Higgs Dynamics During And After Inflation

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Work done in collaboration with:
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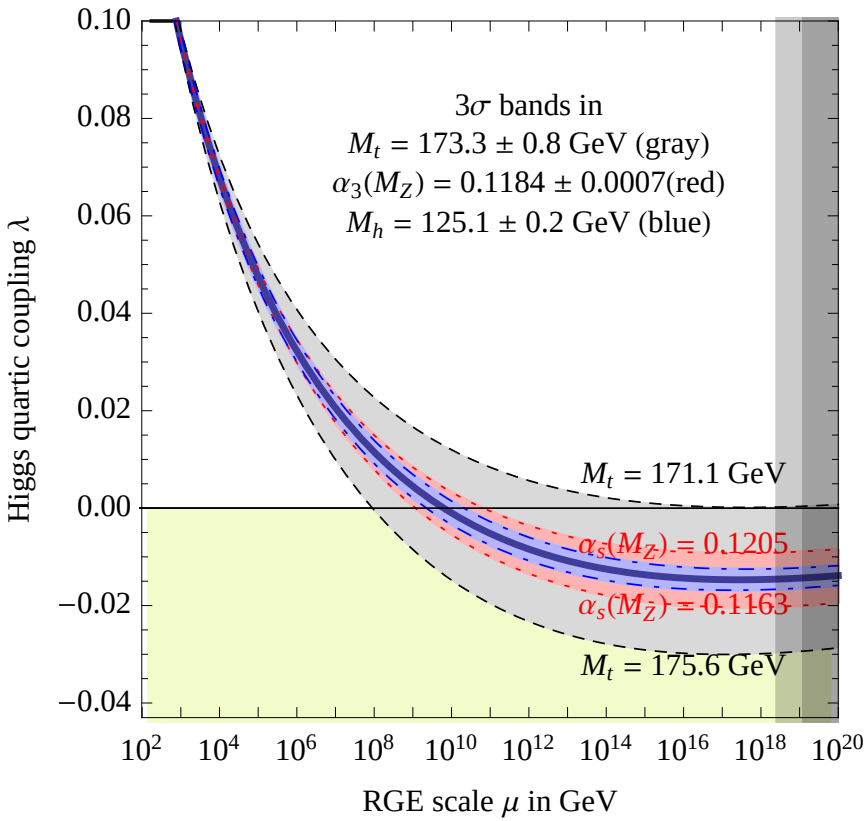
Running of the Higgs self coupling

Buttazzo et al., 1307.3536



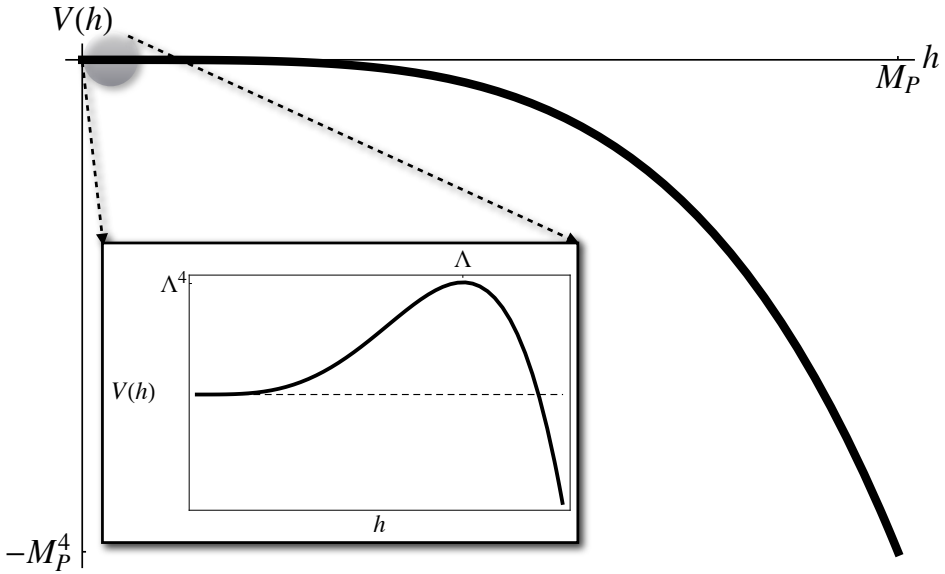
Main contribution at one loop

$$\frac{\mathrm{d}\lambda}{\mathrm{d}\ln\mu} \propto \alpha m_H^4 - \beta m_t^4$$

λ turns negative at $\sim 10^{10}\mathrm{GeV}$

True vacuum at higher values of the Higgs field!

The SM Higgs potential



Cosmological puzzles:

- What put the Higgs in the EW vacuum?
- Why it remained there during inflation?

Possible solutions

Introduce the couplings

- $\frac{1}{2}\lambda_{h\phi}h^2\phi^2$
- $\frac{1}{2}\xi h^2 R$

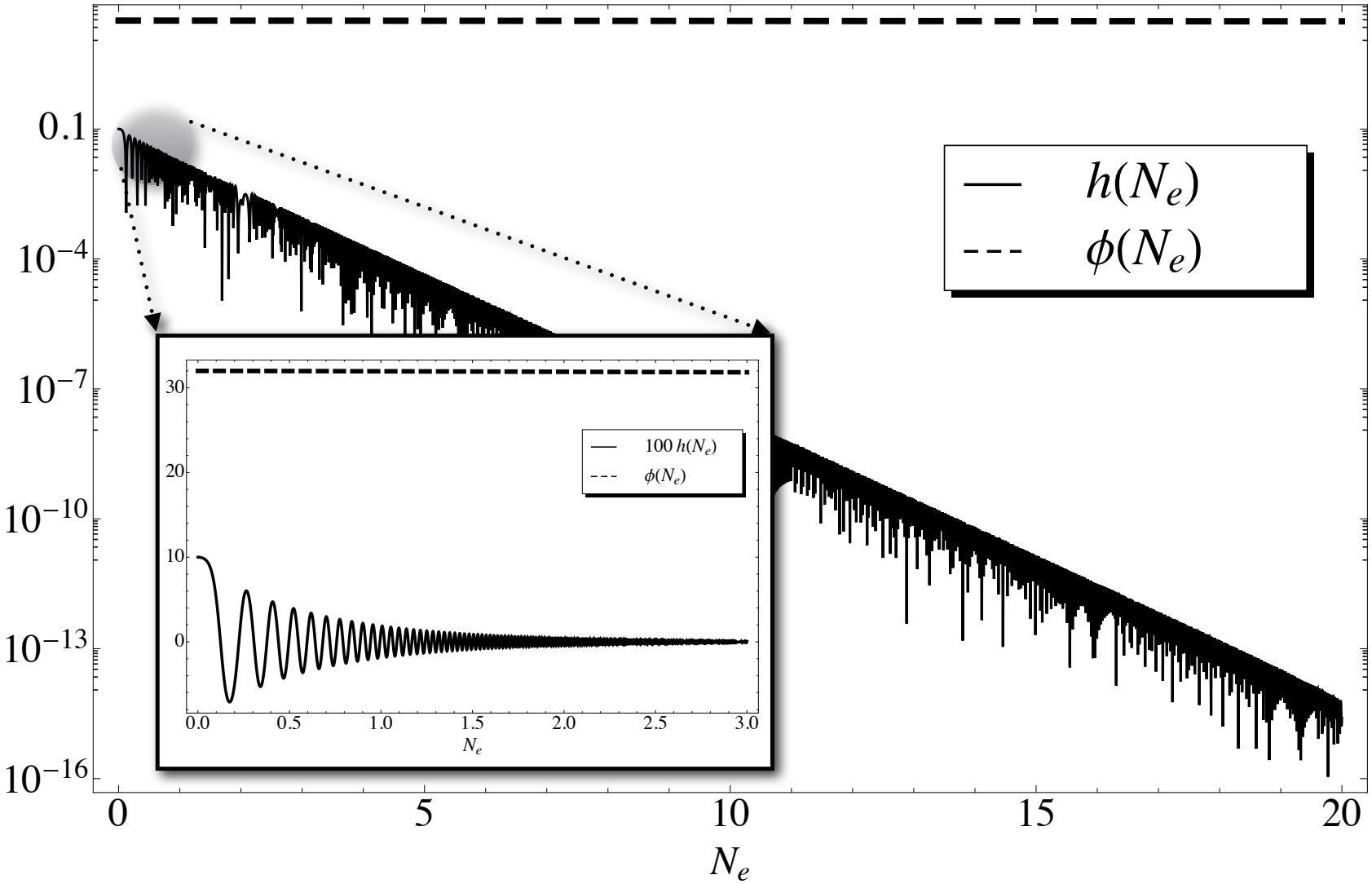
Lebedev & Westphal, 1210.6987

Espinosa, Giudice, Riotto, 1210.6987

Can give a mass for the Higgs that makes it roll towards the origin

$$h \sim h(0)e^{-3Ht/2}$$

Higgs evolution during inflation



The Higgs-inflaton couplings and reheating

The couplings $\lambda_{h\phi}$ and ξ

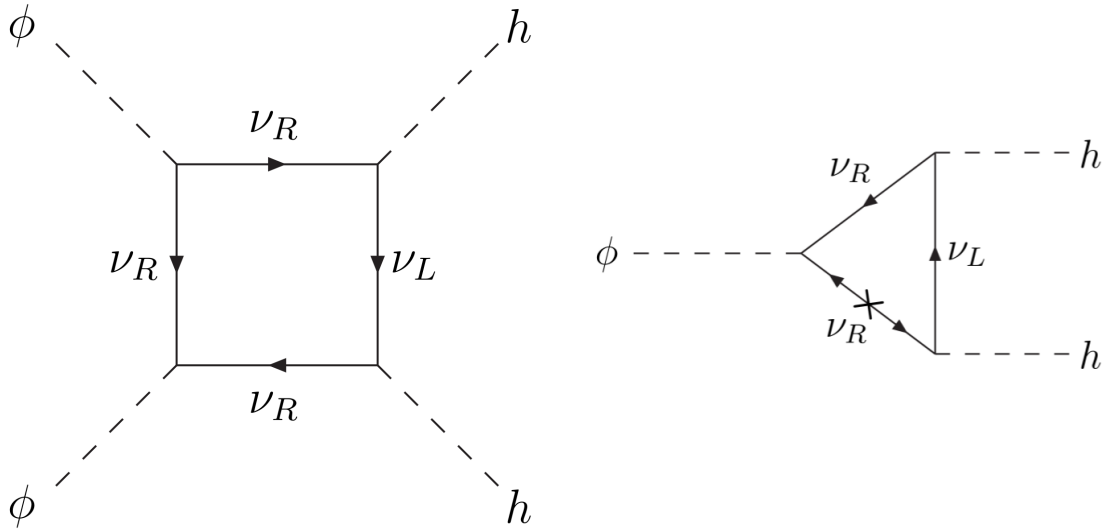
- are generated via loops
- are often required by renormalizability

C. Gross,O. Lebedev, MZ, 1506.05106

Example: reheating through right-handed neutrinos

$$\Delta\mathcal{L} = \lambda_\nu \, \phi \, \nu_R \nu_R / 2 + y_\nu \, h \, \nu_R \nu_L$$

At one-loop

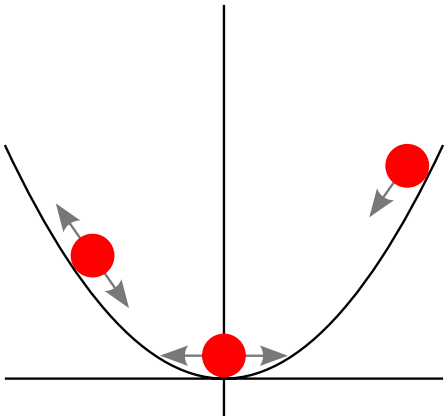


Need to add the counterterms in the lagrangian

Preheating

Kofman, Linde, Starobinsky '97

After inflation the inflaton oscillates around its minimum



$$V(\phi) = \tfrac{1}{2} m^2 \phi^2$$

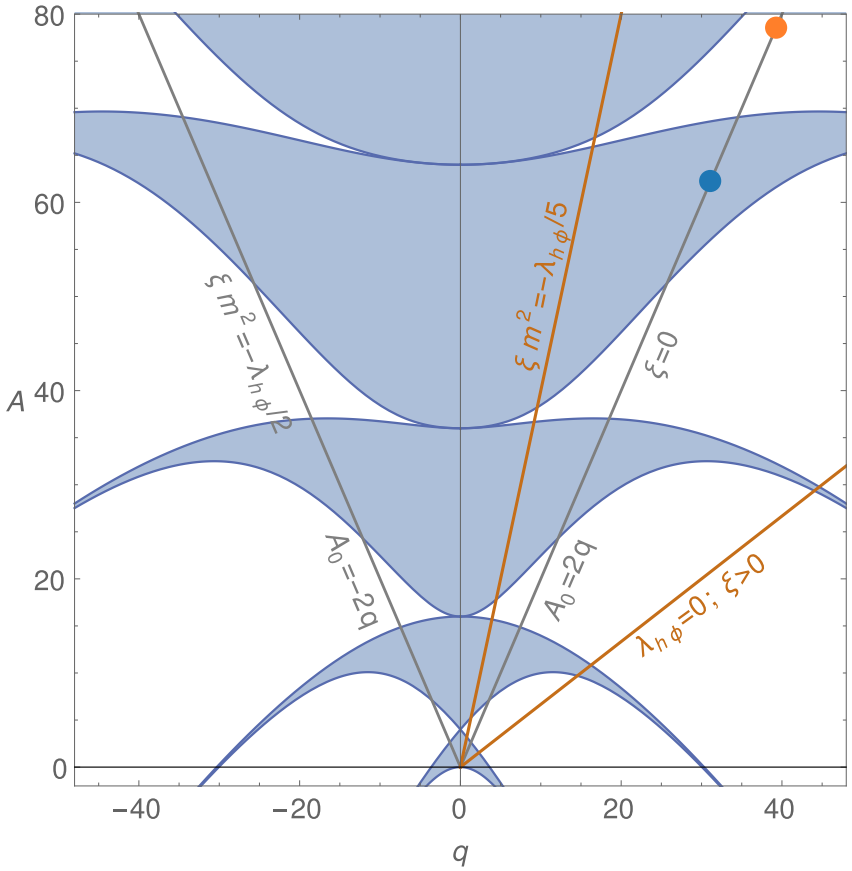
$$\phi \simeq \Phi \cos mt \quad \text{with} \quad \Phi \sim \Phi_0 \, a^{-3/2}$$

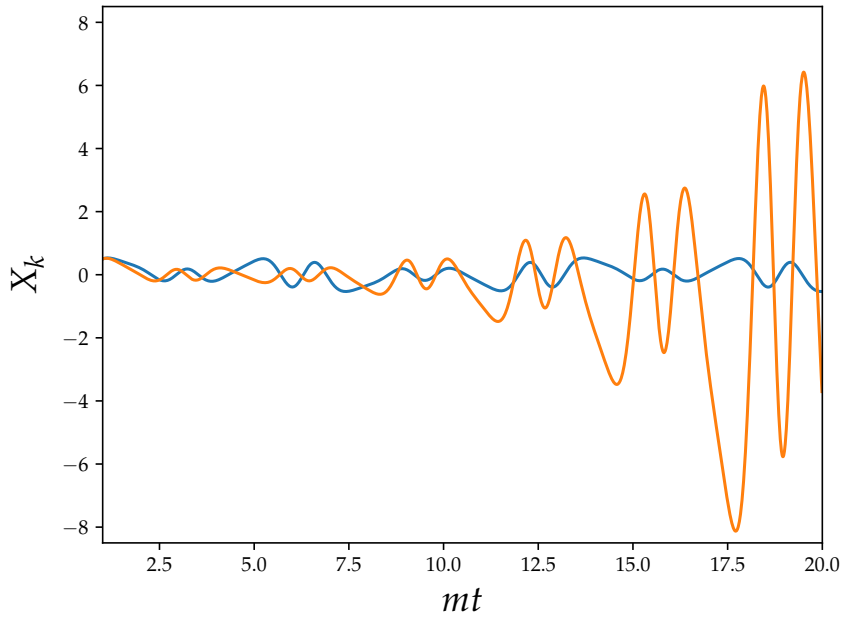
- Periodic mass leads to effective production of Higgs particles

$\langle h^2 \rangle \propto$ Number of Higgs quanta

Mode EoM for the Higgs ($\sigma \sim 0$)

Mathieu Equation: $X_k'' + (A_k + 2q\cos 4z)\, X_k = 0 \qquad z = mt/2$





Preheating with $\sigma \sim 0$

Mathieu Equation: $X_k'' + (A_k + 2q\cos 4z)\, X_k = 0 \qquad z = mt/2$

with

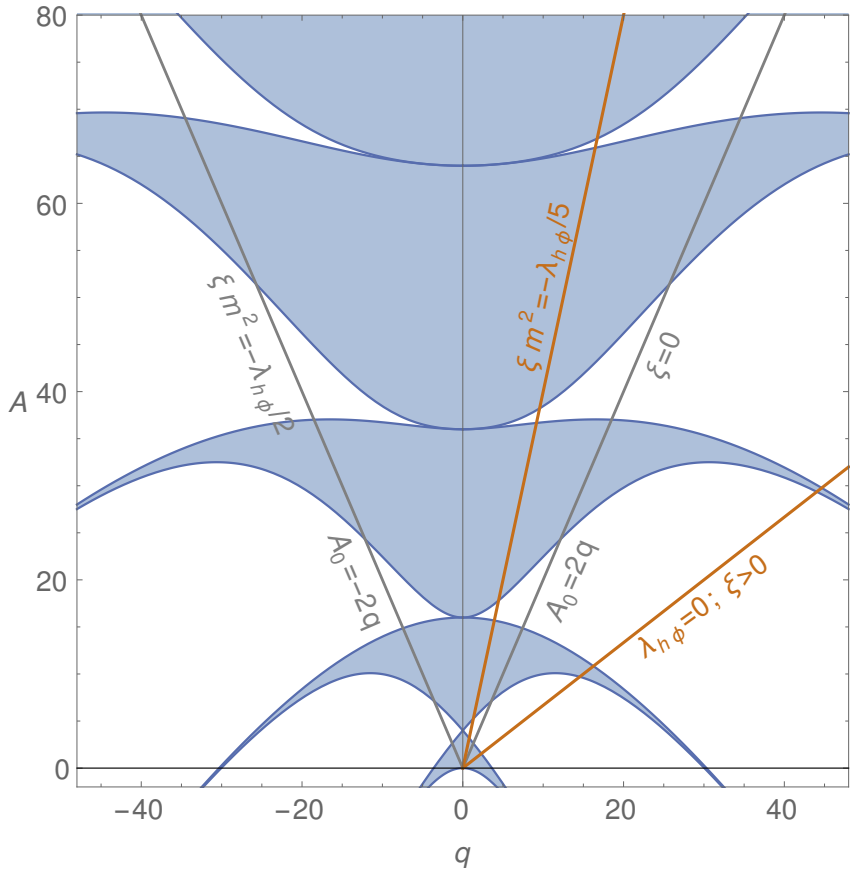
$$A_k = \left(\frac{k}{ma}\right)^2 + 2\left(\lambda_{h\phi} + \xi m^2\right)\frac{\Phi^2}{m^2}$$

$$q = \left(\lambda_{h\phi} + 3\xi m^2\right)\frac{\Phi^2}{m^2}$$

Strength of the resonance:

- Determined by A/q

Ema, Karciauskas, Lebedev, MZ, 1703.04681

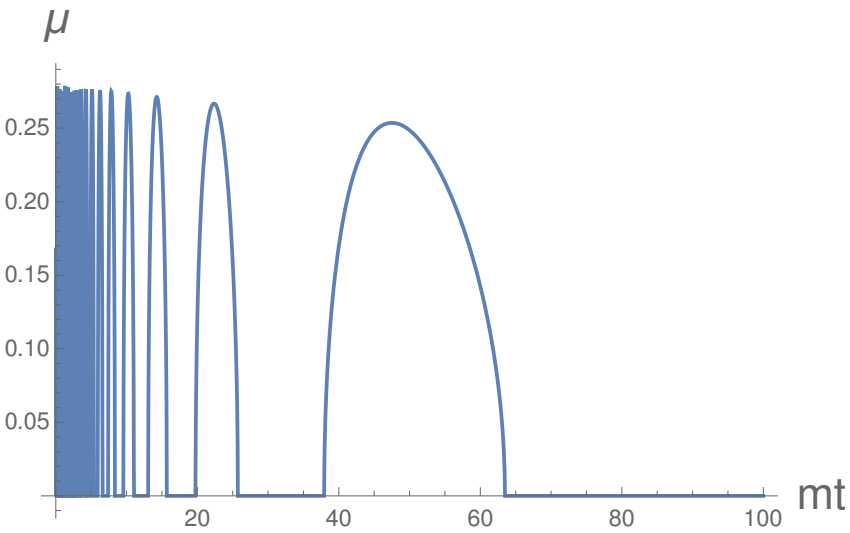


Preheating with $\sigma \sim 0$

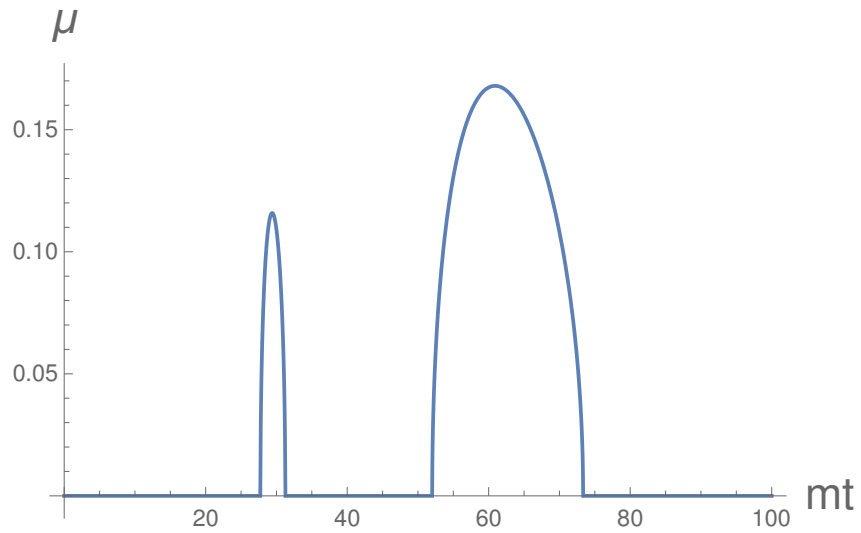
When the mode k is in the white region its amplitude grows as

$$X_k \propto e^{\mu\, \Delta m t}$$

$A_0 = 2q$



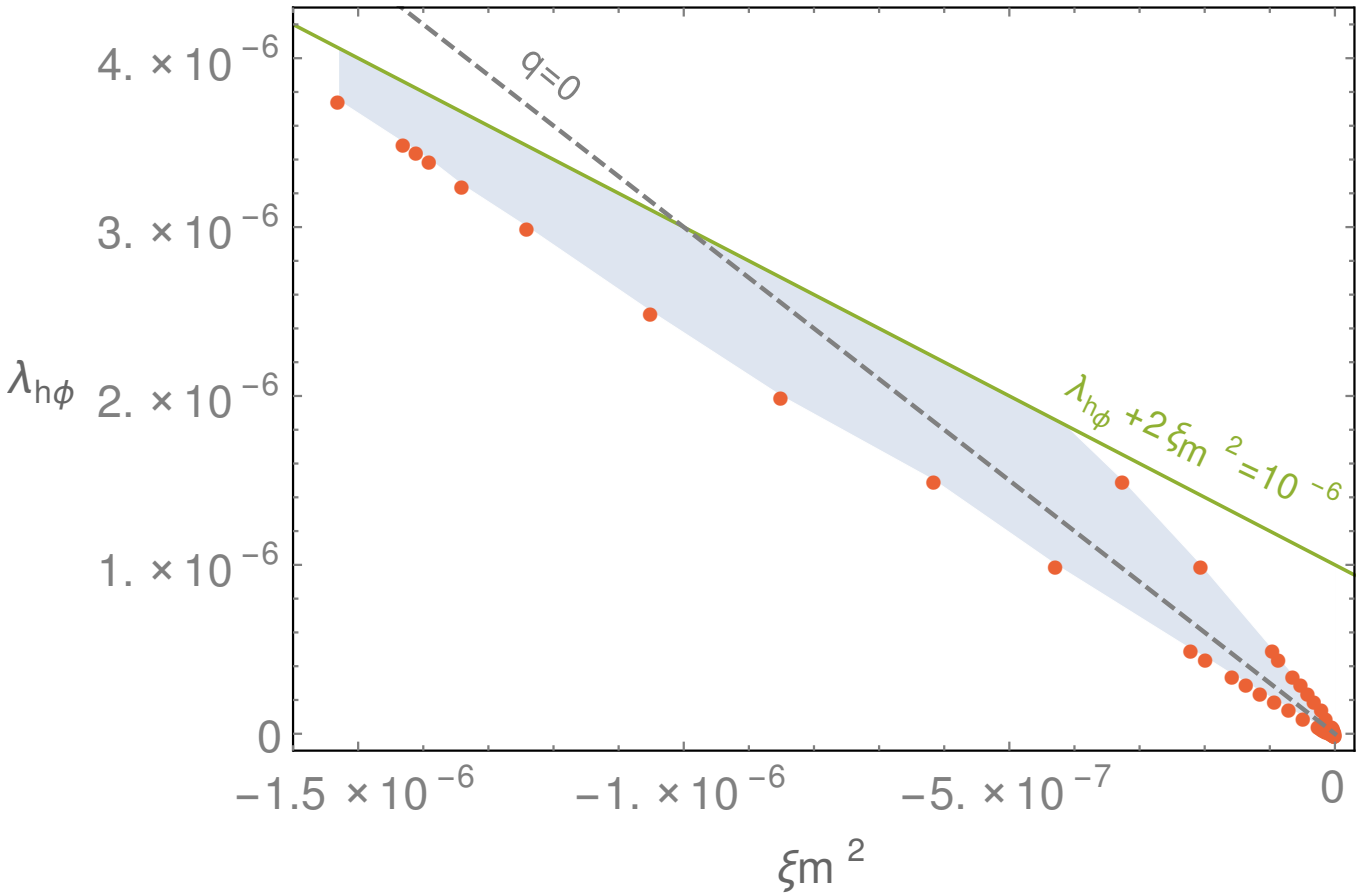
$A_0 = 3q$



Ema, Karciauskas, Lebedev, MZ, 1703.04681

Lattice results

Stable region in parameter space



Ema, Karciauskas, Lebedev, MZ, 1703.04681

Conclusions

The couplings ξ and $\lambda_{h\phi}$ can affect dramatically the Higgs dynamics

In particular they:

- can explain how the universe ended up in the EW vacuum
- are generated by quantum effects
- must not destabilize the vacuum during preheating

Thank you