The $\{m_h, m_t\}$ plane: Standard Model criticality vs. high-scale SUSY

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Motivations

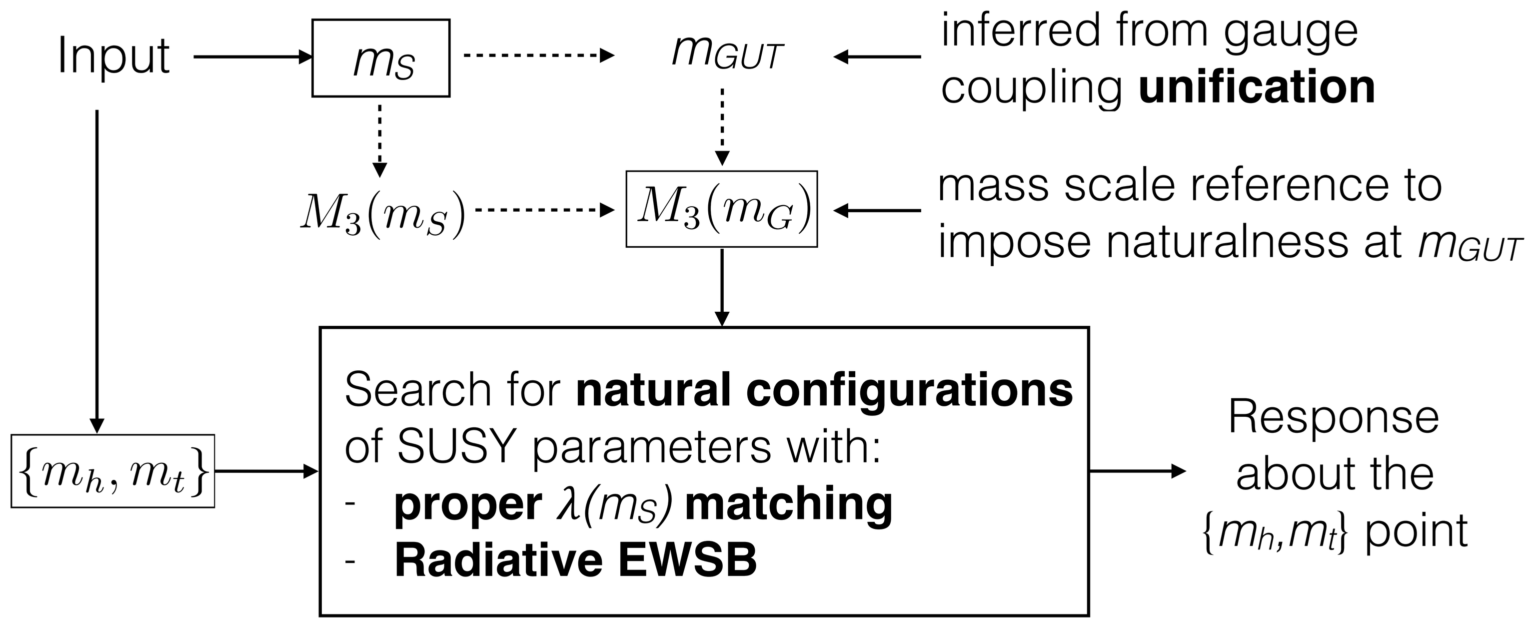
In recent years, the study of Standard Model (SM) behaviour under the Renormalization Group Equation (RGE) flow has revealed an interesting peculiarity: the measured values of Higgs and Top masses lie in the narrow SM metastability region (the region where electroweak vacuum is unstable but sufficiently long-lived compared to the age of the Universe, and the SM can be considered a viable theory up to the Planck scale).
This work shows that also within the Minimal Supersymmetric Standard Model (MSSM), studied with an analogous philosophy, the measured values of m_h and m_t reveal interesting features. These features are somehow equally surprising and perhaps with more fertile implications.

1. Novelty of the work

Former works have focused their attention on single requirements (such as quartic Higgs coupling matching or gauge coupling unification) using as variables the SUSY scale m_S and/or the Higgs mass m_h, but rarely the Top mass m_t, despite many valid motivations for doing so.

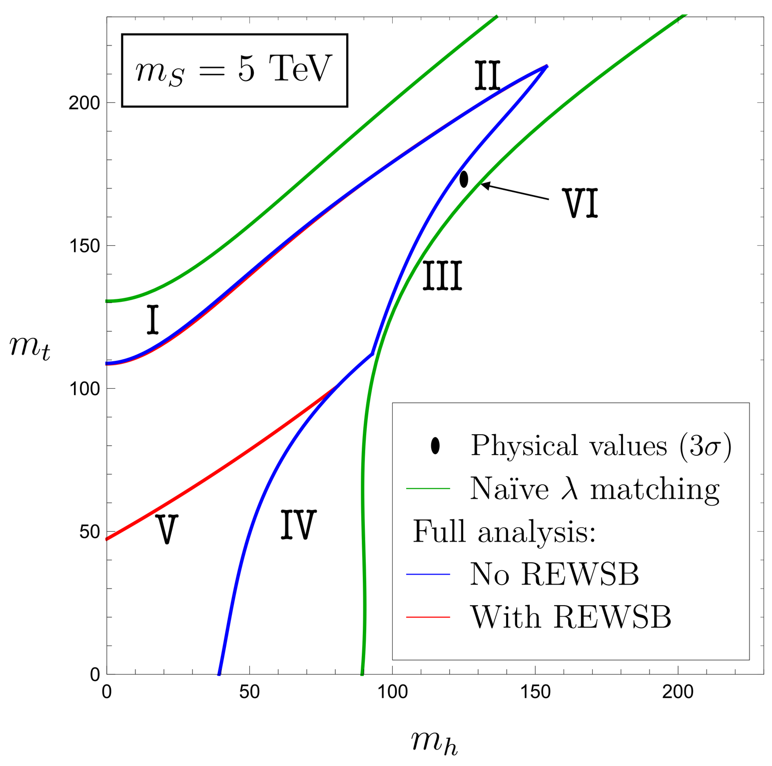
Here we have **analysed the MSSM** for different plausible SUSY-breaking scales (m_S = *2, 5, 100, 1000* TeV), **using the $\{m_h, m_t\}$ plane perspective**, looking for viable configurations with simultaneous:
- gauge coupling unification
- satisfactory quartic Higgs coupling (λ) matching
- natural parameters configuration at the GUT scale
- Radiatively realised ElectroWeak Symmetry Breakdown (REWSB)

2. Details of the performed analysis



3. Results in a low-scale SUSY scenario

Results for m_S = *5* TeV:



Many factors contribute to the final shape:

I. For higher m_t, $\lambda(m_S)$ becomes negative

II. For higher m_t, $y_t(\mu)$ develop a Landau pole before m_{GUT}

III. For higher m_h, $\lambda(m_S)$ becomes too big

IV. For lower m_t / higher m_h, EWSB and $\lambda(m_S)$ matching are incompatible

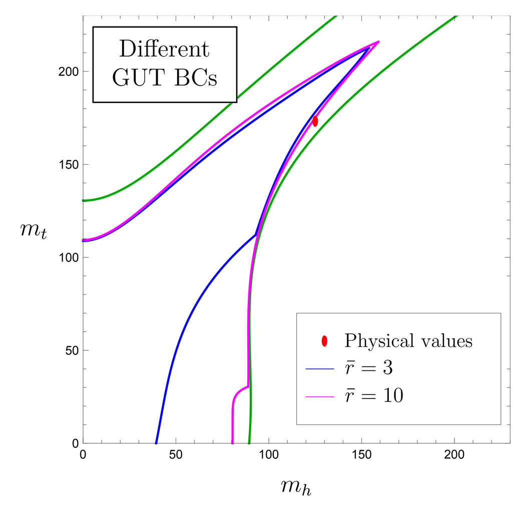
V. For lower m_t, EWSB cannot be radiatively induced

VI. For m_S = 5 TeV, the measured $\{m_h, m_t\}$ values are allowed by a naïve analysis, but excluded by our more sophisticated analysis.

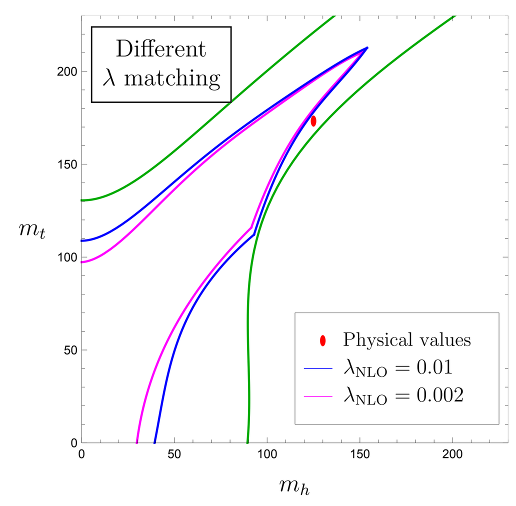
4. Changing the analysis parameters

By modifying the analysis parameters and observing the effects, we get a deeper understanding of the physics that originates the borders:

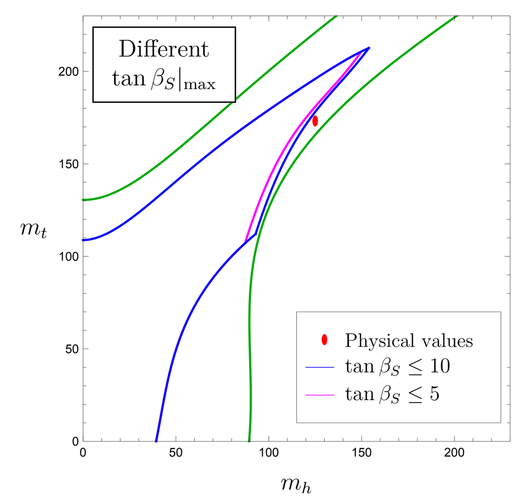
Enlarged natural range at m_{GUT}



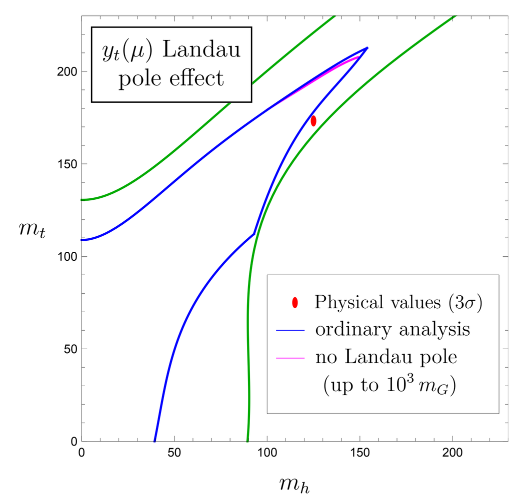
Reduced λ-matching tolerance



Reduced maximal *tan(β)* value

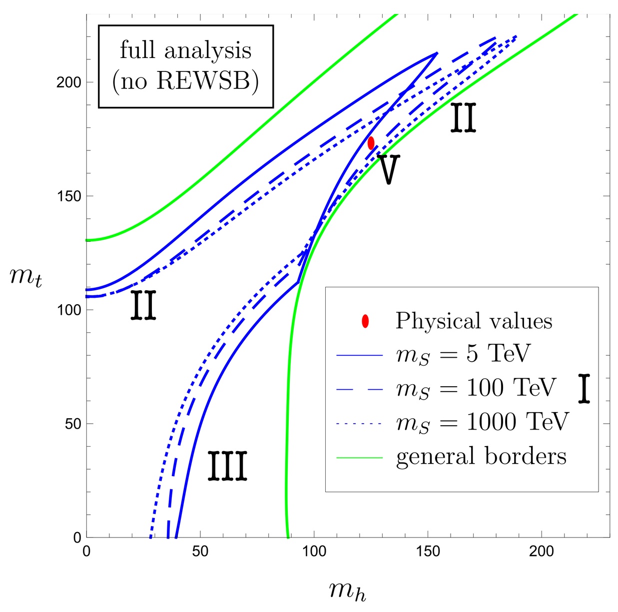


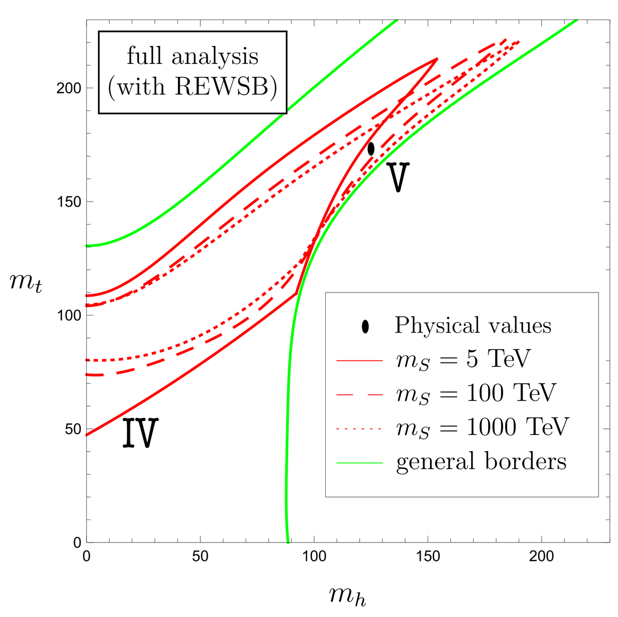
Amplified $y_t(\mu)$ Landau pole effect



5. Comparison for different SUSY scales

By comparing the results for different SUSY scales we can better appreciate the peculiar position of the SM in the space of possible vacua.





I. m_S > *2* TeV, due to direct searches bounds
m_S < 10^6 GeV, otherwise gauge coupling unification is spoiled

II. For high m_t, $d\lambda(\mu)/d\mu<0$. Thus, for higher m_S we have lower $\lambda(m_S)$, causing the observed shift to the right

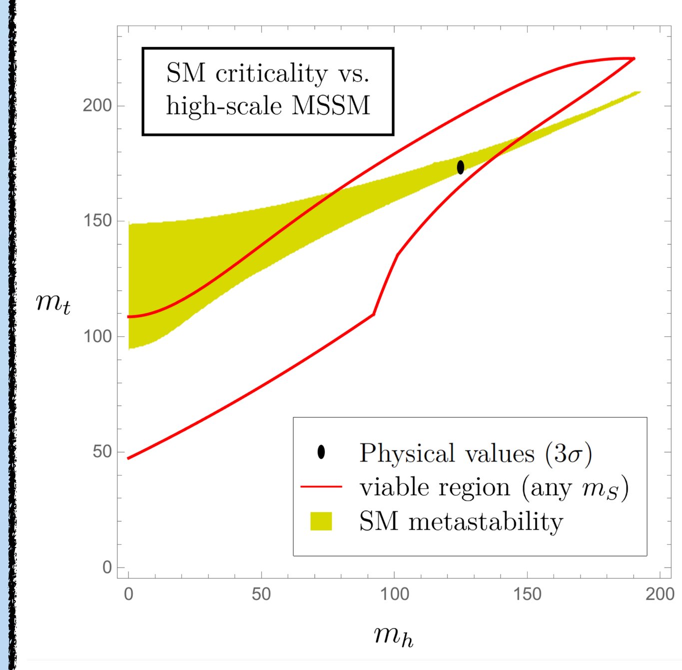
III. For low m_t, $d\lambda(\mu)/d\mu>0$. Thus, for higher m_S we have higher $\lambda(m_S)$, causing the observed shift to the left

IV. For higher m_S we have lower $y_t(m_S)$. This makes REWSB harder to achieve

V. The measured $\{m_h, m_t\}$ values are found in a remarkably narrow window of the parameter space where all the imposed conditions are met for a large range of m_S values

6. Conclusions

This analysis has two important novelties:
- ***m_t* is a scanned** input parameter (as m_h)
- we introduce **a Radiative EWSB** condition



We obtain new and interesting results:
- we **reduce the allowed window** for SUSY models in the $\{m_h, m_t\}$ plane, also as a **consequence of** the **REWSB** condition.
- remarkably, the measured values still lies in the allowed window, which is **narrow in both *m_h* and *m_t*** directions.

It can be appreciated that this coincidence is perhaps as strong and surprising as for the SM vacuum metastability.