Flavor violating Z‘ from SO(10) SUSY GUT in High-scale SUSY

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Based on PLB744 (2015) 395 (arXiv:1503.06156)
with J. Hisano, Y. Muramatsu, M. Yamanaka (Nagoya Univ.)

Why believe the SUSY GUT?

the Standard Model (SM)

Origin of Higgs mass
Origin of gauge groups and non-trivial charges

→ *SUSY (supersymmetry)*
→ *SO(10) GUT*

unify all SM matters and SM gauge groups!

SUSY SO(10) predictions

SUSY particles
Maximal value of Higgs mass
gauge coupling unification

→ *Maybe SUSY scale O(100) TeV (?)*

← *O(TeV) gauginos and O(100) TeV scalars no problem!*

extra U(1) symmetry
Yukawa coupling unification

My Motivations

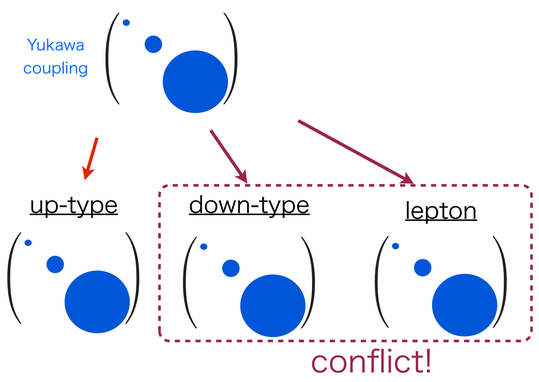
Solution to Yukawa hierarchy and its prediction

conventional setup

SO(10) GUT unifies quarks and leptons into **16** rep.

$W_{\rm min} = h_{ij}\mathbf{16}_i\mathbf{16}_j\mathbf{10}_H$

Yukawa coupling



conflict!

modified setup

Let me modify the minimal setup, introducing extra **10**

$W_{\rm min} = h_{ij}\mathbf{16}_i\mathbf{16}_j\mathbf{10}_H$

$W_Y = h_{ij}\mathbf{16}_i\mathbf{16}_j\mathbf{10}_H + g_{ij}\mathbf{10}_i\mathbf{16}_j\mathbf{16}_H + \mu_{10\,ij}\mathbf{10}_i\mathbf{10}_j$ (extra Higgs)

"SM(-like)" particles: $\hat{Q}^i_L, \hat{U}^{ci}_R, \hat{D}^{ci}_R, \hat{E}^{ci}_R, \hat{L}^i_L$

"extra" quarks and leptons: $D'^{ci}_R, \overline{D'^c}^i, L'^i_L, \overline{L'}^i_L$

$h^{ij}_u Q^i_L \hat{D}^{cj}_R H_d + g_{ij}\langle\mathbf{16}_H\rangle \overline{D'^c}_{Ri}\hat{D}^c_{R,j} + \mu_{10,ij}\overline{D'^c}_{Ri}D'^c_{R,j}$

$h^{ij}_u \hat{L}^i_L E^{cj}_R H_d + g_{ij}\langle\mathbf{16}_H\rangle \overline{L'}_{Li}\hat{L}_{L,j} + \mu_{10,ij}\overline{L'}_{Li}L'_{L,j}$

SM particles given by the linear combination

$D^i_R = c_{ij}\hat{D}^i_R + s_{ij}D'^j_R$
$L^i_L = c_{ij}\hat{L}^i_L + s_{ij}L'^j_L$

Prediction

SUSY-scale Z' from extra U(1) of SO(10) exists!
Z' interaction is flavor violating!

interaction base: $g_X(3\overline{\hat{d}^i_R}\gamma^\mu\hat{d}^i_R - 2\overline{d'^i_R}\gamma^\mu d'^i_R)$

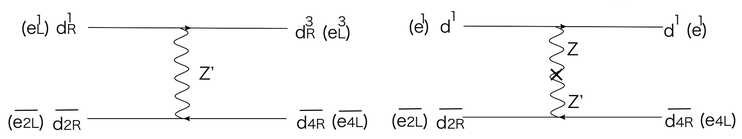
mass base: $g_X A^d_{ij}\overline{d^i_R}\gamma_\mu d^j_R$

different charges of U(1)x induce tree-level FCNCs
$d^i_R = U^{ij}\hat{d}^j_R + U'^{ij}d'^j_R$

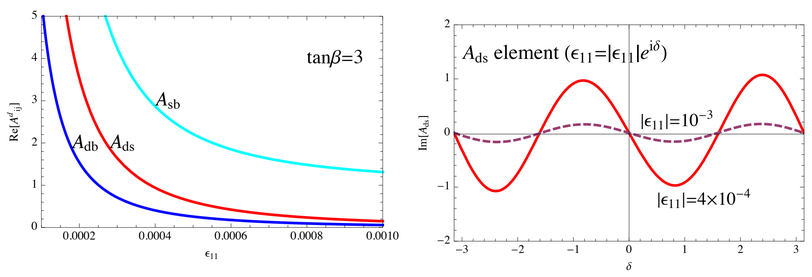
(A_{ij} depends on parameters ε_{ij})

Z' couples fermions almost flavor-universally.

finite Z-Z' mass mixing predicted



size of FCNCs



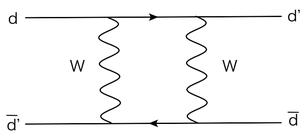
all elements are large!

Flavor physics

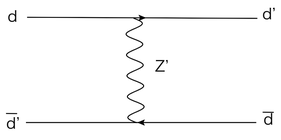
Quark sector

Costraints from mesons

SM prediction



Z' contribution



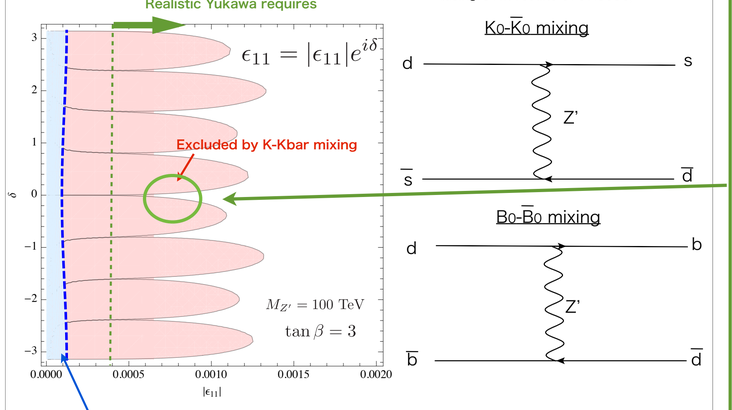
$\underbrace{|V^*_{ts}V_{td}|}_{K\text{ system}} \sim 5\cdot10^{-4} \ll \underbrace{|V^*_{tb}V_{td}|}_{B_d\text{ system}} \sim 10^{-2} < \underbrace{|V^*_{tb}V_{ts}|}_{B_s\text{ system}} \sim 4\cdot10^{-2}$

K system Strongly constrains

Constraints from ΔF=2 process

(using UTfit results 0707.0636)

Realistic Yukawa requires



K0-K̄0 mixing

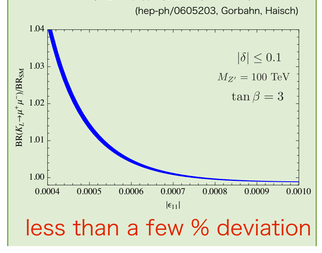
B0-B̄0 mixing

K (semi) leptonic decays — preliminary

$K_L \to \mu\mu$

$B(K_L \to \mu_+\mu_-)_{SD} < 2.5\times10^{-9}$ (hep-ph/0311084, Ishidori, Unterdorfer)

$B(K_L \to \mu_+\mu_-)_{SD} = (0.8\pm0.1)\times10^{-9}$ (hep-ph/0605203, Gorbahn, Haisch)



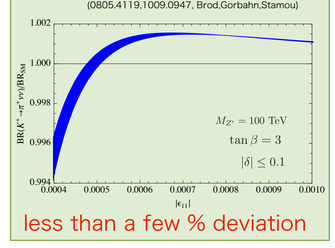
less than a few % deviation

K (semi) leptonic decays — preliminary

$K^+ \to \pi^+\nu\bar{\nu}$

$B(K^+ \to \pi^+\nu\bar{\nu})_{exp} = (17.3)^{+11.5}_{-10.5}\times10^{-11}$ (0911.4789, E391a collaboration)

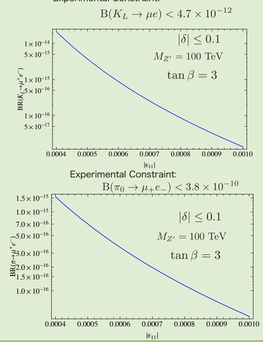
$B(K^+ \to \pi^+\nu\bar{\nu})_{SM} = (8.5\pm0.7)\times10^{-11}$ (0805.4119,1009.0947, Brod,Gorbahn,Stamou)



less than a few % deviation

LFV meson decay — preliminary

Experimental Constraint: $B(K_L \to \mu e) < 4.7\times10^{-12}$



enough small

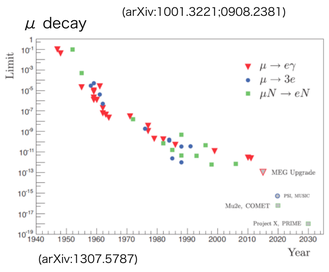
lepton sector

Costraints from LFVs

τ decay

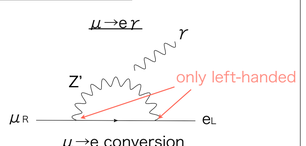
$BR(\tau \to l_i l_j l_k) \lesssim 10^{-8}$
$BR(\tau \to l_i \gamma) \lesssim 10^{-8}$ (arXiv:1001.3221;0908.2381)

μ decay

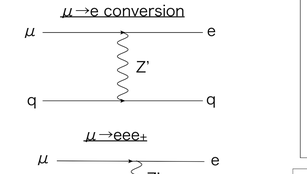


(arXiv:1307.5787)

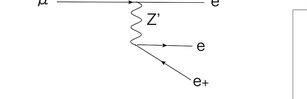
μ→eγ



μ→e conversion

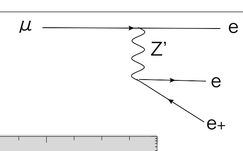


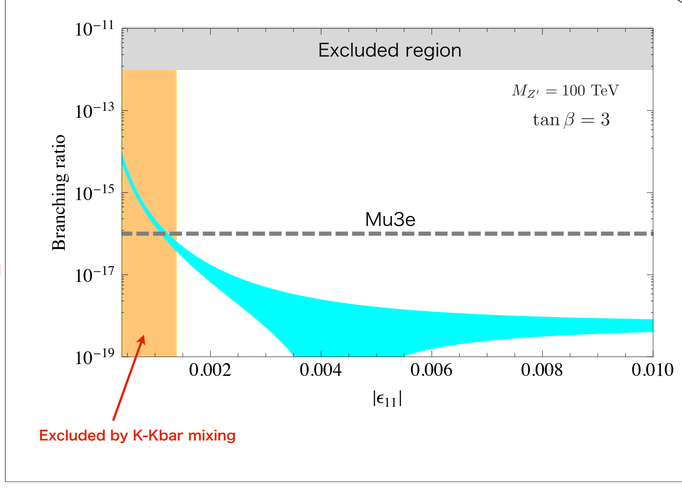
μ→eee+



μ→3e, μ-e conversion are most important

Allowed region for μ→3e





Allowed region for μ→e in Al