Vectorlike Particle, Gauge coupling Unification and Higgs Boson Mass

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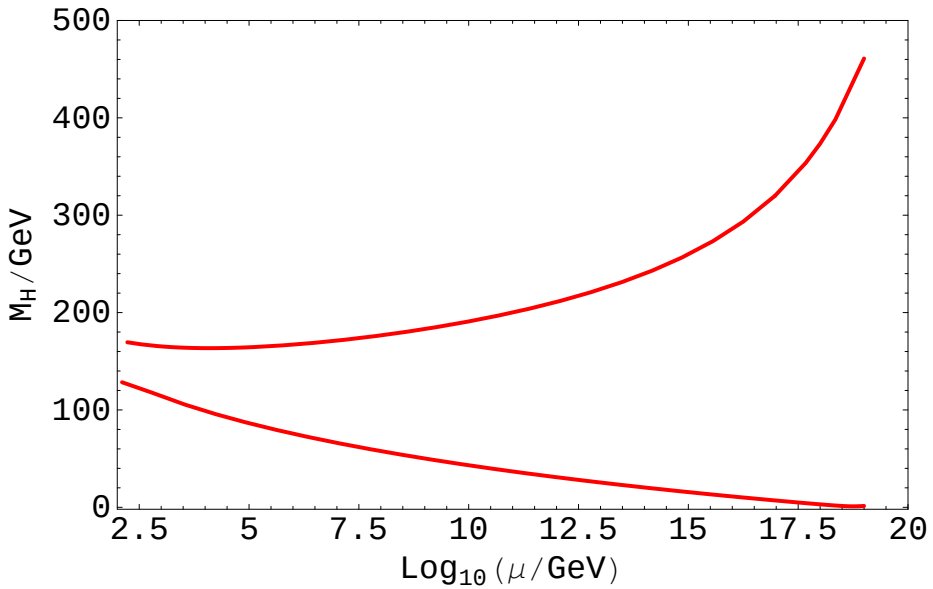
Theoretical bounds on the SM Higgs mass

- $M_H = \sqrt{\lambda}\, \mathrm{V}$
- $\frac{\mathrm{d}}{\mathrm{d}\,\mathrm{t}}\lambda = \frac{1}{16\pi^2}[12\lambda^2 - 12h_t^4 + \ldots]$
- From arguments based on vacuum stability and perturbativity:
  $0.8 \leq \lambda \leq 1.1 \Rightarrow 128\ \mathrm{GeV} \leq M_H \leq 175\ \mathrm{GeV}$

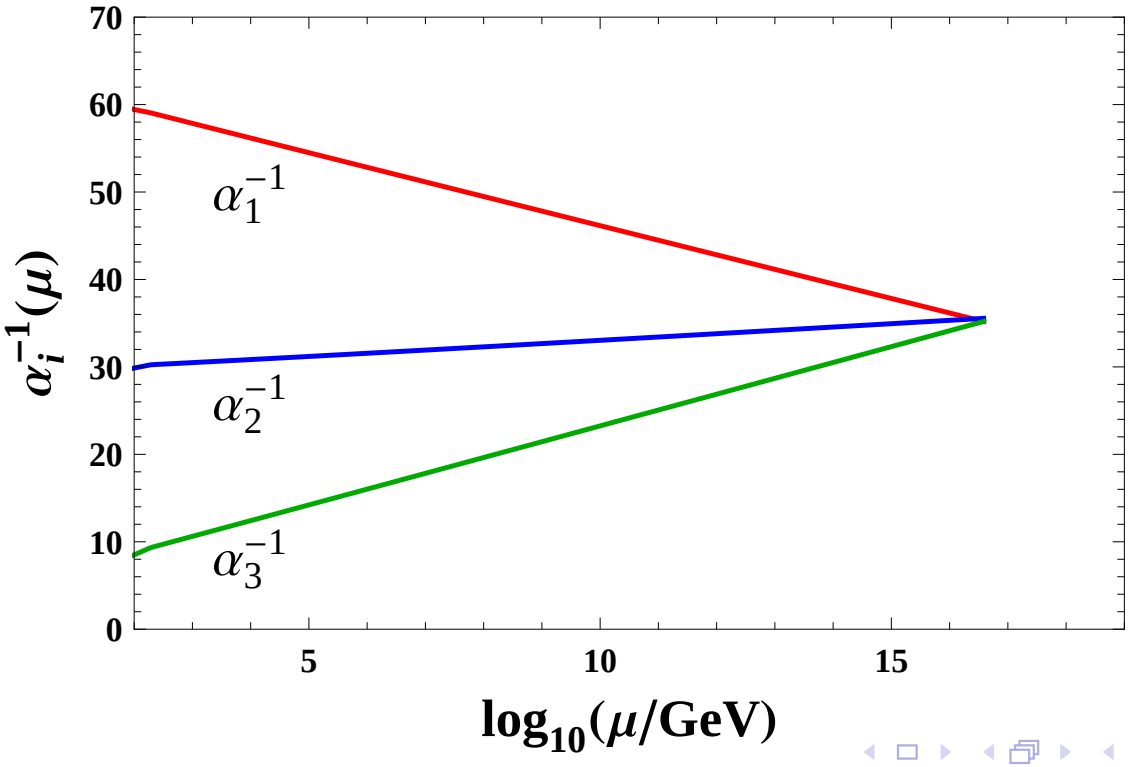


Introducing the following vectorlike fermions the gauge coupling unification can be achieve

$$Q\left(3,2,\tfrac{1}{6}\right)+\overline{Q}\left(\bar{3},2,-\tfrac{1}{6}\right)+D\left(3,1,\tfrac{1}{3}\right)+\overline{D}\left(\bar{3},1,-\tfrac{1}{3}\right)$$

U. Amaldi, W. de Boer, P. H. Frampton, H. Furstenau and J. T. Liu, Phys. Lett. B 281, 374 (1992); J. Chkareuli, I.G., A. Kobakhidze Phys. Lett. B 340 (1994) 63.

For instance when the vectorlike particle mass is $M_{\rm F} \approx 500$ GeV the gauge coupling unification scale is $M_{\rm GUT} \simeq 3 \times 10^{16}$ GeV.



$$Q\left(3,2,\tfrac{1}{6}\right)+\bar{Q}\left(\bar{3},2,-\tfrac{1}{6}\right)+D\left(3,1,\tfrac{1}{3}\right)+\bar{D}\left(\bar{3},1,-\tfrac{1}{3}\right)$$

The SM Lagrangian is supplemented by additiona terms

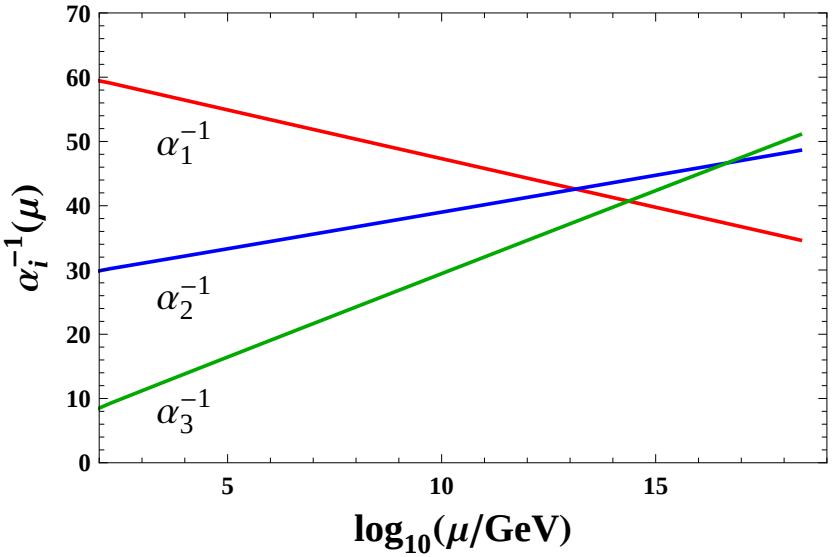
$$\mathcal{L}_{new}=-\kappa_1\bar{Q}\ \bar{D}\ \Phi^c-\kappa_2\ Q\ D\ \Phi-y_1^i\ Q\ d_i^c\ \Phi-y_2^i\ q_i\ D\ \Phi$$
$$-y_3^i\ Q\ u_i^c\ \Phi^c-M_F(\bar{Q}\ Q+\bar{D}\ D)+h.c.$$

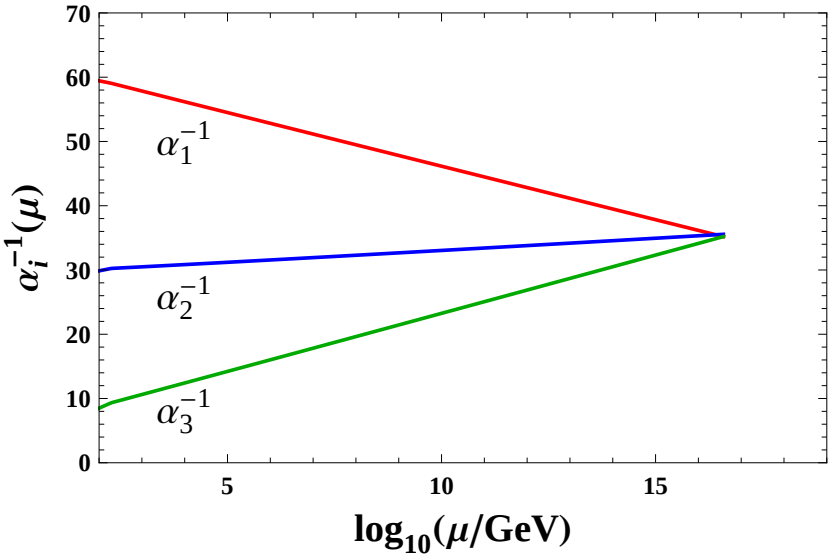
Φ denotes the SM higgs doublet, $\Phi^c\equiv i\sigma_2\Phi^*$, q_i, u_i^c, d_i^c stands for the SM quarks.

- Most of the $y_{1,2,3}^i$ couplings have to be very small due to various experimental constrains.

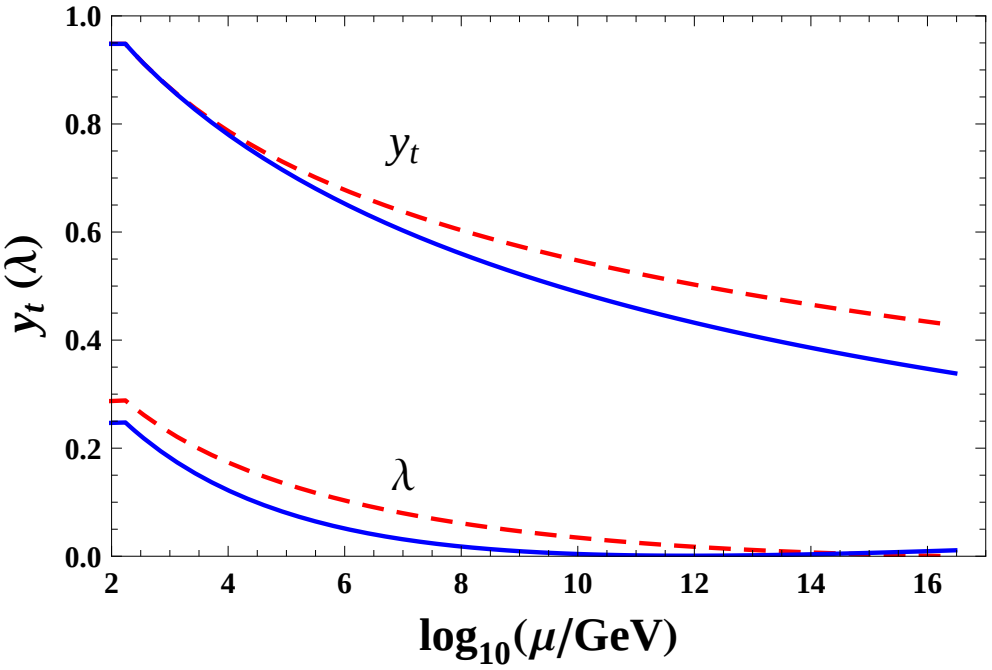
  G. Barenboim, F. J. Botella and O. Vives, Nucl. Phys. B 613, 285 (2001) D. Choudhury, T. M. P. Tait and C. E. M. Wagner, Phys. Rev. D 65, 053002 (2002)

- We consider only $\kappa_{1,2}$ contribution in the RGE.



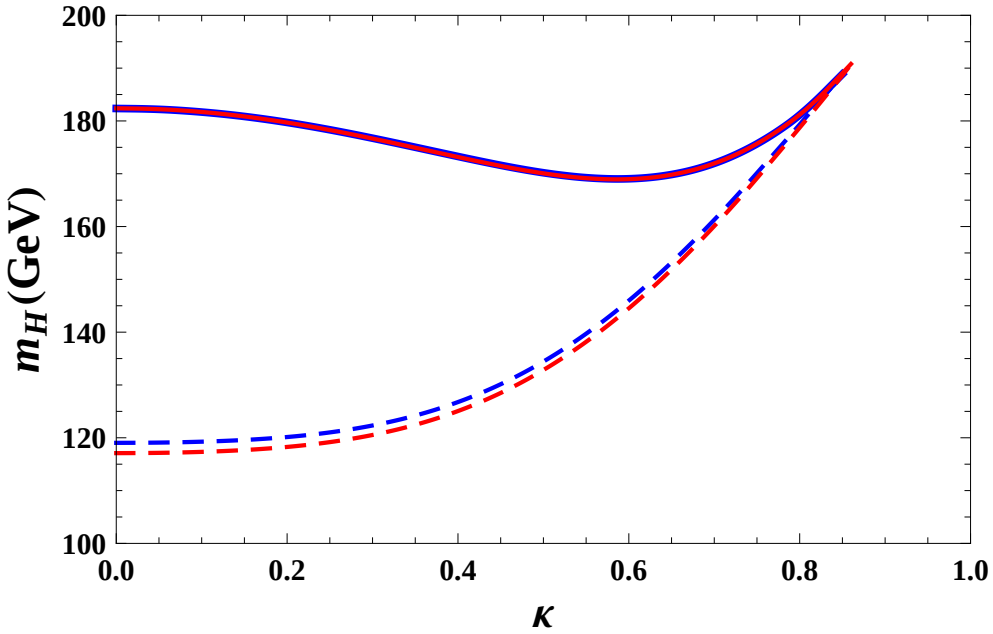


- $\frac{\mathrm{d}}{\mathrm{d}\,t} y_t = \frac{y_t}{16\pi^2}\left[\frac{9}{2} y_t^2 - 8 g_3^2 + \ldots\right]$
- $\frac{\mathrm{d}}{\mathrm{d}\,t} \lambda = \frac{1}{16\pi^2}\left[12\lambda^2 - 12 h_t^4 + \ldots\right]$



We have set $M_{\mathrm{F}} = 500\,GeV$ and $\kappa_i = 0$

- $m_H = 117$ GeV

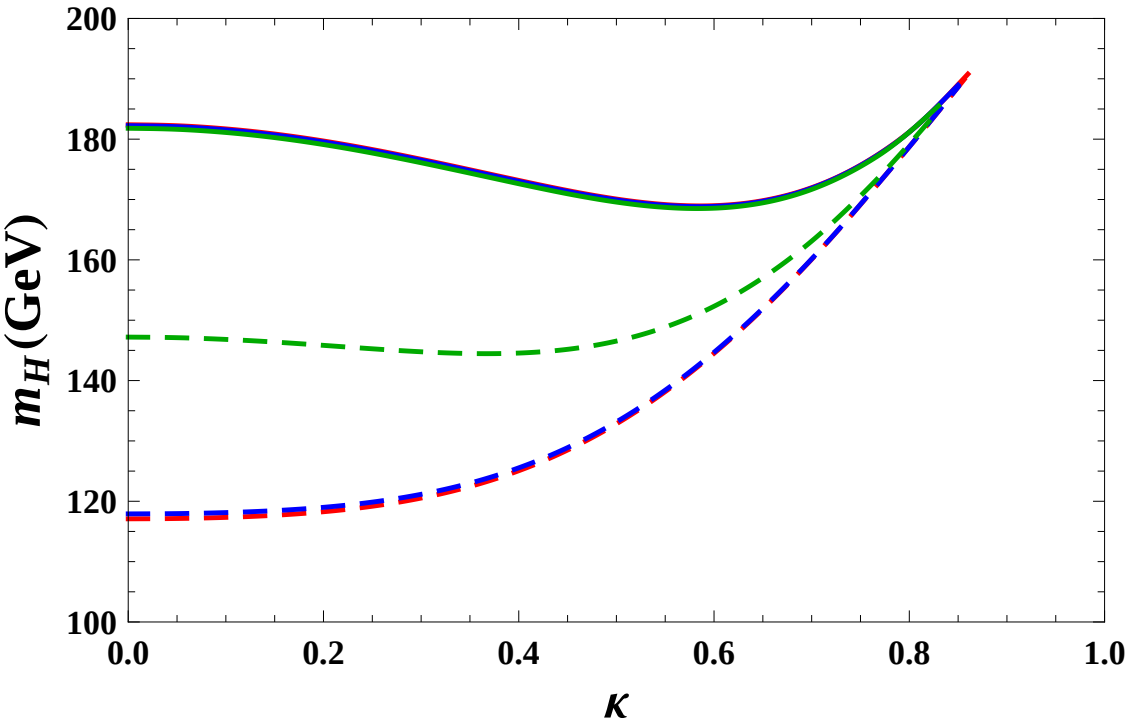


We have set $M_{\rm F} = 500$ GeV red line and $M_{\rm F} = 1$ TeV blue line.

$\kappa \equiv \kappa_1 = \kappa_2$

- $\frac{\rm d}{{\rm d}\,t}\lambda = \frac{1}{16\pi^2}[12\lambda^2 - 12h_t^4 + 12\kappa_i^2\lambda - 12\kappa_i^4 \ldots]$
- $M_{\rm F} = 500$ GeV, $\Rightarrow$ 117 GeV $< m_H <$ 191 GeV
- $M_{\rm F} = 1$TeV, $\Rightarrow$ 119 GeV $< m_H <$ 189 GeV
- The SM case $\Rightarrow$ 128 GeV $< m_H <$ 175 GeV

Type I Seesaw for neutrino and the Higgs Boson Mass



We consider different scales for type I seesaw 10^{13} GeV (red), 10^{14} GeV (blue) and 10^{15} GeV (green)

$$\frac{\mathrm{d}}{\mathrm{d}\,t}\lambda = \frac{1}{16\pi^2}[(\beta_\lambda^{(1)})_{SM} + 12\kappa_i^2\lambda - 12\kappa_i^4 + 4\,\mathrm{tr}[Y_\nu^\dagger Y_\nu]\lambda - 4\,\mathrm{tr}[(Y_\nu^\dagger Y_\nu)^2]]$$

Summary

- This relatively modest extension of the SM, with new vectorlike particles at $M \approx 500$ GeV scale, leads to the SM gauge coupling unification at $M_{\rm GUT} \sim 3 \times 10^{16}$ GeV.
- In this model the SM Higgs boson mass can lie in the following interval: $117 \text{ GeV} < m_H < 191 \text{ GeV}$.
- The new vectorlike fermions should be accessible at the LHC.