High dimensional neutrino masses

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G. Anamiati, O. Castillo-Felisola, R. M. Fonseca, J. C. Helo and M. Hirsch, "High-dimensional neutrino masses," in phase of publication, arXiv:1806.07264

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Preliminaries
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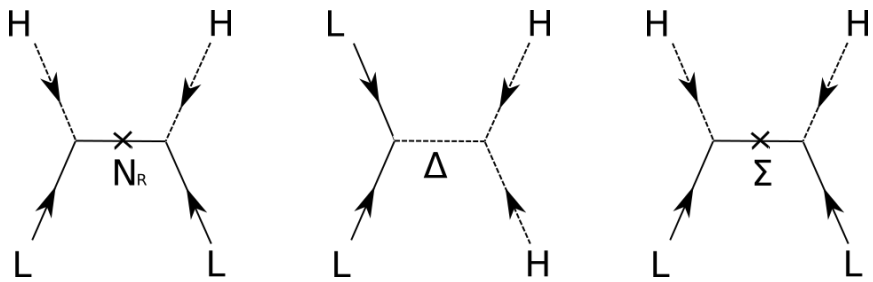
Conclusion

Weinberg operator

The Weinberg operator:

$$\delta\mathcal{L} = \frac{1}{2\Lambda}(\bar{L}^c_\alpha \hat{H}^*)(\hat{H}^\dagger L_\beta)$$

Three ways to generate the $d = 5$ operator at tree level.
type I, type II and type III see-saw mechanism:



Warning!!!

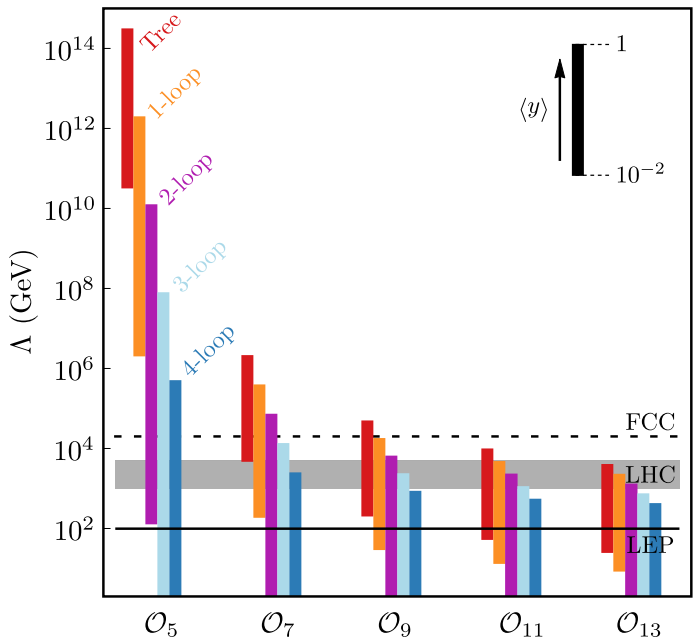
$$m_\nu \propto \frac{v^2}{\Lambda}$$

$\Lambda \sim 10^{14}$ GeV $\rightarrow$ too large to be tested.

Majorana neutrinos

For Majorana neutrinos, one can write

$$m_\nu \propto \epsilon \cdot \left(\frac{1}{16\pi^2}\right)^n \cdot \left(\frac{v}{\Lambda}\right)^{d-5} \cdot \frac{v^2}{\Lambda}$$



Genuine models

Already studied in the literature:

- $d = 5$ neutrino masses at 1-loop, 2-loop and 3-loop
- $d = 7$ neutrino masses at tree level
- $d = 7$ neutrino masses at 1-loop

So, we considered all tree-level decompositions of the $d = 9$, $d = 11$ and $d = 13$ neutrino mass operators. There is a single $\Delta L = 2$ neutrino mass operator of dimension d, which is always of the following form:

$$\mathcal{O}^d \propto LLHH(H^\dagger H)^{(d-5)/2}.$$

Genuine models:

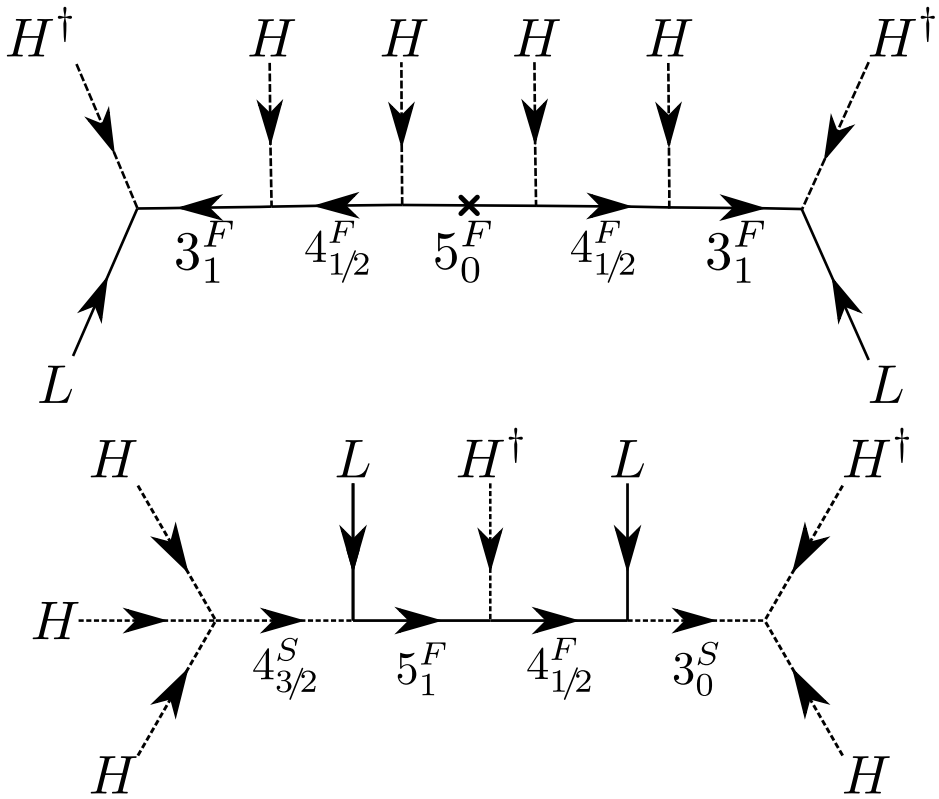
those models which provide the dominant contribution to the neutrino mass matrix, assuming no extra symmetries beyond the standard model ones.

Classification

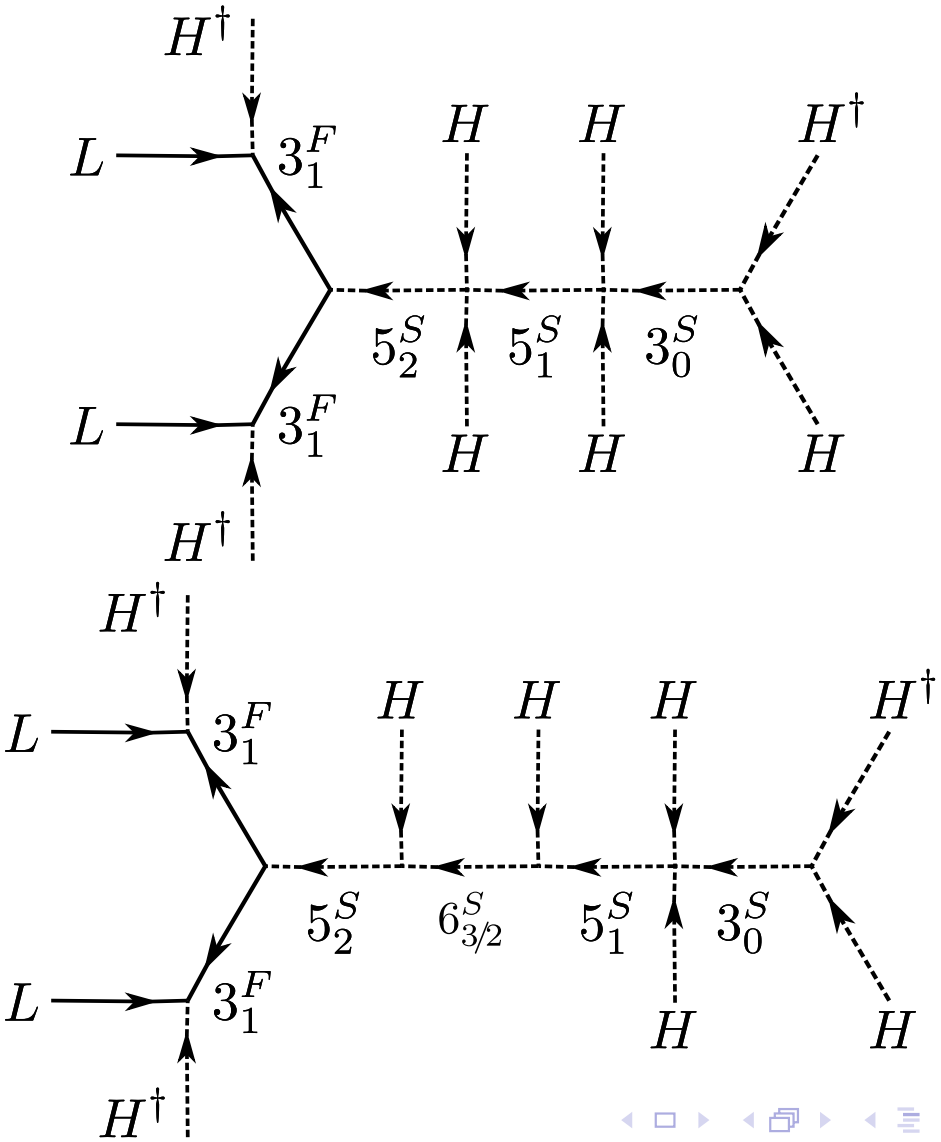
We have found all genuine neutrino mass tree-level topologies, diagrams and models for these operators:

- $d = 9 \rightarrow 18$ topologies and 66 diagrams.
- $d = 11 \rightarrow 92$ topologies and 504 diagrams.
- $d = 13 \rightarrow 576$ topologies and 4199 diagrams.
- a total of 10 genuine models: 2 models at $d = 9$ and $d = 11$ each, and 6 models at $d = 13$.

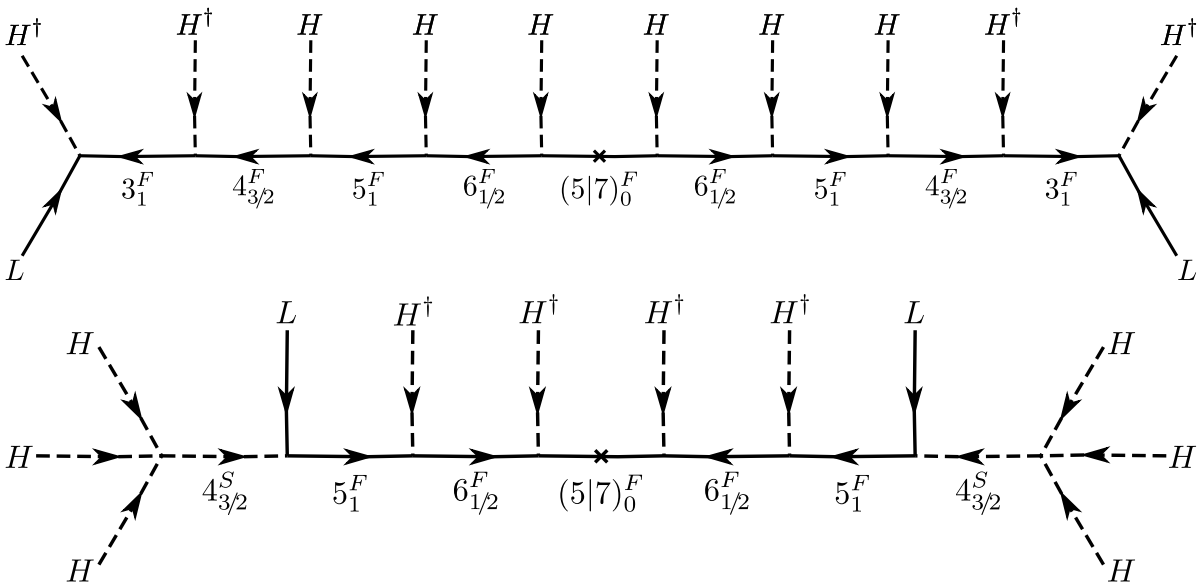
d=9


$H^\dagger$
H
H
H
H
$H^\dagger$
3_1^F
$4_{1/2}^F$
5_0^F
$4_{1/2}^F$
3_1^F
L
L
H
L
$H^\dagger$
L
$H^\dagger$
H
$4_{3/2}^S$
5_1^F
$4_{1/2}^F$
3_0^S
H
H

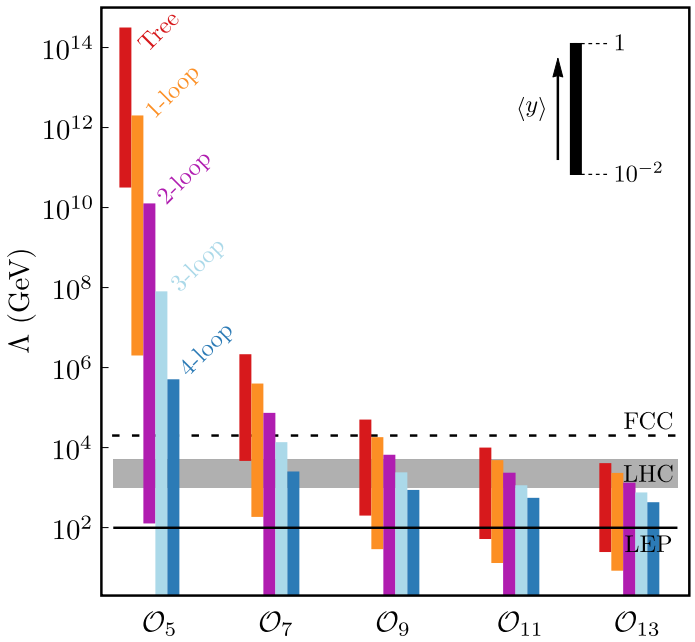
d=11


$H^\dagger$
L
3_1^F
H
H
$H^\dagger$
5_2^S
5_1^S
3_0^S
L
3_1^F
H
H
H
$H^\dagger$
$H^\dagger$
$H^\dagger$
L
3_1^F
H
H
H
$H^\dagger$
5_2^S
$6_{3/2}^S$
5_1^S
3_0^S
L
3_1^F
H
H
$H^\dagger$

d=13



Two more model variations for the first diagram (top row): Replace either one or both of the $\mathbf{4}^F_{3/2}$ by a $\mathbf{4}^F_{1/2}$ (rearranging H and $H^\dagger$ correspondingly). The models with $\mathbf{4}^F_{1/2}$ are only genuine with a $\mathbf{7}^F_0$.

Conclusion

We have discussed the systematic deconstruction of the $d = 9$, $d = 11$ and $d = 13$ neutrino mass operators at tree-level. We have found total of 10 genuine models: 2 models at $d = 9$ and $d = 11$ each, and 6 models at $d = 13$.