Heavy Majorana neutrino effects on MSSM-M_h

Maria J. Herrero, IFT-UAM/CSIC (Madrid, Spain)

Mamallapuram, India, September 26-30, 2011

in collaboration with
S. Heinemeyer, S. Peñaranda and *A. Rodriguez-Sanchez*
main results in JHEP05(2011)063

Motivation

- Why Majorana neutrinos?

– Neutrinos have mass and oscillate in flavor (LFV in ν sector)

– Simplest way to explain ν masses: introduction of ν_R

Dirac masses: $m_D \overline{\nu_L} \nu_R$ (non-violating lepton number)

Majorana masses: $m_M \overline{\nu_R^c} \nu_R$ (violating lepton number)

– Majorana masses $\Rightarrow$ viable BAU via Leptogenesis

- Why heavy Majorana neutrinos?

– Seesaw gives small $m_\nu \sim m_D^2 / m_M$ if $m_D \sim m_{EW} << m_M$

– $m_\nu^{\rm exp} < 2$ eV requires very heavy $m_M \sim 10^{13} - 10^{15}$GeV

- If Dirac: $Y_\nu \sim \mathcal{O}(10^{-12})$, If heavy Majorana: $Y_\nu \sim \mathcal{O}(1)$ large!

$\Rightarrow$ very important pheno implications: large LFV in l sector

- If large m_M, SUSY needed to avoid (extra) hierarchy problem

$\Rightarrow$ large effects on M_h from Maj-ν-RADCOR? (Our work)

Our Model: MSSM-Seesaw. Part I: MSSM

Enlarged Higgs sector: Two Higgs doublets

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2(\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}} (H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}} |H_1 \bar{H}_2|^2$$

gauge couplings, in contrast to SM

physical states: $h^0, H^0, A^0, H^\pm$ Goldstone bosons: $G^0, G^\pm$

Input parameters: (to be determined experimentally)

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_A^2 = -m_{12}^2(\tan\beta + \cot\beta)$$

RADCOR in the MSSM Higgs sector do contain info on NEW phys.

To lowest order, only 2 input parameters: $\tan\beta$ and M_A
To higher order, extra input parameters: $m_{\rm SUSY}$, etc
$\Rightarrow$ M_h, M_H, mixing angle α, $M_{H^\pm}$: derived from input param.

With higher-order corrections: $M_h^2 = m_h^2 + \Delta m_h^2$

$$m_h^2 = \frac{1}{2}\left[M_A^2 + M_Z^2 - \sqrt{(M_A^2+M_Z^2)^2 - 4M_Z^2 M_A^2 \cos^2 2\beta}\right]$$

Δm_h^2 test of the model and sensitivity to new mass scales!

Leading RADCOR is from 1-loop top/stop due to large $Y_t \sim \mathcal{O}(1)$:
$\Delta m_h^2 \sim G_F m_t^4 \log \frac{m_{\rm SUSY}^2}{m_t^2}$. With higher order corrs.: $M_h < 135$ GeV
Our goal: Can one reach sensitivity to m_M in Δm_h?. Necessary:
– discover the Higgs(es) at the LHC (or at the ILC)
– measure its mass/characteristics at the LHC (or at the ILC)
– compare with theory : $\Delta m_h(m_M)$ should be larger than precision
expected precision on SM-like Higgs mass: LHC$\sim$ 0.2 GeV, ILC$\sim$ 0.05GeV

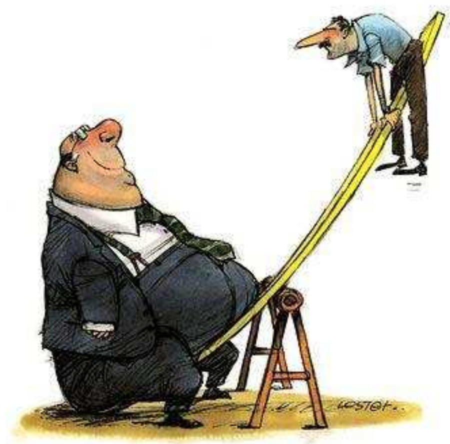
Our Model: MSSM-Seesaw. Part II: Seesaw

Present work: 1 generation ν and $\tilde{\nu}$. Future work: 3 generations.

The neutrino sector:

In the (ν_L, ν_R) basis, the 2×2 neutrino mass matrix is given in terms of the Dirac mass $m_D \equiv Y_\nu v_2$ and the Majorana mass m_M by:

$$M^\nu = \begin{pmatrix} 0 & m_D \\ m_D & m_M \end{pmatrix}$$



$\Rightarrow$ 2 mass eigenstates

ν, N (Majorana fermions)

$$m_{\nu,N} = \frac{1}{2}\left(m_M \mp \sqrt{m_M^2 + 4m_D^2}\right)$$

Seesaw limit: $\xi \equiv m_D/m_M \ll 1$:

$$m_\nu = -m_D\xi + \mathcal{O}(m_D\xi^3) \simeq -\frac{m_D^2}{m_M} \quad \text{light , predom. } \nu_\text{L}$$

$$m_N = m_M + \mathcal{O}(m_D\xi) \simeq m_M \quad \text{heavy , predom. } \nu_\text{R}$$

Higgs-neutrino interactions driven by large $Y_\nu = \sqrt{|m_\nu| m_N}/v_2 \sim \mathcal{O}(1)$

The sneutrino sector:

$$V_{\rm soft}^{\tilde\nu} = m_{\tilde L}^2 \tilde\nu_L^* \tilde\nu_L + m_{\tilde R}^2 \tilde\nu_R^* \tilde\nu_R + (Y_\nu A_\nu H_2^2 \tilde\nu_L \tilde\nu_R^* + m_M B_\nu \tilde\nu_R \tilde\nu_R + \text{h.c.})$$

Two 2×2 mass matrices to describe the $\mathcal{CP}$-even (+) and $\mathcal{CP}$-odd (-) parts of the sneutrino sector:

$$\tilde M_\pm^2 = \begin{pmatrix} m_{\tilde L}^2 + m_D^2 + \frac{1}{2} M_Z^2 \cos 2\beta & m_D(A_\nu - \mu \cot\beta \pm m_M) \\ m_D(A_\nu - \mu\cot\beta \pm m_M) & m_{\tilde R}^2 + m_D^2 + m_M^2 \pm 2 B_\nu m_M \end{pmatrix}$$

Diagonalization yields four mass eigenstates
$\tilde n_1$, $\tilde n_2$, $\tilde n_3$, $\tilde n_4$ ($\tilde\nu_+$, $\tilde N_+$, $\tilde\nu_-$, $\tilde N_-$)

Seesaw limit: $\xi \equiv m_D/m_M \ll 1$:

$$m_{\tilde\nu_+,\tilde\nu_-}^2 = m_{\tilde L}^2 + \frac{1}{2} M_Z^2 \cos 2\beta \mp 2 m_D (A_\nu - \mu\cot\beta - B_\nu)\xi \quad \text{light , predom. } \tilde\nu_{\rm L}$$

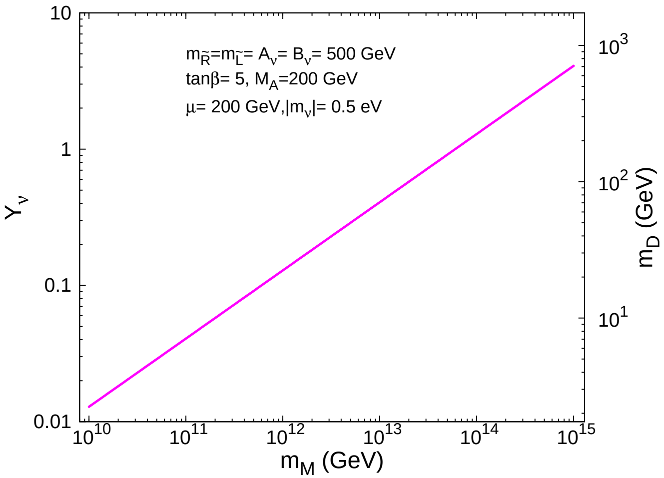
$$m_{\tilde N_+,\tilde N_-}^2 = m_M^2 \pm 2 B_\nu m_M + m_{\tilde R}^2 + 2 m_D^2 \quad \text{heavy , predom. } \tilde\nu_{\rm R}$$

m_M and $m_{\tilde R}$ are the most relevant parameters (see later)

Majorana versus Dirac couplings:

$\rightarrow$ Same interactions in $\mathcal{L}_{\nu\, H}$, but very different size of couplings:

$$\mathcal{L}_{\nu\, H} = -\frac{g m_D}{2M_W s_\beta}\left[(\overline{\nu_L}\nu_R + \overline{\nu_R}\nu_L)(Hs_\alpha + hc_\alpha) - i(\overline{\nu_L}\nu_R - \overline{\nu_R}\nu_L)Ac_\beta\right]$$



$\rightarrow$ large couplings in Majorana case

$Y_\nu^{\text{Maj}} = \sqrt{|m_\nu| m_M}/v_2$; $m_D^{\text{Maj}} = \sqrt{|m_\nu| m_M}$

$Y_\nu^{\text{Maj}} \sim 1$; $m_D^{\text{Maj}} \sim 200$ GeV for:

$|m_\nu| = 0.5$ eV, $m_M = 10^{14}$ GeV, $\tan\beta = 5$

$\rightarrow$ extremely small in Dirac case:

$Y_\nu^{\text{Dirac}} \sim 10^{-12}$; $m_D^{\text{Dirac}} \sim 0.1$ eV

$\rightarrow$ New interactions in $\mathcal{L}_{\tilde{\nu}\, H}$ with respect to the Dirac case:

$$\mathcal{L}_{\tilde{\nu}\, H}^{\text{new}} = -\frac{g m_D m_M}{2M_W s_\beta}\left[(\tilde{\nu}_L\tilde{\nu}_R + \tilde{\nu}_L^*\tilde{\nu}_R^*)(Hs_\alpha + hc_\alpha) - i(\tilde{\nu}_L\tilde{\nu}_R - \tilde{\nu}_L^*\tilde{\nu}_R^*)Ac_\beta\right]$$

$\rightarrow$ In the mass eigen. basis some couplings grow with m_M: $\nu N h$, $\tilde{\nu}\tilde{N}h$,..

Full set of FRs in the physical basis in our paper JHEP05(2011)063

Calculation

M_h, M_H: higher-order corrected $\mathcal{CP}$-even Higgs masses in the MSSM

$M_h^{\nu/\tilde{\nu}}$, $M_H^{\nu/\tilde{\nu}}$: masses in the MSSM-seesaw model

$\rightarrow$ determined as poles of the propagator matrix

Inverse of the propagator matrix:

$$\left(\Delta_{\rm Higgs}\right)^{-1} = -i \begin{pmatrix} p^2 - m_H^2 + \hat{\Sigma}_{HH}(p^2) & \hat{\Sigma}_{hH}(p^2) \\ \hat{\Sigma}_{hH}(p^2) & p^2 - m_h^2 + \hat{\Sigma}_{hh}(p^2) \end{pmatrix}$$

$\rightarrow$ solve the equation:

$$\left[p^2 - m_h^2 + \hat{\Sigma}_{hh}(p^2)\right]\left[p^2 - m_H^2 + \hat{\Sigma}_{HH}(p^2)\right] - \left[\hat{\Sigma}_{hH}(p^2)\right]^2 = 0$$

with renormalized self-energies:

$$\hat{\Sigma}(p^2) = \hat{\Sigma}^{(1)}(p^2) + \hat{\Sigma}^{(2)}(p^2) + \ldots$$
$$\Sigma(p^2) = \Sigma^{(1)}(p^2) + \Sigma^{(2)}(p^2) + \ldots$$

$\Rightarrow$ calculation of $\nu/\tilde{\nu}$ contributions to $\hat{\Sigma}^{(1)}$ (one loop)

Renormalization and formulas "as usual":

$$\hat{\Sigma}_{hh}(p^2) = \Sigma_{hh}(p^2) + \delta Z_{hh}(p^2 - m_h^2) - \delta m_h^2$$
$$\hat{\Sigma}_{hH}(p^2) = \Sigma_{hH}(p^2) + \delta Z_{hH}(p^2 - \tfrac{1}{2}(m_h^2 + m_H^2)) - \delta m_{hH}^2$$
$$\hat{\Sigma}_{HH}(p^2) = \Sigma_{HH}(p^2) + \delta Z_{HH}(p^2 - m_H^2) - \delta m_H^2$$

$$\begin{aligned}
\delta m_h^2 &= \delta M_A^2 c_{\beta-\alpha}^2 + \delta M_Z^2 s_{\alpha+\beta}^2 + \delta\tan\beta\, s_\beta c_\beta (M_A^2 s_{2\alpha-2\beta} + M_Z^2 s_{2\alpha+2\beta}) \\
&\quad + \tfrac{e}{2M_Z s_\mathrm{W} c_\mathrm{W}}(\delta T_H c_{\beta-\alpha} s_{\beta-\alpha}^2 - \delta T_h s_{\beta-\alpha}(1 + c_{\beta-\alpha}^2)) \\
\delta m_{hH}^2 &= \tfrac{1}{2}(\delta M_A^2 s_{2\alpha-2\beta} - \delta M_Z^2 s_{2\alpha+2\beta} - \delta\tan\beta\, s_\beta c_\beta (M_A^2 c_{2\alpha-2\beta} + M_Z^2 c_{2\alpha+2\beta}) \\
&\quad + \tfrac{e}{2M_Z s_\mathrm{W} c_\mathrm{W}}(\delta T_H s_{\alpha-\beta}^3 - \delta T_h c_{\alpha-\beta}^3) \\
\delta m_H^2 &= \delta M_A^2 s_{\alpha-be}^2 + \delta M_Z^2 c_{\alpha+\beta}^2 - \delta\tan\beta\, s_\beta c_\beta (M_A^2 s_{2\alpha-2\beta} + M_Z^2 s_{2\alpha+2\beta}) \\
&\quad - \tfrac{e}{2M_Z s_\mathrm{W} c_\mathrm{W}}(\delta T_H c_{\alpha-\beta}(1 + s_{\alpha-\beta}^2) + \delta T_h s_{\alpha-\beta} c_{\alpha-\beta}^2)
\end{aligned}$$

$$\delta M_Z^2 = \mathrm{Re}\Sigma_{ZZ}(M_Z^2),\ \delta M_W^2 = \mathrm{Re}\Sigma_{WW}(M_W^2),\ \delta M_A^2 = \mathrm{Re}\Sigma_{AA}(M_A^2)$$
$$\delta T_h = -T_h, \quad \delta T_H = -T_H$$

Field and tan β renormalization:

"Normal" : $\overline{\text{DR}}$:

$$\delta Z_{\mathcal{H}_1}^{\overline{\text{DR}}} = -\left[\text{Re}\Sigma'_{HH\,|\alpha=0}\right]^{\text{div}}$$

$$\delta Z_{\mathcal{H}_2}^{\overline{\text{DR}}} = -\left[\text{Re}\Sigma'_{hh\,|\alpha=0}\right]^{\text{div}}$$

$$\delta\tan\beta^{\,\overline{\text{DR}}} = \frac{1}{2}\left(\delta Z_{\mathcal{H}_2}^{\overline{\text{DR}}} - \delta Z_{\mathcal{H}_1}^{\overline{\text{DR}}}\right)$$

$[\,]^{\text{div}}$: $\propto \Delta \equiv 2/\epsilon - \gamma_{\text{E}} + \log(4\pi)$

"More appropriate here: m$\overline{\text{DR}}$:

$$\delta Z_{\mathcal{H}_1}^{\text{m}\overline{\text{DR}}} = -\left[\text{Re}\Sigma'_{HH\,|\alpha=0}\right]^{\text{mdiv}}$$

$$\delta Z_{\mathcal{H}_2}^{\text{m}\overline{\text{DR}}} = -\left[\text{Re}\Sigma'_{hh\,|\alpha=0}\right]^{\text{mdiv}}$$

$$\delta\tan\beta^{\,\text{m}\overline{\text{DR}}} = \frac{1}{2}\left(\delta Z_{\mathcal{H}_2}^{\text{m}\overline{\text{DR}}} - \delta Z_{\mathcal{H}_1}^{\text{m}\overline{\text{DR}}}\right)$$

$[\,]^{\text{mdiv}}$: $\propto \Delta_m \equiv \Delta - \log(m_M^2/\mu_{\overline{\text{DR}}}^2)$

$\Rightarrow$ decoupling "by hand" of large logs (equivalent to set $\mu_{\overline{\text{DR}}} = m_M$)

Calculation of Self-energies:

– all diagrams created with FeynArts $\rightarrow$ T

$\rightarrow$ model file with all $\nu/\tilde{\nu}$ interactions

– further evaluation with FormCalc

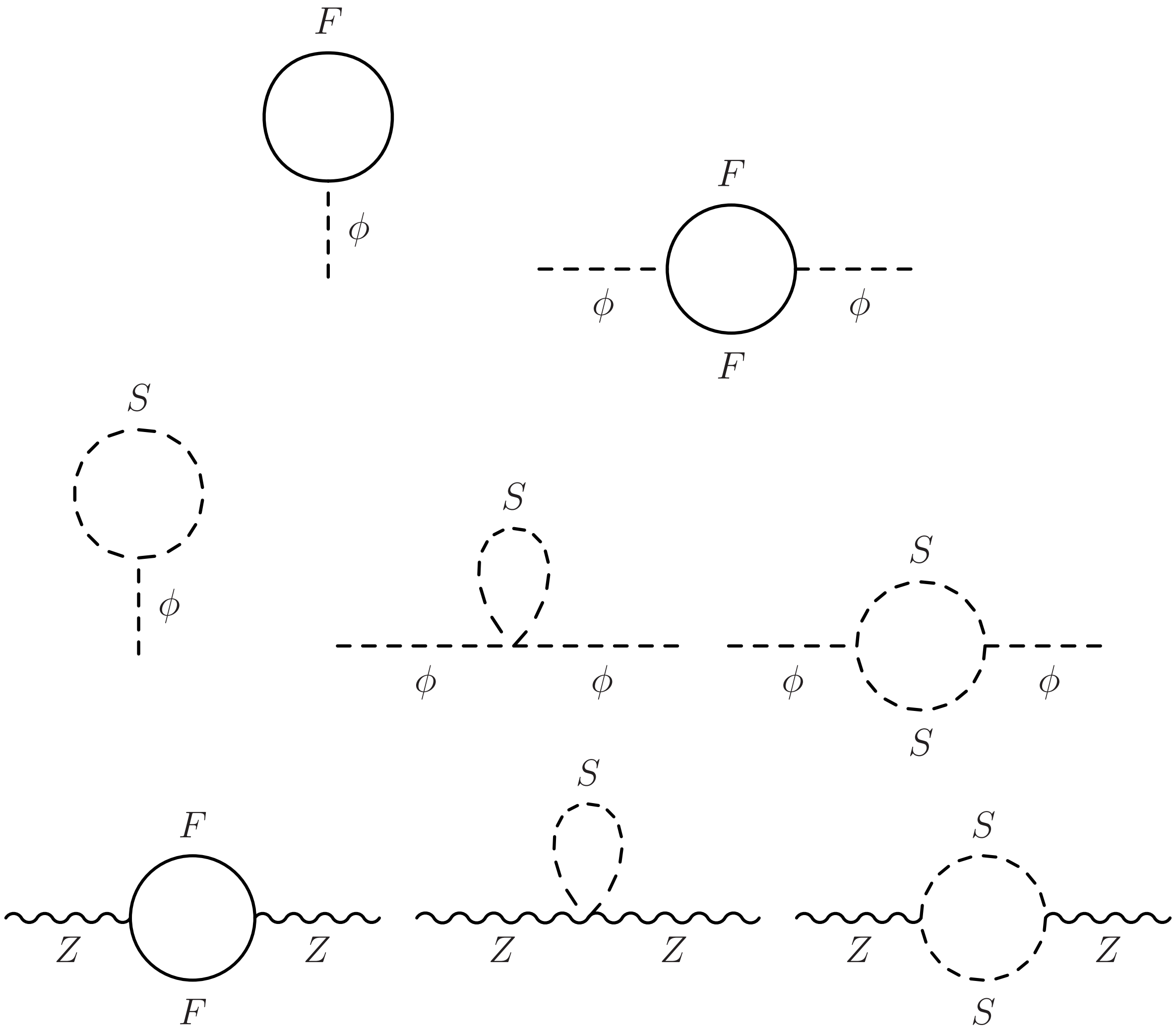
– Dimensional REDuction

– all UV divergences cancel

– results will be included into FeynHiggs (www.feynhiggs.de)

$\rightarrow$ example plots will focus on $\hat{\Sigma}_{hh}(p^2)$ and $\Delta m_h^{\mathrm{m}\overline{\mathrm{DR}}} := M_h^{\nu/\tilde{\nu}} - M_h$

Feynman diagrams:



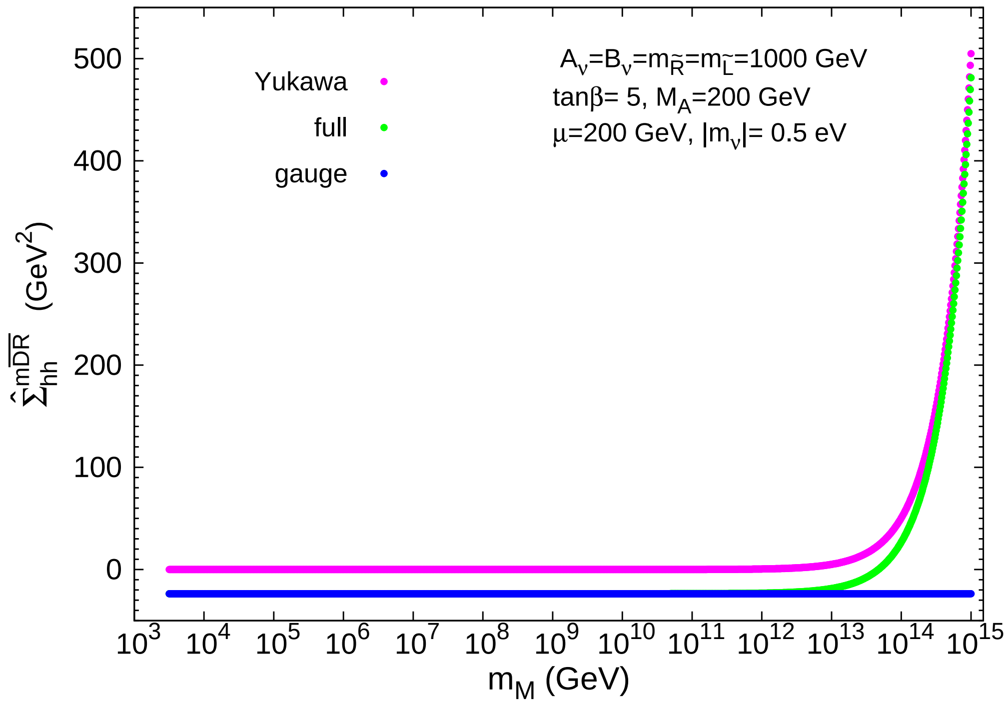
In mass eigenstate basis:

$$\phi = h, H;\ F = \nu, N;\ S = \tilde{\nu}_+, \tilde{\nu}_-, \tilde{N}_+, \tilde{N}_-$$

Results

Gauge part vs. Yukawa part:

$$\hat{\Sigma}(p^2)|_{\text{full}} = \underbrace{\hat{\Sigma}(p^2)|_{\text{gauge}}}_{\text{MSSM}} + \underbrace{\hat{\Sigma}(p^2)|_{\text{Yukawa}}}_{\text{extra}}$$

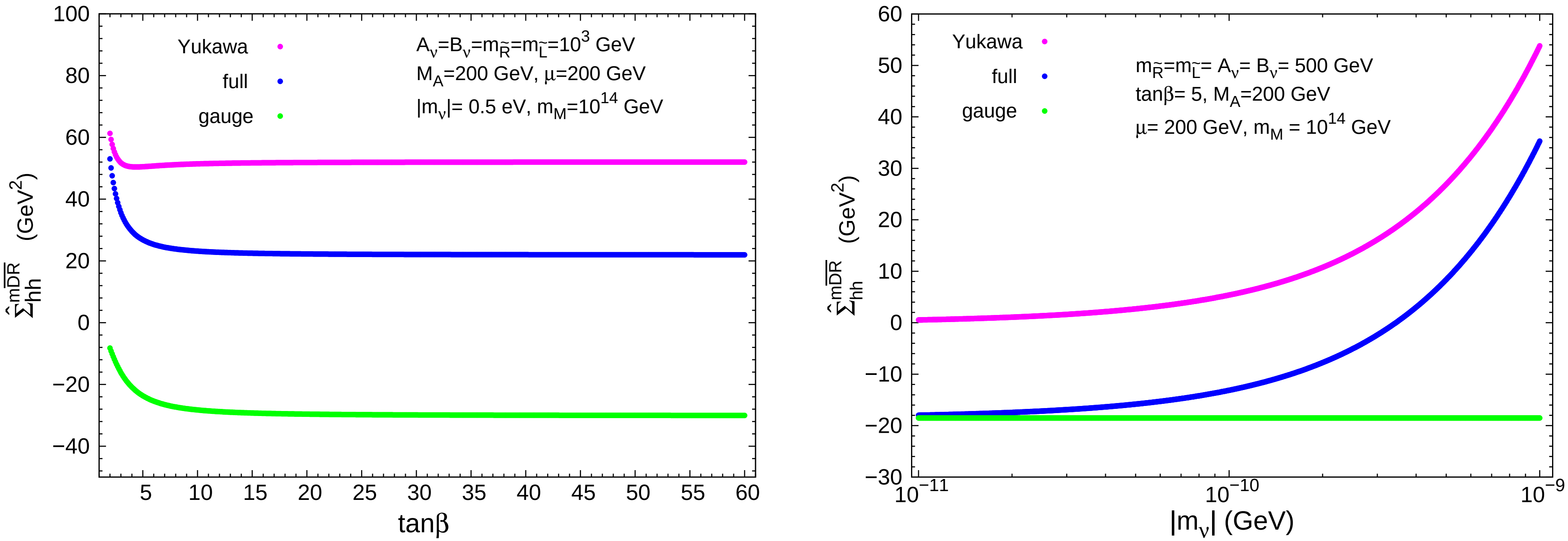


For $m_M < 10^{12}$ GeV, MSSM-seesaw ∼ MSSM (⊕ Dirac neutrinos)

For $m_M > 10^{13}$ GeV, the Yukawa contribution dominates

$\hat{\Sigma}_{hh}^{\mathrm{m}\overline{\mathrm{DR}}}$ grows with m_M , sizeable RADCOR at $10^{13} < m_M(\text{GeV}) < 10^{15}$

Behaviour with $\tan\beta$ and m_ν:



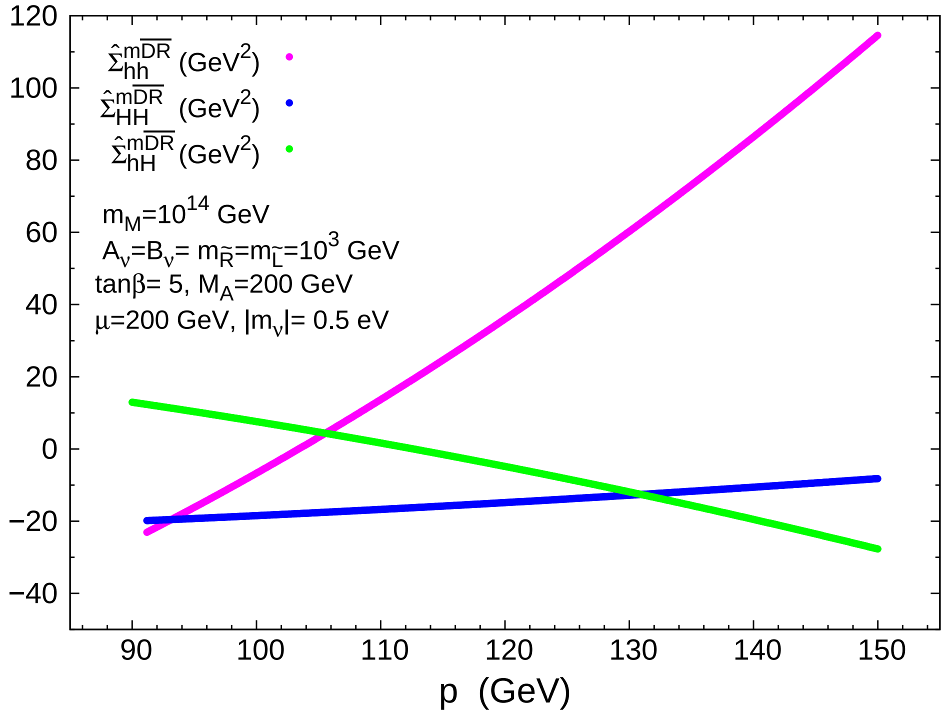
$\rightarrow$ Not very relevant dependence on $\tan\beta$ from $\nu/\tilde{\nu}$ RADCOR:

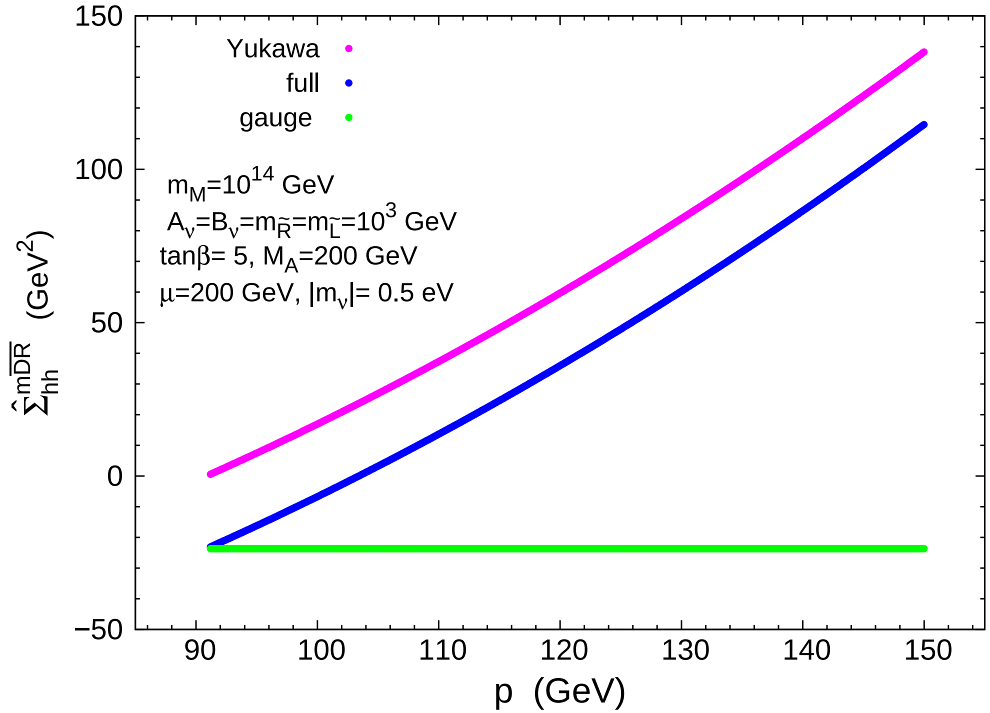
Slightly larger RADCOR at low $\tan\beta$

$\rightarrow$ Relevant dependence on m_ν:

$\hat{\Sigma}_{hh}^{m\overline{DR}}$ grows with $|m_\nu|$, sizeable RADCOR at $0.5 < |m_\nu(\text{eV})| < 1$

Momentum dependence:





⇒ strong momentum dependence

⇒ only present in the Yukawa part

⇒ a mass correction estimate by setting $p = 0$ is not a good approx. here

⇒ (contrary to $\mathcal{O}\left(m_t^4\right)$ corrections) $\mathcal{O}\left(m_D^2\right)$ term dominates (see next)

Analysing the growing with m_M: The seesaw expansion

For $m_D << m_M$ a good approximation is to perform an expansion of $\hat{\Sigma}(p^2)$ in powers of $\xi \equiv m_D/m_M$:

$$\hat{\Sigma}(p^2) = \underbrace{\left(\hat{\Sigma}(p^2)\right)_{|m_D^0}}_{\text{gauge MSSM}} + \underbrace{\left(\hat{\Sigma}(p^2)\right)_{|m_D^2} + \left(\hat{\Sigma}(p^2)\right)_{|m_D^4} + \dots}_{\text{Yukawa}}$$

Our result: the $\mathcal{O}\left(m_D^2\right)$ term dominates and provides a good estimate:

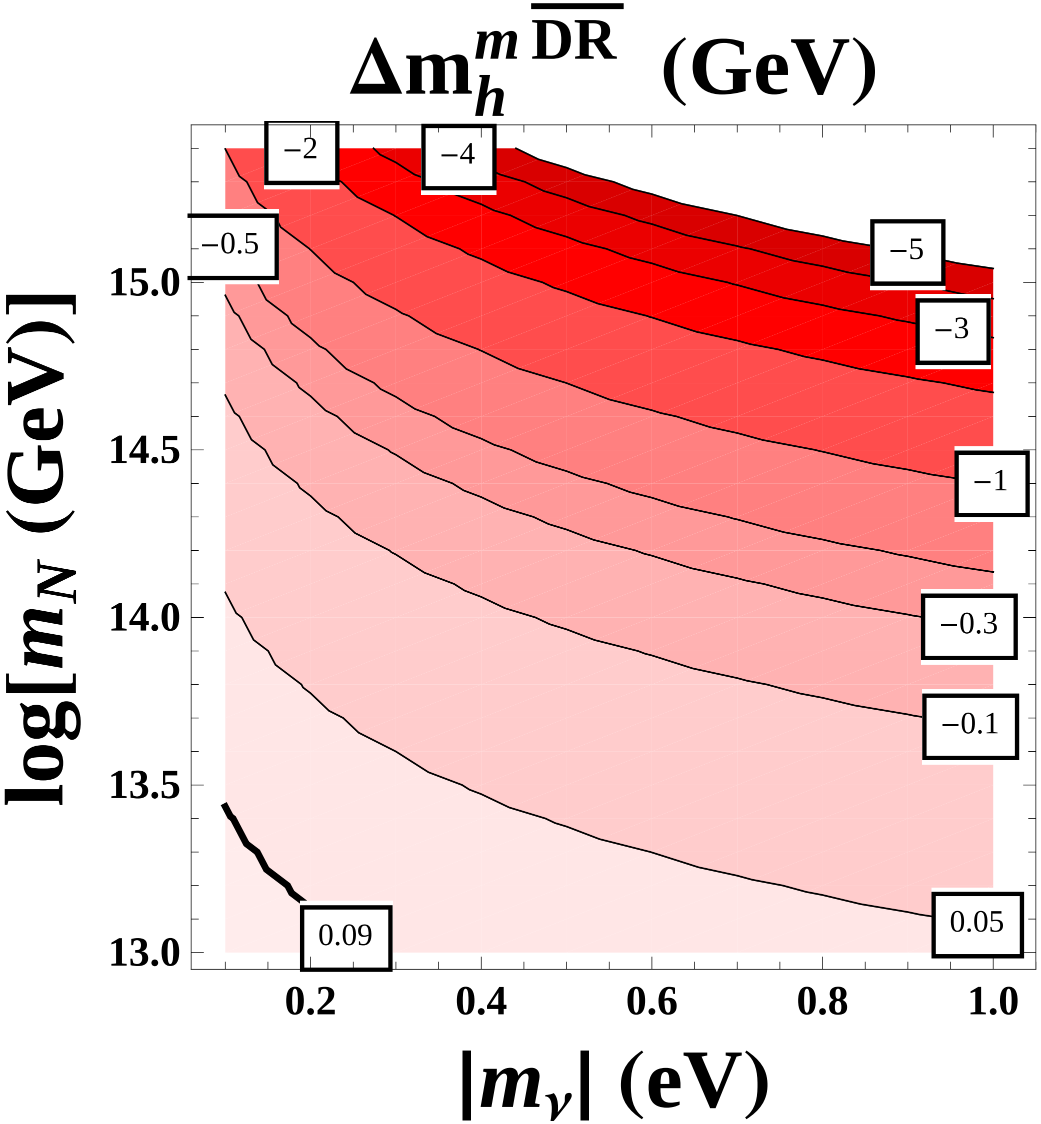
$$\left(\hat{\Sigma}_{hh}^{\mathrm{m}\overline{\mathrm{DR}}}(p^2)\right)_{m_D^2} = \frac{g^2 m_D^2}{64\pi^2 M_W^2 \sin^2\beta}\left[-2M_A^2\cos^2(\alpha-\beta)\cos^2\beta + 2p^2\cos^2\alpha \right.$$
$$\left. - M_Z^2 \sin\beta\sin(\alpha+\beta)\left(2\left(1+\cos^2\beta\right)\cos\alpha - \sin 2\beta\sin\alpha\right)\right]$$

$\rightarrow$ This is in contrast to the one-loop top/stop corrections where the dominant contributions are $\mathcal{O}\left(m_t^4\right)$, and setting $p=0$ is a reasonable approx.

$\rightarrow$ This explains the growing with m_M, due to $m_D^2 = |m_\nu| m_M$.
This growing also appears at the physical Higgs mass correction (see next)

Main result: $\Delta m_h^{\mathrm{m\overline{DR}}}$:

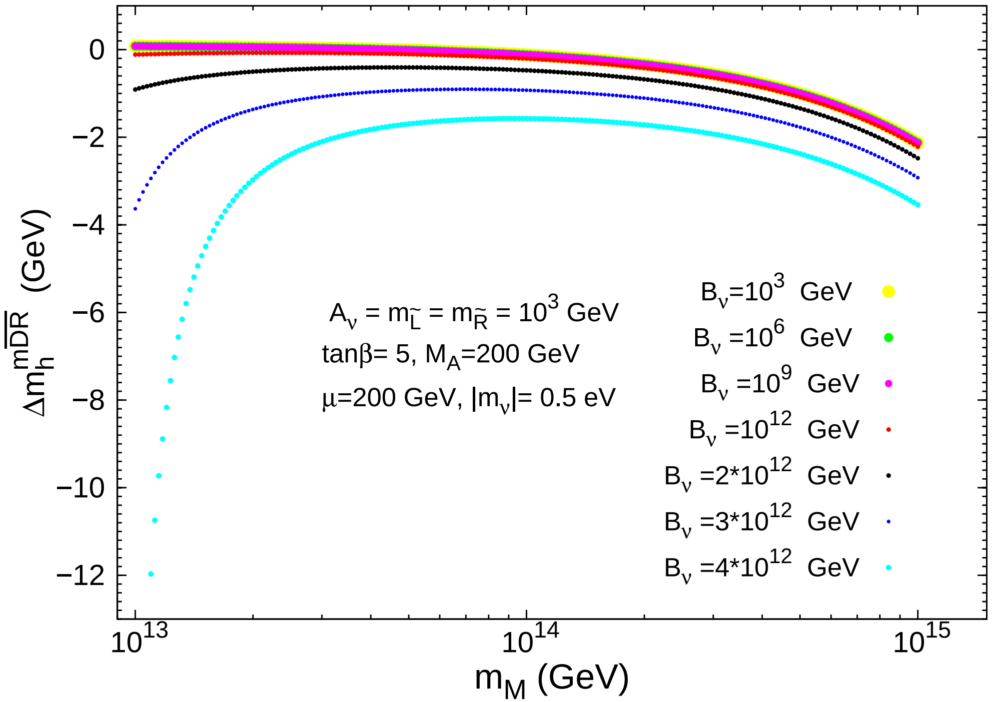
$A_\nu = B_\nu = m_{\tilde{L}} = m_{\tilde{R}} = 1000$ GeV, $M_A = \mu = 200$ GeV, $\tan\beta = 5$



$\Rightarrow$ large negative corrections possible for large $|m_\nu|$ and $m_N(\simeq m_M)$
(up to -5 GeV for $m_M = 10^{15}$ GeV and $|m_\nu| = 1$ eV)

Growing of $\Delta m_h^{\mathrm{m\overline{DR}}}$ with m_M:
due to $Y_\nu = \frac{1}{v_2}\sqrt{m_M\,|m_\nu|}$

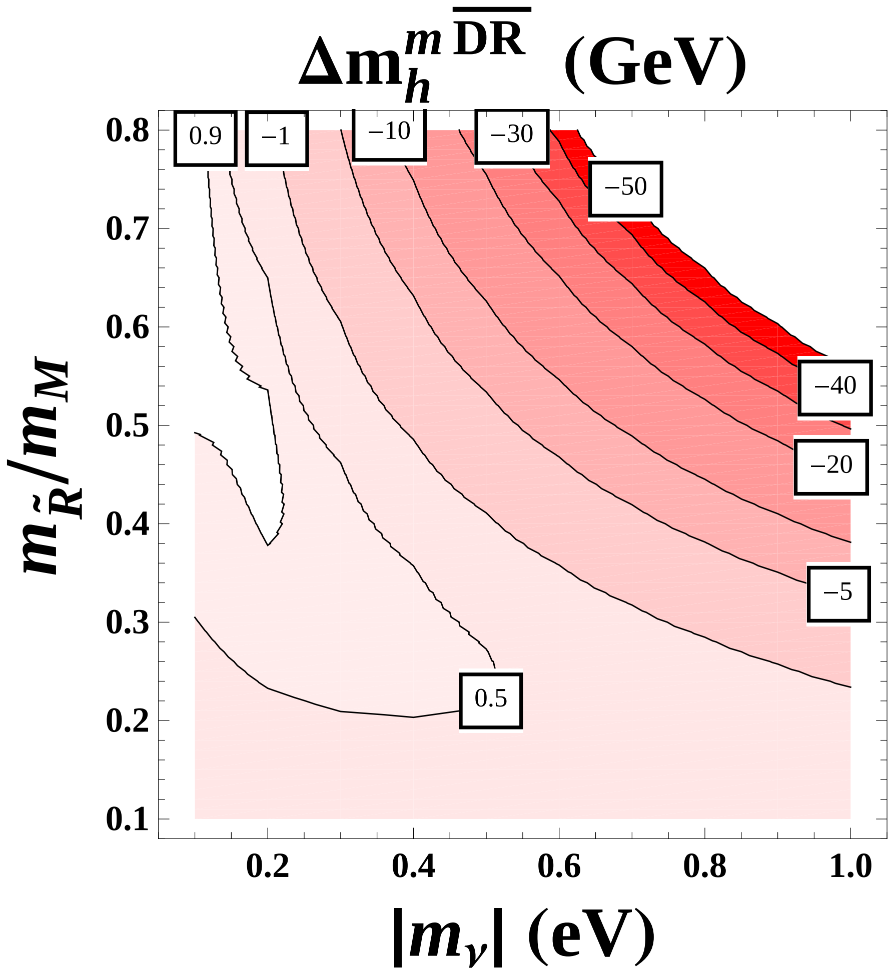
Impact of B_ν



$\Rightarrow$ we get large negative corrections for large $B_\nu \sim m_M$

But so large B_ν gives problems:
too large oscillations in the sneutrino sector $\Rightarrow$
too large 1-loop generated m_ν: Dedes,Haber,Rosiek JHEP11(2007)059
too large LFV rates: Kang,Morozumi,Yokozaki,JHEP11(2010)061
too large EDM: Farzan, PRD69(2004)073009;
Giudice,Paradisi,Strumia,PLB694(2010)26

The largest corrections $\Delta m_h^{\mathrm{m}\overline{\mathrm{DR}}}$: $m_{\tilde{R}} \sim m_M$:



$\Rightarrow$ very large and negative corrections!

$\Delta m_h^{\mathrm{m}\overline{\mathrm{DR}}} \sim -30$ GeV for $m_M = 10^{14}$ GeV,$m_{\tilde{R}}/m_M = 0.7$ and $|m_\nu| = 0.6$ eV

An useful analytical result:

We have found a simple and accurate formula, valid for heavy m_M:

$$\Delta m_h^{\mathrm{m}\overline{\mathrm{DR}}} \simeq -\frac{\hat{\Sigma}_{hh}^{\nu/\tilde{\nu}}(M_h^2)}{2M_h} \approx -\frac{\left(\hat{\Sigma}_{hh}^{\mathrm{m}\overline{\mathrm{DR}}}(M_h^2)\right)_{m_D^2}}{2M_h} \approx$$

$$\frac{-g^2 m_D^2}{128\pi^2 M_W^2 M_h \sin^2\beta}\left[-2M_A^2\cos^2(\alpha-\beta)\cos^2\beta + 2M_h^2\cos^2\alpha\right.$$
$$\left. - M_Z^2 \sin\beta\sin(\alpha+\beta)\left(2\left(1+\cos^2\beta\right)\cos\alpha - \sin 2\beta\sin\alpha\right)\right]$$

(if corrections are not too large . . .
otherwise full pole determination necessary ⇒ FeynHiggs . . .)

Comments:

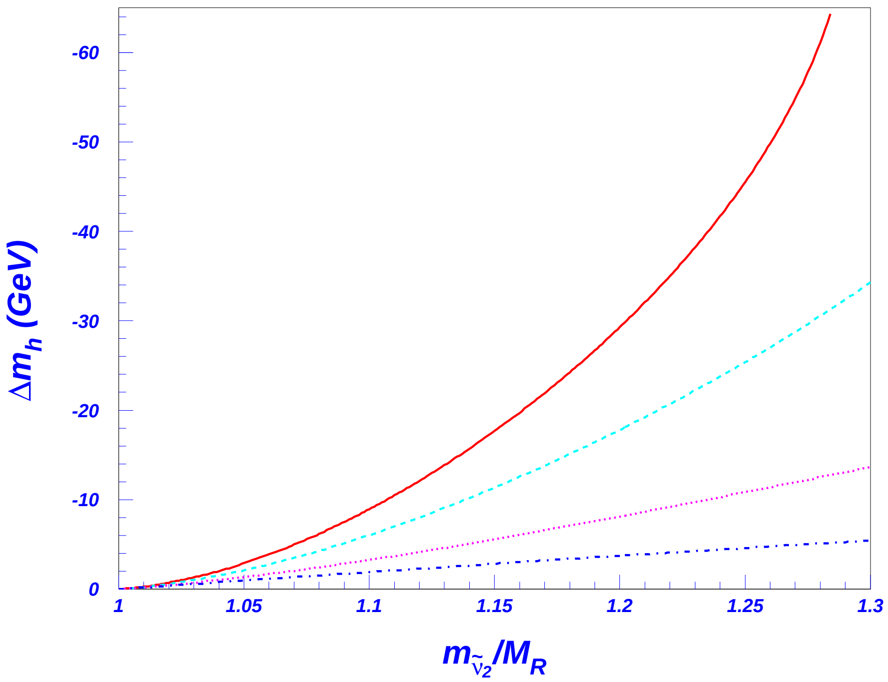
⇒ growing with m_M (and $|m_\nu|$) explained by prefactor $m_D^2 = |m_\nu| m_M$

⇒ result not obtainable in the effective potential approach (it sets $p = 0$)

⇒ result not obtainable in the RGE approach (it mainly provides Llogs)

Comparison with other works:

$\rightarrow$ We agree with Cao, Yang (Phys.Rev.D71(2005)111701):
same size and sign of the corrections for large $m_{\tilde{R}} \sim m_M$



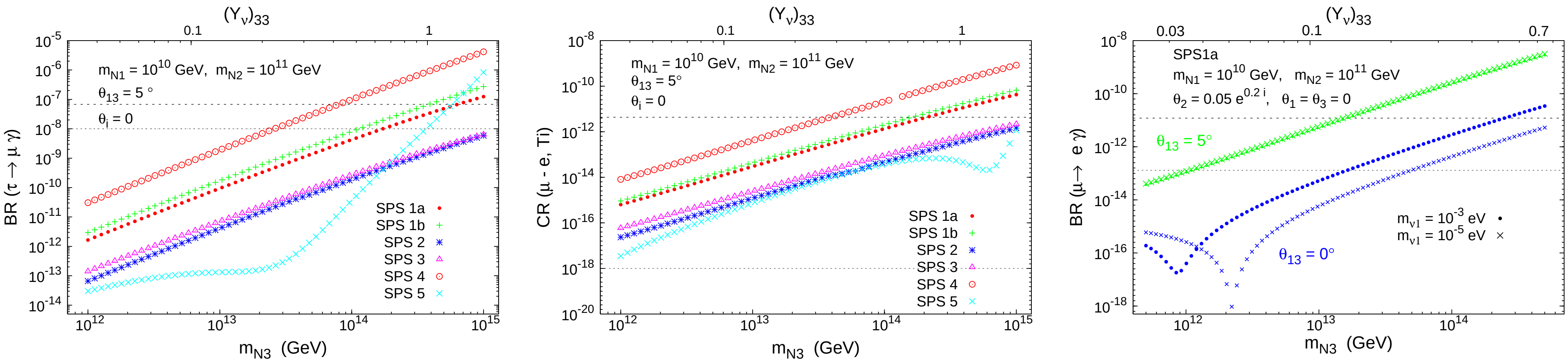
Simplified diagrammatic estimate
$m_M = 10^{14}$ GeV, $A_\nu = B_\nu = 0$,
$M_A = 200$ GeV, $\tan\beta = 30$
See solid red line , $m_{\tilde{L}} = 1000$ GeV
$(m_{\tilde{\nu}_2}/M_R)_{\text{Cao}} = 1.2 \leftrightarrow m_{\tilde{R}}/m_M \sim 0.7$
$\Delta m_h \sim -30$ GeV, OK with us .

$\rightarrow$ We agree qualitatively with Kang, Morozumi, Yokozaki JHEP11(2010)061 on the big impact of large B_ν . They use RGEs with heavy-sneu-thresholds

$\rightarrow$ The computation of Dedes, Haber, Rosiek (JHEP11(2007)059) is not comparable to ours. They use V_{eff} approach $\Rightarrow$ do not capture our leading $\mathcal{O}(m_D^2)$ contribution.

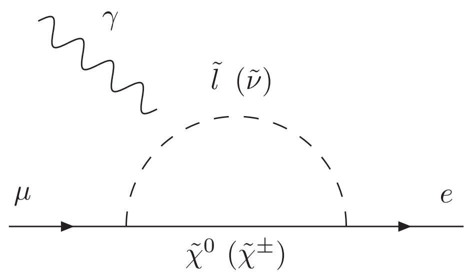
Comparison with LFV:

The large RADCOR from Heavy Majorana neutrinos and the growing with m_M are well known in LFV processes:



(Antusch,Arganda,Herrero,Teixeira,JHEP11(2006)090)
(Arganda,Herrero,Teixeira,JHEP10(2007)104)

$$\mathrm{BR}(\mu \to e\gamma) = \frac{\alpha^3 \tan^2\beta}{G_F^2 m_{\mathrm{SUSY}}^8} \left| \frac{1}{8\pi^2} \left(3M_0^2 + A_0^2\right) \left(Y_\nu^\dagger L Y_\nu\right) \right|^2$$



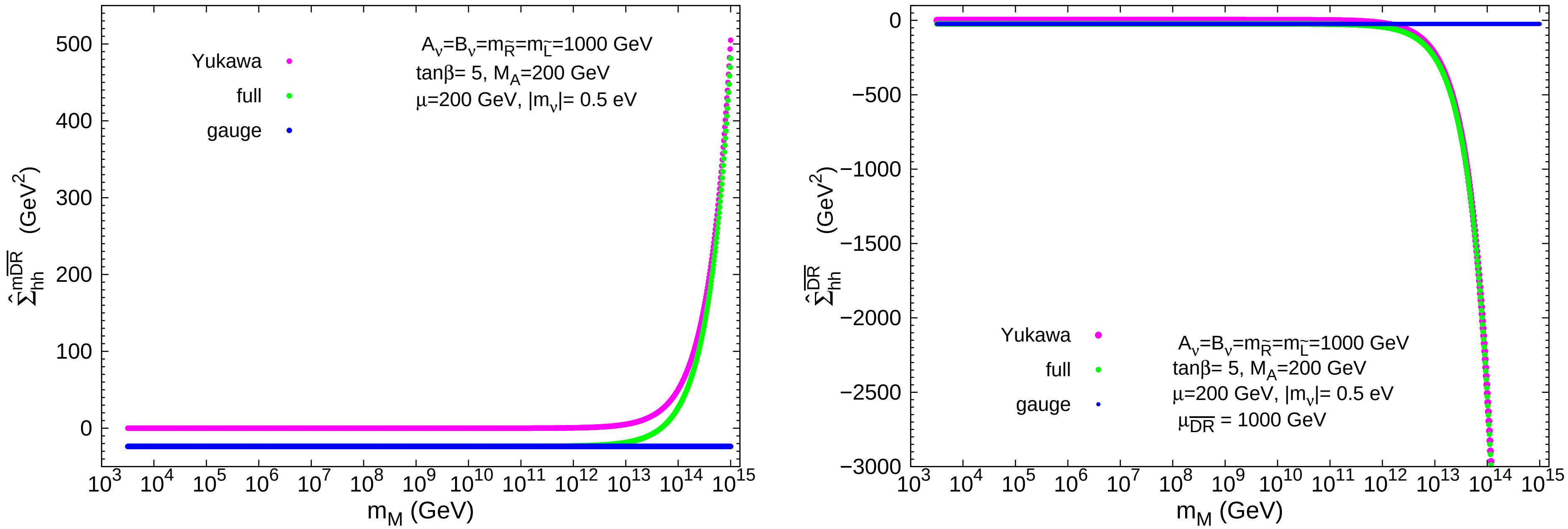
$$v_2^2 \left(Y_\nu^\dagger L Y_\nu\right) \sim m_M m_\nu \log\left(\frac{m_M}{M_X}\right)$$ from internal $\tilde{l}(\tilde{\nu})$

Conclusions

- Neutrinos do have mass and oscillate
  $\Rightarrow$ good motivation for seesaw mass generation via heavy Majorana right-handed neutrinos
- The MSSM Higgs sector is sensitive to the heavy Majorana scale m_M via RADCOR from $\nu/\tilde{\nu}$ sector, due to the large $Y_\nu \sim \mathcal{O}(1)$
- Δm_h grow with m_M. Similar to LFV: $\tau \to \mu\gamma$, $\mu \to e\gamma$, $\mu - e$ conv.,...
- Δm_h numericaly relevant for $m_M > 10^{13}$ GeV:
  – negative $\Rightarrow$ push down the lightest Higgs mass
  – up to ~ -5 GeV if $m_{\tilde{R}} << m_M$
  – up to $\sim (-10, -50)$ GeV if $m_{\tilde{R}} \sim m_M$
  RADCOR larger than the anticipated exp. precision!
  (LHC:$\sim$ 0.2 GeV, ILC:$\sim$ 0.05 GeV)
- In progress: Generalization to three neutrinos/sneutrinos generations
  Connection between neutrino physics/data (oscillations, masses etc) and Higgs physics/data (masses, couplings, etc)?

Backup

m$\overline{\text{DR}}$ versus $\overline{\text{DR}}$:



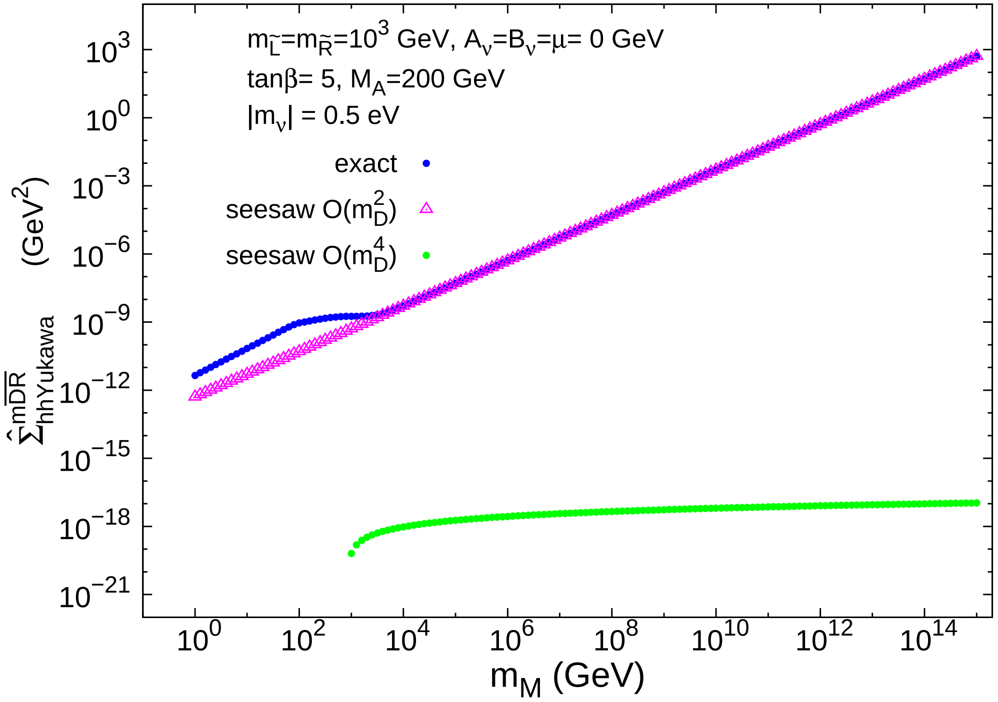
→ Large logs like $\log\left(\frac{m_M}{\mu_{\overline{\text{DR}}}}\right)$ in $\overline{\text{DR}}$. No large logs in m$\overline{\text{DR}}$

→ Growing with m_M faster in $\overline{\text{DR}}$ than in m$\overline{\text{DR}}$

→ Larger radiative corrections in $\overline{\text{DR}}$ than in m$\overline{\text{DR}}$,

→ but $\overline{\text{DR}}$ perturbatively more unstable than m$\overline{\text{DR}}$.

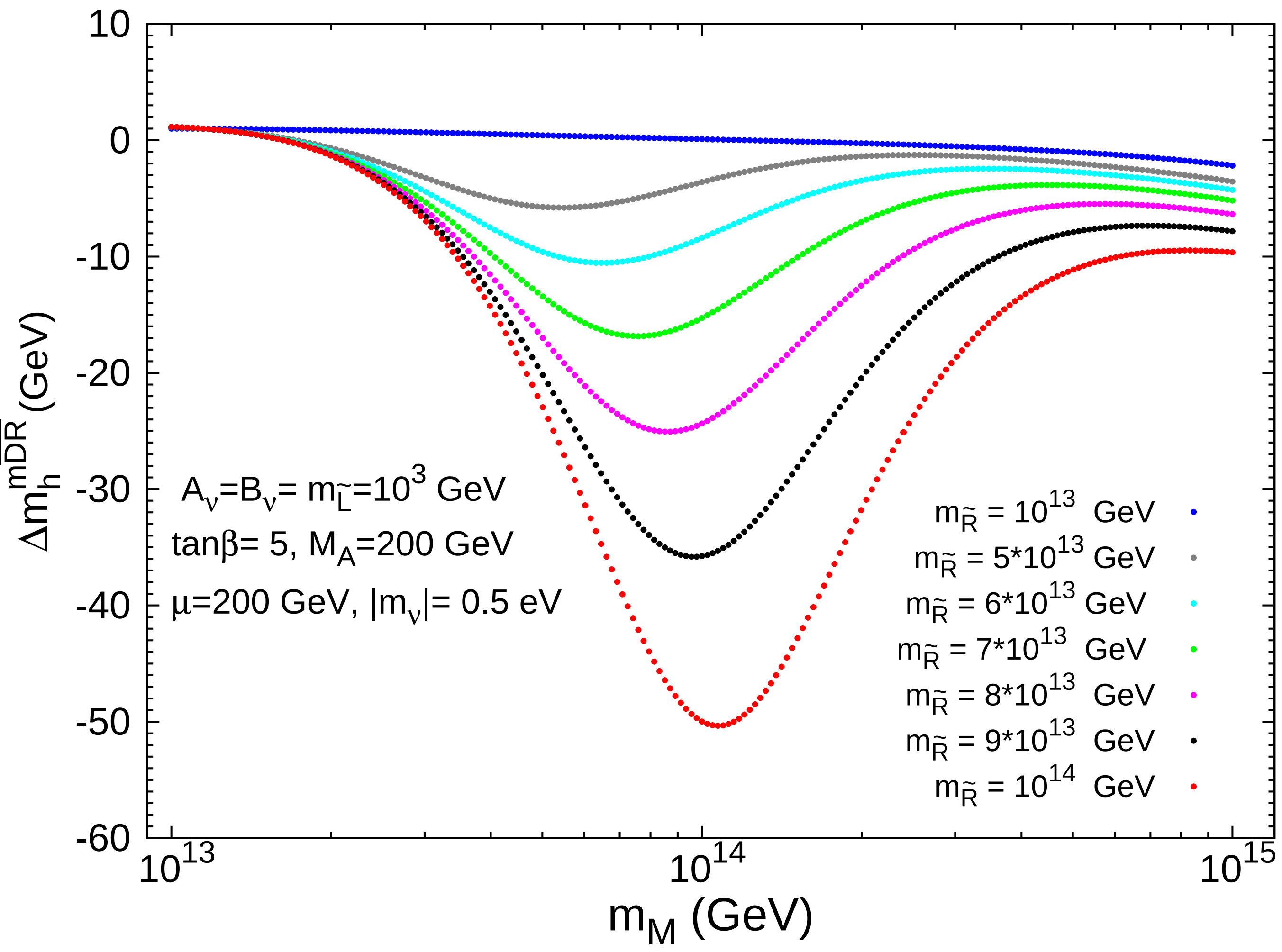
$\mathcal{O}\left(m_D^2\right)$ versus $\mathcal{O}\left(m_D^4\right)$:



→ $\mathcal{O}\left(m_D^2\right)$ dominates $\mathcal{O}\left(m_D^4\right)$ by many orders of magnitude

→ $\mathcal{O}\left(m_D^2\right)$ term in seesaw expansion reproduces accurately the full result

Dependence on $m_{\tilde{R}}$:



⇒ large corrections for $m_{\tilde{R}} \sim m_M$