Higgs boson and Top quark masses as test of Electroweak Vacuum Stability

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International Workshop on
Deep-Inelastic Scattering
and Related Subjects

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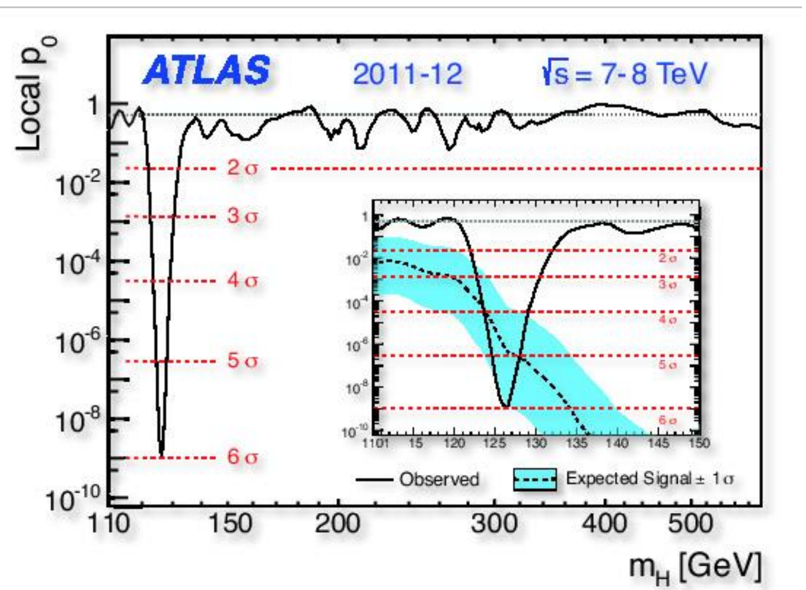
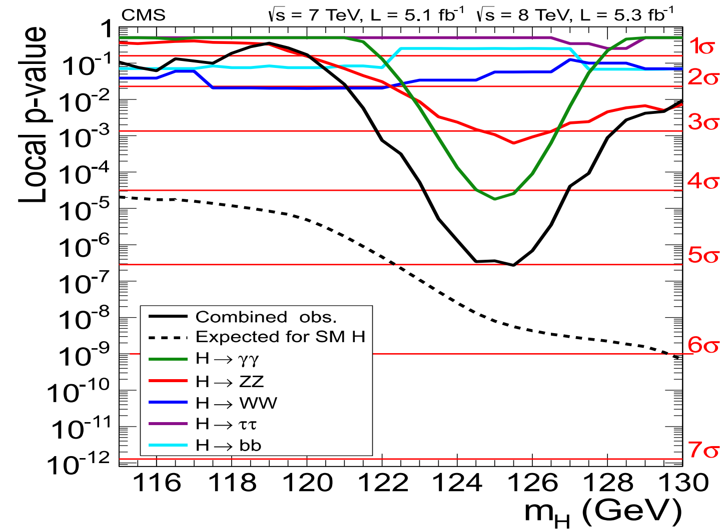


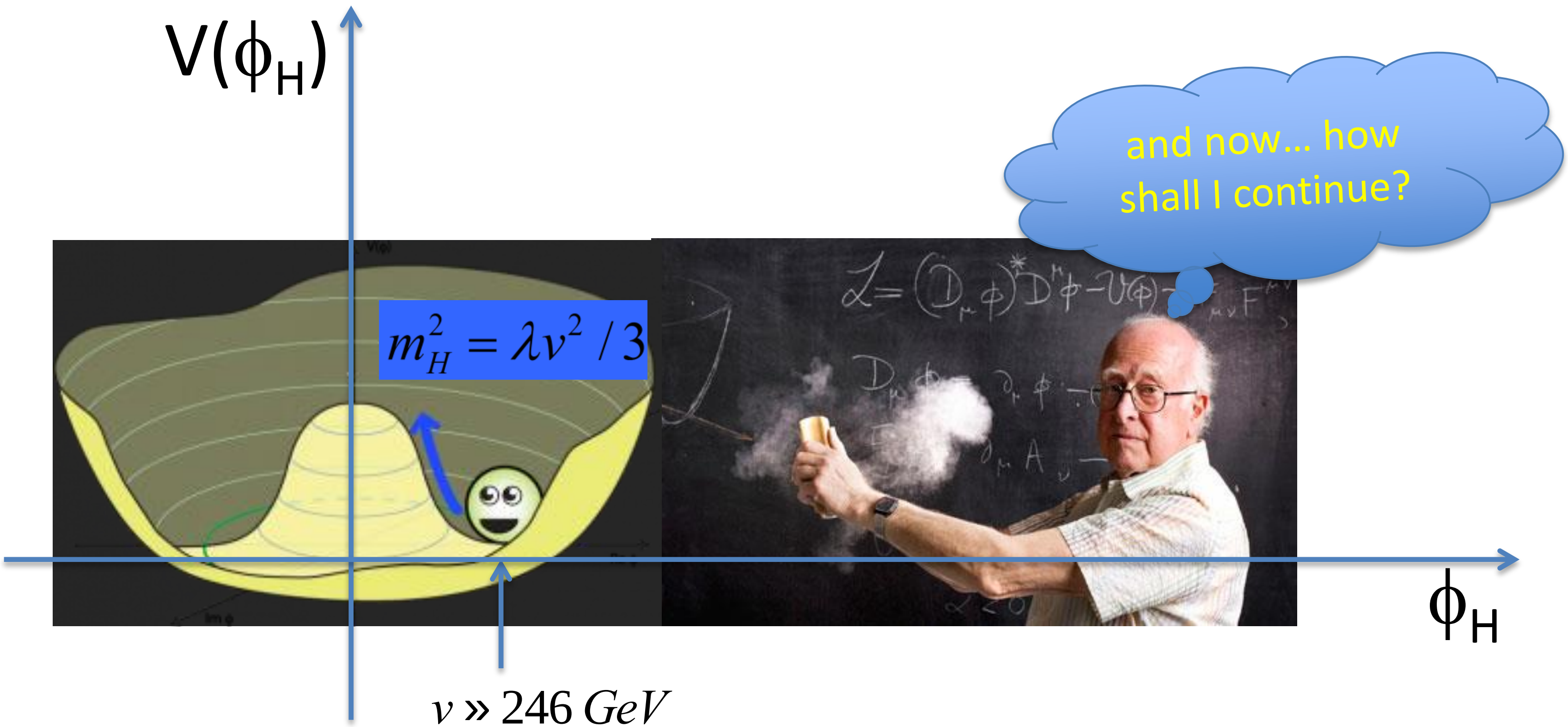


m_H » $125 - 126\ GeV$

SO WHAT?

Consider the Higgs doublet $H = (0, (\phi_H + v)/\sqrt{2})$

and the SM Higgs potential: $V(\phi_H) = \frac{\lambda}{6}\left(|H|^2 - \frac{v^2}{2}\right)^2 \approx \frac{\lambda}{24}\phi_H^4$



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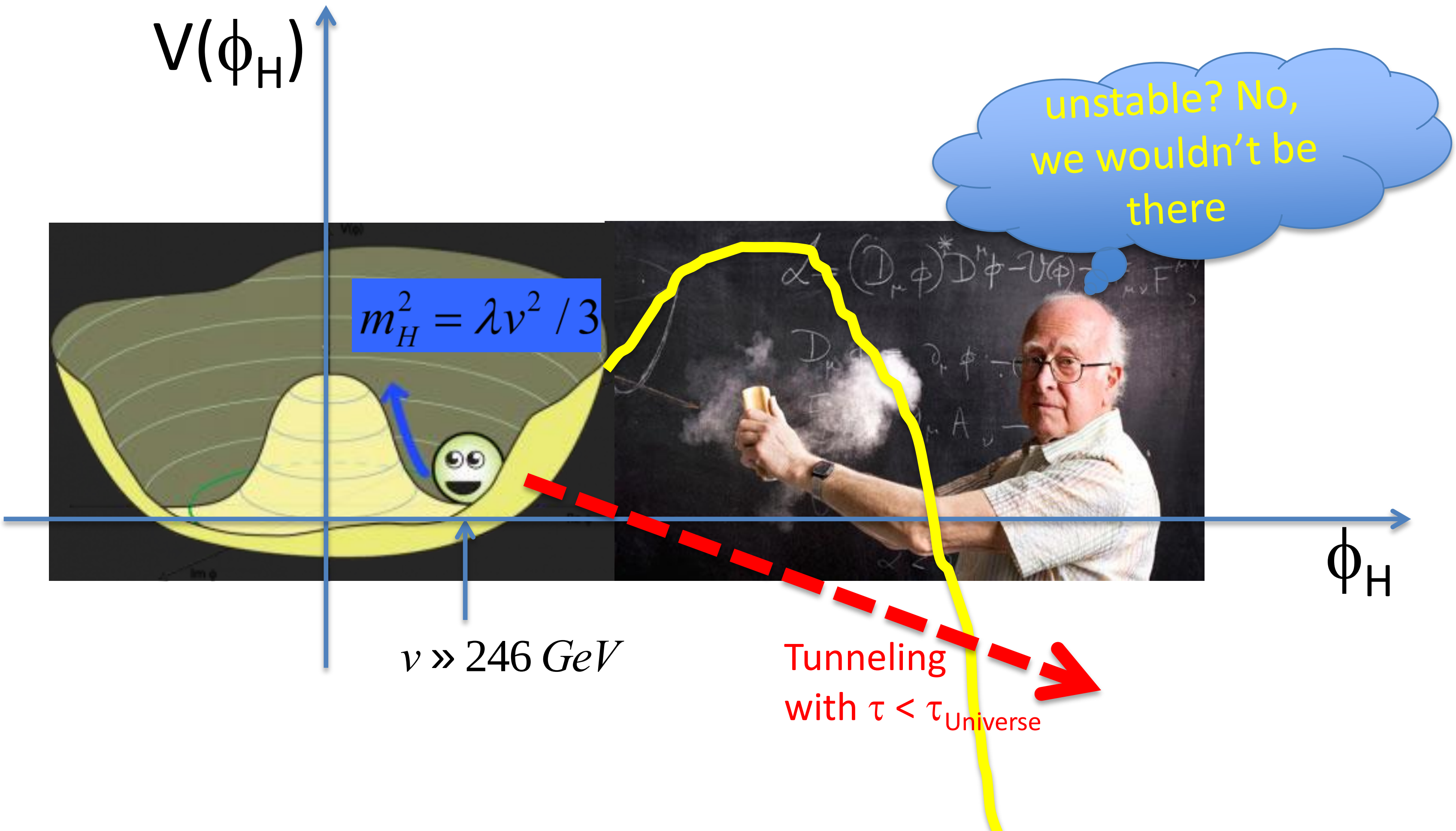

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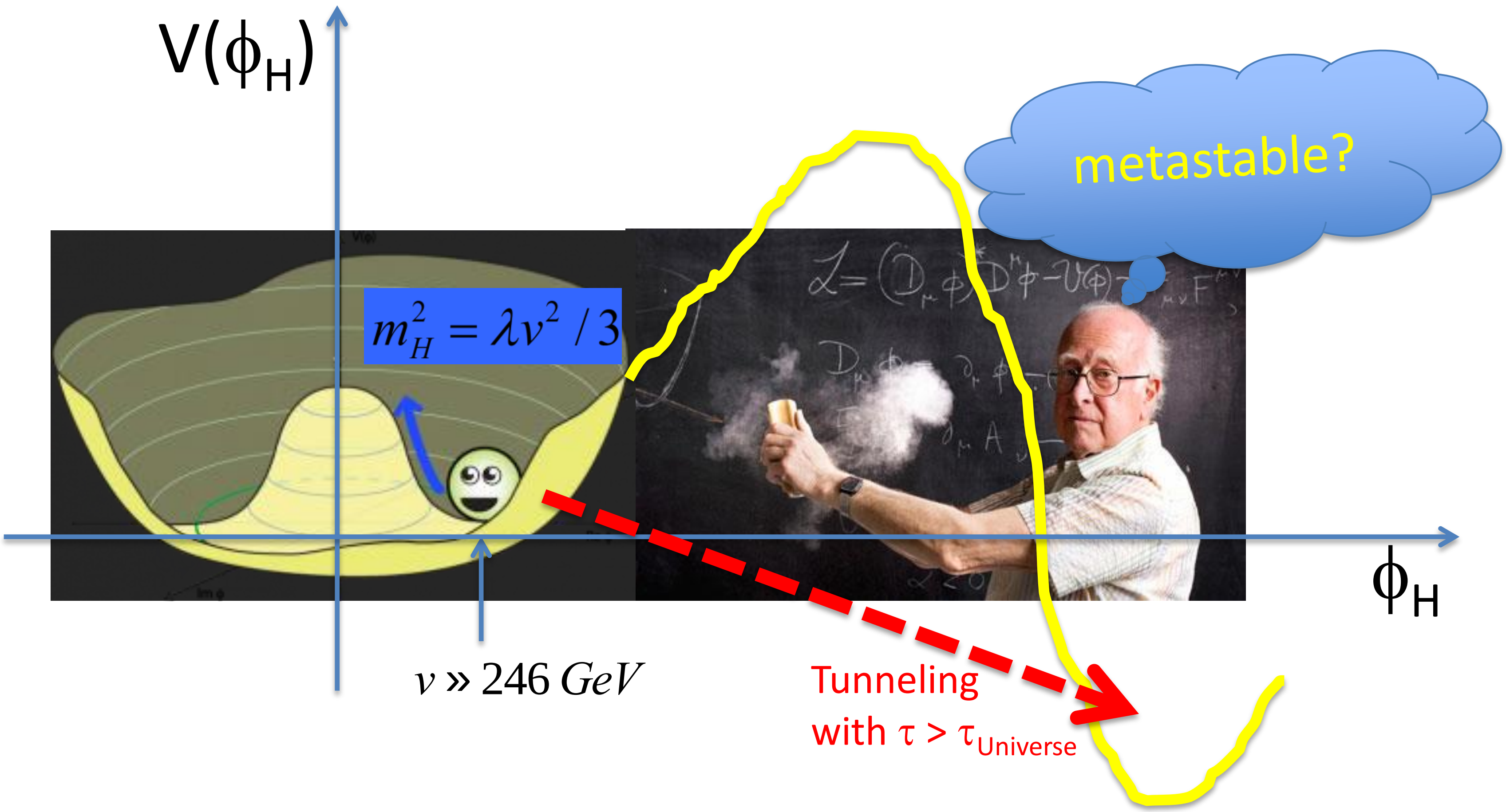

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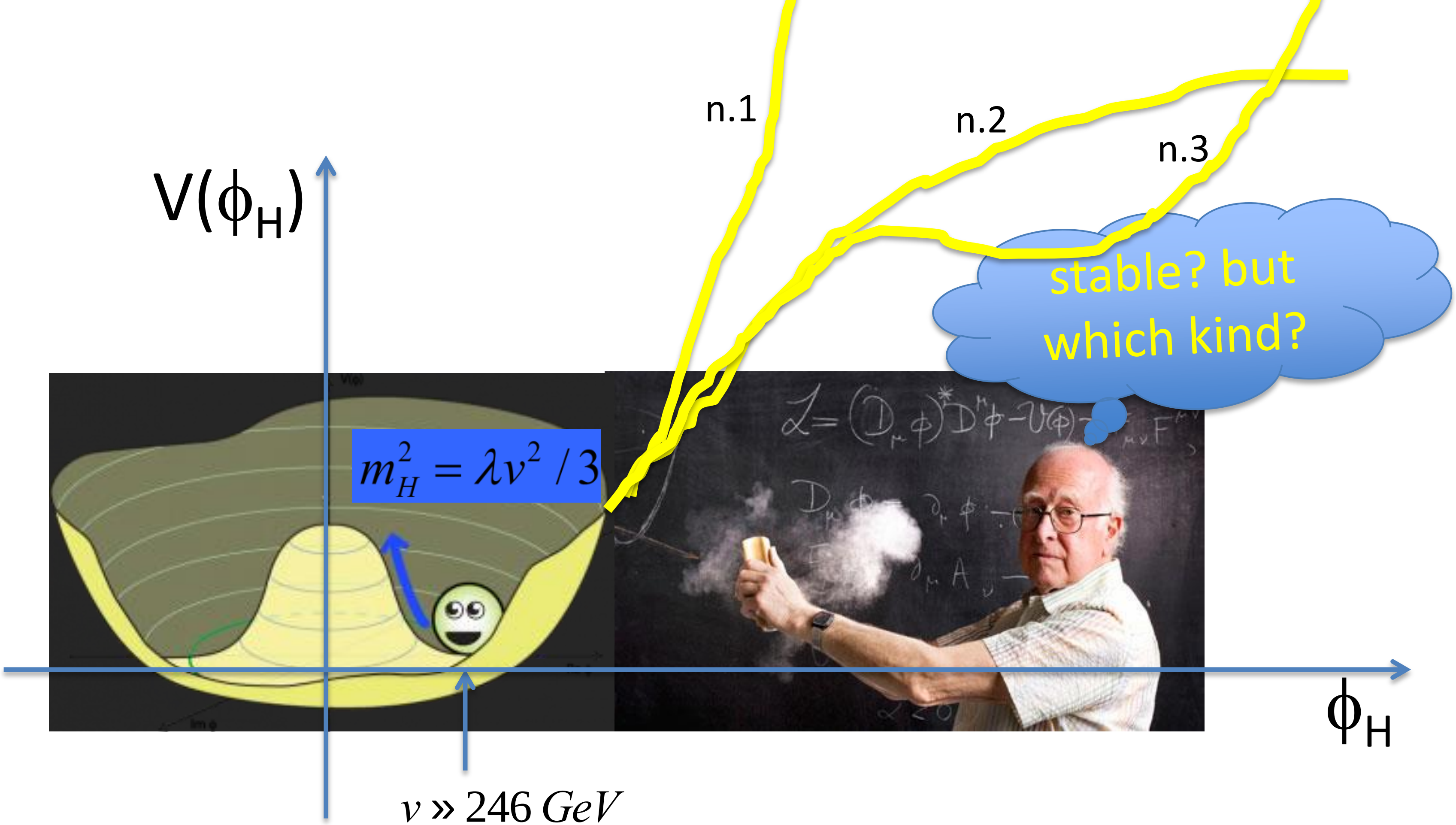

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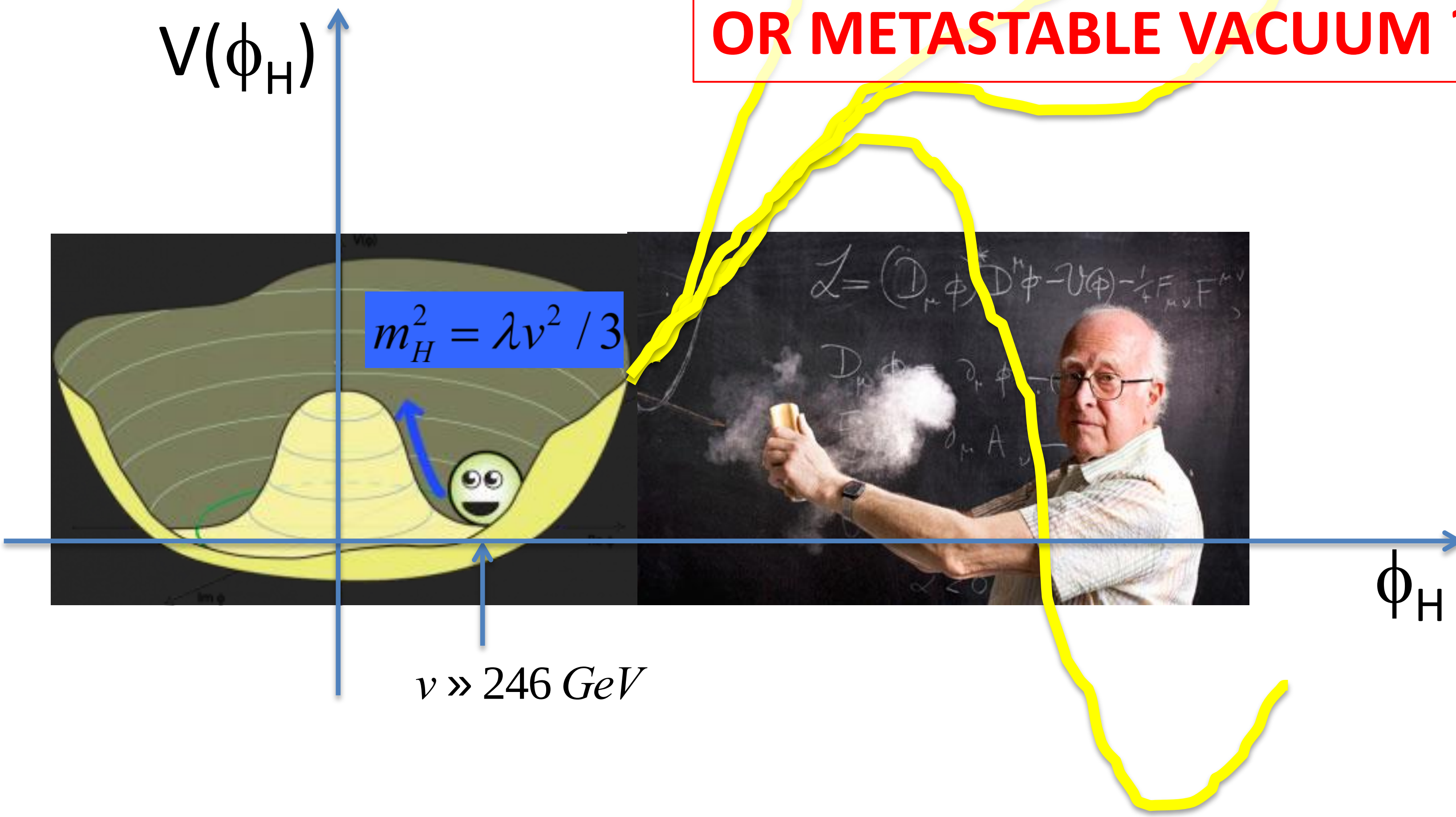

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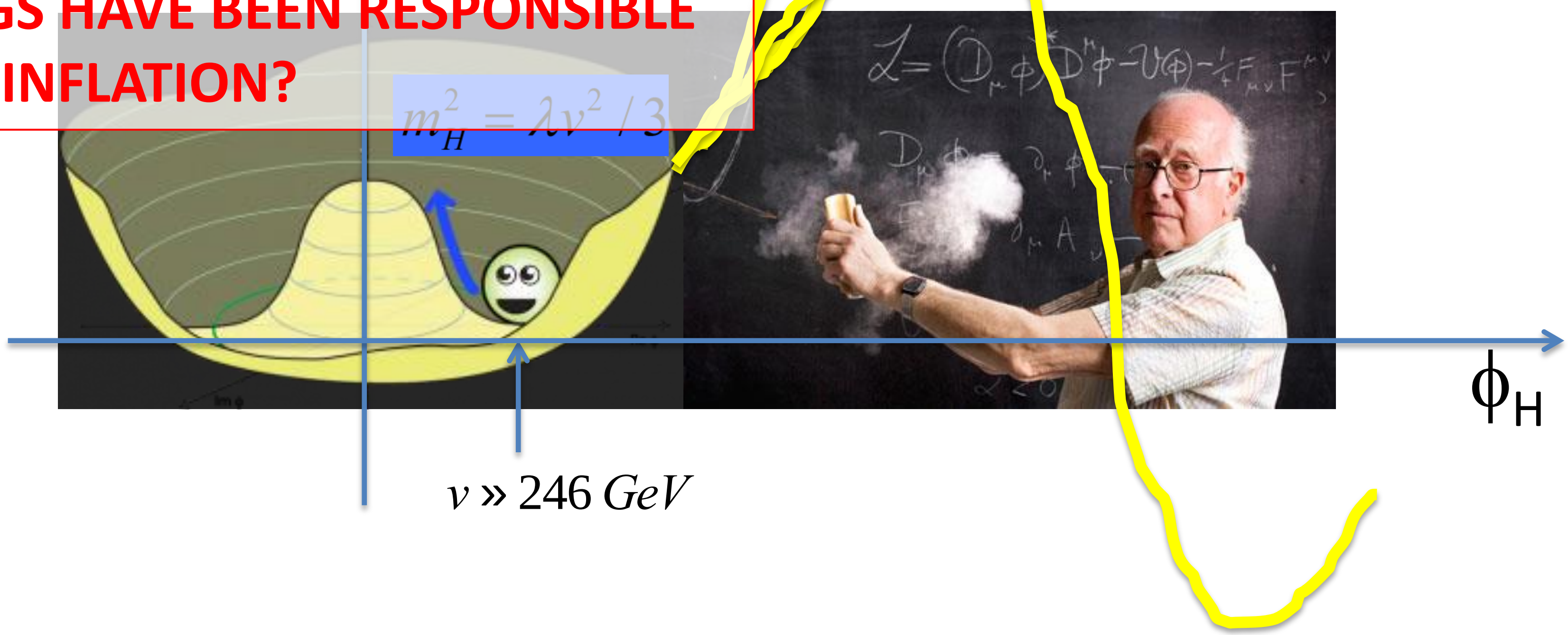

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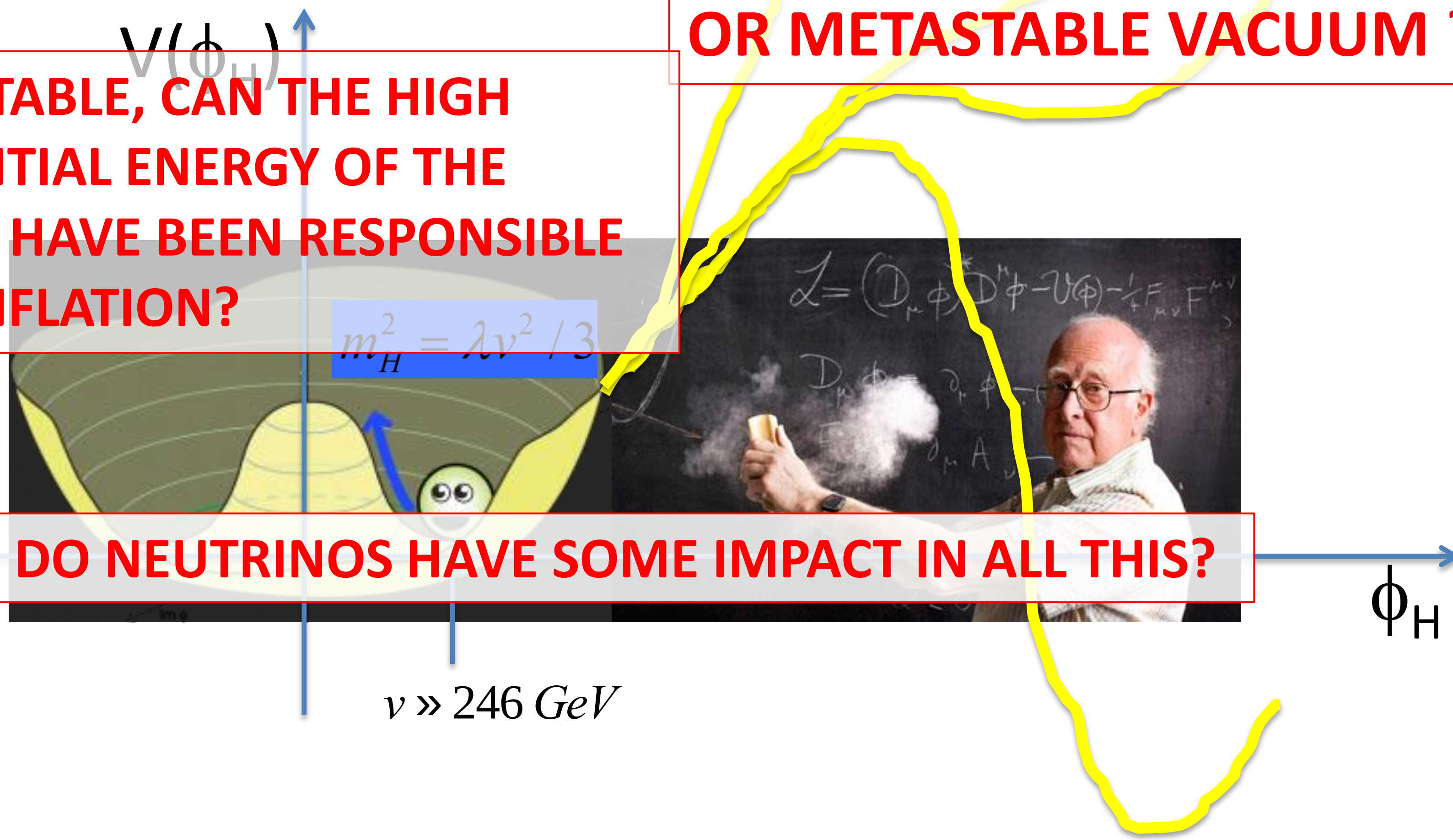

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[Hung, Cabibbo et al ‘79, Lindner, Sher, Casas, Espinosa, Quiros, Giudice, Riotto, Isidori, Strumia, etc]

(Assuming desert) extrapolate the SM Higgs potential at renormalization scale μ via RGE.
This can now be done at NNLO!!

3-loop running for: $g(\mu)$, $g'(\mu)$, $g_3(\mu)$, $\lambda(\mu)$, $y_t(\mu)$

[Mihaila Salomon Steinhauser, arXiv:1201.5868]

[Chetyrkin Zoller, arXiv:1205.2892]

$$\begin{aligned}
\frac{d}{dt}\lambda(t) &= \kappa\beta_\lambda^{(1)} + \kappa^2\beta_\lambda^{(2)} + \kappa^3\beta_\lambda^{(3)}\,,\\
\frac{d}{dt}h_t(t) &= \kappa\beta_{h_t}^{(1)} + \kappa^2\beta_{h_t}^{(2)} + \kappa^3\beta_{h_t}^{(3)}\,,\\
\frac{d}{dt}g(t) &= \kappa\beta_g^{(1)} + \kappa^2\beta_g^{(2)} + \kappa^3\beta_g^{(3)}\,,\\
\frac{d}{dt}g'(t) &= \kappa\beta_{g'}^{(1)} + \kappa^2\beta_{g'}^{(2)} + \kappa^3\beta_{g'}^{(3)}\,,\\
\frac{d}{dt}g_3(t) &= \kappa\beta_{g_3}^{(1)} + \kappa^2\beta_{g_3}^{(2)} + \kappa^3\beta_{g_3}^{(3)}\,,
\end{aligned}$$

$$\kappa = 1/(16\pi^2)$$

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matched directly at m_Z
(larger exp error in α_3)

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matched at 2-loop via m_H (unavoidable theor error)

[Bezrukov Kalmykov Kniehl Shaposhnikov, arXiv:1205.2893]

[Degrassi Di Vita Elias-Miro Espinosa Giudice Isidori Strumia, arXiv:1205.6497]

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[Alekhin Djouadi Moch, arXiv:1207.0980]

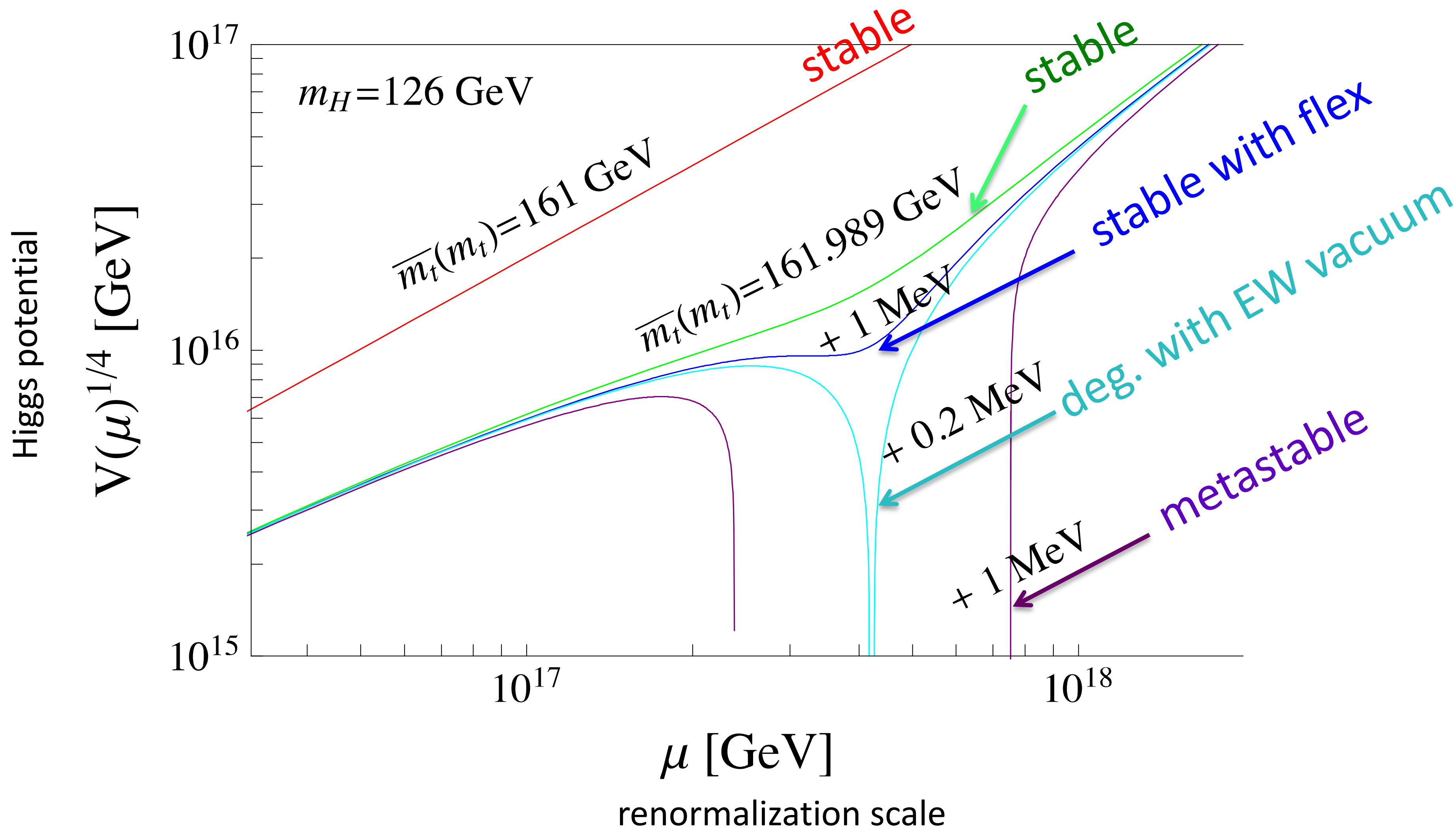
It is inconsistent to use Tevatron measure

BETTER to match directly with MSbar running m_t

$$\overline{m_t}(m_t) = 163.3 \pm 2.7 \ \mathrm{GeV}$$

as done in [IM, arXiv:1209.0393]

POSSIBLE SHAPES FOR THE HIGGS POTENTIAL CLOSE TO THE PLANCK SCALE



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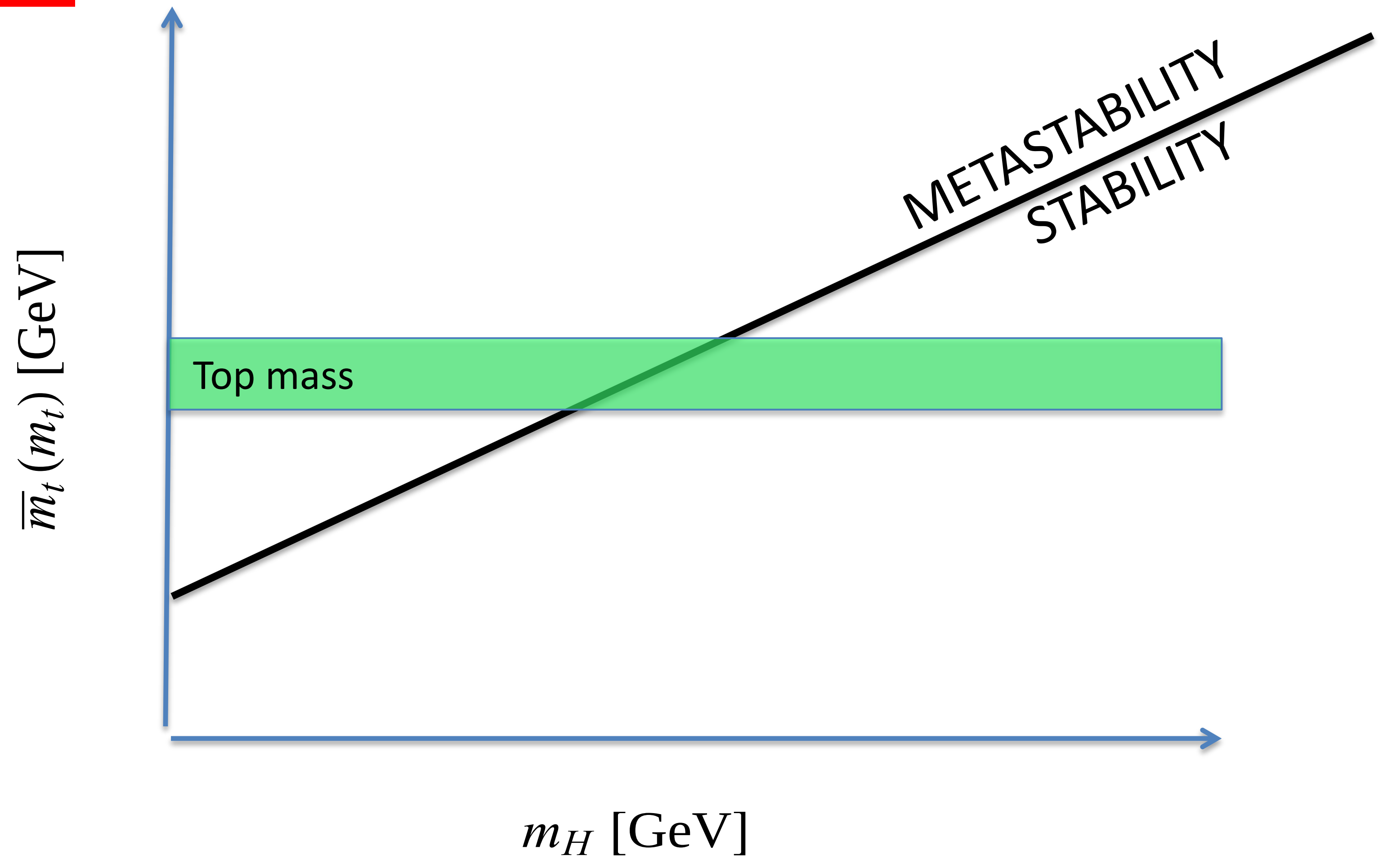
RESULTS



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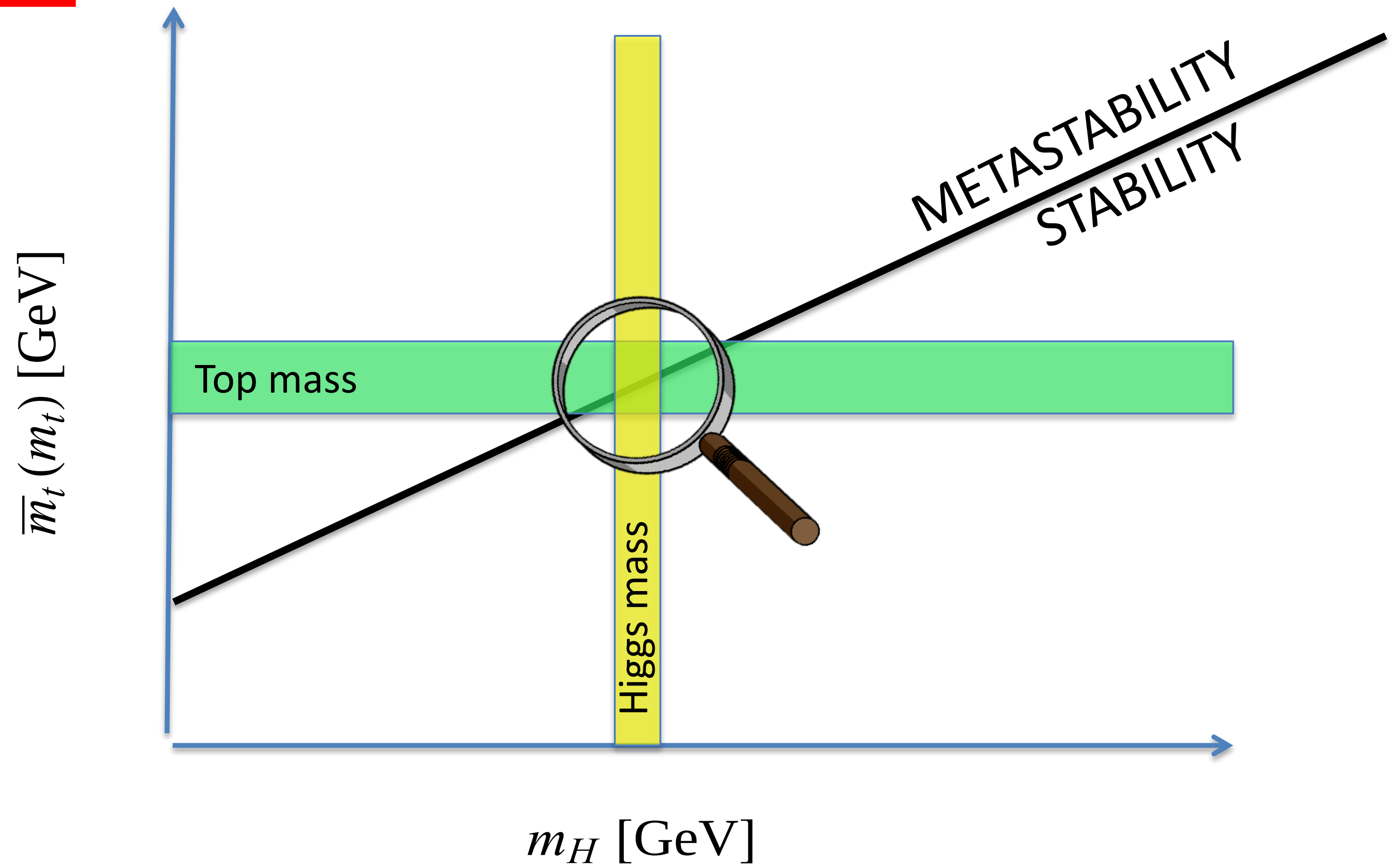

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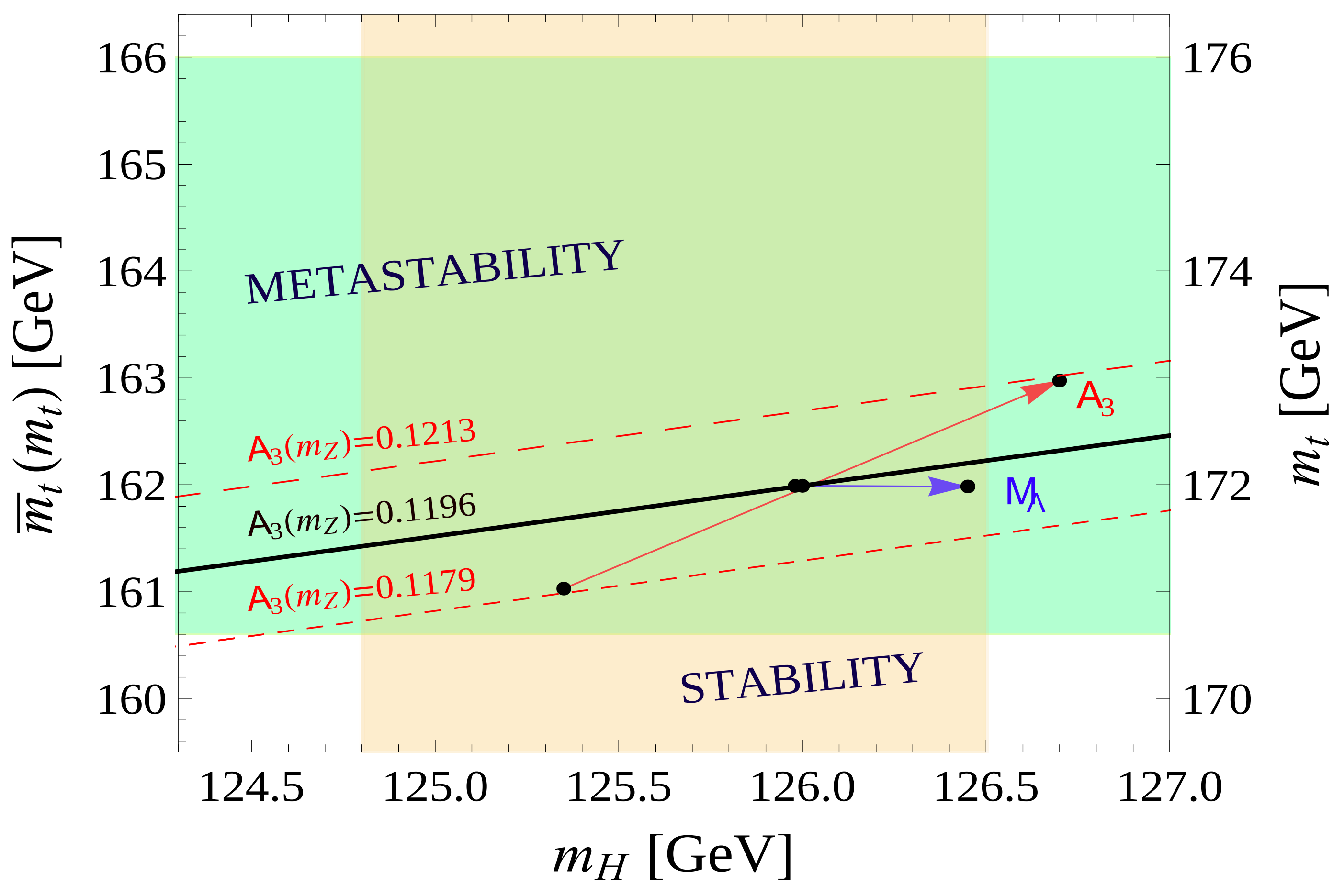

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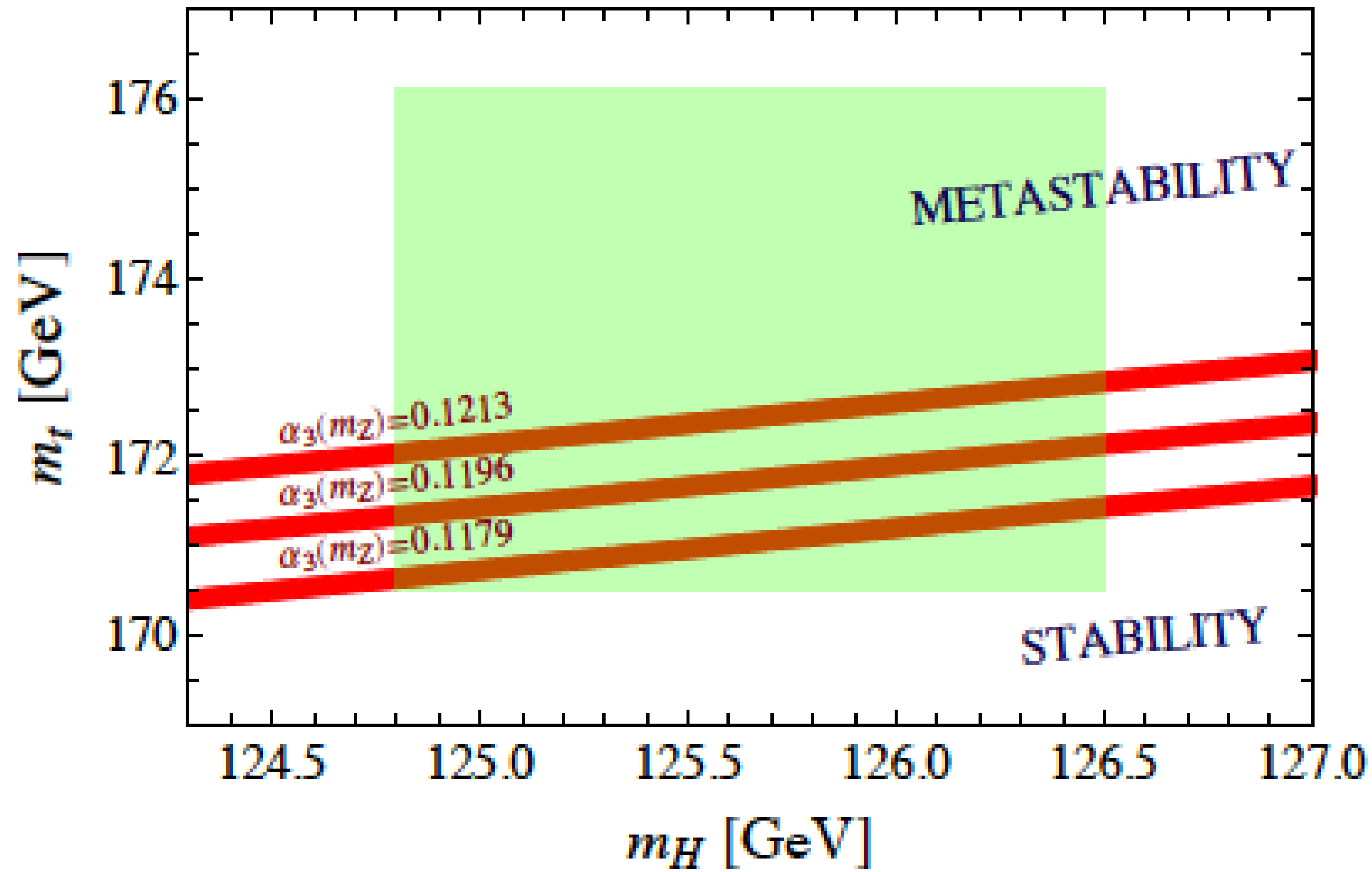

STABILITY BOUND

$$\overline{m_t}(m_t)[\text{GeV}] \leq 162.0 + 0.47\,(m_H[\text{GeV}] - 126) + 0.7\left(\frac{\alpha_3(m_Z) - 0.1196}{0.0017}\right) - 0.2^{(\mu_\lambda)}_{th}$$

[IM, arXiv:1209.0393]

Comparison with previous analysis by Degrassi Di Vita Elias-Miro Espinosa Giudice Isidori Strumia, JHEP 1208 (2012) 098 [arXiv:1205.6497]

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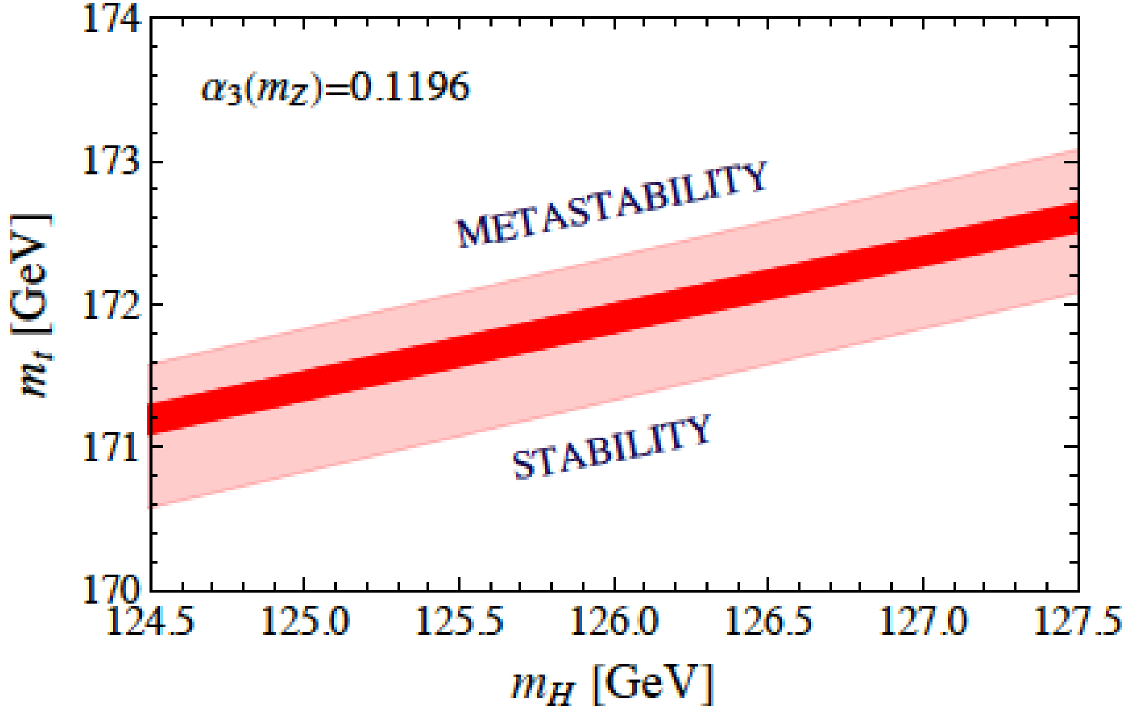

Theoretical uncertainty in the determination of the transition line between stability and metastability according to our analysis (thinner: only μ_λ) and eq. (10) of DDEEGIS(thicker: also error due to y_t matching from m_t pole).

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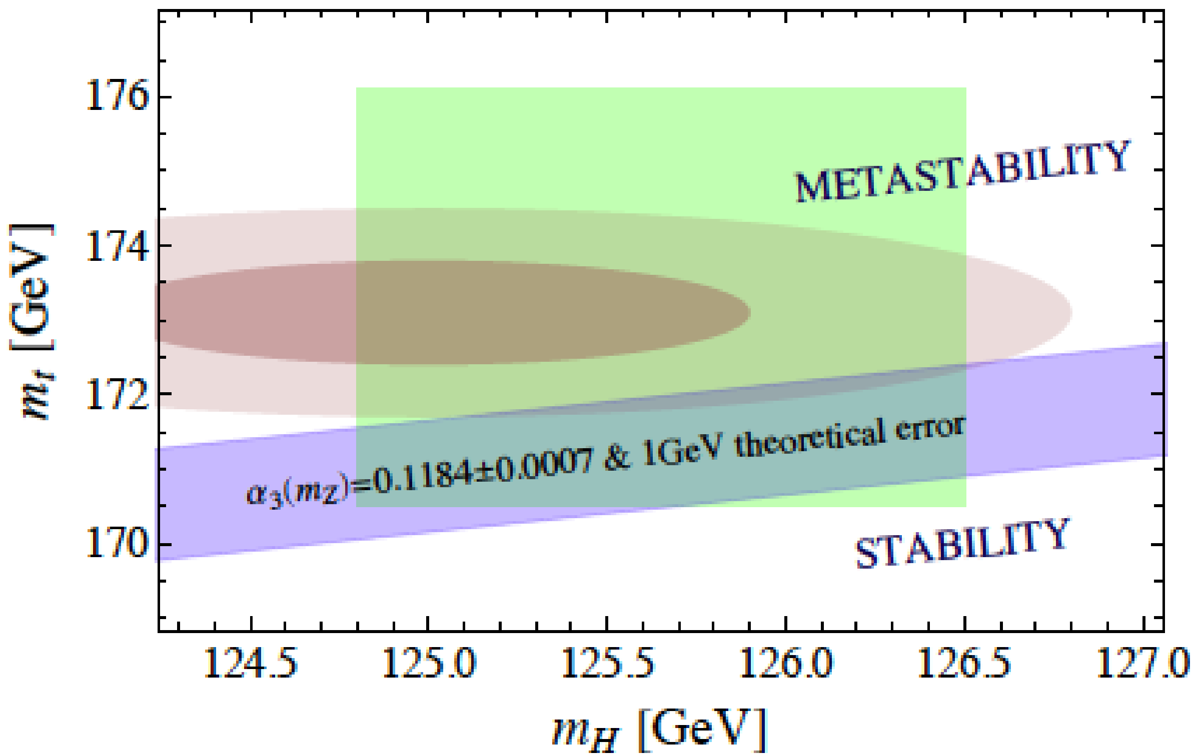
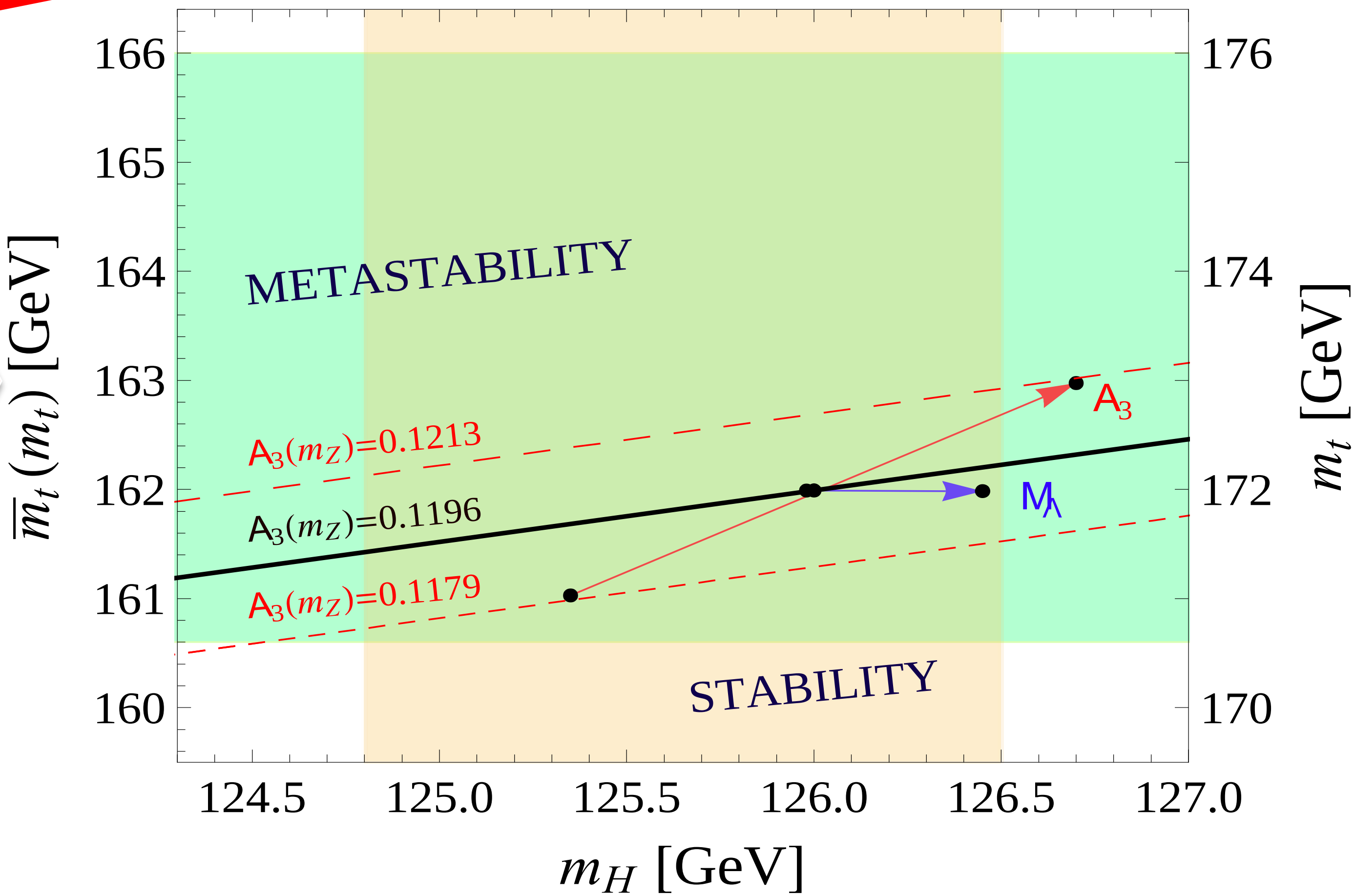


Transition line (blue) between stability and metastability according to Degrassi et al.
The (brown) shaded disks is the 1 and 2 combined ranges for mt and mH used in Degrassi et al. The (green) rectangle allows for the comparison with the ranges of mt and mH used here.

PROSPECTS

NEED MORE PRECISE MEASURE



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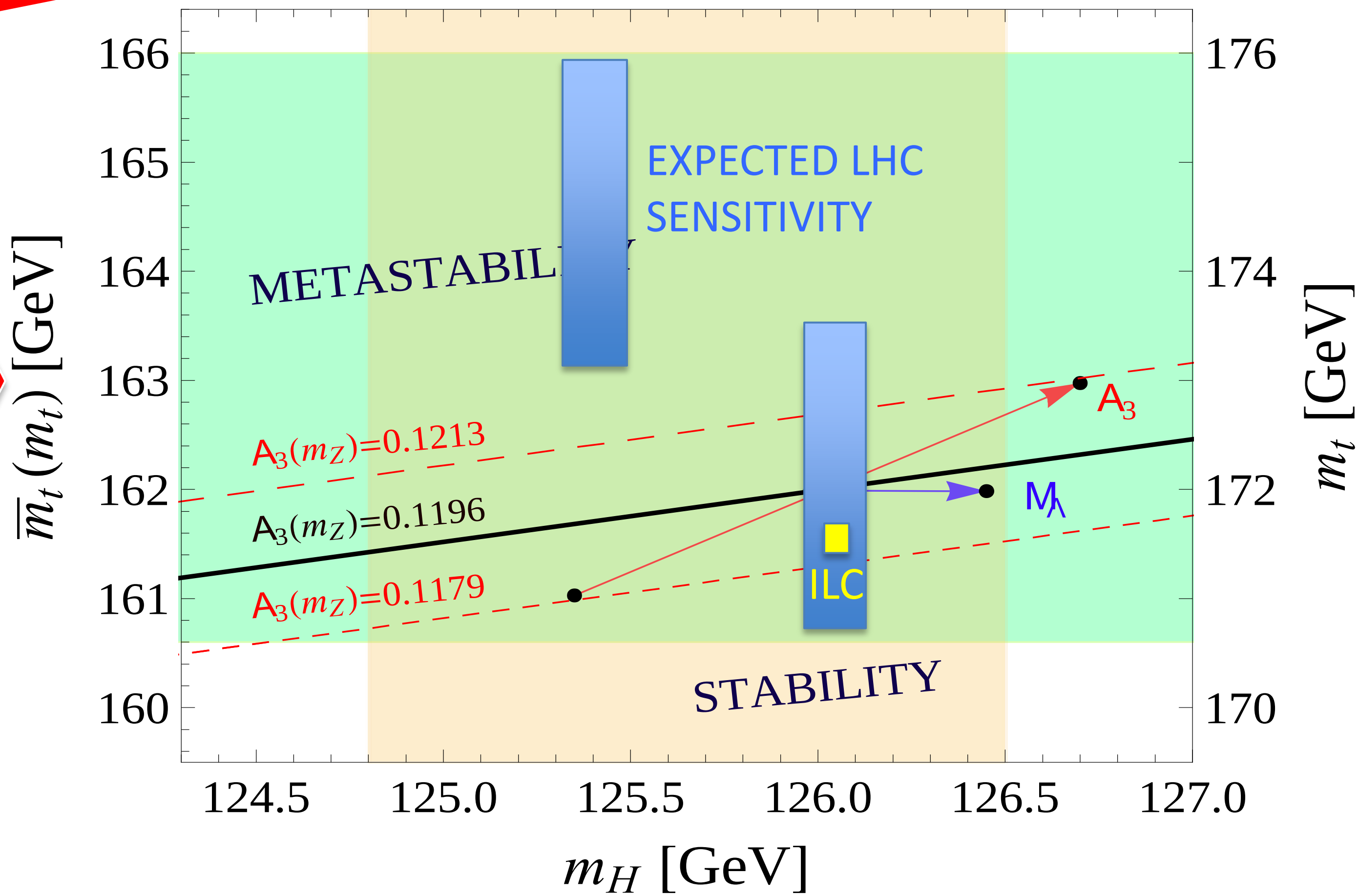

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YES! If, for some reason, there has been a period in which the Hubble rate was dominated by a nearly constant V

$$\left(\frac{a(t)}{a(t)}\right)^2 \equiv H(t)^2 \cong \frac{V(m_0)}{3M_{Pl}^2}$$

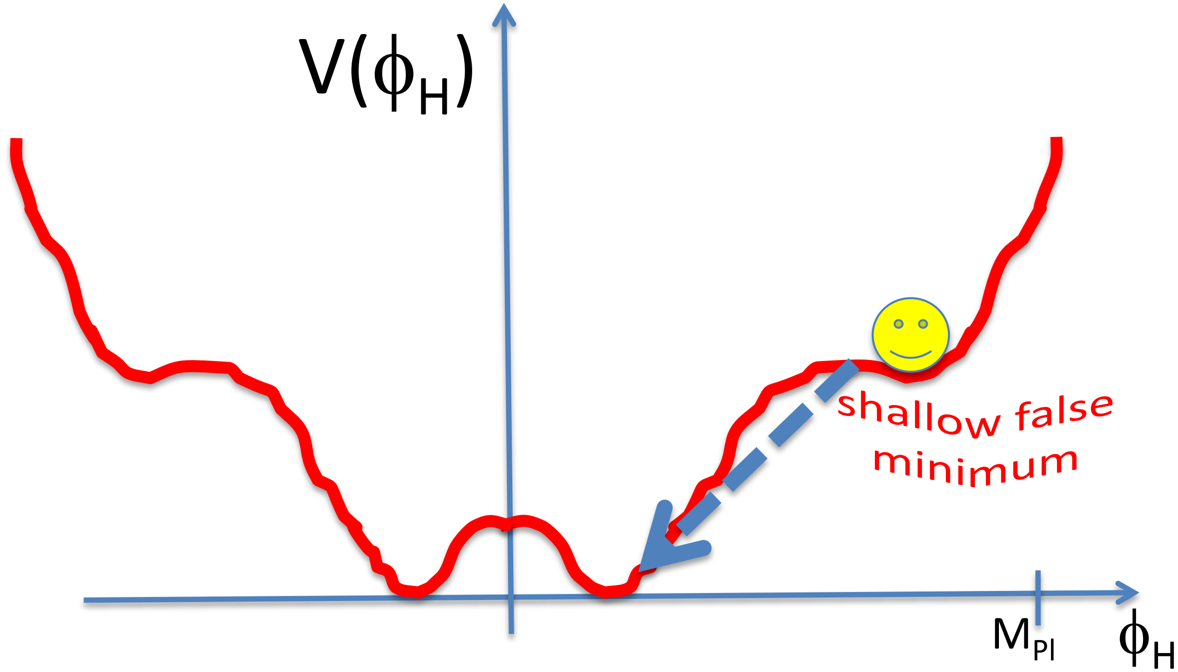
V acts as cosmological constant term

$$a(t) \propto e^{Ht}$$

EXPONENTIAL EXPANSION

EXAMPLE 1

A stable configuration like a shallow false minimum with the Higgs trapped in it during inflation, which ends because of some other mechanism



A model in scalar-tensor gravity & a model with hybrid inflation

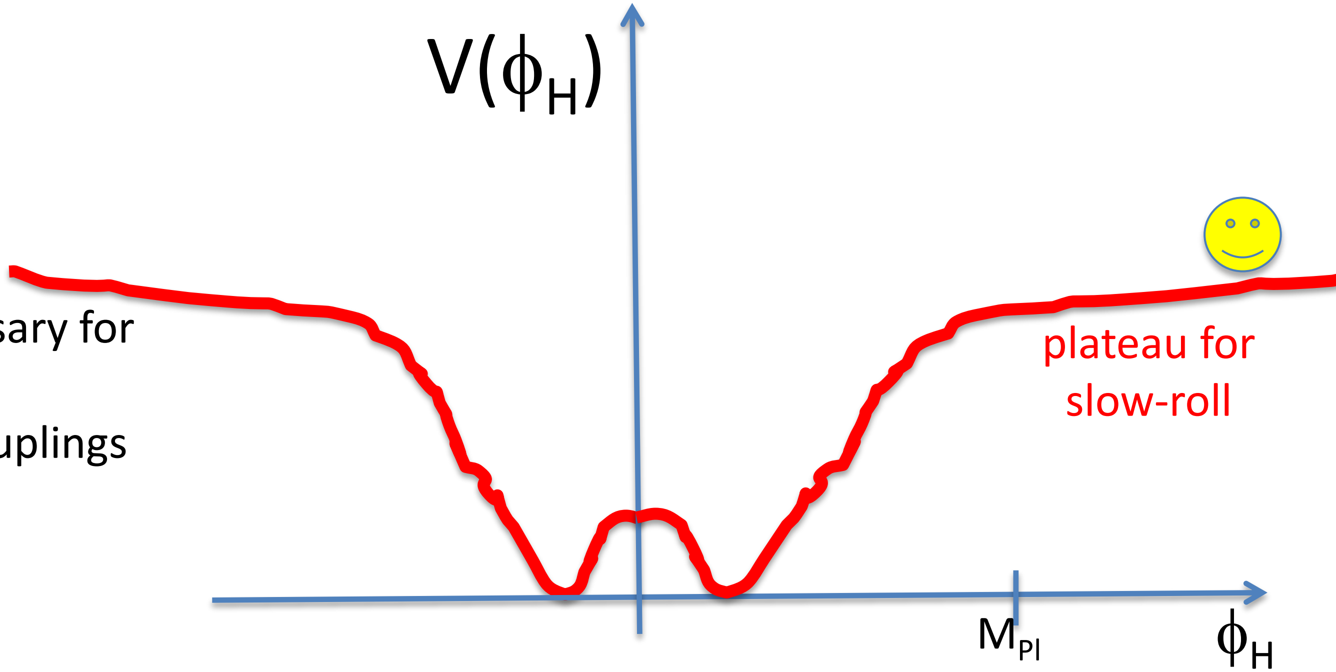
IM Notari, arXiv:1112.2659, 1204.4155

n_s is quite model dependent but tensor-to-scalar-ratio r is not

→ these models can be tested IM Notari, arXiv:1112.5430

EXAMPLE 2

A configuration more
(or as stable as)
an inflection point is necessary for
Higgs inflation via
non-minimal gravitation couplings



Model discussed in

Bezrukov Shaposhnikov, arXiv:0710.3755, …, 1205.2893

3) DO NEUTRINOS HAVE SOME IMPACT IN ALL THIS?

[Casas Ibarra Quiros, Okada Shafi, Giudice Strumia Riotto, Rodejohann Zhang, etc]

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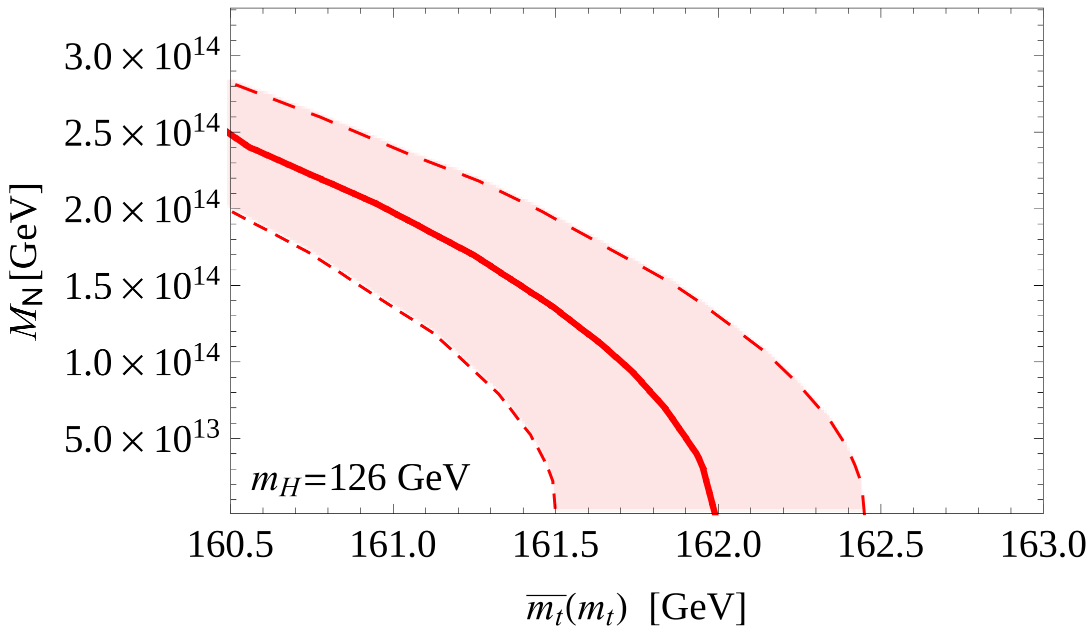

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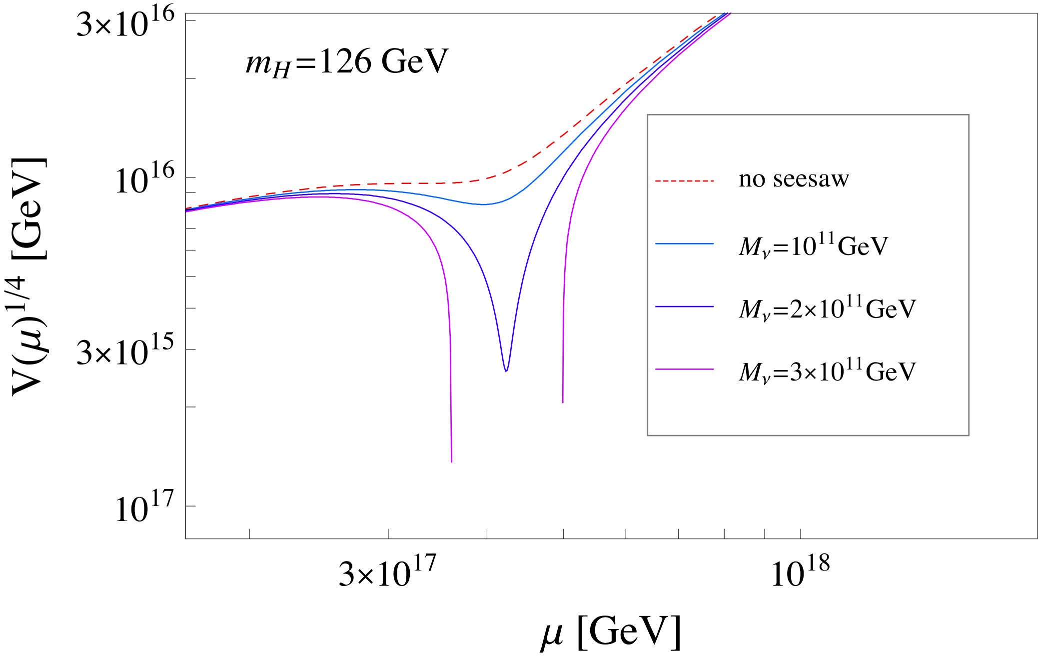
More stringent if one starts from an inflection point configuration



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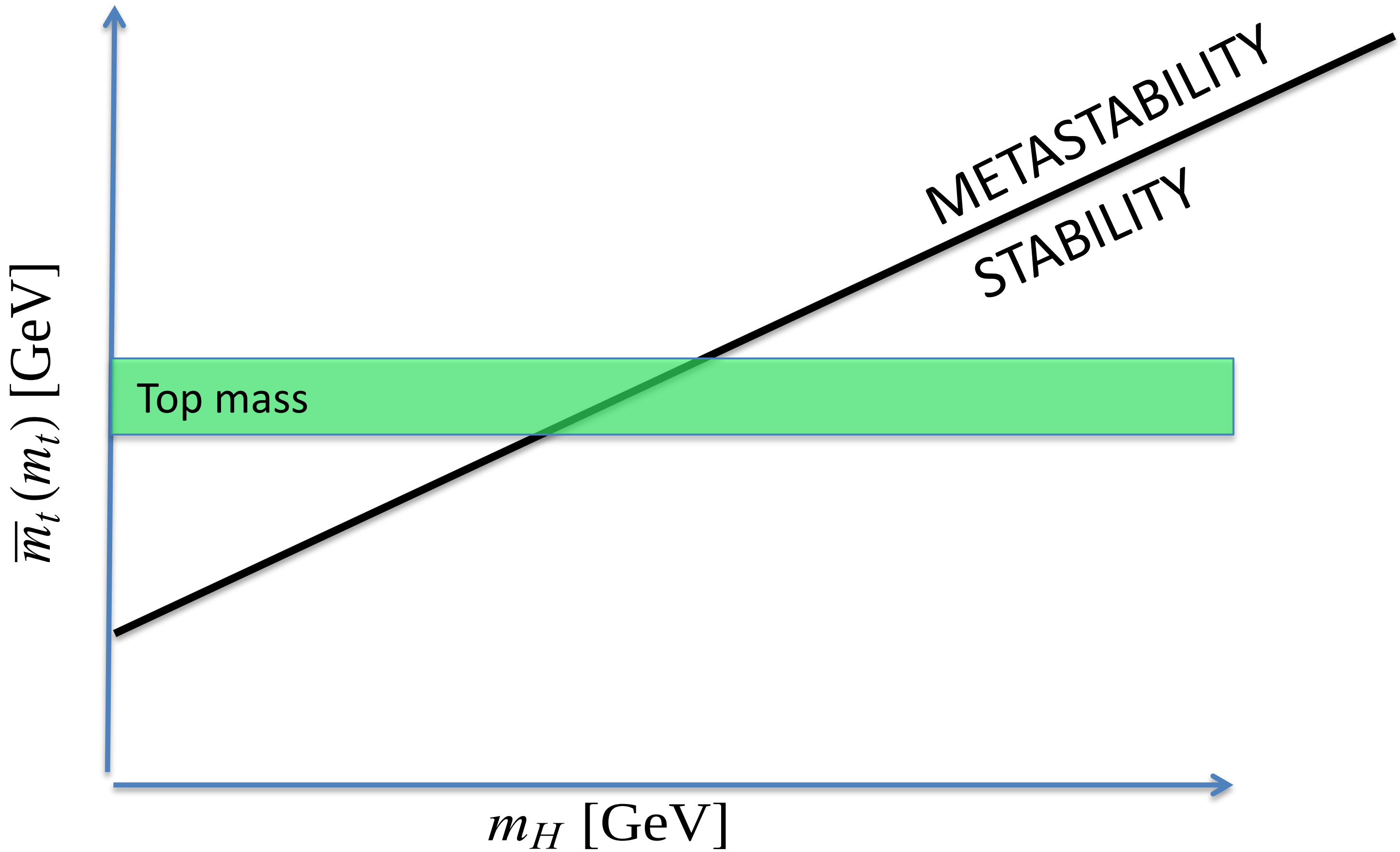
CONCLUSIONS



CONCLUSIONS

1) Intriguing that m_H was found right at the transition between stability and metastabilty

2) Some stable SM configurations very close to transition line (like e.g. shallow false minimum) might have been relevant for primordial inflation