LFV decays of the Higgs boson and dark matter in a new model for Dirac neutrino masses

Based on **the work in progress by KE, S. Kanemura, K. Sakurai and H. Sugiyama**

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Summary

In [7], it was shown that if the signal of h $\to \mu\tau$ is observed in future collider experiments without detecting the signal of $\tau \to \mu\gamma$, almost of all models generating neutrino masses are excluded. We construct a new model for neutrino masses and dark matter which can be survive in such a case.

1. Models generating neutrino masses

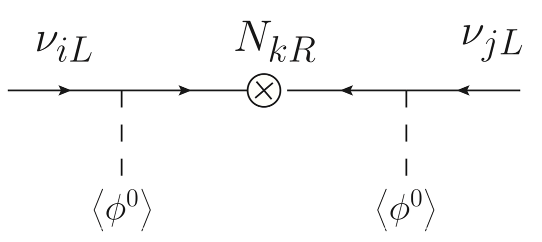
Seesaw mechanisms

	Type-I	Type-II	Type-III
New field	N_{iR}	Δ	Σ_{iR}
Spin	1/2	0	1/2
$SU(2)_L$	**1**	**3**	**3**
$U(1)_Y$	0	1	0

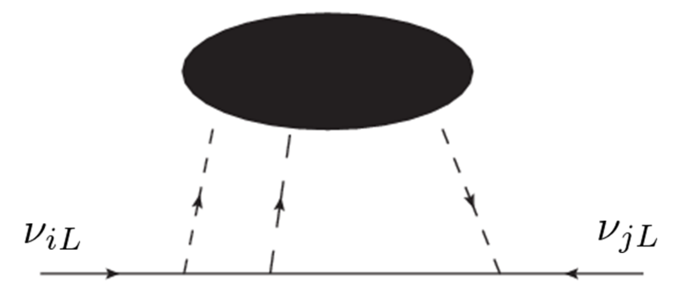
Table1. Seesaw mechanisms ($i = 1 \sim 3$)

Majorana masses are generated by the tree diagram

e.g., Type-I



Models which generate neutrino masses radiatively [1]



Loop diagram

Some models can also explain DM by a new unbroken Z_2 symmetry [2] .

Some models generate Dirac type neutrino masses [3,4]

Classification of simple models [5,6]

In the case of Majorana neutrinos [5]

Assume

1. w/o new sym.

No new fermions.

2. w/ an unbroken Z_2 sym.

	$SU(2)_L$	$U(1)_Y$	Z_2
$\psi_{\alpha R}$	1	0	Odd

($\alpha = 1 \sim 3$)

	Δ	ϕ_2	s^{++}	s_1^+	η	s_2^+	$e_i \to e_j\gamma$: e_{jL}	$e_i \to e_j\gamma$: e_{jR}
$SU(2)_L$	**3**	**2**	**1**	**1**	**2**	**1**		
$U(1)_Y$	+1	+1/2	+2	+1	+1/2	+1		
Z_2	Even				Odd			
M1			○	○			1	1
M2		○	○					1
M3			○					1
M4	○						1	
M5				○		○	1	1
M6		○				○		1
M7						○		1
M8					○		1	

Table1. Classification of models which generate Majorana neutrino masses

In the case of Dirac neutrinos [6]

	$SU(2)_L$	$U(1)_Y$	Z_2	Z'_2
ν_{iR}	**1**	0	Even	Odd

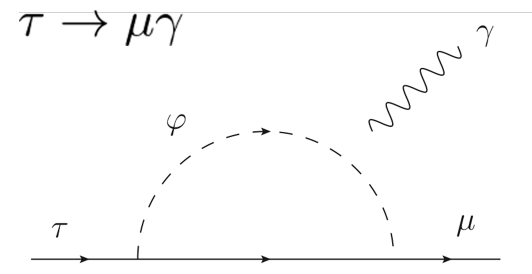
Z'_2 : Softly broken Z_2 sym.

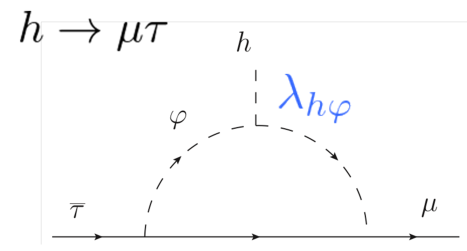
	Δ	ϕ_2	ϕ_ν	s^{++}	s_L^+	s_R^+	s^0	η	s_2^+	s_2^0	$e_i \to e_j\gamma$: e_{jL}	$e_i \to e_j\gamma$: e_{jR}
$SU(2)_L$	**3**	**2**	**2**	**1**	**1**	**1**	**1**	**2**	**1**	**1**		
$U(1)_Y$	+1	+1/2	+1/2	+2	+1	+1	0	+1/2	+1	0		
Z_2	Even							Odd				
Z'_2	Even	Even	Odd	Even	Even	Odd	Even	Even	Even	Odd		
L : Lepton #	−2	0	0	−2	−2	−2	−2	−1	−1	−1		
D1					○	○					1	1
D2	○										1	1
D3		○		○		○						2
D4				○		○						2
D5		○				○	○					1
D6						○	○					1
D7			○								1	
D8					○				○	○	1	1
D9	○								○	○	1	1
D10						○		○			1	1
D11		○				○			○			2
D12						○			○			2
D13		○				○				○		1
D14						○				○		1
D15		○							○	○		1
D16									○	○		1
D17						○		○	○		1	2
D18								○		○	1	

Table2. Classification of Models which generate Dirac neutrino masses

2. LFV decays of the Higgs boson [7]

LFV decays by Yukawa interaction with new scalar φ





When models have only one new Yukawa interaction,

$$\mathrm{Br}(h \to \mu\tau) \sim 10^{-2}\,\mathrm{Br}(\tau \to \mu\gamma)$$

If $h \to \mu\tau$ is observed w/o $\tau \to \mu\gamma$, M2 ∼ 4, M6 ∼ 8 and D5, D6, D13 ∼ 16, D18 and Type-I, III seesaw mechanisms are excluded.

When two kinds of scalars couple with left (right)-handed lepton,

$$\mathrm{Br}(\tau \to \mu\gamma) \propto \left|\frac{(Y_1^\dagger Y_1)_{\tau\mu}}{m_{\varphi_1}^2} + \frac{(Y_2^\dagger Y_2)_{\tau\mu}}{m_{\varphi_2}^2}\right|^2 \ll \left|\frac{(Y_1^\dagger Y_1)_{\tau\mu}}{m_{\varphi_1}^2}\right|^2$$

Can be cancelled

$$\mathrm{Br}(h \to \mu\tau) \propto \left|\lambda_{h\varphi_1}\frac{(Y_1^\dagger Y_1)_{\tau\mu}}{m_{\varphi_1}^2} + \lambda_{h\varphi_2}\frac{(Y_2^\dagger Y_2)_{\tau\mu}}{m_{\varphi_2}^2}\right|^2 \simeq \left|\lambda_{h\varphi_1}\frac{(Y_1^\dagger Y_1)_{\tau\mu}}{m_{\varphi_1}^2}\right|^2$$

Signs of $\lambda_{h\varphi_1}$ and $\lambda_{h\varphi_2}$ are different, the cancellation occur in only $\tau \to \mu\gamma$.

⇨ D3, D4, D11, D12, D17

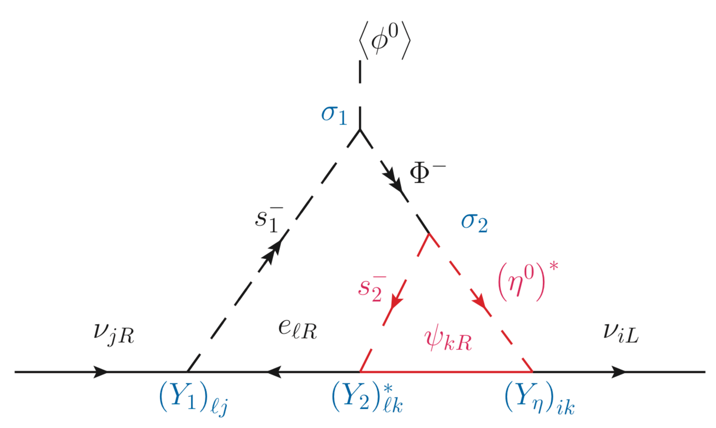
In D3, D4, D11, D12

$$(m_\nu)_{ij} = m_{e_i}(Y\cdots)_{ij} \qquad Y_{ek} \gg Y_{\mu k} > Y_{\tau k}$$

If $h \to \mu\tau$ is observed w/o $\tau \to \mu\gamma$, only D17 may survive in simple models generating neutrino masses.

3. Our model

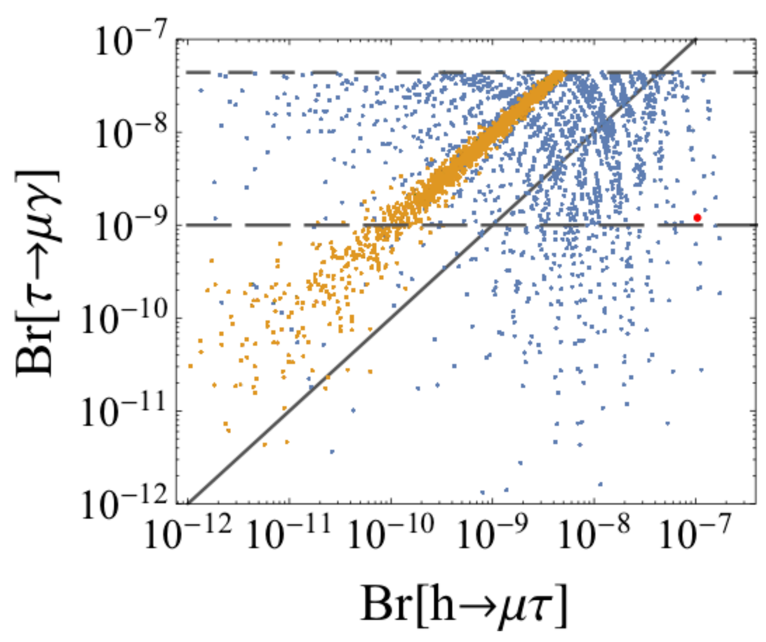
	ν_{iR}	$\psi_{\alpha R}$	Φ	s_1^+	η	s_2^+
Spin J	1/2	1/2	1	1	1	1
$SU(2)_L$	1	1	2	1	2	1
$U(1)_Y$	0	0	3/2	1	1/2	1
Z'_2	−	+	(+)	−	+	+
L	1	0	−2	−2	−1	−1
Z_2	+	−	+	+	−	−



DM candidate : $\psi_{\alpha R}$

$$\mathcal{L} = (Y_1)_{ij}\,\overline{e_{iR}^c}\nu_{jR}s_1^+ + (Y_2)_{i\alpha}\,\overline{e_{iR}^c}\psi_{\alpha R}s_2^+ + (Y_\eta)_{i\alpha}\,\overline{L_{iL}}\eta^c\psi_{\alpha R} + \mathrm{h.c.}$$

$$V \ni \sigma_1\Phi^\dagger\phi s_1^+ + \sigma_2\Phi^\dagger\eta s_2^+$$



Orange points

$\lambda_{hs_1} > 0, \lambda_{hs_2} > 0$

Blue points

$\lambda_{hs_1} > 0, \lambda_{hs_2} < 0$

Red points

Our benchmark scenario

(DM : ψ_{1R})

References

[1] A. Zee, Phys. Lett. B 93, (1980) 389. [2] L. M. Krauss, S. Nasri and M. Trodden, Phys. Rev. D 67, 085002 (2003). [3] S. Nasri and S. Moussa, Mod. Phys. Lett. A 17 (2002) 771. [4] S. Kanemura, K. Sakurai and H. Sugiyama, Phys. Rev. D 96 (2017) no.9, 095024. [5] S. Kanemura and H. Sugiyama, Phys. Lett. B 753 (2016) 161. [6] S. Kanemura, K. Sakurai and H. Sugiyama, Phys. Lett. B 758 (2016) 465. [7] M. Aoki, S. Kanemura, K. Sakurai, H. Sugiyama, Phys. Lett. B 763 (2016) 352.