Mainz Institute for Theoretical Physics

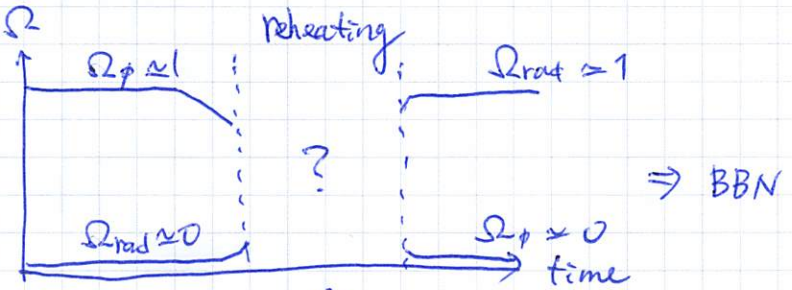
Post-reheating production of inflaton and lab. experiments

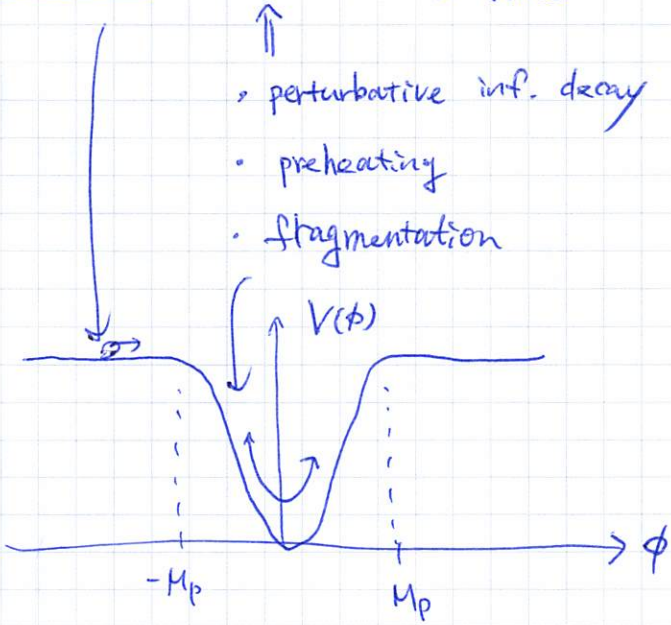
Ref. K.K., T. Takahashi, N. Watanabe [2508.20402]

Outline

1. Intro. to reheating problem
2. Post-reheating inflaton production (Higgs-portal case)

1.





Inflaton $\phi = \bar{\phi}(t) + \delta\phi(t,\vec{x})$

($\bar{\phi}$: condensate, $\delta\phi$: quanta (particle))

$$\mathcal{L}_{inf} = \frac{1}{2}\dot{\bar{\phi}}^2 - V(\bar{\phi})$$

consider

$$|\bar{\phi}| \ll M_P \Rightarrow V(\bar{\phi}) \simeq \lambda M_P^4 \left(\frac{\bar{\phi}}{M_P}\right)^k \quad (k: \text{even \#})$$

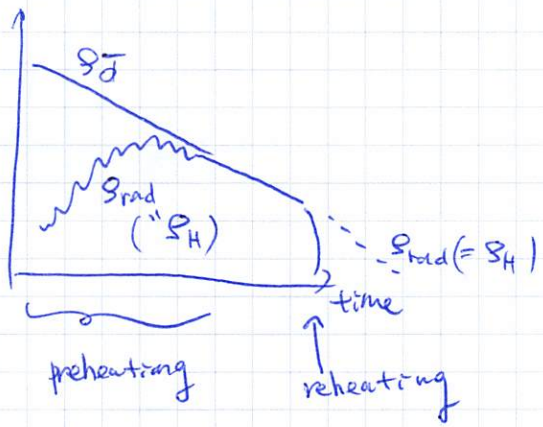
$\lambda \simeq 10^{-12} - 10^{-14}$ (depending on k)

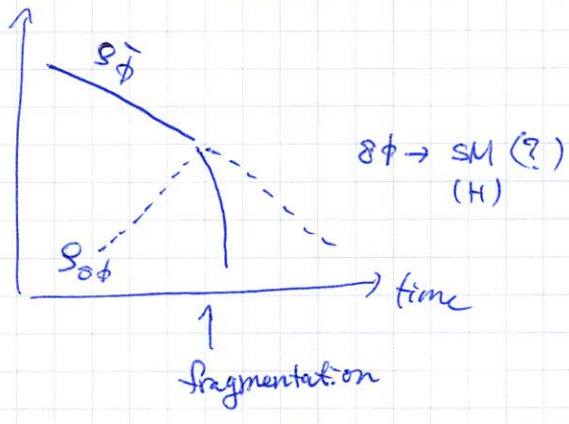
To reheat the Universe, ϕ-SM coupling is needed.

gauge inv. & renormalizable

$$\Rightarrow -\mathcal{L}_{int} = \sigma\phi^2|H|^2 \quad , \quad 2\mu\phi|H|^2$$

In either case





Anyhow reheating should be completed. $\leftrightarrow$ $\rho_{\bar{\phi}} \to 0$

(inflaton disappears)

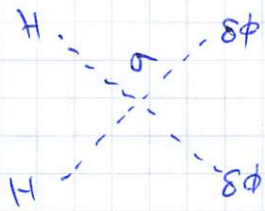
2.

~~Point~~ punchline : $\delta\phi$ is produced even after reheating completes.

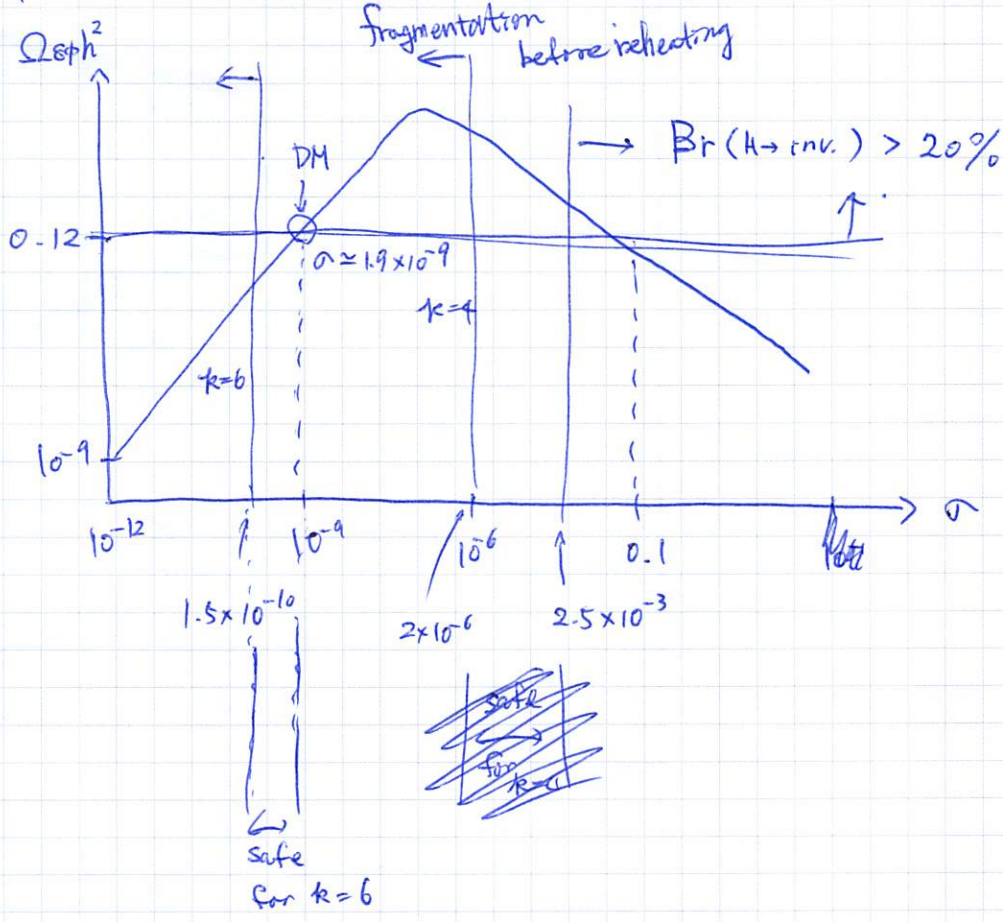
key : $m_\phi(a) = \sqrt{V''(\phi)} = m_\phi(a_e)\left(\frac{a}{a_e}\right)^{-3\frac{k-2}{k+2}}$

$\rightarrow$ $\underline{m_\phi(a) < T \quad \text{for} \quad k \geq 4}$

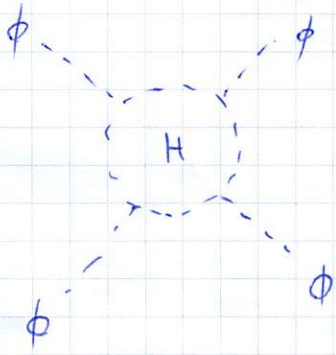
$\sigma\phi^2|H|^2$ After EWSB $\Rightarrow m_\phi = \sigma v$, $(v = 246\,\text{GeV})$



$\Rightarrow$ $n_{\delta\phi}$ from Boltzmann eq. ($n_{\delta\phi}(a_{in.}) = 0$ assume)



$\mu\phi|H|^2$ m_ϕ from radiative correction



$\rightarrow V_{CW} = \frac{(2\mu\phi)^2}{16\pi^2}\left(\ln\frac{2\mu\phi}{\Lambda} - \frac{3}{2}\right)$

$\Rightarrow m_\phi \simeq \frac{\mu}{\pi}$ (Λ is so chosen)

consider $\mu \ll m_h$

After EWSB $\rightarrow$ $\mathcal{L}_{mix} = \frac{1}{2}(2\mu v)\,\delta\phi\, h$

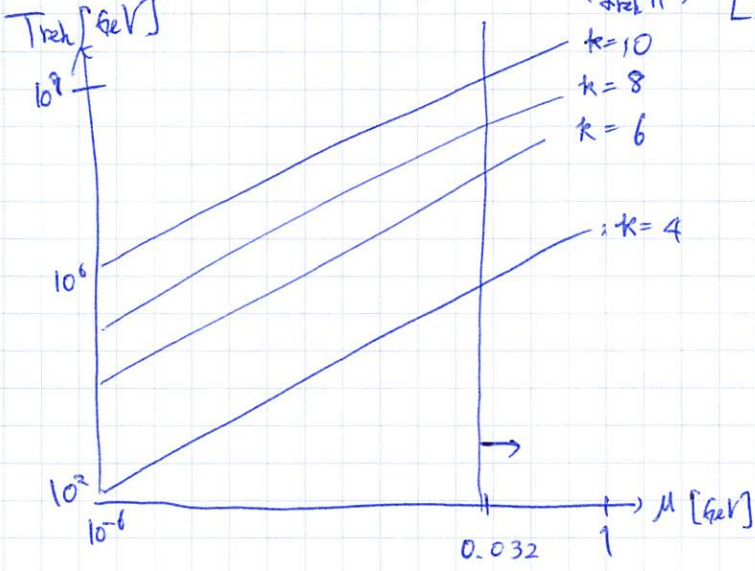
$\Rightarrow$ mixing angle $\theta \simeq \frac{2\mu v}{m_h^2}$ ($m_\phi \ll m_h$)

Dark Higgs search

e.g. $B \rightarrow K^{(*)}\phi(\rightarrow \mu^+\mu^-)$ @ LHCb

$\Rightarrow \theta \lesssim 10^{-3} \leftrightarrow \mu \lesssim 10^{-3}\cdot\frac{m_h^2}{v} \simeq 0.032$ GeV

Combine with reheating: $T_{reh} = \left(\frac{30}{g_{reh}\pi^2}\right)^{1/4}\left[\frac{1}{\sqrt{\pi}^{3/2}}\sqrt{\frac{3}{k(k-1)^3}}\frac{\Gamma(\frac{k}{2})}{\Gamma(\frac{1}{2}+\frac{1}{k})}\left(\frac{\mu}{\lambda^{1/k}M_p}\right)^{5/2}\left(\frac{\mu_{eff}}{\mu}\right)^2\right]^{\frac{k}{5k-10}} M_p$



Upper bound on T_{reh}

k	4	6	8	10
T_{reh}	2.4×10^5	2×10^7	1×10^8	2.4×10^8