Higgs Decays in the Low Scale Type I See-Saw Model

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Description of the model

- $$\mathcal{L}_\nu = -\overline{\nu_{\ell L}}(M_D)^*_{\ell a}\nu_{aR} - \frac{1}{2}\overline{\nu^C_{aL}}\,(M_N)^*_{ab}\,\nu_{bR} \;+\; \text{h.c.}\,, \tag{1}$$

  M_N is the $k \times k$ Majorana mass matrix of the RH neutrinos ν_{aR} and M_D is a $3 \times k$ neutrino Dirac mass matrix

- If the RH neutrinos masses are in the range (100 - 1000 GeV), in order to reproduce the correct neutrino masses it is necessary that:

$$|(m_\nu)_{\ell'\ell}|\,, \simeq |\sum_k (RV)^*_{\ell' k}\; M_k\; (RV)^\dagger_{k\ell}| \lesssim 1\ \text{eV}\ \ell, \ell = e, \mu, \tau\,. \tag{2}$$

  where $R \approx (M_D\, M_N^{-1})^*$ and V as the unitary matrix that diagonalizes the RH neutrino mass matrix, $M_N = V^* diag(M_1, M_2, ...)V^\dagger$,

- This can be accomplished if there are two right handed neutrinos that satisfy:

$$(RV)_{\ell 2} \quad \approx \quad \pm i\,(RV)_{\ell 1}\sqrt{\frac{M_1}{M_2}}\,,\ \ell = e,\mu,\tau\,, \tag{3}$$

  which naturally occurs if there exists an approximately conserved lepton charge .
  A. Ibarra, E. Molinaro and S. T. Petcov (2010)

- Constraints from $(\beta\beta 0)_{0\nu}$-decay rate imply $\left(\frac{M_2}{M_1} - 1\right) \lesssim 10^{-3}$.
- The SM is effectively extended by the addition of 2 RH neutrinos that form a Pseudo-Dirac heavy Neutrino.

Parameters of the Model

- The combination RV determines the mixing between the Pseudo-Dirac Neutrino and the $W^{\pm}$, Z and H.
- Neutrino oscillations imply:

$$\left|(RV)_{\ell 1}\right|^2 = \frac{1}{2}\frac{y^2 v^2}{M_1^2}\frac{m_3}{m_2+m_3}\left|U_{\ell 3} + i\sqrt{m_2/m_3}U_{\ell 2}\right|^2 , \quad \text{NH}, \tag{4}$$

$$\left|(RV)_{\ell 1}\right|^2 = \frac{1}{2}\frac{y^2 v^2}{M_1^2}\frac{m_2}{m_1+m_2}\left|U_{\ell 2} + i\sqrt{m_1/m_2}U_{\ell 1}\right|^2 \text{IH}, \tag{5}$$

$$(RV)_{\ell 2} = \pm i\,(RV)_{\ell 1}\sqrt{\frac{M_1}{M_2}}\,, \ \ell = e, \mu, \tau\,, \tag{6}$$

for some Yukawa coupling y.

New Higgs Decay Channels

In this scenario, the Higgs boson can decay into a light and the heavy pseudo-Dirac neutrino provided $M_1 < m_h$.

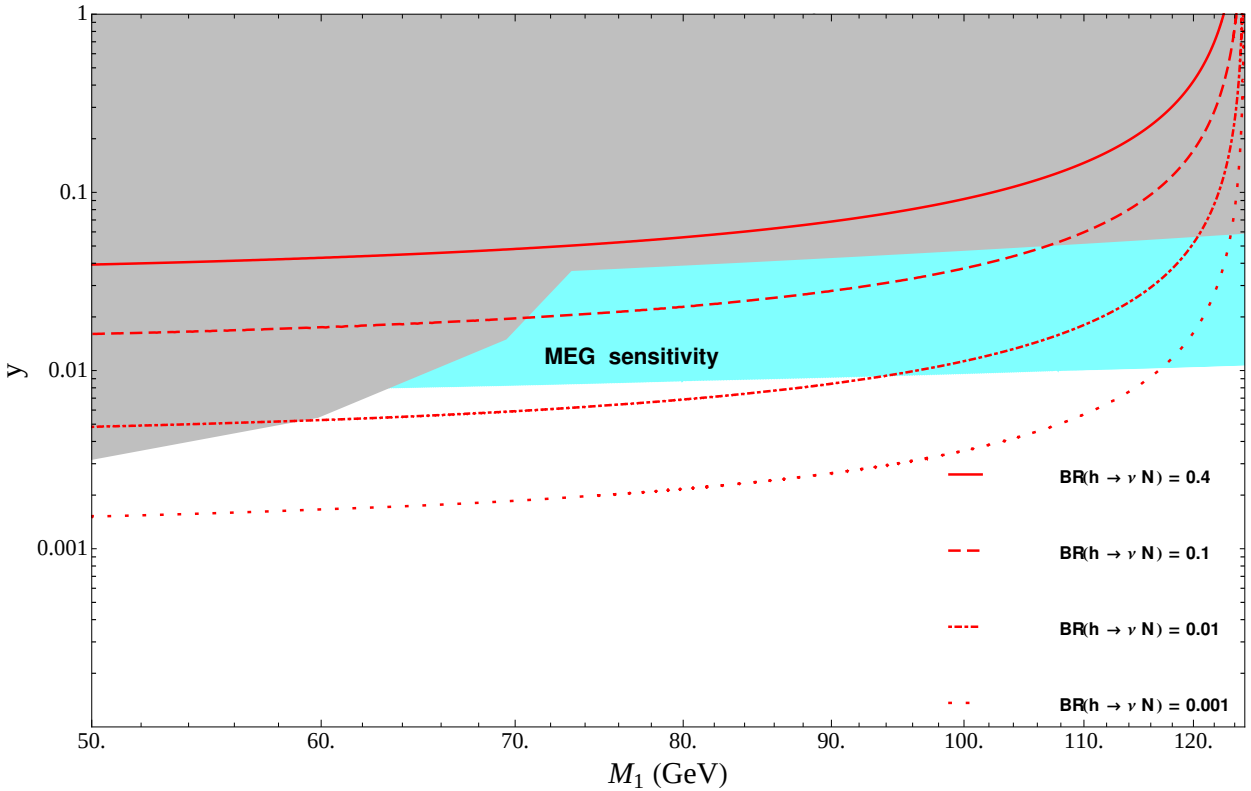


Figure: (a) Values of y probed by Higgs decays into N_{PD} for $m_h = 125$ GeV (solid lines). The gray region is excluded by LEP2 data and searches of lepton flavor violation. The cyan area represents the region of the parameter space which can be probed by the MEG experiment with the projected sensitivity to BR$(\mu \to e\gamma) = 10^{-13}$.

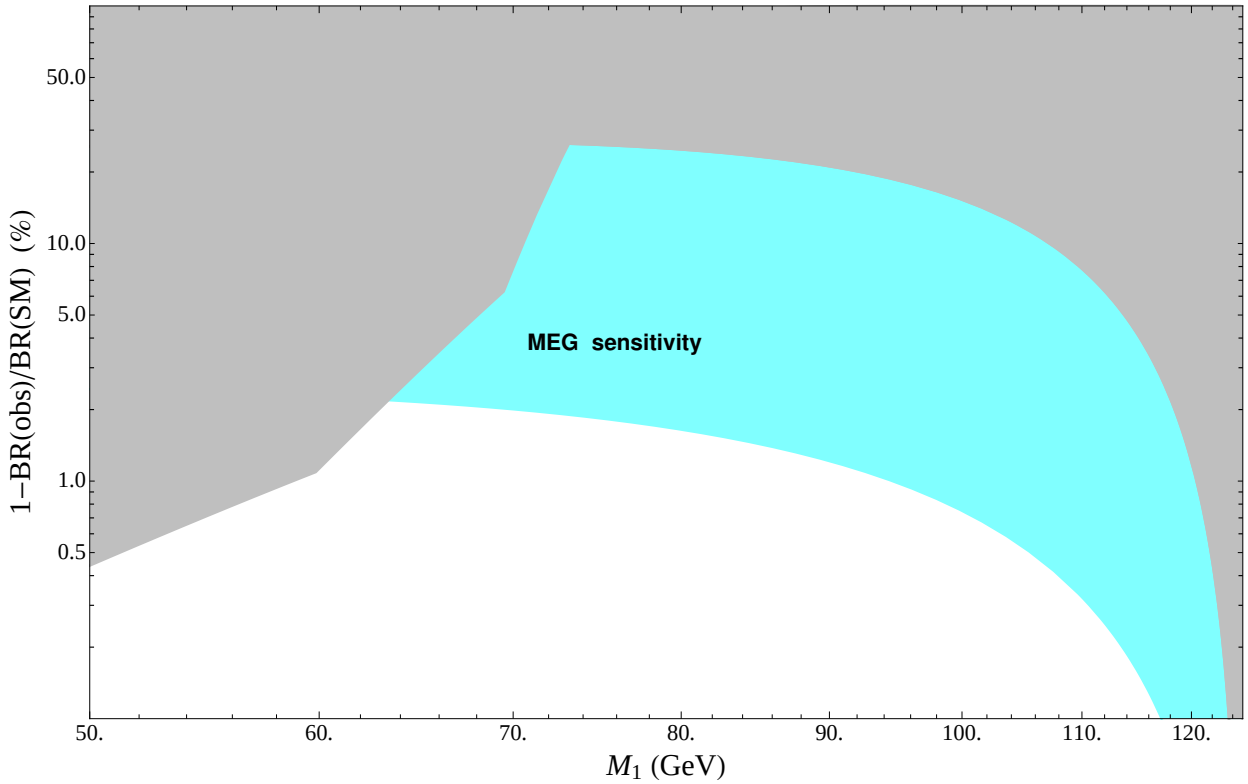


Figure: (b)Relative reduction of the Standard Model Higgs boson branching fraction to a generic channel for $m_h = 125$ GeV. The color convention is the same as in the previous plot.

Searches for the New Channel $h \to \nu N$ at LHC

- The presence of a new Higgs boson decay channel, does not modify the SM Higgs boson production mechanisms at LHC,
- We consider explicitly the final state with the heavy neutrino subsequently decaying into a charged lepton and an on-shell W boson, which in turn decays hadronically. The processes of interest in our analysis are then:

$$p\,p \;\to\; h \;\to\; \nu_{\alpha L}\,\ell^{+}_{\beta}\,j\,j\,,\bar{\nu}_{\alpha L}\,\ell^{-}_{\beta}\,j\,j\,,\;\alpha,\beta = e,\mu$$

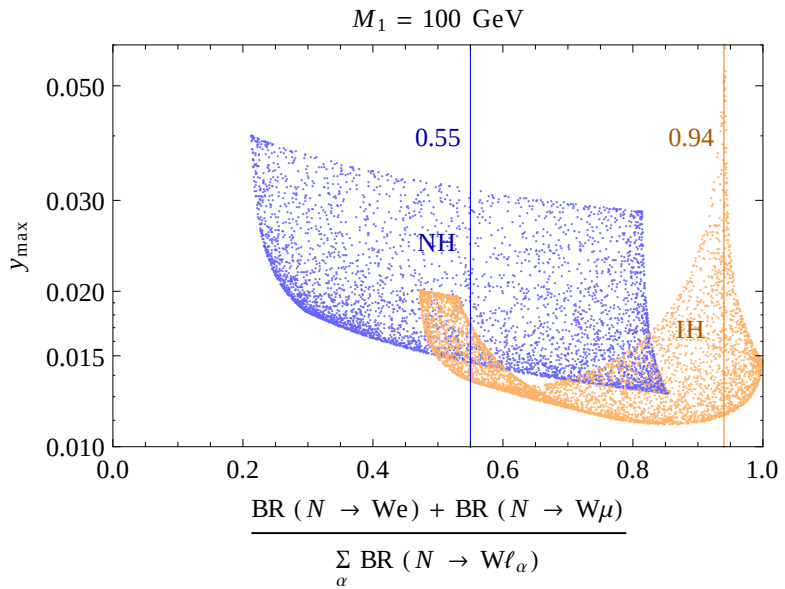


Figure: Upper limit on the Yukawa coupling for various values of the relative branching fraction for decays into e and μ for normal hierarchy (blue) and for inverted hierarchy (orange) and $M_1 = 100$ GeV. We also show in the plot the benchmark points taken in our analysis.

Sensitivity of the LHC to the coupling y vs M_1

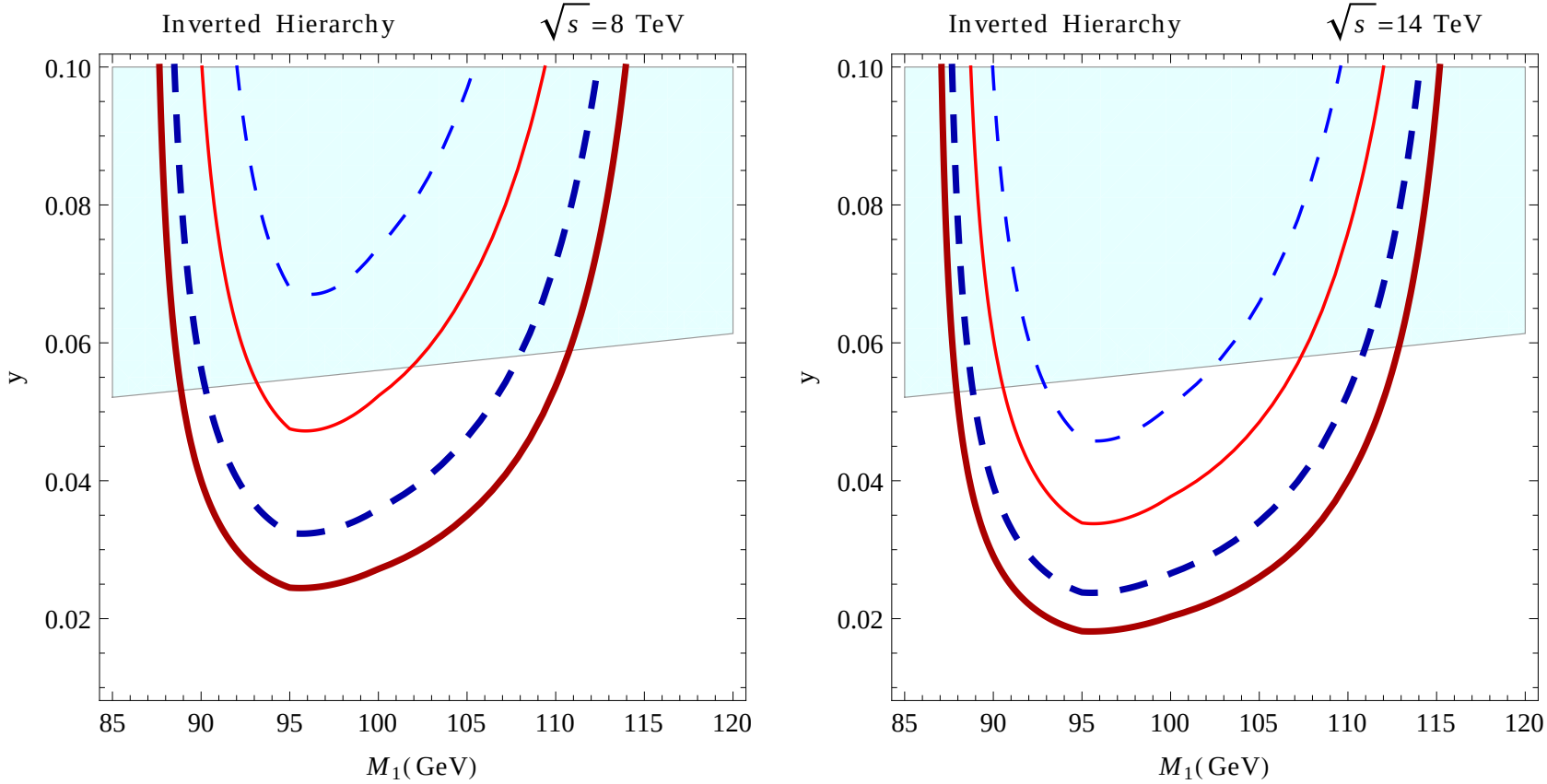
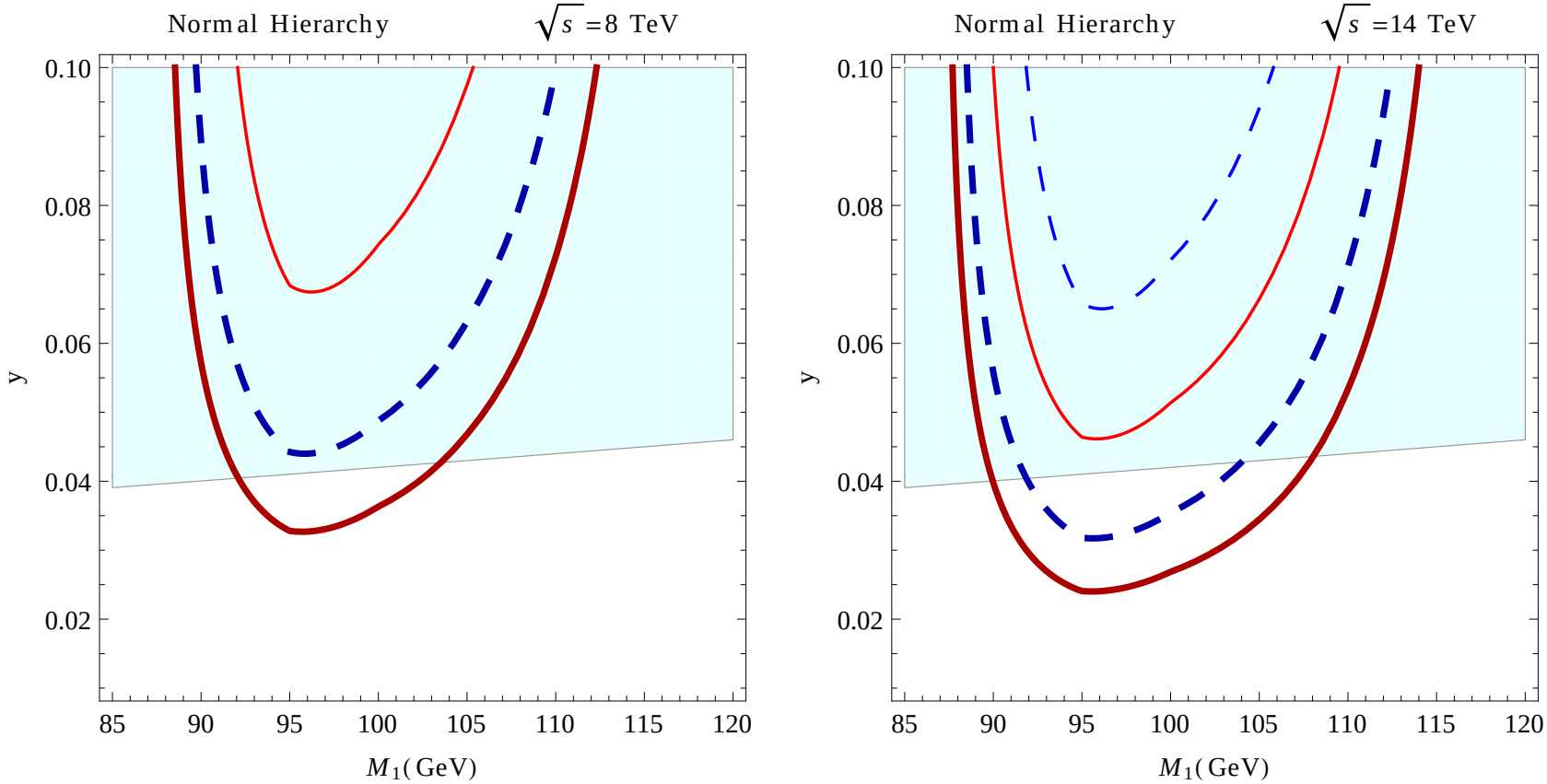


Figure: Sensitivity of the LHC to the coupling y vs M_1 at 3σ (continuous line) and 5σ (dashed line) and an integrated luminosity $\mathcal{L} = 1\ \text{fb}^{-1}$ (thin line) and $\mathcal{L} = 10\ \text{fb}^{-1}$ (thick line). The shaded region is excluded by the current experimental upper limit $\text{BR}(\mu \to e\gamma) \leq 2.4 \times 10^{-12}$.



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