The Cosmology of Higgs EFT

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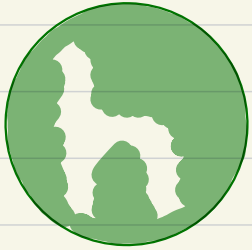
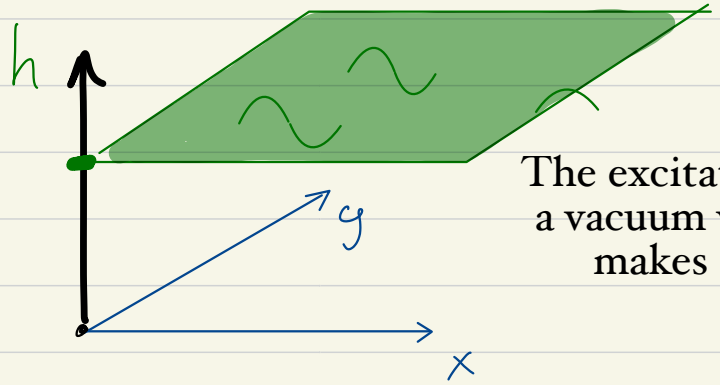
日本

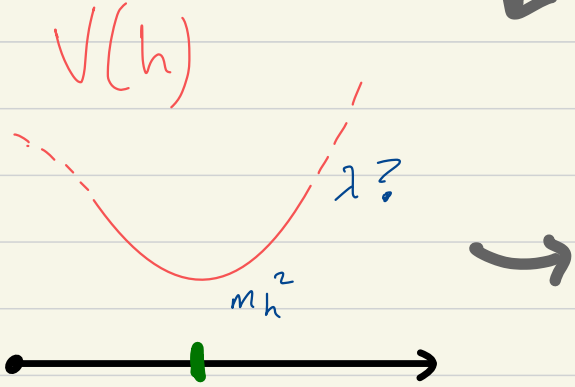
The Characterisation of the Higgs



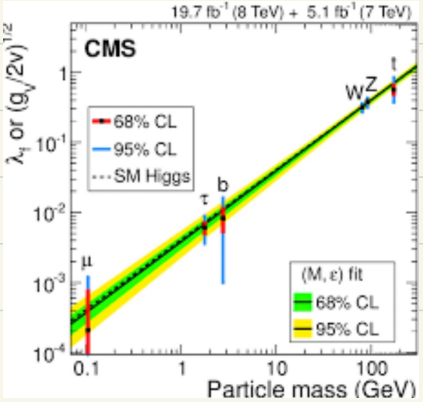
The picture of the Higgs is coming into focus



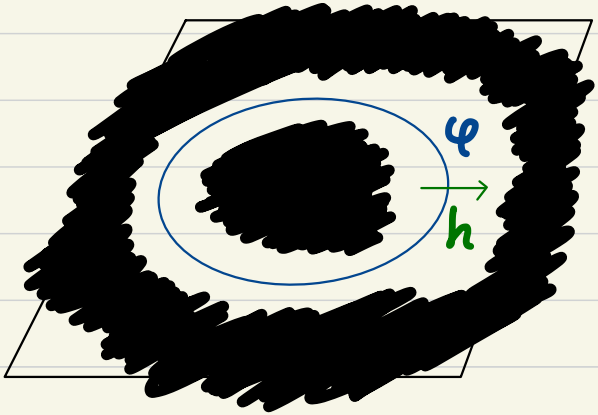
The excitation around a vacuum value which makes a difference here (EW)



This excitation around this vev probes our neighbourhood



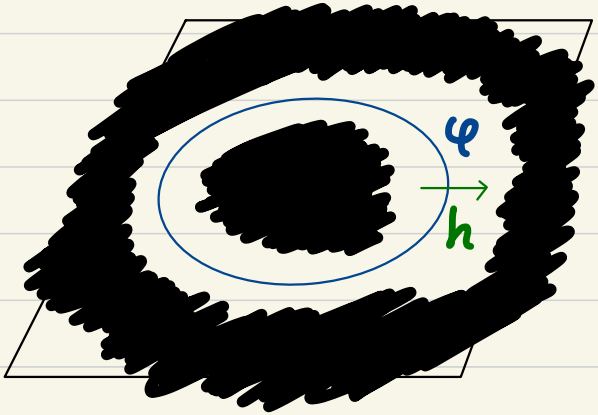
Where does the Higgs particle live?



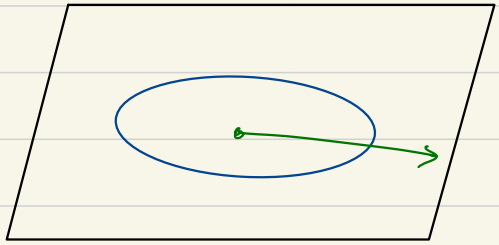
The LHC however
cannot see beyond
this neighbourhood

What if we want to see the world beyond our neighbourhood?

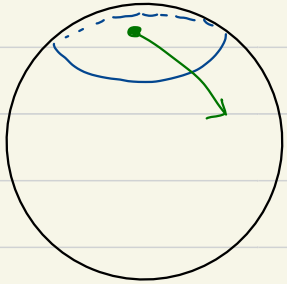
Where does the Higgs particle live?



We can imagine,
aka ask theory

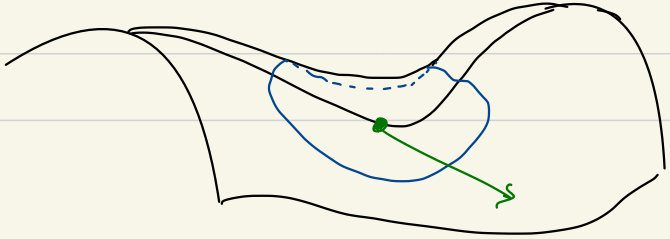


SM



Composite

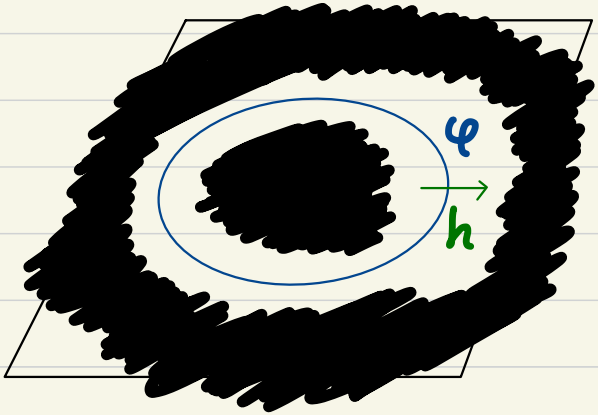
$SO(5) \to SO(4)$



μ^4 ?

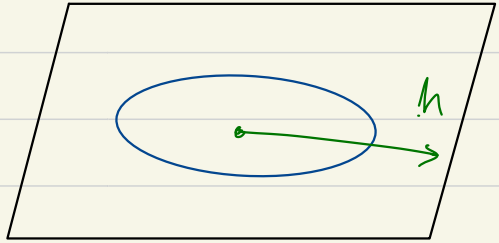
All These Have an Invariant Point

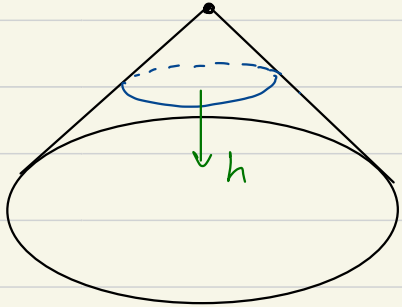
Where does the Higgs particle live?

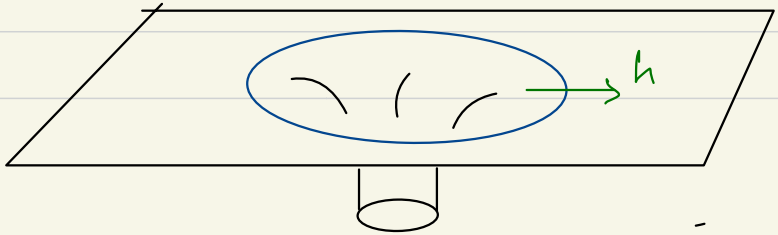


We can imagine,
aka ask theory

But some
might
not







SMEFT or HEFT/SMEFT?

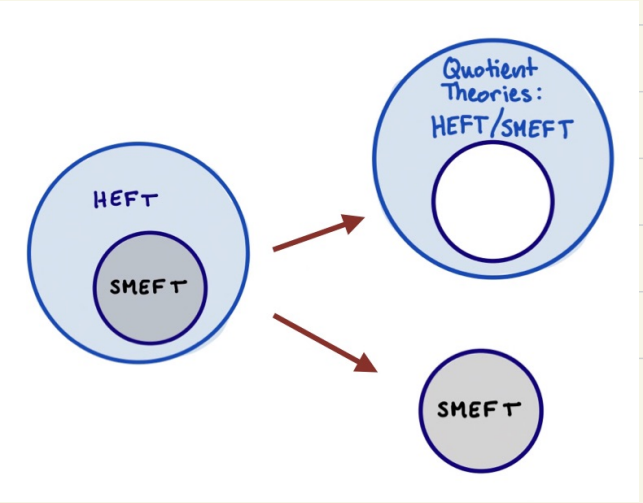
This very visual distinction has a rigorous formulation

[Alonso, Jenkins & Manohar, 2015]
[Cohen, Craig, Sutherland & Lu 2020]

CCWC linearisation lema

If an invariant point exists, the system admits a linear representation

Electroweak TH • $U(\varphi)$ $U^\dagger U = \mathbb{1}_{2\times 2}$ • h



HEFT/SMEFT

SMEFT

$$H = U(\varphi)\begin{pmatrix} 0 \\ \frac{v+h}{\sqrt{2}} \end{pmatrix}$$

The Existence of such a Point is however non-local

[See also unitarity]

This non-local Q finds an A in Cosmology

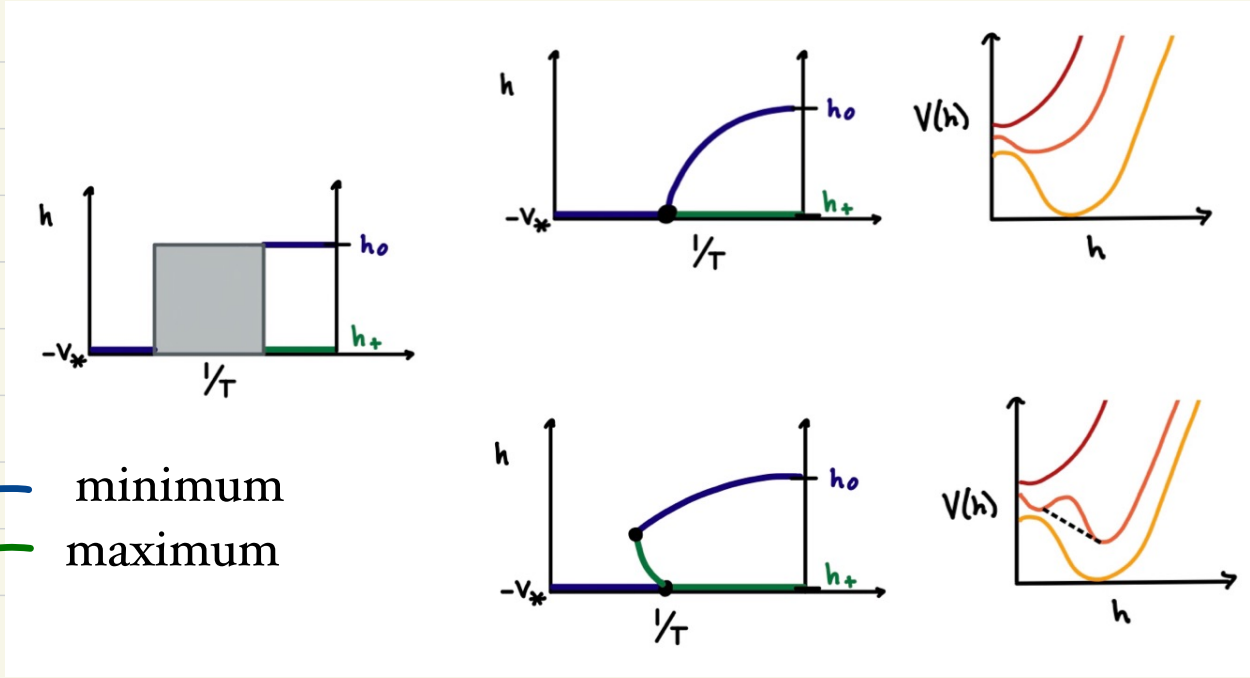
Think of a first order phase transition e.g.

[Banta 2022]
[Kanemura, Nagai & Tanaka 2022]

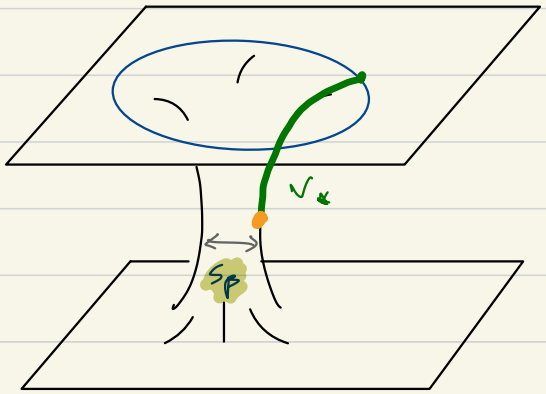
This non-local Q finds an A in Cosmology

Review the SM case with extrema history

The SM

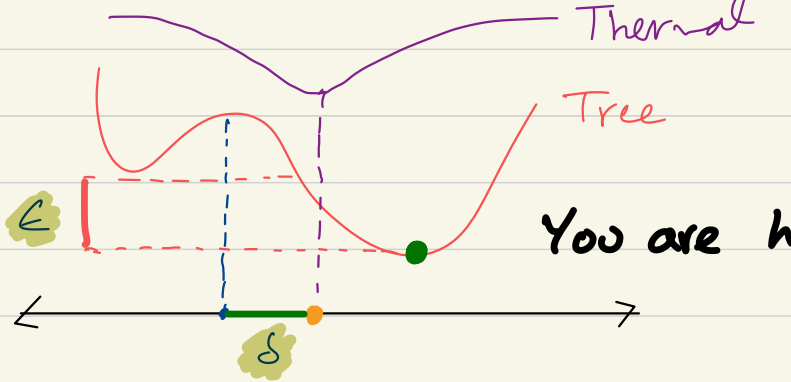


Our quotient theory



$$ds^2 = dh^2 + v^2\left[s_\beta^2 + c_\beta^2\left(1+\frac{h}{v_\chi}\right)^2\right] d\Omega_6^2$$

$$\mathcal{L}_y = -y\sqrt{s_\beta^2 + c_\beta^2(1+h/v_\chi)^2}\;\bar{\psi}\,u\,\psi_R$$



$$V_0(h) = \frac{m_h^2}{2}h^2 + \frac{m_h\sqrt{\lambda}}{2}\gamma_4(1-\epsilon)h^3 + \frac{\lambda\gamma_4^2}{8}h^4$$

A^{scalar}_{ijkl}

$\propto R_{ijkl}\,s$

LHC

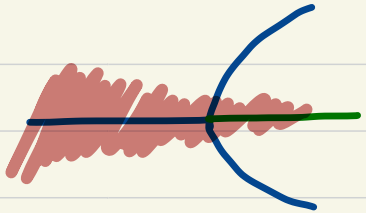
Finite temperature potential

$$V_{eff}(h) = V_0(h) + \sum_i \left[\frac{m_i^2(h)}{64\pi^2} \left(m_i^2(h) \left(\log\left(\frac{m_i^2(h)}{m_i^2(0)} \right) - \frac{3}{2} \right) + 2 m_i^2(0) \right) \right]$$

$$+ \frac{T^4}{2\pi^2} \sum_i J_{s_i}\left(\frac{m_i^2(h)}{T^2} \right)$$

One loop in thermal and vacuum corrections

Performed in Feynman gauge



$$\varepsilon_{IR} = \frac{g^2 T}{\pi m_W(h)}$$

Infrared problem restrictions

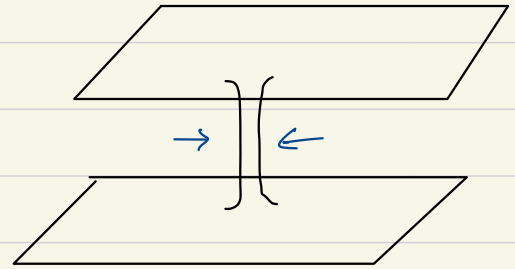
$$\varepsilon_{IR} < 1$$

UV cutoff $T > 4\pi v$

Symmetry restoration at high temperature

$\beta \to 0$

$F^2(h) = s_\beta^2 + c_\beta^2 \left(1 + \frac{h}{v_*}\right)^2$

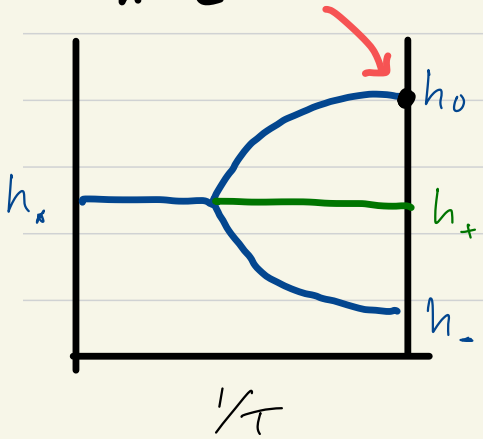


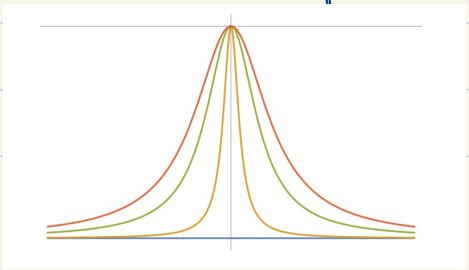
$m^2_{ell,GB} = \frac{F'}{F} V'$

$\phi \equiv v_* + h$

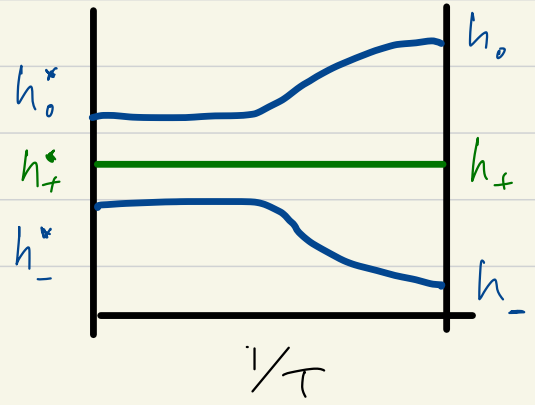
$V_{sing} \sim \frac{\phi^2}{\phi^2 + t_\beta^2}$

You are here

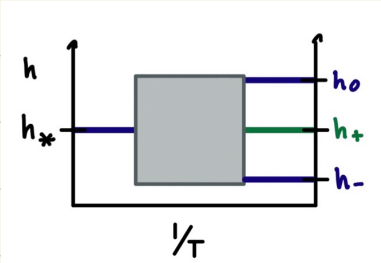




Non-decoupling non-local effect

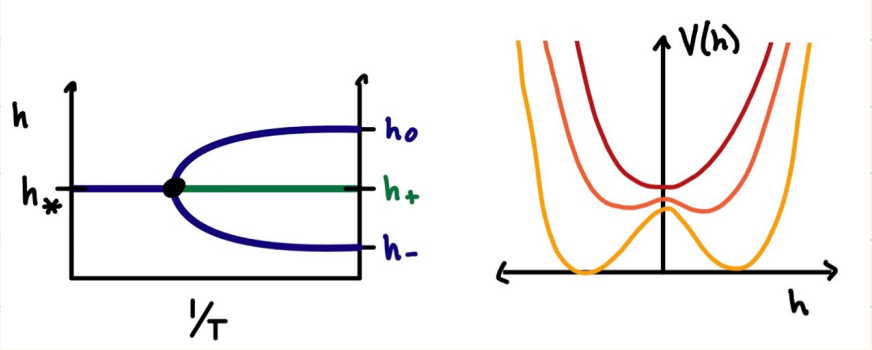


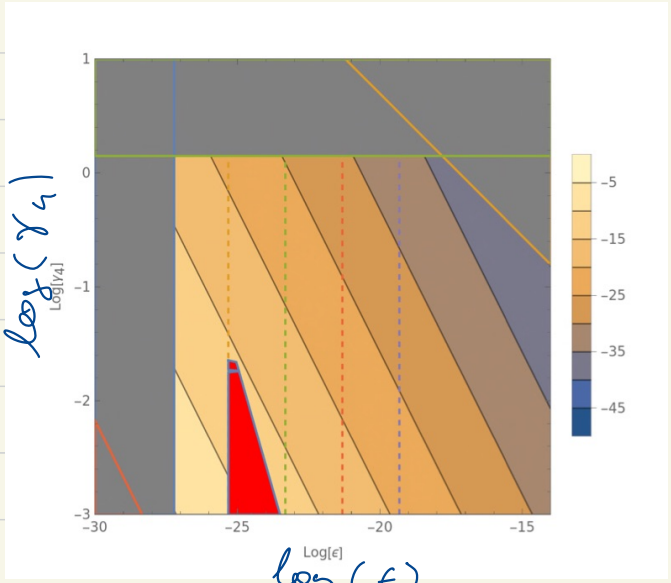
Walls



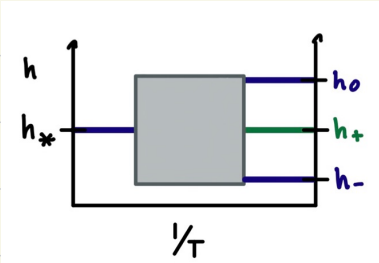
The SM-like potential is symmetric under Higgs parity

New minimum!





Walls + LHC



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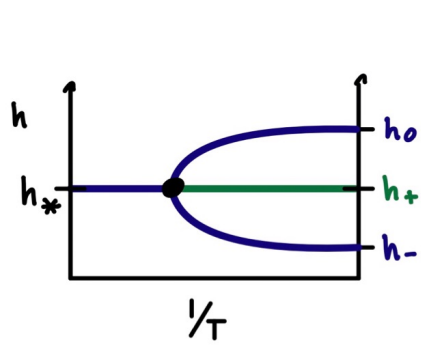
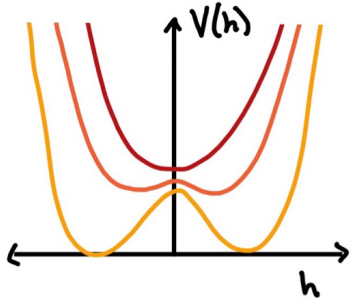
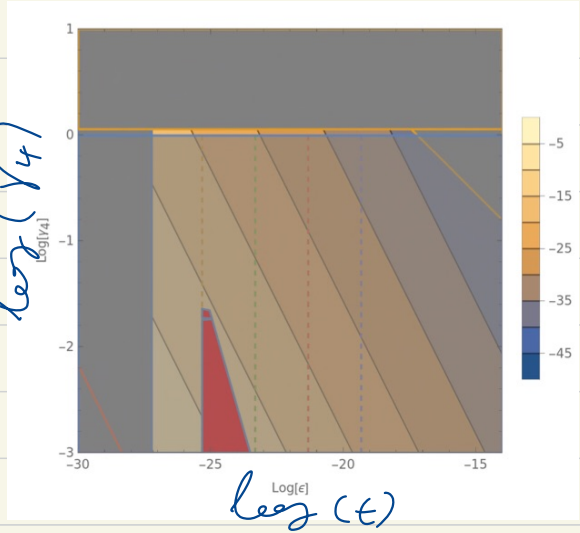
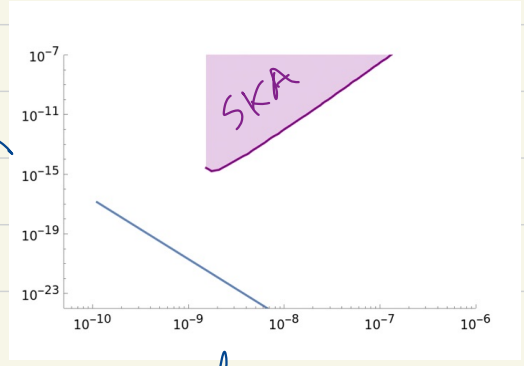
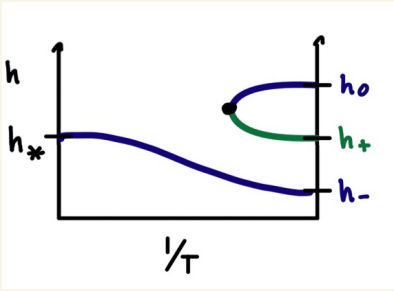






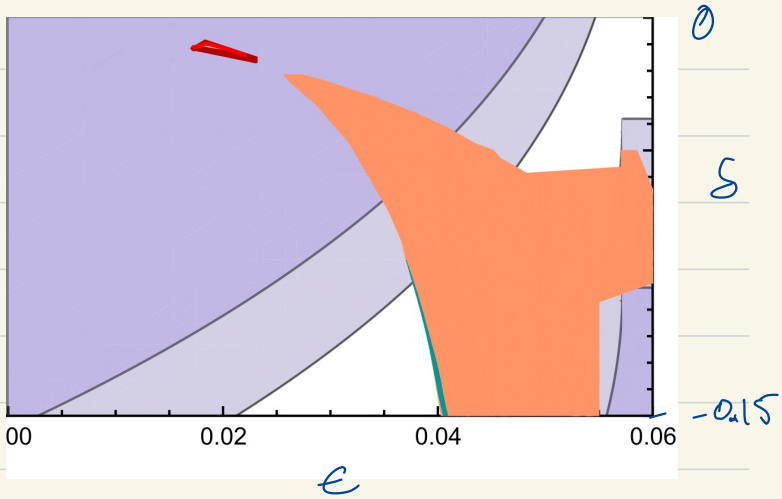


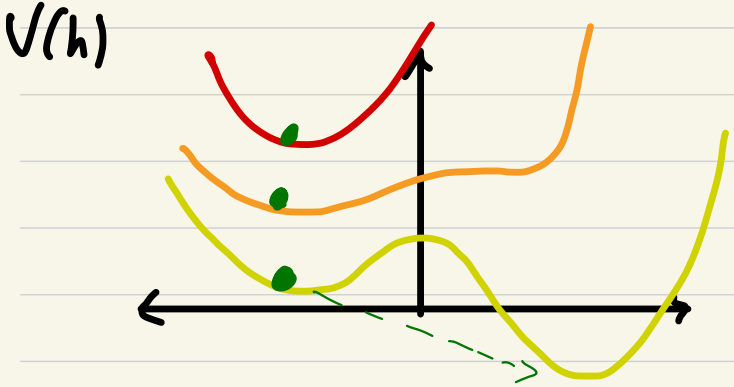
Bubbles + LHC

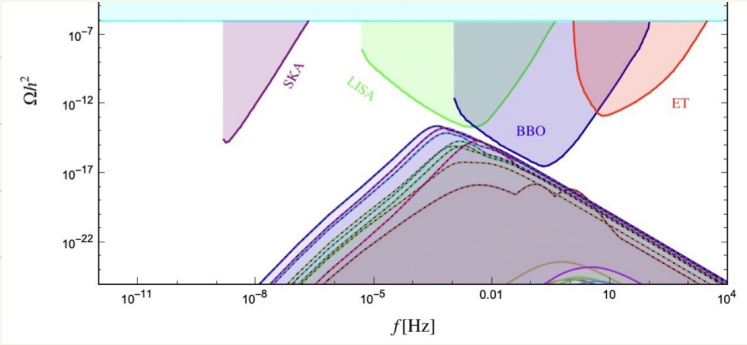


negative delta
positive epsilon

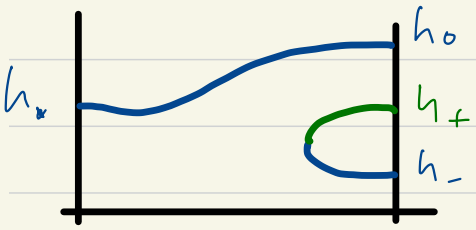
High and low
minima differ!







Doom



positive delta
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High and low
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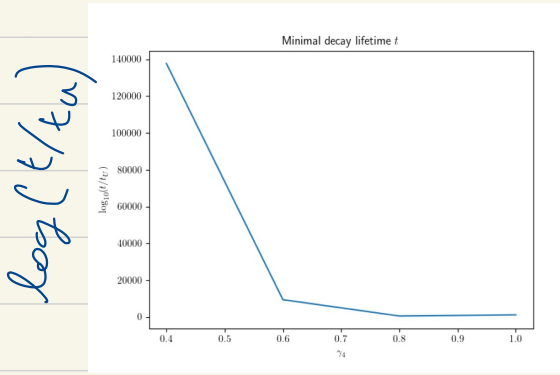
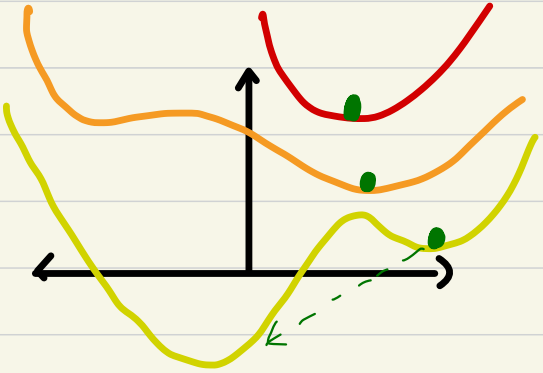
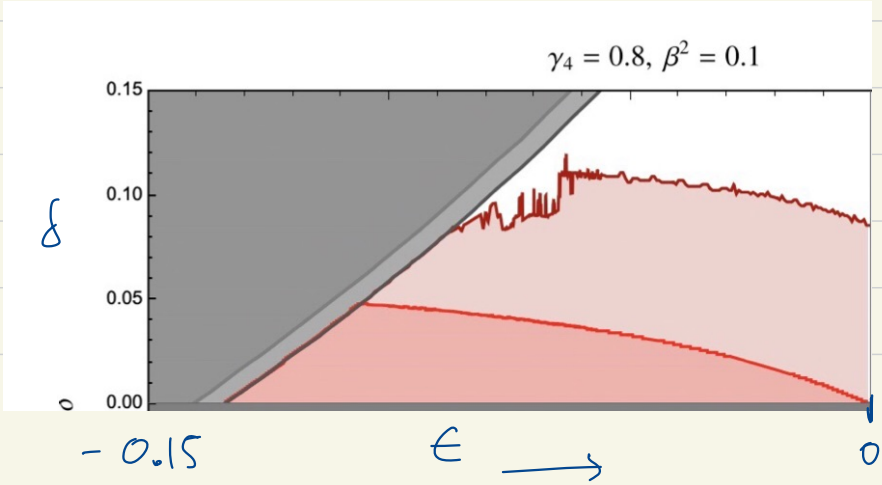


log(t/t_U)





Summary

Characterising the Higgs particle will take multiple sources

One of the fundamental questions within reach is the presence or absence of symmetry restoring point

Our toy HEFT/SMEFT theory showed cosmological phenomenology and an interplay with LHC

Much more to explore