Flavour violation in ``minimal'' SUSY SU(5) models

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In preparation.
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``minimal'' SUSY SU(5)

- "minimal" SUSY SU(5)

$\boxed{5_H,\ \bar{5}_H,\ 24_H,}\quad 10_i,\ \bar{5}_i\ ,\ 1_{i'}$ mass

$$W_H = M_5 \bar{5}_H 5_H + \lambda_5 \bar{5}_H 24_H 5_H + M_{24} 24_H^2 + \lambda_{24} 24_H^3$$

$$W_M = Y_{10} 10_i 10_j 5_H + Y_5 \bar{5}_i 10_j \bar{5}_H + \cdots$$

+ possible non-renormalizable terms

~~SU(5)~~ & ~~SM~~ breaking part is unchanged.

Plan

- Introduction
- Problems of GUTs & Solutions
  - Double-Triplet Splitting
  - Fermion Spectra
  - Proton Decay
- Analysis
- Summary

Introduction

- LFV vs. QFV in SUSY-GUTs

LFV ← ν Yukawa

Type I

$$LNH_u$$

F. Borzumati & A. Masiero (1986)

Type II

$$LLT$$
$$\bar{T}H_uH_u$$

A. Rossi (2002)

Introduction

- LFV vs. QFV in SUSY-GUTs

LFV ← ν Yukawa

Dependence

QFV ← ν Yukawa

Type I: LNH_u

Type II: LLT, $\bar{T}H_uH_u$

Grand Unification realistic??

T. Moroi (2000)

- Double-Triplet Splitting
- Fermion Spectra
- Proton Decay

⇨ New Physics above GUT

Introduction

- Type I vs. Type II Seesaw

Type I LFV > QFV Decoupling $\bar{5}_i 1_j 5_H$ "Minimal Ansatz"

$$Y_\nu = U^*_{\rm MNS}\sqrt{\hat{m}_\nu}R\sqrt{\hat{M}_N}$$

~~H_u^C~~

$$D_i^c N_j^c H_u^C + L_i N_j^c H_u$$

$$\tilde{m}_i^2 = \tilde{m}_0^2 \qquad A = A_0 Y$$

$$m_\nu = Y_\nu M_N^{-1} Y_\nu^T v_u^2$$

$L_i N_j^c H_u$

M_Z — $M_{\rm seesaw}$ — $M_{\rm GUT}$ — M_p

Type II LFV $\sim$ QFV $\bar{5}_i \bar{5}_j 15_H$

~~H_u^C~~

$$D_i^c D_j^c S_H \qquad D_i^c L_j Q_H \qquad L_i L_j T_H$$

$$D_i^c D_j^c S_H \qquad D_i^c L_j Q_H \qquad L_i L_j T_H$$

$$\tilde{m}_i^2 = \tilde{m}_0^2 \qquad A = A_0 Y$$

$$m_\nu = Y_\nu \lambda_U v_u^2 / M_T$$

Problems of GUTs & Solutions

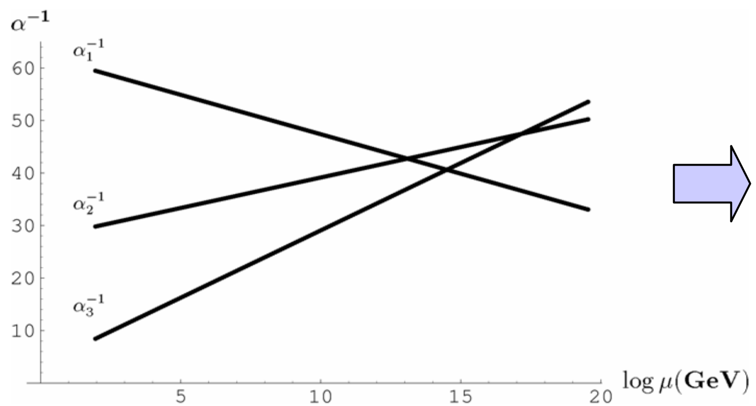
- SUSY-GUT
  - fascinating extension of SM
    - •unifications of forces and of matter
    - •stabilization of the weak scale
  - gauge coupling unification (GCU)

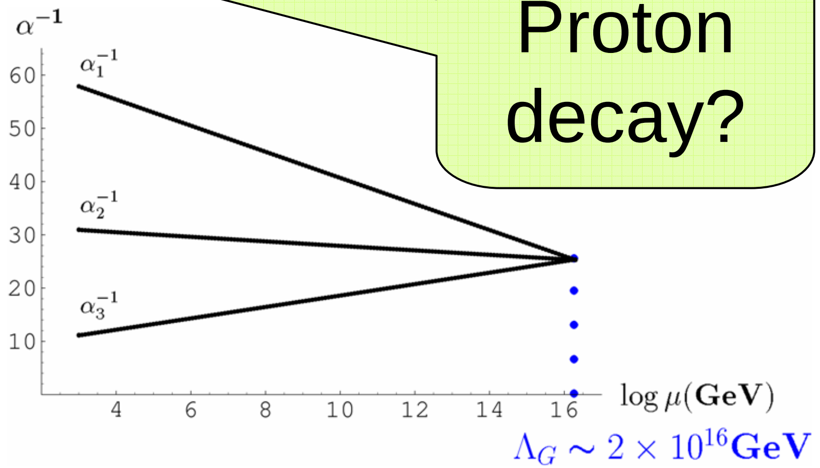
Higgs?

Wrong relation?

~~SUSY~~?

Proton decay?





Problems of GUTs & Solutions

- SUSY-GUT
  - The Hierarchy problem is solved.
  - Gauge Coupling Unification

  But ・・・

  - DT Splitting problem
  - Proton decay (vs. GCU)
  - Fermion Yukawa
  - SUSY flavor problem ⟵ Minimal Ansatz

⇨ LFV ⟷ QFV

Problems of GUTs & Solutions

- DT Splitting problem

$$\bar{5}_H = (H_d^C, H_d)\,, \quad 5_H = (H_u^C, H_u)$$

$$\langle 24_H \rangle = \begin{pmatrix} 2v & 0 \\ 0 & -3v \end{pmatrix}\,, \quad v \sim 10^{16}\mathrm{GeV}$$

$$W_{\mathrm{DT}} = \bar{5}_H\,(M_5 - \lambda_5 24_H)\,5_H$$

$$m_{\mathbf{3}} = m + 2v\ >\ 10^{16}\mathrm{GeV}$$
$$m_{\mathbf{2}} = m - 3v\ \sim\ 10^{2}\mathrm{GeV}$$

← Fine-turning of 10^{14}!!

Problems of GUTs & Solutions

- Solutions for DTS problem
  - In Xtra Dim.
  - Sliding Singlet mechanism
  - Dimopoulos-Wilczek mechanism
  - GIFT mechanism
  - Missing Partner mechanism

4D

SU(5)

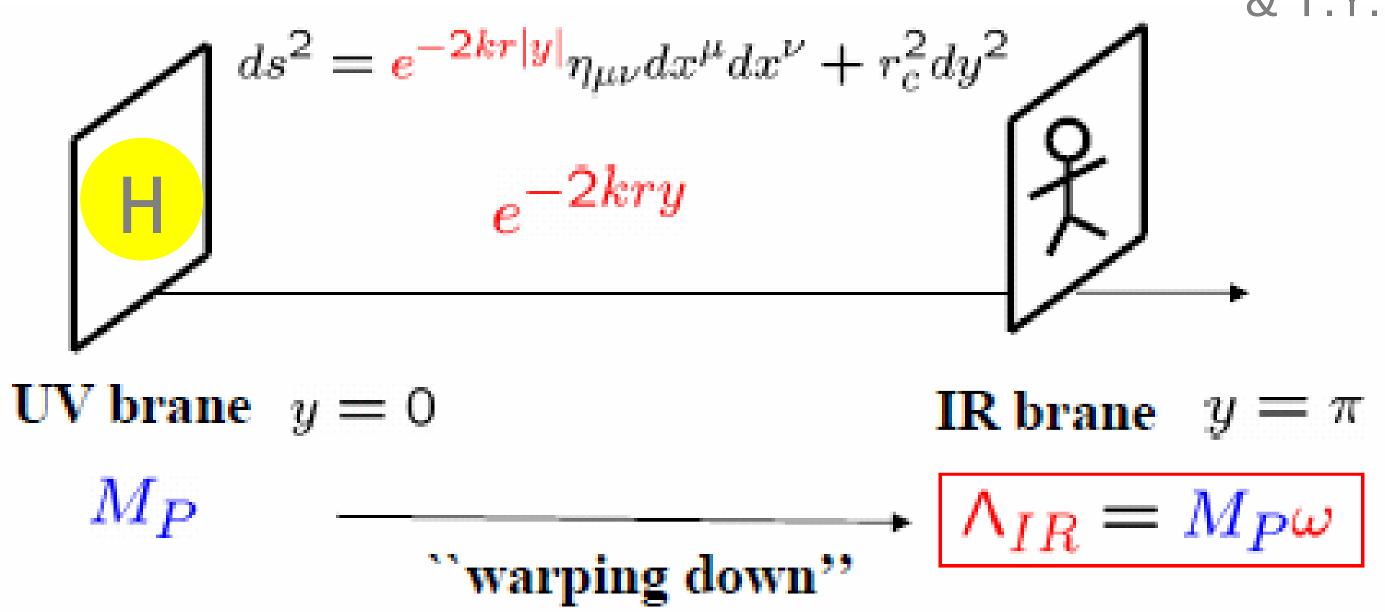
$$\underset{\bar{5}_H}{\begin{pmatrix} \bar{3} \\ \bar{2} \end{pmatrix}} \overset{\langle 75_H \rangle}{\longleftrightarrow} \underset{50_H}{\begin{pmatrix} 3 \\ \text{others} \end{pmatrix}} \begin{matrix} \longleftrightarrow \\ \longleftrightarrow \end{matrix} \underset{\overline{50}_H}{\begin{pmatrix} \bar{3} \\ \text{others} \end{pmatrix}} \overset{\langle 75_H \rangle}{\longleftrightarrow} \underset{5_H}{\begin{pmatrix} 3 \\ 2 \end{pmatrix}}$$

⇨ Non-Perturbative below M_p.

Problems of GUTs & Solutions

- Low Scale Gravity Mediation

H.Itoh, N.Okada & T.Y. (2006)



If Gravity mediation with the Minimal Ansatz.

⇒ Lower cutoff scale $\Lambda_{\rm IR}$!!

Gravitino LSP (SuperWIMP).

Problems of GUTs & Solutions

- Solutions for DTS problem
  - In Xtra Dim.
  - Sliding Singlet mechanism
  - Dimopoulos-Wilczek mechanism
  - GIFT mechanism
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4D

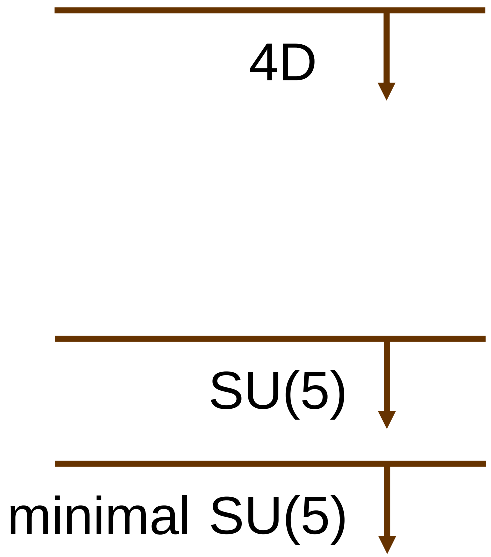
SU(5)

$$\bar{5}_H \begin{pmatrix} \bar{3} \\ \bar{2} \end{pmatrix} \overset{\langle 75_H \rangle}{\longleftrightarrow} 50_H \begin{pmatrix} 3 \\ \text{others} \end{pmatrix} \begin{matrix} \longleftrightarrow \\ \longleftrightarrow \end{matrix} \bar{50}_H \begin{pmatrix} \bar{3} \\ \text{others} \end{pmatrix} \overset{\langle 75_H \rangle}{\longleftrightarrow} 5_H \begin{pmatrix} 3 \\ 2 \end{pmatrix}$$

⇨ Non-Perturbative below M_p.

Problems of GUTs & Solutions

- Solutions for DTS problem
  - In Xtra Dim.
  - Sliding Singlet mechanism
  - Dimopoulos-Wilczek mechanism
  - GIFT mechanism
  - Missing Partner mechanism
  - Fine-tuning



Not natural, but technically natural.

It is true for both μ & B.

Y.Kawamura, H.Murayama & M.Yamaguchi (1995)

Problems of GUTs & Solutions

- Fermion Spectrum

  Wrong GUT relation: $M_d = M_e^T$

  - Non-Renormalizable Operators

    $\kappa\,\bar{5}_i 24_H 10_j \bar{5}_H \xrightarrow{\langle 24_H \rangle}$ GUT breaking

    $\mathcal{O}(M_{\rm GUT}/M_{\rm cutoff})$

    ⇨ Little effects on RGE

    ~~New mixing~~ in Flavor

- Proton Decay

  NRO can suppress only Yukawa of H^C. ⇨ $M_C \sim M_{\rm GUT}$ is allowed.

D.E. Costa & S. Wiesenfelds (2003)

Analysis

- Parameters & Benchmark values
  - We change M_{cutoff} .
  - GUT parameters : $M_{GUT} = M_C = 2 \times 10^{16}$ GeV

    $$\lambda_{24} = 1, \quad \lambda_{15} = 0$$
  - Seesaw parameters :

    Type I : $\hat{M}_N = M_R \mathbf{1}, \quad \mathbf{R} = \mathbf{1}, \quad M_R = 10^{15}\mathrm{GeV}$

    Type II: $M_T = 10^{15}\mathrm{GeV}, \quad \lambda_U = \lambda_D \sim 1$
  - Low energy parameters :

    m_ν : NH, $\sin\theta_{13} = 0, \quad \theta_{\mathrm{Maj}} = 0$
  - ~~SUS~~Y parameters : $\tilde{m}_0^2 = A_0 = M_{1/2} = 1\mathrm{TeV}$

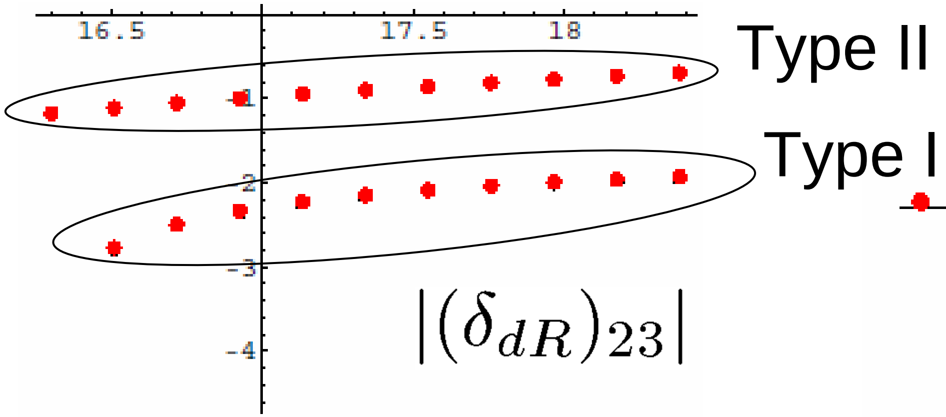
Analysis

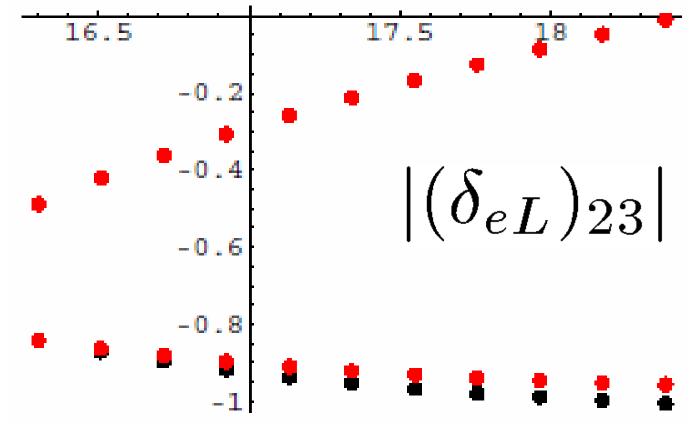
Preliminary.

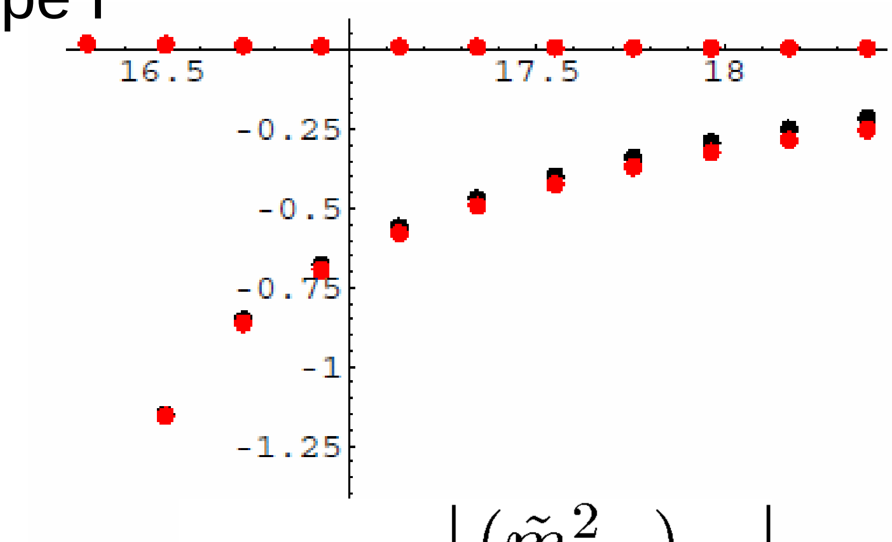
- Results : $M_{seesaw} = 10^{15}$ GeV

● : $\lambda_{24} = 1$

● : $\lambda_{24} = 0.01$





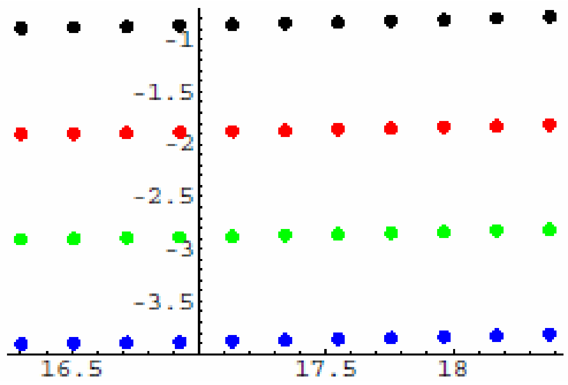


$$|R_{23}| = \left| \frac{(\tilde{m}^2_{dR})_{23}}{(\tilde{m}^2_{eL})_{23}} \right|$$

Analysis

Preliminary.

- Results : M_{seesaw} =10^{12}GeV (Type II)

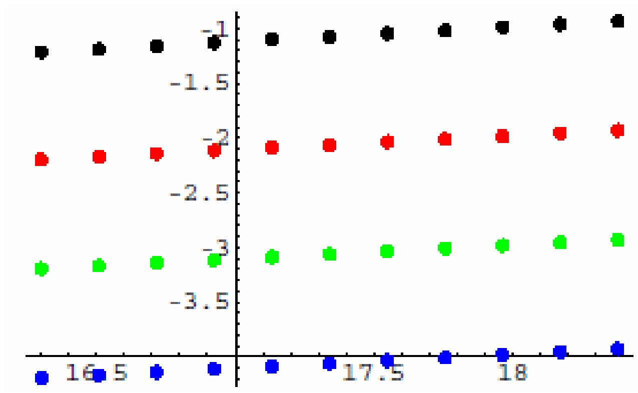


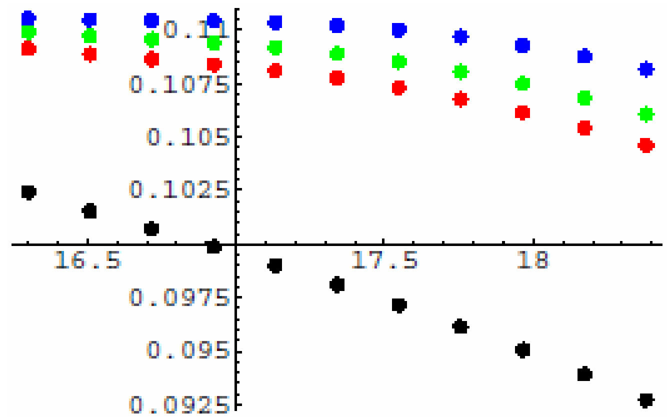
● : $Y_\nu^2 \sim 10^{-1}$

● : $Y_\nu^2 \sim 10^{-2}$

● : $Y_\nu^2 \sim 10^{-3}$

● : $Y_\nu^2 \sim 10^{-4}$





$\mathrm{Log}_{10}|R_{23}| \sim 0.1$

Summary

- We investigate LFV & QFV in “minimal” SU(5) models with Type I / TypeII seesaw.
  - Cutoff dependence:
    Type I : sensitive
    Type II: QFV/LFV is insensitive
  - λ_{24} dependence : quite small

- Future works
  - More exhaustive scan.
  - Phenomenological constraints
  - More natural model : MP, SO(10)…