On electroweak vacuum stability during inflation

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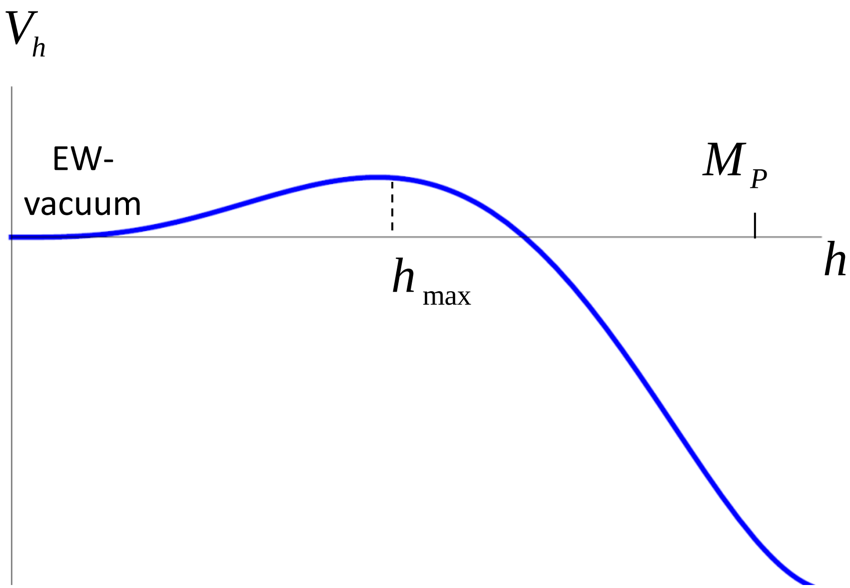
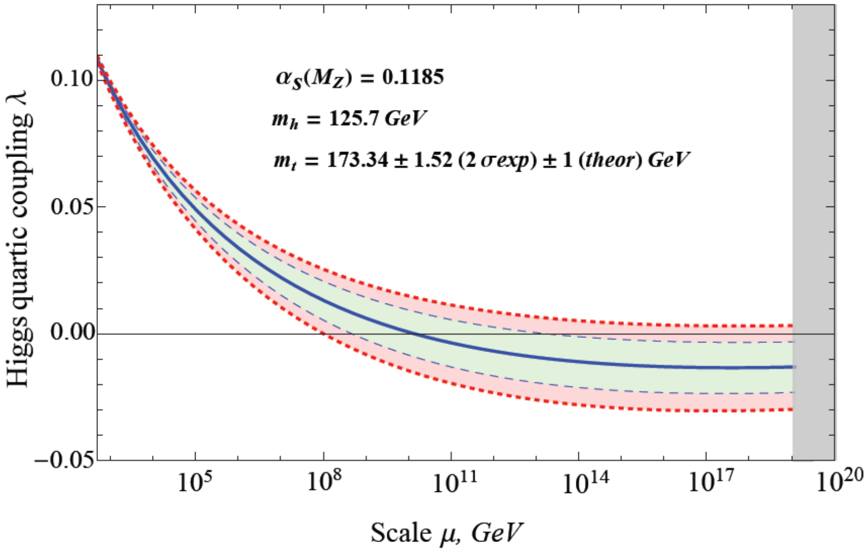
Plan

- Motivation
- Methods
- Conclusion

Effective Higgs potential



Schematic plot of the effective Higgs potential



Running of the Higgs quartic coupling in the Standard Model

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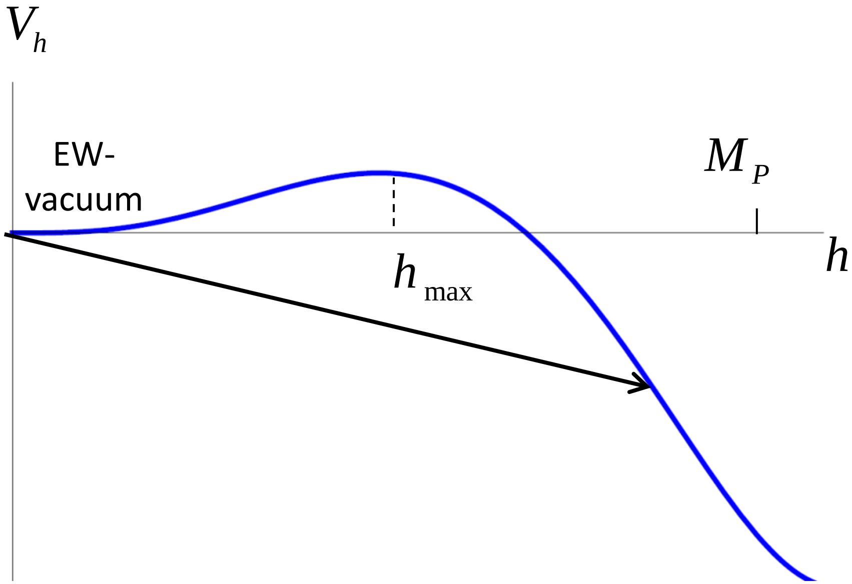

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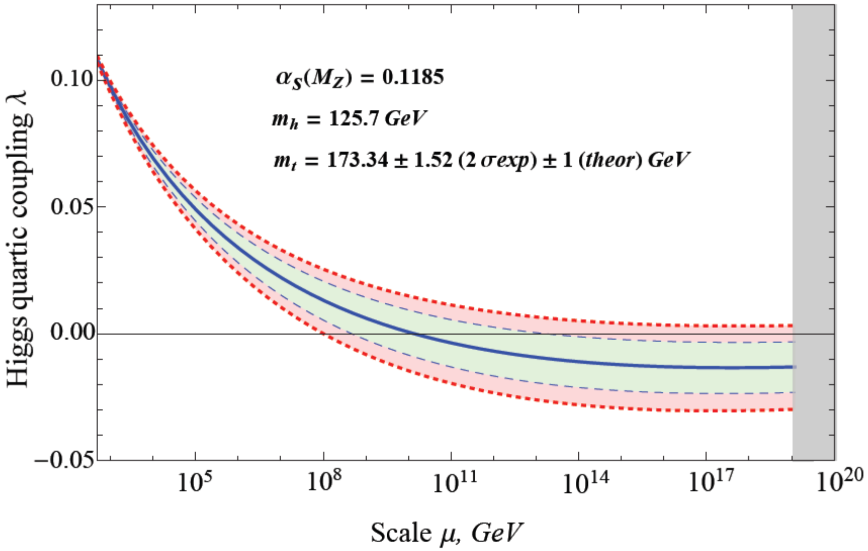

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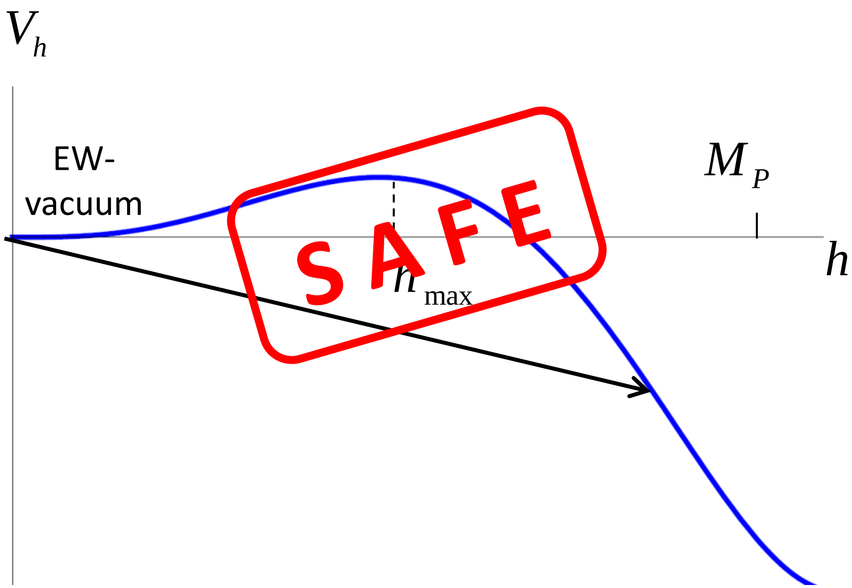

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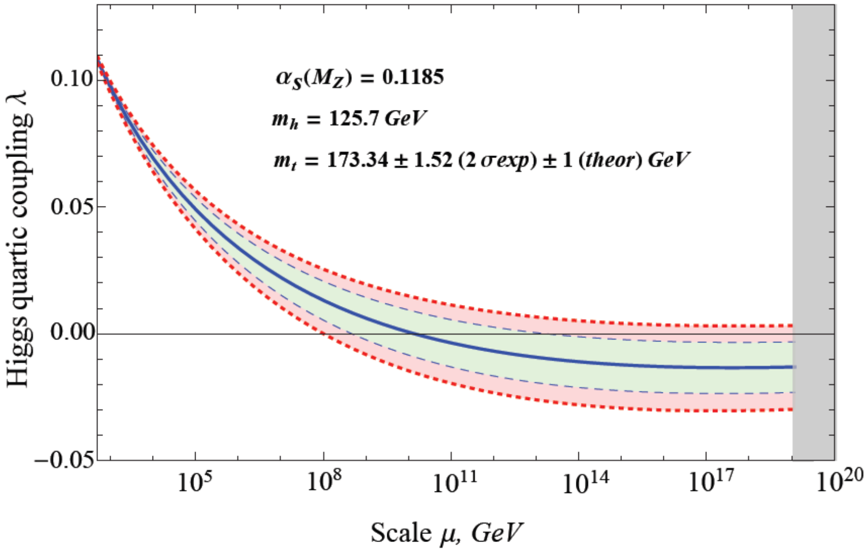

Running of the Higgs quartic coupling in the Standard Model

In the present Universe, EW-vacuum is sufficiently long-lived.

G. Degrassi, S. Di Vita, J. Elias-Miro, J. R. Espinosa, G. F. Giudice, G. Isidori and A. Strumia, JHEP 1208, 098 (2012) [arXiv:1205.6497 [hep-ph]];
D. Buttazzo, G. Degrassi, P. P. Giardino, G. F. Giudice, F. Sala, A. Salvio and A. Strumia, JHEP 1312, 089 (2013) [arXiv:1307.3536 [hep-ph]]; …

What about other epochs?

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Hubble parameter H

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Cosmological horizon → Gibbons-Hawking temperature → Thermal bath with $T = \frac{H}{2\pi}$

↓

Thermal fluctuations of *h* of the order $\delta h \sim H$

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Not good if $H > h_{\max}$

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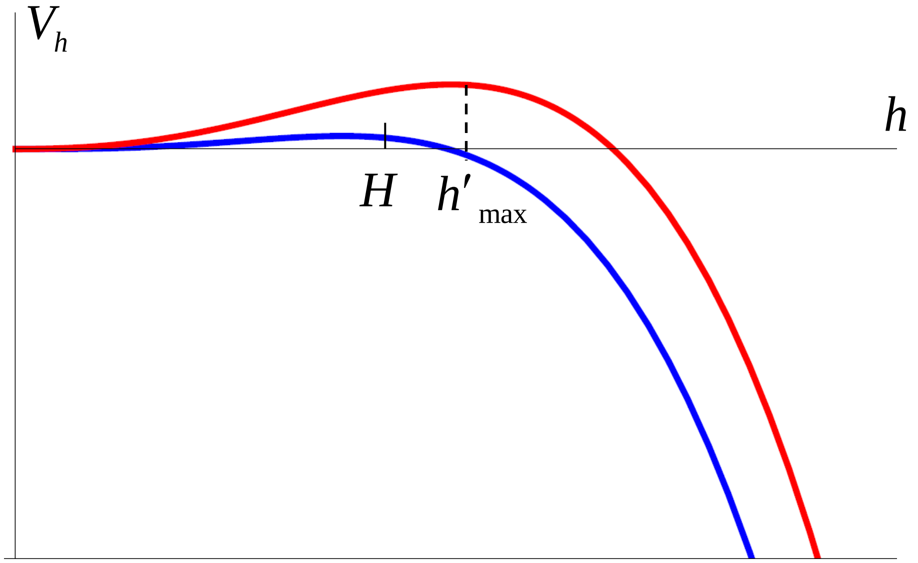

Improved effective Higgs potential

For example, $m_{eff} = \xi R$

or $m_{eff} = \alpha f(\phi)$

J. R. Espinosa, G. F. Giudice and A. Riotto, JCAP 0805, 002 (2008) [arXiv:0710.2484[hep-ph]];
O. Lebedev and A. Westphal, Phys. Lett. B 719, 415 (2013) [arXiv:1210.6987 [hep-ph]]

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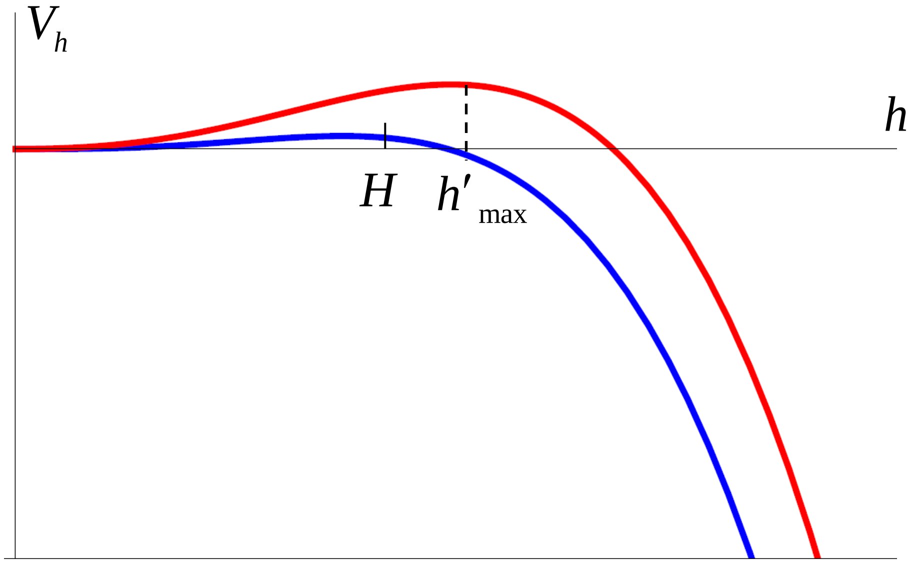

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Overbarrier transitions become suppressed

But what about quantum tunneling?

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Coleman De Luccia transitions: toy models

1. $V = \dfrac{\lambda h^4}{4}, \ \lambda < 0, \ H = 0$ $\qquad h_{\bar{\chi}}(\chi) = \sqrt{\dfrac{8}{|\lambda|}} \dfrac{\bar{\chi}}{\chi^2 + \bar{\chi}^2}$ $\qquad S_E = \dfrac{8\pi^2}{3|\lambda|}$

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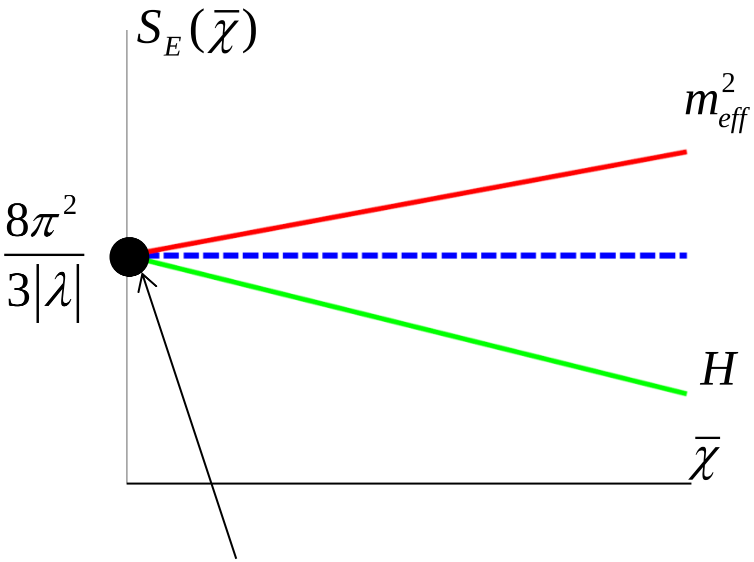
They break the scale invariance of the model.



Singular instanton

I. Affleck, Nucl. Phys. B 191, 429 (1981).

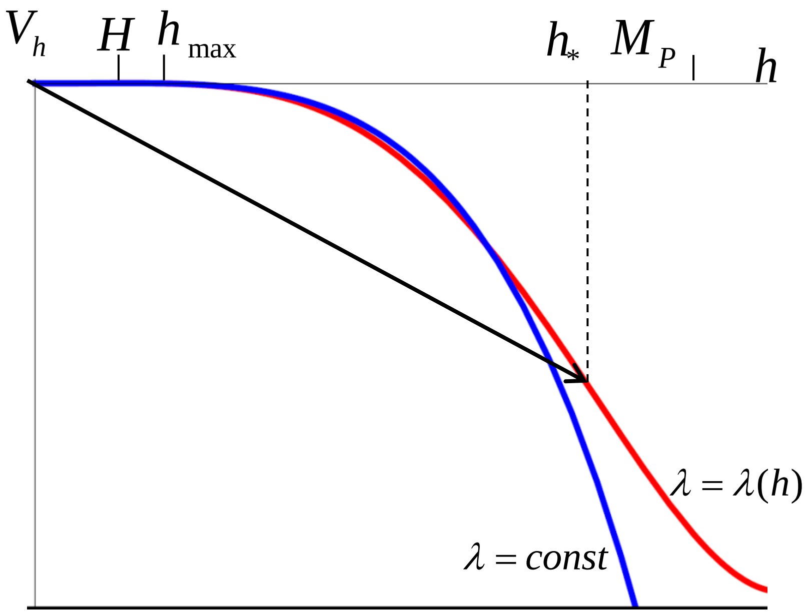
$$S_E(\bar{\chi}) = \frac{8\pi^2}{3|\lambda|}\left(1 + 3\left(m_{eff}^2 - 2H^2\right)\bar{\chi}^2 \log(l/\bar{\chi})\right)$$

$$l = \min(m_{eff}^{-1}, H^{-1})$$

$$\bar{\chi} \ll l$$

So, if $m_{eff}^2 > 2H^2$, the only (nonhomogeneous) solution has $\bar{\chi} = 0$.

Coleman De Luccia transitions: running coupling



$\lambda(h)$ provides the additional source of scale invariance breaking.

For $m_{eff}^2 = H = 0,$

$$S_E = \frac{8\pi^2}{3|\lambda(h_*)|}, \qquad \bar{\chi} \sim h_*^{-1}$$

As far as $lh_* \ll 1$, the m_{eff}^2 and H corrections can be evaluated as before.

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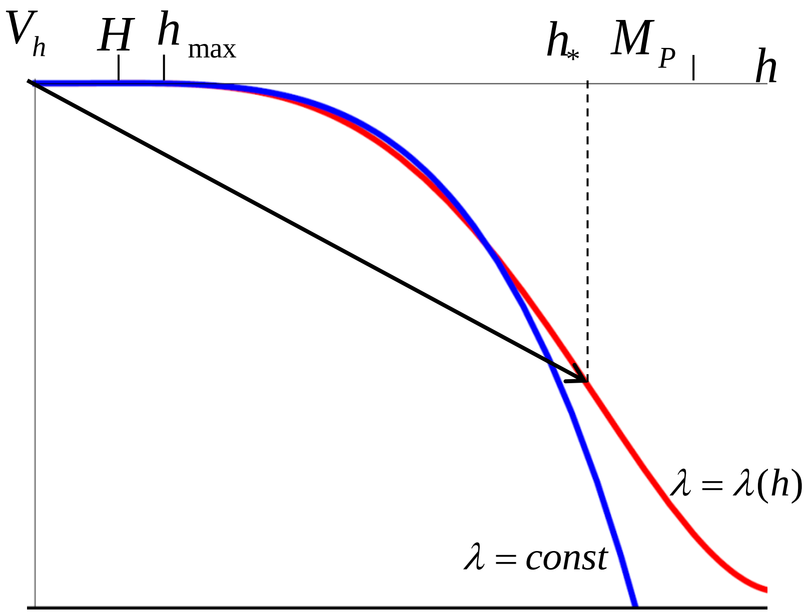

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Applicability conditions

- $H \approx const$,
- Shift of ϕ due to Higgs force should be small (if $m_{eff} = \alpha f(\phi)$)
- Inflaton energy density dominates (not actually true in the core of the bounce)

G. Isidori, G. Ridolfi and A. Strumia, Nucl. Phys. B 609, 387 (2001) [hep-ph/0104016].

Conclusion

- For realistic values of H and h_*, both curvature and effective mass corrections to the CDL-bounce are negligible. Bounce is almost the same as in flat space-time.
- Gravitational corrections to the bounce can be taken into account.

For example, if $m_{eff} = \xi R$, then $\Delta S_{E,grav} = \dfrac{256\pi^3(1-12\xi)}{45(M_P\bar{\chi}\lambda)^2} + O\left(\dfrac{(\bar{\chi}/l)^2}{(M_P\bar{\chi}\lambda)^2}\right)$

- Further corrections to the bounce action can come from Planck-suppressed higher-order operators in the Higgs action. The analysis of these corrections is the same as in flat space-time.

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Related topics

- Thermal corrections from other species;
- Initial conditions;
- Fate of AdS regions;
- …

Thank you for attention!