

Higgs Instability in BSM Models

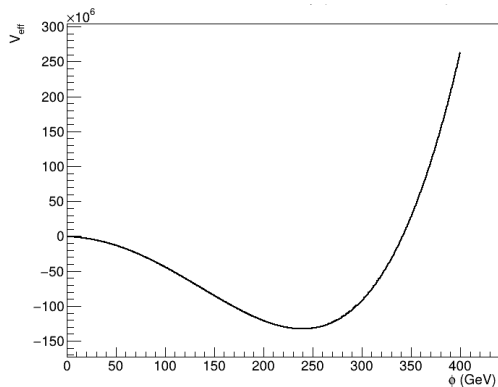
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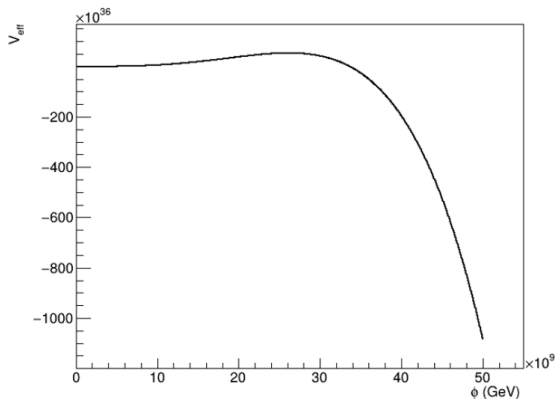
Higgs Potential Landscape

At the lower energies, the Higgs potential has the familiar “Mexican hat” shape. This is the EW vacuum that we enter following the EWSB.



Higgs Potential Landscape

If we extrapolate the SM up to higher energy scales, it turns out that the EW vacuum is not the true vacuum. Given the current best values of the SM parameters, it is a false vacuum.



Higgs Potential Landscape

At tree level we have:

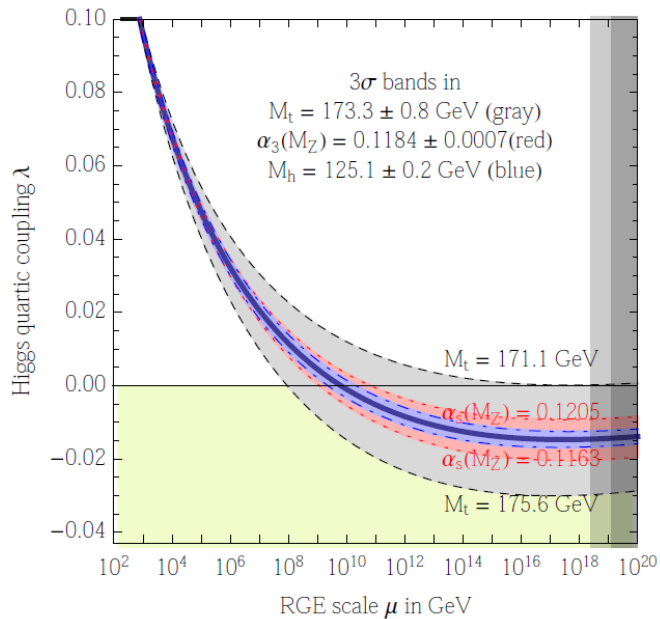
$$V_0(\phi) = \frac{\mu^2}{2}\phi^2 + \frac{\lambda}{4}\phi^4 \approx \frac{\lambda}{4}\phi^4 \quad \mu^2 < 0$$

At high energies the quartic term dominates. The sign of λ changes the sign of the potential, allowing for a deeper vacuum.

The Universe can be:

- Stable: $\lambda > 0$ at all energies.
- Metastable: $\Gamma > \text{age of the Universe}$.
- Unstable: $\Gamma < \text{age of the Universe}$.

Our Universe is **metastable**, and λ becomes negative at $\sim 10^{10}$ GeV.



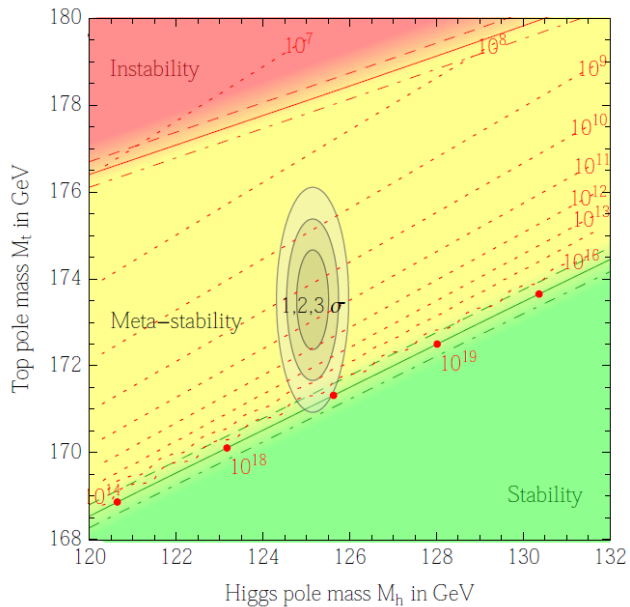
Important Parameters

$$V_0(\phi) = \frac{\mu^2}{2}\phi^2 + \frac{\lambda}{4}\phi^4$$

$$\lambda \simeq \frac{M_h^2}{v^2}$$

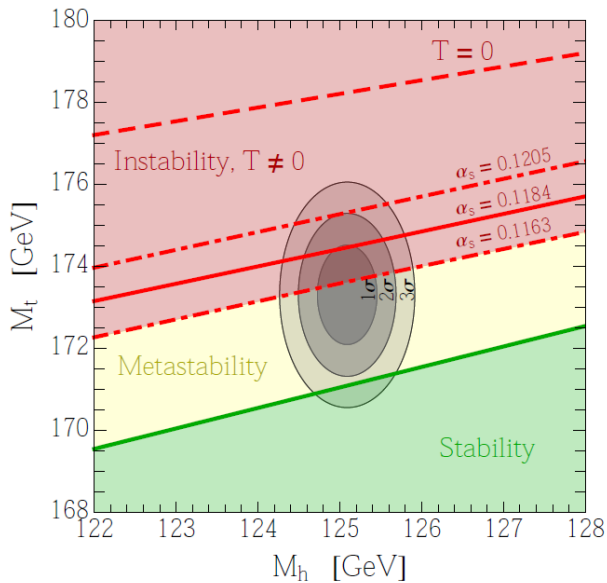
$$\beta_\lambda^{(1)} \supset -6Y_t^4$$

$$\beta_{Y_t}^{(1)} \supset -8g_3^2 Y_t$$



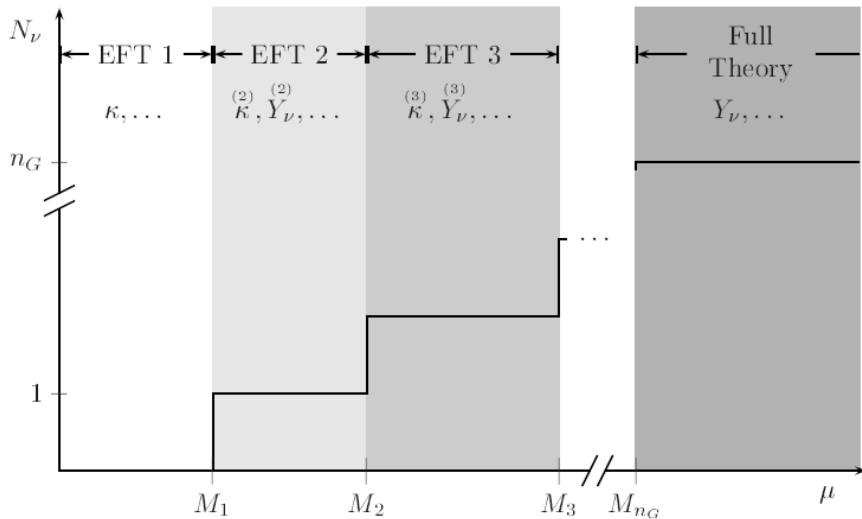
Age of the Universe as a benchmark

- Since our Universe has to be at least the age that it already is, we can use that to put some bounds on SM parameters.
- Current best estimates of the SM parameters lie well within the metastable region, far away from the unstable region.
- Thermal corrections do affect the phase diagram!



Next Steps

- Can use age of the Universe to deduce bounds on various parameters.
- Currently working on applying this to the type-I seesaw sterile neutrinos.
- Could lead to some insight regarding bounds on the masses of sterile neutrinos.



Future Goals

- Use this testing method for other models that extend the SM.
- Instabilities at high energies may not cause catastrophic tunnelling, but may leave other signs.
- Effects on dynamics during inflation/reheating.
- These can contribute to scalar perturbations that can create GW background signals.
- Useful to study how such signals differ based on different models - waiting for LISA!

Thank you for listening!