

Flavor violating Z' from $SO(10)$ SUSY GUT in high-scale SUSY scenario

Yuji Omura (KMI, Nagoya Univ.)

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

Standard Model $(SU(3)_C \times SU(2)_L \times U(1)_Y)$

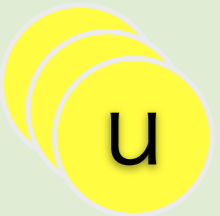
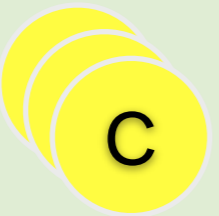
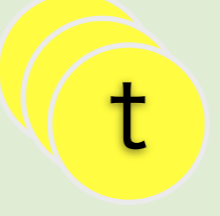

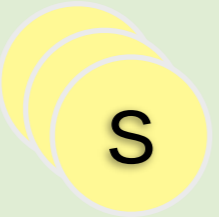
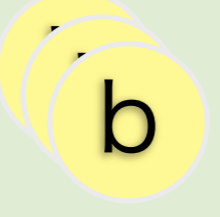
is very successful in particle physics

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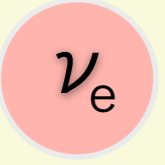
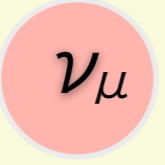




is very successful in particle physics

spin-1/2

quarks $SU(3)_c$ -charged


			EM-charge $+2/3$
			$-1/3$

leptons


			0
			-1


spin-1

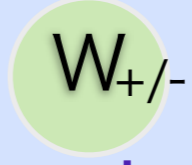
$SU(3)_c$ gauge


gluon

$SU(2)_L \times U(1)_Y$


massive



photon


massive

carry forces

spin-0

Higgs

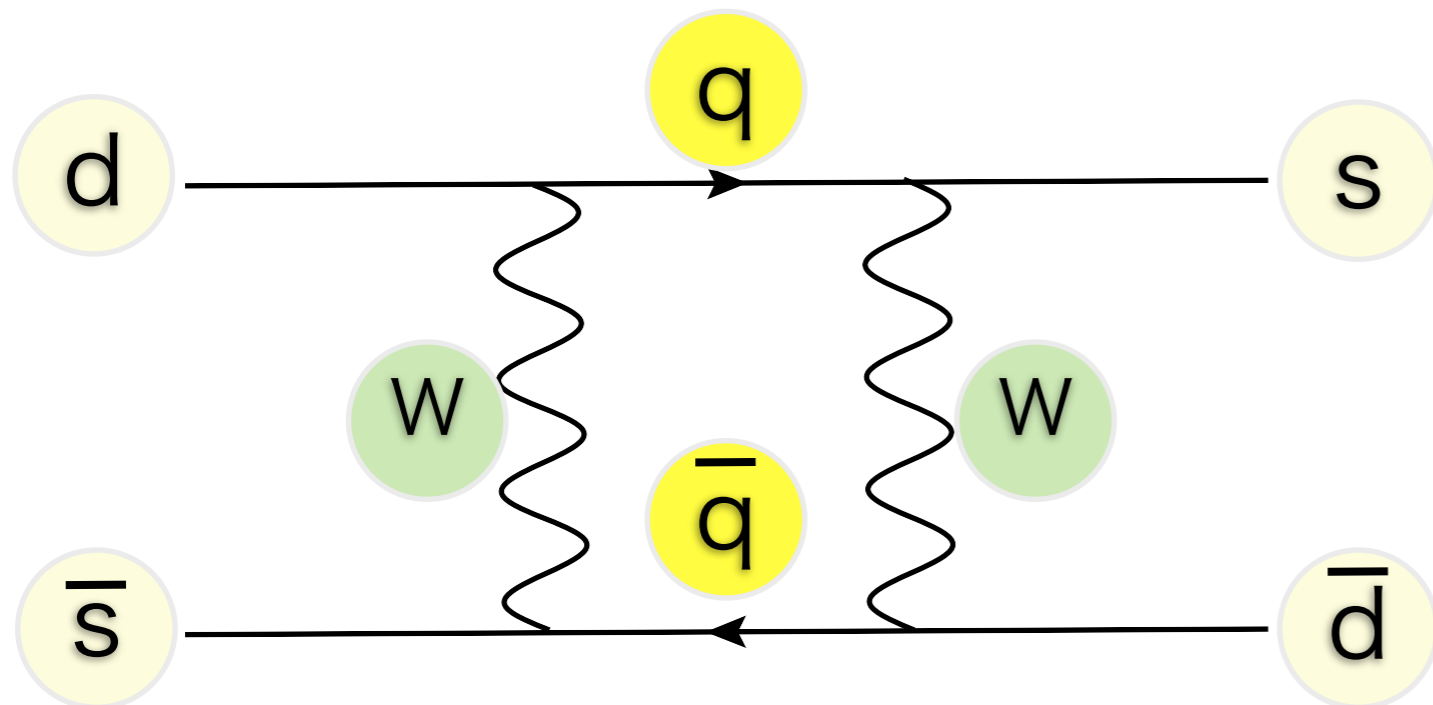


breaks
 $SU(2)_L \times U(1)_Y$

Of course, the SM is very successful in **flavor physics** as well.

- No tree-level FCNCs.
- Flavor changing processes are very suppressed by the GIM mechanism.

For instance,



K_0 - \bar{K}_0 mixing predicted by the one-loop, and very small.

This is **not the end of the story!**

because of

Dark matter

and

there are many “why” in the SM.

Standard Model $(SU(3)_c \times SU(2)_L \times U(1)_Y)$

is very successful in particle physics

Why?

spin-1/2


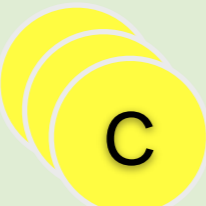
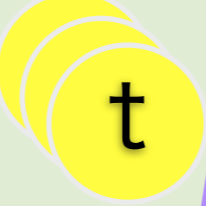

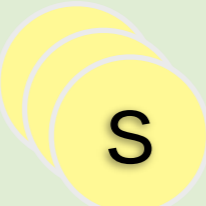
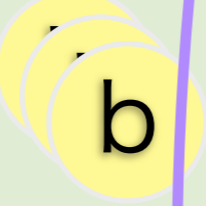
Why?

spin-1







spin-0

quarks $SU(3)_c$ -charged

EM-charge


 u	 c	 t	+2/3
 d	 s	 b	-1/3

leptons


 ν_e	 ν_μ	 ν_τ	0
 e	 μ	 τ	-1


spin-1

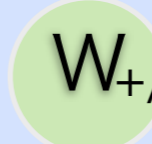
$SU(3)_c$ gauge

 g
gluon

$SU(2)_L \times U(1)_Y$


 Z
massive

 γ
photon

 $W_{+/-}$
massive

spin-0

Higgs

 H

breaks $SU(2)_L \times U(1)_Y$

Why?

carry forces

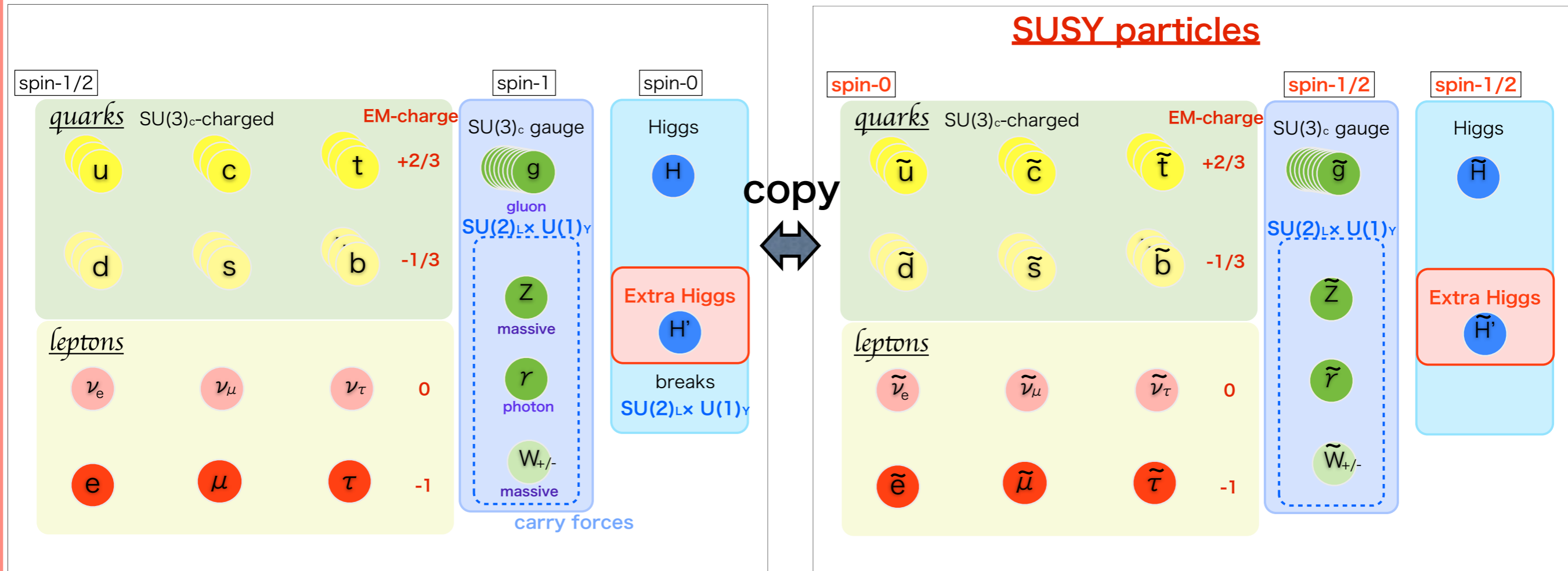
Supersymmetric

Grand Unified Theory

is very natural explanation!

SUSY can explain why $SU(2)_L \times U(1)_Y$ breaking happen around 246 GeV

Supersymmetric SM



no quadratic divergence

radiative $SU(2)_L \times U(1)_Y$ breaking

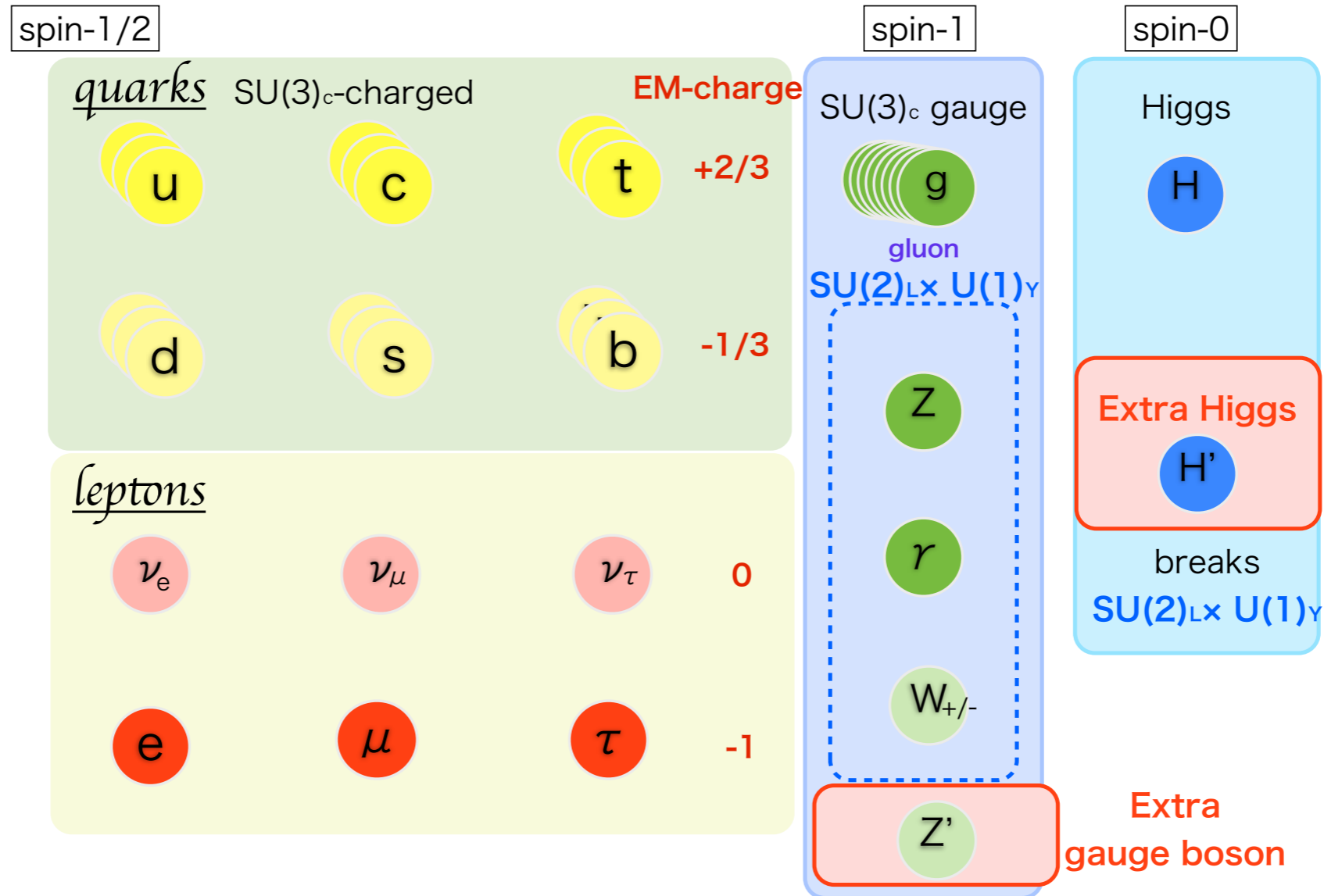
dark matter

Grand Unified Theory (GUT)

**is a good answer
to the origin of gauge symmetry**

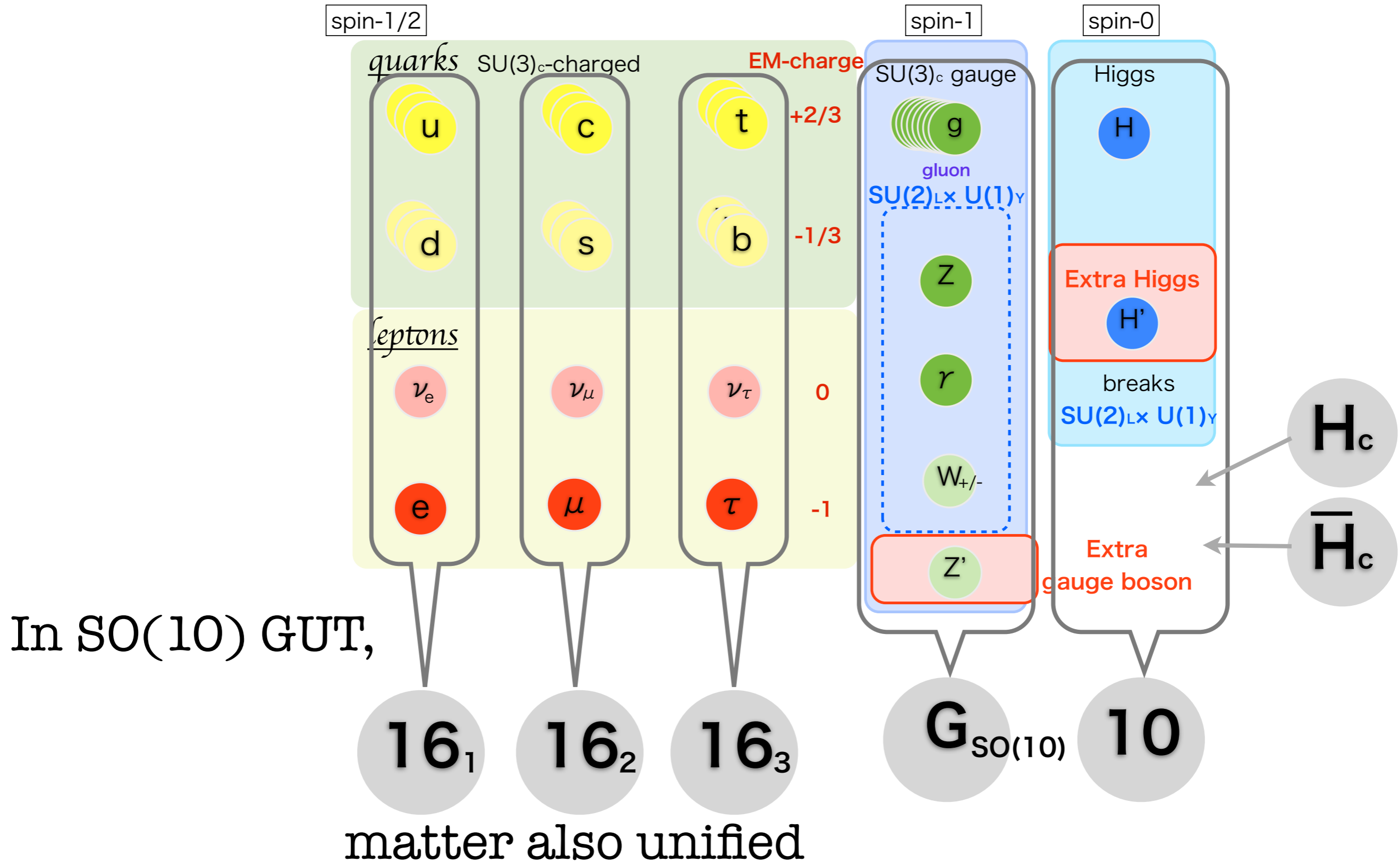
SM gauge groups naturally embedded into **GUT**

SO(10) Embedding: $SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_X \rightarrow SO(10)$
 slightly extended SM extra



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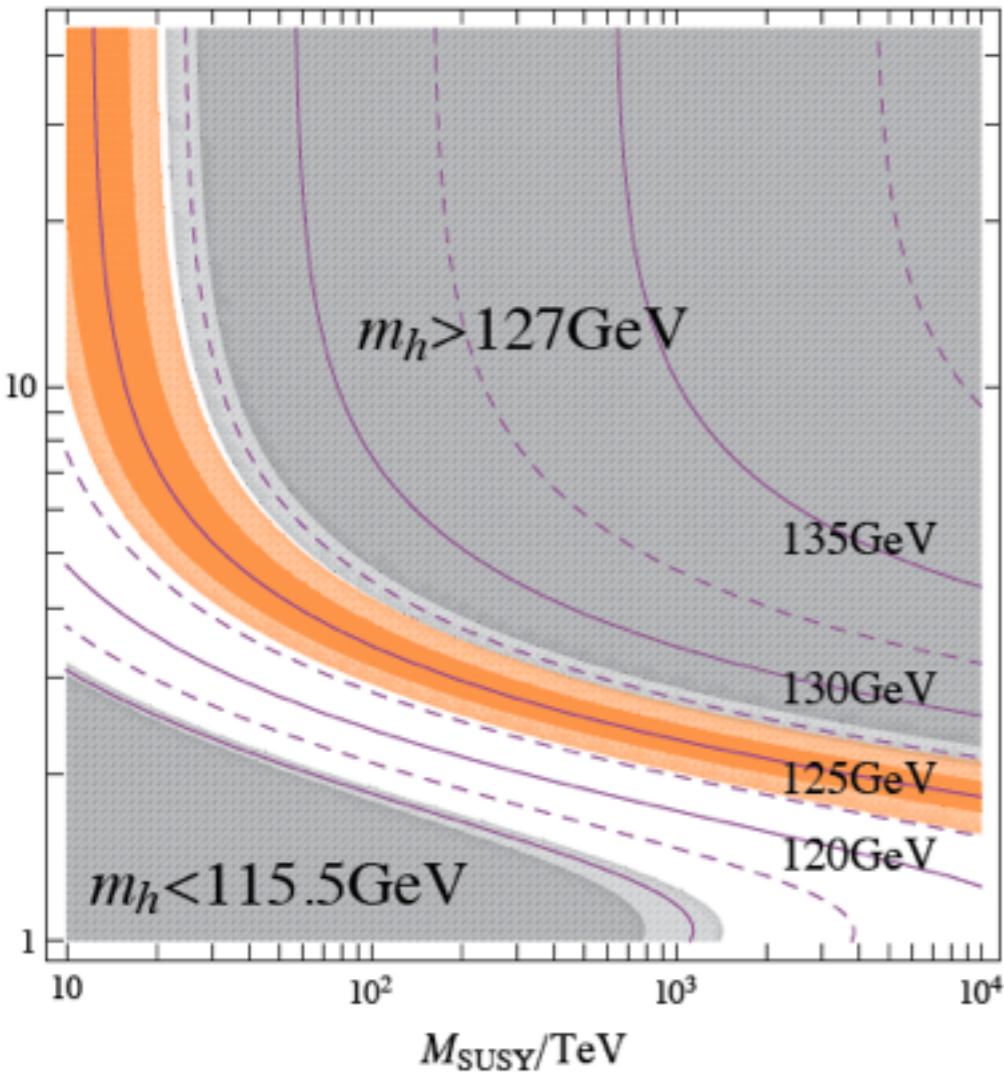


supersymmetric $SO(10)$ GUT looks very elegant and natural
but story is not so simple...

supersymmetric SO(10) GUT looks very elegant and natural but story is not so simple...

Problem 1

It is difficult to achieve 125 GeV Higgs in the MSSM.



(Ibe, Matsumoto, Yanagida, 1202.2253)

SUSY search also getting severe!

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary

$\sqrt{s} = 7, 8 \text{ TeV}$

Model	e, μ, τ, γ	Jets	E_T^{miss}	$[\mathcal{L} d(\text{fb}^{-1})]$	Mass limit	Reference			
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	\tilde{q}, \tilde{g} 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	1405.7875	
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	850 GeV	$m(\tilde{q})=0 \text{ GeV}, m(1^{\text{st}} \text{ gen. } \tilde{q})=m(2^{\text{nd}} \text{ gen. } \tilde{q})$	1405.7875	
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$ (compressed)	1 γ	0-1 jet	Yes	20.3	250 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0) = m(c)$	1411.1559	
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	1.33 TeV	$m(\tilde{q})=0 \text{ GeV}$	1405.7875	
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0 \rightarrow qqW\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20	1.2 TeV	$m(\tilde{q}) < 300 \text{ GeV}, m(\tilde{\chi}^\pm)=0.5(m(\tilde{q})+m(\tilde{g}))$	1501.03555	
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0 \rightarrow qq\ell\ell/\ell\nu/\nu\nu\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20	1.32 TeV	$m(\tilde{q})=0 \text{ GeV}$	1501.03555	
	GMSB ($\tilde{\ell}$ NLSP)	1-2 $\tau + 0-1 \ell$	0-2 jets	Yes	20.3	1.6 TeV	$\tan\beta > 20$	1407.0603	
	GGM (bino NLSP)	2 γ	-	Yes	20.3	1.28 TeV	$m(\tilde{q}) > 50 \text{ GeV}$	ATLAS-CONF-2014-001	
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	619 GeV	$m(\tilde{q}) > 50 \text{ GeV}$	ATLAS-CONF-2012-144	
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	900 GeV	$m(\tilde{q}) > 220 \text{ GeV}$	1211.1167	
3 rd gen. \tilde{g} med.	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	690 GeV	$m(\text{NLSP}) > 200 \text{ GeV}$	ATLAS-CONF-2012-152	
	Gravitino LSP	0	mono-jet	Yes	20.3	865 GeV	$m(\tilde{G}) > 1.8 \times 10^{-4} \text{ eV}, m(\tilde{g})=m(\tilde{q})=1.5 \text{ TeV}$	1502.01518	
	$\tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	1.25 TeV	$m(\tilde{q}) < 400 \text{ GeV}$	1407.0600	
	$\tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	1.1 TeV	$m(\tilde{q}) < 350 \text{ GeV}$	1308.1841	
	$\tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	1.34 TeV	$m(\tilde{q}) < 400 \text{ GeV}$	1407.0600	
	$\tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	1.3 TeV	$m(\tilde{q}) < 300 \text{ GeV}$	1407.0600	
	3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	100-620 GeV	$m(\tilde{q}) < 90 \text{ GeV}$	1308.2631
		$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow t\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 b	Yes	20.3	275-440 GeV	$m(\tilde{q}) = 2m(\tilde{\chi}_1^0)$	1404.2500
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$	1-2 e, μ	1-2 b	Yes	4.7	110-167 GeV	$m(\tilde{q}) = 2m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=55 \text{ GeV}$	1209.2102, 1407.0583
		$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	90-191 GeV	215-530 GeV	1403.4853, 1412.4742
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$		0-1 e, μ	1-2 b	Yes	20	210-640 GeV	$m(\tilde{q})=1 \text{ GeV}$	1407.0583, 1406.1122	
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$		0	mono-jet/c-tag	Yes	20.3	90-240 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0) < 85 \text{ GeV}$	1407.0608	
$\tilde{t}_1\tilde{t}_1$ (natural GMSB)		2 e, μ (Z)	1 b	Yes	20.3	150-580 GeV	$m(\tilde{q}) > 150 \text{ GeV}$	1403.5222	
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$		3 e, μ (Z)	1 b	Yes	20.3	290-600 GeV	$m(\tilde{q}) < 200 \text{ GeV}$	1403.5222	
EW direct		$\tilde{\ell}_L\tilde{\ell}_L, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	90-325 GeV	$m(\tilde{q})=0 \text{ GeV}$	1403.5294
		$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm \rightarrow \tilde{\ell}\nu(\tilde{\nu})$	2 e, μ	0	Yes	20.3	140-465 GeV	$m(\tilde{q})=0 \text{ GeV}, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{q}))$	1403.5294
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm \rightarrow \tilde{\tau}\nu(\tilde{\nu})$	2 τ	-	Yes	20.3	100-350 GeV	$m(\tilde{q})=0 \text{ GeV}, m(\tilde{\tau}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{q}))$	1407.0350	
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp \rightarrow \tilde{\ell}_L\nu_L^c(\tilde{\nu}), \tilde{\ell}\tilde{\nu}_L^c(\tilde{\nu})$	3 e, μ	0	Yes	20.3	700 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=0, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{q}))$	1402.7029	
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp \rightarrow W\tilde{\chi}_1^0 Z$	2-3 e, μ	0-2 jets	Yes	20.3	420 GeV	$m(\tilde{q})=m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=0, \text{sleptons decoupled}$	1403.5294, 1402.7029	
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp \rightarrow W\tilde{\chi}_1^0 h, \tilde{h} \rightarrow b\tilde{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	250 GeV	$m(\tilde{q})=m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=0, \text{sleptons decoupled}$	1501.07110	
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_2^0 \rightarrow \tilde{\ell}_R\tilde{\ell}$	4 e, μ	0	Yes	20.3	620 GeV	$m(\tilde{q})=m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=0, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_2^0)+m(\tilde{q}))$	1405.5086	
	Long-lived particles	Direct $\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	270 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^\pm)=160 \text{ MeV}, \tau(\tilde{\chi}_1^\pm)=0.2 \text{ ns}$	1310.3675
		Stable, stopped \tilde{g} R-hadron	0	1-5 jets	Yes	27.9	832 GeV	$m(\tilde{q})=100 \text{ GeV}, 10 \mu\text{s} < \tau(\tilde{g}) < 1000 \text{ s}$	1310.6584
		Stable \tilde{g} R-hadron	trk	-	-	19.1	1.27 TeV	-	1411.6795
GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(e, \mu)+\tau(e, \mu)$		1-2 μ	-	-	19.1	537 GeV	$10 < \tan\beta < 50$	1411.6795	
GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$		2 γ	-	Yes	20.3	435 GeV	$2 < c\tau < 3 \text{ ns}, \text{SPS8 model}$	1409.5542	
$\tilde{q}\tilde{q}, \tilde{\chi}_1^0 \rightarrow qq\mu$ (RPV)		1 μ , displ. vtx	-	-	20.3	1.0 TeV	$1.5 < c\tau < 156 \text{ mm}, \text{BR}(\mu)=1, m(\tilde{\chi}_1^0)=108 \text{ GeV}$	ATLAS-CONF-2013-092	
RPV		LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e + \mu$	2 e, μ	-	-	4.6	1.61 TeV	$\lambda'_{111}=0.10, \lambda'_{132}=0.05$	1212.1272
		LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	1.1 TeV	$\lambda'_{111}=0.10, \lambda'_{1233}=0.05$	1212.1272
		Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	1.35 TeV	$m(\tilde{q})=m(\tilde{g}), c\tau_{LS} < 1 \text{ mm}$	1404.2500
		$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow e\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	750 GeV	$m(\tilde{q})=0 > 2 \times m(\tilde{\chi}_1^\pm), \lambda'_{121} \neq 0$	1405.5086
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp, \tilde{\chi}_1^\pm \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \tau\tilde{\nu}_e, e\tau\tilde{\nu}_e$	3 $e, \mu + \tau$	-	Yes	20.3	450 GeV	$m(\tilde{q}) > 0.2 \times m(\tilde{\chi}_1^\pm), \lambda'_{133} \neq 0$	1405.5086	
	$\tilde{g} \rightarrow qq\tilde{q}$	0	6-7 jets	-	20.3	916 GeV	$\text{BR}(\tilde{q})=\text{BR}(\tilde{b})=\text{BR}(\tilde{c})=0\%$	ATLAS-CONF-2013-091	
Other	$\tilde{g} \rightarrow \tilde{t}_1 t, \tilde{t}_1 \rightarrow b\tilde{s}$	2 e, μ (SS)	0-3 b	Yes	20.3	850 GeV	-	1404.250	
	Scalar charm, $\tilde{c} \rightarrow c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	490 GeV	$m(\tilde{q}) < 200 \text{ GeV}$	1501.01325	

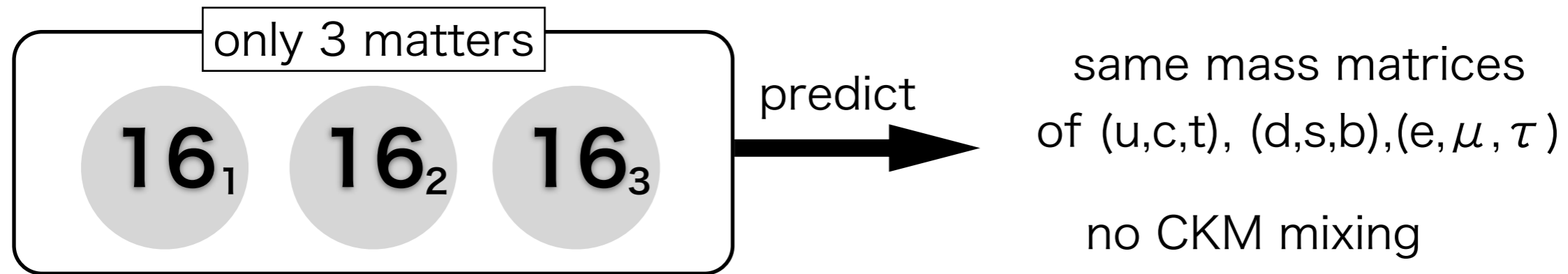
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Problem 2

It is difficult to realize the realistic Yukawa couplings in the GUT.

Problem 2

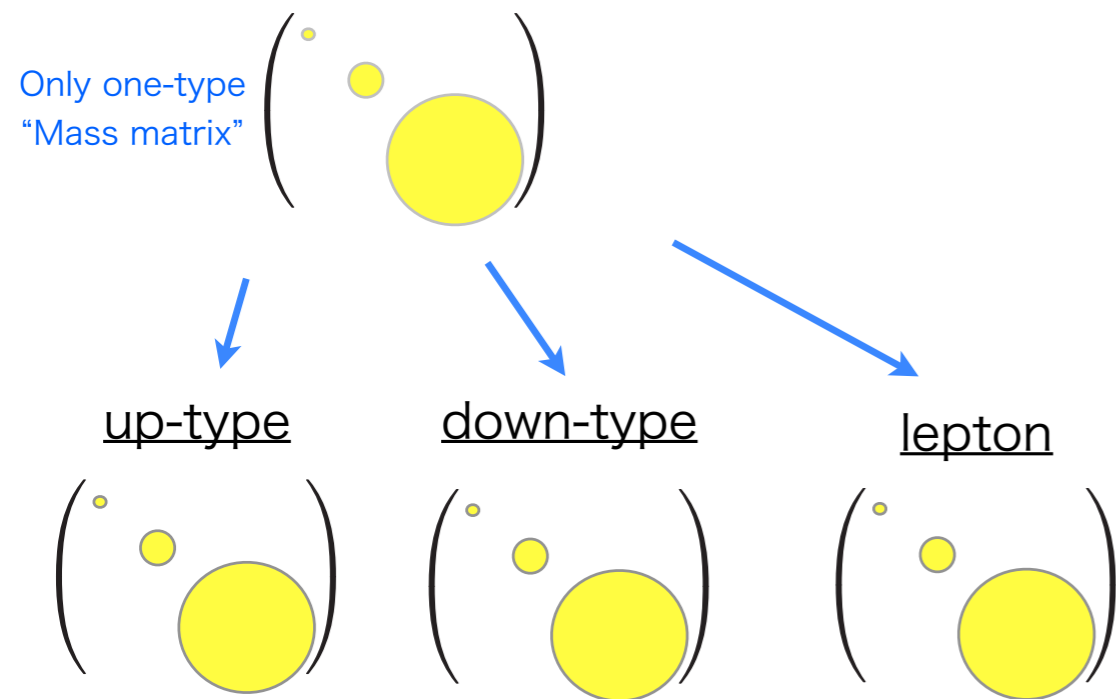
It is difficult to realize the realistic Yukawa couplings in the GUT.



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

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

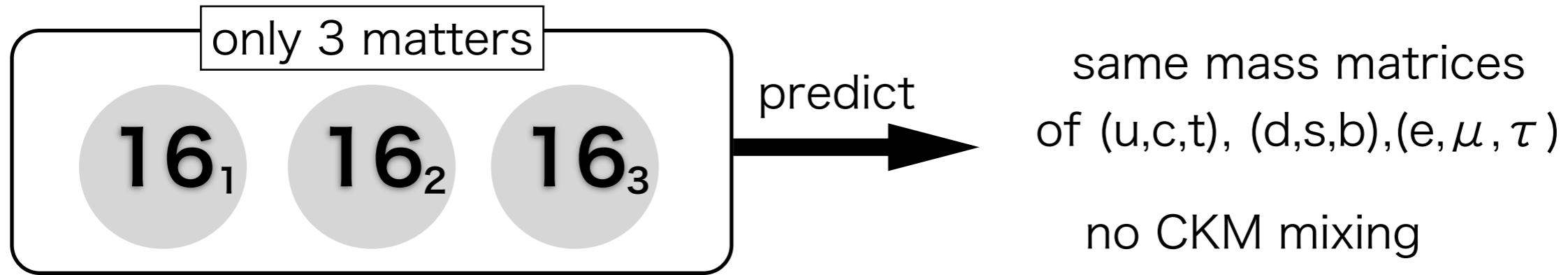
$$@ \tan \beta = 1$$



same mass spectrum

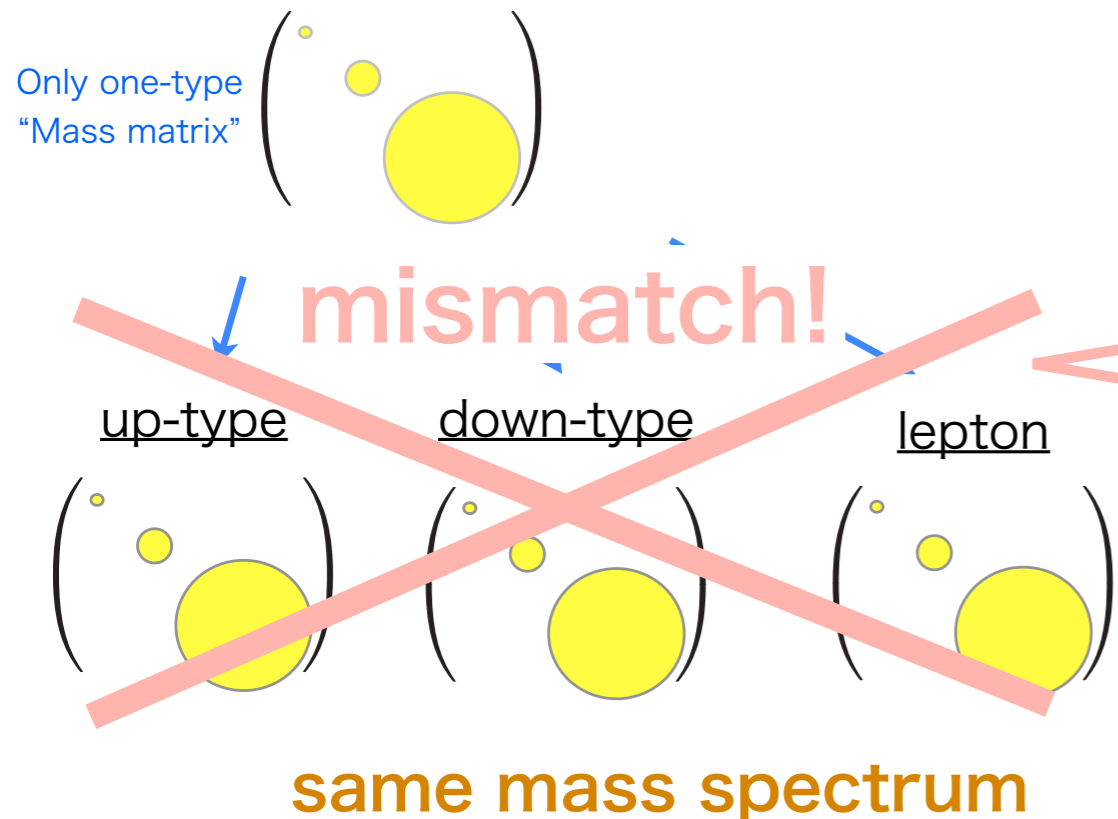
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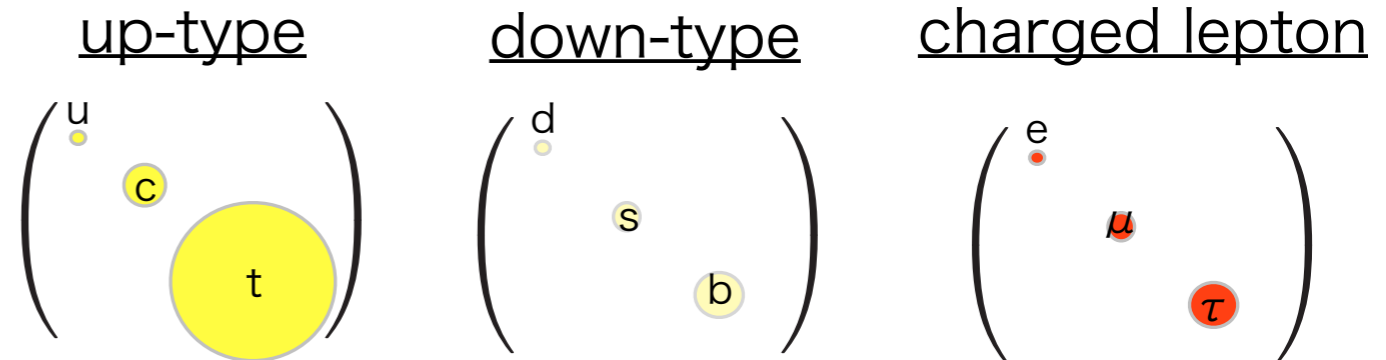
SO(10) GUT unifies quarks and leptons into

$$W_{\min} = h_{ij} 16_i 16_j 10_H \quad @ \tan \beta = 1$$



Realistic Mass Forms

hierarchical masses



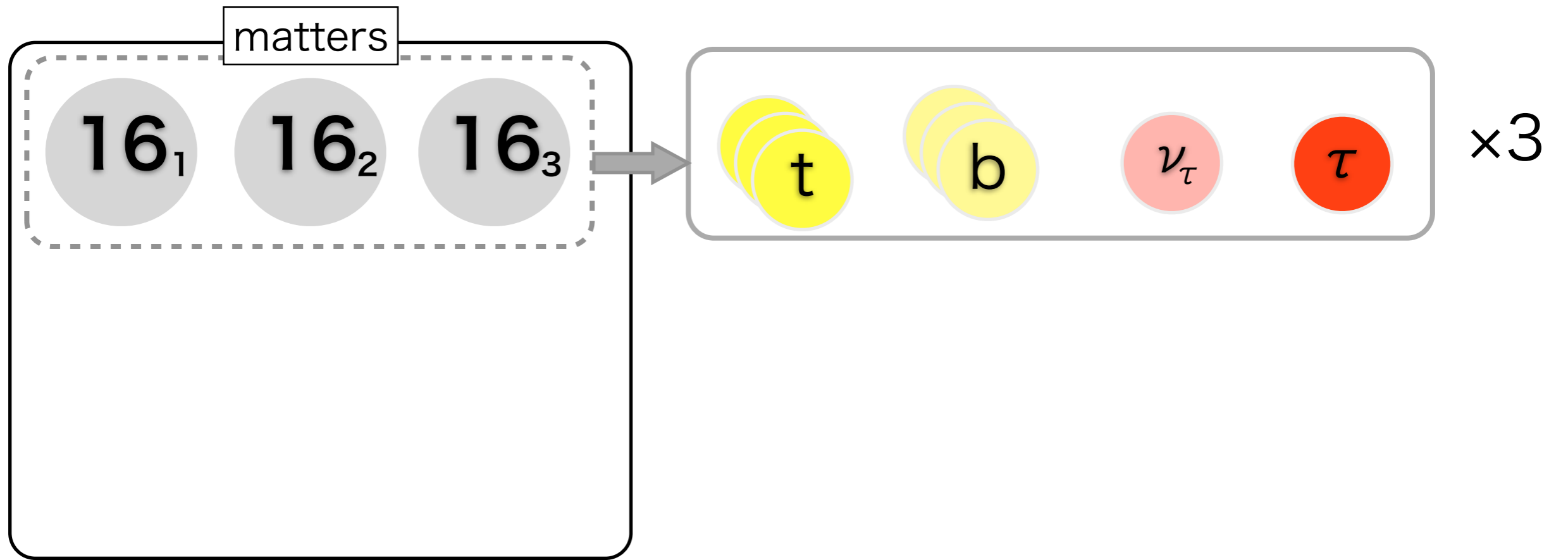
CKM mixing from the different mass matrices

We need extra something.

Our setup

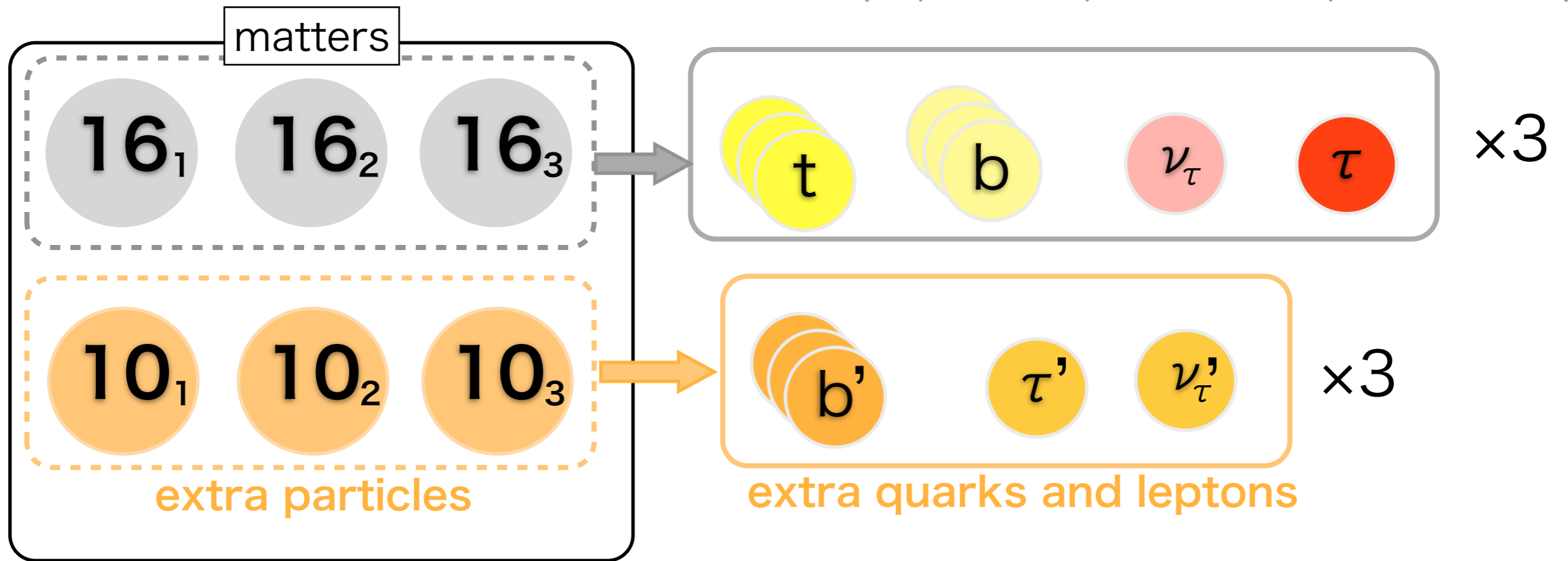
(extension of the minimal $SO(10)$
GUT to solve the problems)

minimal setup



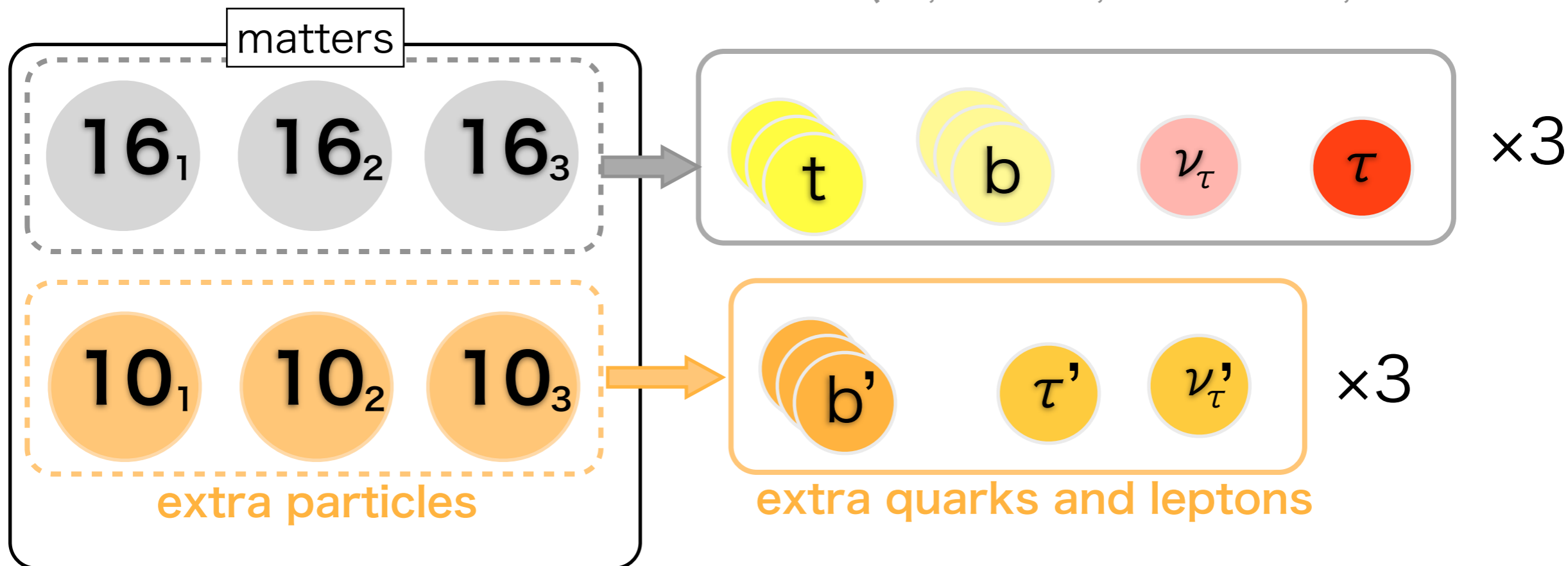
Let me add extra matters ($\mathbf{10}_1, \mathbf{10}_2, \mathbf{10}_3$)

(YO, J. Hisano, Y. Muramatsu, M. Yamanaka)



Let me add extra matters ($\mathbf{10}_1, \mathbf{10}_2, \mathbf{10}_3$)

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Then SM particles are given by the linear combinations:

ex)

minimal

extended

$$|(b_R^c)_{SM}\rangle = |b_R^c\rangle \quad \Rightarrow \quad |(b_R^c)_{SM}\rangle = (\cos \theta_b) |b_R^c\rangle + (\sin \theta_b) |b_R^{\prime c}\rangle$$

3rd generation

$$m_b \approx m_t \times (1/60)$$

top: $\left(\begin{array}{c} \text{yellow circle} \\ m_t \end{array} \right) t_L t_R^c$

bottom: $\left(\begin{array}{c} \text{yellow circle} \\ m_t \end{array} \right) b_L \hat{b}_R^c$

3rd generation

$$m_b \approx m_t \times (1/60)$$

top: $\left(\begin{array}{c} \text{yellow circle} \\ m_t \end{array} \right) t_L t_R^c$

from
 $g^{ij} \mathbf{16}_i \mathbf{10}_j \mathbf{16}_H + \mu_{10}^{ij} \mathbf{10}_i \mathbf{10}_j$

“extra” quarks

bottom: $\left(\begin{array}{c} \text{yellow circle} \\ m_t \end{array} \right) b_L \hat{b}_R^c$

$+ M' \overline{b'_R}^c \hat{b}_R^c + \mu_{10} \overline{b'_R}^c b'_R$
mass mixing

3rd generation

$$m_b \approx m_t \times (1/60)$$

top: $\left(\begin{matrix} \text{yellow circle} \\ m_t \end{matrix} \right) t_L t_R^c$

from $g^{ij} \mathbf{16}_i \mathbf{10}_j \mathbf{16}_H + \mu_{10}^{ij} \mathbf{10}_i \mathbf{10}_j$

“extra” quarks

bottom: $\left(\begin{matrix} \text{yellow circle} \\ m_t \end{matrix} \right) b_L \hat{b}_R^c$

$+ M' \overline{b'_R}^c \hat{b}_R^c + \mu_{10} \overline{b'_R}^c b_R'^c$
mass mixing

$(\text{green dot}) b_R^c + (\text{green circle}) b_R''^c$

bottom quark

$M_h \overline{b'_R}^c b_R''^c$

$$m_b = \left(\begin{matrix} \text{yellow circle} \\ m_t \end{matrix} \right) \times \left(\begin{matrix} \cos \theta_b \\ \text{green dot} \end{matrix} \right) \quad \text{bottom quark mainly from } \mathbf{10} \text{ rep. } (b_R'^c)$$


The mixing between 10 and 16 can realize the hierarchy between top and bottom.

(High-scale SUSY predict small $\tan \beta$)

But it is difficult for only the mixing to achieve the all elements of realistic Yukawa coupling.

$$(\text{mixing}) = \tan \beta (V_{CKM})_{ub} \frac{m_b}{m_u} > 1$$

We add Higher-dim. operators


$$(h_{u ij} + \epsilon_{d ij}) Q_{L i} \hat{D}_{R j}^c H_d + (h_{u ij} + \epsilon_{e ij}) \hat{L}_{L i} E_{R j}^c H_d$$

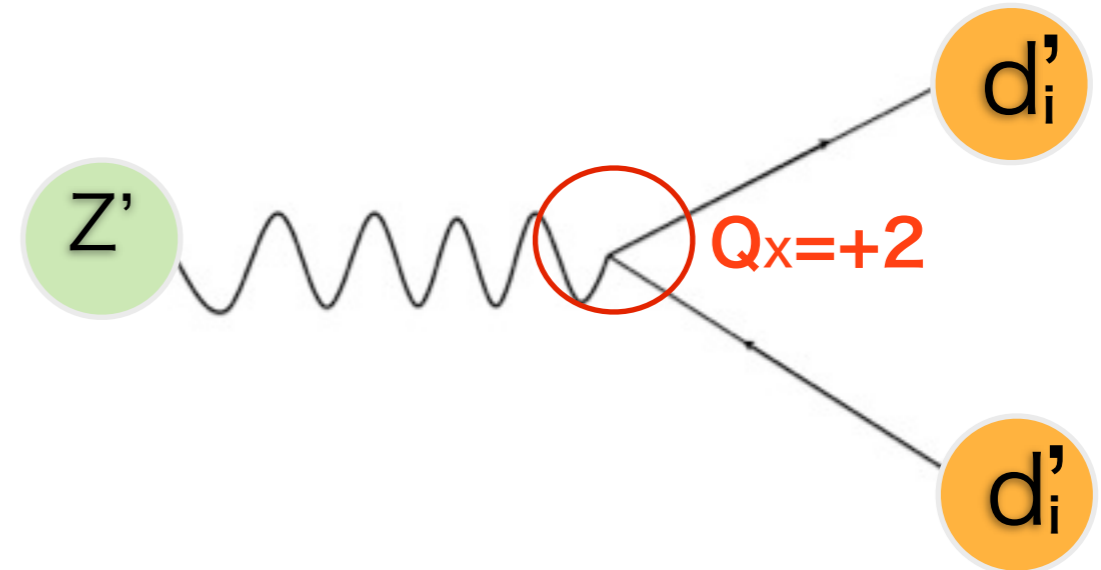
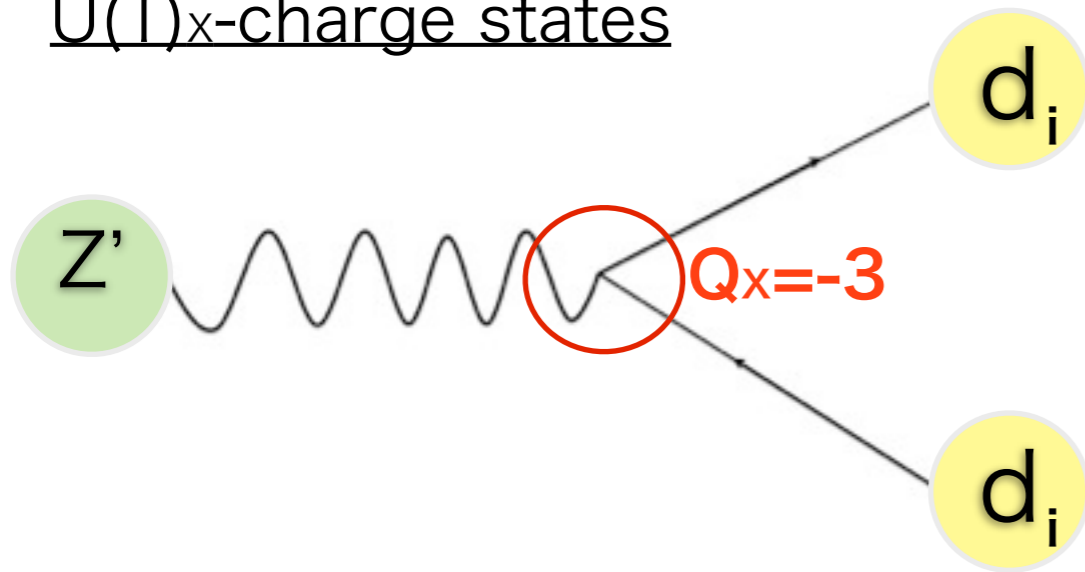
Next question

How prove this model?

Crucial point is

d_i and d'_i carry different $U(1)_x$ charges
extra

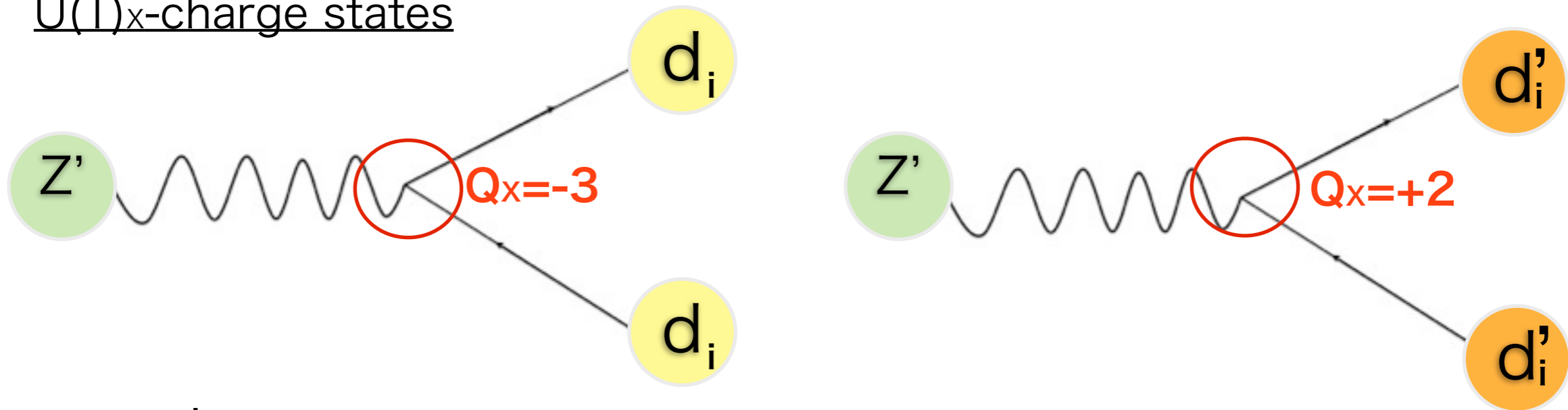
$U(1)_x$ -charge states



Crucial point is

d_i and d'_i carry different $U(1)_X$ charges
extra

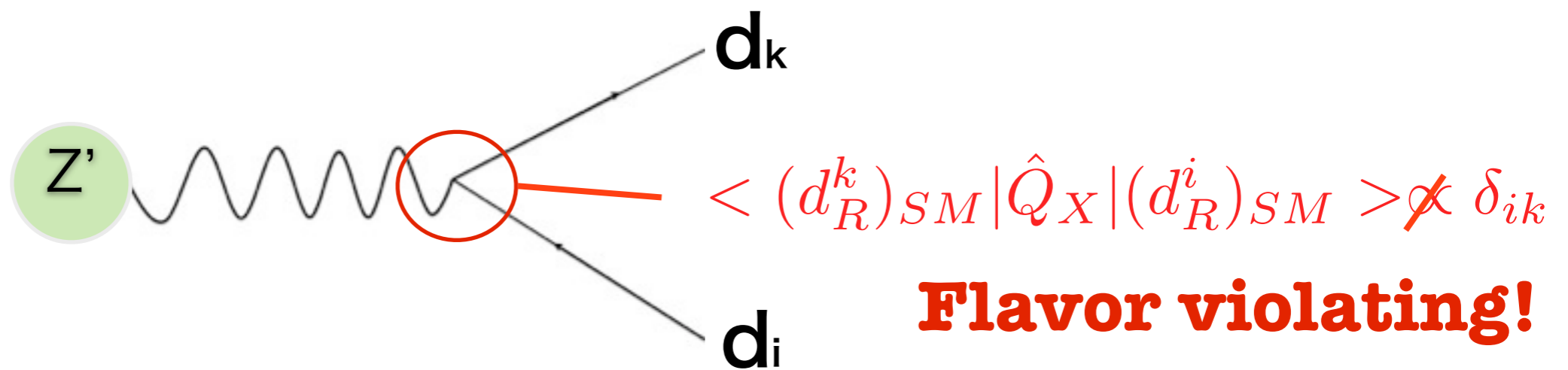
$U(1)_X$ -charge states



mass eigenstates

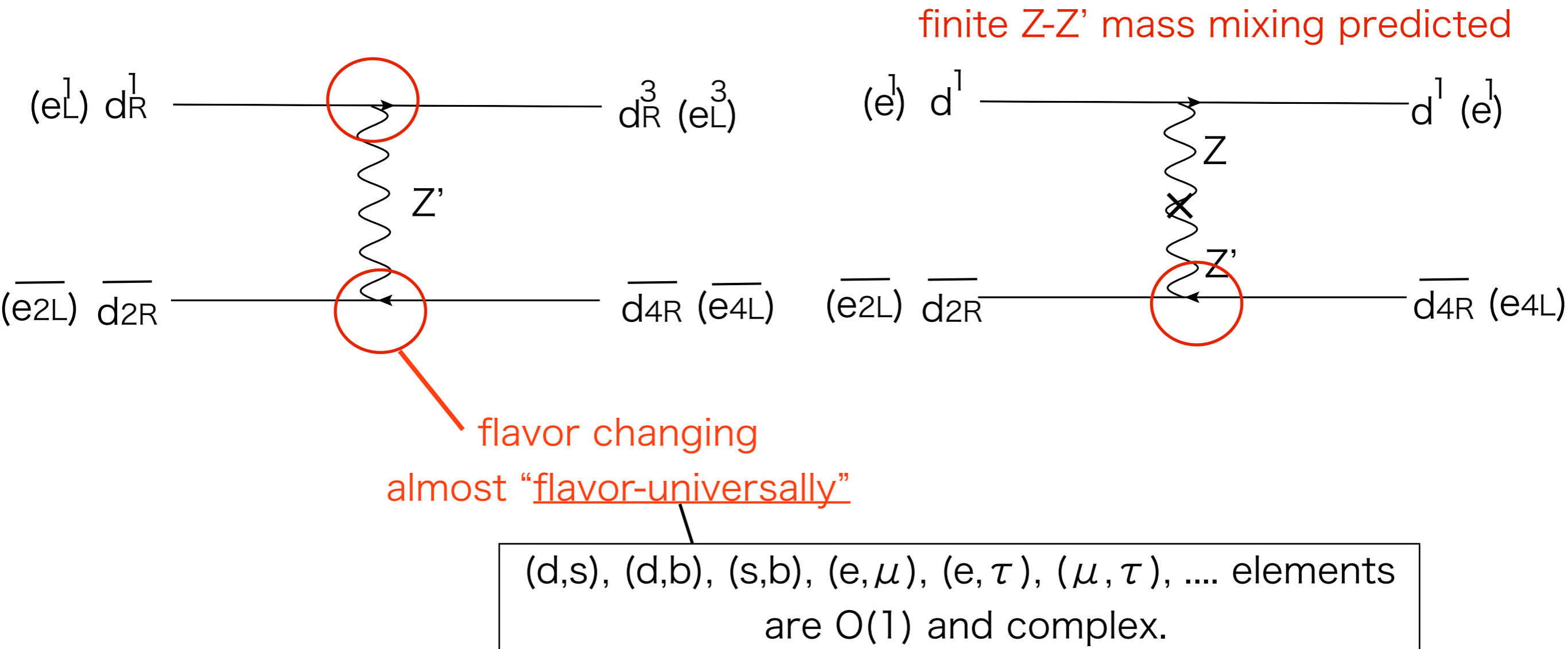
down-type quarks

$$|(d_R^i)_{SM}\rangle = U_{ij} |d_R^j(-3)\rangle + U'_{ij} |d_R^j(+2)\rangle$$



Flavor violating!

Contributions to Flavor Physics



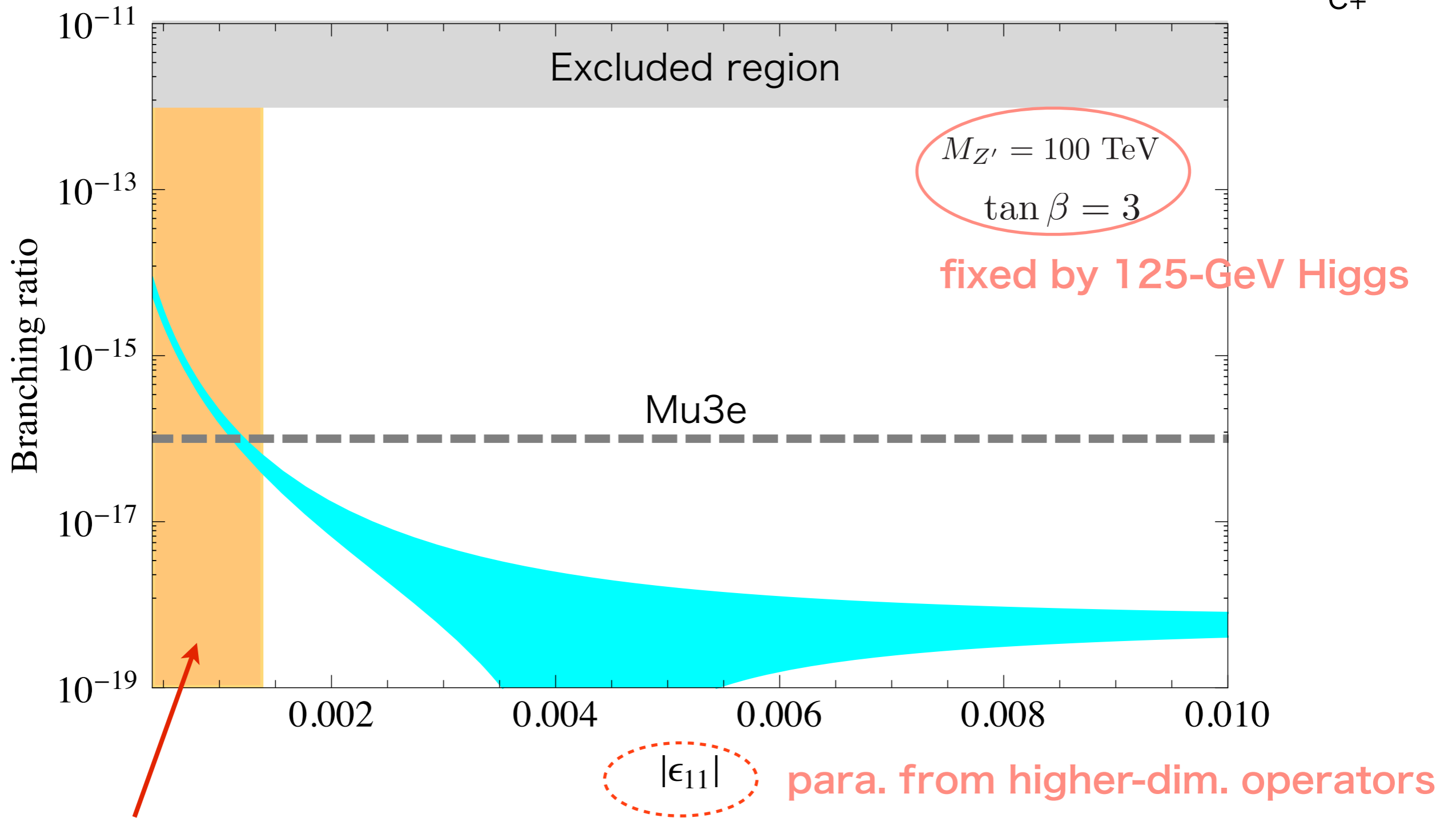
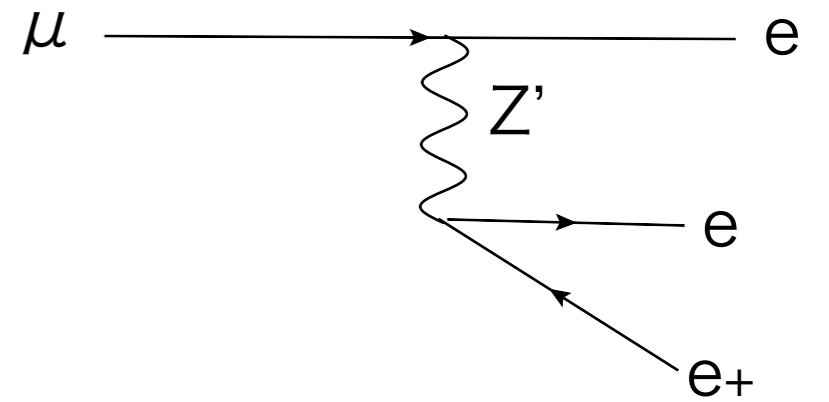
Very nice predictions

because it is usually difficult to prove GUTs.

Note that

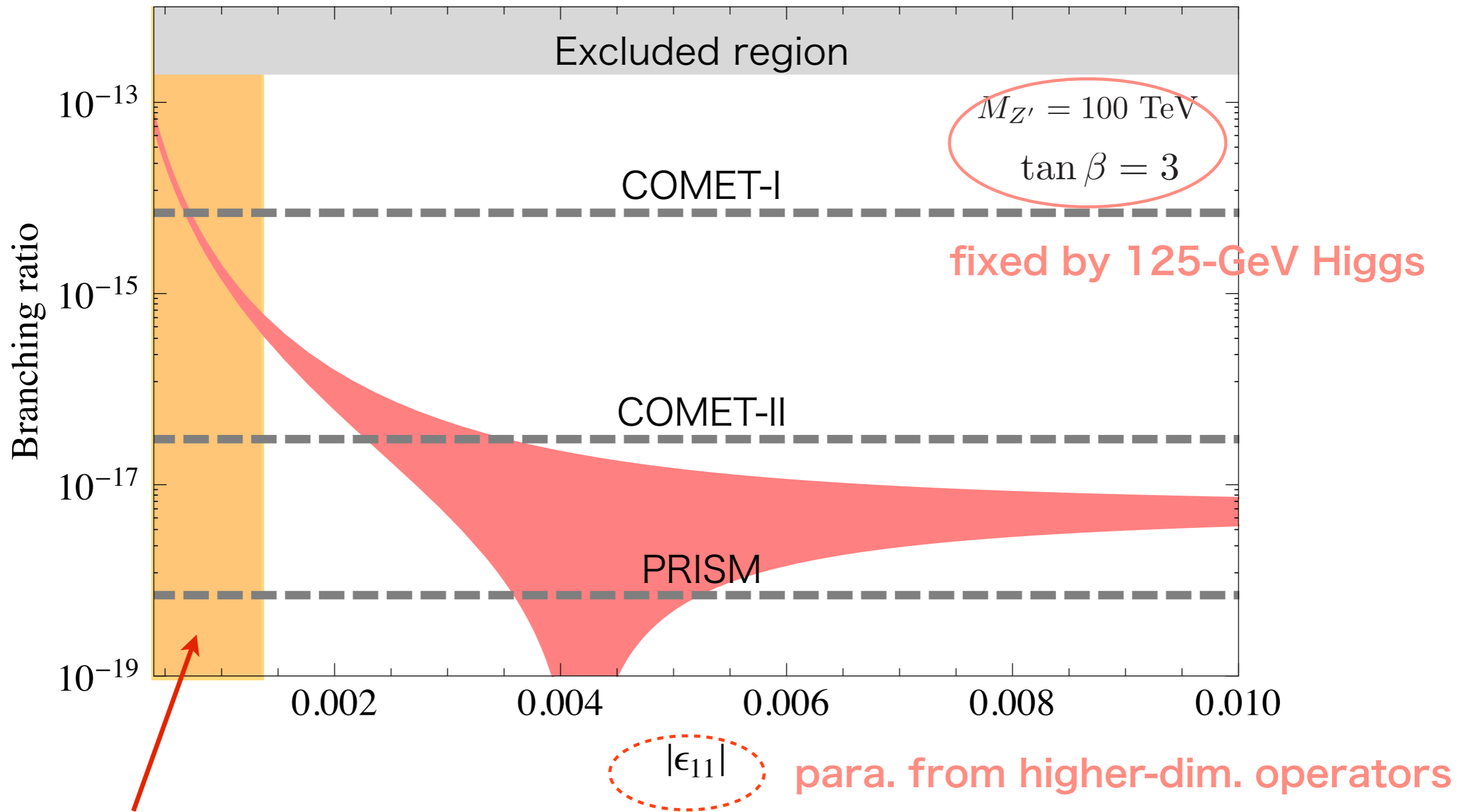
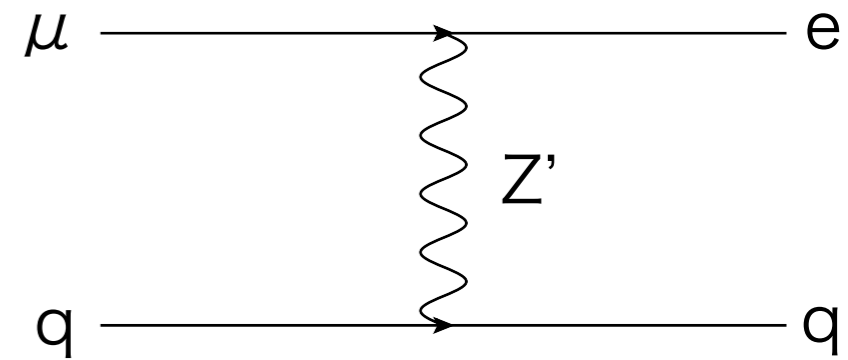
1. In order to achieve the 125 GeV Higgs,
SUSY scale is around 100TeV.
2. $U(1)'$ is assumed to be broken radiatively.
→ Z' is also around 100 TeV.
3. We have $O(1)$ flavor changing gauge coupling of Z' in all elements.
→ Important processes are K and μ physics
because of the strongest constraints and the sensitivity to the New physics.

Allowed region for $\mu \rightarrow 3e$



deviations of $K_L \rightarrow \mu \mu, \mu e, K_+ \rightarrow \pi_+ \nu \nu$ are less than O(1)%.

Allowed region for $\mu N \rightarrow e N$



deviations of $K_L \rightarrow \mu \mu, \mu e, K_+ \rightarrow \pi_+ \nu \nu$ are less than O(1)%.

Summary

- Higgs discovered! What is next?
- We are waiting for discovery of new physics.
- Flavor violations will be very good processes to find the evidence of new physics. SM predicts tiny flavor violation.

- I discussed SUSY SO(10) GUT.

125GeV Higgs mass

realistic Yukawa



flavor violating
O(100)-TeV Z'

assuming U(1)' from SO(10) is radiatively broken.

- K and μ physics are the most important.

Thank you

Backup

μ decays

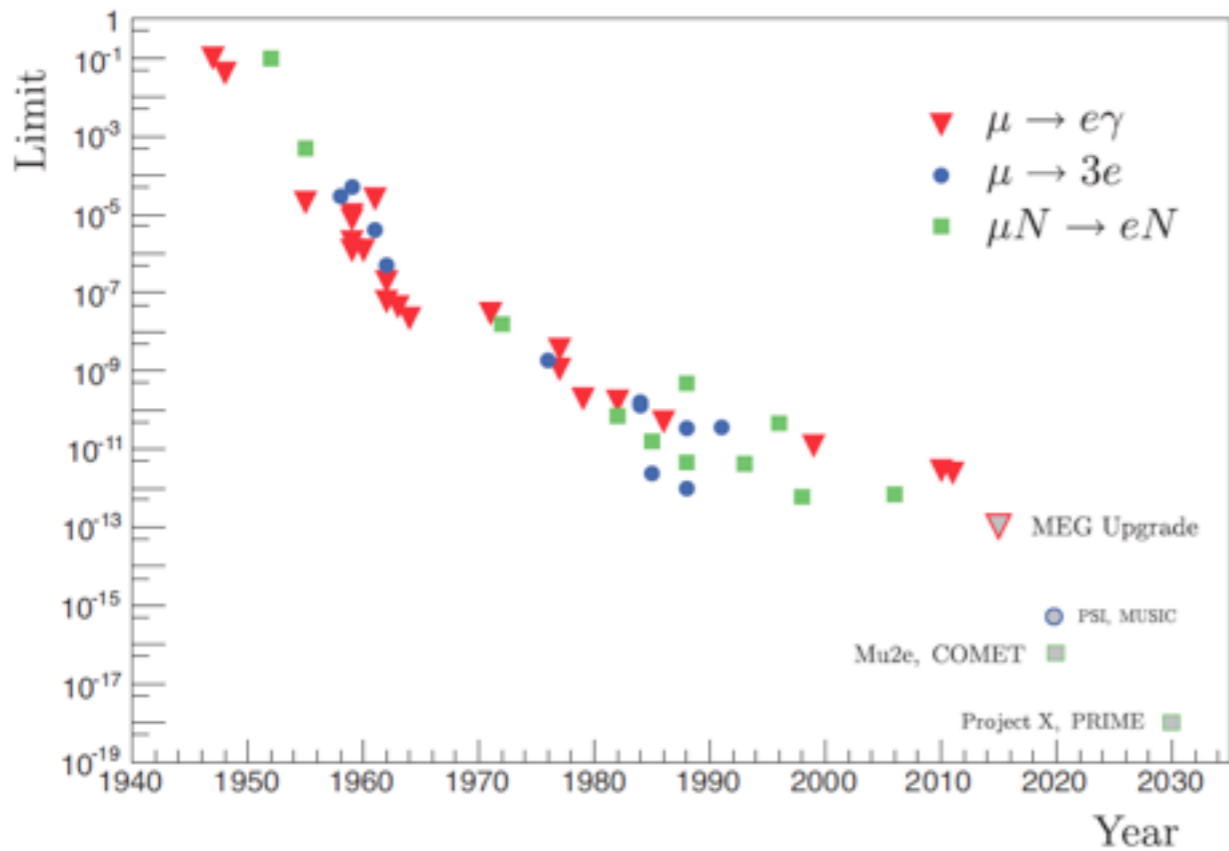
τ decay

$$\text{BR}(\tau \rightarrow l_i l_j l_k) \lesssim 10^{-8}$$

$$\text{BR}(\tau \rightarrow l_i \gamma) \lesssim 10^{-8}$$

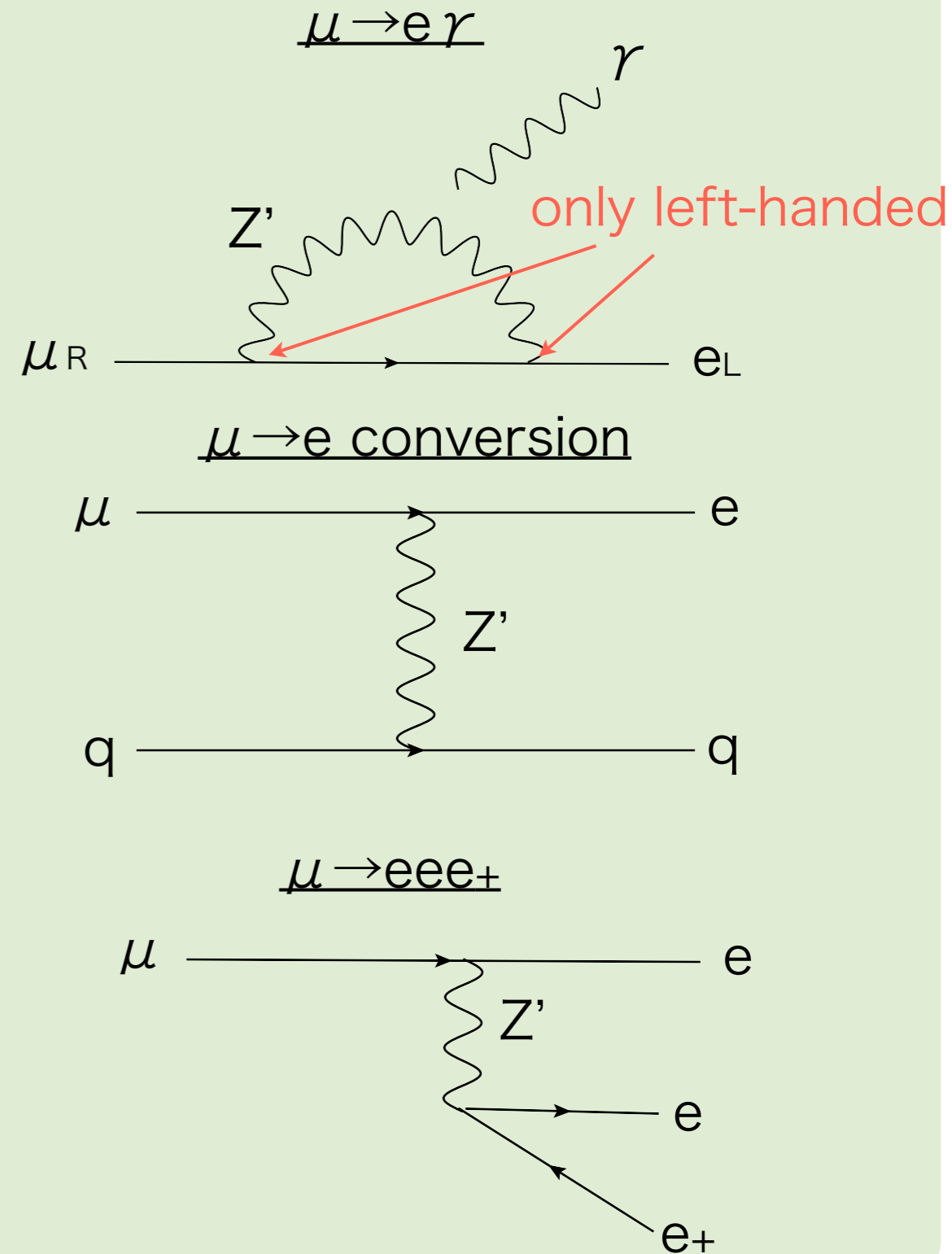
(arXiv:1001.3221;0908.2381)

μ decay



(arXiv:1307.5787)

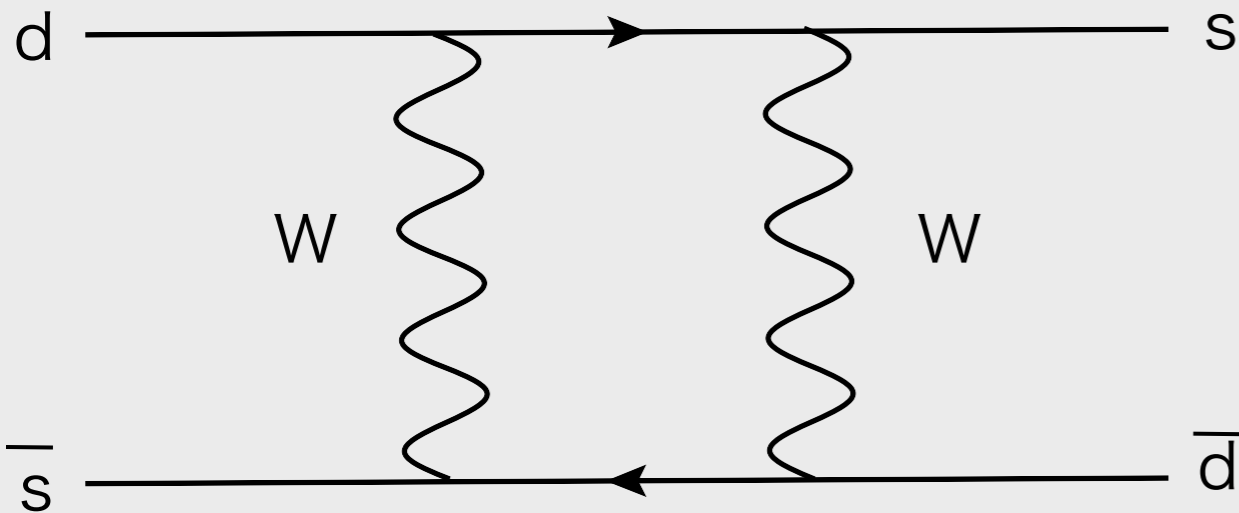
VS



$\mu \rightarrow 3e$, μ -e conversion are most important

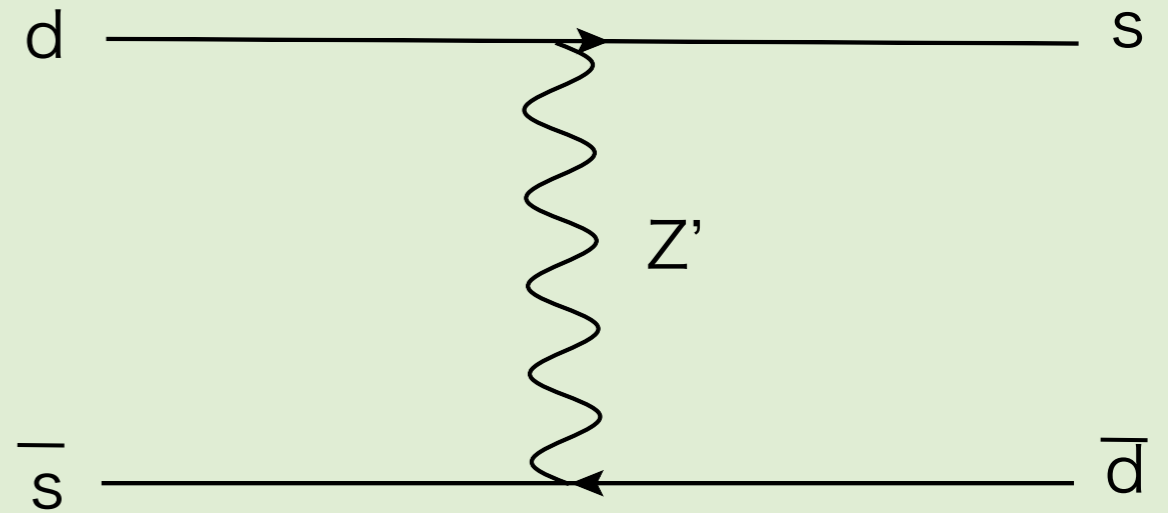
K physics

SM prediction



vs

Z' contribution



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

K system is more sensitive to new physics