# One-loop finite corrections to seesaw neutrino masses

D. Aristizabal Sierra
IFPA, AGO Department, Université de Liége, Belgium

## Neutrino masses

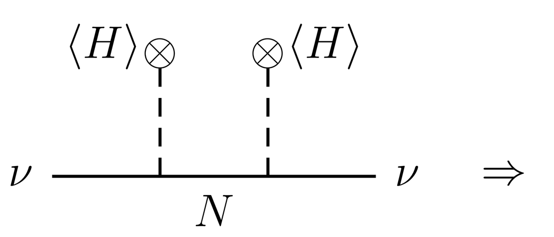
Neutrino oscillation experiments have firmly established neutrinos have tiny but non-zero masses and that the mixing angles in the leptonic sector are in sharp contrast with the small mixing that characterizes the quark sector.
Neutrino oscillation parameters arise from global fits to data coming from different sources[1].

| Parameter | Best fit | $2\sigma$ | $3\sigma$ |
|---|---|---|---|
| $\Delta m^2_{21}$ $[10^{-5}\text{eV}^2]$ | $7.59^{+0.23}_{-0.18}$ | 7.22-8.03 | 7.03-8.27 |
| $\lvert\Delta m^2_{31}\rvert$ $[10^{-3}\text{eV}^2]$ | $2.40^{+0.12}_{-0.11}$ | 2.18-2.64 | 2.07-2.75 |
| $\sin^2\theta_{12}$ | $0.318^{+0.019}_{-0.016}$ | 0.29-0.36 | 0.27-0.38 |
| $\sin^2\theta_{23}$ | $0.50^{+0.07}_{-0.06}$ | 0.39-0.63 | 0.36-0.67 |
| $\sin^2\theta_{13}$ | $0.013^{+0.013}_{-0.009}$ | $\leq 0.039$ | $\leq 0.053$ |

Table 1: Current best-fit values with $1\sigma$ errors and $2\sigma$ and $3\sigma$ intervals for the three flavor neutrino oscillation parameters from global data including solar, atmospheric, reactor and accelerator experiments

## Standard seesaw

The standard model fermion sector is extended with three electroweak fermionic singlets, $N_i$. The light neutrino mass matrix arises via a 5-dim operator mediated by the new the new fermioinc singlets



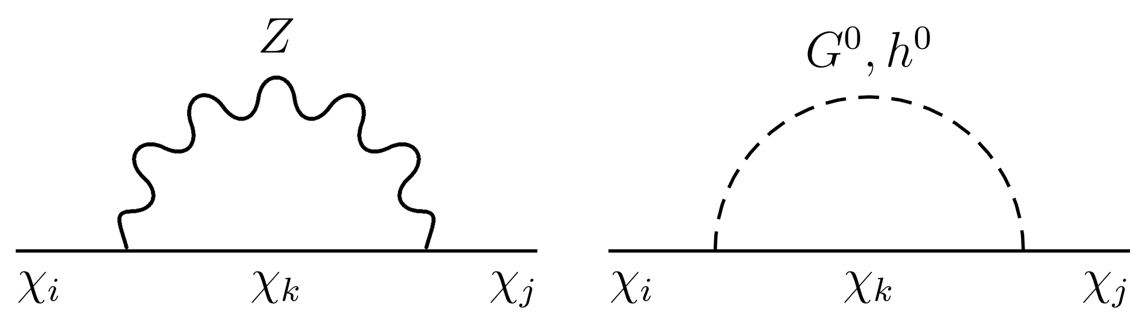

$$\Rightarrow \quad \boldsymbol{m_\nu^{\text{eff}}} = \boldsymbol{m_\nu^{(0)}} = v^2 \boldsymbol{\lambda}^T \hat{\boldsymbol{M}}_{\boldsymbol{N}}^{-1}\boldsymbol{\lambda}$$

The new Yukawa couplings can be parametrized according to the Casas-Ibarra parametrization in which neutrino data is used as an input:

$$\boldsymbol{\lambda} = \frac{\hat{\boldsymbol{M}}_{\boldsymbol{N}}^{\mathbf{1/2}}\ \boldsymbol{R}\ \hat{\boldsymbol{m}}_{\boldsymbol{\nu}}^{\mathbf{1/2}}\ \boldsymbol{U}^{\dagger}}{v}$$

## One-loop corrections

Arise from one-loop self-energy diagrams mediated by heavy neutrinos




Including these corrections the neutrino mass matrix becomes

$$\boldsymbol{m_\nu^{\text{eff}}} = \boldsymbol{m}_\nu^{(0)} + \boldsymbol{m}_{\boldsymbol{\nu}}^{(1)} = -v^2\boldsymbol{\lambda}^T\,\hat{\boldsymbol{M}}_{\boldsymbol{N}}^{\mathbf{-1}}\,\boldsymbol{\lambda} + \boldsymbol{\delta M_L}$$

with the loop correction given by

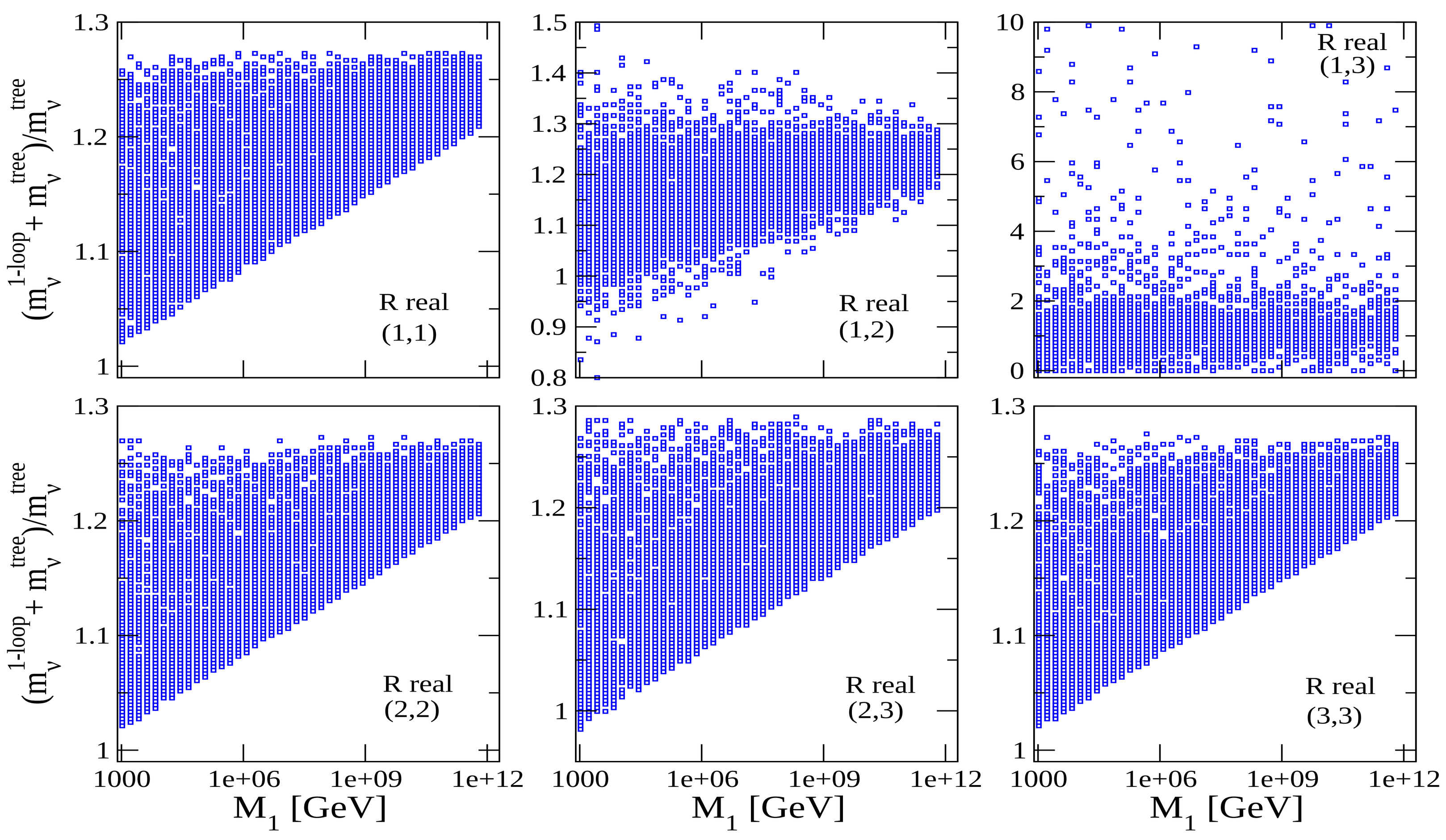
$$\boldsymbol{\delta M_L} = v^2\boldsymbol{\lambda}^{\boldsymbol{T}}\hat{\boldsymbol{M}}_{\boldsymbol{N}}^{\mathbf{-1}}\left\{\frac{g^2}{64\pi^2 M_W^2}\left[m_h^2\ln\left(\frac{\hat{\boldsymbol{M}_{\boldsymbol{N}}}^2}{m_h^2}\right) + 3M_Z^2\ln\left(\frac{\hat{\boldsymbol{M}_{\boldsymbol{N}}}^2}{M_Z^2}\right)\right]\right\}\boldsymbol{\lambda}$$

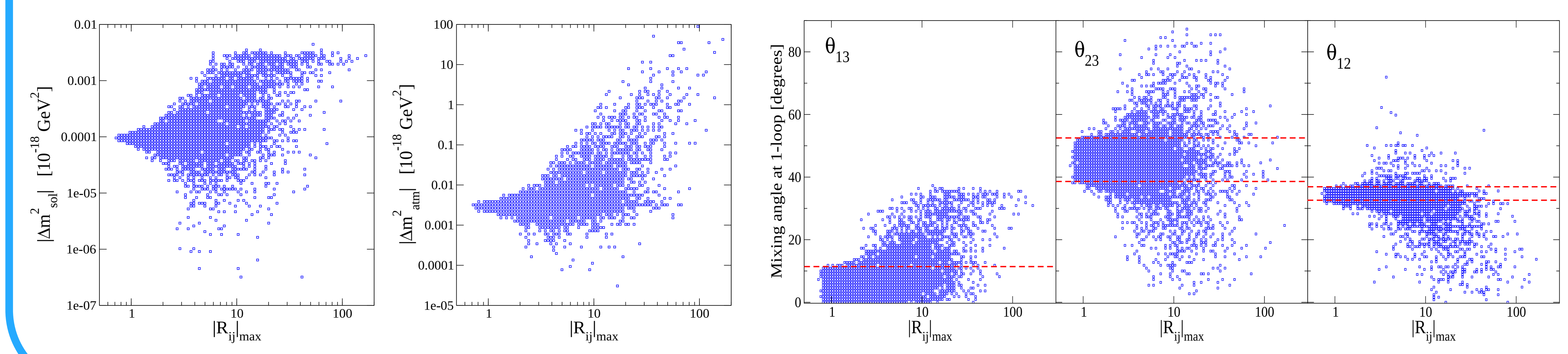
## Importance of the corrections

The relevance of these corrections depend on the region of parameter space in which neutrino masses and mixing angles are calculated. Using the Casas-Ibarra parametrization the discussion can be divided in two cases: $\boldsymbol{R}$ real and $\boldsymbol{R}$ complex for either normal or inverted hierarchy ($m_{\nu_1} \ll m_{\nu_{2,3}}$ or $m_{\nu_3} \ll m_{\nu_{1,2}}$) [2].

### Normal hierarchy: $\boldsymbol{R}$ real

The results are displayed in the figure at the right. Apart from the element (1,3) all the corrections increase as the lightest fermionic singlet mass $M_1$ increases as well. They can reach values up to order 30% (50% for the (1,2) entry). Corrections to the (1,3) entry can be much more larger as this element, at the tree-level, can be very small and so it can receive large fractional corrections.



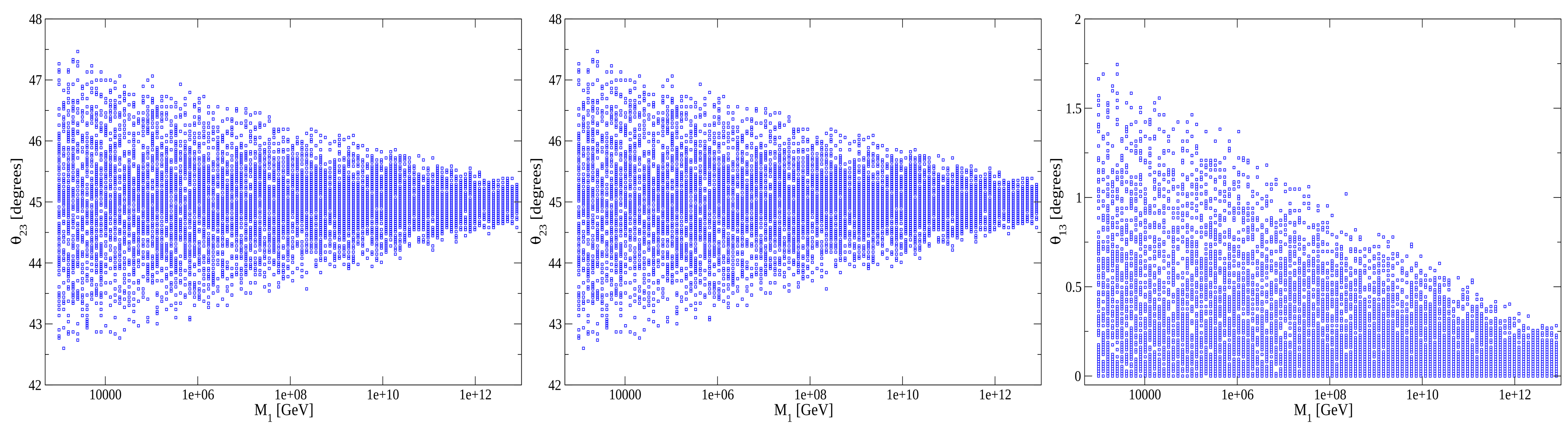




### Normal hierarchy: $\boldsymbol{R}$ complex

This case covers fine-tuned models which due to the 1-loop corrections are barely reconciliable with neutrino data. The figure to the left shows the dependence of the light neutrino observables with the largest element of the matrix $\boldsymbol{R}$.

## Specific example: TBM

The TriBiMaximal (TBM) mixing pattern [3] ($\theta_{12} = 35.3°$, $\theta_{23} = 45°$ and $\theta_{13} = 0°$) is a well experimentally motivated scenario to study the influence of the 1-loop finite corrections on the different neutrino mixing angles.
Taking the TBM as input at tree-level one can analyse the impact of the corrections on this neutrino mixing pattern. The results are displayed in the figures at the right.




## References

[1] T. Schwetz, M. A. Tortola, J. W. F. Valle. New J. Phys. **10**, 113011 (2008).

[2] D. Aristizabal Sierra, C. E. Yaguna, Accepted for publication in JHEP, arXiv:1106.3587 [hep-ph].

[3] P. F. Harrison, D. H. Perkins and W. G. Scott, Phys. Lett. B **530**, 167 (2002).

## Conclusions

1-loop finite corrections to the seesaw neutrino mass matrix can be sizable. Indeed, our findings show that fine-tuned models are barely reconcilible with data once these corrections are taken into account. As an example we have analysed the impact of these corrections on the TBM mixing pattern. Specially important are the corrections to the reactor angle which we have shown can be as large as $\sim 2°$.
Due to their size and importance these corrections must necessarily be taken into account in the study and analysis of seesaw models.