

# Vacuum stability and scalar masses in the SWSM

## 1. The superweak extension

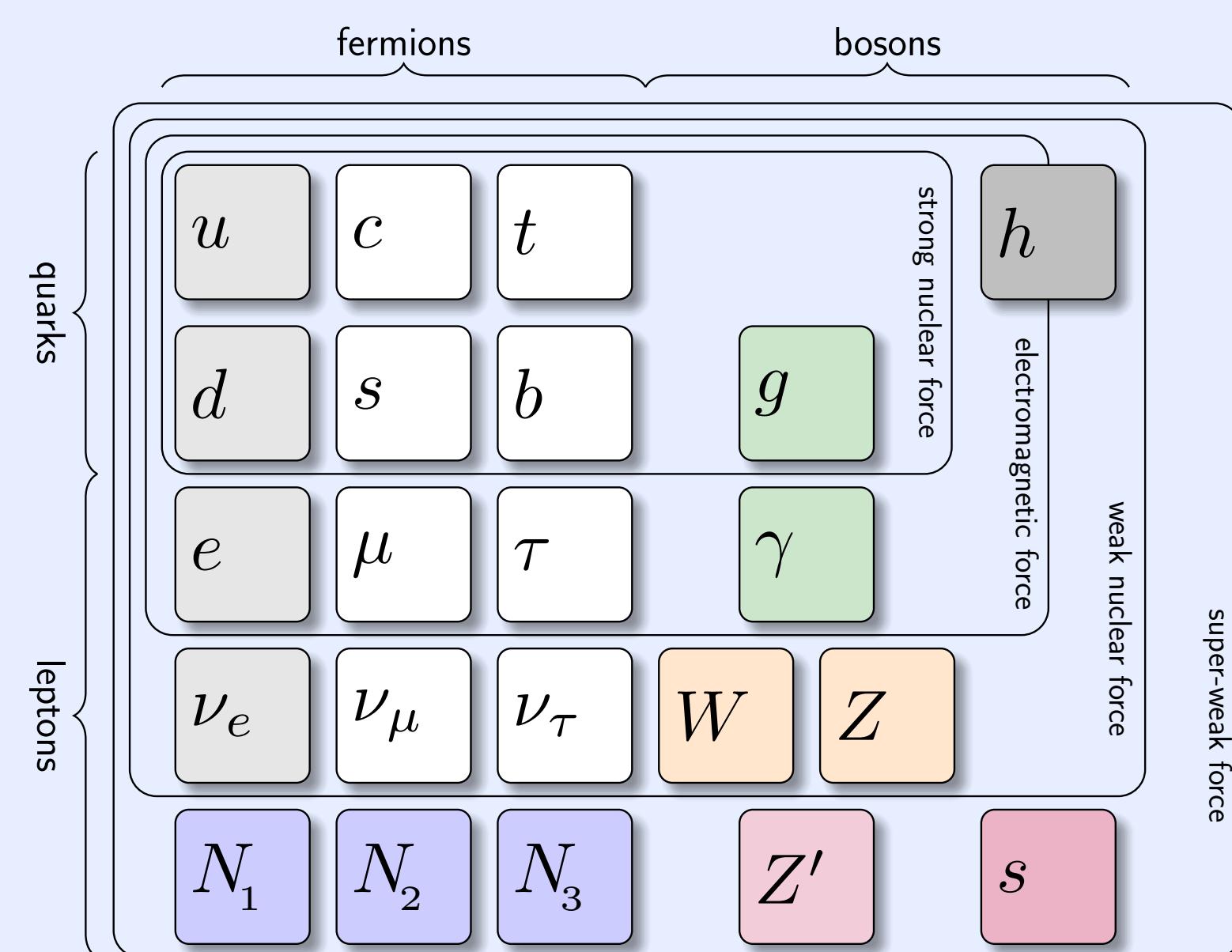


Figure 1: The standard model particle sheet with the superweak (SW) extension [1]. The forces act on all particles within the respective box.

- Gauged  $U(1)_z$ , 1 complex scalar singlet, 3 generations of right-handed neutrinos
- Restrict parameter space of the model
- Vacuum stability, W-boson mass, direct searches for new scalar

Similar analyses exist in the context of the singlet scalar extension (SSSM), focusing on vacuum stability [2] and exclusion limits by collider searches [2, 3]. The SSSM is a special case of the SWSM in the limit of vanishing SW gauge coupling and  $N_i$  Yukawa couplings (denoted by  $y_x$  here).

## 2. Scalar sector: vacuum stability analysis

- The standard model vacuum is metastable at high energies
- We investigate absolute stability in the SW extension.
- After spontaneous symmetry breaking (SSB):

$$\phi = \frac{1}{\sqrt{2}} \begin{pmatrix} -i\sqrt{2}\sigma^+ \\ v + H + i\sigma_\phi \end{pmatrix}, \quad \text{and} \quad \chi = \frac{1}{\sqrt{2}} (\omega + S + i\sigma_\chi). \quad (1)$$

- The scalar potential is

$$V(\phi, \chi) = V_0 - \mu_\phi^2 |\phi|^2 - \mu_\chi^2 |\chi|^2 + \lambda_\phi |\phi|^4 + \lambda_\chi |\chi|^4 + \lambda |\phi|^2 |\chi|^2. \quad (2)$$

- The propagating mass eigenstates are obtained after the rotation

$$\begin{pmatrix} h \\ s \end{pmatrix} = \begin{pmatrix} \cos \theta_s & -\sin \theta_s \\ \sin \theta_s & \cos \theta_s \end{pmatrix} \begin{pmatrix} H \\ S \end{pmatrix}. \quad (3)$$

- Stability conditions checked by solving the two-loop RGE, generated by SARAH [4] in the range  $\mu \in (M_t, M_{Pl})$

- Perturbativity is also checked

## 3. Parameter scan

- We scan:  $\lambda_\phi(M_t)$ ,  $\lambda_\chi(M_t)$ ,  $\lambda(M_t)$  and  $y_x(M_t)$
- Require the existence of  $w(M_t)$ , for nontrivial phenomenology (use SPheno [5])

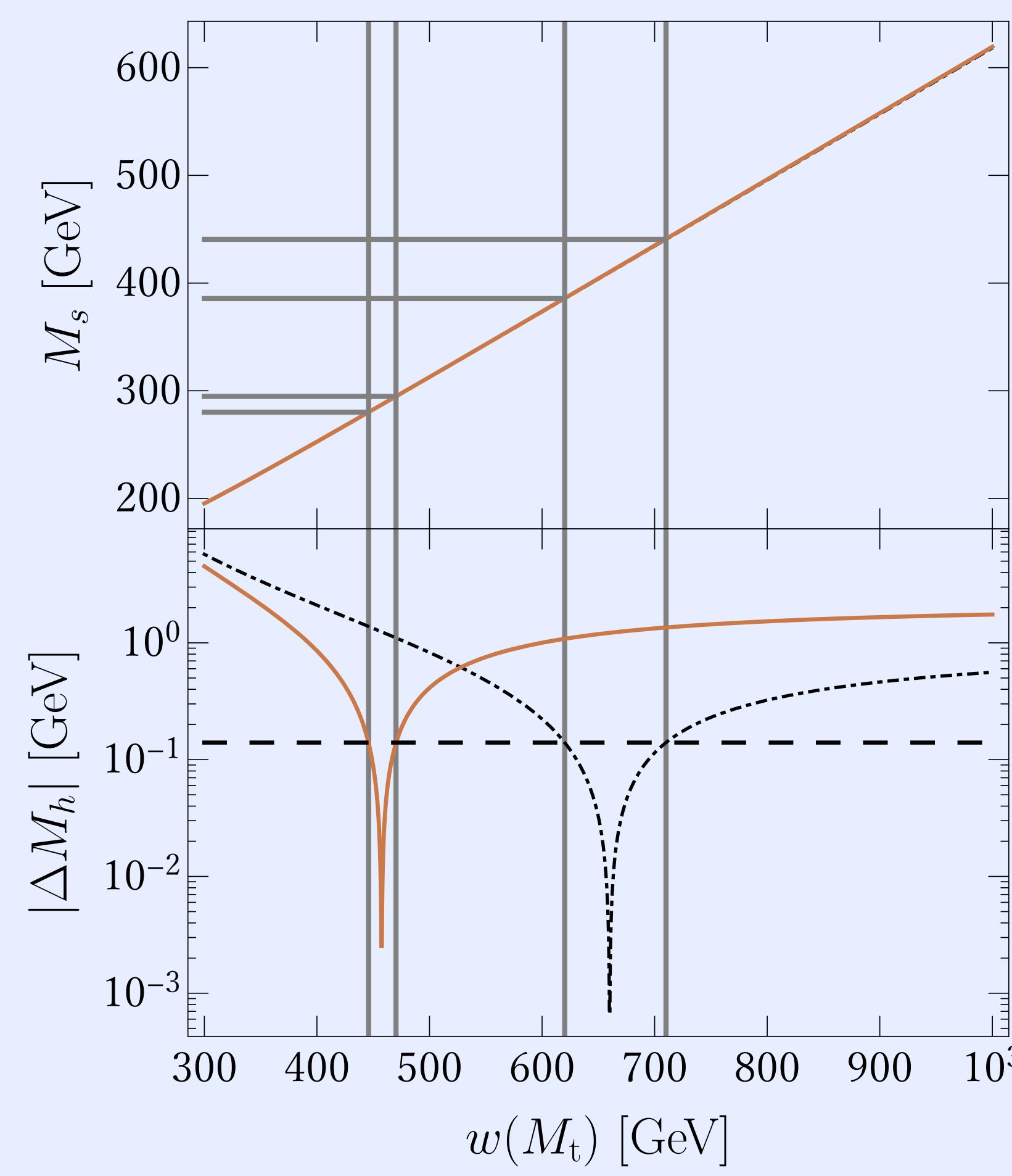


Figure 2: Benchmark for extracting  $w(M_t)$  from  $|M_h - 125.1 \text{ GeV}|$ . The black dash-dotted curves are tree level, the solid colored ones are at one loop.

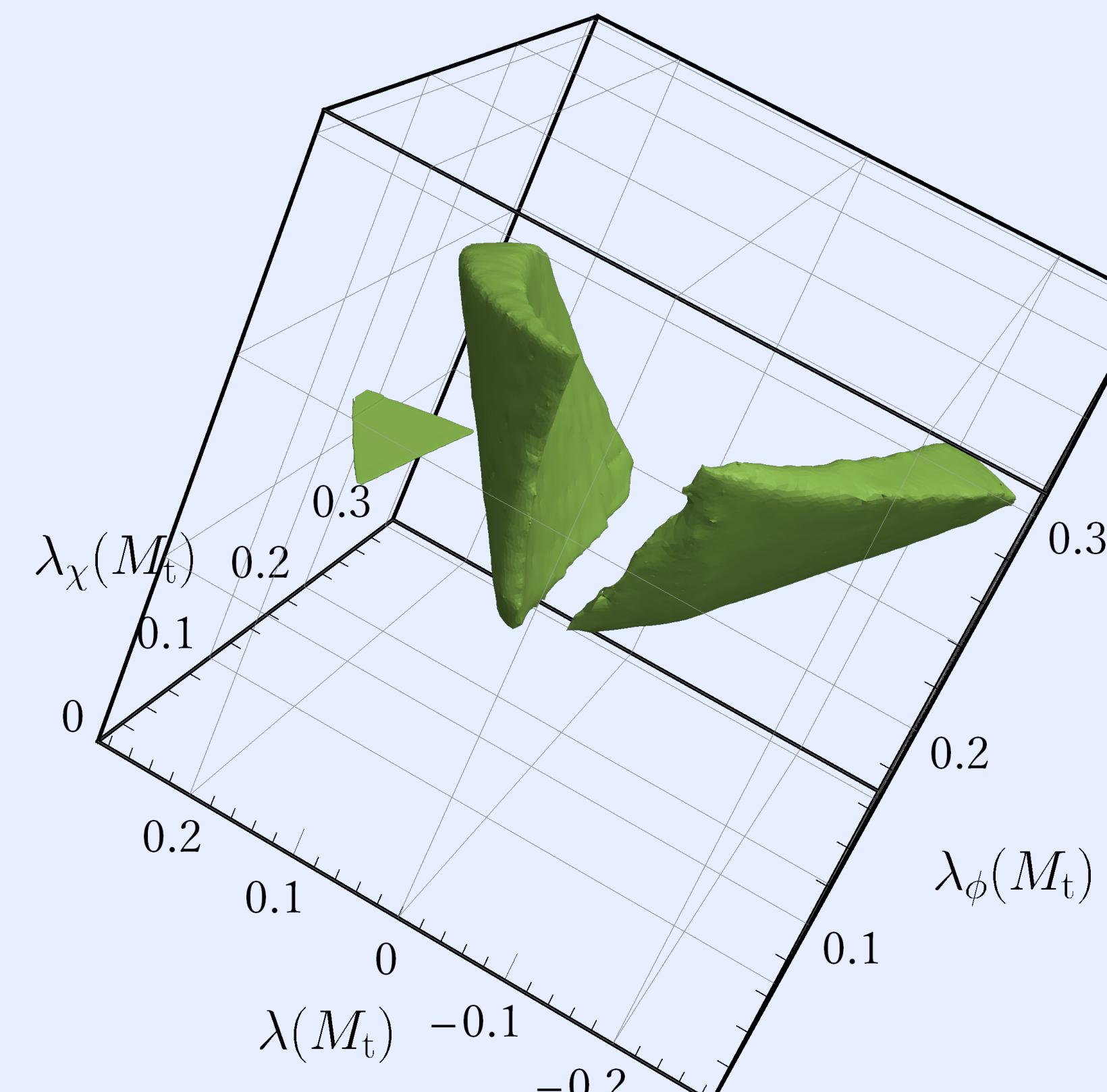


Figure 3: Three dimensional parameter space at  $y_x(M_t) = 0.4$

## 4. W mass in the SW extension

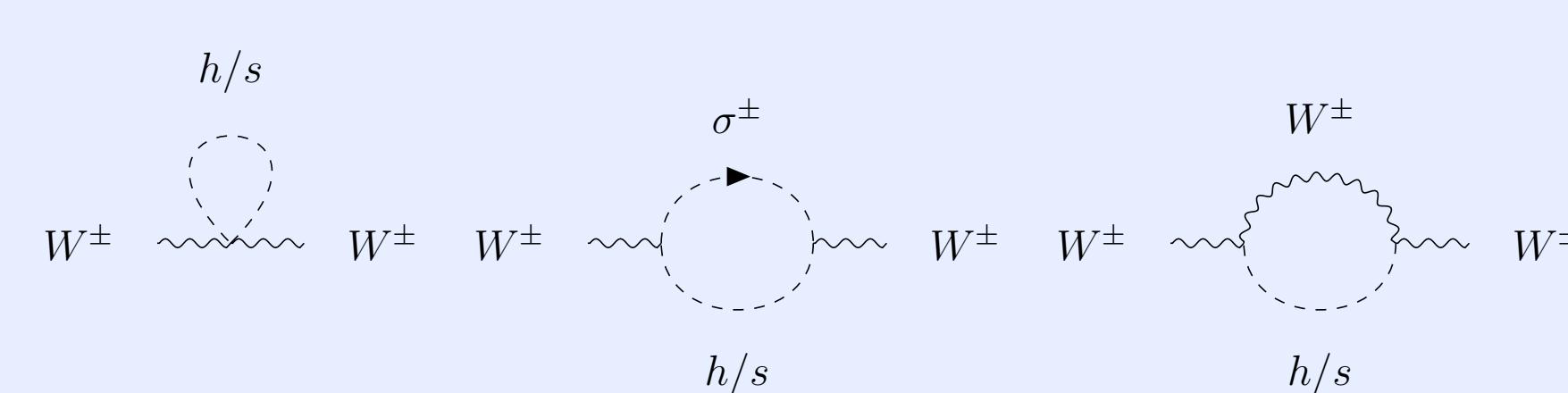


Figure 4: Slices of the parameter space

- Gray region: excluded by HiggsBounds 5.
- Colored region: stable vacuum.
- Above dashed line: excluded by W-boson mass measurements, ignoring the new CDF result [7].
- For more details please check arXiv:2204.07100 or [arXiv:2204.07100](https://arxiv.org/abs/2204.07100) or

## References

- [1] Zoltán Trócsányi. Super-weak force and neutrino masses. *Symmetry*, 12(1):107, 2020.
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- [5] W. Porod and F. Staub. SPheno 3.1: Extensions including flavour, CP-phases and models beyond the MSSM. *Comput. Phys. Commun.*, 183:2458–2469, 2012.
- [6] Philip Bechtle, Daniel Dercks, Sven Heinemeyer, Tobias Klingl, Tim Stefański, Georg Weiglein, and Jonas Wittbrodt. HiggsBounds-5: Testing Higgs Sectors in the LHC 13 TeV Era. *Eur. Phys. J. C*, 80(12):1710, 2020.
- [7] T. Altonen et al. High-precision measurement of the W boson mass with the CDF II detector. *Science*, 376(6589):170–176, 2022.