ElectroWeak Stability and Higgs Inflation

Giuseppe Iacobellis

(Supervisor: dr. Isabella Masina)

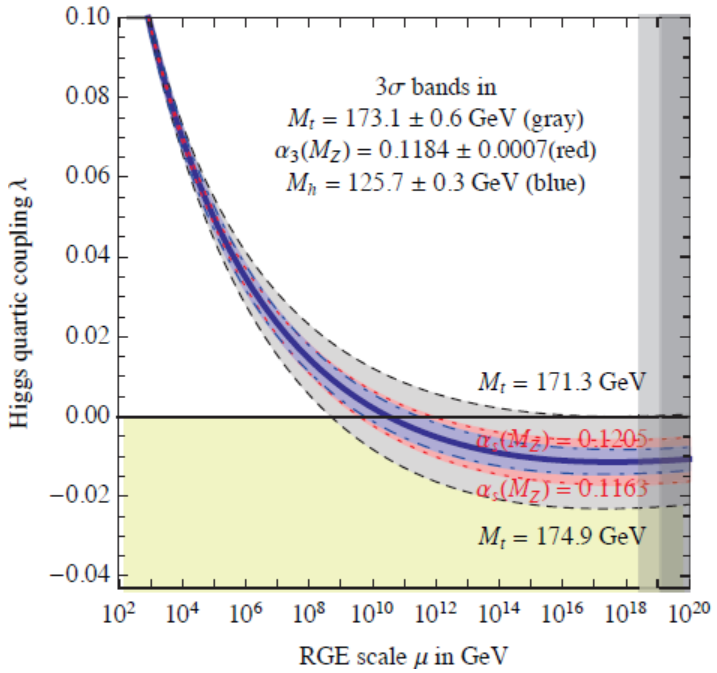
University of Ferrara and INFN

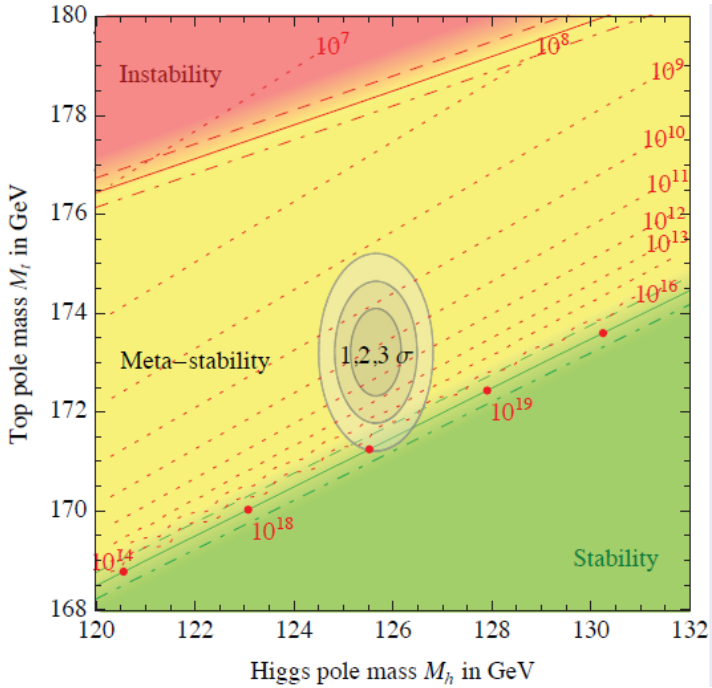
Xmas Theory Workshop

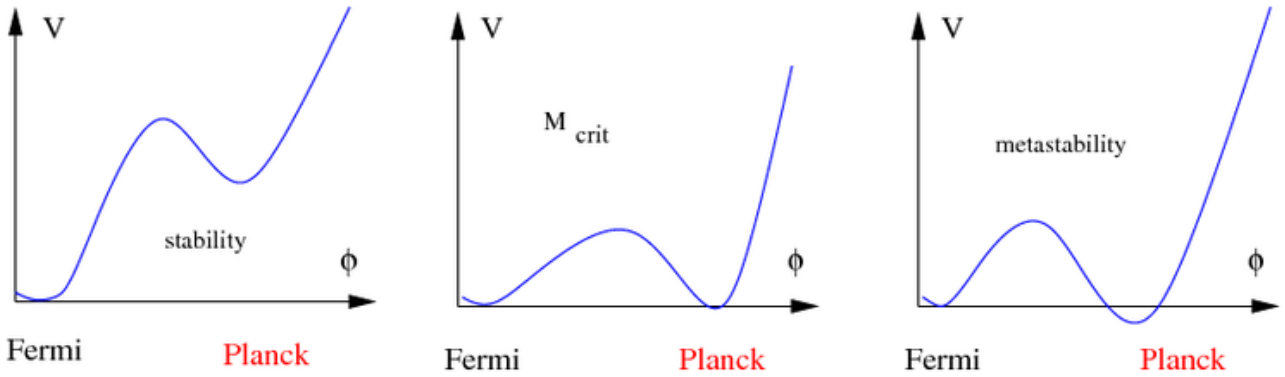
Bari, 22th December 2015

Electroweak vacuum stability

...a very special universe!







NNLO calculation: tools and issues

- Two-loop matching procedure for top quark *Yukawa coupling* and *Higgs quartic coupling*, with pole masses at some suitable scale;
- Running of the SM couplings through the three-loop *Renormalization Group Equation*:

$$\frac{d}{d\ln\left(\frac{\mu}{m_Z}\right)}\lambda_i = \beta_{\lambda_i}(\lambda_i),$$

$$\lambda_i = \left(\lambda_h(t), g(t), g'(t), g_s(t), y_t\right);$$

- The two-loop effective potential improved by RGE and $\hbar$ - expansion method is highly scale independent:

$$\mu(t) \sim \kappa h(t), \qquad \kappa = \mathcal{O}(1)$$

Saving false vacuum: SM extensions

Global Lagrangian

$$\mathcal{L} = \mathcal{L}_{\mathcal{SM}} + \mathcal{L}_{\mathcal{S}} + \mathcal{L}_{\mathcal{N}}\,,$$

$$\mathcal{L}_{\mathcal{S}} = -\frac{m_s^2}{2}s^2 - \frac{\lambda_{\phi s}}{2}\left|\mathcal{H}\right|^2 s^2 - \frac{\lambda_s}{24}s^4 + (\text{kinetic terms})\,,$$

$$\mathcal{L}_{\mathcal{N}} = \left(\frac{M_N}{2}\bar{N}^c N + h_\nu \bar{L}_\alpha \mathcal{H} N + \text{c.c.}\right) + (\text{kinetic terms})$$

I-type seesaw mechanism

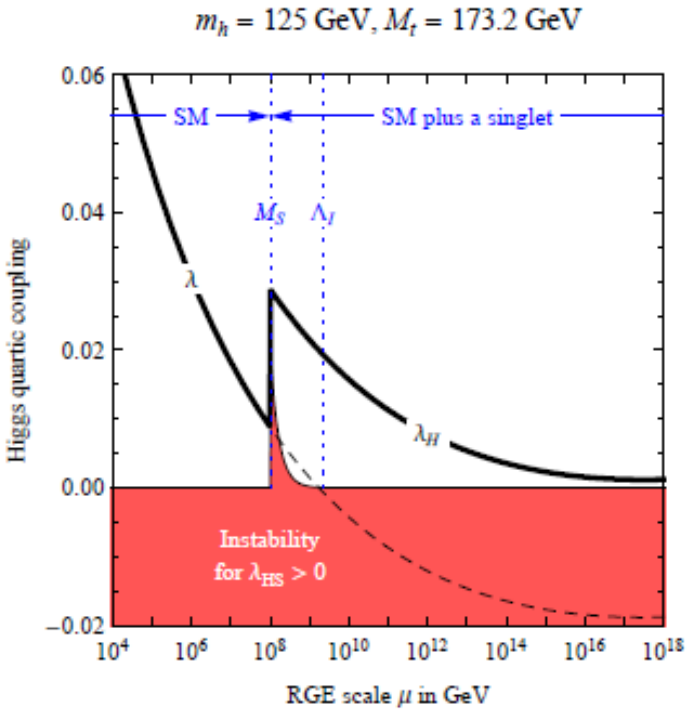
$$m_\nu = h_\nu \frac{v^2}{M_N}, \qquad M_N \gg v$$

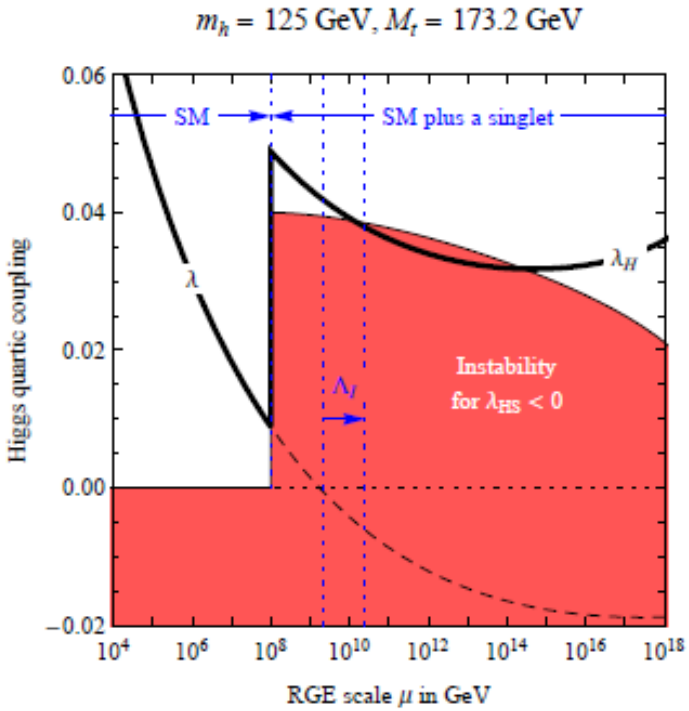
Other generations can be generated by lighter right-handed neutrinos

- Z_2 symmetry
- $m_s <$ instability scale
  $\rightarrow$ stability!
- tree-level threshold effect:

$$\lambda = \lambda_\phi - \frac{\lambda_{\phi s}^2}{\lambda_s}$$

Saving false vacuum: SM extensions (1)





ξ-inflation: motivation and results

Scalar fields can (should?) be non-minimally coupled to gravity, when it is considered

$$\mathcal{S}_J = \int d^4x\sqrt{-g}\left[\frac{M_P^2}{2}R - \xi\mathcal{H}^\dagger\mathcal{H}R + \mathcal{L}_{\mathcal{SM}}\right]$$

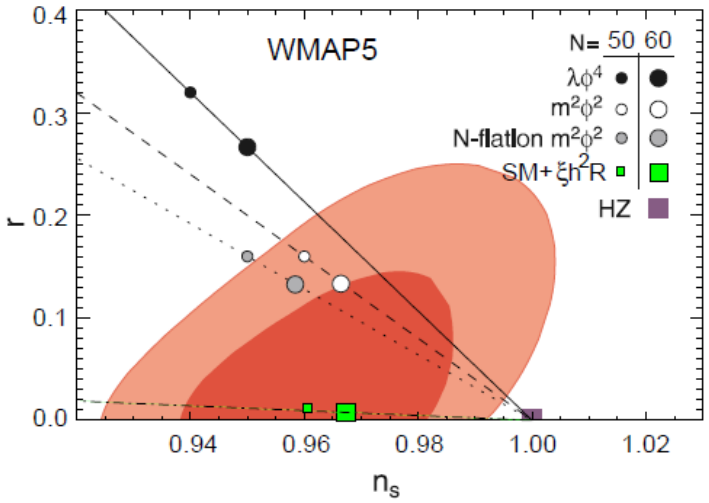
When $h \gg M_P/\sqrt{\xi}$, the potential is flat and slow-roll inflation can occurr and no new degrees of freedom were introduced

At tree-level we have:

$$\xi \sim \mathcal{O}(10^4)$$

Predictions

$$n_s \simeq 0.967, \quad r \simeq 0.0031$$



Summary/What next?

- The higher the loop order, the less the dependence of the physical observables on κ;
- The SM false vacuum scenario is no longer viable in a NNLO analysis for a successful inflationary phase;
- In a non-minimally coupled scenario a low ξ is not suitable to reproduce the current upper bound on r;
- It's hard to disentangle experimentally the Starobinsky' predictions and the Higgs inflation ones

...coming next

- Try to save the false vacuum critical inflation with minimal SM extension (full model);
- Re-do the full analysis with a more accurate determination (from both an experimental and theoretical side) of the top quark mass. Also a more constrained upper bound on r is awaited.

Merry Xmas and Happy New Year!