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

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In preparation.
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S. Mishima (Princeton)

``minimal'' SUSY SU(5)

- “minimal”SUSY SU(5)

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

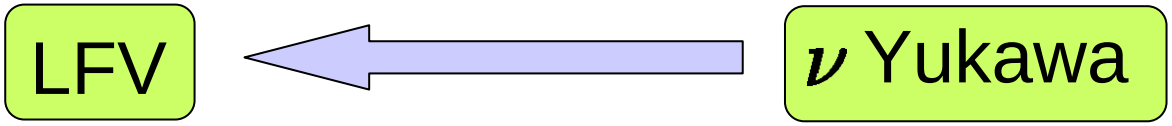
  ~~SU(5)~~ & ~~SM~~ breaking part is unchanged.

Plan

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

Introduction

- LFV vs. QFV in SUSY-GUTs



Type I

LNH_u

F. Borzumati &
A. Masiero (1986)

Type II

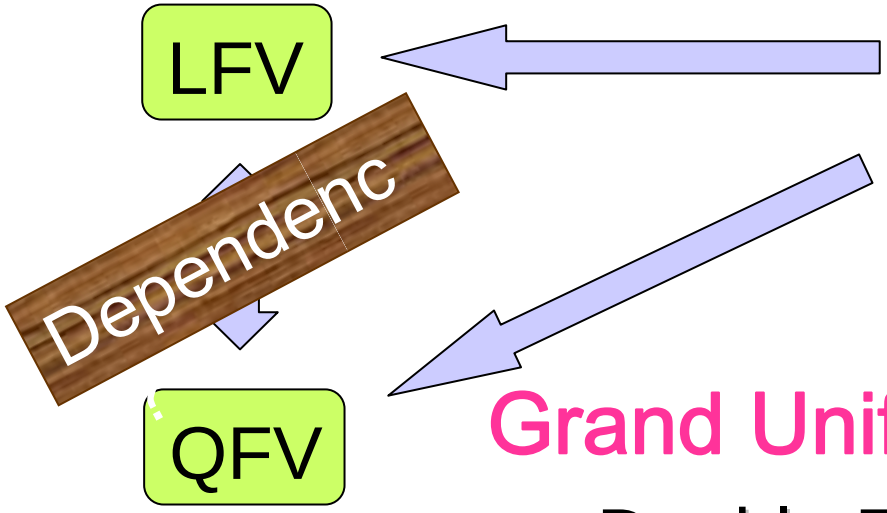
LLT

$\bar{T}H_uH_u$

A. Rossi (2002)

Introduction

- LFV vs. QFV in SUSY-GUTs



Type I LNH_u

Type II LLT $\bar{T}H_uH_u$

Grand Unification realistic??

- Double-Triplet Splitting
- Fermion Spectra
- Proton Decay

⇨ New Physics above GUT

Introduction

- Type I vs. Type II Seesaw

Type I LFV > QFV

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

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

Decoupling

$\bar{5}_i 1_j 5_H$

$\cancel{H_u^C}$

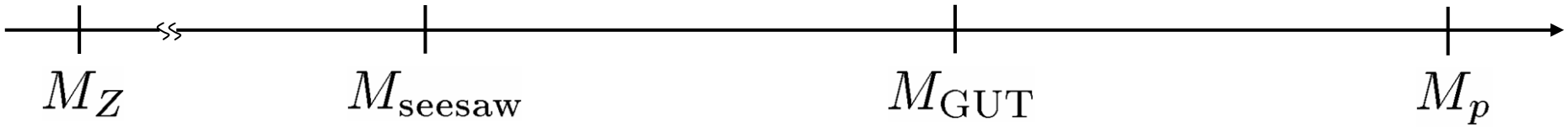
$D_i^c N_j^c H_u^C$ + $L_i N_j^c H_u$

$L_i N_j^c H_u$

"Minimal Ansatz"

$\tilde{m}_i^2 = \tilde{m}_0^2$

$A = A_0 Y$



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

Type II LFV ~ QFV

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

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

$\cancel{H_u^C}$

$\bar{5}_i \bar{5}_j 15_H$

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

$\tilde{m}_i^2 = \tilde{m}_0^2$

$A = A_0 Y$

Problems of GUTs & Solutions

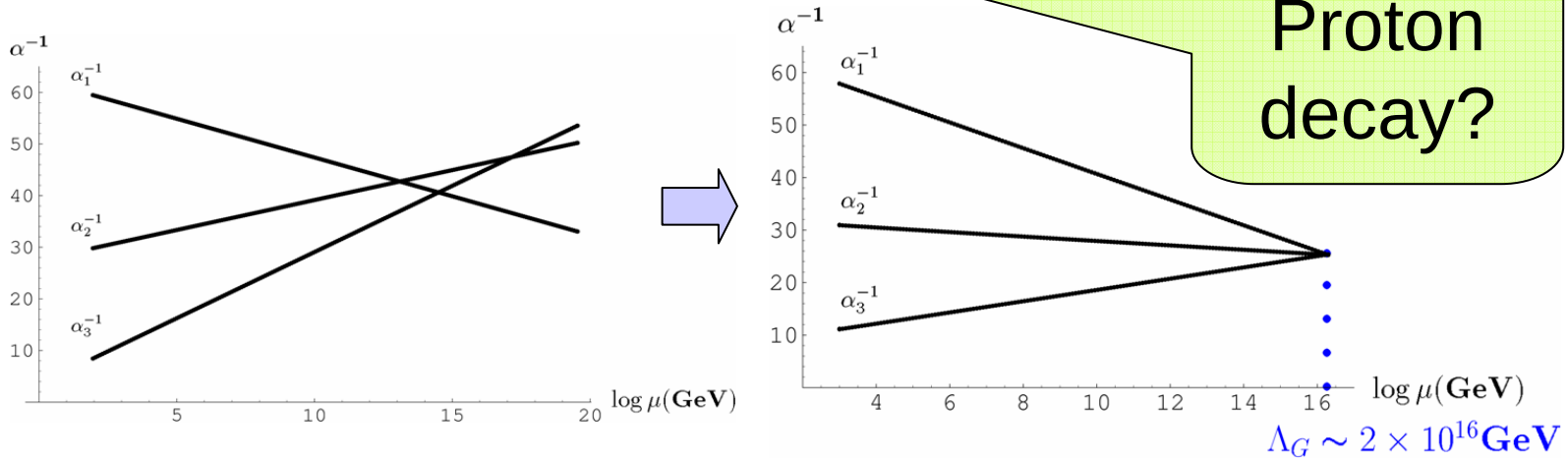
- SUSY-GUT
  - fascinating extension of SM
    - •unifications of forces and of matter
    - •stabilization of the weak scale
  - gauge coupling unification (GCU)

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

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

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

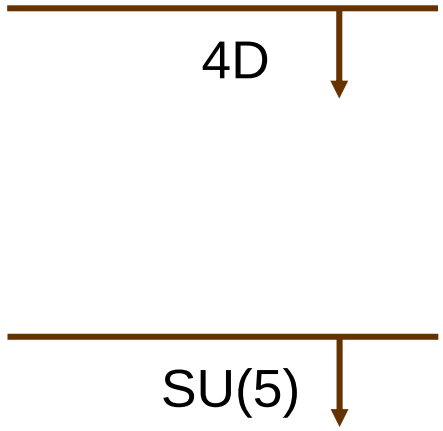
$$W_{\mathrm{DT}} = \bar{5}_H \left(M_5 - \lambda_5 24_H\right) 5_H$$

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

⟵ 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



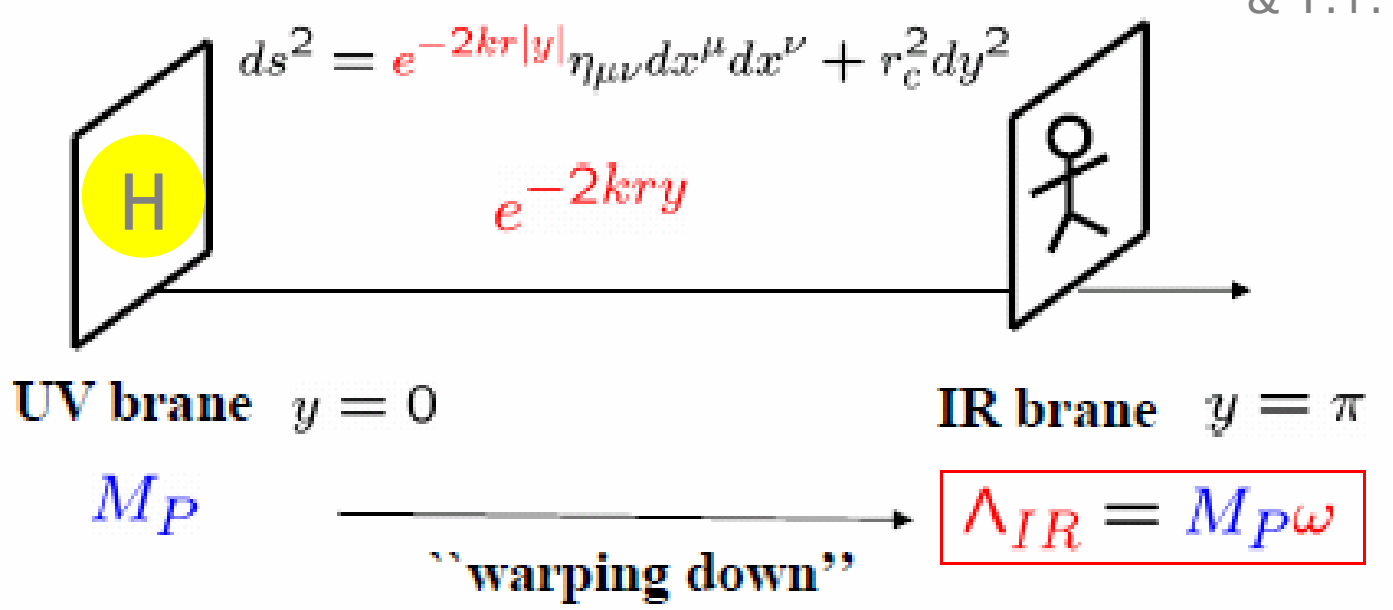
$$\begin{pmatrix} \bar{5}_H \\ \bar{3} \\ \bar{2} \end{pmatrix} \overset{\langle 75_H \rangle}{\longleftrightarrow} \begin{pmatrix} 50_H \\ 3 \\ \text{others} \end{pmatrix} \longleftrightarrow \begin{pmatrix} \bar{50}_H \\ \bar{3} \\ \text{others} \end{pmatrix} \overset{\langle 75_H \rangle}{\longleftrightarrow}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

⇨ Non-Perturbative below M_p.

Problems of GUTs & Solutions

- Low Scale Gravity Mediation

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



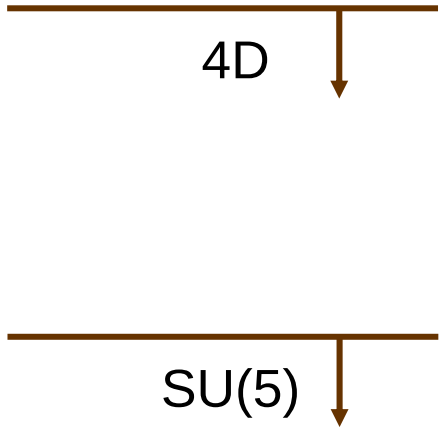
If Gravity mediation with the Minimal Ansatz.

⇨ 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
  - Missing Partner mechanism



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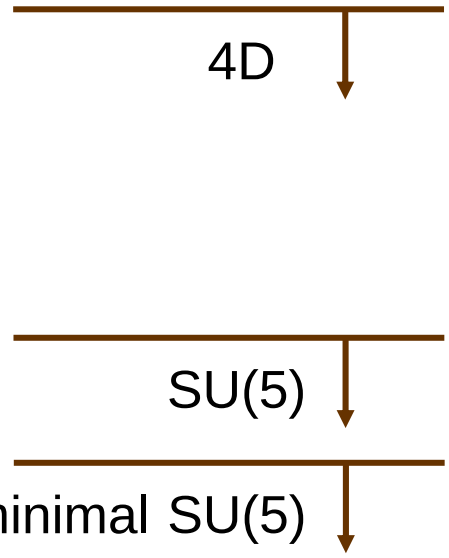
⇨ Non-Perturbative below M_p.

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 :

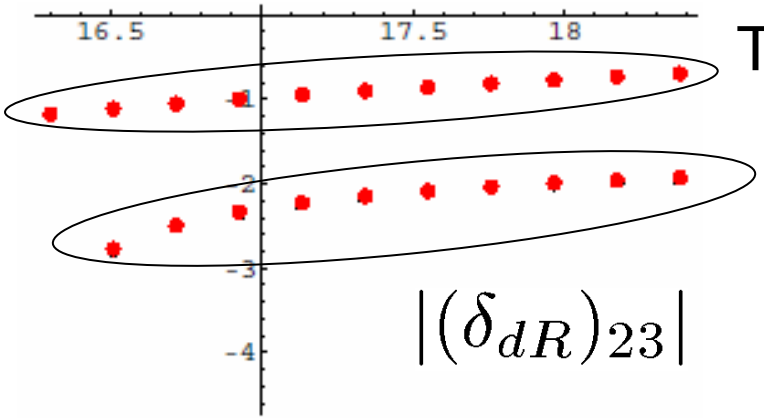
    m_ν : NH, $\quad \sin\theta_{13} = 0, \quad \theta_{\mathrm{Maj}} = 0$
  - ~~SUSY~~ parameters : $\tilde{m}_0^2 = A_0 = M_{1/2} = 1\mathrm{TeV}$

Analysis

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

● : $\lambda_{24}=1$

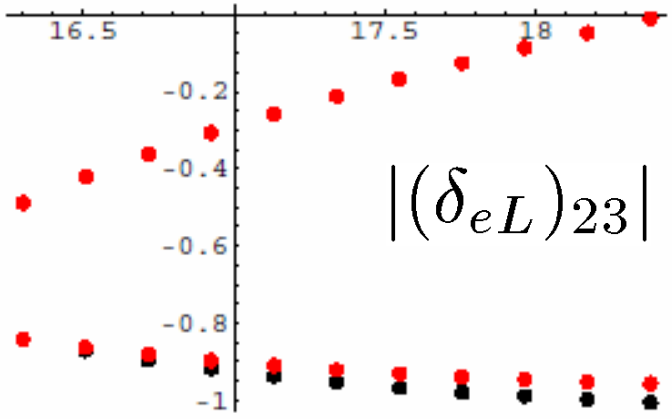
● : $\lambda_{24}=0.01$



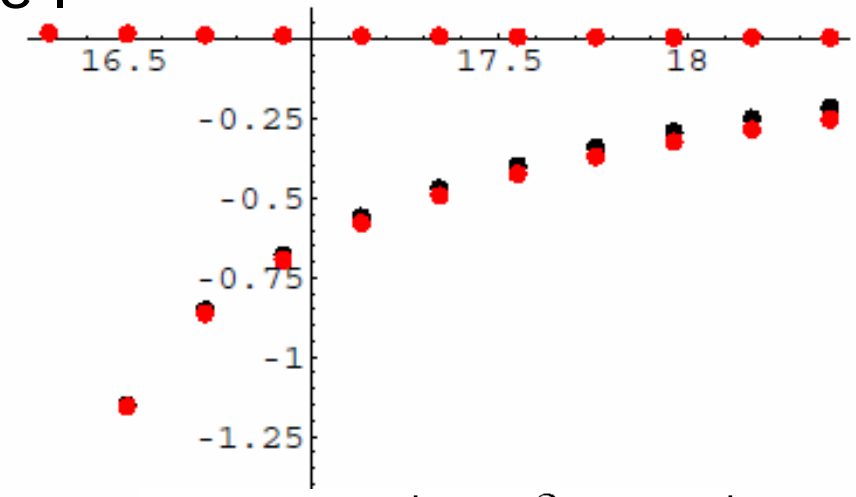
Type II

Type I

$|(\delta_{dR})_{23}|$



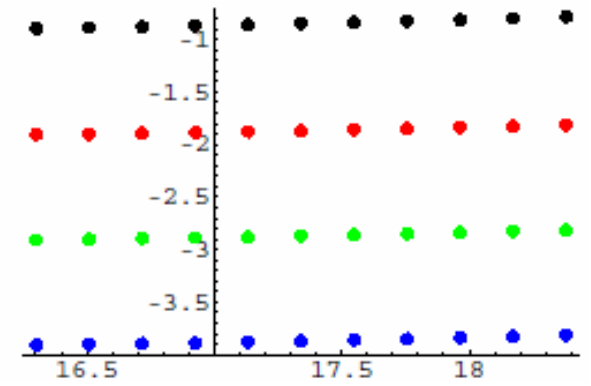
$|(\delta_{eL})_{23}|$

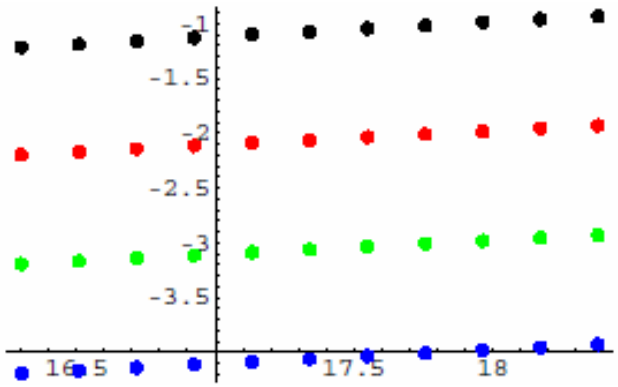


$$|R_{23}| = \left| \frac{(\tilde{m}^2_{dR})_{23}}{(\tilde{m}^2_{eL})_{23}} \right|$$

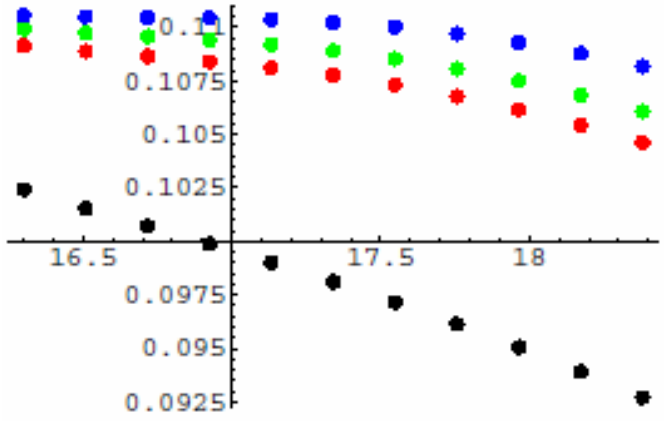
Analysis

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





$\bullet$: $Y_\nu^2 \sim 10^{-1}$
$\bullet$: $Y_\nu^2 \sim 10^{-2}$
$\bullet$: $Y_\nu^2 \sim 10^{-3}$
$\bullet$: $Y_\nu^2 \sim 10^{-4}$



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

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)…