Warm Quasi-single Field Inflation

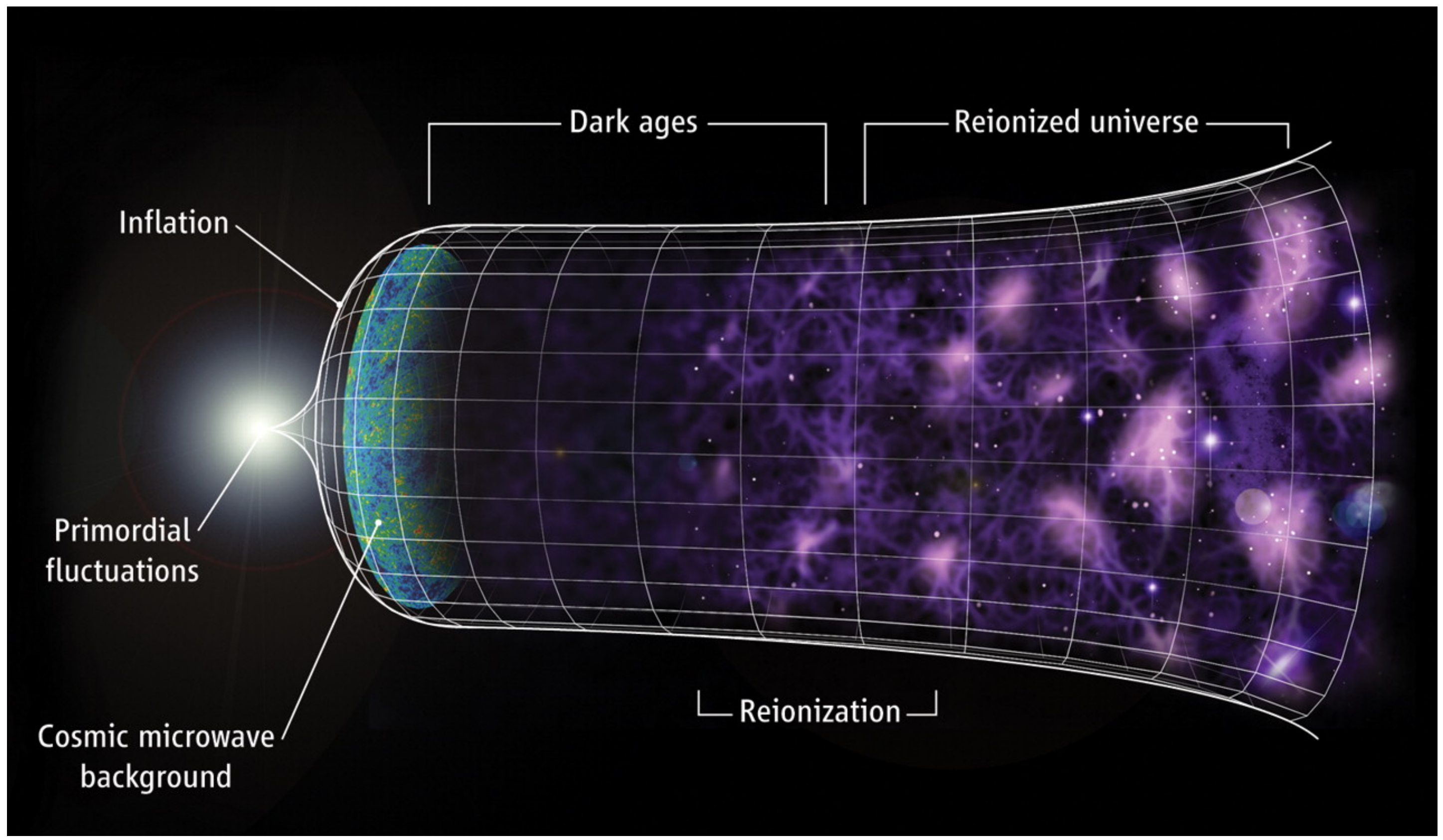
Siyi Zhou
the Hong Kong University of Science and Technology

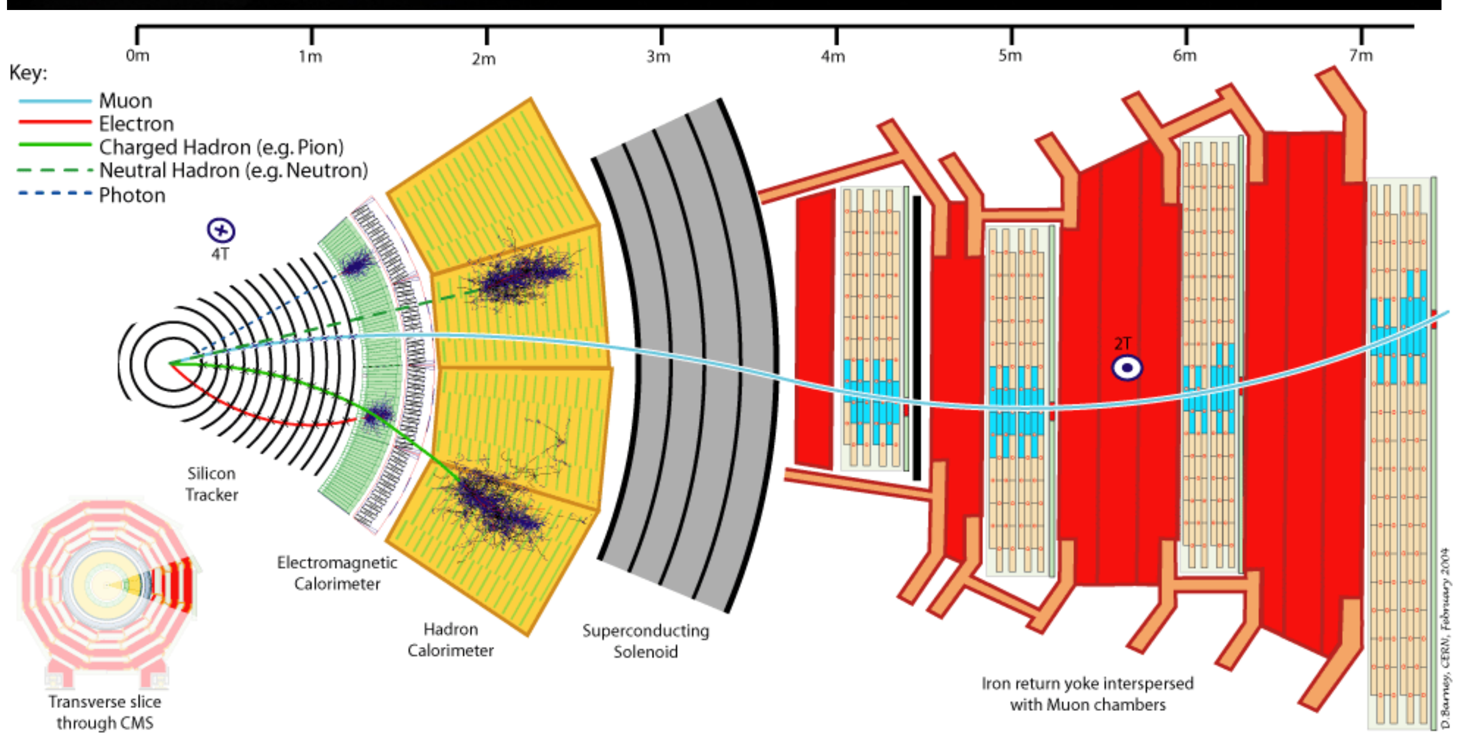
Based on the work with Xi Tong and Yi Wang: 1801.05688
JCAP 1806 (2018) no.06, 013

Motivation

- **Single Field Inflation: One scalar inflaton**
- **Quasi-Single Field Inflation/Cosmological Collider Physics: One scalar inflaton+ massive fields m~H, spin s**
  0911.3380 Chen, Wang
  1503.08043 Arkani-Hamed, Maldacena
- **(Also see Yi Wang, Daniel Baumann, Yi-Peng Wu, Hayden Lee's talk)**
- **Multi-Field Inflation: Multiple inflatons**

Cosmological Collider





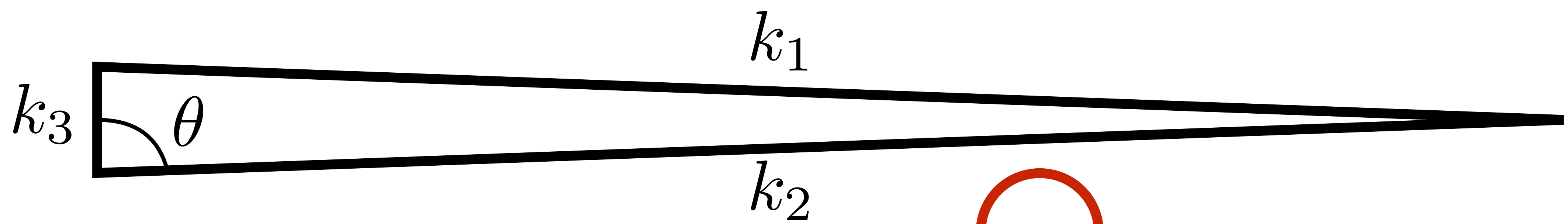
Motivation

- **How to probe the UV physics during inflation from primordial Non-Gaussianity?**
- **Standard Model**
- **Supersymmetry**
- **String theory**
- **Vasiliev gravity**
- **Modified gravity**

Quasi-single Field Inflation

Squeezed limit non-Gaussianity

distinct shape



$$\frac{\langle \zeta_{\boldsymbol{k}_1} \zeta_{\boldsymbol{k}_2} \zeta_{\boldsymbol{k}_3} \rangle'}{\langle \zeta_{\boldsymbol{k}_1} \zeta_{-\boldsymbol{k}_1} \rangle \langle \zeta_{\boldsymbol{k}_3} \zeta_{-\boldsymbol{k}_3} \rangle} \sim \left[F(\mu) \left(\frac{k_1}{k_3} \right)^{i\mu} + \text{c.c.} \right] P_s(\cos\theta)$$

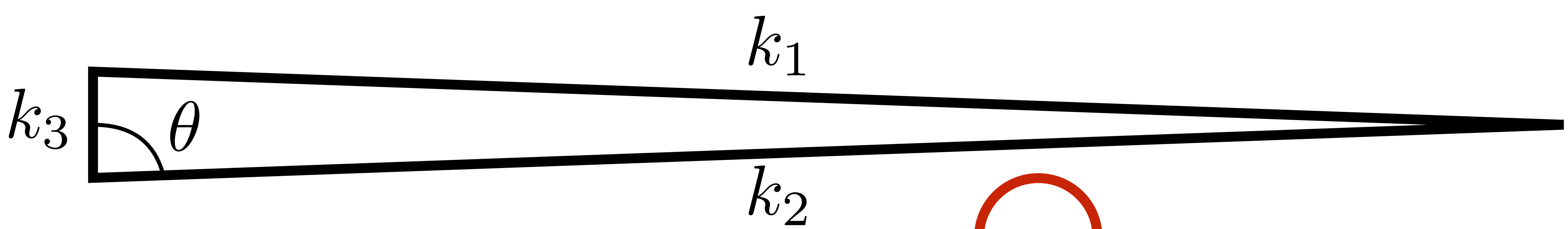
$$F(\mu) \sim e^{-\pi\mu}, \quad \mu = \sqrt{\frac{m^2}{H^2} - \frac{9}{4}}$$

Signal of the massive field is too small!

Quasi-single Field Inflation

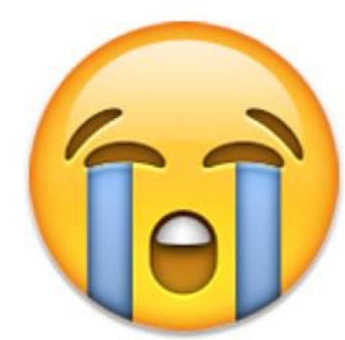
Squeezed limit non-Gaussianity

distinct shape



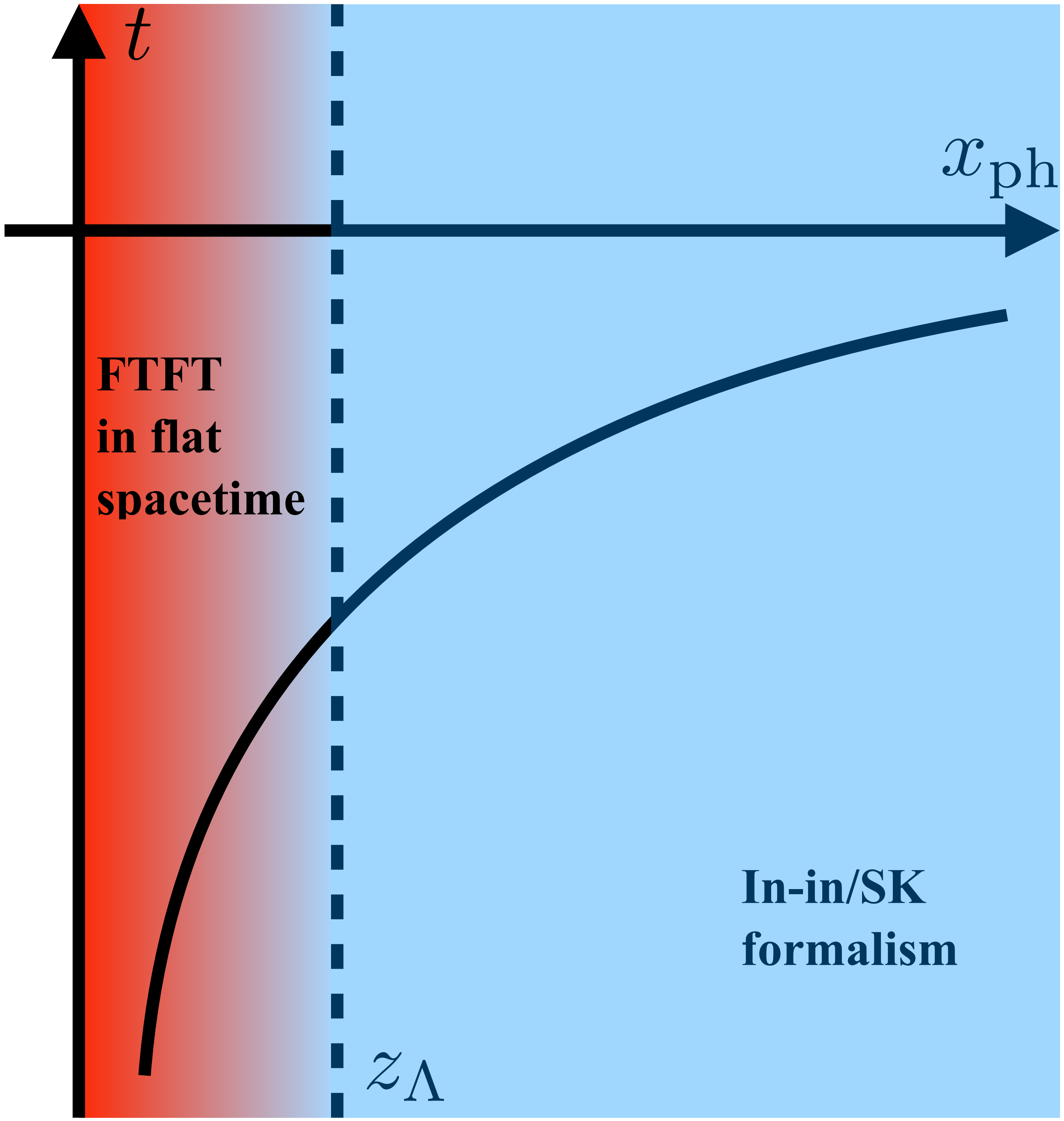
$$\frac{\langle \zeta_{\boldsymbol{k}_1} \zeta_{\boldsymbol{k}_2} \zeta_{\boldsymbol{k}_3} \rangle'}{\langle \zeta_{\boldsymbol{k}_1} \zeta_{-\boldsymbol{k}_1} \rangle \langle \zeta_{\boldsymbol{k}_3} \zeta_{-\boldsymbol{k}_3} \rangle} \sim \left[F(\mu) \left(\frac{k_1}{k_3} \right)^{i\mu} + \text{c.c.} \right] P_s(\cos\theta)$$

$$F(\mu) \sim e^{-\pi\mu}, \quad \mu = \sqrt{\frac{m^2}{H^2} - \frac{9}{4}}$$



Signal of the massive field is too small!

Physical Picture



How to evade exponential suppression of the signal?

Boltzmann factor

$$\frac{1}{e^{E/T}-1}$$

Cold Quasi-single Field Inflation $E \to m$, $T = \frac{H}{2\pi}$ $\longrightarrow$ $e^{-2\pi\mu}$

Warm Quasi-single Field Inflation $E \to z_\Lambda$, T $\longrightarrow$ (T big) $\left(\frac{T}{z_\Lambda}\right)^n$

Mass

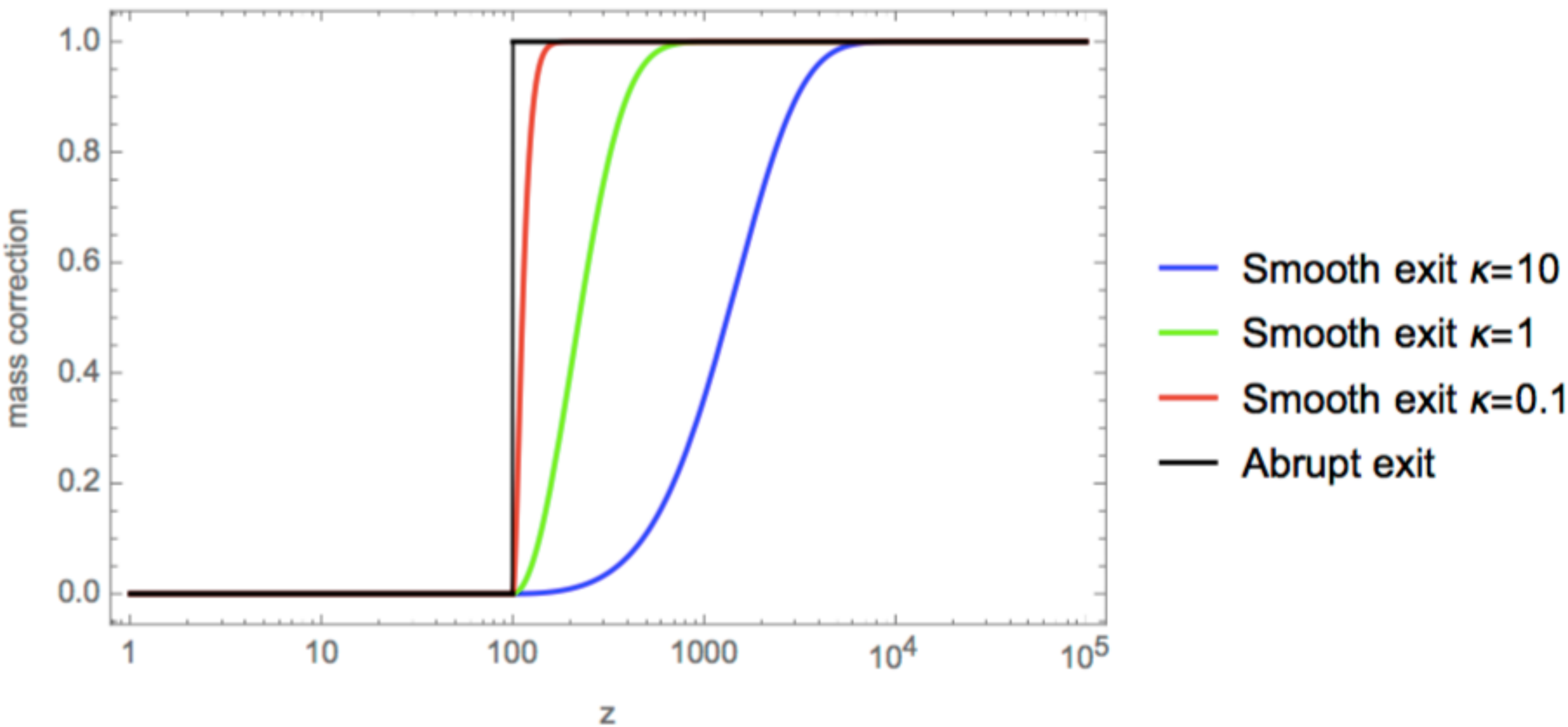
In the thermal bath, the mass of the massive field is corrected

$$\Delta m^2(T) = \frac{\lambda T^2}{24}$$

This effect can be captured by the interacting Hamiltonian

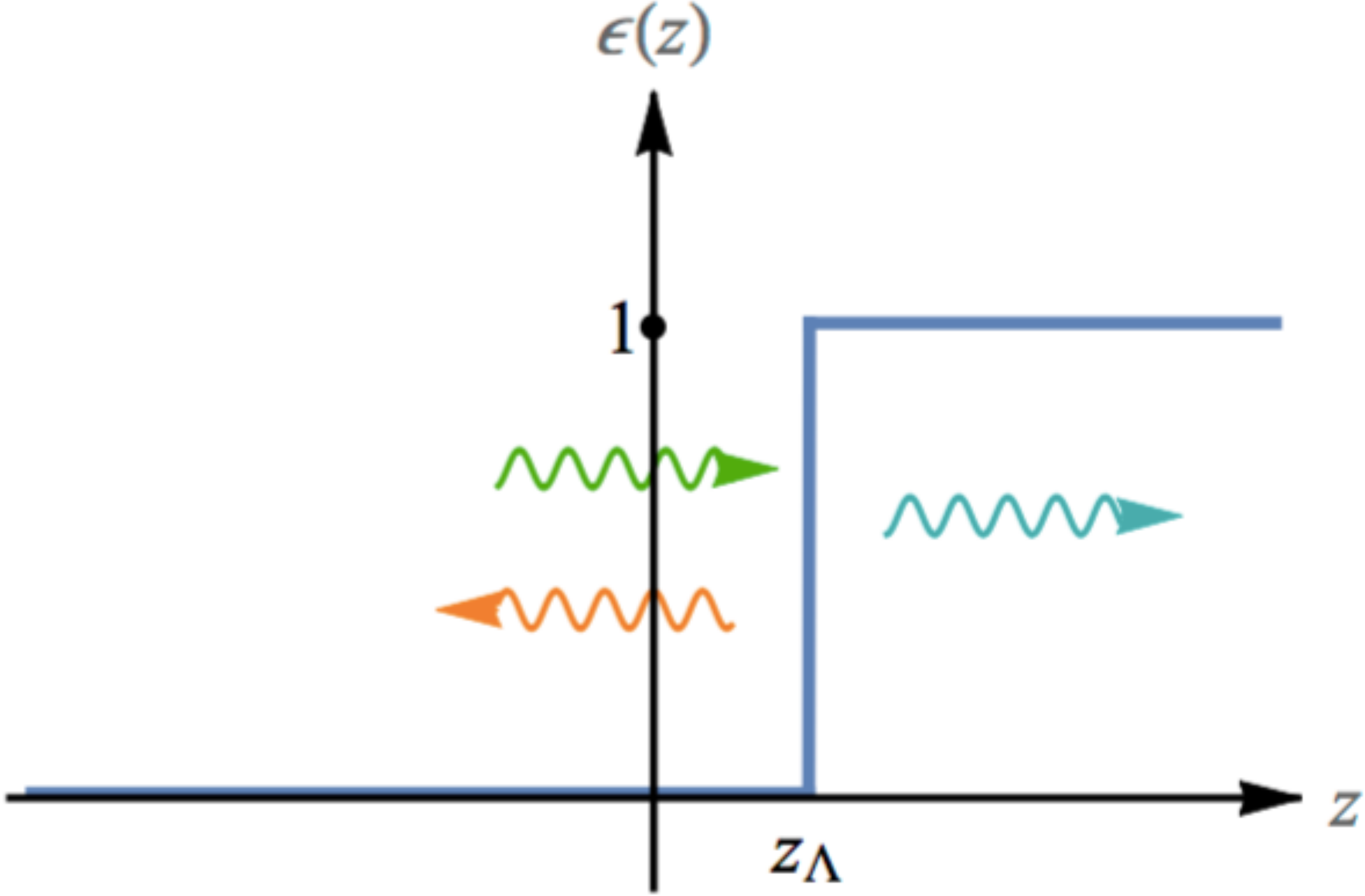
$$\tilde{\mathcal{H}}_I \sim \frac{1}{2}\Delta m^2(T) a^4 \sigma^2 \epsilon(T)$$

Mass



mass correction
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100
1000
10^4
10^5
z
Smooth exit κ=10
Smooth exit κ=1
Smooth exit κ=0.1
Abrupt exit

An Intuitive Understanding



An Intuitive Understanding

$$\begin{aligned} v_k(\tau_\Lambda^-)|_{m^2+\Delta m^2} &= \alpha v_k(\tau_\Lambda^+)|_{m^2} + \beta v_k(\tau_\Lambda^+)^*|_{m^2} \\ v_k'(\tau_\Lambda^-)|_{m^2+\Delta m^2} &= \alpha v_k'(\tau_\Lambda^+)|_{m^2} + \beta v_k'(\tau_\Lambda^+)^*|_{m^2} \ . \end{aligned}$$

$$\alpha \approx 1 - \frac{i\Delta m^2(T)}{2Hz_\Lambda} + \mathcal{O}\left(\frac{\Delta m^4(T)}{H^2 z_\Lambda^2}\right)$$

$$\beta = \frac{\Delta m^2(T)}{4H^2 z_\Lambda^2} e^{2iz_\Lambda} + \mathcal{O}\left(\frac{\Delta m^2(T)}{H^2 z_\Lambda^3}\right)$$

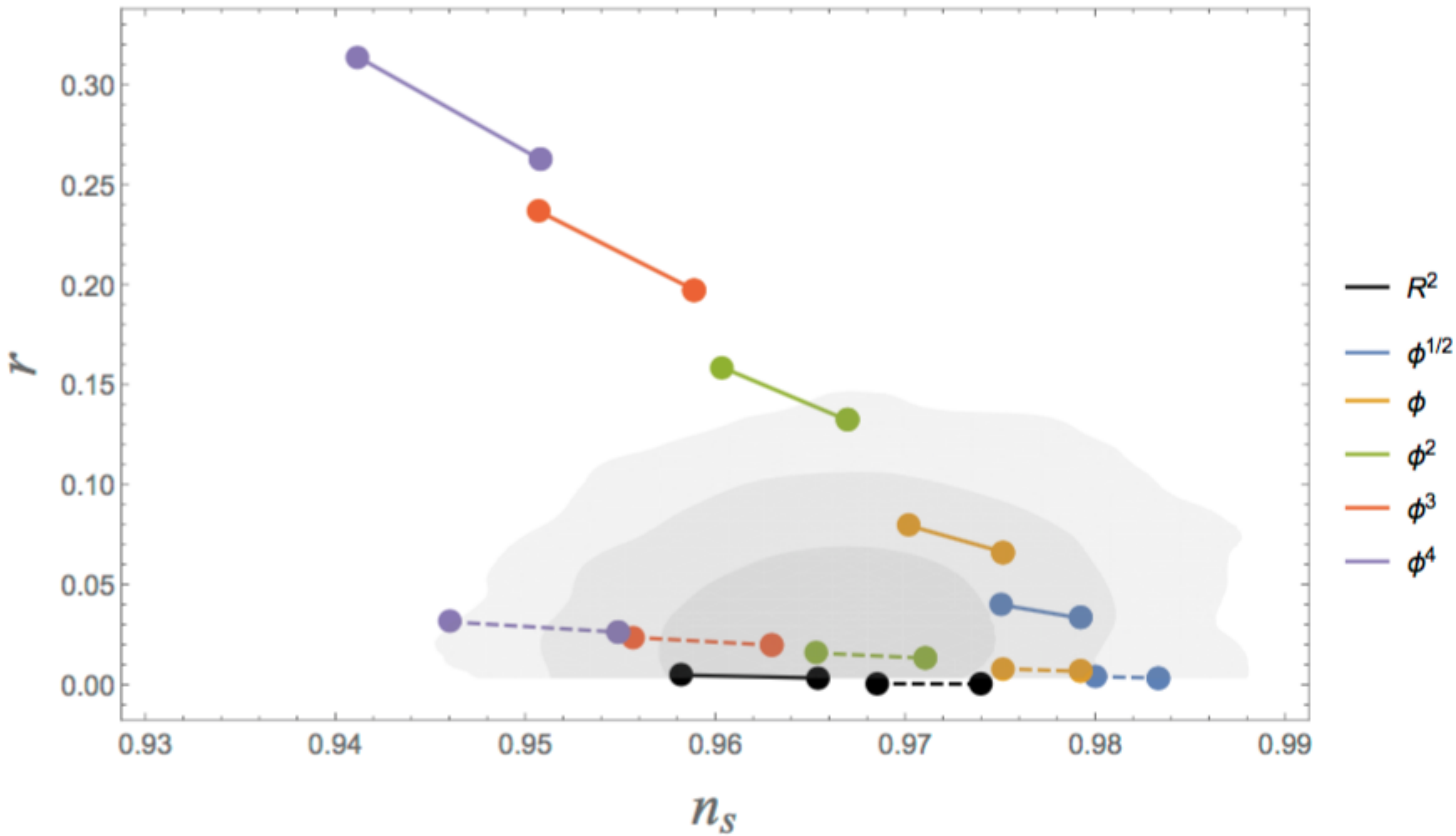
Final Result

$$\frac{\langle \zeta_{\boldsymbol{k}_1} \zeta_{\boldsymbol{k}_2} \zeta_{\boldsymbol{k}_3} \rangle'}{\langle \zeta_{\boldsymbol{k}_1} \zeta_{-\boldsymbol{k}_1} \rangle \langle \zeta_{\boldsymbol{k}_3} \zeta_{-\boldsymbol{k}_3} \rangle} \sim \left[G(T, z_\Lambda) \left(\frac{k_1}{k_3} \right)^{i\mu} + \text{c.c.} \right]$$

$$G(T, z_\Lambda) \sim \frac{T^2}{z_\Lambda^2}$$

Signal of the massive field is unsuppressed!

Small r



0.30
0.25
0.20
0.15
0.10
0.05
0.00
r
0.93
0.94
0.95
0.96
0.97
0.98
0.99
n_s
R^2
$\phi^{1/2}$
ϕ
ϕ^2
ϕ^3
ϕ^4

Thank you !