delta_i^{gr}= \frac{\epsilon_i}{\alpha_G}$, ϵ_i being the parameters inducing gravitational correction. At the mass scale M_R , the left-right symmetry breaking is realized by the VeVs of the right handed doublet $H_R(1,2,1)_{-1/2,1/2}$ and $\overline{H}_R(1,2,1)_{1/2,-1/2}(G_{22311}) \subset 16_{1/2} + \overline{16}_{-1/2}$ (SO(10) $\otimes U(1)_\Psi$) $\subset$ 27+$\overline{27}$. Thus the corresponding beta function coefficients (b_i') between M_R to M_U are given by:

$$\begin{pmatrix} b'_\Psi \\ b'_{B-L} \\ b'_{2L=2R} \\ b'_{3C} \end{pmatrix} = \begin{pmatrix} 23/3 \\ 9 \\ 2 \\ -3 \end{pmatrix} \qquad (13)$$

Thus for a given value of M_R , we can predict $\alpha_i^{-1}(M_U)$ for i=2L,2R,3C,$U(1)_{B-L}$,$U(1)_\Psi$. We now return back to consider the evolution of $U(1)_\chi$ from M_R to M_χ. As per (2), we can write down the coupling α_χ^{-1} at M_R as,

$$\alpha_\chi^{-1} = \frac{1}{N_\chi^2}\left[6\,\alpha_\Psi^{-1} + \frac{1}{(3/2)\alpha_{B-L}+\alpha_{2R}}\right] \qquad (14)$$

Here we have used the corresponding normalizations for $U(1)_\Psi$ as $\sqrt{6}$, for $U(1)_{B-L}$ as $\sqrt{\frac{3}{2}}$ and for $U(1)_\chi$ as $N_\chi = \left(7 - 2C_{12}^2 + \left(\frac{5}{3}\right) C_{12}^4\right)^{1/2}$. Here C_{12} = *Cos* θ_{12}, for θ_{12} is the mixing angle such that, $\tan\theta_{12} = \frac{g_{2R}}{\sqrt{\frac{3}{2}}\, g_{B-L}}$. Between the mass scales M_R and M_χ, the gauge coupling of $U(1)_\chi$ runs down according to the renormalization group equation,

$$\alpha_\chi^{-1}(M_\chi) = \alpha_\chi^{-1}(M_R) + \frac{b_\chi}{2\pi}\{\ln(M_R/M_\chi)\} \qquad (15)$$

b_χ is the beta function value for $U(1)_\chi$. Using (9), it can be given by,

$$b_\chi = 6 + \frac{1}{N_\chi^2}\Sigma\,\chi_i^2 \qquad (16)$$

where χ_i can be calculated by the relation given in (2). Here the second term has the contributions from the bi-doublet $(2,2,1)_{-1}\subset 10_{-1}$ and the singlet $S(1,1,1)_2$ (under G_{2241} space) contained in 27 representation of E_6. The values of χ_i^2, N_χ and b_χ for different M_R scale are noted in the Table 1.

Table 1: Beta function value of $U(1)_\chi$ corresponding to different M_R

M_R(GeV)	C_{12}^2	$\sum\chi_i^2 = \chi_\phi^2 + \chi_S^2$	N_χ^2	b□
10^4	0.3198	8.4626	6.5308	7.2958
10^5	0.3305	8.4481	6.521	7.295
10^6	0.3423	8.4325	6.5106	7.2951
10^7	0.3553	8.4256	6.4998	7.2947
10^8	0.3697	8.3972	6.4884	7.2942
10^9	0.3857	8.3773	6.476	7.2935

Using the standard method, we now do the analytical calculations to calculate the mass scales involved in the model. Using the evolution equations, the boundary condition (7), the combinations $\{e^{-2}(M_Z) - \frac{8}{3} g_3^{-2}(M_Z)\}$, $\{e^{-2}(M_Z) - \frac{8}{3} g_{2L}^{-2}(M_Z)\}$ and the relation: $\{e^{-2}(M_Z) = \frac{5}{3} g_Y^{-2}(M_Z) + g_{2L}^{-2}(M_Z)\}$, we obtain the following expressions for the unification mass scale M_U, the GUT coupling constant $\alpha_G (= g_0^2/4\pi)$ and $\sin^2\Theta_w$

$$\alpha_G^{-1} = \frac{1}{9(2+\epsilon)}\left[3\alpha^{-1}(M_Z) + 10\alpha_S^{-1}(M_Z) - \frac{3}{\pi} ln\left(\frac{M_R}{M_z}\right)\right] \quad (17)$$

$$ln\left(\frac{M_U}{M_Z}\right) = \frac{-1}{9(2+\epsilon)}[\left\{2\pi\left(\frac{8}{3}\alpha_S^{-1}(M_Z) - \alpha^{-1}(M_Z)\right) + 2ln\left(\frac{M_R}{M_z}\right)\right\} - \epsilon\left\{2\pi\left(\frac{1}{3}\alpha_S^{-1}(M_Z) + \alpha^{-1}(M_Z)\right) - 2\ln\left(\frac{M_R}{M_z}\right)\right\}] \quad (18)$$

$$sin^2\theta_w = \frac{-1}{9(2+\epsilon)}\begin{bmatrix}\left\{-5 - \frac{14\alpha(M_z)}{3\alpha_s(M_z)} + \frac{14\alpha(M_z)}{\pi} ln\left(\frac{M_R}{M_z}\right)\right\} \\ +\epsilon\left\{\frac{5}{2} - \frac{43\alpha(M_z)}{3\alpha_s(M_z)} + \frac{2\alpha(M_z)}{\pi} ln\left(\frac{M_R}{M_z}\right)\right\}\end{bmatrix} \quad (19)$$

Here, ϵ_i being the dimensionless parameters as defined in (6) and (7). We have used the experimentally allowed values of $\alpha^{-1} = 4\pi e^{-2}(M_Z)=127.9$ and $\alpha_s = \frac{g_3^2(M_z)}{4\pi} = 0.118$ to obtain $sin^2\theta_w$, $\alpha_G^{-1}$and M_U for given values of M_R. The numerical result is tabulated in Table 2 (without correction i.e. for $\epsilon = 0$) and in Table-3(with correction).

Table 2: Values of $sin^2\theta_w$, M_U and α_G^{-1} for different values of M_R (without gravitational correction, $\epsilon = 0$).

M_R(Gev)	$\sin^2\theta_w$	M_U(Gev)	α_G^{-1}
10^4	0.2858	5.23×10^{17}	25.75
10^5	0.2813	4.05×10^{17}	25.6
10^6	0.2769	3.14×10^{17}	25.5
10^7	0.2724	2.4×10^{17}	25.4
10^8	0.2679	1.88×10^{17}	25.26
10^9	0.2635	1.45×10^{17}	25.1
10^{11}	0.2546	8.7×10^{16}	24.9

Table 3: Values of $sin^2\theta_w$, M_U and α_G^{-1} for different values of M_R and ϵ.

M_R (Gev)	ϵ	$sin^2\theta_w$	M_U (Gev)	$\propto_G^{-1}$
10^4	0.177	0.23122	4.25×10^{19}	23.658
10^5	0.1623	0.231193	2.31×10^{19}	23.706
10^6	0.1475	0.231213	1.25×10^{19}	23.755
10^7	0.133	0.231163	6.77×10^{18}	23.802
10^8	0.1183	0.231189	3.66×10^{18}	23.852
10^9	0.103	0.23141	1.94×10^{18}	23.909

It is observed that, in the absence of gravitational correction, for M_R = 10^4- 10^{11} GeV, the model gives (Table -2) a high value of $sin^2\theta_w$ which is not permissible. Thus the model does not allow low M_R in the absence of gravitational correction. However, for non-vanishing ∈, we can have admissible $sin^2\theta_w$ for low M_R (as given in table-3). When we gradually increase the intermediate mass scale from 10^5 GeV to 10^9 GeV, the required value of gravitational correction (ϵ) goes on decreasing for allowed value of $sin^2\theta_w$.

We can also check the consistency of the result by a graphical analysis. Now using evolution equations (8), (11), (12) and the boundary condition (7), we have plotted the evolution of gauge couplings α_i^{-1}, for i= $SU(3)_C$, $SU(2)_{L=R}$, $U(1)_{B-L}$ and $U(1)_\Psi$ for different values of M_R and ϵ_i (Figure 1,2). Using the input values of the Standard Model couplings measured on the Z-pole at LEP, we have shown the plots for $M_R = 10^4$ and 10^9 GeV. It is observed that, corresponding to a given value of M_R, the running couplings of $SU(3)_C$, $SU(2)_L$, $SU(2)_R$ and $U(1)_{B-L}$ get unified at a very high scale close to the Planck scale $(M_P)\approx 10^{19}$GeV for a single value of ϵ.

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$M_R = 10^4$ GeV, ϵ = 0.177

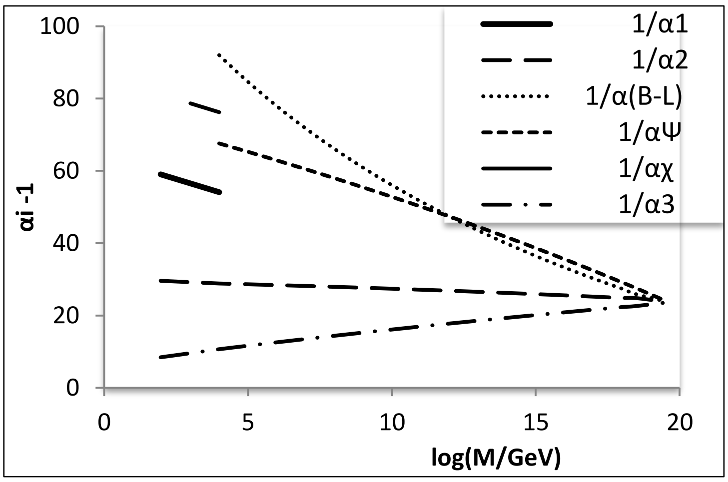

Fig- 1. Gauge coupling evolution

$M_R = 10^9$ GeV, ϵ = 0.103

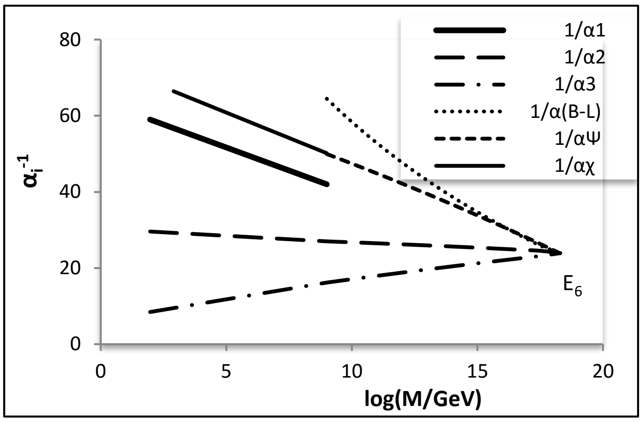

Fig. 2. Gauge coupling evolution

4. Discussion

We have considered a super symmetric E_6 model with intermediate Left-right symmetry. Unlike the conventional string motivated models, the Higgs content of the model includes {27+$\overline{27}$+650}, which is obtained as a result of dimensional reduction of E_8 theory in D=10 dimension. The presence of {650} Higgs triggers gravitational correction via dimension five operators $F^{\alpha\beta} F_{\alpha\beta} \phi$, i.e. $78\otimes78\otimes 650$ in the Lagrangian. This correction allows a low Left-right symmetry breaking scale M_R of the order of 10^4 - 10^9 GeV with the modified unification scale at ~10^{18} Gev. This is also expected, as E_6 may be viewed as remnant of E_8 theory at the Planck scale. For suitable choice of the correction parameter ϵ, the model allows consistent value for electro-weak mixing angle $\sin^2\theta_W$ very close to the permitted value 0.2311 ± 0.000130. It is also noted that, the high unification scale helps to avoid the problem of Higgsino mediated proton decay, which is a generic problem of supersymmetric models. The preferred solutions with naturally larger value of M_U exhibit the virtue of suppression of Higgsino mediated proton decay by a factor of $(M_U^0/M_U)^2 = 10^{-4}$ - 10^{-6}. Further the model can also predict a light left handed neutrino through the double seesaw mechanism [11], with the presence of the singlet $S(1,1,1)_2$. Due to the low energy signature of right-handed gauge bosons ($W_R^{\pm}$ and Z_0) the model can be testable at LHC.

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References

[1] F Gursey and P Sikivie, *Phys. Rev. Lett*. **36**, 775 (1977), *Phys. Rev*. **D 16** 816; F Gursey, P Ramond and P Sikivie *Phys. Lett*. **B 60**, 177 (1975)

[2] P Candelas et al., *Nucl. Phys*. **B 258**, 46(1985); MBGreen, JH Schwarz and E Witten 1987 Superstring Theory (Cambridge University Press, Cambridge, England).

[3] Q Shafi and C Wetterich, *Phys. Rev. Lett*. **52**, 875 (1984); CT Hill *Phys. Lett*. **B47**, 135 (1984); MK Parida, PK Patro and AK Mohanty, *Phys.Rev*. **D39**, 316 (1989); LJ Hall, arxive: hep-ph/9210240; hep-ph/9210235

[4] PK Patra and MK Parida, *Phys. Rev*. **D44**, 2179 (1991) ; MK Parida, *Phys. Rev*. **D 57**, 2736 (1998); MK Parida, B Purkayastha, CR Das and BD Cajee, *Euro. Phys. J*. **C28**, 353 (2003); SK Majee, MK Parida, A Raychaudhuri and A Sarkar, *Phys.Rev*. **D 75**, 075003 (2007)

[5] J Chakrabortty and A Raychaudhuri, *Phys. Rev*. **D 81**, 055004 (2010); J Chakrabortty and A Raychaudhuri, preprint arxiv: 10061252[hep-ph].

[6] M Fukugita and T Yanagida, *Phys. Lett*. **B 174**, 48 (1986); S Davidson and A Ibarra, Phys. Lett. **B 535**, 25 (2002); T Hambye and G Senjanovic *Phys. Lett*. **B 582**, 73 (2004)

[7] GD Ambrosio, et al *Phys. Lett*. **B 604**, 199 (2004); MC Chen *TASI* (2006) Lectures in Leptogenesis, Arxive : Hep-h/0703087V2 (2007).

[8] MY Kholpov and AD Linde, *Phys. Lett*. **B 138**, 265 (1984); JR Ellis, DV Nanopoulos, KA Olive and SJ Ray, *Astropart. Phys*. **4**, 371 (1996); M Kawasaki and T Moroi, *Prog. Theor. Phys*. 93, 879 (1995)

[9] M Koca, *Phys. Lett*. **B 141**, 400 (1984)

[10] R Howl and SF King, *Phys. Lett*. **B652**, 331 (2007); R Howl and SF King *JHEP* **0801**, 030(2008); R Howl, Ph.D. Thesis, University of Southampton and references therein; SF. King, S Moretti and R Nevzorov *Phys. Lett*. **B 650**, 57 (2007); *Phys.Lett*. **B 634**, 278 (2006); *Phys.Rev*. **D73**, 035009 (2006)

[11] F Wang, *Nucl. Phy*. **B 851**, 104 (2011)

[12] R Foot, H Lew, XG He and G C Joshi, *Z. Phys*. **C 44**, 441 (1989)